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### 低軌道デブリ地上光学観測システムの検討

#### Investigation of ground-based optical observation system for LEO objects

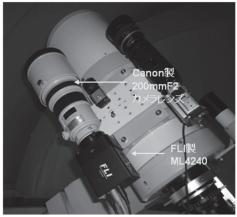
### ○柳沢俊史, 黒崎裕久(宇宙航空研究開発機構) OToshifumi Yanagisawa and Hirohisa Kurosaki (JAXA)

低軌道は多くの地球観測衛星等が投入される重要な軌道である。近年、デブリや衛星同士の衝突、破砕 事故などで低軌道の環境は悪化の一途をたどっている。人類の宇宙活動を継続するために、このような状況 に早急に対処する必要がある。現在、低軌道デブリはレーダーによって主に観測されている。一方、光学観 測装置による低軌道デブリの観測可能性が議論され始めている。光学観測装置による低軌道デブリの観測 は日照や天候による影響をうけるという弱点をもつが費用が抑えられるという利点がある。市販の安価な CCD カメラや PC を多数利用した光学観測システムを世界中に展開することにより、現在のレーダー観測網を上回 る能力を引き出すことができるかもしれない。

今回は低軌道デブリを対象とした40台の光学観測装置を持つ2つの観測サイトでの精密軌道決定の有効 性の検討を行った。STK を用いたシュミレーションにより、多くの観測データの中から、経度の離れた2局、4 台の観測装置の観測データにおける同一物体の対応付けが可能であることがわかった。このことはこのよう な観測システムを用いることにより、多数の未カタログデブリの精密な軌道決定ができるということを示してい る。

The low earth orbit is very important as many earth observation satellites are entered. Recently, this orbit is deteriorated by numerous pieces of space debris which is caused by collisions of satellite, breakups and so on. In order to maintain human activities in space, we have to cope with the space debris problem as soon as possible. Currently radar equipments are primary methods to observe LEO debris. Optical observation has an advantage of low cost, although it is effected by lighting condition of the sun and weather. The optical observation system consisted of large number of cost-effective CCDs and high-speed PCs at various sites in the world may overcome the current radar observation network.

We have examined the possibilities of precise orbit determination using two observation sites containing 40 sets of optical equipments. Simulations using STK have shown that identical objects were recognized from the data of 4 individual equipments installed on 2 separate sites using the lots of circular orbital elements calculated from many observation data. This enables us to determine orbits of many un-cataloged LEO objects precisely.



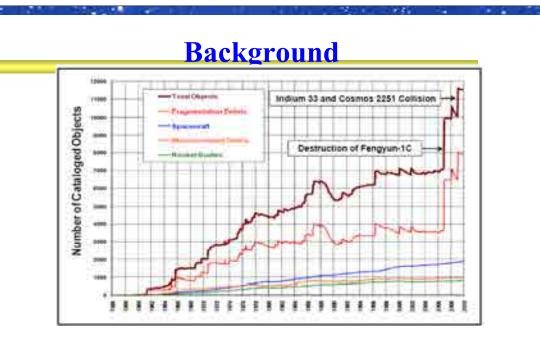
低軌道デブリ光学観測装置 Optical observation equipment for LEO debris



## Abstract

The low earth orbit is very important as many earth observation satellites are entered. Recently, this orbit is deteriorated by numerous pieces of space debris which is caused by collisions of satellite, breakups and so on. In order to maintain human activities in space, we have to cope with the space debris problem as soon as possible. Currently radar equipments are primary methods to observe LEO debris. Optical observation has an advantage of low cost, although it is effected by lighting condition of the sun and weather. The optical observation system consisted of large number of cost-effective CCDs and high-speed PCs at various sites in the world may overcome the current radar observation network.

We have examined the possibilities of precise orbit determination using two observation sites containing 40 sets of optical equipments. Simulations using STK have shown that identical objects were recognized from the data of 4 individual equipments installed on 2 separate sites using the lots of circular orbital elements calculated from many observation data. This enables us to determine orbits of many un-cataloged LEO objects precisely.



LEO environment (around 800-1000km altitude where lots of Japanese satellites reside) is being deteriorated rapidly by the ASAT, the collision caused by Iridium 33 and Cosmos 2251, and so on.

Error of conjunction assessments become large because of inaccuracy of TLE. Japanese satellites in LEO fully rely on the alert information of JSpOC of U.S. However we don't know how accurate it is.

Japan needs to have own methods to evaluate the environment of LEO.





Phased array of Kamisaibara Spaceguard Center

#### **Observation methods of LEO debris**



Russian ISON network using a lot of optical telescopes

#### **DRadar observation**

24-hour observation. SSN of U.S. Japan also has a radar observation facility owned by JSF(Japan Space Forum) in Kamisaibara. Its detection ability is 1m at 600km altitude which is not enough for small sized LEO debris. A disadvantage of radar observation system is a huge expenditure for its construction and maintenance.

#### **20**ptical observation

A few hours observation because of lighting condition of the Sun. Effected by weather conditions. ISON network of Russia. Basic research is being carried out by Innovative technology research center of JAXA. Very cost effective system.

Investigated the usefulness of the large array of optical sensors for LEO debris observation

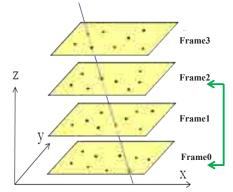
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# **Observation equipments and data analysis software**





Concept of the line-identifying technique

#### **Observation equipments :**

-Canon EF200mmFL IS USM

•FLI 2K2K back-illuminated CCD camera ML4240

FOV: 7.65 × 7.65°

**Exposure interval : 1.5 sec** 

#### Data analysis software:

The line-identifying technique developed for GEO debris detection. It can detect moving objects with constant velocity.

**Many frames** 

Candidates are searched using a threshold and a shape

**Candidates which create** 

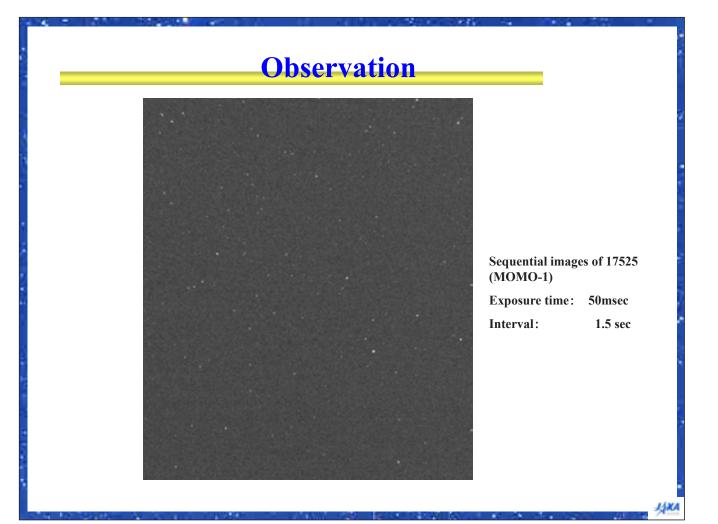
straight line are detected as

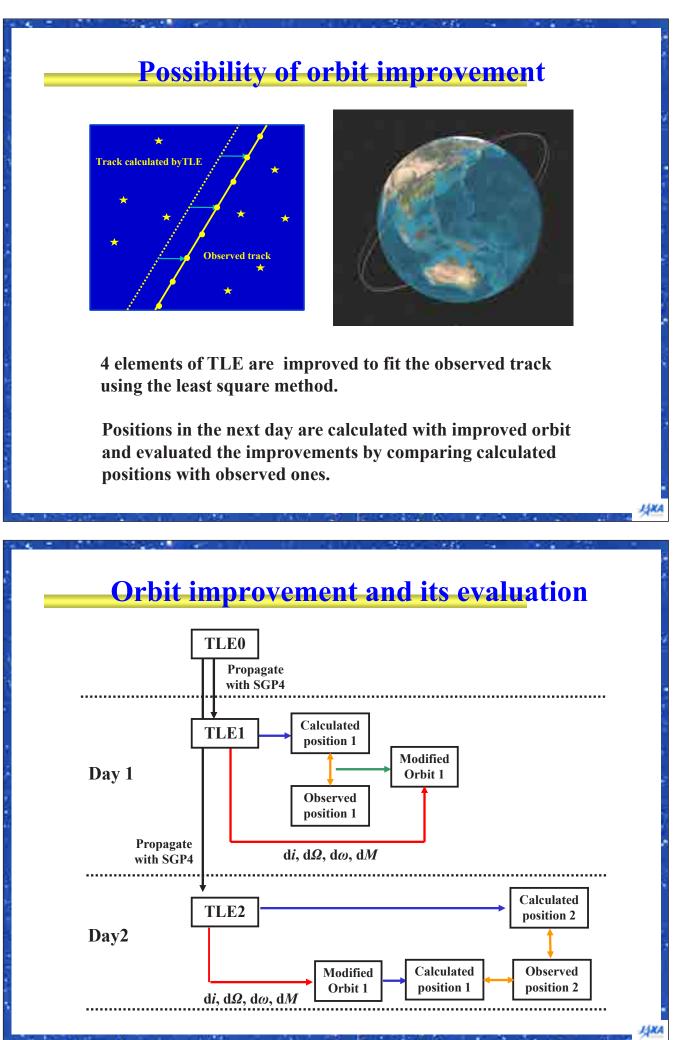
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parameter

