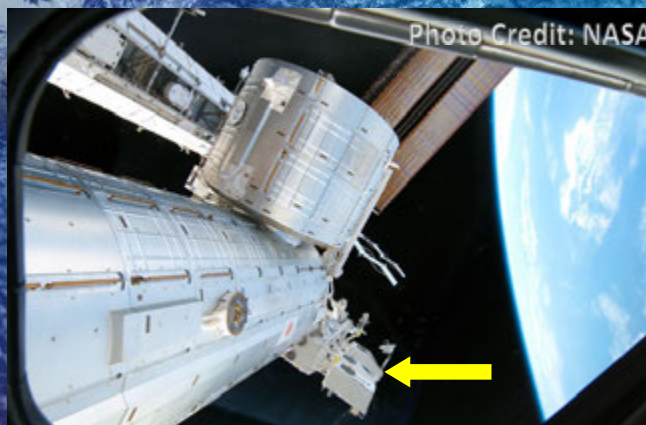


Instrument Development and Onboard Operation

T. Nishibori, S. Mizobuchi (JAXA)



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1

Scope of This Presentation

- Data Processing System (DPS-L0/L1) is shortly introduced and its development history are shown.
- Operation and instrument status during the scientific operation phase are briefly presented.
- Overall performance and data quality during the scientific observation phase are evaluated.
- It may not helpful for scientific analysis so much, but will help to understand SMILES.

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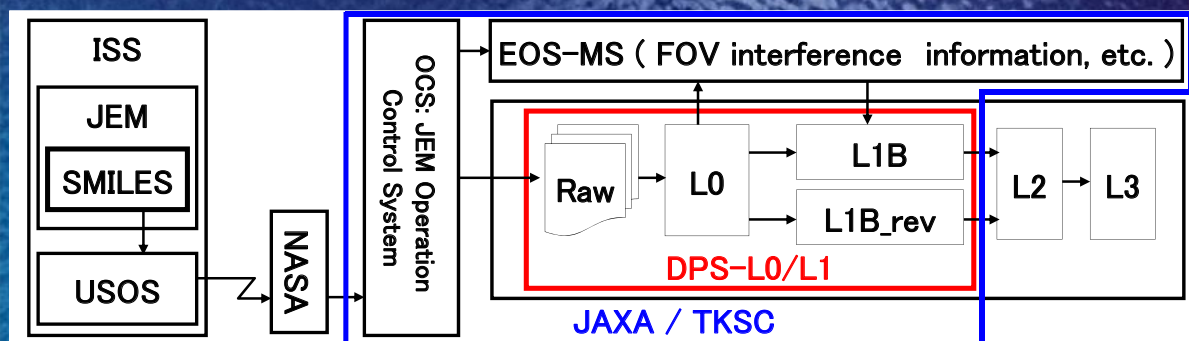
LEVEL1 PROCESSING SYSTEM

Ref.: S. Ochiai et al., "Superconducting Submillimeter-Wave Limb-Emission Sounder on the International Space Station I: Radiometric and spectral calibration and data processing," Journal of the National Institute of Information and Communications Technology, vol. 55, no. 1, pp. 83–95, 2008. [Online]. Available: <http://www.nict.go.jp/publication/shuppan/kihou-journal/journal-vol55no1/07-02.pdf>

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Data Flow



Level 0 [L0] (= Mission Data)

- Raw binary data constructed by SMILES on-board computer every 53 s. (DPS-L0/L1 reconstructs it from the down-linked packets.)
- Including AOS outputs, star tracker outputs, all house-keeping data and so on.

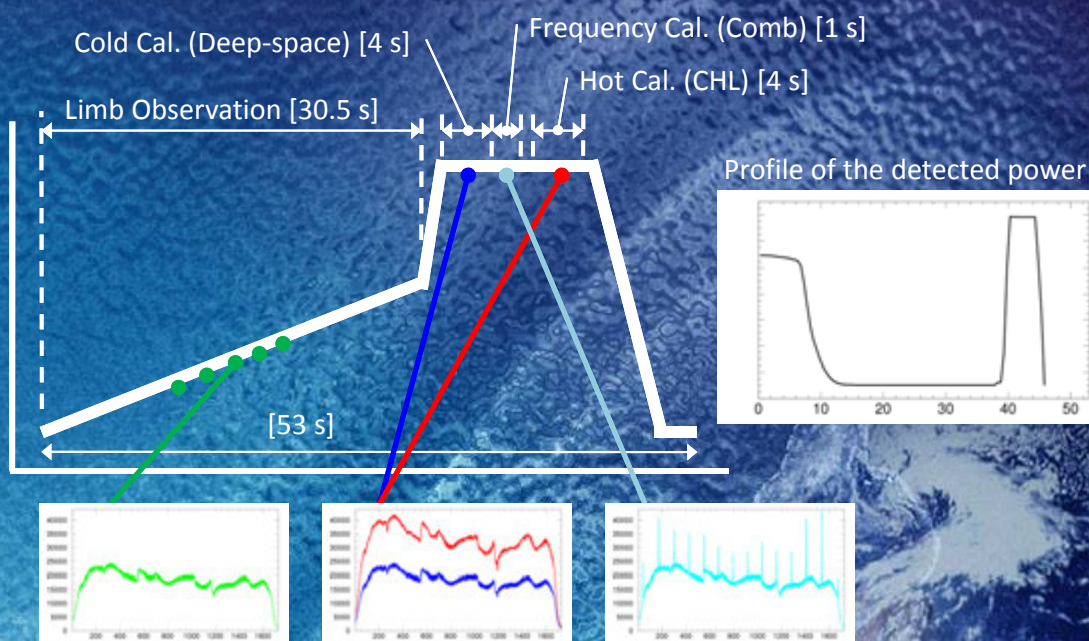
Level 1B [L1B/L1B_rev]

Calibrated limb emission spectra. Including the spectra, tangent points, calibrated frequencies, SZA, Doppler speed, flags and so on.

