



Les Exoplanètes

et la quête d'une biologie extraterrestre

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quelques dates

1781: découverte d'Uranus

1846: découverte de Neptune

1989: découverte de HD 114762b (10 M_{Jup})

1992: corps planétaires en orbite autour du pulsar PSR 1257+12

1995: découverte de 51 Peg b

1999: première planète en transit: HD 209458b

2016: 2087 planètes identifiées, 3000+ candidats

A deep-field astronomical image showing a vast field of stars. The background is a dense field of small, faint white and grey stars. Several prominent stars are highlighted with a bright blue glow and a central white crosshair. These blue stars are located in the upper center, lower left, and lower right. There are also several faint orange and red stars scattered throughout the field, particularly on the left side. The overall scene is a rich, multi-colored stellar population.

détection directe



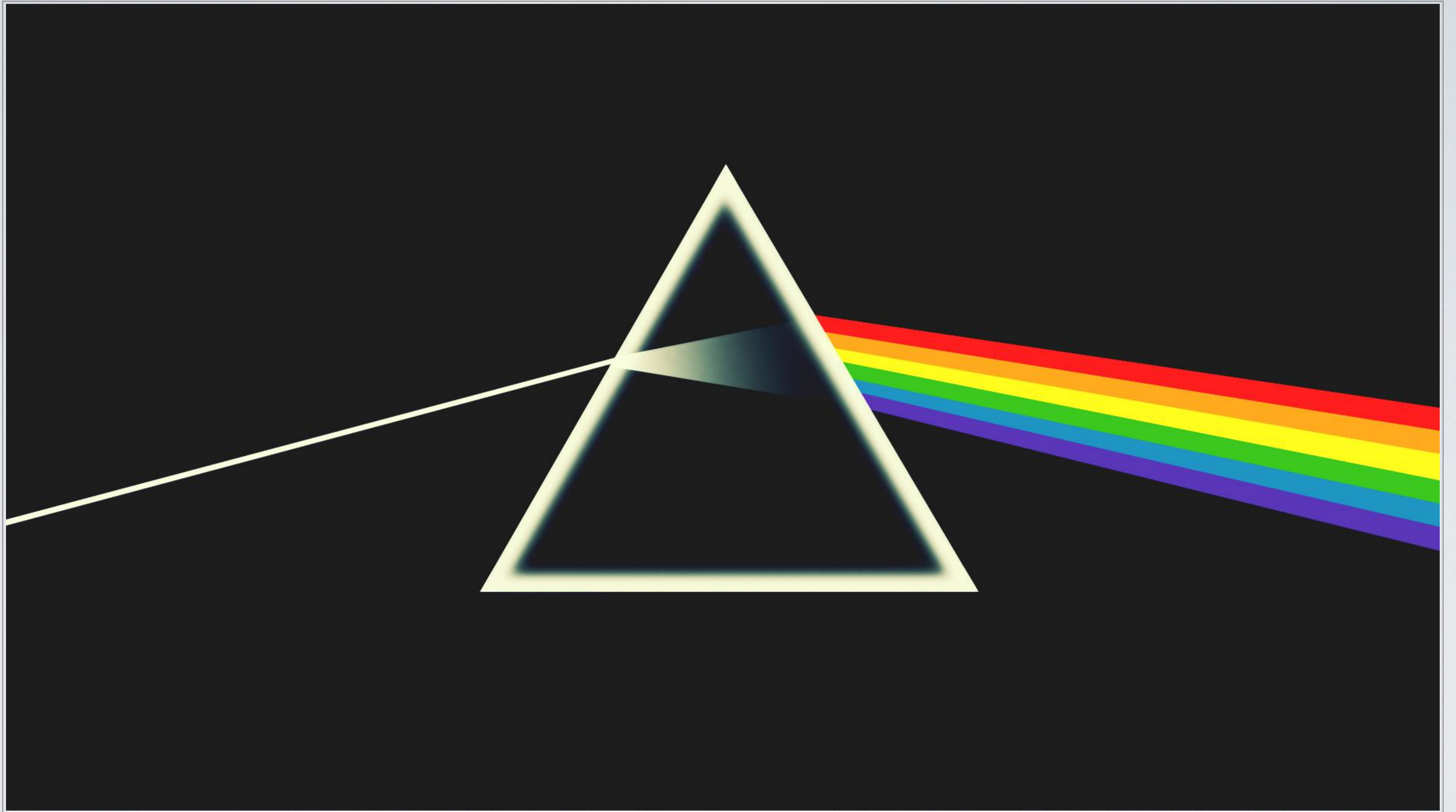


A deep space photograph of a star field. The background is a dense field of small, distant stars. Several prominent stars are highlighted with a bright blue glow and a white crosshair, indicating they are the focus of the study. There are also some faint, diffuse orange and red structures scattered across the field, likely representing interstellar dust or nebulae. The text "techniques indirectes" is centered in the lower half of the image.

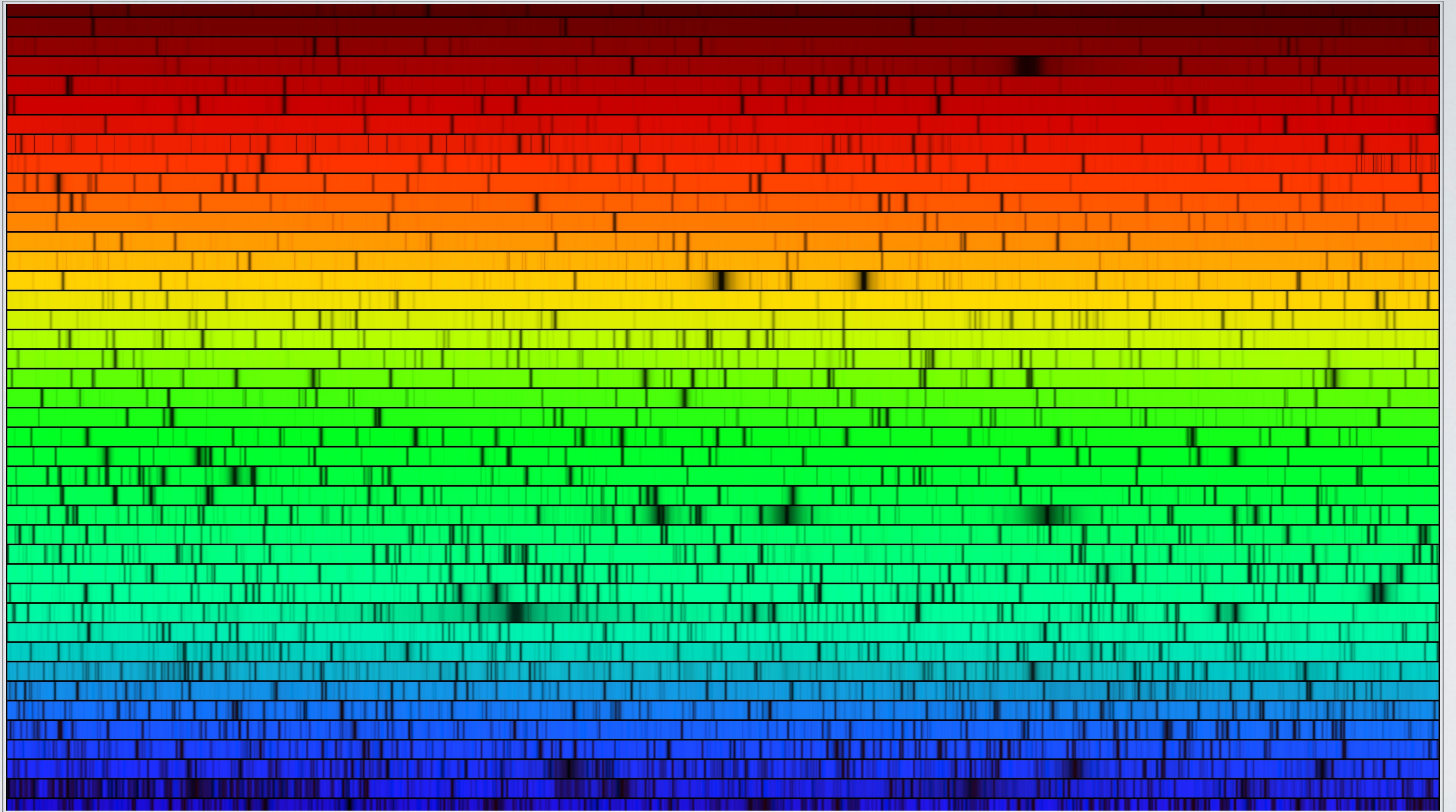
techniques indirectes

A dense field of stars, likely a star cluster or galaxy core, with several stars highlighted in blue. The text "vitesses radiales" is centered in the image. The background is a dark, grainy field of numerous small stars. Three prominent stars are circled in blue: one at the top center, one at the bottom left, and one at the bottom right. There are also several fainter stars circled in orange, primarily on the left side of the image. The text "vitesses radiales" is written in a white, sans-serif font, centered horizontally and vertically.

