UV Space Telescope for exoplanetary system

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Exoplanet transit observation

Detection ➡ Characterization

1st generation

2006.12.27-2013.6.24
CoRoT
COnvection ROtation et Transits planétaires

2009.3.7-
Kepler

2nd generation

2014-
Kepler2

2024
PLATO
PLAnetary Transits and Oscillations of stars

2017
TESS
Transiting Exoplanet Survey Satellite

1990.4.24-
Hubble

2003.8.25-
Spitzer

2018.10-
JWST ... 0.6-28μm
James Webb Space Telescope

2017
CHEOPS ... 0.4-1.1μm
CHaracterising ExOPlanets Satellite

2017
FINESSE ... 0.7-5μm
Fast INfrared Exoplanet Spectroscopic Survey Explorer

SPICA ... Near-to-mid IR
SPace Infrared telescope for Cosmology & Astrophysics

VIS-IR

Exoplanet around M Dwarf

2014-
Kepler2

2024
PLATO
PLAnetary Transits and Oscillations of stars

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2018.10-
JWST ... 0.6-28μm
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Terrestrial planet(s) in habitable zone around M Dwarfs near the solar system to be detected.

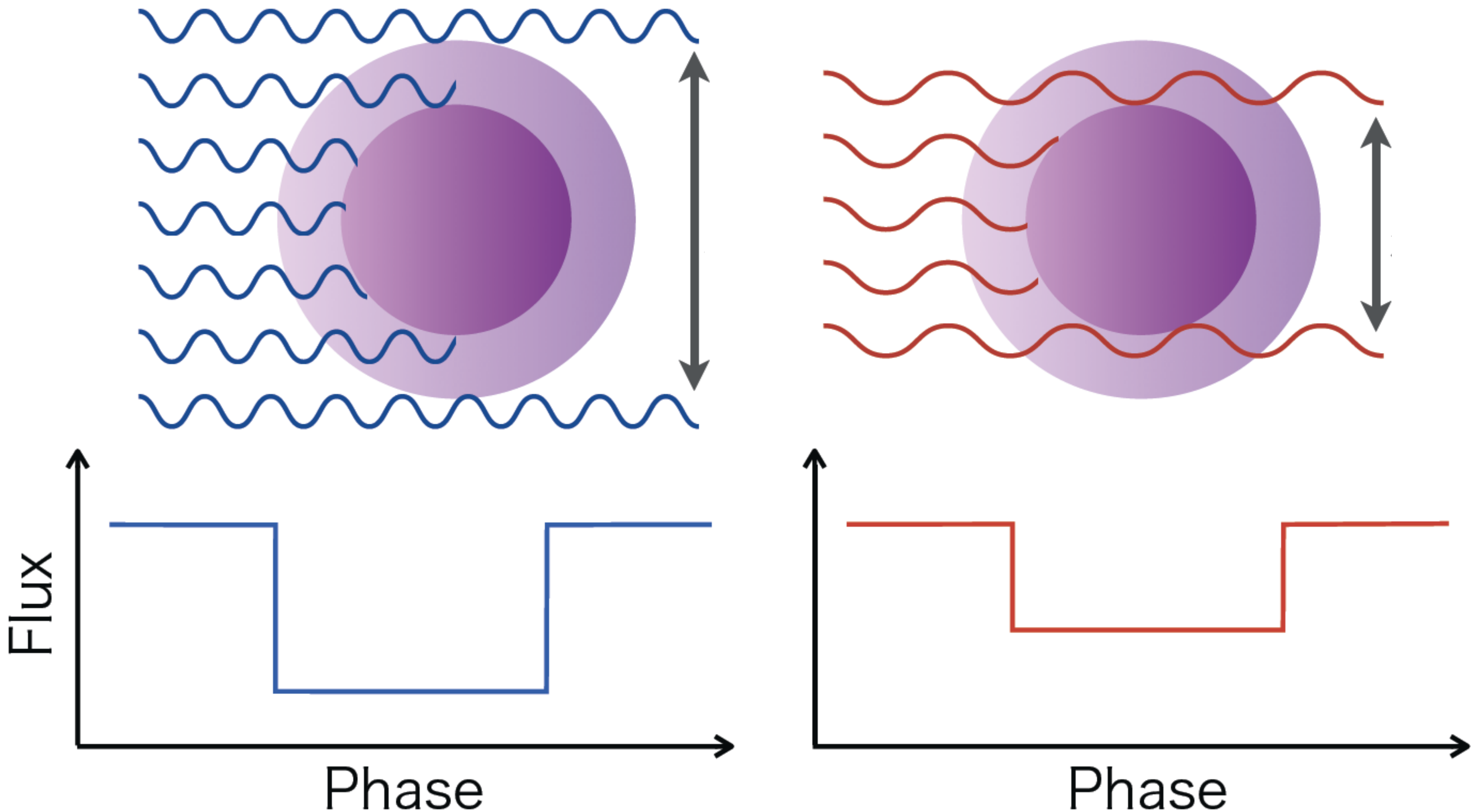
- M-type (50/63) in 5pc
- Small star → transit depth ↑
- Habitable zone close to star

