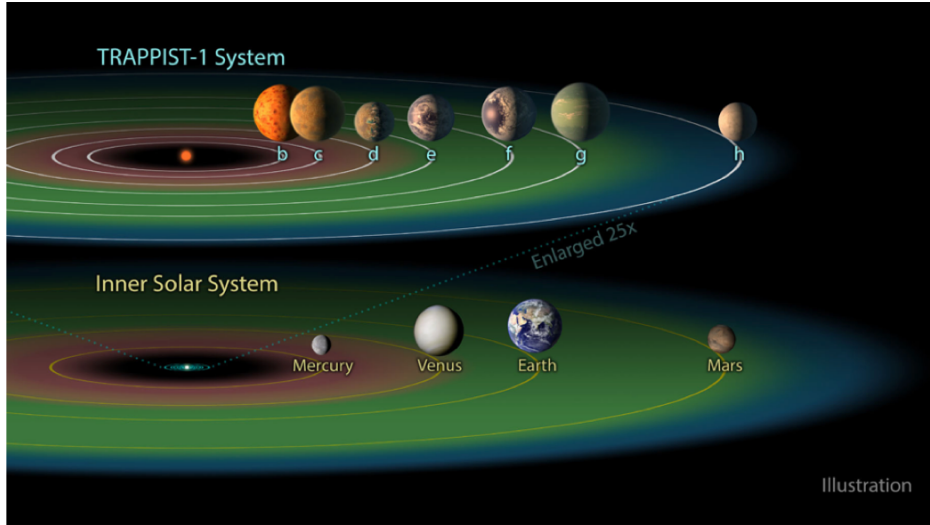


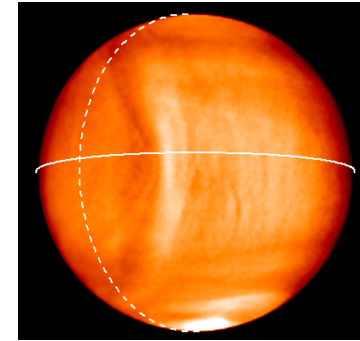
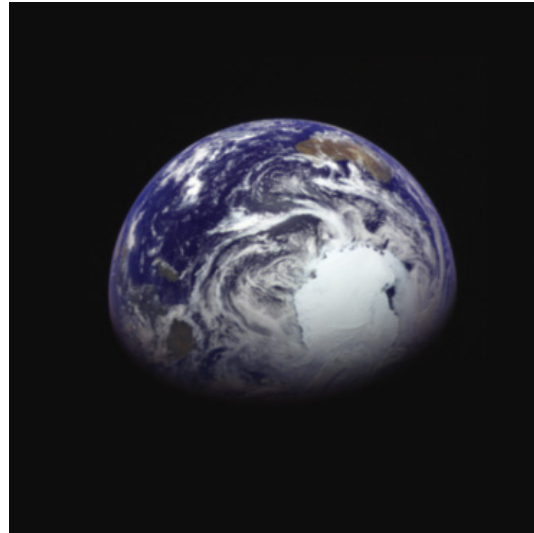
WSO-UV搭載用系外惑星観測装置 (紫外線分光器とコロナグラフ)

○亀田 真吾(立教大)・生駒 大洋(東大)・村上 豪(JAXA)・
成田 憲保(東大)・塩谷 圭吾(JAXA)・西川 淳(NAOJ)・田
村 元秀(東大)・小玉 貴則(東大)・寺田 直樹(東北大)・吉川
一朗(東大)・杉田 精司(東大)・倉本 圭(北大)



- WSO-UV:口径1.7m紫外線望遠鏡(GSO) ロシア
- 系外惑星大気観測のアイディア・装置提供依頼
 - 水素・酸素原子外気圏観測
 - MCP検出器の効率向上
 - コロナグラフによる中間質量惑星の観測アイディア・検出器

地球と金星



大きさほぼ同じ

生命・文明

海洋

N_2 (78%), O_2 (21%), Low CO_2

磁場有り

生命無し

海無し

CO_2 (96%)