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Observation Data



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Development History

- 2009.09.11 : SMILES Launch
 - 2009.10.12 : First light
 - 2010.04.21 : Observation stop
 - 2011.02 : L1B data release (Ver.006) 
 - 2011.08 : L1B data release (Ver.007) 
 - 2012.12 : L1B data release (Ver.008) 
- A large yellow arrow points from the "2010.04.21 : Observation stop" entry to the "Real time process (Ver.005)" text.

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Upgrade Item (Ver.006)

1. Correction of instrument parameter
2. Correction of frequency calibration algorithm
3. Correction of relative time lag variation
4. Correction of attitude information under a certain condition
5. Data quality flag addition



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Upgrade Item (Ver.007)

1. Correction of absolute time lag
2. Correction of the interpolation method under a certain condition
3. Correction of nonlinearity effect
4. Data quality flag by using a special correlation



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Upgrade Item (Ver.008)

1. A smoothing treatment of the altitude data
2. Data quality flag by using a instrument status parameter
3. Correction of frequency calibration algorithm
4. Recalibration of the instrument parameters
5. Correction of the interpolation method under a certain condition
6. Correction of nonlinearity effect



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OPERATION STATISTICS

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Operation History

2009					2010								
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep

Launch 

Initial C/O 

Normal Operation 

Local Oscillator Trouble 

Cryocooler Trouble 

Scientific Operation
(LO/L1b)

12 Oct 2009

21 Apr 2010

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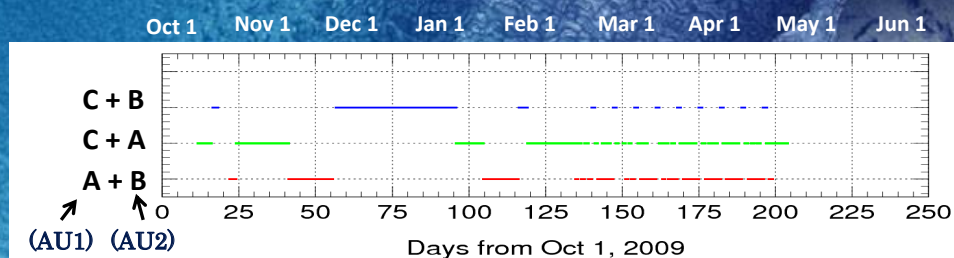
11

Band Selection

Band A : 624.27 – 625.57 GHz (O_3 , $H^{37}Cl$)

Band B : 626.37 – 625.07 GHz (O_3 , $H^{35}Cl$)

Band C : 650.37 – 649.07 GHz (ClO)

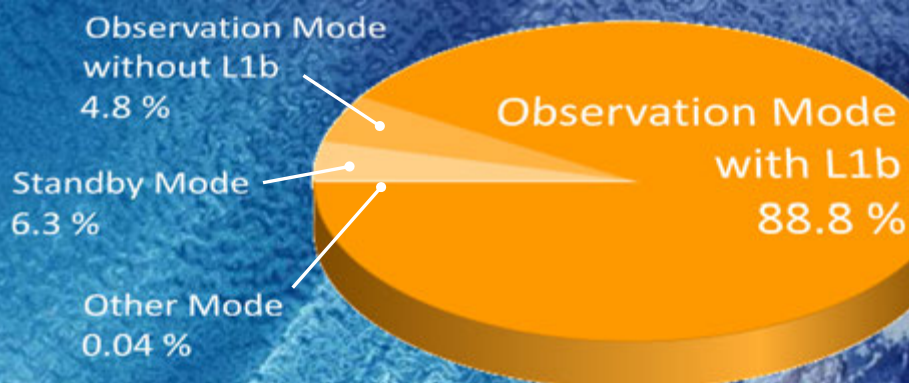


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L0/L1b Yield (1/2)

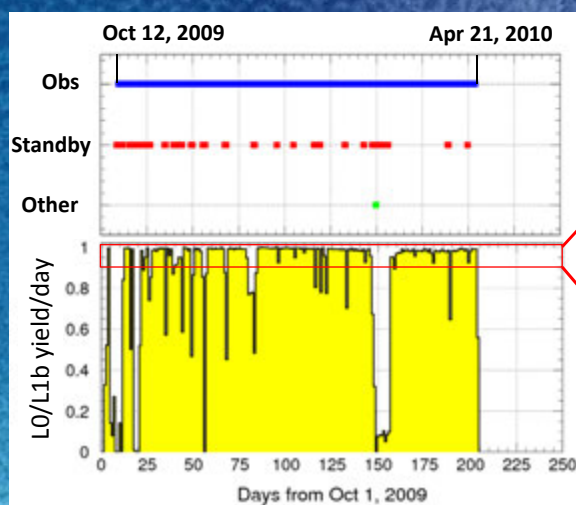
- Period:
12-Oct-2009 ~ 21-Apr-2010 (total 191 days)