→Short orbital period
→frequent transit

NIR-MIR observation

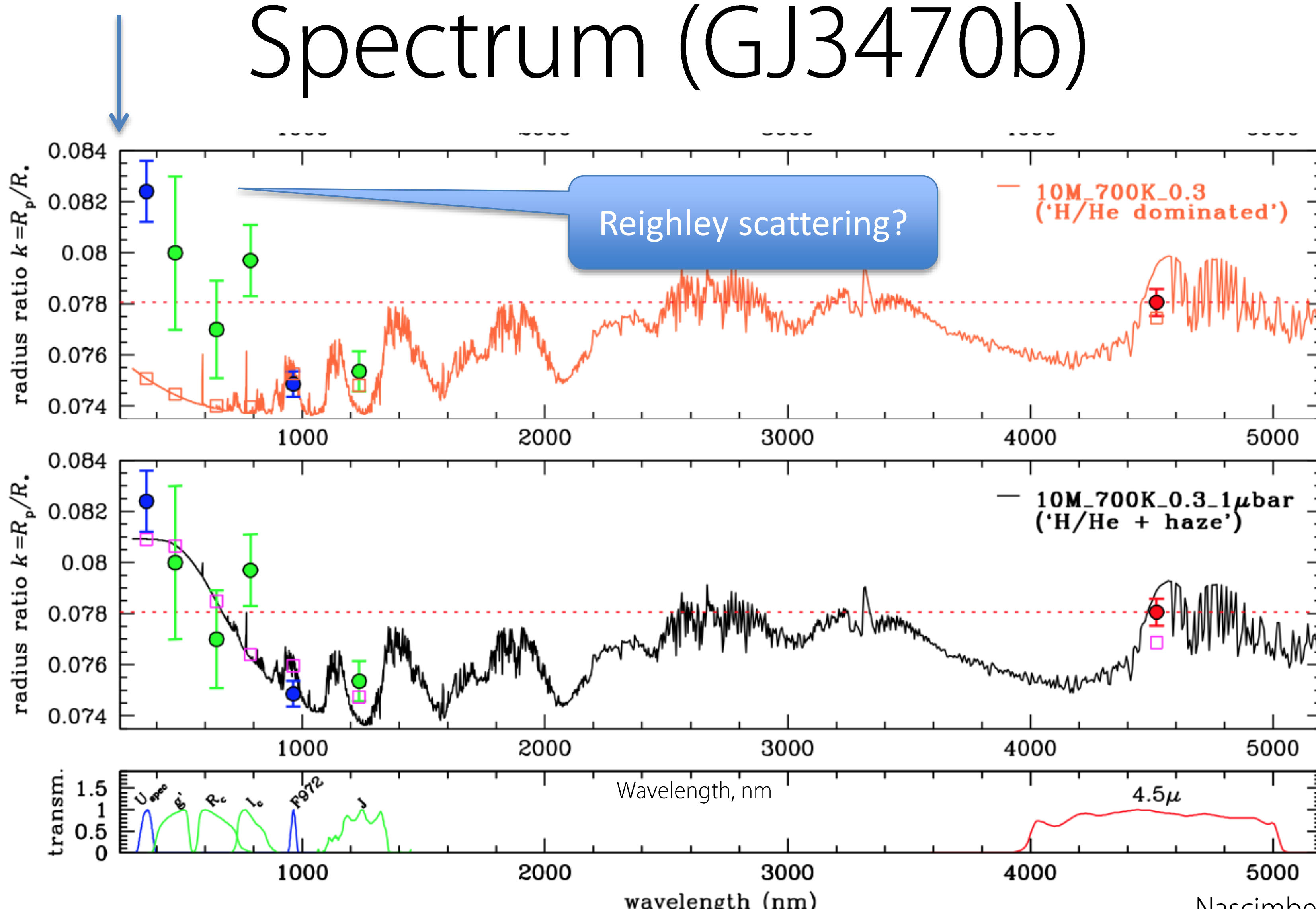
→Atmospheric molecular absorption (H_2O, CH_4, CO, etc)

Atmospheric thickness



At the wavelength of absorption line, apparent planet size increases.
->transit spectrum -> atmospheric composition

Spectrum (GJ3470b)