磁場無し

系外ではどうやって区別するか？

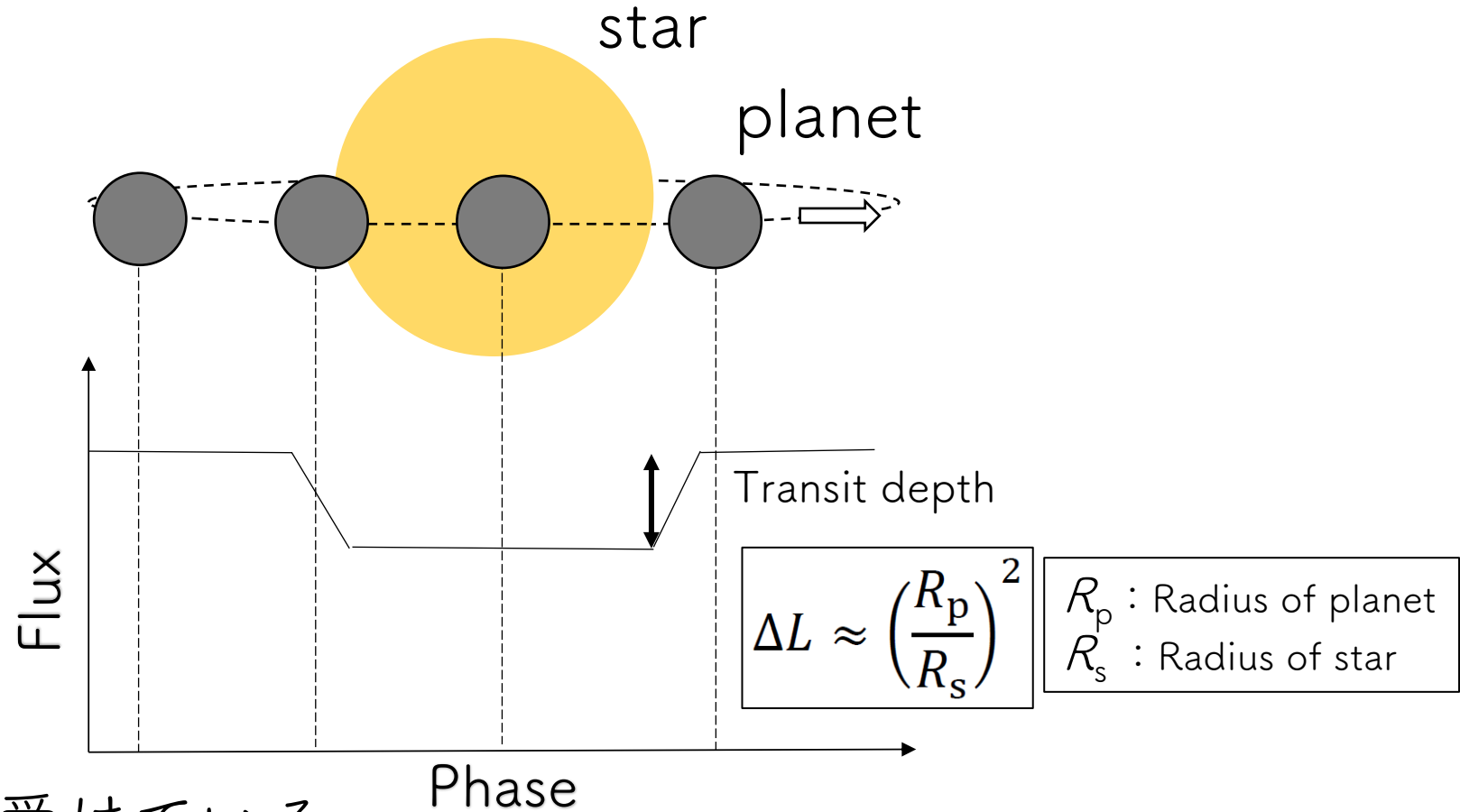
Transit (Light curve) observation

- 大きさ
- 軌道情報

- + ドップラーで
- 質量

→ 地球型で
ほどよい輻射を受けている
かどうか、は分かる。

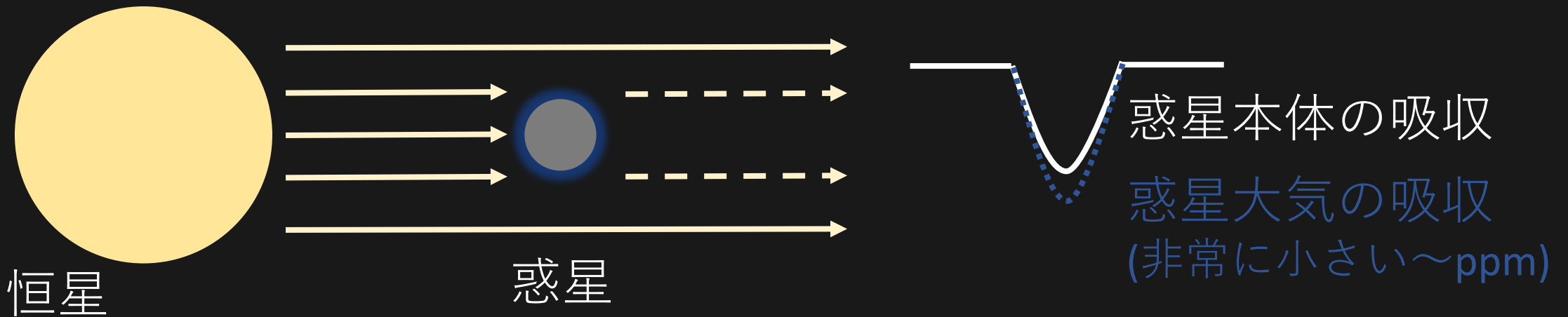
→ 大気は？



トランジット観測による地球と金星の判別

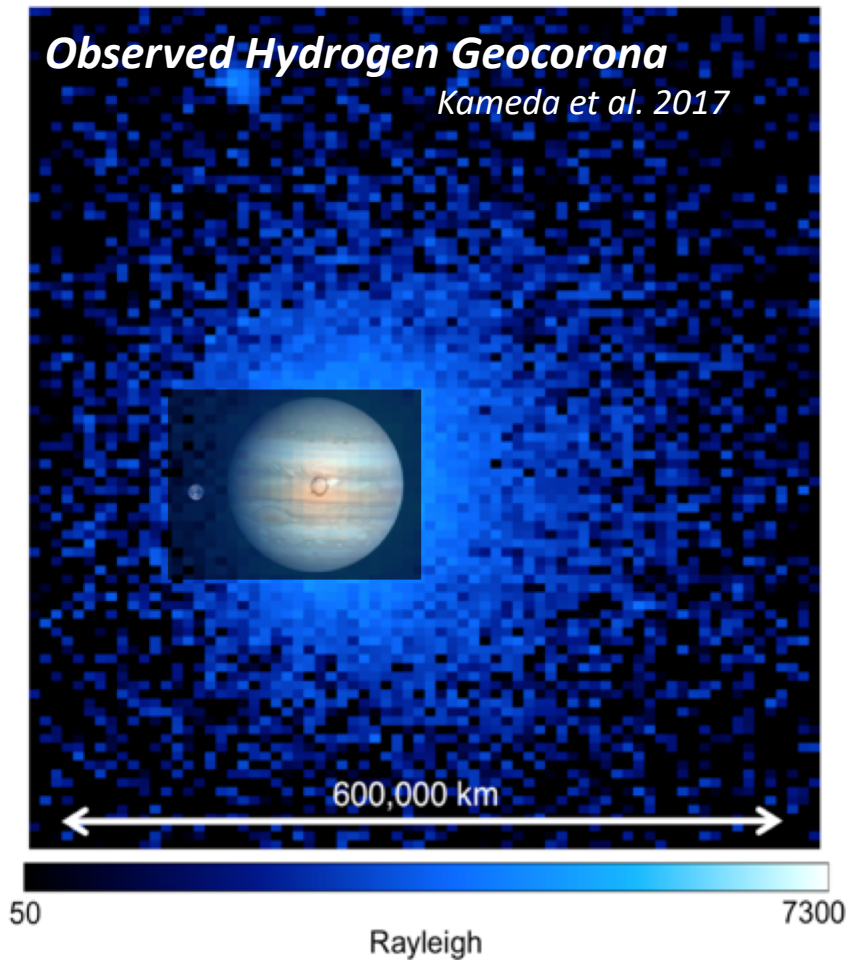
JWST（口径6.4m、可視～近赤外）でも容易ではない

(Kaltenegger & Traub, 2009)

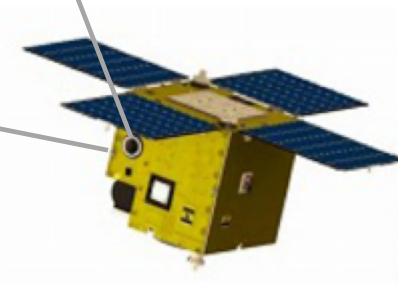
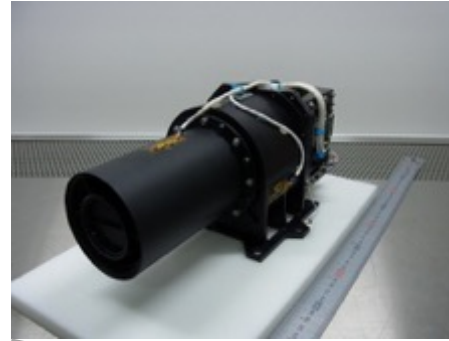


主星からの強いEUV放射によって広がった外圏の酸素原子の検出により、地球のような惑星と金星のような惑星を判別する

地球型惑星の外気圏（原子が主）



*Lyman Alpha Imaging Camera (LAICA)
onboard PROCYON*



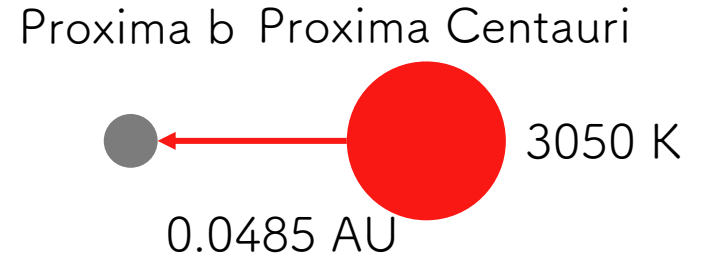
**The Earth looks
extremely large
in the UV**

熱輻射とEUV輻射

最も近い恒星と系外惑星

Proxima Centauri (10-40 nm)

88.9 erg/cm²/s @Proxima b (Linsky+2014)