moving object

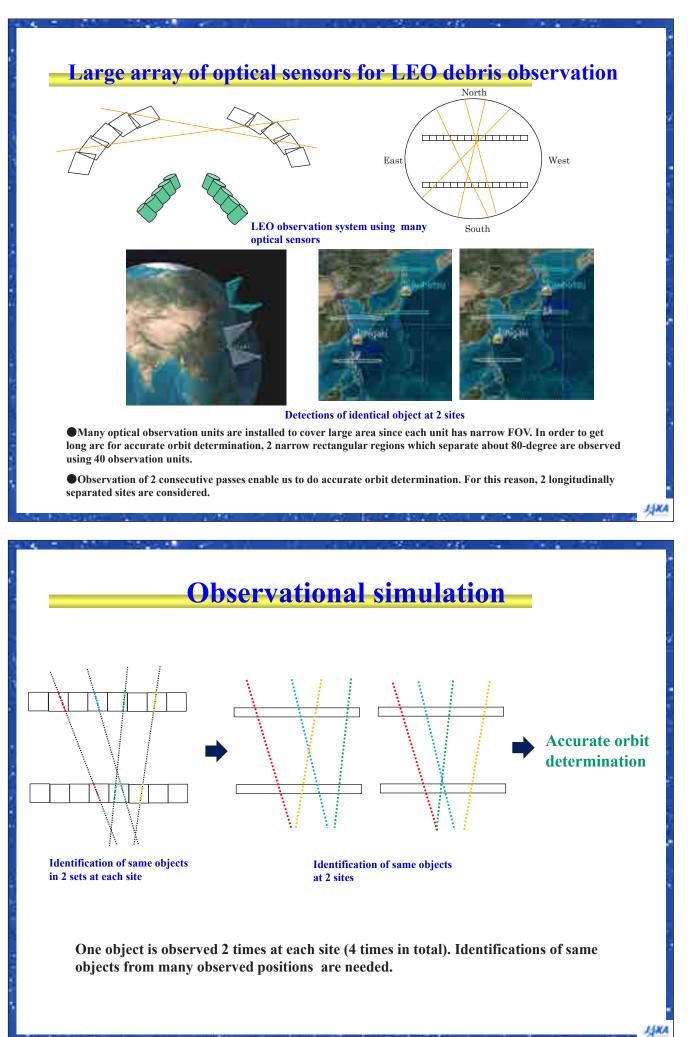
The equipments and the software enable us to detect LEO objects of 60cm at 1000km altitude.