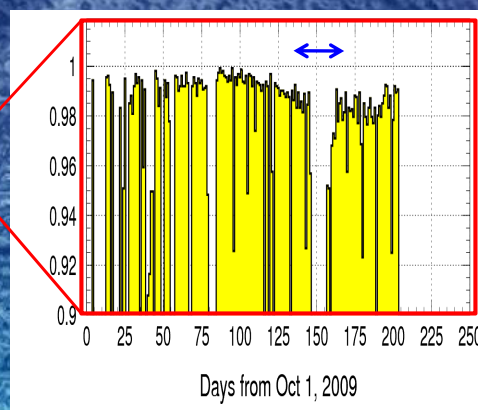
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L0/L1b Yield (2/2)



Ethernet communication
trouble (24 Feb – 5 Mar)



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“Available” Data

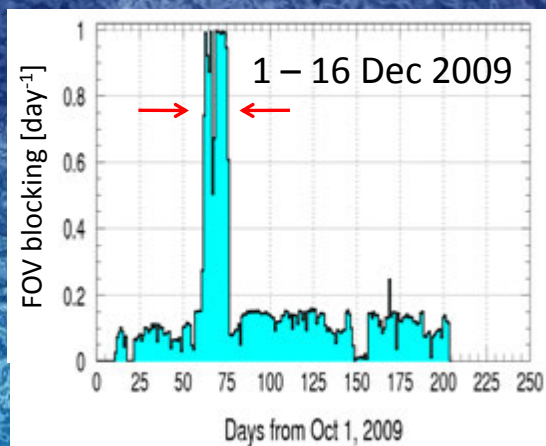
- Total 276,990 L1b (ver. 008) data are available in the operation period (12-Oct-2009 ~ 21-Apr-2010).
- The number of L1b data may be much lower for atmospheric analysis.
 - No FOV interference
 - Proper tangent height
 - ...

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FOV Interference

- ISS's solar paddle across the FOV cases ~10 % loss in every orbit



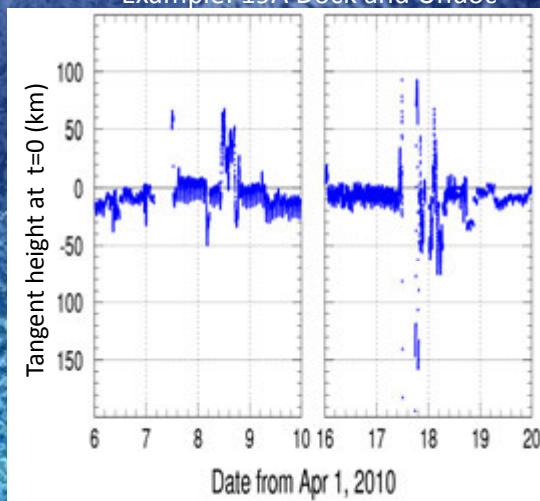
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Attitude Variation due to Dock and Undock Events

Date	Vehicle	Event
2009/10/11 01:07	18S	Undock
2009/10/18 01:40	35P	Dock
2009/10/30 17:32	HTV1	Undock
2009/11/12 15:41	5R	Dock
2009/11/16 19:28	ULF3	Dock
2009/11/25 09:53	ULF3	Undock
2009/12/01 03:34	19S	Undock
2009/12/22 22:48	21S	Dock
2010/02/05 04:25	36P	Dock
2010/02/09 17:06	20A	Dock
2010/02/20 00:54	20A	Undock
2010/03/18 08:03	20S	Undock
2010/04/04 05:25	22S	Dock
2010/04/07 07:44	19A	Dock
2010/04/17 12:52	19A	Undock

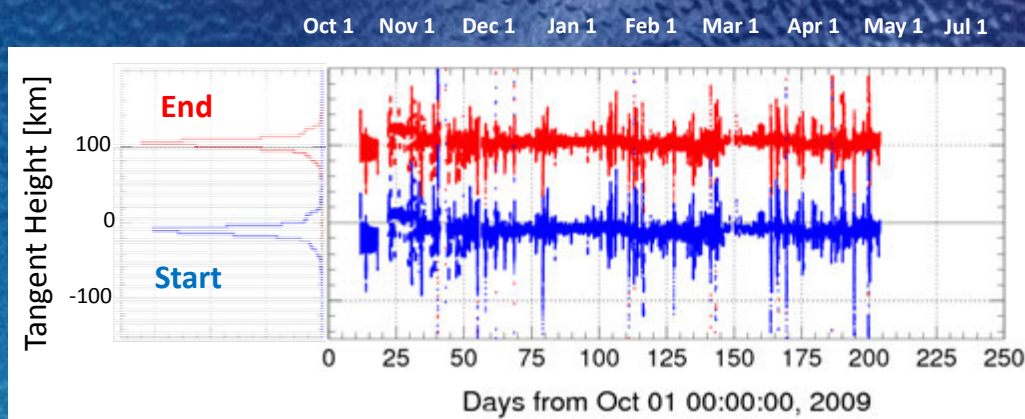
Example: 19A Dock and Undock



3. SMILES Science evaluation panel

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Tangent Height Variation



Scan period	Mean [km]	Sigma [km]
End of Scan (t=30s)	103.17	12.32
Start of Scan (t=0s)	-10.27	13.99