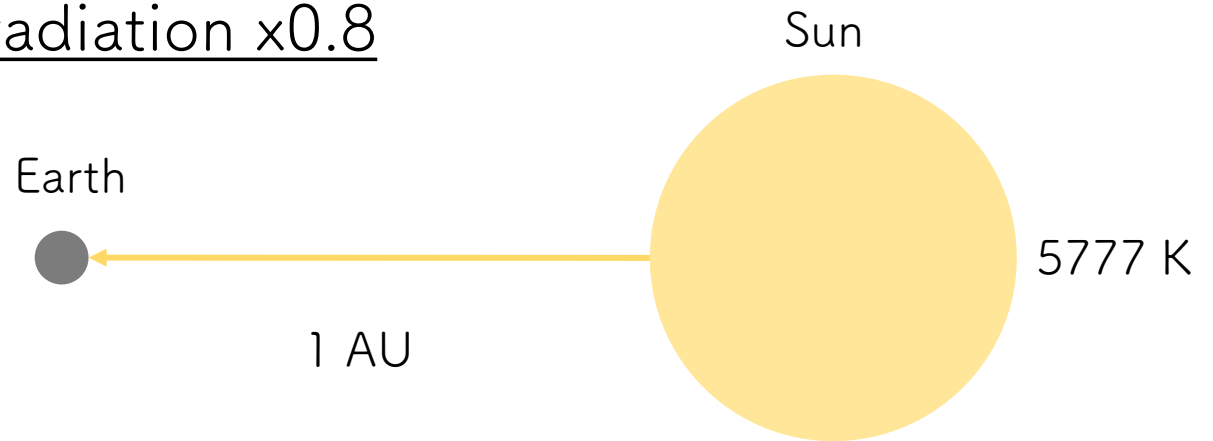


Thermal irradiation x0.8

Solar EUV (10-117 nm)

2.44~6.53 erg/cm²/s @Earth

(Linsky+2014)

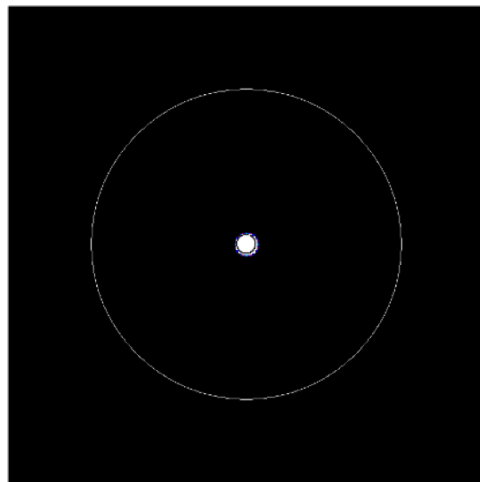
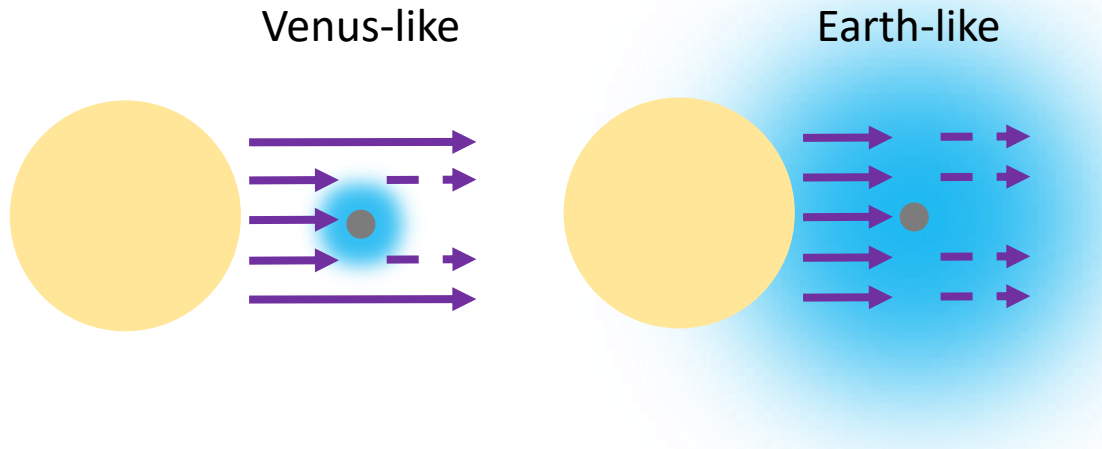


> **x14** EUV irradiation @ Proxima b

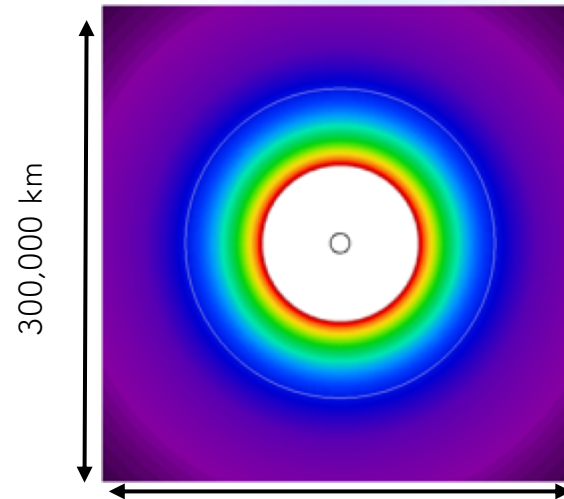


低温度星 : 太陽系近傍の恒星の80%
Kepler以降の主ターゲット
(TESS, PLATO2.0)
○地球型惑星が検出され始めた 8

Hot Oxygen Corona of Earth-like Planets



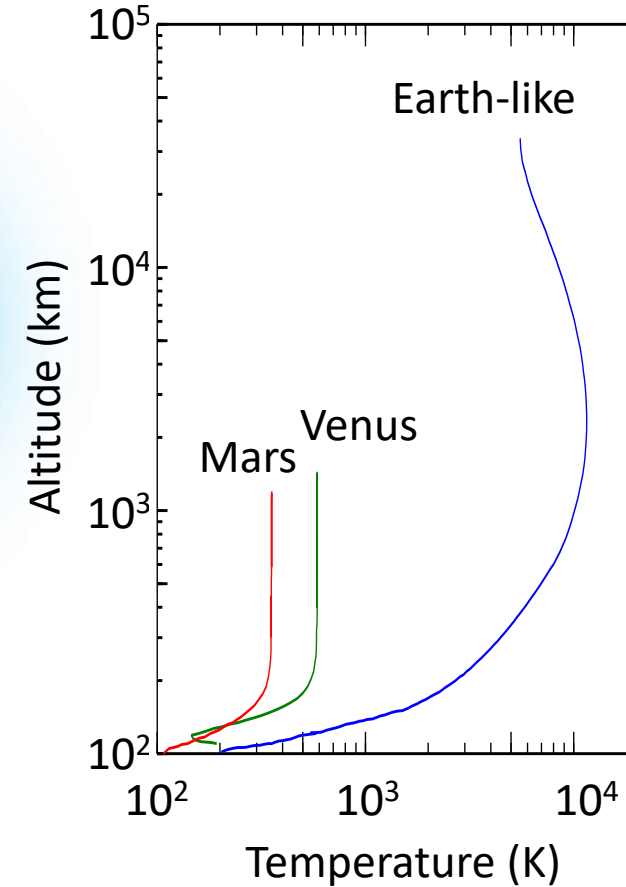
Black: Planet White: Star



300,000 km
300,000 km
Transit depth ~24%

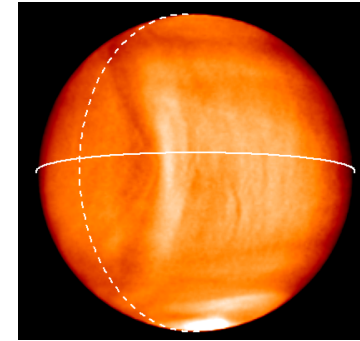
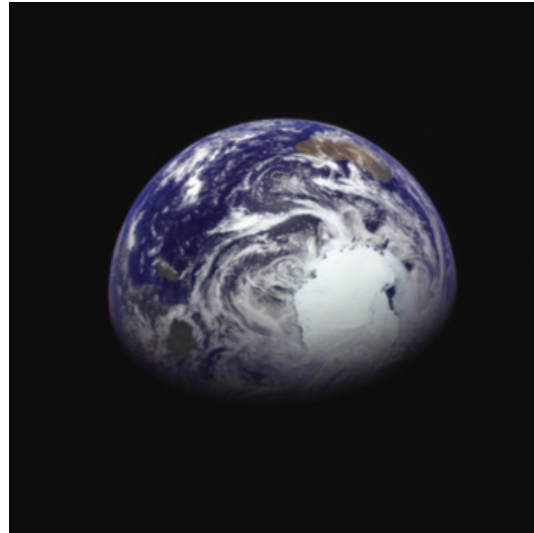
Temperature of atmospheres with high EUV irradiation