Nascimbeni+2013

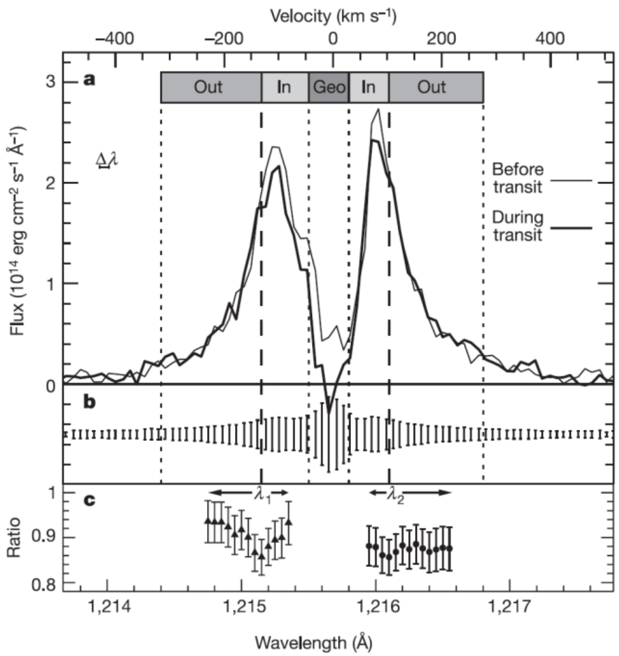
Spectrum of GJ3470b
(top)H/He dominated (bottom)H/He with haze

Space Telescope is necessary for the spectrum shorter than 300 nm.

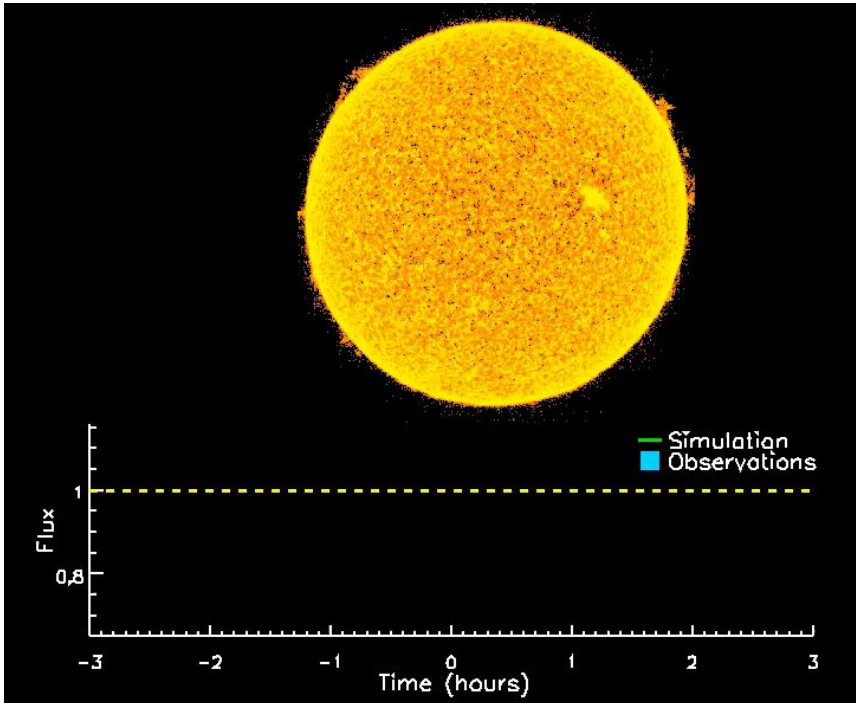
HD209458b Hydrogen Ly α

Vidal-Madjar et al. (2003) determined that HD209458b absorbed ~15% of the stellar Lyman-alpha, whereas the planet obscures only 1.5% of the stellar flux in the visible.

- This implies the presence of an atomic-hydrogen cloud around the planet of ~3.3 planetary radius, which corresponds to about 80% of the Roche radius