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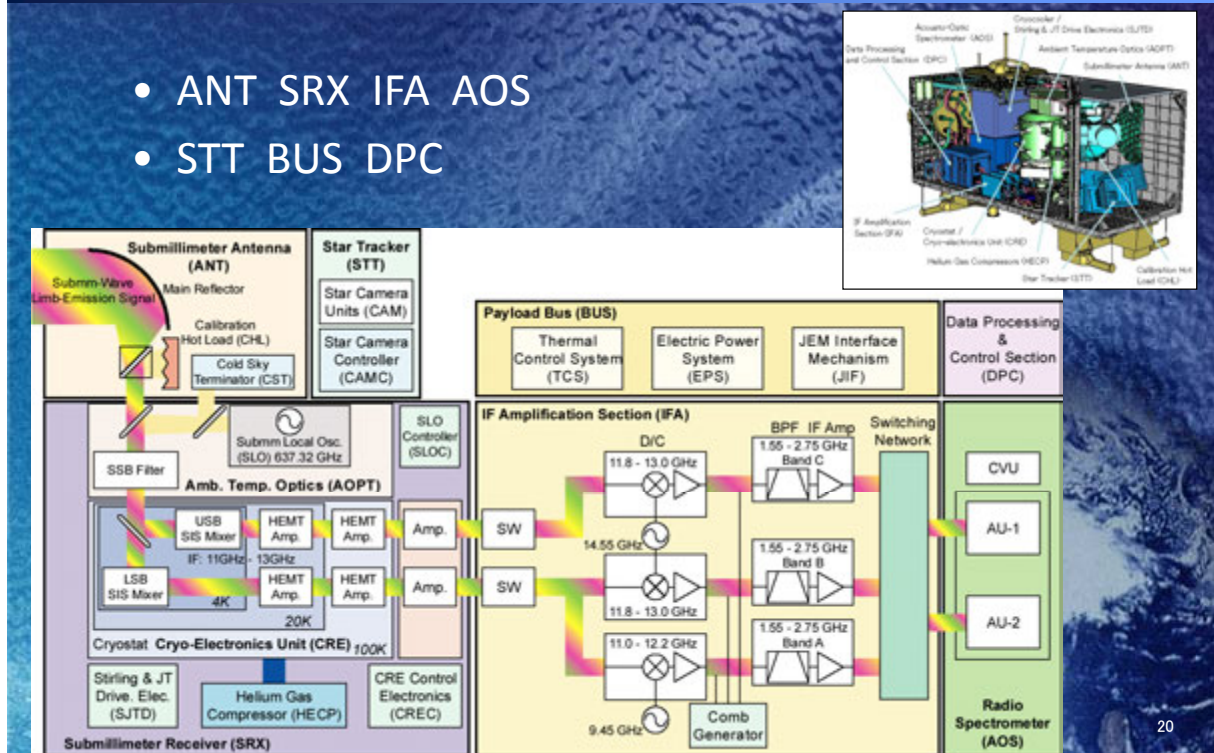
INSTRUMENT STATUS

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Instrument Block Diagram

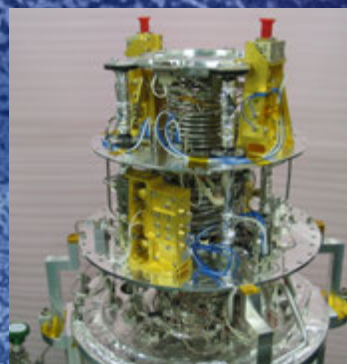
- ANT SRX IFA AOS
- STT BUS DPC



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Mechanical Cooler and SIS Mixer

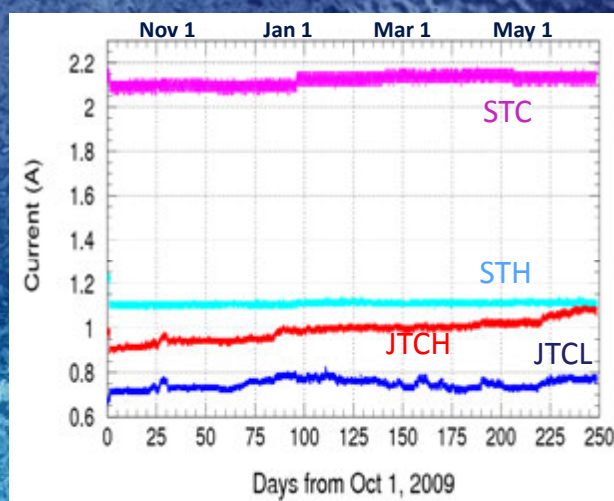
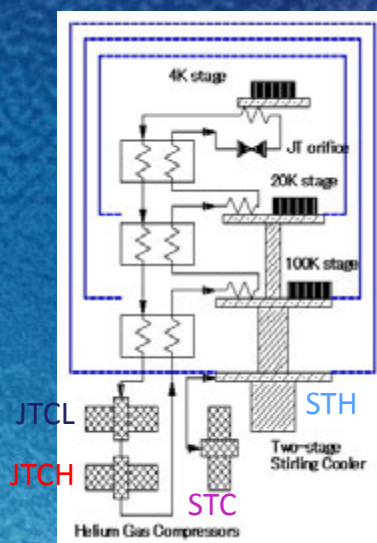
- **Mechanical Cooler**
 - **Two-stage stirling and J-T**
 - **Cooling Capacity :**
20mW @ 4K, 200mW @ 20K,
1000mW @ 100K
 - **Power Consumption : < 300 W**
 - **Mass : 90 kg**
- **SIS Mixer**
 - **RF : 640 GHz**
 - **IF : 11-13 GHz**
 - **Junction : Nb/AlO_x/Nb, ~ 7 kA/cm²**
 - **RF Matching : PCTJ with Integrated Circuit**
 - **Fabricated at Nobeyama RO**