Kulikov+07, Tian+08



Only the Earth-like planet has extended oxygen corona

地球と金星



生命・文明
海洋
N₂(78%),
磁場有り

大きさほぼ同じ

大気冷却

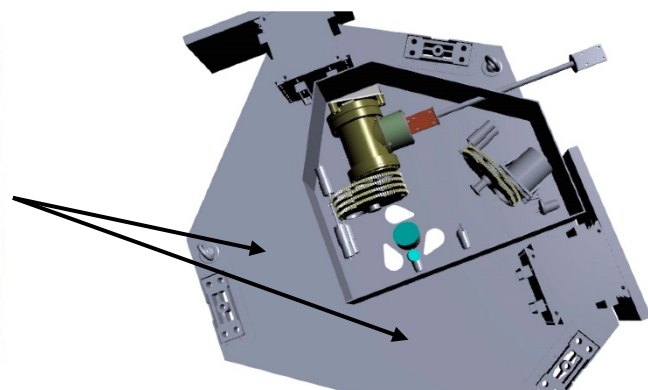
O₂(21%), Low CO₂

生命無し
海無し
CO₂ (96%)
磁場無し

どうやって区別するか？

World Space Observatory-Ultraviolet (WSO-UV)

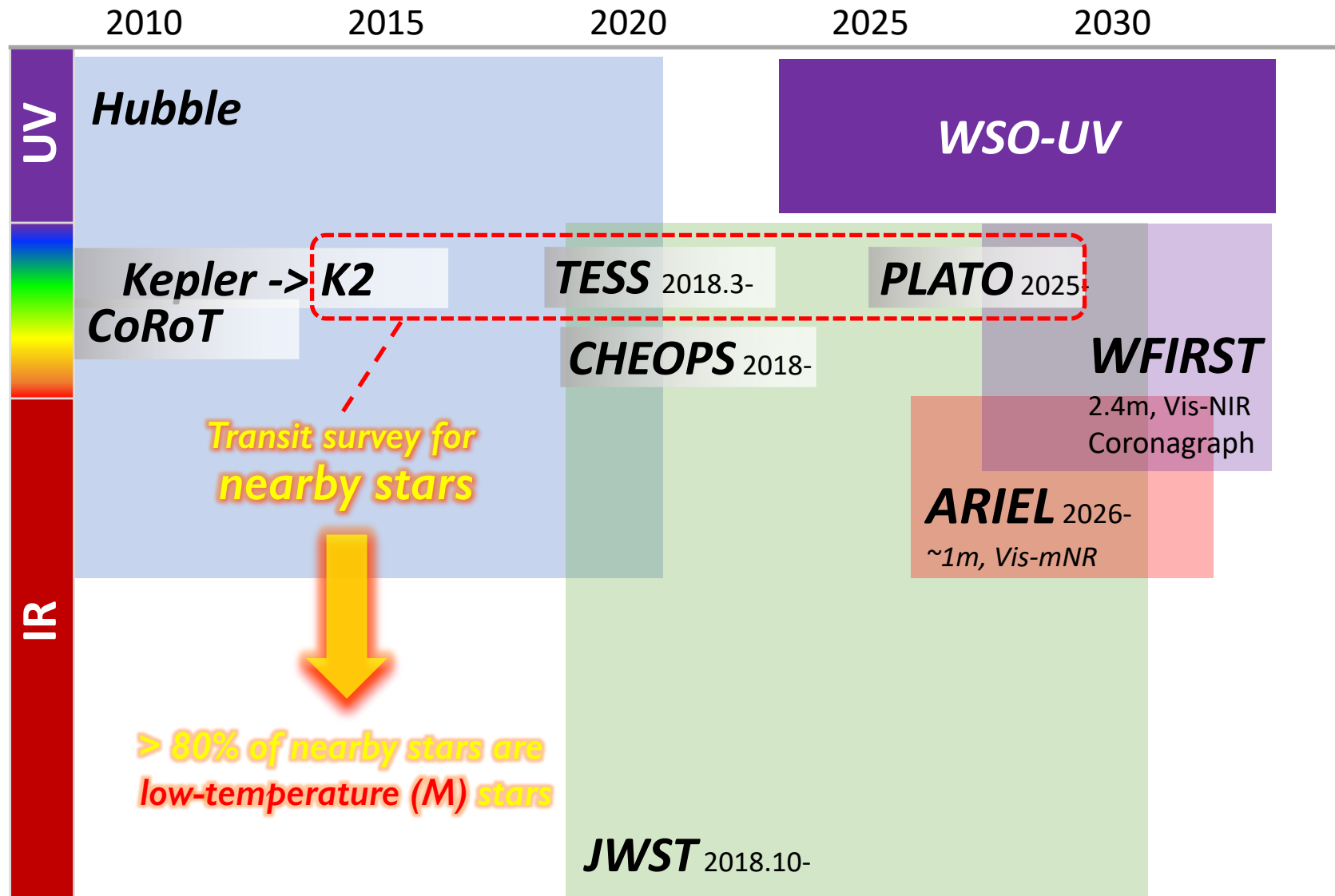
- Target launch: 2023
- Diameter : 1.7 m
- Spectral range : ~110-320 nm
(H Lya 122nm, O I 130nm)
- Orbit: GSO (6.6 Re)-> outside of oxygen geocorona