| Accessing construction       Construction         stat       tate(U)       betwee Rate       calculate Rate       0 - C in Rate         111-09-07       17,86601       65,0433       39,0416       66,0022       89,1431       19,255       -307,166         2011-09-07       17,86601       65,0433       39,0416       66,0022       89,1431       19,205       -307,166         2011-09-07       17,86601       65,0433       39,0416       66,0022       89,1431       19,205       -307,166         2011-09-07       17,86618       65,0918       91,4444       65,0092       80,2430       19,207       -307,166         2011-09-07       17,86184       64,0019       91,7382       19,217       123,007       -318,081         2011-09-07       17,86281       68,3423       85,3432       83,3188       86,4364       106,127       -328,684         2011-09-07       17,86281       68,3423       85,3432       83,3188       86,4354       106,027       38,427       133,224       -318,387         2011-09-07       17,86481       62,0831       44,0382       92,0444       84,4673       106,124       -308,0425         2011-09-07       17,86481       62,0831       44,0382       92,04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |           |                      |                    |                   |             |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|----------------------|--------------------|-------------------|-------------|---|
| date         time(UT)         Observed RA, Dec         Calculated RA, Dec         O-C in RA, Dec           2011-03-07         17.86012         68.0438         34.0316         86.0322         38.1318         73.550         -300.852           2011-03-07         17.86012         68.0438         34.0501         05.5735         30.7440         19.275         -337.165           2011-03-07         17.86156         65.091         34.1484         85.0423         32.2498         104.006         -332.644           2011-03-07         7.86154         64.550         37.752         04.1220         37.3411         129.940         -318.681           2011-03-07         7.66271         62.4774         36.0006         09.7535         06.4351         107.273         -399.651           2011-03-07         7.66271         62.4033         35.4321         83.318         86.4455         106.277         -328.654           2011-03-07         7.66275         62.4033         34.3382         82.0455         5.0078         132.724         -313.634           2011-03-07         7.66471         01.64672         01.4472         01.4464         01.024         -339.825           2011-03-07         7.66451         01.4673         01.274         <                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |           |                      |                    | •                 |             |   |
| date         time(UT)         Observed RA, Dec         Calculated RA, Dec         O-C in RA, Dec           2011-03-07         17.86012         68.0438         34.0316         86.0322         38.1318         73.550         -300.852           2011-03-07         17.86012         68.0438         34.0501         05.5735         30.7440         19.275         -337.165           2011-03-07         17.86156         65.091         34.1484         85.0423         32.2498         104.006         -332.644           2011-03-07         7.86154         64.550         37.752         04.1220         37.3411         129.940         -318.681           2011-03-07         7.66271         62.4774         36.0006         09.7535         06.4351         107.273         -399.651           2011-03-07         7.66271         62.4033         35.4321         83.318         86.4455         106.277         -328.654           2011-03-07         7.66275         62.4033         34.3382         82.0455         5.0078         132.724         -313.634           2011-03-07         7.66471         01.64672         01.4472         01.4464         01.024         -339.825           2011-03-07         7.66451         01.4673         01.274         <                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |           | nalveie              | recult 1           | $\mathbf{O}$      |             | - |
| 2011-09-07 17.66012   66.0433 39.0916   86.0922 38.1319   79.560 -360.682<br>2011-09-07 17.66055   65.5300 39.1464   85.093 60.2735 38.7419   104.006 -392.684<br>2011-09-07 17.6618   65.0919 39.1484   85.0832 80.2406   104.006 -392.684<br>2011-09-07 17.6618   64.2094 37.2540   84.1820 37.7312   129.072 -316.736<br>2011-09-07 17.6617   0.7774 38.0000   02.7358 60.1951   107.273 -399.681<br>2011-09-07 17.6623   01.7774 38.0000   02.7583 60.1951   107.273 -399.681<br>2011-09-07 17.6623   02.7774 38.0000   02.7583 60.1951   107.273 -399.681<br>2011-09-07 17.6625   02.3143 35.8033   02.6871 35.9837   121.09 -311.191<br>2011-09-07 17.6655   02.4003 35.4121   02.4593 55.000   138.224 -313.584<br>2011-09-07 17.6655   02.4003 35.4121   02.4593 55.000   138.224 -313.584<br>2011-09-07 17.6655   02.4031 34.3082   82.0845 35.0278   125.768 -322.724<br>2011-09-07 17.6655   00.7501 33.4211   02.274 39.5519   144.646 -301.074<br>2011-09-07 17.6655   00.7501 33.4201   00.7254 39.5193   144.000 -310.238<br>2011-09-07 17.6654   01.5616 83.42778   79.6009 92.5047   138.978 -322.728<br>2011-09-07 17.6654   78.5160 31.3230   78.4733 32.0038   152.315 -308.803<br>2011-09-07 17.6654   58.5160 31.3230   78.4733 32.0038   152.315 -308.803<br>2011-09-07 17.6654   58.5160 31.3230   78.4733 32.303   142.617 -273.628<br>2011-09-07 17.6654   58.5160 31.3230   78.4733 32.303   142.617 -273.628<br>2011-09-07 17.6654   58.5160 31.3230   78.4733 32.303   135.172 -271.623<br>2011-09-07 17.6654   58.5647 5.1138   68.687 5.1135   137.688 -283.183<br>2011-09-07 17.66745   58.5647 5.1136   68.687 5.1135   137.688 -283.183<br>2011-09-07 17.68741   64.1385 7.528   64.41433 7.7238   135.172 -271.628<br>2011-09-07 17.68745   64.3685 5.0055   63.3265   6.1352   137.688 -283.183<br>2011-09-07 17.68745   64.1365 7.0055   63.3268   64.1363   144.741 -255.472<br>2011-09-07 17.68816   62.4033 4.5926   62.6891 4.41835   144.5442 -271.488<br>2011-09-07 17.68848   62.4033 4.5926   62.6891 4.41835   144.5442 -271.488<br>2011-09-07 17.68848   62.4033 4.5926   62.6891 4.41835   144.5442 -271.488<br>2011-09-07 17.68848  |           | - /                  |                    | •                 |             |   |
| 2011-09-07 17.866012   86.0438 39.0816   86.0222 38.1818   79.560 -360.682<br>2011-09-07 17.060150   85.916 31.464 85.07.85 30.7440   09.275 -337.165<br>2011-09-07 17.06150   84.8509 37.7052   04.6239 37.7332   129.072 -316.736<br>2011-09-07 17.06150   84.8509 37.7052   04.6239 37.7332   129.072 -316.736<br>2011-09-07 17.06151   84.2094 37.2560   84.1820 97.3411   127.840 -318.681<br>2011-09-07 17.06237   80.774 38.0000   09.7558 86.4345   106.127 -328.854<br>2011-09-07 17.06237   80.3423 38.3432   83.8186 36.4345   106.127 -328.854<br>2011-09-07 17.06237   81.3448 35.8983   82.0871 35.5897   121.109 -311.181<br>2011-09-07 17.06457   81.4465 34.4673   01.6134 34.5509   130.224 -319.364<br>2011-09-07 17.06545   81.4465 34.4673   01.6134 34.5509   144.646 -301.074<br>2011-09-07 17.06545   81.4465 34.4673   01.6134 34.5509   144.000 -310.238<br>2011-09-07 17.06545   81.3486 32.9075   80.2874 32.5371   133.878 -322.728<br>2011-09-07 17.06545   81.3486 32.9075   80.2874 32.5371   133.878 -322.728<br>2011-09-07 17.06642   79.9170 32.4170   79.009 32.5947   154.201 -312.763<br>2011-09-07 17.06644   64.7388 3.2280   84.6398 8.3057   142.617 -279.827<br>2011-09-07 17.06644   64.7388 3.2280   84.6398 8.3057   142.617 -279.827<br>2011-09-07 17.08645   64.7388 3.2280   84.6398 8.3057   142.617 -279.827<br>2011-09-07 17.08645   64.7388 3.2280   84.6398 8.3057   142.617 -279.827<br>2011-09-07 17.08645   64.328 4.2080   84.6398 8.3057   142.617 -279.827<br>2011-09-07 17.08645   64.328 4.2080   84.6398 8.3057   142.617 -279.827<br>2011-09-07 17.08645   64.328 4.2080   84.6398 8.3057   142.617 -279.827<br>2011-09-07 17.08645   64.328 4.2186   146.44.440 -273.848   136.628 -265.135<br>2011-09-07 17.08645   64.328   6.2051   6.3144   63.8888   6.7106   138.658 -205.135<br>2011-09-07 17.08785   63.3251   6.314   63.8888   6.7106   138.658 -205.135<br>2011-09-07 17.080785   63.3251   6.6314   63.8888   6.2168   146.741 -255.472<br>2011-09-07 17.08084   62.4039   8.5002   62.8041   4.6536   146.741 -255.472<br>2011-09-07 17.08084   62.4039   8.5002   62.8041   4.6536   146.741 -255.4   | date      | (ime(UI) Ubserv      | ed KA,Dec Galcul   |                   |             |   |
| 2011-03-07 17.06056   05.5900 20.6500   05.5735 30.7440   09.275 -337.166<br>2011-03-07 17.06156   04.8500 37.7052   04.6233 37.7332   120.072 -316.736<br>2011-03-07 17.06156   04.8500 37.7052   04.6233 37.7332   120.072 -316.736<br>2011-03-07 17.06156   04.8700 37.743 2   04.6233 37.7332   120.072 -316.136<br>2011-03-07 17.06157   05.774 38.0000   09.7538 36.0351   107.273 -339.651<br>2011-03-07 17.06227   05.774 38.0000   09.7538 36.0351   107.273 -339.651<br>2011-03-07 17.06237   05.343 02.4303 35.4121   02.4530 35.5037   121.105 -311.131<br>2011-03-07 17.06258   02.4303 35.4121   02.4530 35.5030   138.224 -319.364<br>2011-03-07 17.06558   02.4303 35.4121   02.4530 35.5030   138.224 -319.364<br>2011-03-07 17.06558   01.4665 34.4673   01.6134 34.5509   144.66 -301.074<br>2011-03-07 17.06558   01.7718 3.4231   00.7554 33.5133   141.000 -310.238<br>2011-03-07 17.06558   01.3718 3.4231   00.7554 33.5133   141.000 -310.238<br>2011-03-07 17.06558   01.3718 3.4231   00.7554 33.5133   142.017 -312.768<br>2011-03-07 17.06558   01.3718 3.4231   00.7554 33.5133   142.617 -729.827<br>2011-03-07 17.06568   73.510 31.3230   79.4778 32.0088   152.316 -308.803<br>2011-03-07 17.86568   73.5160 31.3230   79.4778 32.0088   152.316 -308.803<br>2011-03-07 17.86568   73.5160 31.3230   79.4778 32.0088   152.316 -308.803<br>2011-03-07 17.86568   73.5160 31.3230   79.4778 32.0088   152.316 -308.803<br>2011-03-07 17.86568   78.5160 31.3230   78.4778 32.0088   152.316 -308.803<br>2011-03-07 17.86568   61.3251   6.6314   63.8686   6.7106   138.655 -285.155<br>2011-03-07 17.86574   64.1865 7.1529   64.1433 7.2233   135.172 -271.273<br>2011-03-07 17.86574   64.366 7.5152   150.052   137.668 -238.163<br>2011-03-07 17.88574   64.3667 6.1138   83.6287   6.1352   137.668 -238.163<br>2011-03-07 17.88575   65.3251   5.6054   63.1134   5.7166   140.741 -255.472<br>2011-03-07 17.88584   62.4033 .5002   62.0033 .6552   155.005 -269.9593<br>2011-03-07 17.89158   61.5437   2.4168   61.6651   2.1182   133.048 -256.474<br>2011-03-07 17.89158   61.5437   2.4168   61.6551   1.5208   140.741 -255.472<br>20 | 2011-08-  | 07 17.86012   86.043 | 3 33.0816   86.032 |                   |             |   |