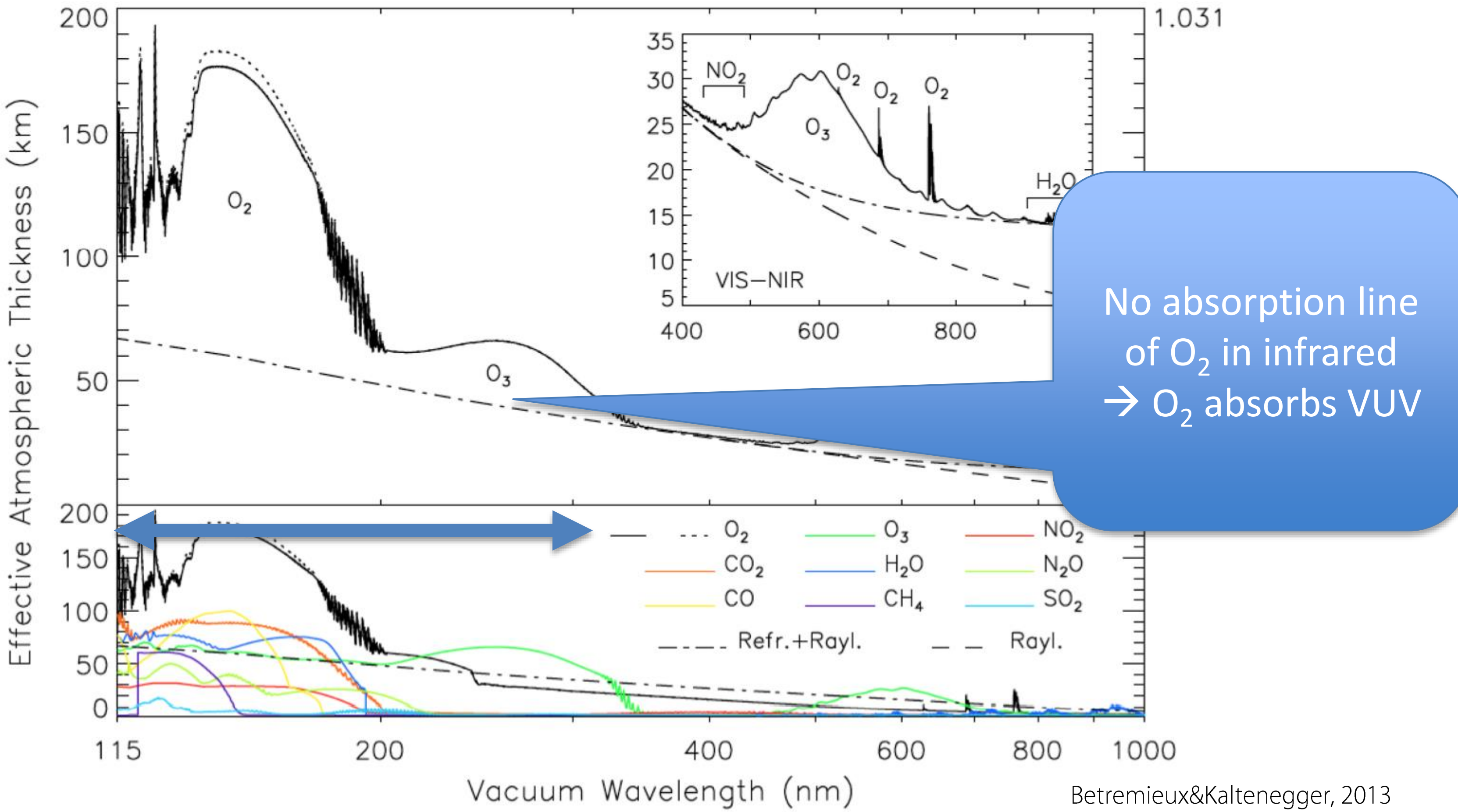
Vidal-Madjar+2003



http://www2.iap.fr/exoplanetes/index_en.html

VUV 115-310nm

Photodissociation of Atmospheric molecule



Betremieux&Kaltenegger, 2013

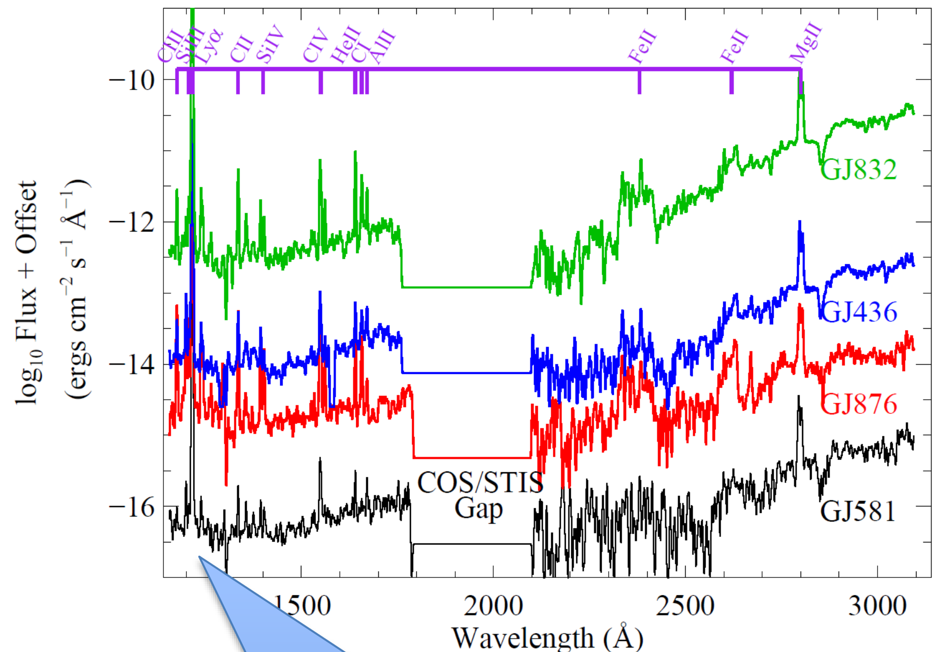
Transit depth spectrum of Earth

Stellar (M dwarf) UV flux as heat source

- ~80% (50/63) of the stars at the distance of 5pc from the sun is M dwarf (~3000K)

Lyman alpha emission is dominant for UV flux from M dwarf.

"Temporal variability of Atmosphere and UV flux"



France+2012

Atmosphere: NIR-MIR Space or Lar

UV: HST → ???