Science addition to WSO-UV Exoplanet exploration..., IKI RAS 29 July 2016

Space Telescopes

for exoplanet detection & characterization

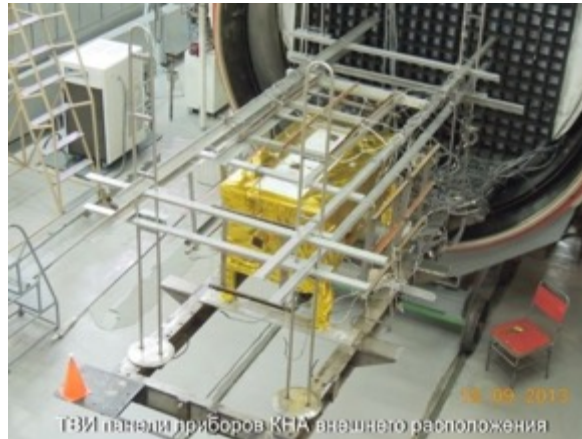
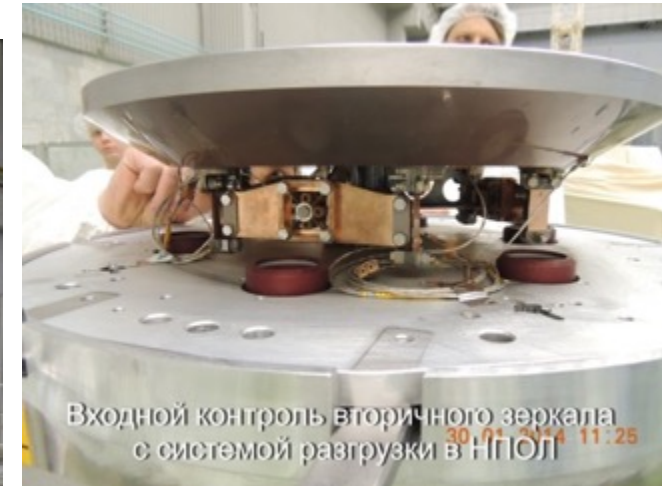
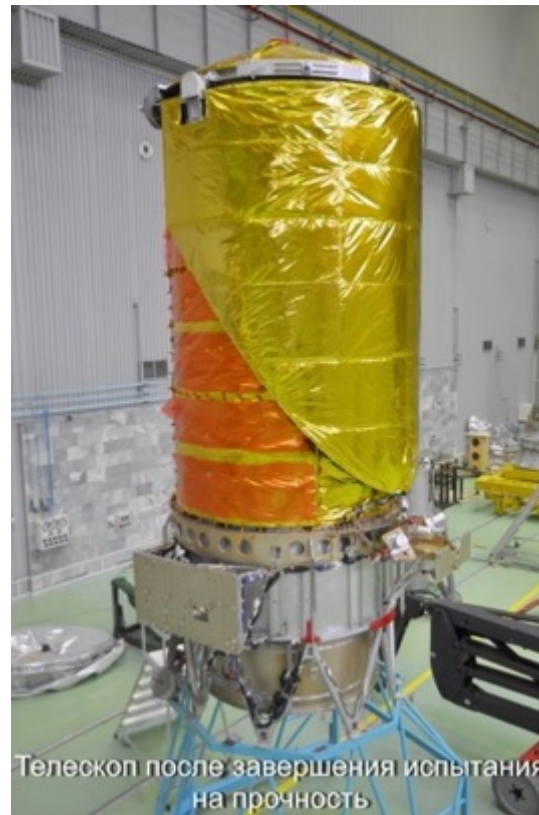


ロシア側状況

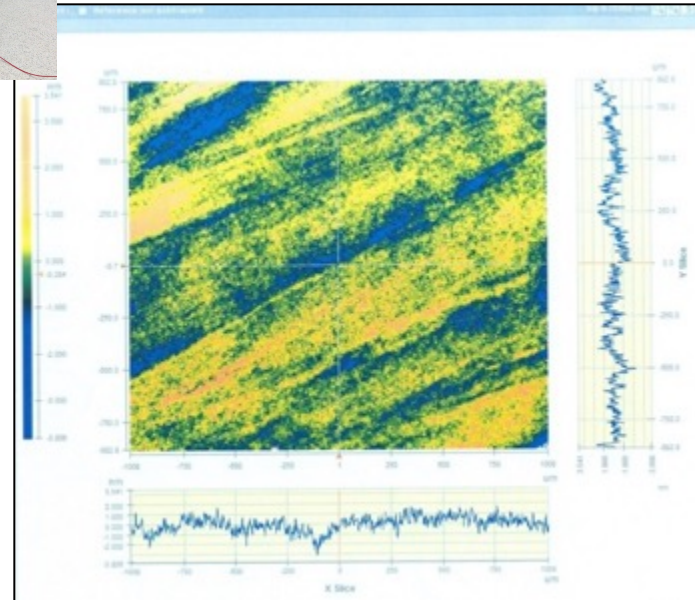
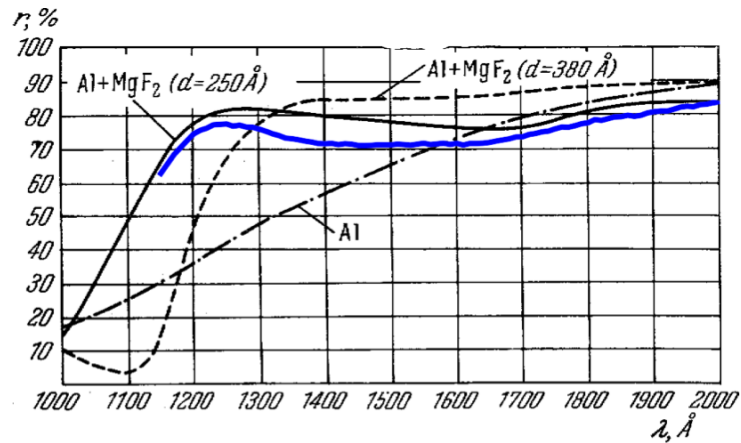
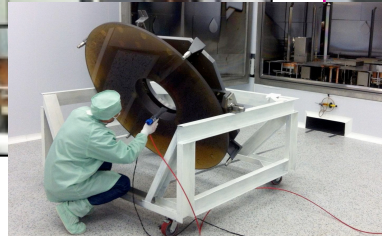
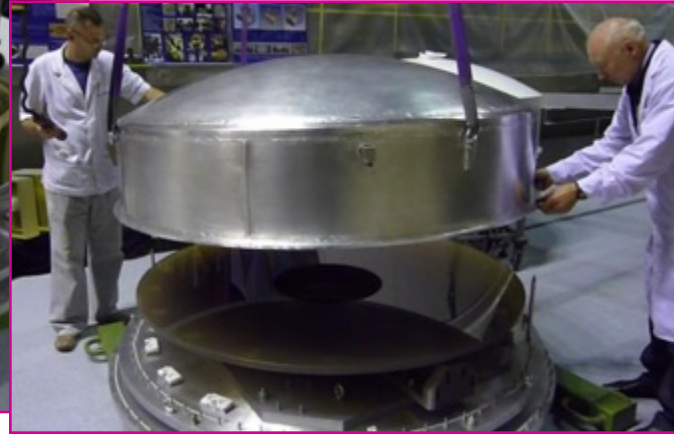
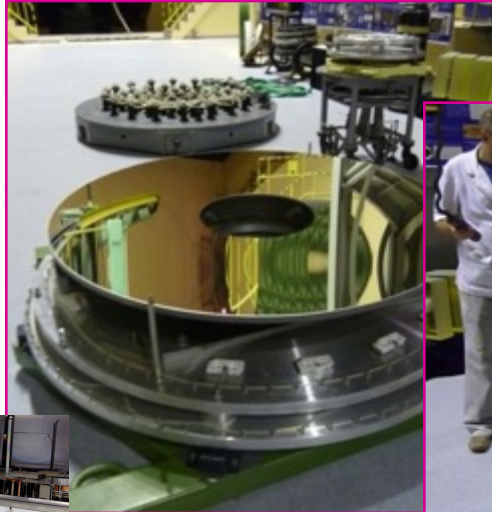
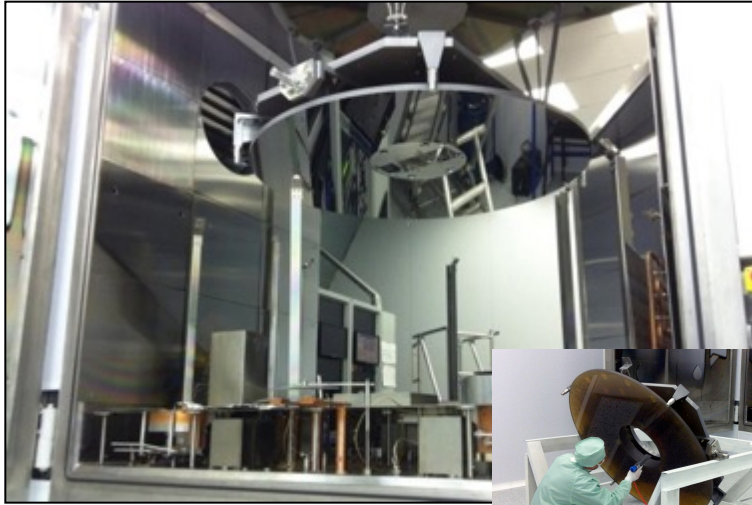
- ロシア側の衛星計画の進捗状況