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Compressor Performance

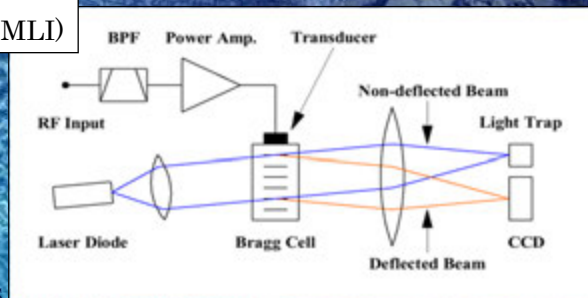
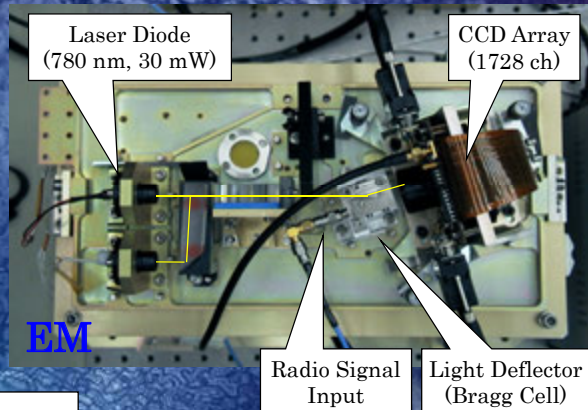
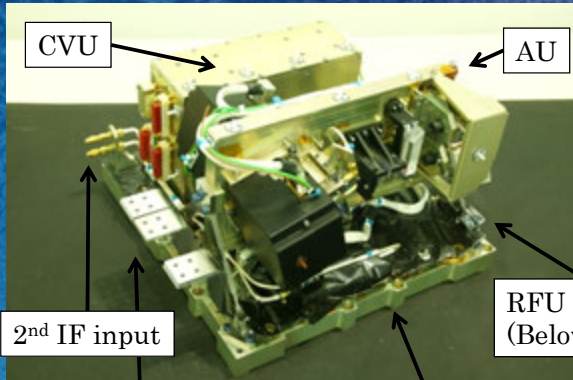


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AOS (Acousto-optical spectrometer)

- AU (Analyzer Unit)
- RFU (Radio Frequency Unit)
- CVU (Control Video Unit)



Ref.: H. Ozeki et al., "On orbit performance of radio spectrometers of Superconducting Submillimeter-Wave Limb-Emission Sounder (JEM/SMILES)," in Proc. SPIE Remote Sensing, Prague, Czech Republic, Sep. 2011.

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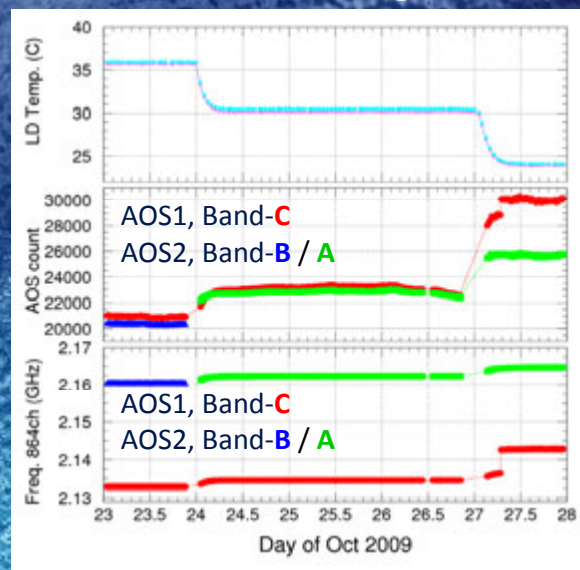
AOS Thermal Control Inhibition

- The AOS Temperature should be kept stable for the atmospheric observation and lower for the long lifetime.
- The cooling system for thermal control of JEM worked effectively.