vitesses radiales



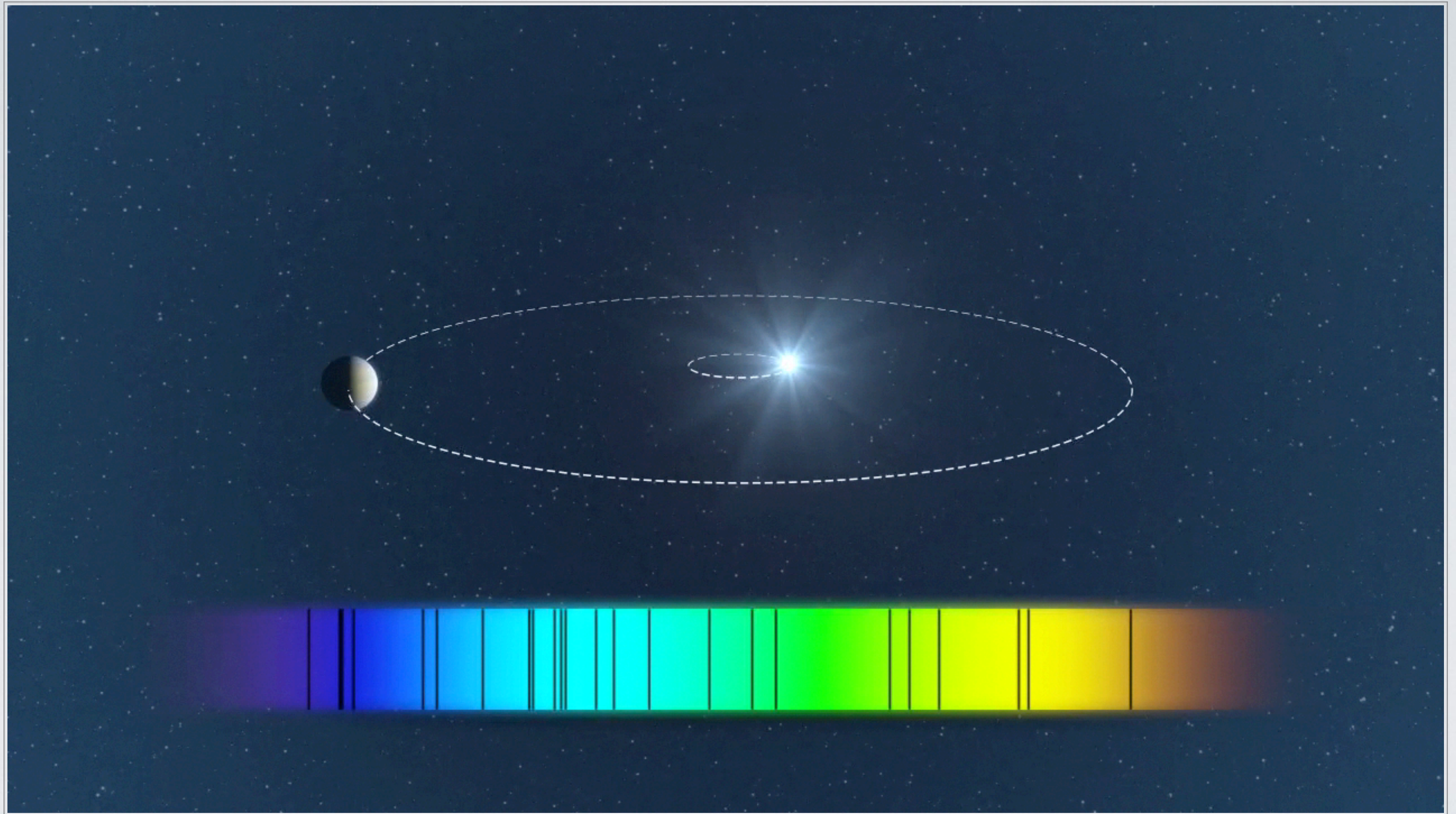
Newton 1704; Pink Floyd 1973



le Soleil selon Kurucz

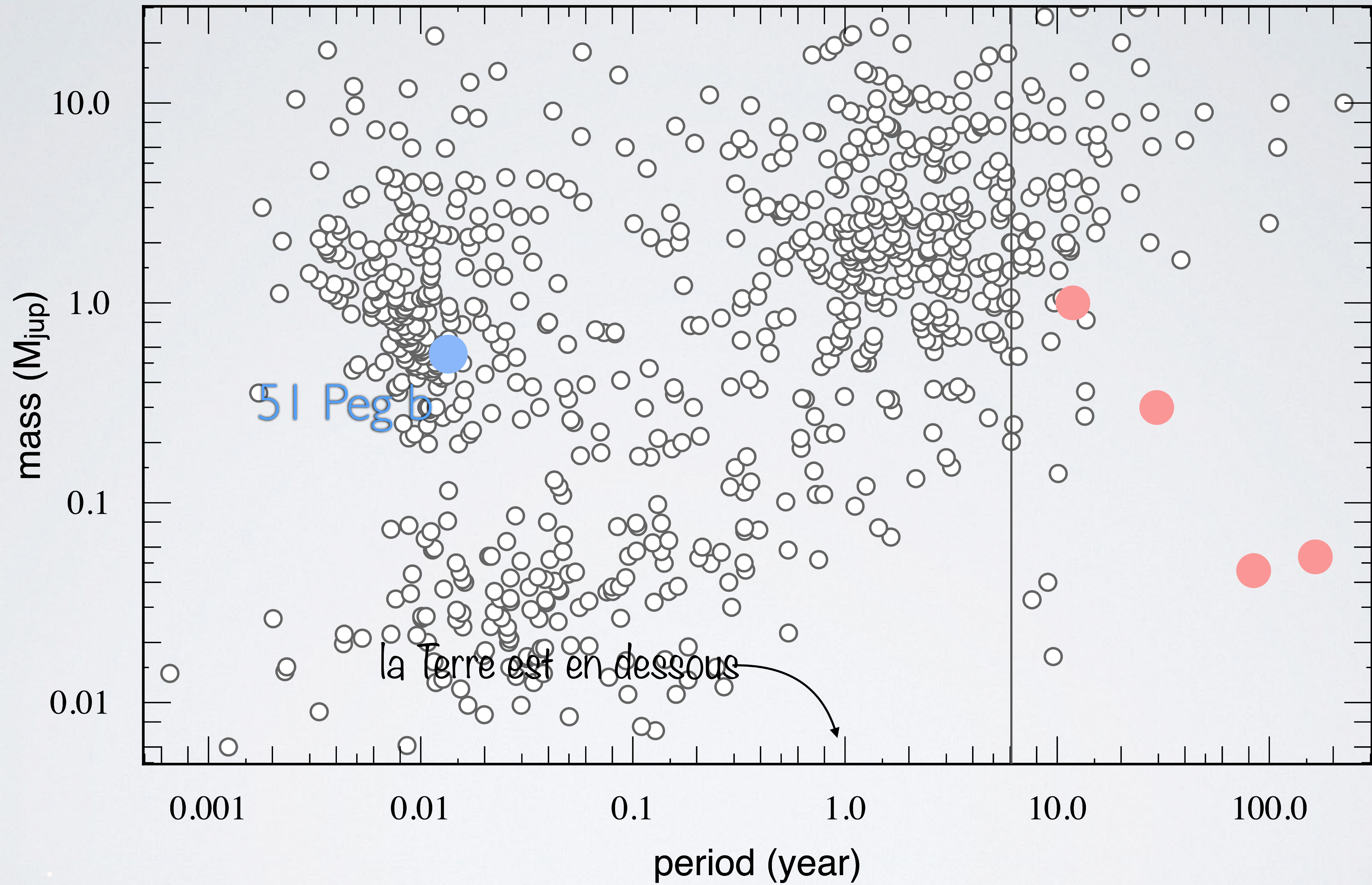
Terre = 9 cm/s en 1 an

Jupiter = 10 m/s en 11 ans



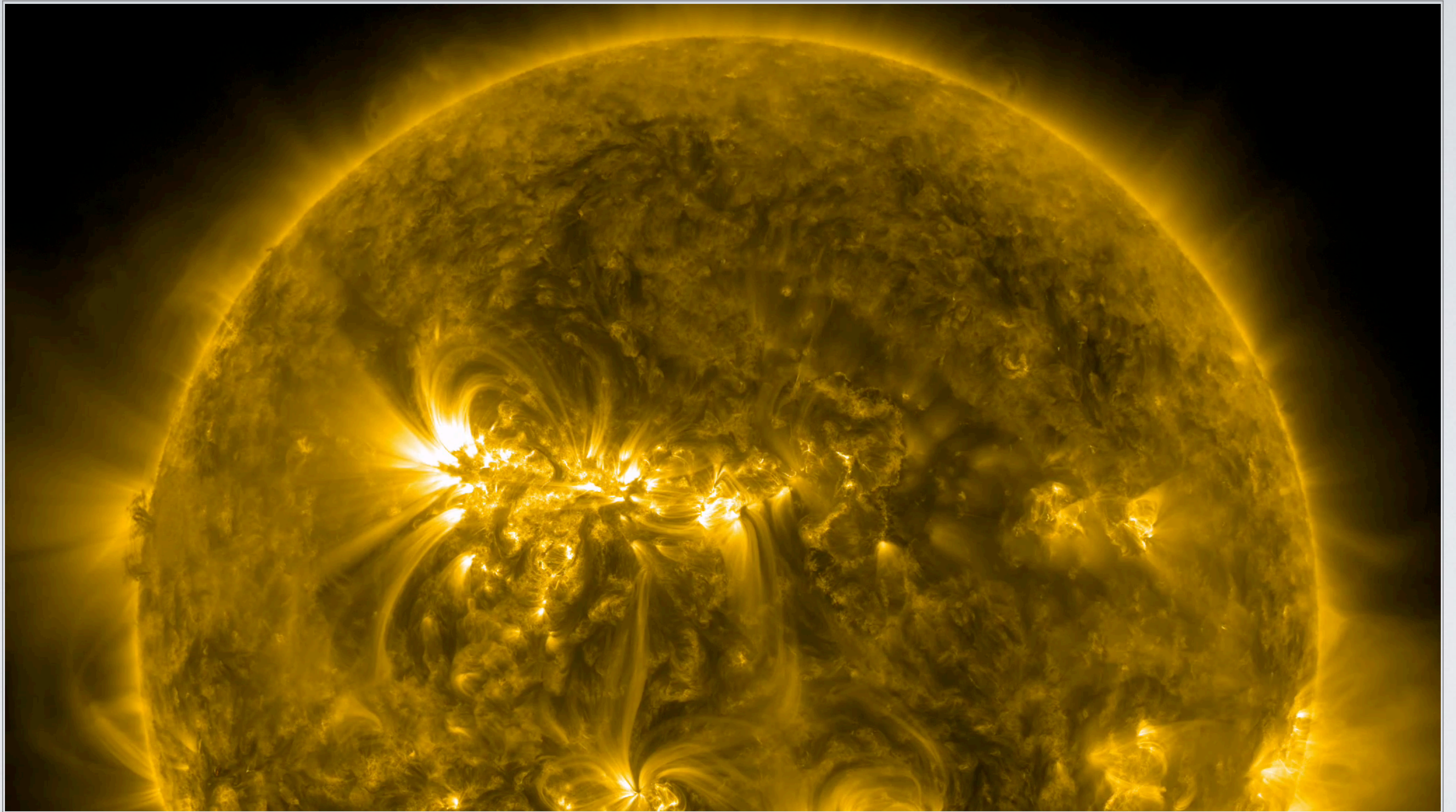
l'effet Doppler

les planètes avec une masse mesurée

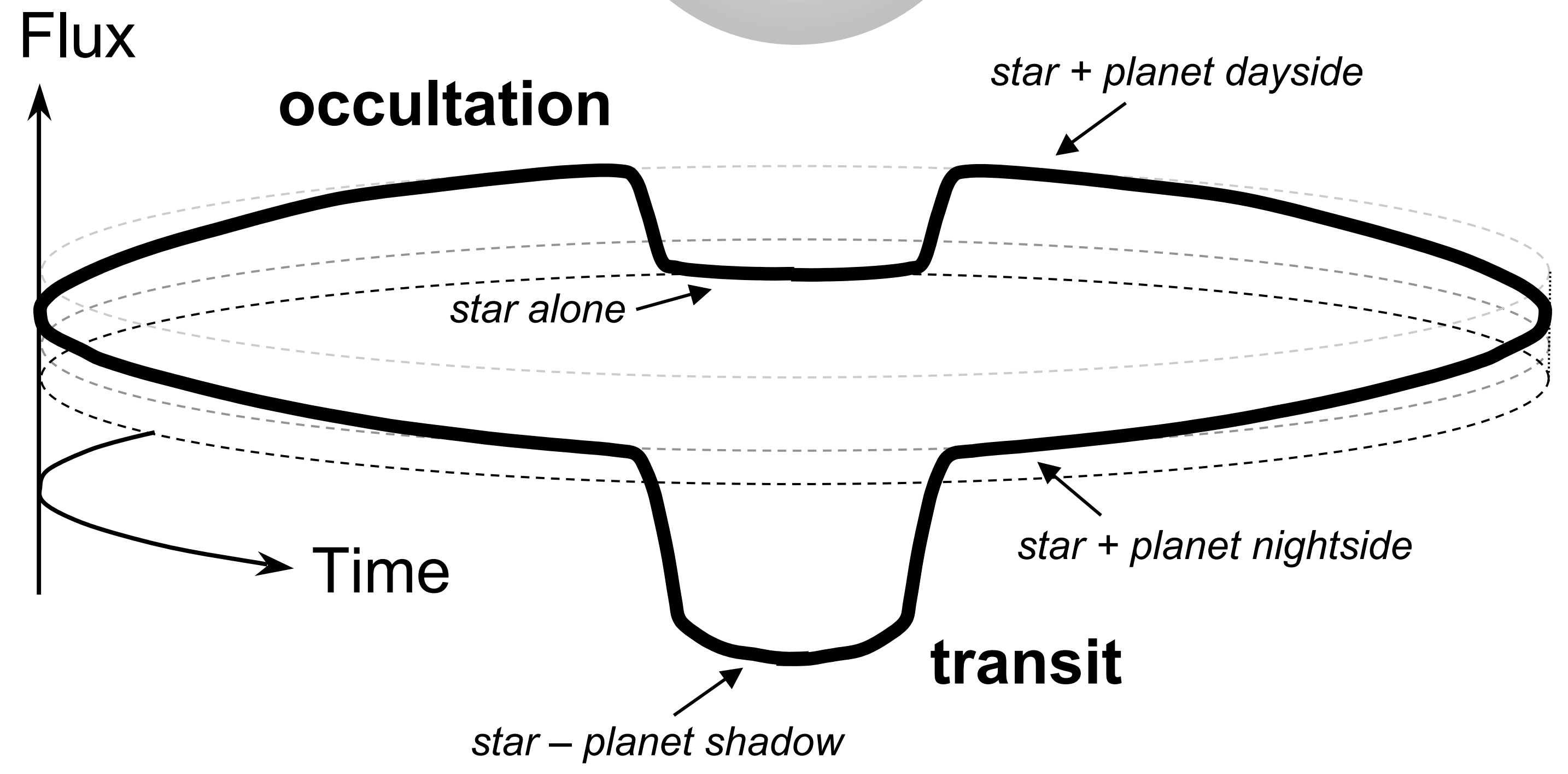