The T-170M telescope



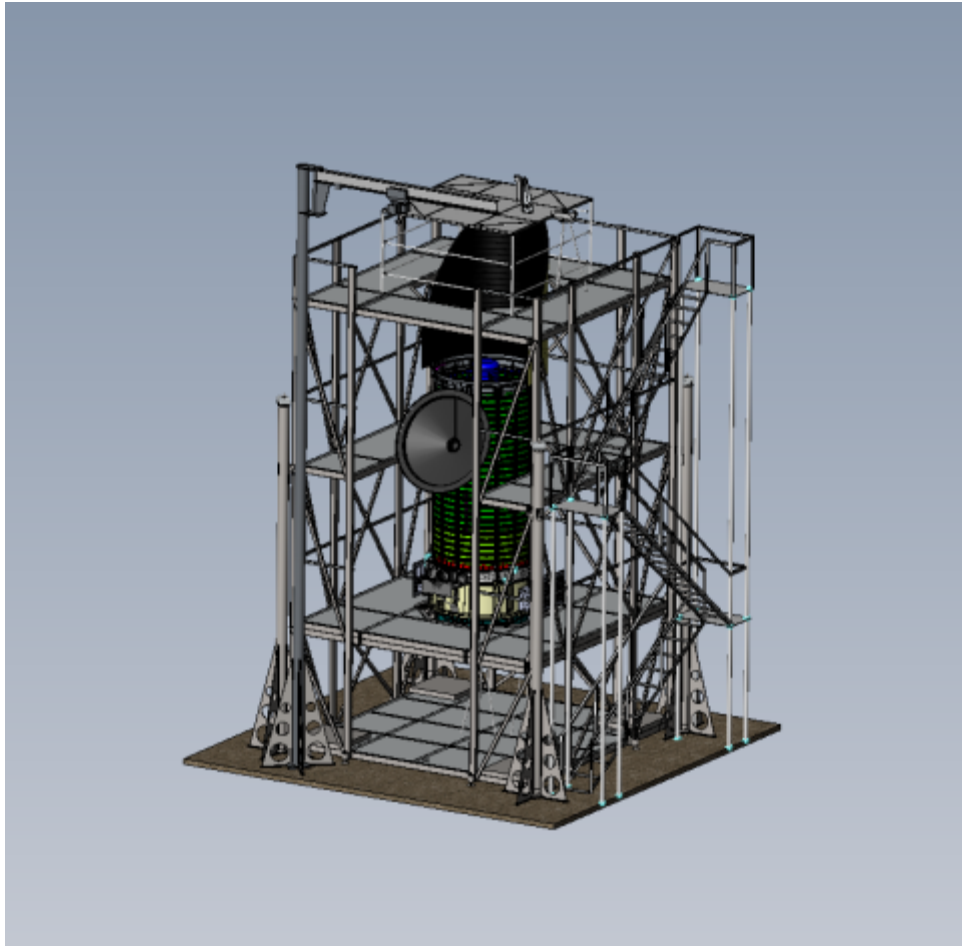
Optics (LZOS, Russia) + coating (LUCH company, Russia)



rms = 0.75 nm

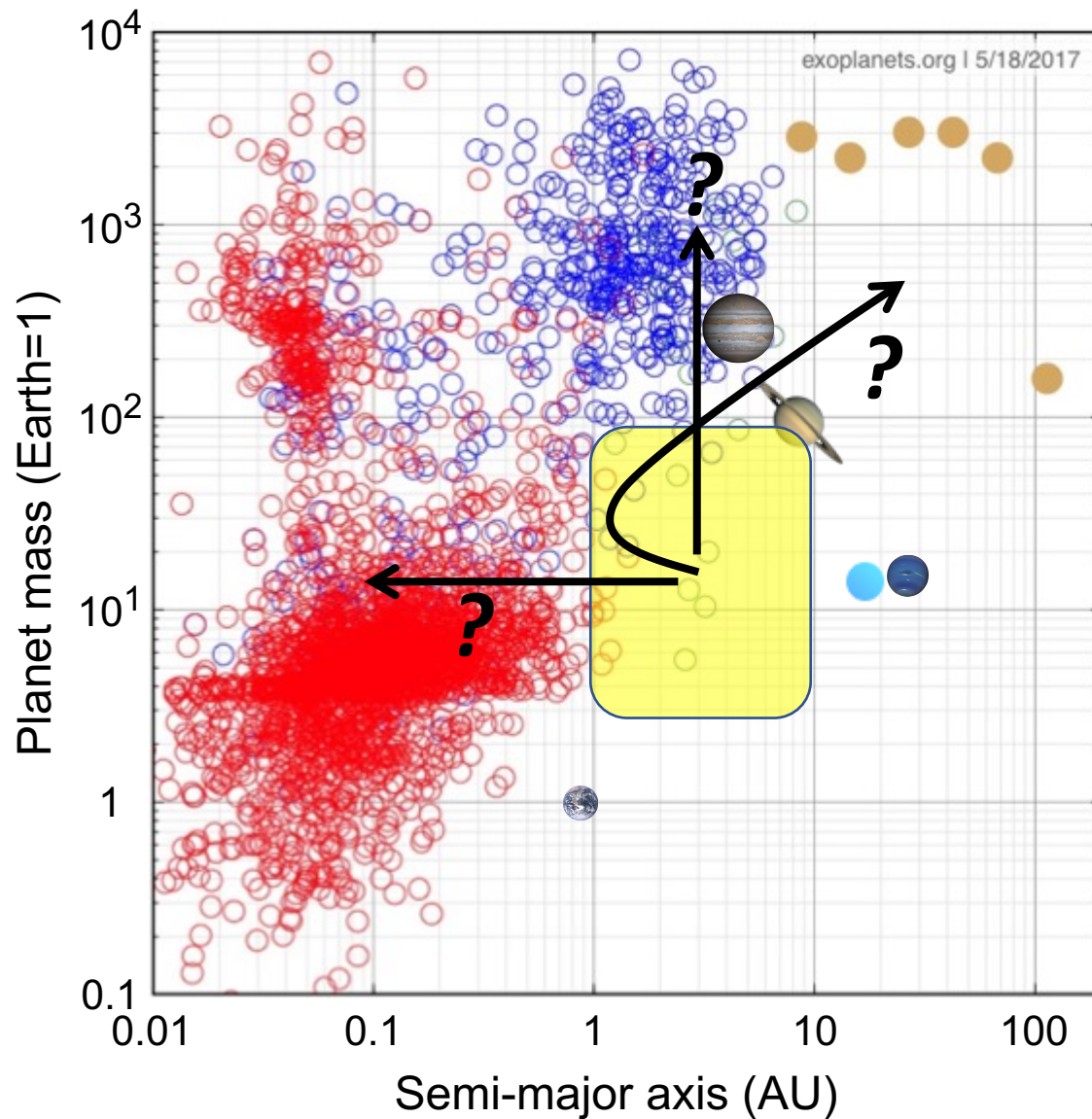
1 mm

Telescope AIV facilities



ロシア担当
コロナグラ
フ

Exoplanets Detected So Far



- Transit
- Radial velocity
- Microlensing
- Direct imaging

Unknown is how many planets of *middle mass* exist in *middle orbits*

... Those planets have the greatest impact on planetary system formation

惑星系形成
(惑星移動・物質輸送)