AOS thermal control heaters were turned off:

1. 24 Oct 00:24:33 OPPL
2. 27 Oct 00:42:45 BAPL1
3. 27 Oct 00:44:57 BAPL2

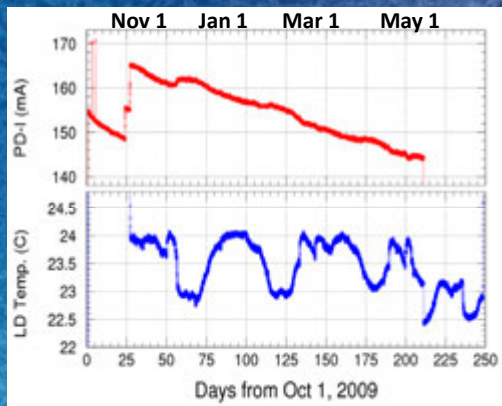


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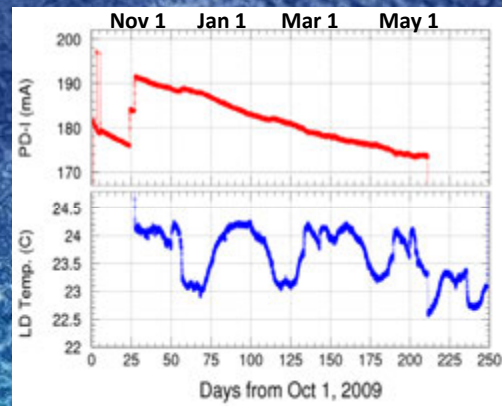
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AOS Laser Diode

AOS1



AOS2



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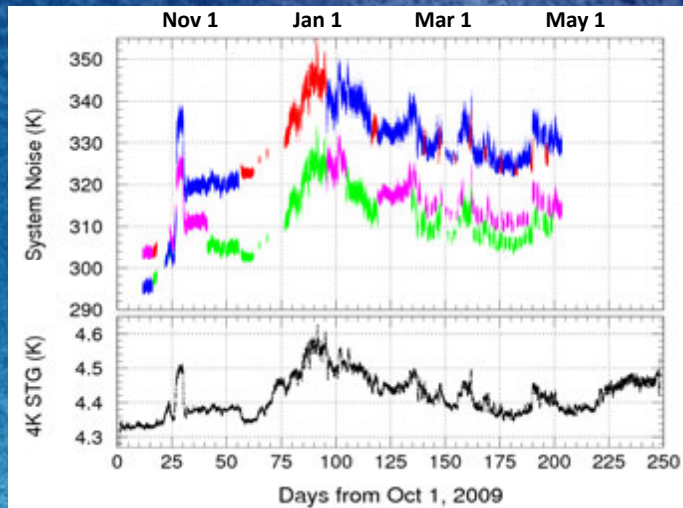
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OVERALL PERFORMANCE

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System Noise Temperature

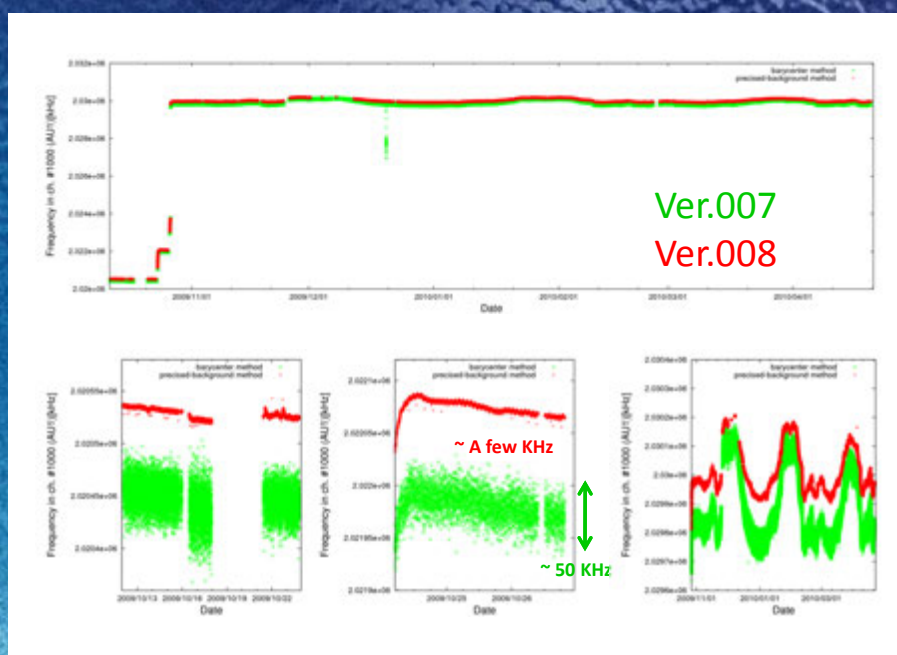


Band-A (AOS1)
 Band-A (AOS2)
 Band-B (AOS2)
 Band-C (AOS1)