| 2011-09-07 17.06150   84.6509 37.7052   84.6239 37.7392   129.072 - 316.738<br>2011-09-07 17.06134   84.2034 37.2640   84.120 37.3411   129.840 - 318.681<br>2011-09-07 17.06137   80.7774 38.0000   90.7536 36.4951   07.273 - 339.651<br>2011-09-07 17.06237   80.7774 38.0000   90.7536 36.4351   07.273 - 339.651<br>2011-09-07 17.06237   82.3423 38.3422   83.3186 64.3456   106.127 - 328.654<br>2011-09-07 17.06533   82.4303 35.4121   02.4530 35.5030   130.224 - 319.364<br>2011-09-07 17.06547   81.6465 34.4673   01.6134 34.5503   144.646 - 301.074<br>2011-09-07 17.06551   80.7501 33.43381   82.0837   01.6134 34.5503   144.646 - 301.074<br>2011-09-07 17.06551   80.7501 33.4301   00.7254 35.50278   125.788 - 322.724<br>2011-09-07 17.06551   80.7501 33.4301   00.7254 35.50371   139.878 - 322.728<br>2011-09-07 17.06551   80.310 32.9076   80.2754 32.50371   154.201 - 312.768<br>2011-09-07 17.06551   80.310 32.9076   80.2754 32.50371   154.201 - 312.768<br>2011-09-07 17.86588   79.5160 31.9220   84.6388   80.5171   42.817 - 273.658<br>2011-09-07 17.86581   64.7398 8.2280   84.6388   80.5171   42.817 - 273.658<br>2011-09-07 17.86581   65.3251   6.5344   63.8583   51.812 - 273.658<br>2011-09-07 17.86581   63.847   7.529   84.1453   51.812 - 273.658<br>2011-09-07 17.86581   63.847   8.1386   63.627   6.1552   137.658 - 238.163<br>2011-09-07 17.86581   63.847   8.1386   63.6287   6.1552   137.658 - 238.163<br>2011-09-07 17.86784   64.1985   63.5064   83.1134   53.768 - 238.163<br>2011-09-07 17.86784   64.9308   62.6014   63.6583   6.1766   130.658 - 265.135<br>2011-09-07 17.86784   62.4013   5.5065   63.3693   5.6022   140.025 - 272.598<br>2011-09-07 17.86784   62.4033   5.5026   62.8681   4.4586   140.741 - 255.472<br>2011-09-07 17.86784   62.4033   5.5026   62.8681   4.6584   133.568 - 238.163<br>2011-09-07 17.86784   62.4033   5.5026   62.8681   4.6584   133.568 - 236.444<br>2011-09-07 17.86784   62.4033   5.5002   62.8683   5.6022   155.009 - 269.989<br>2011-09-07 17.88784   62.4033   5.5002   62.8681   4.6584   133.568 - 236.444<br>2011-09-07 17.88784   61.3424   2.5588   6   |           |                      |                    |                   |             |   |
| 2011-09-07 17.86194   84.2094 97.2540   84.1820 97.8411   129.940 -319.681<br>2011-09-07 17.86227   00.7774 98.0000   09.7596 96.951   107.273 -339.651<br>2011-09-07 17.86228   83.3423 95.3422   83.3186 86.4951   107.273 -329.651<br>2011-09-07 17.86283   62.3143 95.3828   92.6871 155.9837   121.108 -311.191<br>2011-09-07 17.66583   62.4903 95.4121   02.4590 95.5000   138.224 -319.364<br>2011-09-07 17.66541   61.6465 14.4673   01.6134 94.5950   144.646 -301.074<br>2011-09-07 17.66545   01.7591 93.4231   00.7254 95.5193   144.646 -301.074<br>2011-09-07 17.66545   01.7591 93.4231   00.7254 95.5193   144.646 -301.074<br>2011-09-07 17.66548   80.3186 92.9075   80.2874 92.9371   139.978 -322.728<br>2011-09-07 17.66548   75.516 91.34201   00.7254 95.5193   141.000 -310.238<br>2011-09-07 17.66548   75.516 91.3220   74.4783 72.0988   152.316 -308.603<br>2011-09-07 17.66542   75.9170 92.4176   79.0099 92.5047   154.261 -312.768<br>2011-09-07 17.86548   64.7388 8.2280   64.6398 8.3057   142.617 -279.827<br>2011-09-07 17.86544   64.4740 7.7076   64.4522 7.7386   151.812 -273.688<br>2011-09-07 17.86544   64.4740 7.7076   64.4526 7.5136   130.655 -265.135<br>2011-09-07 17.86741   64.1865 7.1525   64.1433 7.2283   135.172 -271.273<br>2011-09-07 17.86741   64.1865 7.1525   64.1433 7.2281   130.655 -265.135<br>2011-09-07 17.86741   64.970 5.6055   63.3649 5.6022   140.025 -272.588<br>2011-09-07 17.86741   64.4070 5.6055   63.3649 5.6022   140.025 -272.588<br>2011-09-07 17.86741   64.4070 5.6055   63.3649 5.6022   140.025 -272.588<br>2011-09-07 17.86874   64.4089   62.6031 4.4836 1.3145   130.655 -265.135<br>2011-09-07 17.86974   64.4070 5.6055   63.3649 5.6022   140.025 -272.588<br>2011-09-07 17.88984   62.4039 3.5902   62.8041 4.4836   133.856 -238.163<br>2011-09-07 17.88984   62.4039 3.5902   62.8041 4.4836   133.856 -238.163<br>2011-09-07 17.88985   62.5088 4.0088   62.6031 4.41581   150.457 -251.138<br>2011-09-07 17.88918   61.9124 2.58898   61.8144 2.4183   33.856 -236.444<br>2011-09-07 17.88151   61.6437 2.0416   61.6551 2.1132   139.048 -275.638<br>2011-09-07 17.88154   61. | 2011-09-  |                      |                    |                   |             |   |
| 2011-09-07 17.86237   09.7774 36.0000   09.7536 96.951   107.279 -339.651<br>2011-09-07 17.86237   09.7774 36.0000   09.7536 96.951   107.279 -339.651<br>2011-09-07 17.86235   02.3143 35.8933   02.8071 35.9897   121.109 -311.151<br>2011-09-07 17.86355   02.4303 35.4121   02.4530 35.000   138.224 -313.864<br>2011-09-07 17.86431   02.0831 34.3832   02.4530 35.0278   125.768 -322.724<br>2011-09-07 17.86548   01.465 34.4673   01.6134 34.5509   144.646 -301.074<br>2011-09-07 17.86551   00.7501 33.431   00.7254 35.3937   141.000 -310.238<br>2011-09-07 17.86558   08.3188 22.3075   80.2794 22.39371   139.373 -322.728<br>2011-09-07 17.86588   08.3188 22.3075   80.257   124.2617 -273.627<br>2011-09-07 17.86588   78.5160 31.9230   78.4773 32.0038   152.316 -308.803<br>2011-09-07 17.86588   78.5160 31.9230   78.4773 32.0038   152.316 -308.803<br>2011-09-07 17.86588   63.3251 8.6314   63.8688 6.7106   138.557 -273.627<br>2011-09-07 17.86823   68.8647 8.1138   68.6237 6.1352   137.688 -238.163<br>2011-09-07 17.86823   68.8647 8.1138   68.6237 6.1352   137.688 -238.163<br>2011-09-07 17.86823   68.8647 8.1138   63.6237 6.1352   137.688 -238.163<br>2011-09-07 17.86823   68.8647 8.1138   63.6237 6.1352   137.688 -238.163<br>2011-09-07 17.86823   68.8647 8.1138   63.6237 6.1352   137.688 -238.163<br>2011-09-07 17.88824   64.4740 7.0766   64.422 7.3366   140.741 -255.472<br>2011-09-07 17.88823   68.8647 8.1138   63.6237 6.1352   137.688 -238.163<br>2011-09-07 17.88824   62.9013 4.5926   62.8014 4.6836   140.741 -255.472<br>2011-09-07 17.88915   62.9013 4.5926   62.801 4.6839   135.365 -261.138<br>2011-09-07 17.88915   62.4003 3.0402   52.0631 4.6839   135.665   133.865 -265.1188<br>2011-09-07 17.88915   62.4003 3.0402   52.063 3.0439   56.622   140.025 -275.038<br>2011-09-07 17.88915   62.4039   4.5926   62.8014 4.6836   140.741 -255.472<br>2011-09-07 17.88918   61.9124 2.5939   61.8748 2.6839   135.366 -284.404<br>2011-09-07 17.88918   61.9124 2.5939   61.8548 1.4528   145.868 -268.404<br>2011-09-07 17.88918   61.9124 2.5939   61.8548 1.4528   148.680 -256.878<br>2011-09-07 17.88923 | 2011-09-0 | 07 17.06150   04.650 | 9 37.7052   04.623 | 9 97.7992   129.0 | 72 -316.736 |   |
| 2011-09-07 17.86281   83.3423 38.3432   83.3186 36.4345   106.127 -328.854<br>2011-09-07 17.86325   82.3143 35.8833   92.871 35.3837   121.108 -311.181<br>2011-09-07 17.86433   82.433 35.8833   92.871 35.3837   121.108 -311.181<br>2011-09-07 17.86443   82.4331 34.3862   82.0345 35.9278   125.788 -322.724<br>2011-09-07 17.86516   81.1716 33.9217   81.1488 34.0153   100.830 -336.825<br>2011-09-07 17.86518   80.7551 31.4331   00.7254 33.5393   144.664 -301.074<br>2011-09-07 17.86519   80.7551 31.4331   00.7254 33.5393   144.606 -310.236<br>2011-09-07 17.86519   80.3186 32.9076   80.2874 32.3971   133.978 -322.728<br>2011-09-07 17.86519   80.3186 32.9076   80.2874 32.3971   133.978 -322.728<br>2011-09-07 17.86519   80.3186 32.9076   84.6398 8.3057   142.617 -273.827<br>2011-09-07 17.88659   84.4740 7.9076   64.4222 7.7386   151.812 -273.688<br>2011-09-07 17.88659   64.7388 8.2280   64.6398 8.3057   142.617 -273.827<br>2011-09-07 17.88659   64.328 8.2280   64.6398 8.3057   142.617 -273.827<br>2011-09-07 17.88659   64.386 7.8516   63.8686 6.7106   138.859 -205.135<br>2011-09-07 17.88659   63.9251 8.5014   63.8888 6.7106   138.859 -205.135<br>2011-09-07 17.88629   64.8647 8.1138   63.6287 6.1352   137.688 -238.163<br>2011-09-07 17.88629   63.8647 8.1138   63.6287 6.1352   137.688 -238.163<br>2011-09-07 17.88059   64.2029 3.5002   62.8601 4.4630   140.741 -255.472<br>2011-09-07 17.88059   62.9019 4.5926   62.8601 4.6539   140.741 -255.472<br>2011-09-07 17.88059   62.4039 3.5002   62.8601 4.6539   133.368 -284.444<br>2011-09-07 17.88059   62.4039 3.5002   62.8601 4.6539   135.368 -284.444<br>2011-09-07 17.88059   62.4039 3.5002   62.8609   14.854   133.360 -285.444<br>2011-09-07 17.88059   61.4044 1.5550   61.8551   1.4288   145.464 -275.852<br>2011-09-07 17.88059   61.4044  | 2011-09-  | 07 17.86184   84.208 |                    |                   | 40 -313.681 |   |
| 2011-09-07 17.86825   82.3143 35.8833   82.8871 35.9897   121.109 -311.181<br>2011-09-07 17.86843   82.4803 35.4121   02.4530 35.5008   138.224 -319.364<br>2011-09-07 17.86431   82.0831 34.8382   82.0455 35.5008   138.224 -319.364<br>2011-09-07 17.86457   01.4665 34.4673   01.6134 34.5509   144.646 -301.074<br>2011-09-07 17.86548   81.1718 33.9217   81.1488 34.0153   100.980 -336.825<br>2011-09-07 17.86548   80.3188 32.8075   80.2874 32.8371   133.978 -322.728<br>2011-09-07 17.86548   80.3188 32.8075   80.2874 32.8371   133.978 -322.728<br>2011-09-07 17.86548   78.5160 31.9230   78.4778 32.0088   152.316 -308.803<br>2011-09-07 17.86548   78.5160 31.9230   78.4778 32.0088   152.316 -308.803<br>2011-09-07 17.86548   84.4740 7.7076   64.4322 7.7336   151.812 -273.688<br>2011-09-07 17.86548   64.7388 3.2220   64.6388 8.0377   142.617 -279.627<br>2011-09-07 17.86548   64.7388 3.2220   64.4588 8.1057   142.617 -279.627<br>2011-09-07 17.86548   64.7400 7.7076   64.4322 7.7336   151.812 -273.688<br>2011-09-07 17.86548   64.7400 7.606   63.8688 8.7106   138.658 -805.135<br>2011-09-07 17.86823   63.3251 6.6314   63.8688 6.7106   138.658 -805.135<br>2011-09-07 17.86823   63.8647 8.1138   68.6237 6.1362   137.688 -233.168<br>2011-09-07 17.80813   62.4070 3.6005   63.3049 5.8422   140.025 -222.589<br>2011-09-07 17.80813   62.4070 3.6005   63.3049 5.8422   140.25 -272.589<br>2011-09-07 17.80813   62.4078 3.6005   63.3049 5.8427 6.1352   137.688 -233.168<br>2011-09-07 17.80813   62.4078 3.6005   63.3049 5.8422   140.25 -272.589<br>2011-09-07 17.80813   62.4039 3.5002   62.8693 4.4536   140.741 -255.472<br>2011-09-07 17.80814   62.5019 4.5526   62.8693 4.4536   140.741 -255.472<br>2011-09-07 17.80914   62.5019 4.5526   62.8693 4.4584   133.580 -286.989<br>2011-09-07 17.89913   61.4074 2.5598   61.8748 2.6893   135.862 -284.404<br>2011-09-07 17.89913   61.4074 2.5598   61.8748 2.6893   135.868 -286.444<br>2011-09-07 17.89138   61.3124 2.5593   81.8748 2.6893   135.868 -286.444<br>2011-09-07 17.89138   61.4074 2.5508   61.6451 2.1182   133.048 -275.838<br>2011-09-07 17.89138   61.4 |           |                      |                    |                   |             |   |
| 2011-09-07 17.86589   82.4903 15.4121   82.4530 35.5008   138.224 -319.864<br>2011-09-07 17.86413   82.0631 34.3382   82.0845 35.0278   125.788 -322.724<br>2011-09-07 17.86457   01.6465 34.4673   01.6134 34.509   144.646 -301.074<br>2011-09-07 17.86598   81.1718 33.9217   81.1488 34.0153   100.986 -336.825<br>2011-09-07 17.86598   80.3186 12.9076   80.2874 32.5193   144.066 -310.288<br>2011-09-07 17.86648   79.5160 31.9230   79.4773 32.0038   162.316 -308.803<br>2011-09-07 17.86648   78.5160 31.9230   79.4773 32.0038   162.316 -308.803<br>2011-09-07 17.86648   78.5160 31.9230   79.4773 32.0038   162.316 -308.803<br>2011-09-07 17.86648   64.7388 8.2280   84.6538 8.3057   142.617 -279.627<br>2011-09-07 17.86644   64.1865 7.1528   64.4322 7.7386   151.812 -273.688<br>2011-09-07 17.86644   64.1965 7.1528   64.1433 7.2233   135.172 -271.273<br>2011-09-07 17.86741   64.1865 7.1528   64.1433 7.2233   135.172 -271.273<br>2011-09-07 17.86741   64.1965 6.0954   69.1134   63.8686   6.7106   138.655 -265.135<br>2011-09-07 17.86741   62.5013 4.5926   62.8691 4.6836   140.741 -255.472<br>2011-09-07 17.80815   62.8508 4.0888   82.6193 4.6836   140.741 -255.472<br>2011-09-07 17.80815   62.4533 3.5002   62.8693 4.6843   135.366 -284.464<br>2011-09-07 17.80815   62.4503 3.5002   62.8693 4.6864   135.86 -286.444<br>2011-09-07 17.80815   62.4533 3.5002   62.8693   4.1541   150.457 -261.138<br>2011-09-07 17.80815   62.4533 3.5002   62.8693   4.5644   135.366 -286.444<br>2011-09-07 17.80148   61.3124 2.5598   61.8748 2.6893   135.366 -284.464<br>2011-09-07 17.80148   61.3124 2.5098   61.8651 2.1102   133.046 -275.858<br>2011-09-07 17.80148   61.4064 1.5550   61.8551 1.6288   146.668 -256.878                                                                                                   |           |                      |                    |                   |             |   |