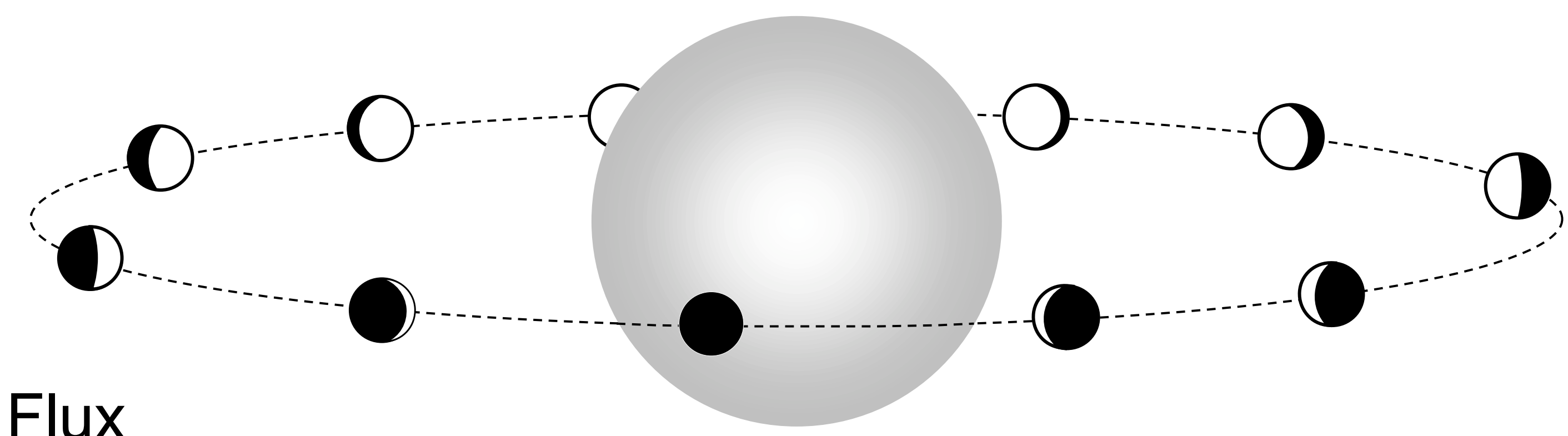


A deep space photograph of a star field. The background is a dense field of small, distant stars. Several prominent stars are highlighted with a bright blue glow and a white crosshair. In the upper left and center, there are faint, wispy orange and red nebulae. The overall scene is dark and rich with celestial detail.