VUV as heat source
→HST

Targets of UVST for exoplanetary systems

(1) UV flux monitoring after detection of terrestrial planets in habitable zone in 2020s

(2) Atmospheric hydrogen loss on hot Jupiter

→ Temporal variability, verification

(3)UV spectroscopy for atmosphere

(4)Measurement of total amount of atmosphere including O_2, etc

(1)(2) ~several tens cm class

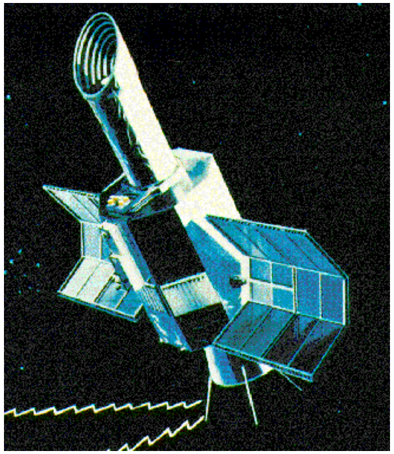
(3),(4) large size is necessary (~ m)

Ly α flux variability

Near solar system stars（~10pc）: 143

[Spectral Type]
T : 6、M : 115、K : 11、G : 7、A : 1、D : 3

36 observed M stars



IUE : Mikulski Archive for Space Telescopes

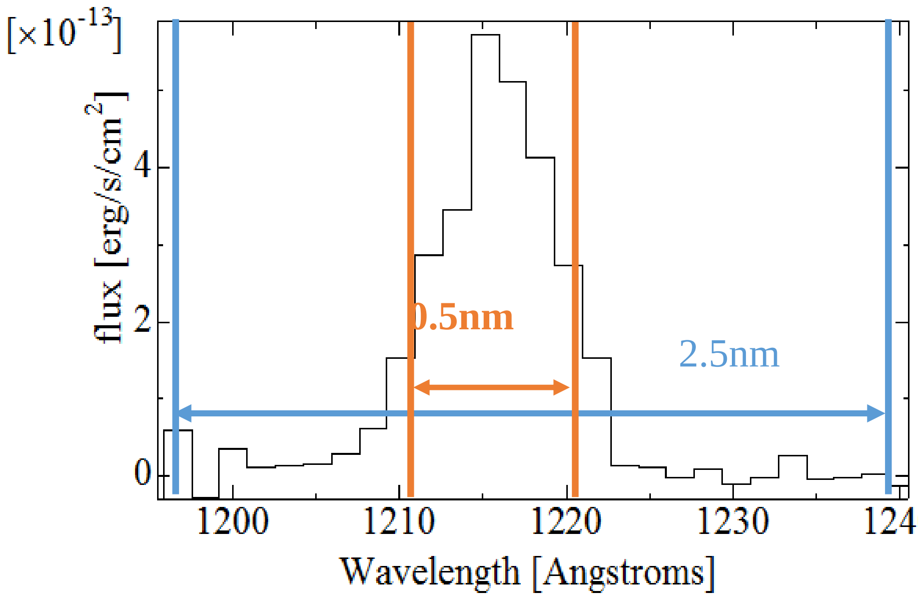
HST:
Hubblesite

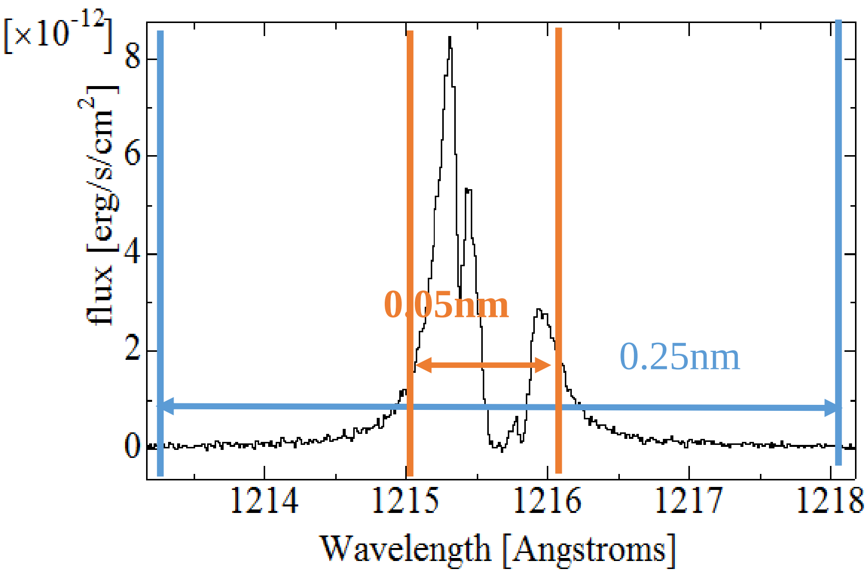
Temporal variability

① International Ultraviolet Explorer(IUE) : 56
→ 1987～1996

② Hubble Space Telescope(HST) : 10

Ly α spectrum



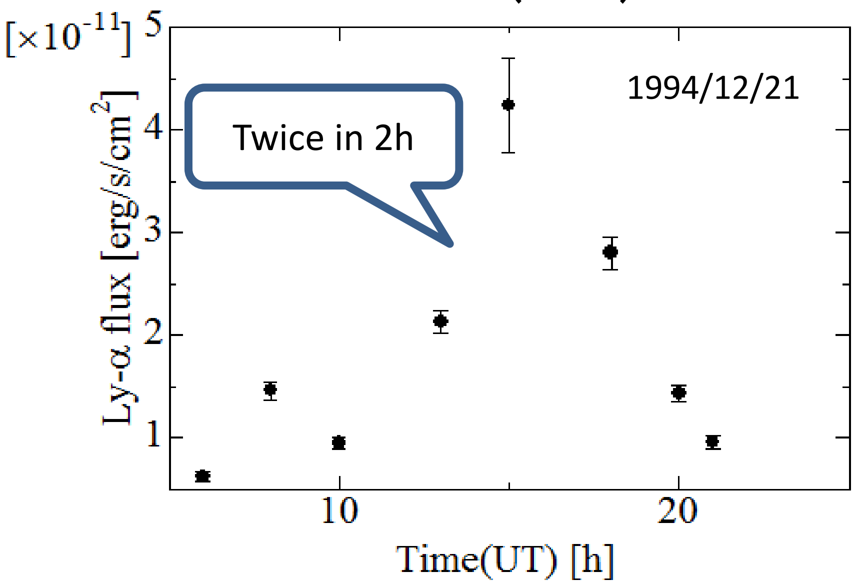


IUE：±1.5nm

HST：±0.15nm

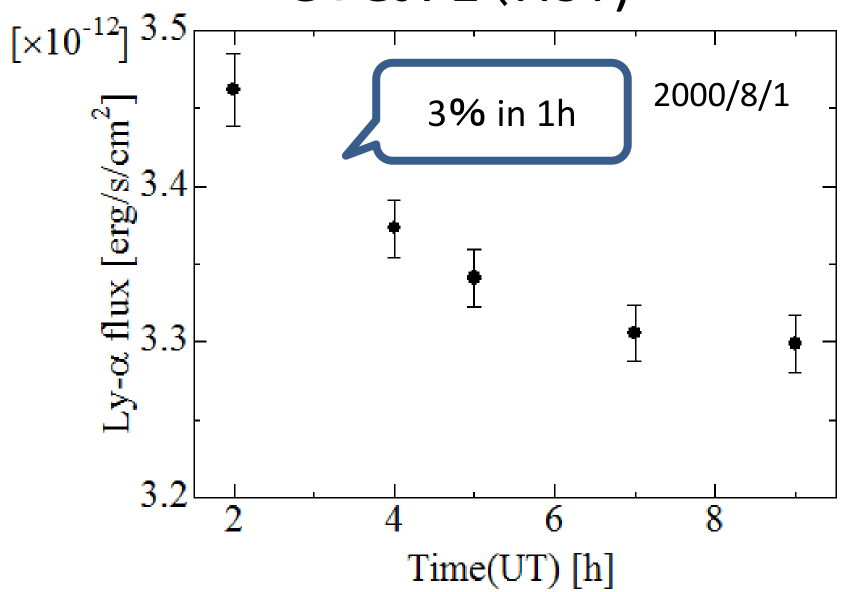
RESULT

M：GJ285（IUE）



variable

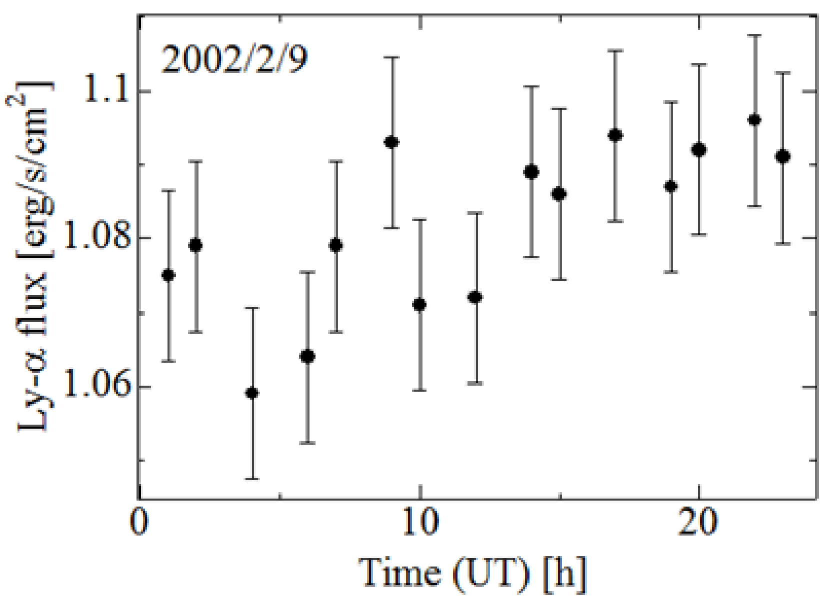
G：GJ71（HST）



stable

Solar ly α

Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics(TIME-D)



2002/2/9

- Stable (~ 2% in several hours)