| 2011-09-07 17.86413   82.0831 84.9382   82.0845 85.0278   125.788 -322.724<br>2011-09-07 17.86457   81.4465 34.4673   01.6134 34.5509   144.646 -301.074<br>2011-09-07 17.86518   81.1718 83.9217   81.1488 84.0153   100.880 -388.825<br>2011-09-07 17.86518   80.7501 134.4031   00.7254 32.9371   133.973 -322.728<br>2011-09-07 17.86518   80.3188 82.9076   80.2874 32.9371   133.973 -322.728<br>2011-09-07 17.86588   78.5160 31.9230   79.4773 32.0088   162.316 -308.803<br>2011-09-07 17.86688   78.5160 31.9230   79.4773 32.0088   162.316 -308.803<br>2011-09-07 17.86688   78.5160 31.9230   79.4773 32.0088   161.812 -273.688<br>2011-09-07 17.86684   64.4740 7.7076   64.422 7.7386   151.812 -273.688<br>2011-09-07 17.86674   64.1867 7.1528   64.4143 7.2233   135.172 -271.273<br>2011-09-07 17.86741   64.1867 7.1528   64.4143 7.2233   136.85 -265.135<br>2011-09-07 17.86741   64.1867 8.1138   63.6587 6.1365   138.658 -265.135<br>2011-09-07 17.86741   64.1967 8.0065   60.3689 5.6822   140.025 -272.598<br>2011-09-07 17.86873   63.4070 5.6065   60.3689 5.6822   140.025 -272.598<br>2011-09-07 17.88817   63.1536 5.0354   63.1134 5.1716   145.442 -274.488<br>2011-09-07 17.88817   63.1536 5.0354   63.1134 5.1716   145.442 -274.488<br>2011-09-07 17.88915   62.4099 3.5002   62.8091 4.4589   140.741 -255.472<br>2011-09-07 17.88915   62.4099 3.5002   62.8091 4.4589   135.366 -286.989<br>2011-09-07 17.88915   62.4099 3.5002   62.8091 4.4589   133.864   133.860 -286.989<br>2011-09-07 17.88918   61.9124 2.5898   61.8748 2.6899   135.368 -284.404<br>2011-09-07 17.8818   61.9124 2.5898   61.8748 2.6899   135.368 -284.404<br>2011-09-07 17.8818   61.9124 2.5898   61.8651 1.8288   148.64 -275.838<br>2011-09-07 17.88185   61.5437 2.0416   61.6651 2.1102   139.048 -275.838<br>2011-09-07 17.88185   61.4064 1.55 |           |                      |                    |                   |             |   |
| 2011-09-07 17.06457   01.6465 34.4679   01.6134 34.5509   144.646 -011.074<br>2011-09-07 17.06551   00.7501 33.4331   00.7254 33.5139   141.000 -10.236<br>2011-09-07 17.06642   79.9170 32.4176   79.0009 32.5047   133.978 -322.728<br>2011-09-07 17.06642   79.9170 32.4176   79.0009 32.5047   154.201 -312.768<br>2011-09-07 17.06642   79.9170 32.4176   79.0009 32.5047   154.201 -312.768<br>2011-09-07 17.86688   64.4740 7.7076   64.6388 8.3057   142.617 -279.627<br>2011-09-07 17.88684   64.4740 7.7076   64.4322 7.7886   151.812 -273.688<br>2011-09-07 17.88684   64.4740 7.7076   64.4322 7.7886   151.812 -273.688<br>2011-09-07 17.88684   64.4740 7.7076   64.439 7.2283   135.172 -271.273<br>2011-09-07 17.88741   64.1865 7.1528   64.1433 7.2283   135.172 -271.273<br>2011-09-07 17.88741   64.1865 7.1528   64.1433 7.2283   137.688 -238.168<br>2011-09-07 17.88741   64.1865 7.1528   64.1433 7.2283   136.182 -273.688<br>2011-09-07 17.88741   64.1865 7.1528   64.1433 7.2283   135.172 -271.273<br>2011-09-07 17.88741   64.1865 7.1528   64.1433 7.2283   135.62 -271.273<br>2011-09-07 17.88741   64.1965 1.5065   60.3609 6.1052   137.688 -238.168<br>2011-09-07 17.88741   64.1965 4.022   140.025 -272.538<br>2011-09-07 17.88873   63.8047 8.1138   63.6287 6.1352   136.658 -265.135<br>2011-09-07 17.88873   63.4070 5.6065   60.3609 5.6022   140.025 -272.538<br>2011-09-07 17.88873   62.4039 3.5002   62.9691 4.1591   150.457 -251.138<br>2011-09-07 17.88915   62.8508 4.0888   82.6191 4.1591   150.457 -251.138<br>2011-09-07 17.89815   62.8508 4.0888   82.6191 4.1591   150.457 -251.138<br>2011-09-07 17.89138   61.3124 2.5899   61.8748 2.6893   135.368 -284.444<br>2011-09-07 17.89138   61.3124 2.5899   61.8748 2.6893   135.368 -284.444<br>2011-09-07 17.89138   61.3124 2.5899   61.8748 2.6893   135.368 -284.444<br>2011-09-07 17.89138   61.4064 1.5550   61.8851 1.8268   148.680 -256.828<br>2011-09-07 17.89138   61.4064 1.5550   61.8851 1.8268   148.680 -256.828                                                                                                                                            |           |                      |                    |                   |             |   |
| 2011-09-07 17.86586   81.1718 33.9217   81.1486 34.0153   100.980 -386.825<br>2011-09-07 17.66551   80.7501 33.4301   80.7254 39.5193   141.000 -310.238<br>2011-09-07 17.86588   80.3186 32.9075   80.2874 32.9371   133.978 -322.728<br>2011-09-07 17.86588   78.5160 31.3230   79.4773 32.0088   162.316 -308.803<br>2011-09-07 17.86588   78.5160 31.3230   79.4773 32.0088   162.316 -308.803<br>2011-09-07 17.86584   64.7388 8.2280   64.4322 7.7386   151.812 -273.658<br>2011-09-07 17.86584   64.74740 7.7076   64.4322 7.7386   135.172 -271.273<br>2011-09-07 17.86584   64.1865 7.1529   84.1433 7.2283   135.172 -271.273<br>2011-09-07 17.86584   64.4740 7.1076   63.8080 6.7106   130.858 -205.135<br>2011-09-07 17.86584   64.4770 5.6055   69.3609 5.6022   140.025 -272.588<br>2011-09-07 17.00973   63.4070 5.6055   69.3609 5.6022   140.025 -272.588<br>2011-09-07 17.00973   62.5013 4.5926   62.1081 4.6636   140.741 -255.472<br>2011-09-07 17.00949   62.4070 5.0055   69.3609 5.6022   155.005 -269.503<br>2011-09-07 17.00949   62.4033 3.5002   62.5003 9.6552   155.009 -269.503<br>2011-09-07 17.00949   62.4033 3.5002   62.5003 9.6552   155.009 -269.503<br>2011-09-07 17.88015   62.5018 4.0888   82.6031 4.6181   150.457 -251.138<br>2011-09-07 17.09449   62.4033 3.5002   62.5003 9.6552   155.009 -269.503<br>2011-09-07 17.88015   62.6168 3.0848   82.6031 4.6181   150.457 -251.138<br>2011-09-07 17.88015   62.6108 4.0888   82.6031 4.6181   133.850 -295.444<br>2011-09-07 17.88015   62.6168 3.0848   62.1133 8.1864   133.850 -295.444<br>2011-09-07 17.88015   62.4073 2.0416   61.6051 2.1102   133.043 -275.838<br>2011-09-07 17.88015   61.4074 2.5599   81.8749 2.6889   135.868 -284.404<br>2011-09-07 17.88015   61.4064 1.5550   81.8651 1.8288   148.680 -256.878                                                                                                                                                                                                                                                                                                                                                          |           |                      |                    |                   |             |   |
| 2011-09-07 17.06551   00.7501 30.4301   00.7254 30.5133   141.000 -310.236<br>2011-09-07 17.86588   80.3186 32.3075   80.2874 32.3971   133.978 -322.728<br>2011-09-07 17.06642   79.9170 32.4170   79.8003 92.5047   154.201 -312.763<br>2011-03-07 17.86686   78.5160 31.9230   78.4778 32.0088   162.316 -308.803<br>2011-03-07 17.88650   64.7388 8.2280   64.6388 8.3057   142.617 -273.628<br>2011-03-07 17.88650   64.4740 7.7076   64.4322 7.7386   151.812 -273.688<br>2011-03-07 17.88741   64.1865 7.1529   64.1493 7.2283   135.172 -271.273<br>2011-03-07 17.88741   64.1865 7.1529   64.1493 7.2283   135.172 -271.273<br>2011-03-07 17.88723   63.9251 8.6314   63.8686 6.7106   130.855 -205.135<br>2011-03-07 17.88723   63.4070 5.6065   63.869 5.41952   137.688 -233.163<br>2011-03-07 17.88823   62.4070 5.6065   63.869 5.6022   140.025 -222.558<br>2011-03-07 17.88814   62.9013 4.5926   62.8601 4.6836   140.741 -255.472<br>2011-09-07 17.88805   62.8508 4.0883   82.6081 4.1581   150.457 -251.138<br>2011-09-07 17.88805   62.8508 4.0883   82.6091 4.1581   150.457 -251.138<br>2011-09-07 17.88805   62.8508 4.0883   82.6091 4.1581   150.457 -251.138<br>2011-09-07 17.88805   62.4033 3.5802   62.8601 4.6836   140.741 -255.472<br>2011-09-07 17.88805   62.8508 4.0883   82.6091 4.1581   150.457 -251.138<br>2011-09-07 17.88805   62.8508 4.0883   82.6091 4.1581   150.457 -251.138<br>2011-09-07 17.88805   62.4033 3.5802   62.8603 4.6836   140.741 -255.472<br>2011-09-07 17.88805   62.4033 3.5802   62.8603 4.6836   140.741 -255.472<br>2011-09-07 17.88805   62.4033 3.5802   62.8603 4.6836   140.741 -255.472<br>2011-09-07 17.88015   61.6437 2.0416   61.6051 2.1193 8.1884   133.360 -296.444<br>2011-09-07 17.88185   61.6437 2.0416   61.6051 2.1182   139.048 -276.038<br>2011-09-07 17.88185   61.6437 2.0416   61.6051 2.1182   139.048 -275.038<br>2011-09-07 17.8823   61.4064 1.5550   61.3851 1.6268   148.680 -258.378                                                                                                                                                                                                |           |                      |                    |                   |             |   |
| 2011-09-07 17.86642   79.9170 32.4176   79.8009 32.5047   154.201 -312.769<br>2011-09-07 17.86686   78.5160 31.9280   79.4773 32.0088   162.316 -308.803<br>2011-09-07 17.88650   64.7388 8.2280   64.6938 8.3057   142.617 -279.827<br>2011-09-07 17.88654   64.4740 7.7076   64.4322 7.7386   151.812 -273.668<br>2011-09-07 17.88741   64.1865 7.1523   64.1433 7.2283   135.172 -271.273<br>2011-09-07 17.88745   63.9251 6.6314   63.8868 6.7106   130.855 -265.135<br>2011-09-07 17.88674   64.1865 7.1529   64.1433 7.2283   137.688 -233.163<br>2011-09-07 17.88617   68.8647 6.1138   63.8687 6.1352   137.688 -233.163<br>2011-09-07 17.88617   68.1536 5.0954   63.1639 5.6022   140.025 -272.530<br>2011-09-07 17.08711   62.9013 4.5926   62.8601 4.6636   140.741 -255.472<br>2011-09-07 17.88015   62.8508 4.0888   82.6091 4.1531   150.457 -251.138<br>2011-09-07 17.88015   62.4033 3.5802   62.8603 9.6552   155.009 -269.9803<br>2011-09-07 17.88015   62.4033 3.5802   62.8603 9.6552   155.009 -269.9803<br>2011-09-07 17.88015   61.6437 2.0416   61.6051 2.1103 8.1864   133.360 -286.444<br>2011-09-07 17.88023   61.4064 1.5550   61.8651 1.4288   148.680 -258.878                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 2011-09-  | 07 17.06551   00.750 |                    | 4 00.5100   141.0 | 00 -310.236 |   |
| 2011-09-07 17.86686   78.6160 31.9280   78.4778 32.0088   162.316 -308.603<br>2011-09-07 17.88650   64.7388 9.2280   64.6998 8.9057   142.617 -279.627<br>2011-09-07 17.88654   64.4740 7.7076   64.4322 7.7386   151.812 -273.688<br>2011-09-07 17.88741   64.1865 7.1529   64.1433 7.2283   135.172 -271.273<br>2011-09-07 17.88741   64.1865 7.1529   64.1433 7.2283   135.172 -271.273<br>2011-09-07 17.88623   68.6647 8.1188   63.6868 6.7106   130.659 -205.135<br>2011-09-07 17.88623   68.6647 8.1188   63.6868 6.7106   130.659 -205.135<br>2011-09-07 17.88623   68.6647 8.1188   63.6868 6.7106   140.748 -272.538<br>2011-09-07 17.88617   68.1586 5.0954   63.1194 5.1716   145.442 -274.468<br>2011-09-07 17.08811   62.9013 4.5926   62.0801 4.6836   140.741 -255.472<br>2011-09-07 17.88015   62.9013 4.5926   62.8601 4.1531   150.457 -251.138<br>2011-09-07 17.88015   62.4039 3.5902   62.8603 9.4552   155.009 -269.983<br>2011-09-07 17.88015   61.6437 2.0416   61.6651 2.1183 8.1684   133.360 -236.444<br>2011-09-07 17.88123   61.4064 1.5550   61.8651 1.4288   148.680 -258.878                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 2011-09-0 | 07 17.86598   80.318 | 8 82.9075   80.287 | 4 82.8971   133.9 | 78 -322.728 |   |