la méthode du transit



le transit de Vénus



WASP-80b

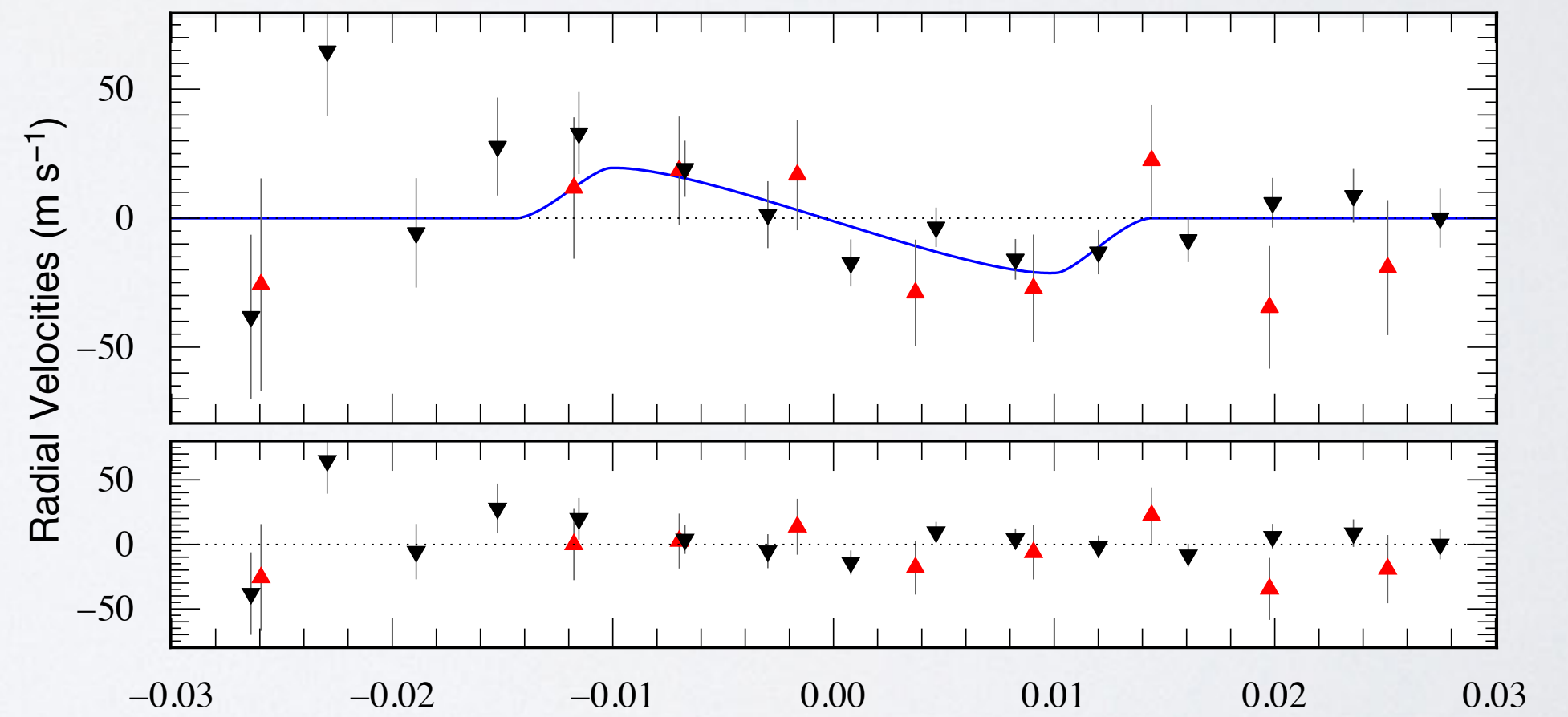
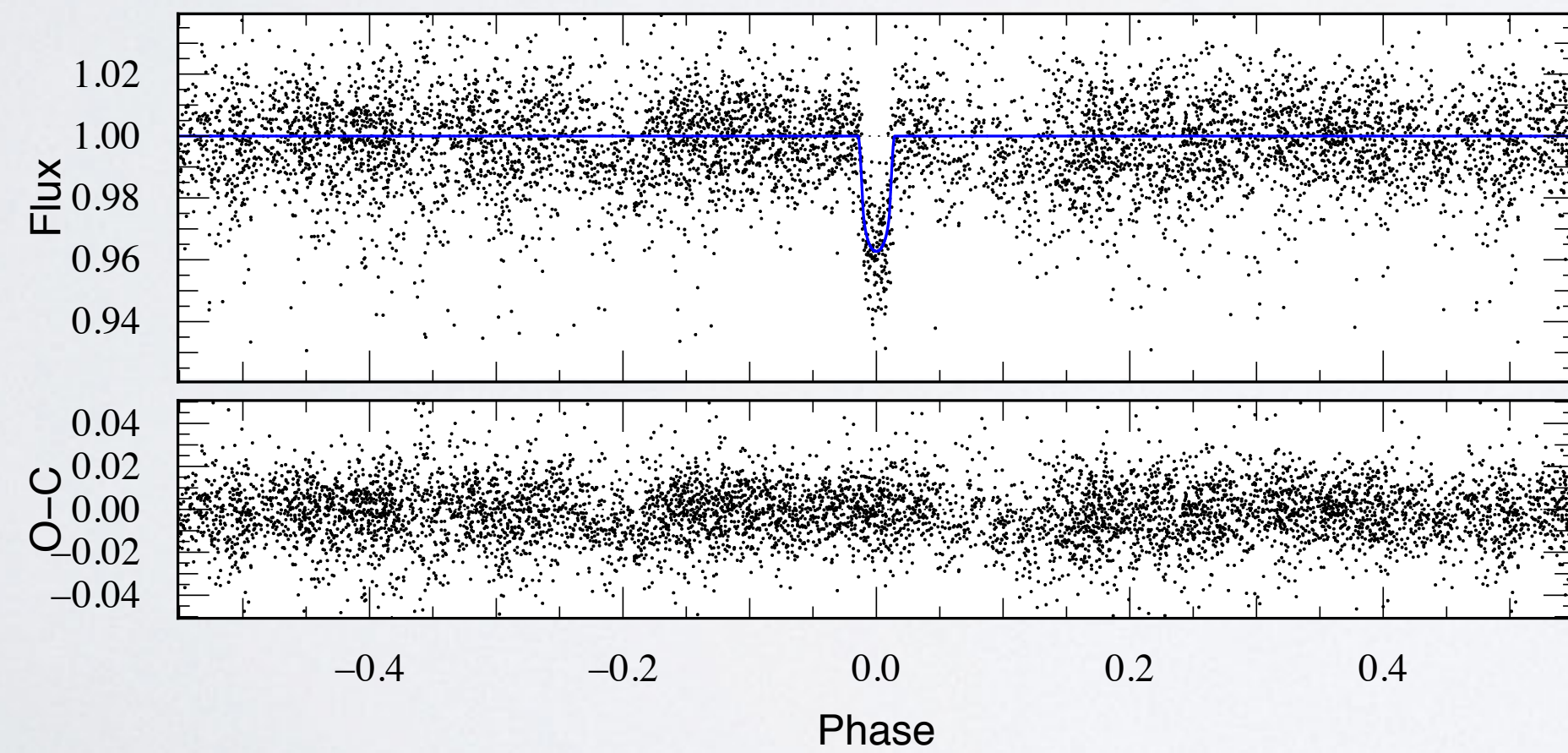