Ly-α flux of G star is stable
↓
Hydrogen around Hot Jupiter is observable

Ly-α flux of M star is unstable
↓
Monitoring

S/N

$$S/N\ ratio = \frac{N_{\text{signal}}}{\sigma_{\text{signal}}} = \frac{N_{\text{signal}}}{\sqrt{N_{\text{signal}} + 2N_{\text{background}}}}$$

- Interplanetary Ly-α emission ($N_{\text{background}}$) ~ 500R (Ajello et al., 1994)
- attitude stability、stellar Ly-α flux (N_{signal}) (Wood et al., 2005)
- Observation outside geocorona
- 10% transit depth

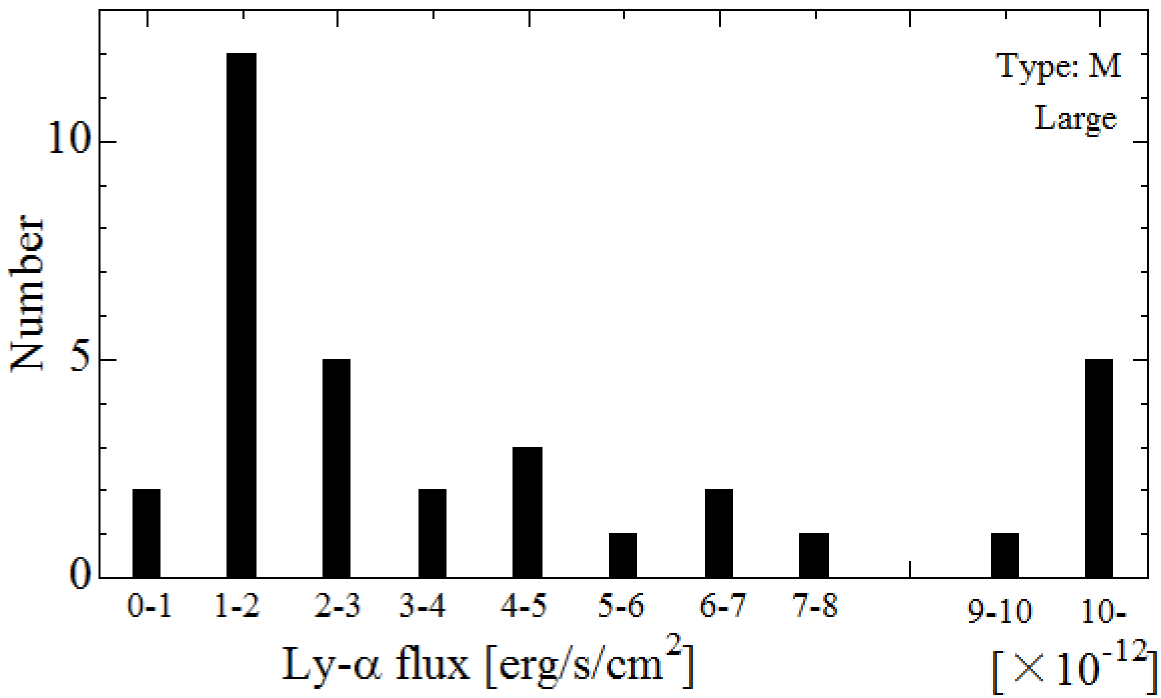
⇒**S/N> 30**

specification

D, cm	10	30	100
Trans. (filter)	0.2		
Efficiency(Optics)	0.7		
QE	0.2		
Effective Area, cm^2	2.3	21	231

$$(\text{Effectivce area}) = \pi \times \left(\frac{D}{2}\right)^2 \times (\text{Trans. (filiter)}) \times (\text{Efficiency (Optics)}) \times \text{QE}$$