| 2011-09-07 17.88650   64.7388 8.2280   64.6398 8.3057   142.617 -279.627<br>2011-09-07 17.88634   64.4740 7.7076   64.4322 7.7336   151.812 -273.688<br>2011-09-07 17.88741   64.1865 7.1529   64.1433 7.2283   135.172 -271.273<br>2011-09-07 17.88745   63.3251 6.6314   63.6866 6.7106   138.658 -265.135<br>2011-09-07 17.88623   63.6847 8.1138   63.6267 6.1352   137.688 -233.163<br>2011-09-07 17.88623   63.6847 8.1138   63.6267 6.1352   137.688 -233.163<br>2011-09-07 17.88751   62.3013 4.5926   62.8619 5.6022   140.025 -272.538<br>2011-09-07 17.88611   62.3013 4.5926   62.8619 5.6022   140.025 -272.538<br>2011-09-07 17.88815   62.8508 4.0883   82.6081 4.6636   140.741 -255.472<br>2011-09-07 17.89805   62.8508 4.0883   82.6081 4.1581   150.457 -251.138<br>2011-09-07 17.88882   62.8508 4.0883   82.6081 4.1581   150.457 -251.138<br>2011-09-07 17.88882   62.4033 3.5802   62.8603 3.6552   155.009 -269.983<br>2011-09-07 17.88882   62.4033 3.5802   62.8603 3.8552   155.009 -269.983<br>2011-09-07 17.88882   62.4033 3.5802   62.8603 3.8564   133.368 -284.464<br>2011-09-07 17.88182   61.3124 2.5899   81.8748 2.8889   135.368 -284.464<br>2011-09-07 17.88185   61.6437 2.0416   61.6651 2.1132   139.043 -275.636<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 1.4268   148.680 -258.878                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 2011-09-  |                      |                    |                   | 81 -312.769 |   |
| 2011-09-07 17.88684   64.4740 7.7076   64.4822 7.7836   151.812 -273.688<br>2011-09-07 17.88741   64.1965 7.1529   64.1493 7.2283   135.172 -271.273<br>2011-09-07 17.88745   63.9251 6.6314   63.8888 6.7106   138.855 -285.135<br>2011-09-07 17.88823   68.8647 6.1138   68.6287 6.1952   137.688 -233.163<br>2011-09-07 17.88817   68.1536 5.0954   68.1134 5.1716   145.442 -274.468<br>2011-09-07 17.88817   68.1536 5.0954   68.1134 5.1716   145.442 -274.468<br>2011-09-07 17.88817   68.1536 5.0954   68.1134 5.1716   145.442 -274.468<br>2011-09-07 17.88817   68.26508 4.0888   82.6881 4.1581   150.457 -251.138<br>2011-09-07 17.88905   62.6508 4.0888   82.6891 4.1581   150.457 -251.138<br>2011-09-07 17.88912   62.1563 3.0848   62.1183 3.1864   133.360 -296.444<br>2011-09-07 17.88912   62.1563 3.0848   62.1183 3.1864   133.360 -296.444<br>2011-09-07 17.88138   61.9124 2.5898   61.8748 2.6889   135.368 -296.444<br>2011-09-07 17.88223   61.4643 2.0416   61.6051 2.1102   139.048 -275.838<br>2011-09-07 17.88223   61.4464 1.5550   61.8643 2.5858   1.48288   148.680 -258.878                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |           |                      |                    |                   |             |   |
| 2011-09-07 17.88741   64.1965 7.1529   64.1493 7.2283   135.172 -271.273<br>2011-09-07 17.88745   63.9251 6.6314   63.8868 6.7106   138.855 -285.135<br>2011-09-07 17.88823   68.8647 8.1188   88.6287 6.1352   137.688 -233.163<br>2011-09-07 17.88817   68.1536 5.0954   63.1134 5.1716   145.442 -274.468<br>2011-09-07 17.88817   62.4033 3.5002   62.8601 4.6636   140.741 -255.472<br>2011-09-07 17.88005   62.4033 3.5002   62.8603 8.6552   155.009 -269.903<br>2011-09-07 17.88082   62.1563 3.0848   62.1183 3.1864   133.360 -236.444<br>2011-09-07 17.88188   61.9124 2.5898   61.8748 2.6889   135.368 -236.444<br>2011-09-07 17.88128   61.9124 2.5898   61.8748 2.6889   135.368 -236.444<br>2011-09-07 17.88128   61.9124 2.5898   61.8748 2.6889   135.368 -236.444<br>2011-09-07 17.88128   61.4064 1.5550   61.8651 2.1102   139.048 -275.838<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 2.1102   139.048 -275.838<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 2.1102   139.048 -275.838                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |           |                      |                    |                   |             |   |
| 2011-09-07 17.00705   63.9251   6.6314   63.0088   6.7106   130.059 -205.135<br>2011-09-07 17.00073   63.4070   5.6065   63.3609   5.6022   140.025 -272.500<br>2011-09-07 17.00073   63.4070   5.6065   63.3609   5.6022   140.025 -272.500<br>2011-09-07 17.00861   62.3013   4.5926   62.0601   4.6636   140.741 -255.472<br>2011-09-07 17.00861   62.8008   4.0888   82.6081   4.1581   150.467 -251.138<br>2011-09-07 17.80049   62.4039   3.5002   62.8009   4.1581   150.467 -251.138<br>2011-09-07 17.80949   62.4039   3.5002   62.8009   4.1581   150.467 -251.138<br>2011-09-07 17.80949   62.4039   3.5002   62.8009   4.1581   153.668 -298.444<br>2011-09-07 17.80138   61.9124   2.5899   61.8749   2.6899   135.368 -298.444<br>2011-09-07 17.80135   61.6437   2.0416   61.6051   2.1102   139.048 -275.038<br>2011-09-07 17.88123   61.4064   1.5550   61.8851   1.6288   148.680 -258.878<br>2011-09-07 17.8823   61.4064   1.5550   61.8851   1.6288   148.680 -258.878                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |                      |                    |                   |             |   |
| 2011-09-07 17.88823   63.6847 6.1138   63.6287 6.1952   137.688 -293.163<br>2011-09-07 17.00073   60.4070 5.6065   60.3609 5.6022   140.025 -272.590<br>2011-09-07 17.88817   68.1536 5.0954   68.1134 5.1716   145.442 -274.468<br>2011-09-07 17.00861   62.9019 4.5926   62.0601 4.6696   140.741 -255.472<br>2011-09-07 17.88005   62.8508 4.0888   82.6091 4.1581   150.467 -251.138<br>2011-09-07 17.89049   62.4039 3.5902   62.9609 4.1581   150.467 -251.138<br>2011-09-07 17.88082   62.1563 3.0843   62.1133 3.1664   133.360 -296.444<br>2011-09-07 17.89138   61.9124 2.5899   61.8749 2.6899   135.368 -294.404<br>2011-09-07 17.89135   61.6437 2.0416   61.6051 2.1102   139.048 -275.038<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 1.6288   148.680 -258.878<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 2.1102   139.048 -275.038<br>2011-09-07 17.8823   61.4064 1.5550   61.8651 2.1102   148.680 -258.878                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |                      |                    |                   |             |   |
| 2011-09-07 17.00073   69.4070 5.6065   69.3009 5.6022   140.025 -272.590<br>2011-09-07 17.80817   69.1536 5.0954   69.3009 5.6022   140.025 -272.590<br>2011-09-07 17.00961   62.9019 4.5926   62.0601 4.6636   140.741 -255.472<br>2011-09-07 17.8005   62.8608 4.0888   62.6091 4.1581   150.467 -251.138<br>2011-09-07 17.80049   62.4039 9.5902   62.9009 9.6552   155.009 -269.909<br>2011-09-07 17.80182   62.1563 3.0848   62.1193 8.1864   133.360 -296.444<br>2011-09-07 17.89185   61.6437 2.0416   61.6051 2.1192   139.048 -275.036<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 1.6268   148.680 -258.878<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 1.6268   148.680 -258.878                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |                      |                    |                   |             |   |
| 2011-09-07 17.00061   62.0010 4.5926   62.0601 4.6636   140.741 -255.472<br>2011-09-07 17.89005   62.6508 4.0883   82.6091 4.1531   150.457 -251.138<br>2011-09-07 17.89043   62.4033 3.5902   62.9603 9.6552   155.009 -269.983<br>2011-09-07 17.89052   62.1563 3.0843   62.1133 3.1864   133.360 -266.444<br>2011-09-07 17.89136   61.9124 2.5899   81.8748 2.6889   135.368 -294.404<br>2011-09-07 17.89135   61.6437 2.0416   61.6651 2.1132   139.043 -275.836<br>2011-09-07 17.88223   61.4064 1.5550   81.8651 1.6288   148.680 -258.878<br>stddev in RA = 133.458 1.645Km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |                      |                    |                   |             |   |
| 2011-09-07 17.89005   62.6508 4.0888   82.6091 4.1591   150.467 -251.138<br>2011-09-07 17.09049   62.4039 3.5002   62.9603 9.6552   155.009 -269.903<br>2011-09-07 17.89082   62.1563 3.0848   62.1183 3.1864   133.360 -266.444<br>2011-09-07 17.89186   61.9124 2.5899   61.8748 2.6899   135.366 -284.464<br>2011-09-07 17.89185   61.6437 2.0416   61.6051 2.1182   139.048 -275.036<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 1.6288   148.620 -256.878<br>stddev in RA = 139.458 1.645km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 2011-09-  | 07 17.88817   68.158 | 6 5.0954   68.113  | 4 5.1716   145.4  | 42 -274.488 |   |
| 2011-09-07 17.09049   62.4033 3.5002   62.0603 3.6552   155.009 -269.903<br>2011-09-07 17.09082   62.1563 3.0843   62.1193 3.1864   133.360 -296.444<br>2011-09-07 17.09185   61.9124 2.5099   61.051 2.1192   135.368 -294.404<br>2011-09-07 17.09185   61.6437 2.0416   61.6051 2.1102   139.043 -275.036<br>2011-09-07 17.08223   61.4064 1.5550   61.8651 1.6268   148.680 -258.876<br>stddev in RA = 133.458 1.645Km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 2011-09-  | 07 17.00961   62.901 | 3 4.5926   62.060  | 1 4.6636   140.7  | 41 -255.472 |   |
| 2011-09-07 17.88082   62.1563 3.0843   62.1193 3.1864   133.350 -295.444<br>2011-09-07 17.89138   61.9124 2.5899   61.8748 2.6889   135.368 -294.404<br>2011-09-07 17.89185   61.6437 2.0416   61.6051 2.1102   139.043 -275.036<br>2011-09-07 17.88223   61.4084 1.5550   61.8651 1.6268   148.680 -258.876<br>stddev in RA = 133.458 <b>1.645km on orbit</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |           |                      |                    |                   |             |   |
| 2011-09-07 17.89138   61.9124 2.5899   61.8748 2.6889   135.368 -284.404<br>2011-09-07 17.89185   61.6437 2.0416   61.6051 2.1102   139.043 -275.838<br>2011-09-07 17.88223   61.4084 1.5550   61.8851 1.6288   148.680 -258.878<br>stddev in RA = 133.458 1.645km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |           |                      |                    |                   |             |   |
| 2011-09-07 17.09105   61.6437 2.0416   61.6051 2.1102   139.043 -275.036<br>2011-09-07 17.88223   61.4064 1.5550   61.8651 1.6268   148.680 -258.876<br>atdeev in RA = 133.458 1.645km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |           |                      |                    |                   |             |   |
| 2011-09-07 17.88229   61.4084 1.5550   61.8651 1.6288   148.680 -258.878<br>stddev in RA = 193.458 1.645km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |           |                      |                    |                   |             |   |
| stddev in RA = 188,458 1.645km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |           |                      |                    |                   |             |   |
| 20000Y IN NM - 100,400                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | ,         |                      |                    |                   |             |   |
| stddev in Dec = 301.052 0.727km on orbit                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | stddev    | in RA = 133.458      |                    |                   |             |   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | stddev    | in Dec = 301.052     | 0.727km on orbit   |                   |             |   |