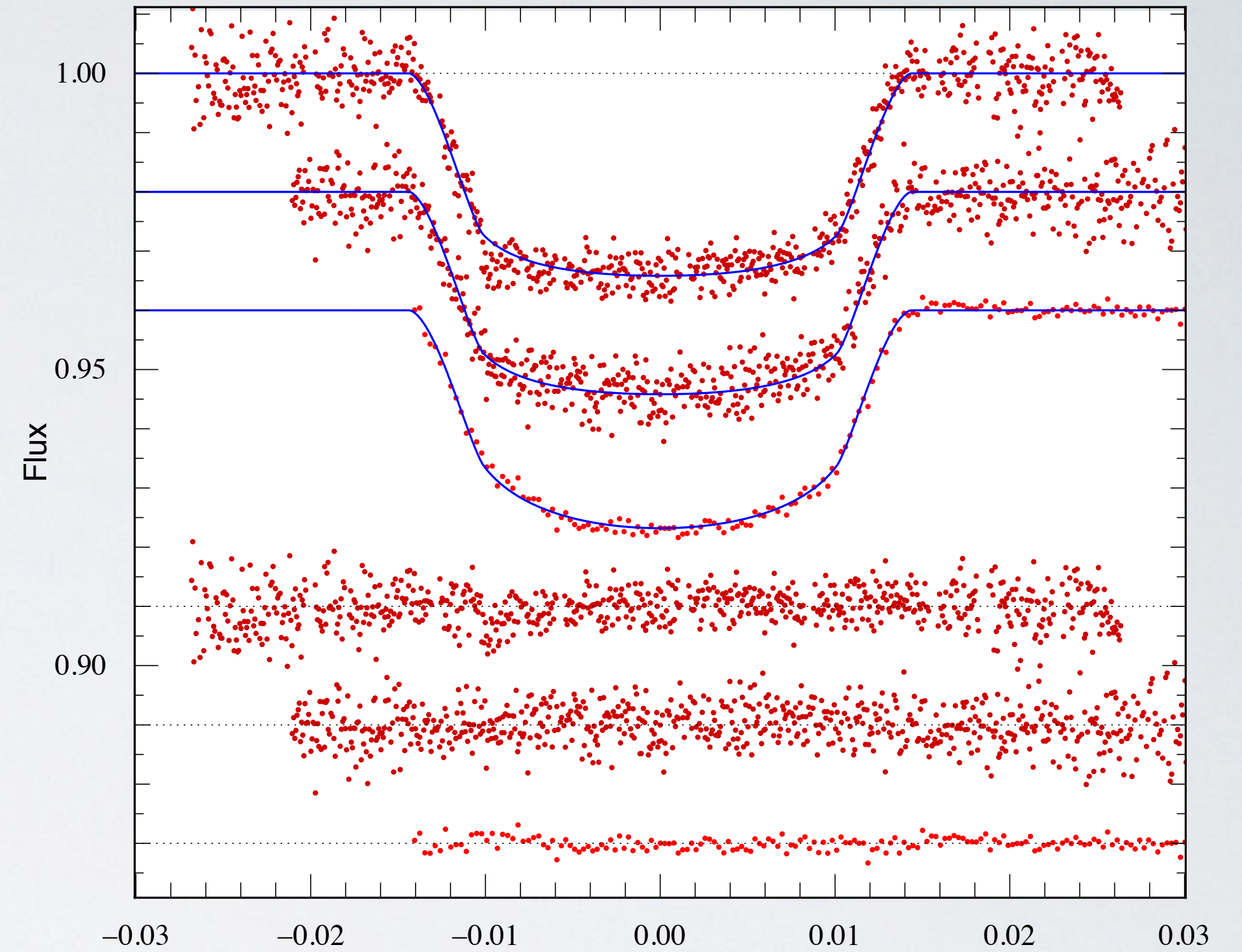
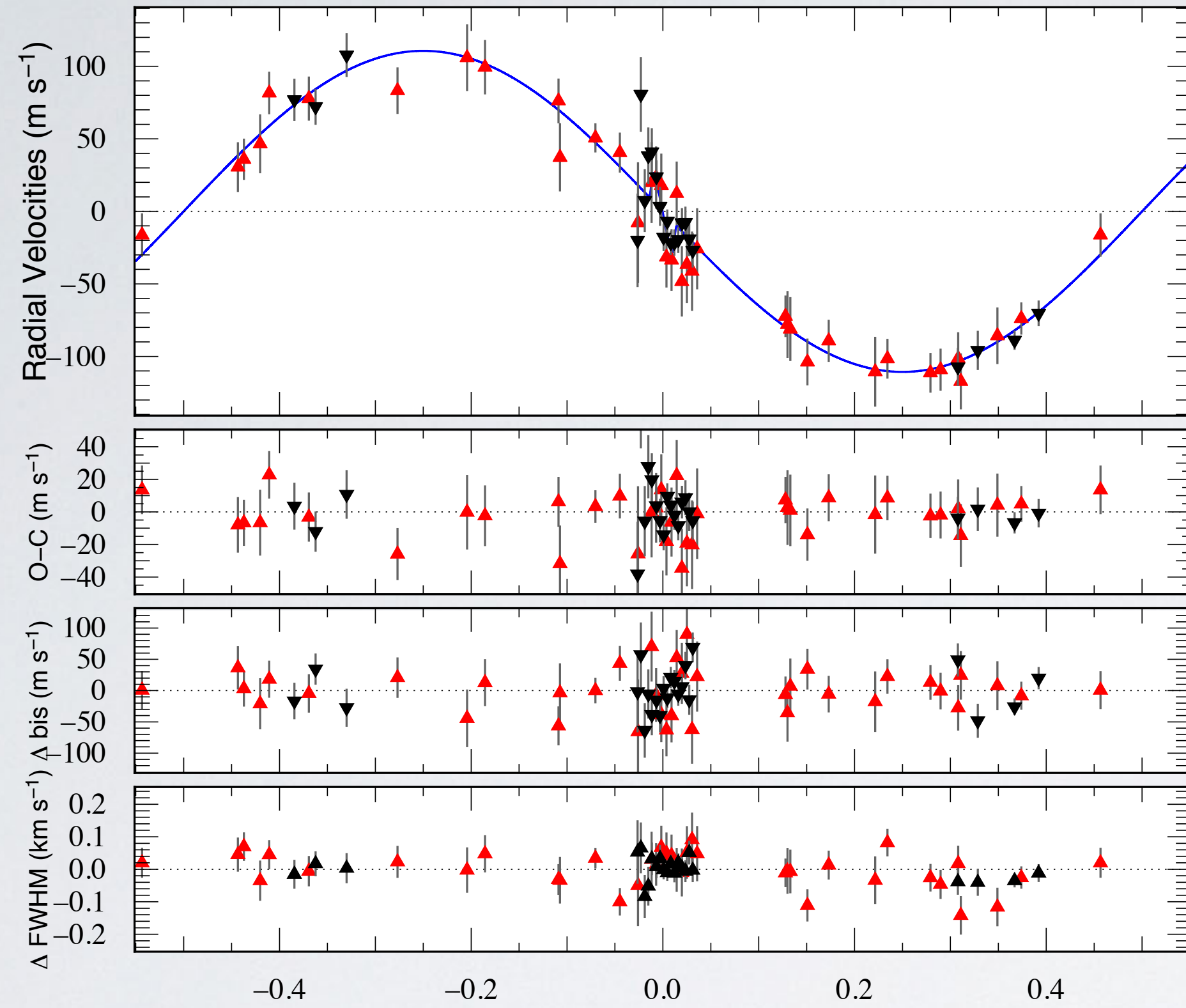
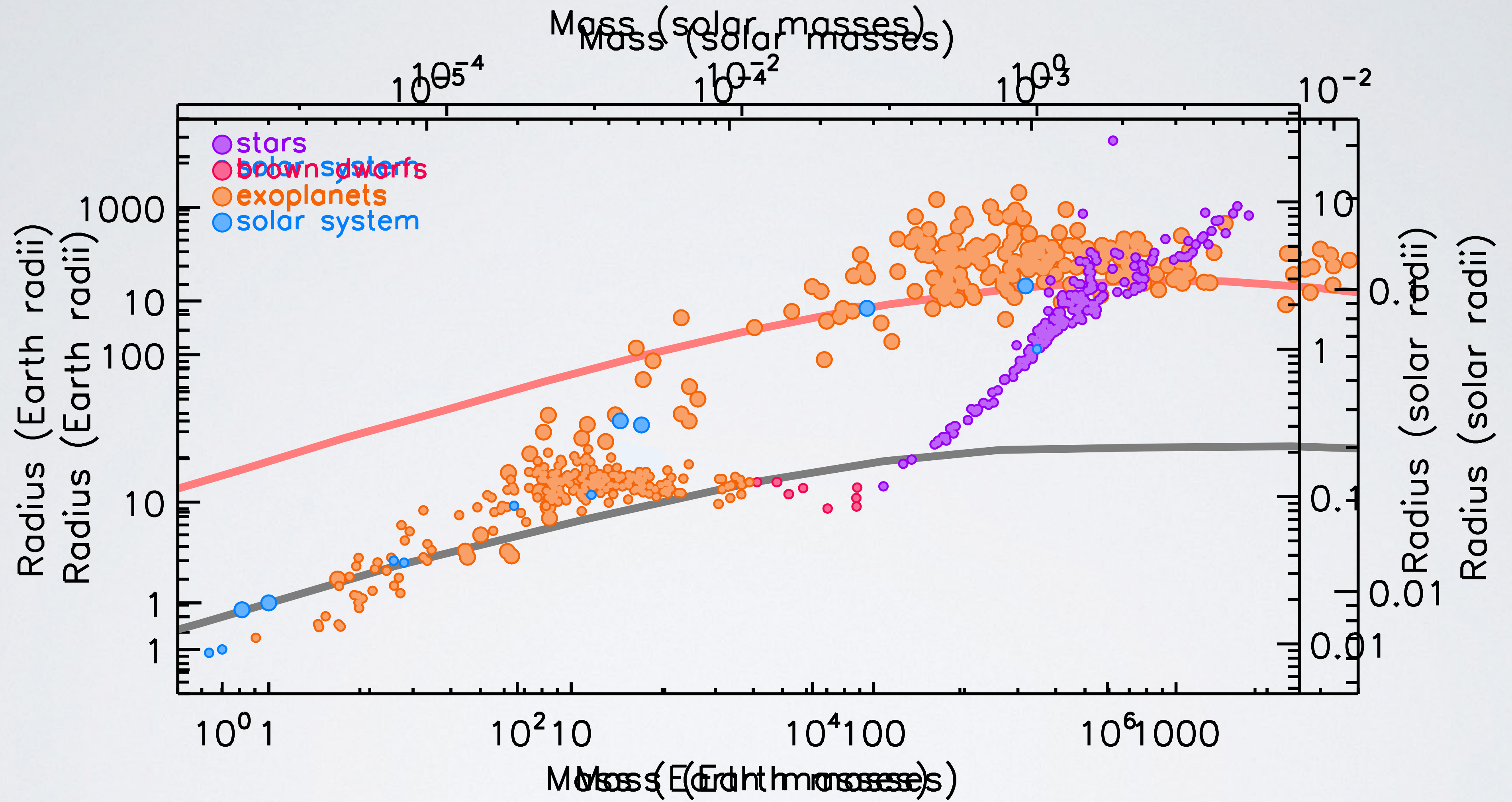