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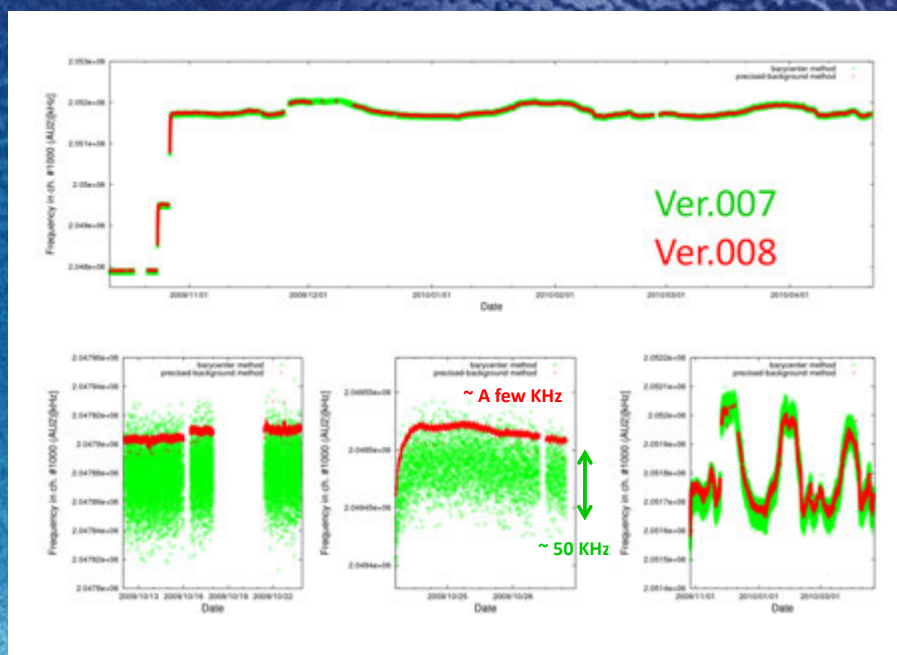
Frequency Calibration (AOS1)



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Frequency Calibration (AOS2)



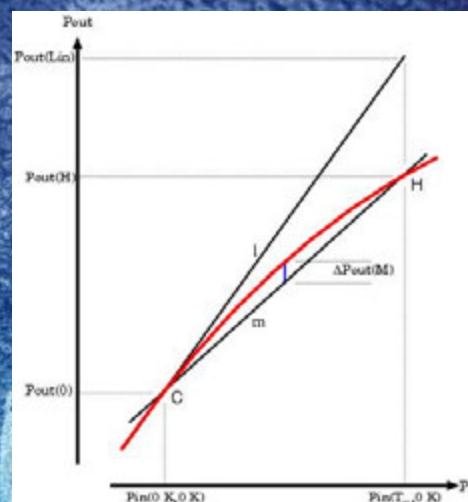
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Gain Nonlinearity

- Gain nonlinearity causes a systematic error in the measured atmospheric emission.
- The intensity scaling may have an error of up to 3% by the non-linearity.
- Gain linearity was measured in ground system tests.
- The measured gain linearity was almost consistent with the estimation
- We could know the gain linearity in the accuracy of less than 1%.

Ref.: S. Ochiai et al., "Gain nonlinearity calibration of submillimeter radiometer for JEM/SMILES," IEEE J. Sel. Topics Appl. Earth Obs. Remote Sens., vol. 5, no. 3, pp. 962-969, 2012.