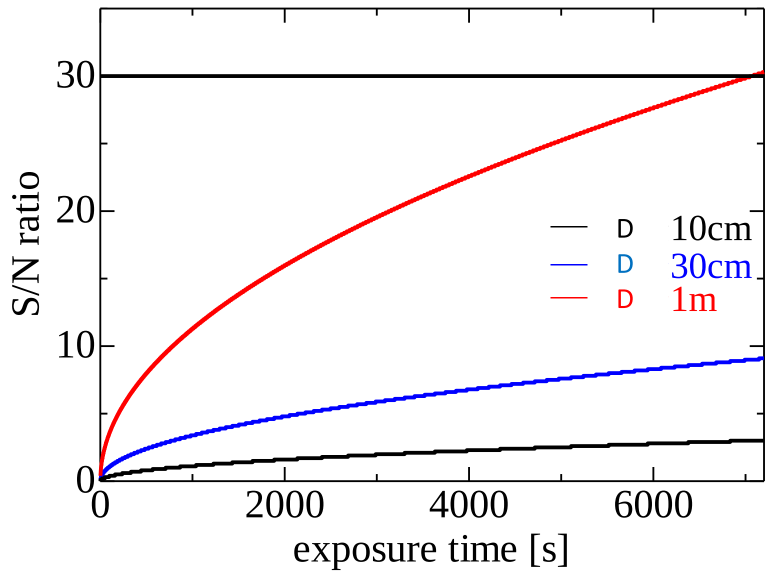
Stellar Ly α flux



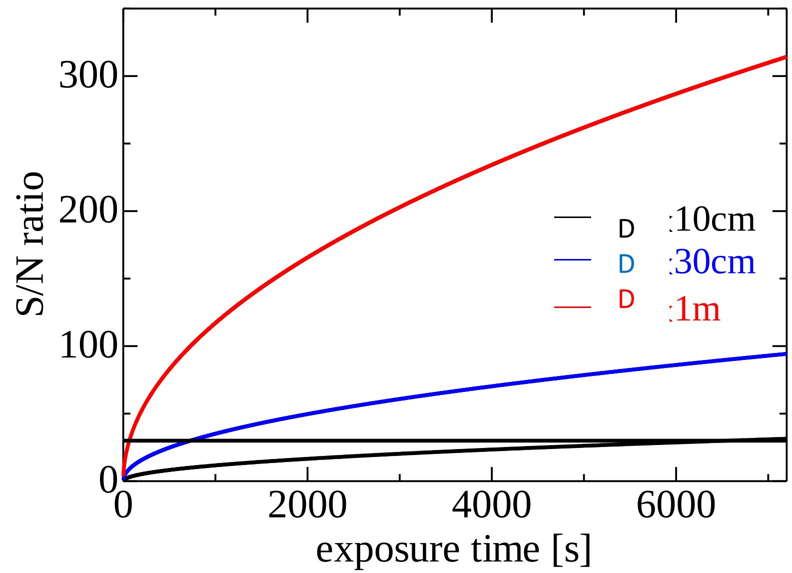
- 10^{-11} -10^{-12} erg/s/cm2

S/N　Ly-α flux 1×10^{-12} erg/s/cm^2

Stability 1arcmin



Stability 1 arcsec

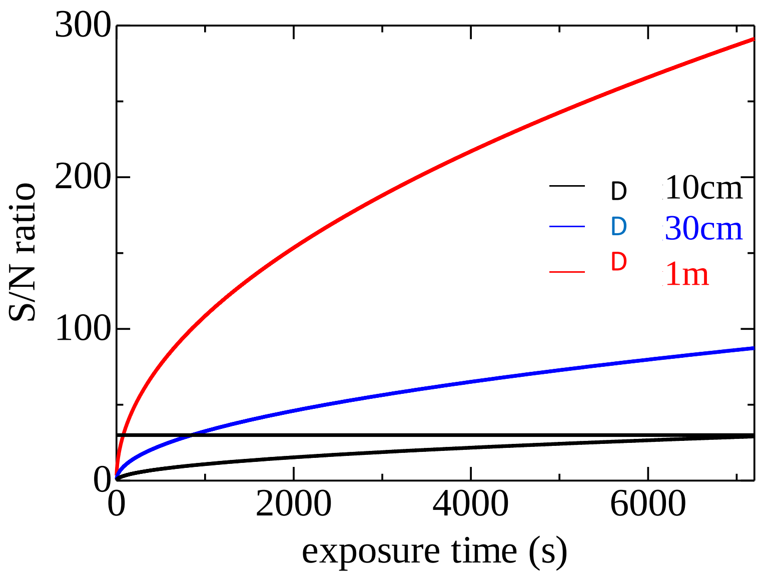


D1m、exp 2h
S/N>30

D10cm、exp 2hで
S/N > 30

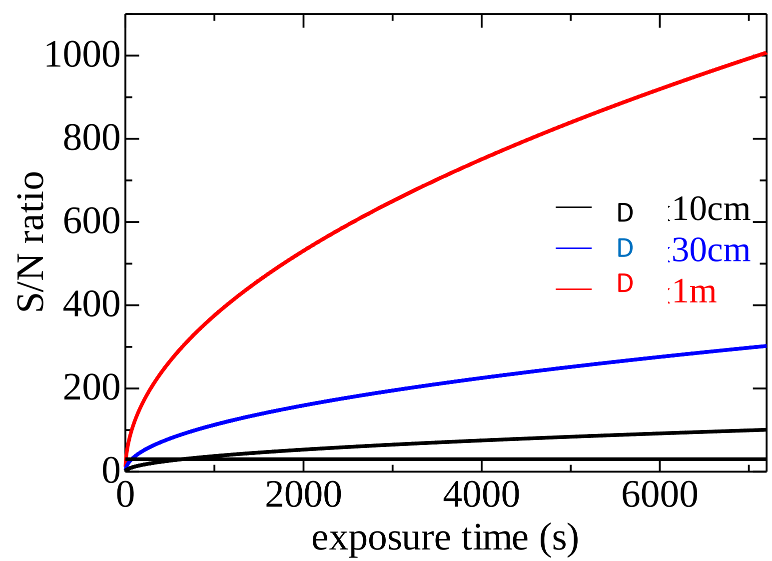
S/N Ly-α 1 × 10^{-11} erg/s/cm^2

Stability 1arcmin



D10cm、exp2h
S/N>30

Stability 1 arcsec



10cm、6 min
S/N>30

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Meeting on May 23, 2015