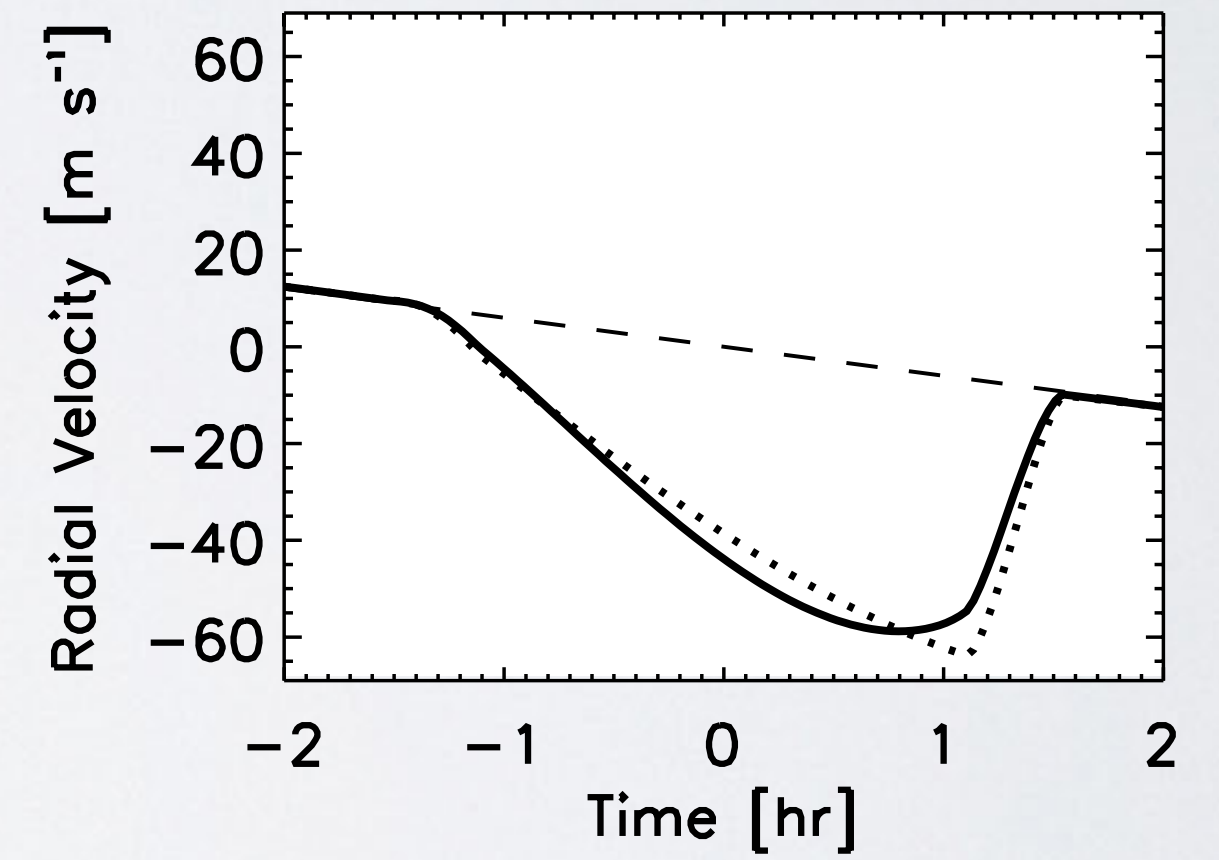
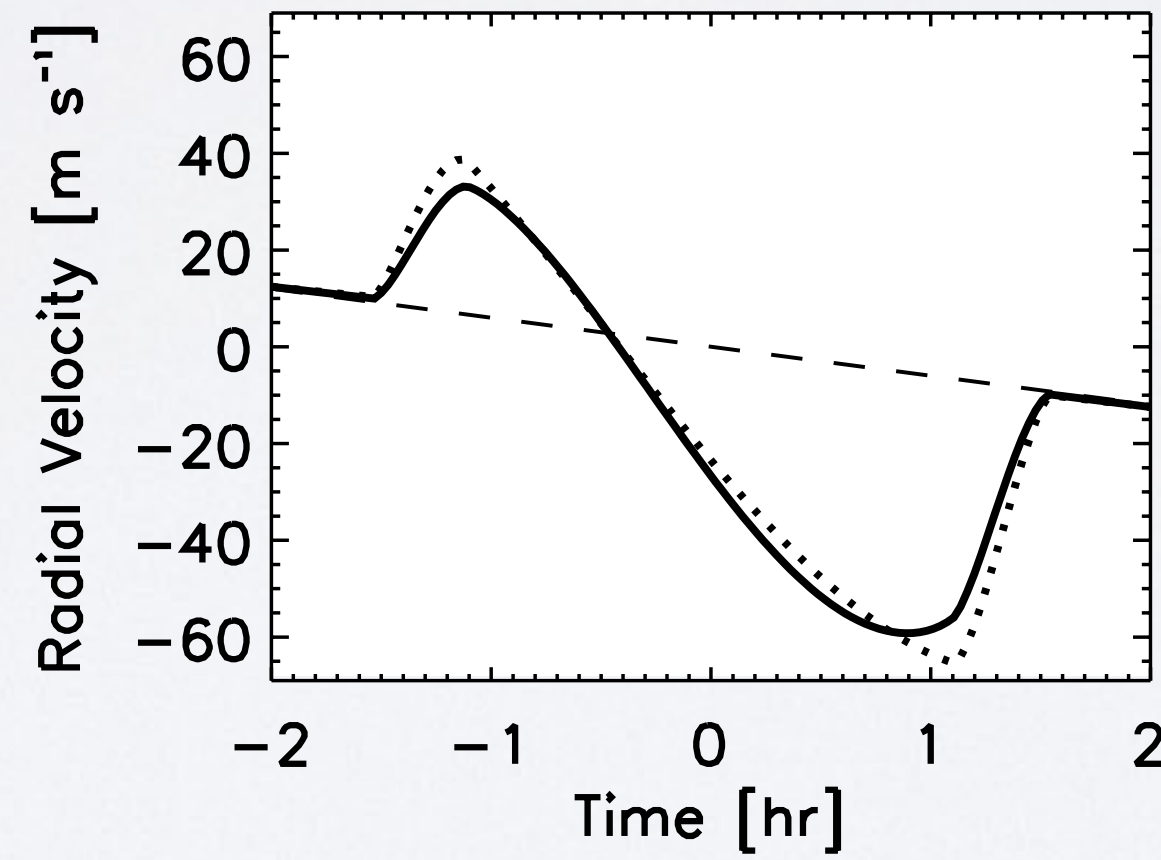
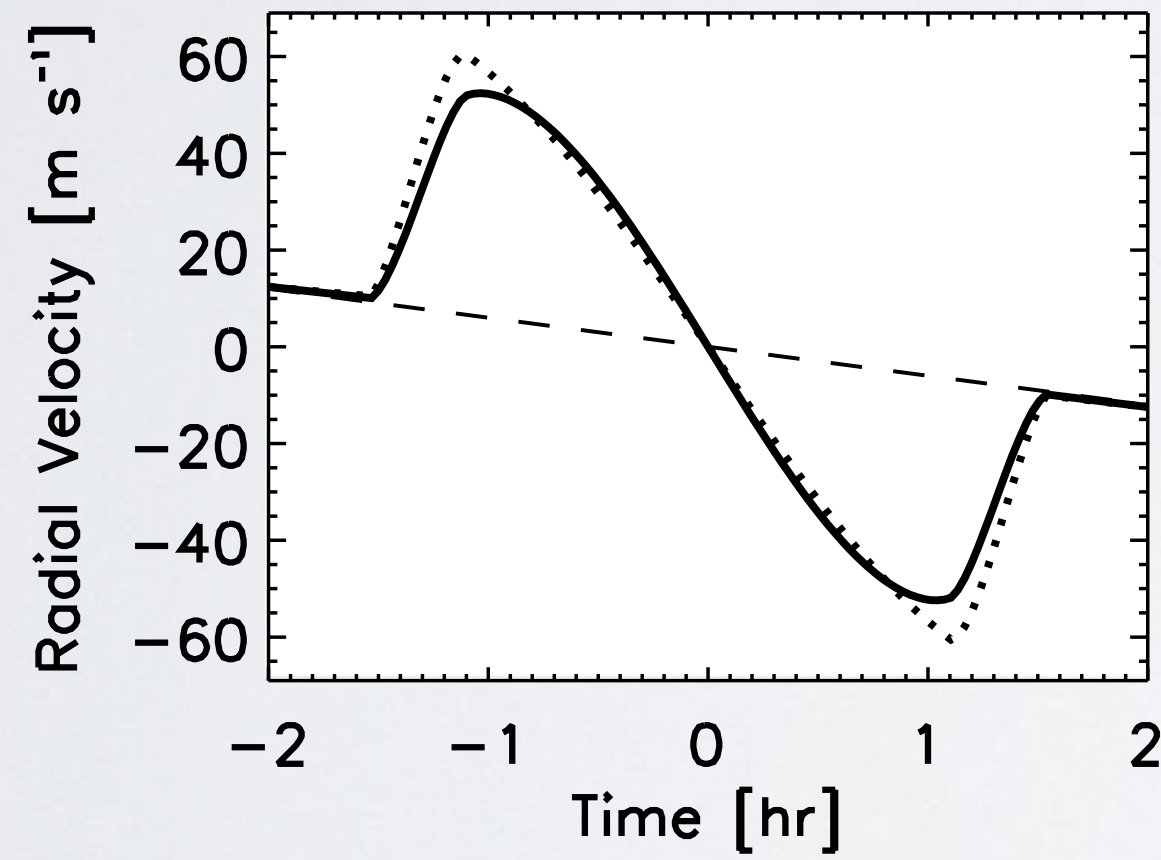