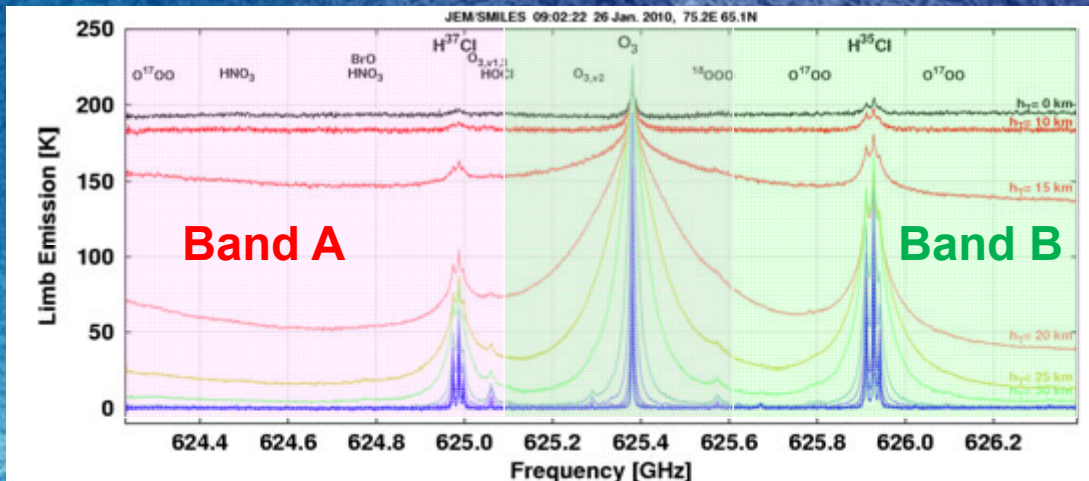


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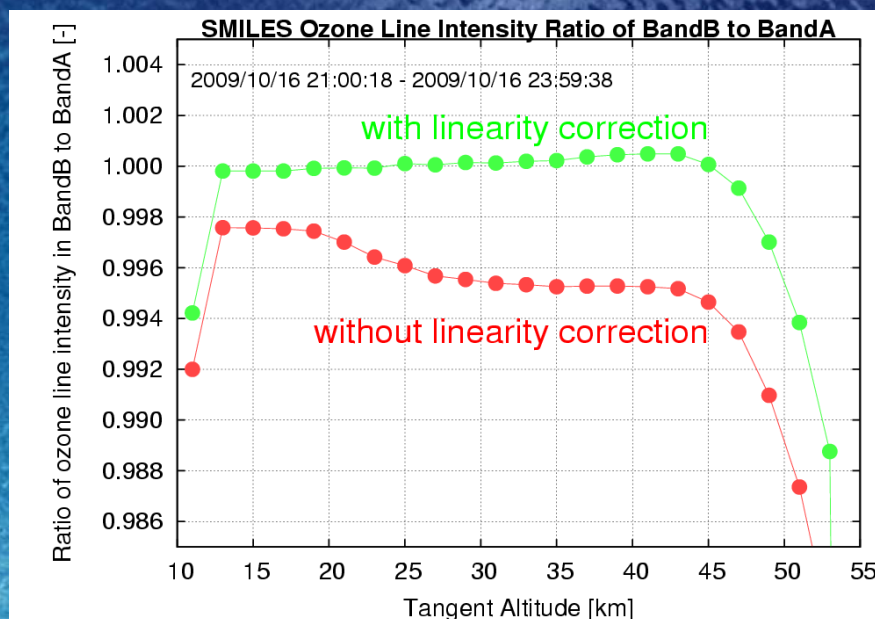
Nonlinearity Correction (1/2)

- SMILES can simultaneously observe ozone line at 625.371 GHz with two receiver backends.
- Observed intensities with two bands must be identical within an error.



Nonlinearity Correction (2/2)

- Nonlinearity correction improves coincidence.





DATA QUALITY

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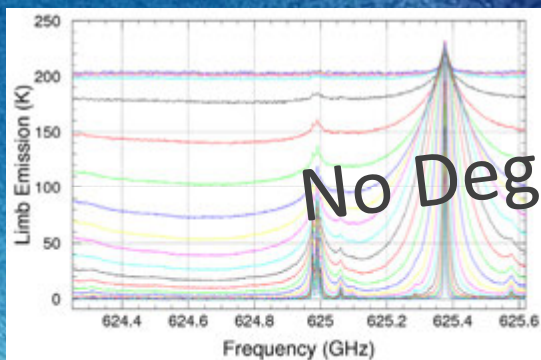
33

Spectrum comparison

- Band-A spectrum at the first and the final scan...

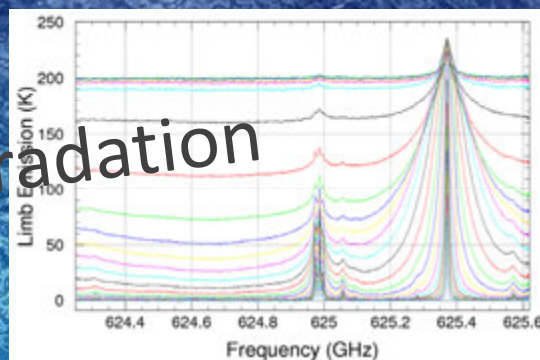
“First Light”

12 Oct 2009, 02:08 (GMT)



“Final Light”

21 Apr 2010, 08:59 (GMT)



No Degradation

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Summary

- Observation data obtained in 12 Oct 2009 – 21 Apr 2010 are available.
- AOS thermal control heaters were turned off in two steps.
- We found deteriorations with age in some instrumental parameters.
 - Decreasing of photo diode current for AOS
 - Increasing of JT compressor driving current
- These deteriorations may not affect L0/L1b data qualities.
- We found no degradation in the data quality throughout the scientific operation period.

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Publication list

K. Kikuchi et al., "Flight model performance of 640-GHz superconductor insulator/superconductor mixers for JEM/SMILES mission," *J. Infrared, Millimeter, and Terahertz Waves*, pp. 1205–1211, 2010.

T. Manabe et al., "Measurement of the offset-Cassegrain antenna of JEM/SMILES using a near-field phase-retrieval method in the 640-GHz band," *IEEE Trans. Antennas Propag.*, vol. 60, no. 8, pp. 3971–3976, 2012.

T. Manabe et al., "Submillimeter-wave antenna and receiver optics for JEM/SMILES," *IEICE Transactions on Communications*, vol. J95-B, no. 9, pp. 990–1002, 2012 (in Japanese).

S. Mizobuchi et al., "In-orbit measurement of the AOS (acousto-optical spectrometer) response using frequency comb signals," *IEEE J. Sel. Topics Appl. Earth Obs. Remote Sens.*, vol. 5, no. 3, pp. 977–983, 2012.

S. Ochiai et al., "Gain nonlinearity calibration of submillimeter radiometer for JEM/SMILES," *IEEE J. Sel. Topics Appl. Earth Obs. Remote Sens.*, vol. 5, no. 3, pp. 962–969, 2012.

S. Ochiai et al., "Receiver performance of the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) on the International Space Station," *Geoscience and Remote Sensing, IEEE Transactions on*, vol. 51, no. 7, 2013.

Y. Iida et al., "Space-borne submillimeter wave calibration load with specular absorbers," *J. Remote Sensing Society of Japan* (in press, in Japanese), vol. 33, no. 2, 2013.

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