| NG 1 111 112                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                    | 46 - 64 Mar                          | 1.1200-0.810                       | 54 - 164 - 263  |             |  |  |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------|------------------------------------|-----------------|-------------|--|--|--|
| <b>Analysis result 2(O-C(improved))</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                    |                                      |                                    |                 |             |  |  |  |
| date                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | • /                                                |                                      | ed RA,Dec O-C in R                 |                 |             |  |  |  |
| 2011-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 9-07 17.06012   86.0493                            | 39.0016   06.0545                    | 39.0900   -23.900                  | -58.865         |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.06056   85.5988                            | 38.6503   85.6023                    |                                    | -33,396         |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.88106   85.0919                            | 38.1484   85.0926                    |                                    | -28.175         |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 9-07 17.06150   04.6509                            | 37.7052 84.6478                      |                                    | -11.200         |             |  |  |  |
| 2011-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 8-07 17.86184 84.2084                              | 37.2640 84.2064                      | 37.2560   13.626                   | -7.168          |             |  |  |  |
| 2011-01                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 8-07 17.88287   88.7774                            | 38.8008   83.7784                    | 36.8037   -4.478                   | -32.144         |             |  |  |  |
| 2011-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 9-07 17.06201   00.0420                            | 36.3432   83.3438                    | 36.3409 -7.056                     | -20.307         |             |  |  |  |
| 2011-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 8-07 17.88325   82.9143                            | 35.8833   82.9128                    | 35.8838   6.530                    | -1.808          |             |  |  |  |
| 2011-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 9-07 17.86369   82.4903                            | 35.4121   02.4053                    | 35.4146   22.301                   | -9.094          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.86418   82.0631                            | 34.9382 82.0611                      |                                    | -11.618         |             |  |  |  |
| -                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 8-07 17.88457   81.8465                            | 34.4673   81.6405                    | 34.4843 26.215                     | 10.838          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.06506   01.1710                            | 33.9217   01.1761                    |                                    | -24.172         |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.86551   80.7581                            | 33.4881 80.7684                      | 38.4322 20.115                     | 3.244           | -           |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.88598   80.3186                            | 32.9075   80.3158                    | 32.9099   11.944                   | -8.536          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.06642   79.9170                            | 32.4178 79.9097                      | 32.4172   31.199                   | 2.040           |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.88686   78.5160                            | 31.9280   79.5070                    | 31.8212   38.236                   | 8.580           |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 9-07 17.09650   64.7988                            | 8.2280   84.7393                     | 8.2244   -1.807                    | 13.192          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.00694   64.4740                            | 7.7076   64.4720                     | 7.7026 7.160                       | 17.846          | · · · · · · |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.88741   64.1865<br>9-07 17.00705   60.9251 | 7.1523   64.1882<br>6.6314   63.9268 | 7.1477   -9.718<br>6.6305   -6.253 | 18.711<br>3.979 |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.88828   68.8647                            | 6.1138   63.6668                     | 6.1155 -7.640                      | -6.155          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.88878   68.4078                            | 5.6085   83.4081                     | 5.8029   -4.729                    | 12.887          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.00917   63.1536                            | 5.0954   63.1537                     | 5.0920   -0.332                    | 3.473           |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.88961   62.9013                            | 4.5928   82.9005                     | 4,5851 2,749                       | 28,905          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.09005   62.6500                            | 4.0883   62.6496                     | 4.0801 4.246                       | 29.656          |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 8-07 17.83048   62.4033                            | 3.5802   62.4008                     | 8.5776 8.580                       | 3.212           |             |  |  |  |
| 2011-01                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 8-07 17.89092   62.1563                            | 3.0843   82.1600                     |                                    | -17.828         |             |  |  |  |
| 2011-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 9-07 17.09106   61.9124                            | 2.5099   61.9156                     | 2.5922 -11.490                     | -8.421          |             |  |  |  |
| 2011-0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 8-07 17.89185   61.8437                            | 2.0418 81.6458                       | 2.0421 -8.057                      | -1.687          |             |  |  |  |
| 2011-03                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 8-07 17.89228   61.4064                            | 1.5550   £1.4060                     | 1.5511   1.311                     | 14.118          |             |  |  |  |
| , and the second se                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                    | 0.0001                               |                                    |                 |             |  |  |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                    | 0.082km on orbit                     |                                    |                 | •           |  |  |  |
| stdde                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | v in Dec = 19.596                                  | ).107km on orbit                     |                                    |                 | J.SKA       |  |  |  |
| and the second se |                                                    |                                      |                                    |                 |             |  |  |  |