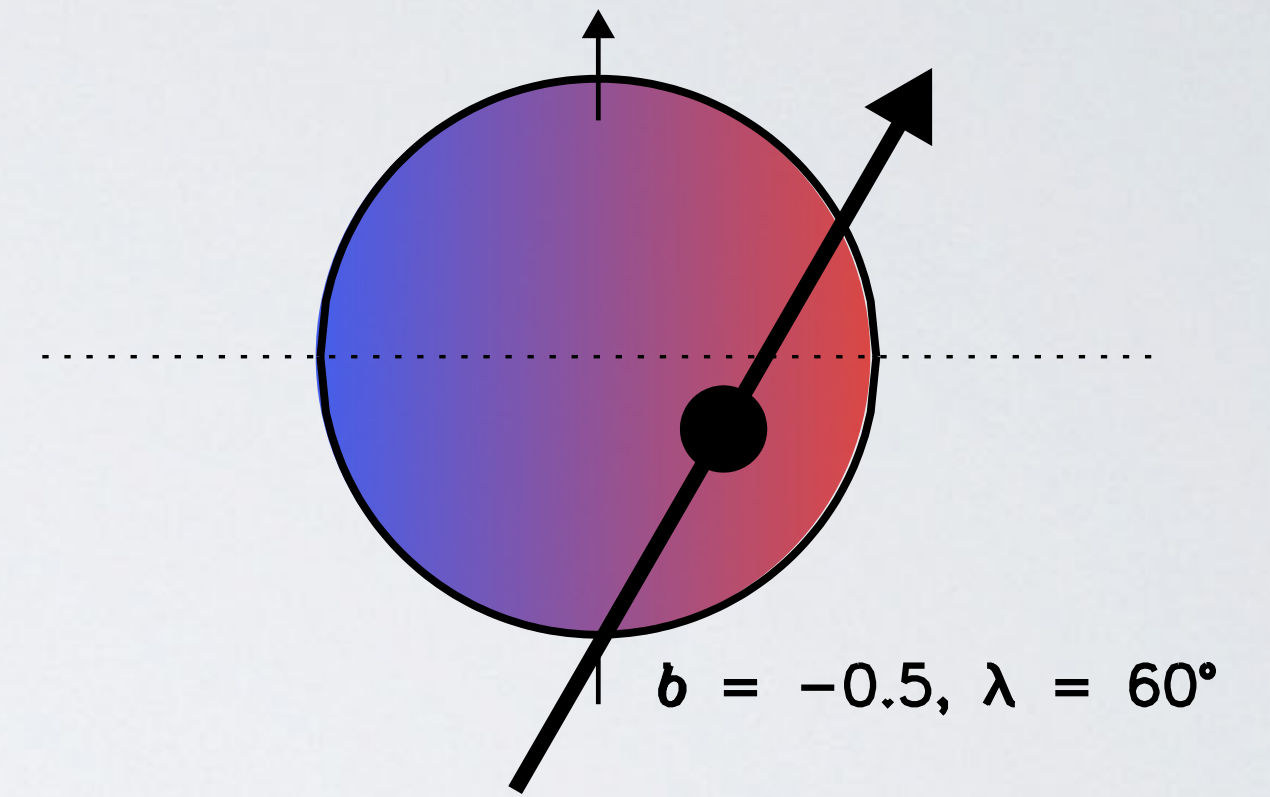
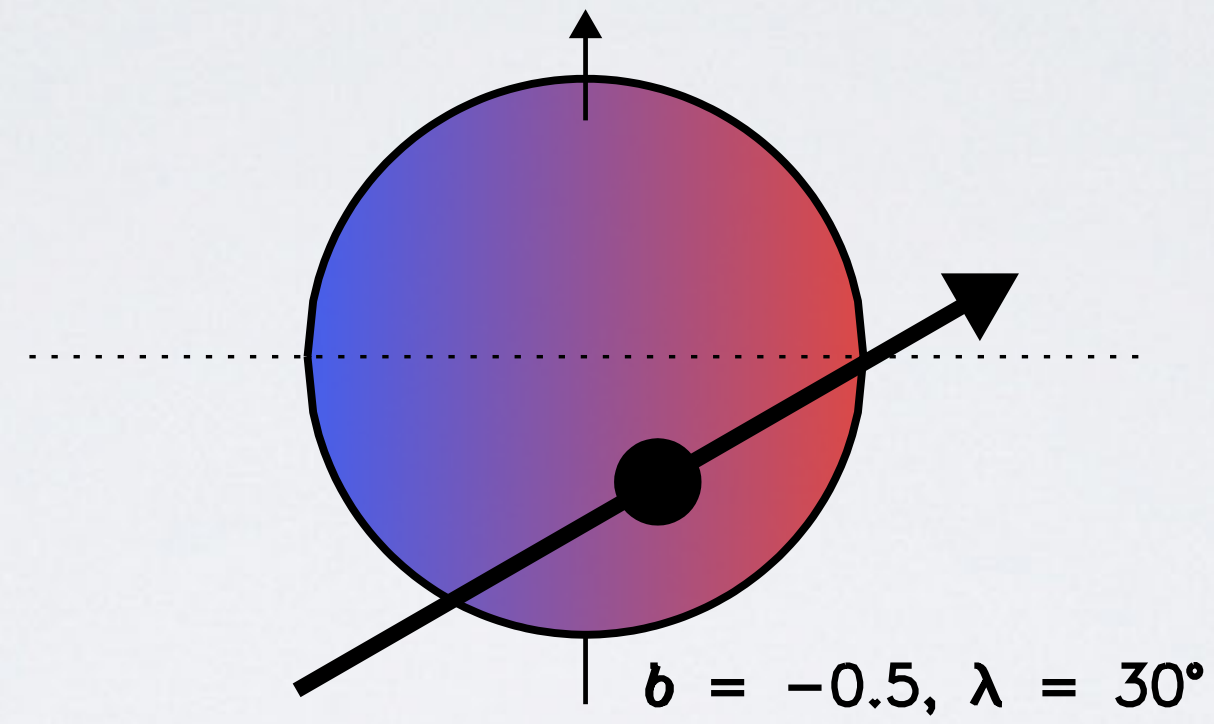
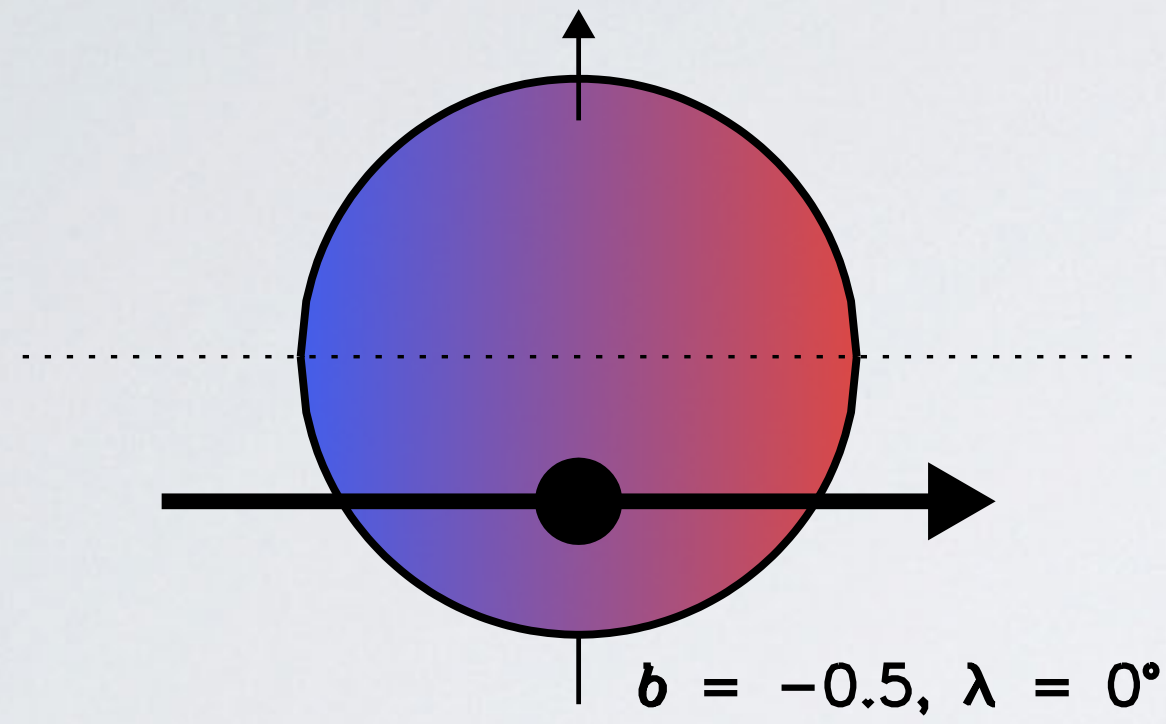