UVSPEX(UV spectrograph for exoplanets) instrument

Overview

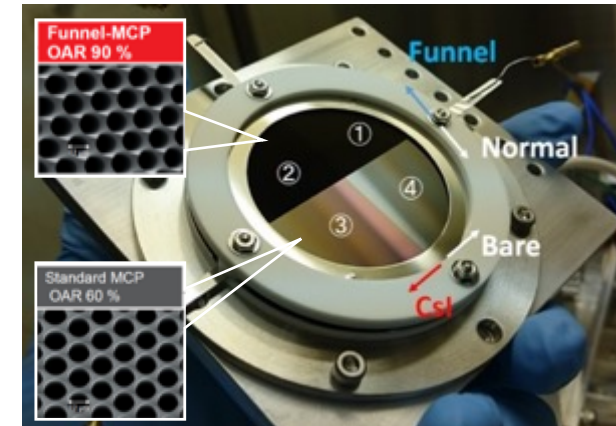
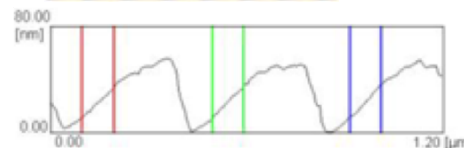
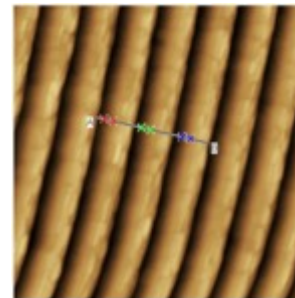
- Simple layout: slit + concave grating + detector
- Proven components (grating: CLASP, detector: BepiColombo/PHEBUS-FUV, PROCYON/LAICA)

Specifications

Spectral range		115–140 nm
Spectral resolution		<0.5 nm @130 nm
Total efficiency		~4.6%
Slit	Width	2.5 arc-sec (= 200 μm)
Grating	Type	Laminar
	Shape	Toroidal
	Coating	Al + MgF2
	Efficiency	29% (ref. CLASP)
	N	2400 g/mm
	f	250 mm
Detector	Type	CsI photocathode + microchannel plates (MCPs) + resistive anode encoder (RAE)
	Efficiency	16% (ref. LAICA)
	Effective area	ϕ 30 mm
	Resolution	80 μm

Development status for options

- Blazed grating samples (plane) were successfully manufactured
- Test model of Funnel-MCP achieved **1.7 times higher** quantum efficiency than normal MCP (4.6%→7.8%)



UV Spectrograph for Exoplanets (UVSPEX)

By UVSPEX

Proxima Centauri + Earth-like Proxima b

~16 pc away can be detected in 1 year.

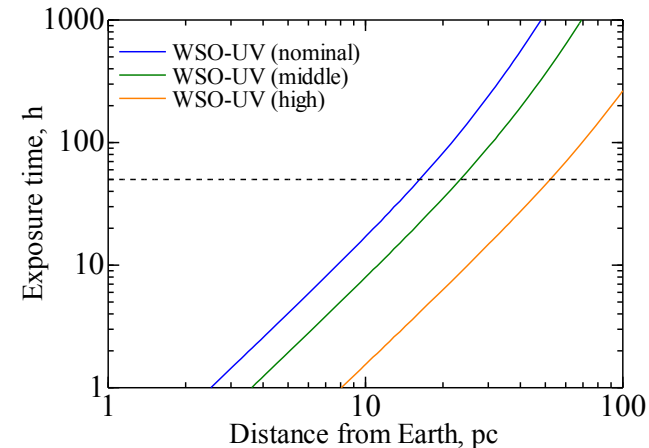
Numbers of $<2R_{\text{Earth}}$ planets around M dwarfs within 20 pc

Distance (pc)	<5	5-10	10-15	15-20
Numbers	3	6	5	7

Expected Numbers of TESS Targets based on Monte Carlo Simulations by Sullivan et al. (2015)

Among them, 3 planets are located in HZ around M dwarfs (i.e., effective incident flux S within $0.2-0.8 S_{\text{Earth}}$: Kopparapu et al. 2013).

9 planets are with S of $0.2-2.0 S_{\text{Earth}}$.



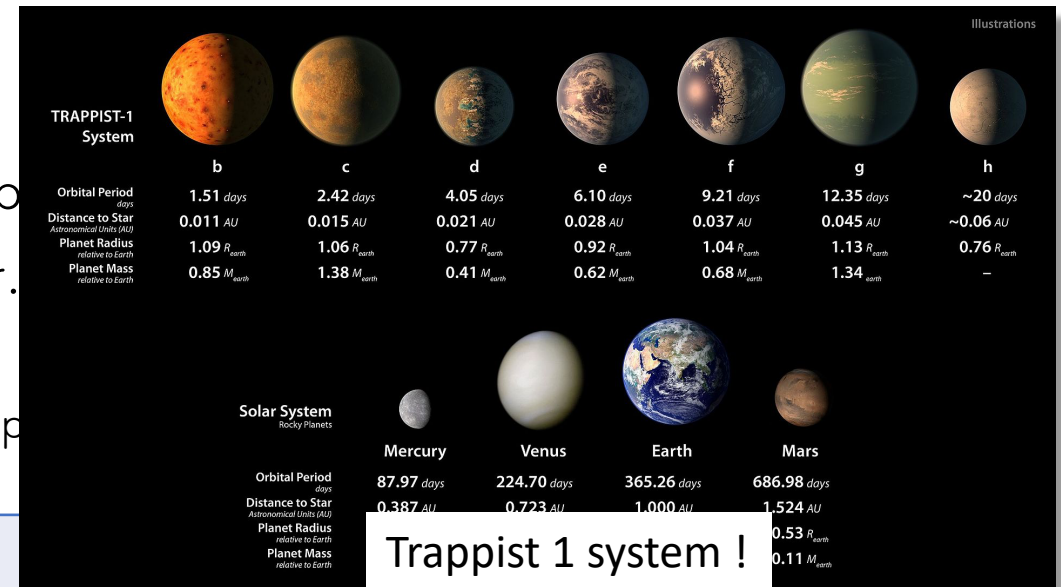
UV Spectrograph for Exoplanets (UVSPEX)

By UVSPEX

Proxima Centauri + Earth-like Proxima b
 ~16 pc away can be detected in 1 year.