**Observed coordinates(RA and Dec) of each object at each site are calculated every second interval using STK(Satellite Tool Kit) software.** 

# **Observational simulation**

Set 1
Set 2
Set 2

**Identification at each site** 

872 and 636 objects were detected at the set 1 and 2 of Ishigaki, respectively. 473 objects were detected at both sets.

916 and 934 objects were detected at the set 1 and 2 of Rikubetsu, respectively. 458 objects were detected at both sets.

#### **Identification conditions**

**①**Difference of observation times: Less than 700-sec

- **②**Change rate of circular radiuses: Less than 0.1-degree
- **③**Difference of inclinations: Less than 1.0-degree
- **④**Difference of RAANs: Less than 1.0-degree

**⑤**Difference of direction cosines at the middle of observation time of 2 set: Less than 5.0-degree



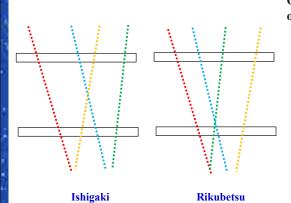
465 objects out of 473 ones at Ishigaki (98.3%) and 454 objects out of 458 ones at Rikubetsu (99.1%) are identified.

422

15XA

ISKA

# **Observational simulation**



Out of Ishigaki's 463 and Rikubetsu's 454 identified objects, 154 objects were observed at both sites.

#### **Identification condition**

- ① Difference of observation times: 5600-7700-sec
- **②** Change rate of circular radiuses: Less than 0.05
- 3 Difference of inclinations: Less than 1.5-degree

(4) Difference of RAANs: Less than 1.0-degree: Less than 1.0-degree

**⑤**Difference of direction cosines at the middle of observation time of either of the two sits: Less than 90-degree

143 objects out of 154 ones (92.9%) are identified

Same object identifications out of many observation data taken at 2 sets of observation units at 2 sites are possible. Which means objects coordinates separating about 80-degree of 2 passes are available. Therefore, accurate orbital determinations will be carried out.

### Future Plan

• Improvement of equipments : Camera lens  $\rightarrow$  Small telescope

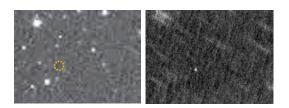
 Improvement of equipments<sup>(2)</sup>: Development of fast detection devices (CMOS sensor and so on)

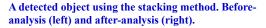
Improvement of analysis method:

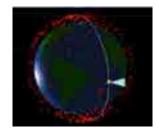
Line-identifying method  $\rightarrow$  Stacking method

### **Objective: Detection of 10cm objects at 1000km altitude**

Orbit determination experiment using the data taken at Rikubetsu and Ishigaki
 Cooperation with space based optical observation system for LEO debris







Space based optical observation system

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## **Summary**

It is possible to establish a large array system of optical sensors for LEO debris observation which is able to carry out accurate orbit determination of many LEO objects with relatively low cost.

In the future, we would like to improve observation equipments and analysis methods to detect 10cm objects at 1000km altitude. We also will carry out actual orbit determinations using the data taken at 2 separated observation site and evaluate its accuracy.