Numbers of $<2R_{\text{Earth}}$ planets around M dwarfs within 20 pc

Distance (pc)	<5	5-10	10-20
Numbers	3	6	5

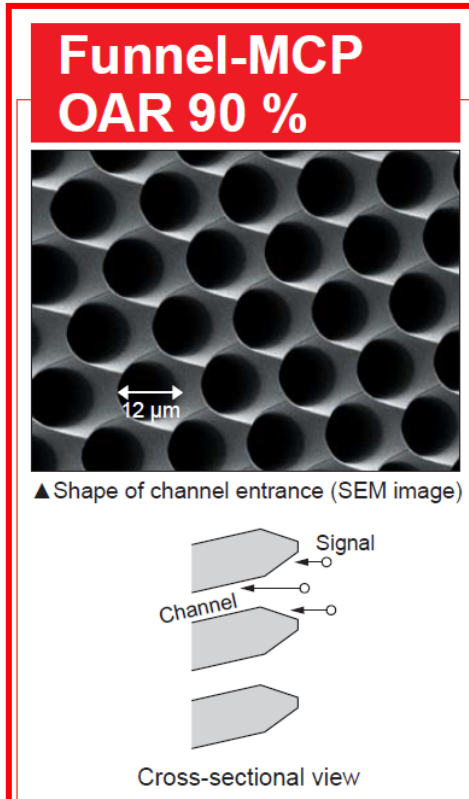


based on Monte Carlo Simulations by Sullivan et al. (2015)

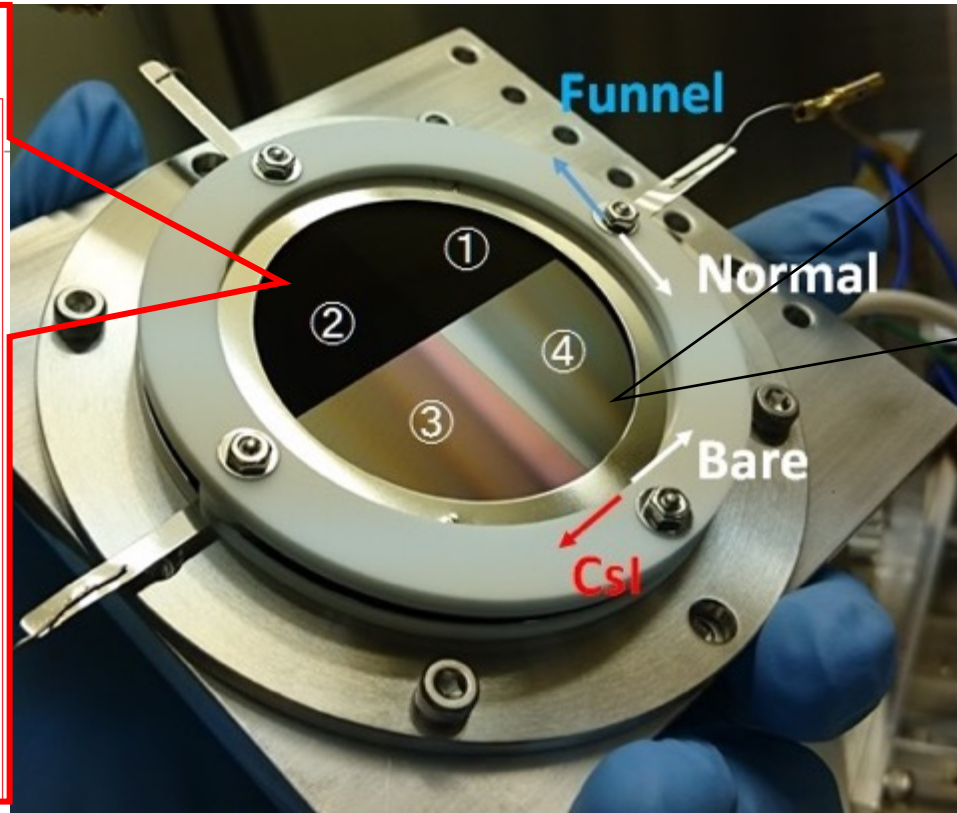
Among them, 3 planets are located in HZ around M dwarfs (i.e., effective incident flux S within $0.2-0.8 S_{\text{Earth}}$: Kopparapu et al. 2013).

9 planets are with S of $0.2-2.0 S_{\text{Earth}}$.

Development: Improvement of efficiency

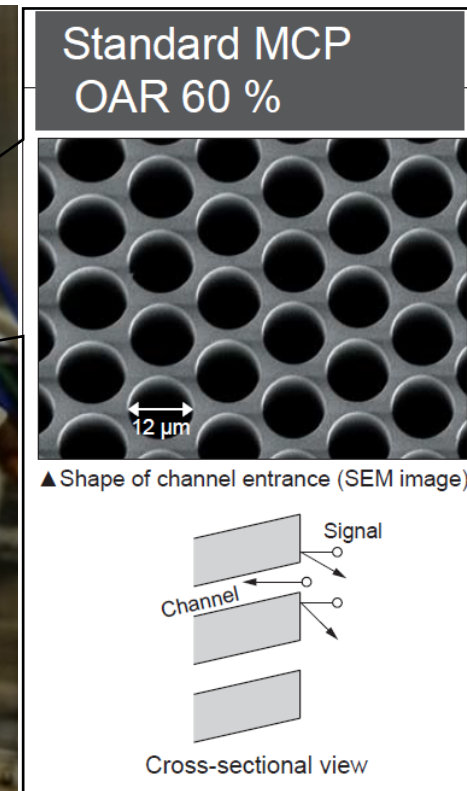


Proposed by
Rikkyo Univ.



Test model

1. Funnel + Bare
2. Funnel + CsI
3. Normal + CsI
4. Normal + Bare



[Hamamatsu Photonics K.K.]




スケジュール

2023年打ち上げ予定
2018年9月に△PDR

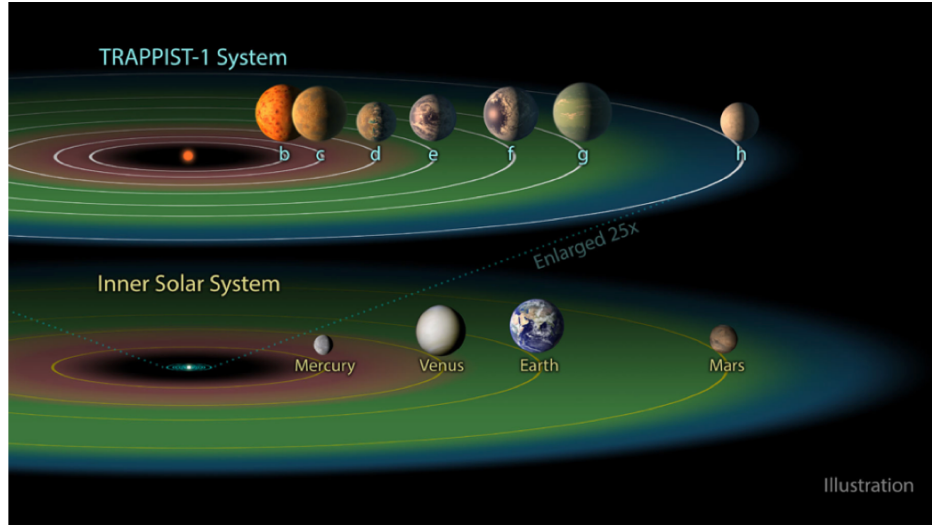
この時点で日本提供装置の
スペースを残すかどうか？

来週モスクワで打ち合わせ
(国際共同ミッション推進研究)

モスクワの天気

01月14 日 (日)	01月15 日 (月)	01月16 日 (火)	01月17 日 (水)
 曇	 晴一時雪	 晴一時雪	---
-8℃ -11℃	-7℃ -10℃	-6℃ -10℃	---
80%	78%	73%	---
1	0	1	---

まとめ



- WSO-UV:口径1.7m紫外線望遠鏡 (GSO)
- 系外惑星大気観測のアイディア・装置提供依頼
 - 水素・酸素原子外気圏観測 → 水の進化・超大型計画と良い勝負
 - MCP検出器の効率向上 → 数十個の地球型惑星の特徴付け
 - コロナグラフによる中間質量惑星の観測アイディア・検出器 → 惑星移動・物質輸送
- 2018年9月に Δ PDR