diagramme mass/rayon

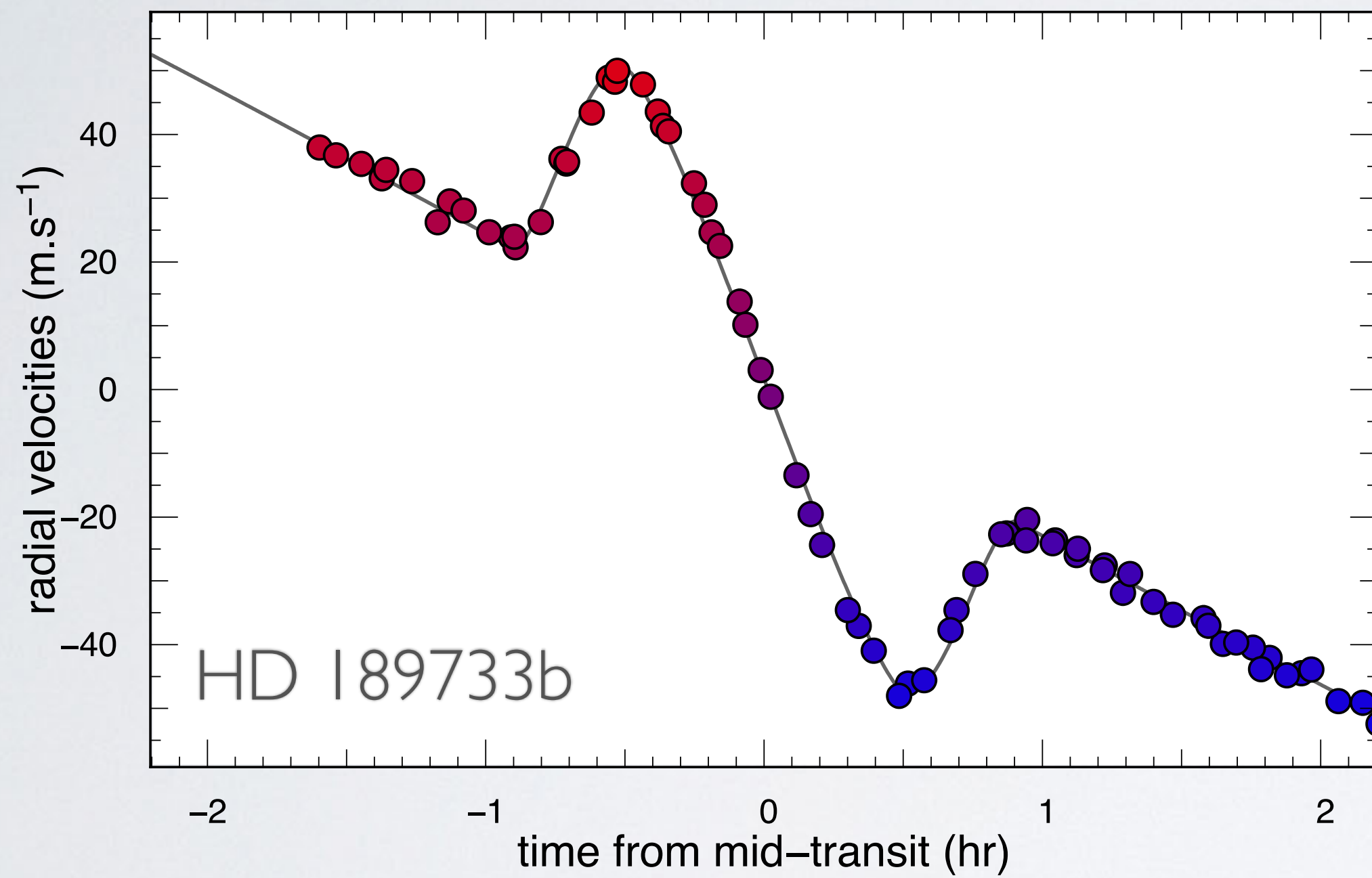


l'effet Rossiter-McLaughlin

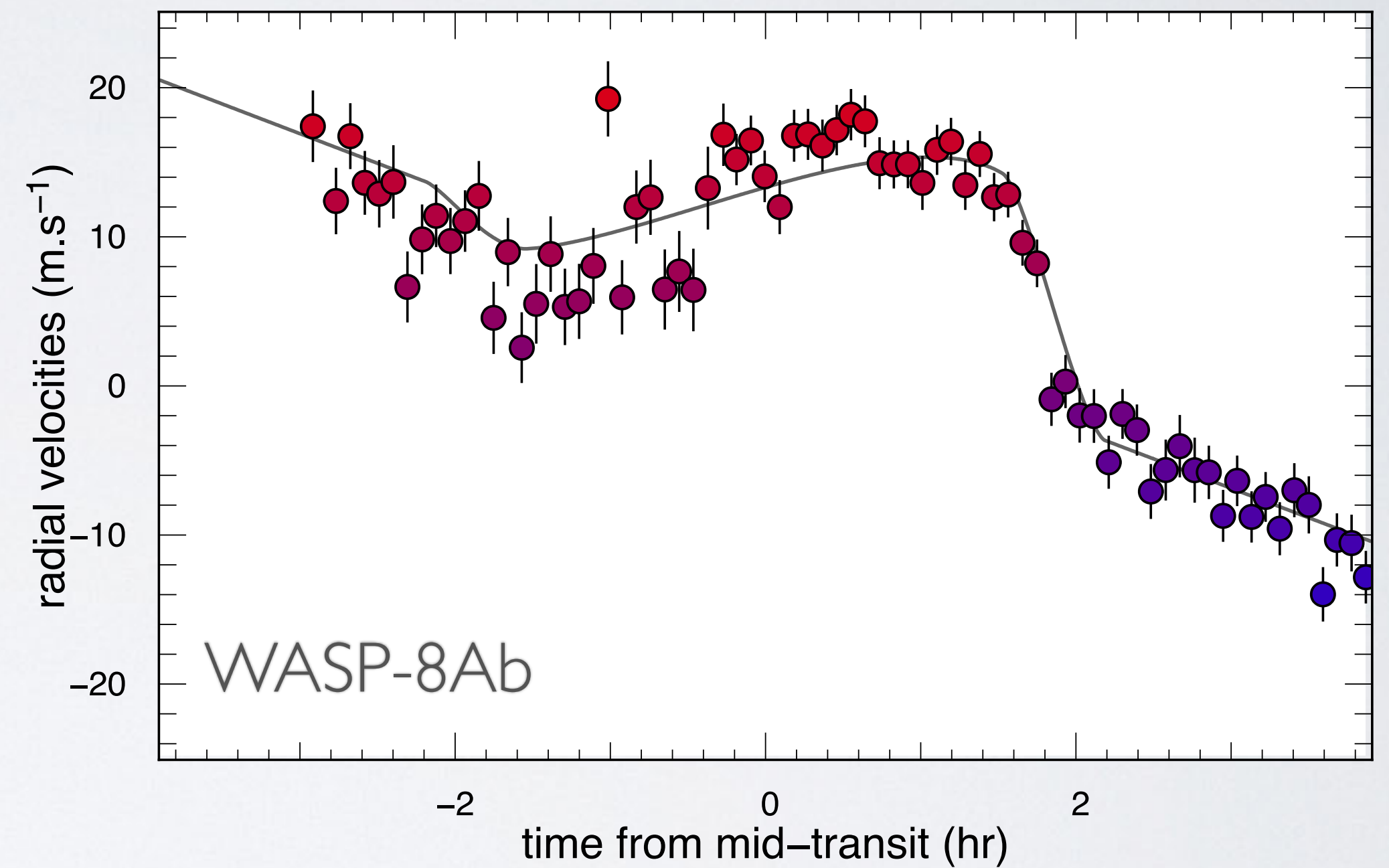


des planètes alignée, d'autre misalignée

coplanaire



rétrograde





caractérisation des atmosphères

spectroscopie de transmission

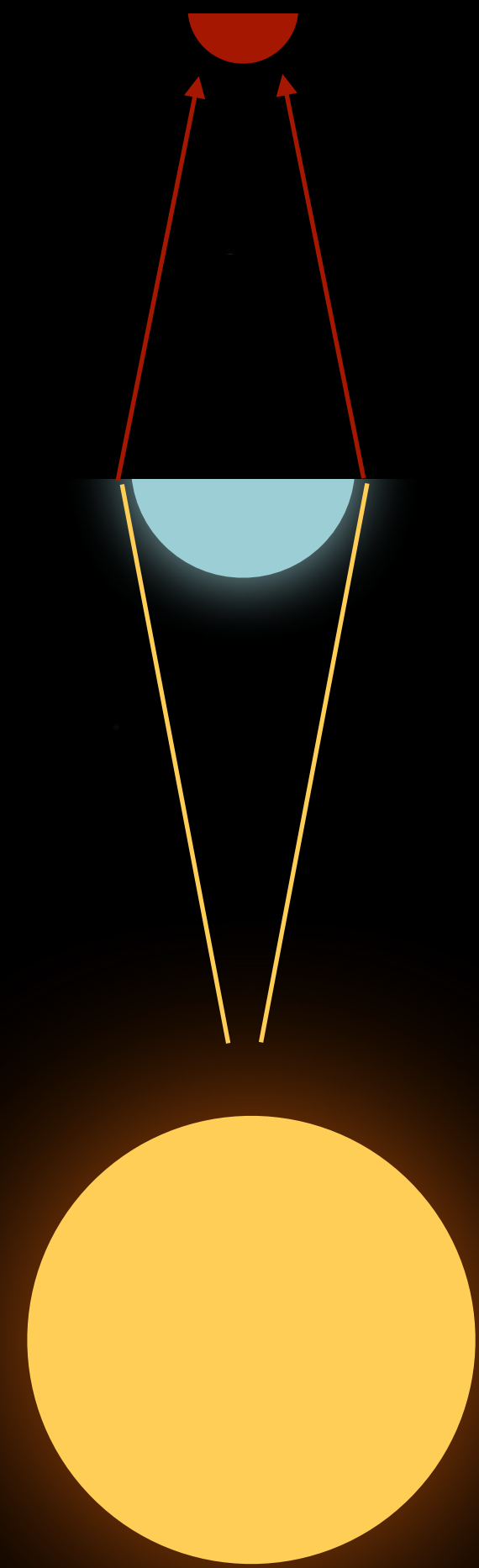
The image features a large, semi-transparent yellow circle on the left side. A dark blue, tapered beam-like shape extends from the right edge of the yellow circle towards the right side of the frame. The beam has a black circular end on the left and a red outline. The background is a light, off-white color. The text "spectroscopie de transmission" is centered horizontally across the upper part of the image, overlapping the yellow circle and the white background.



la lune

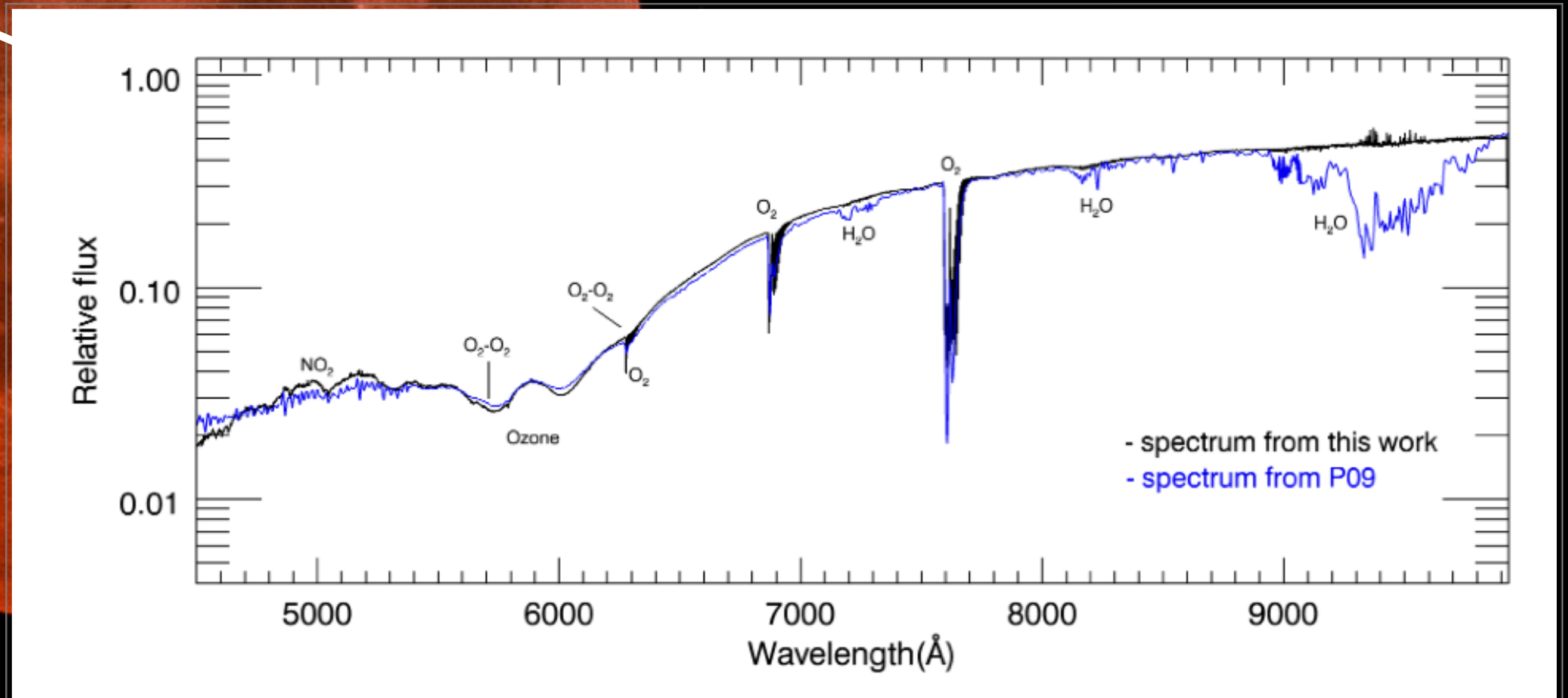
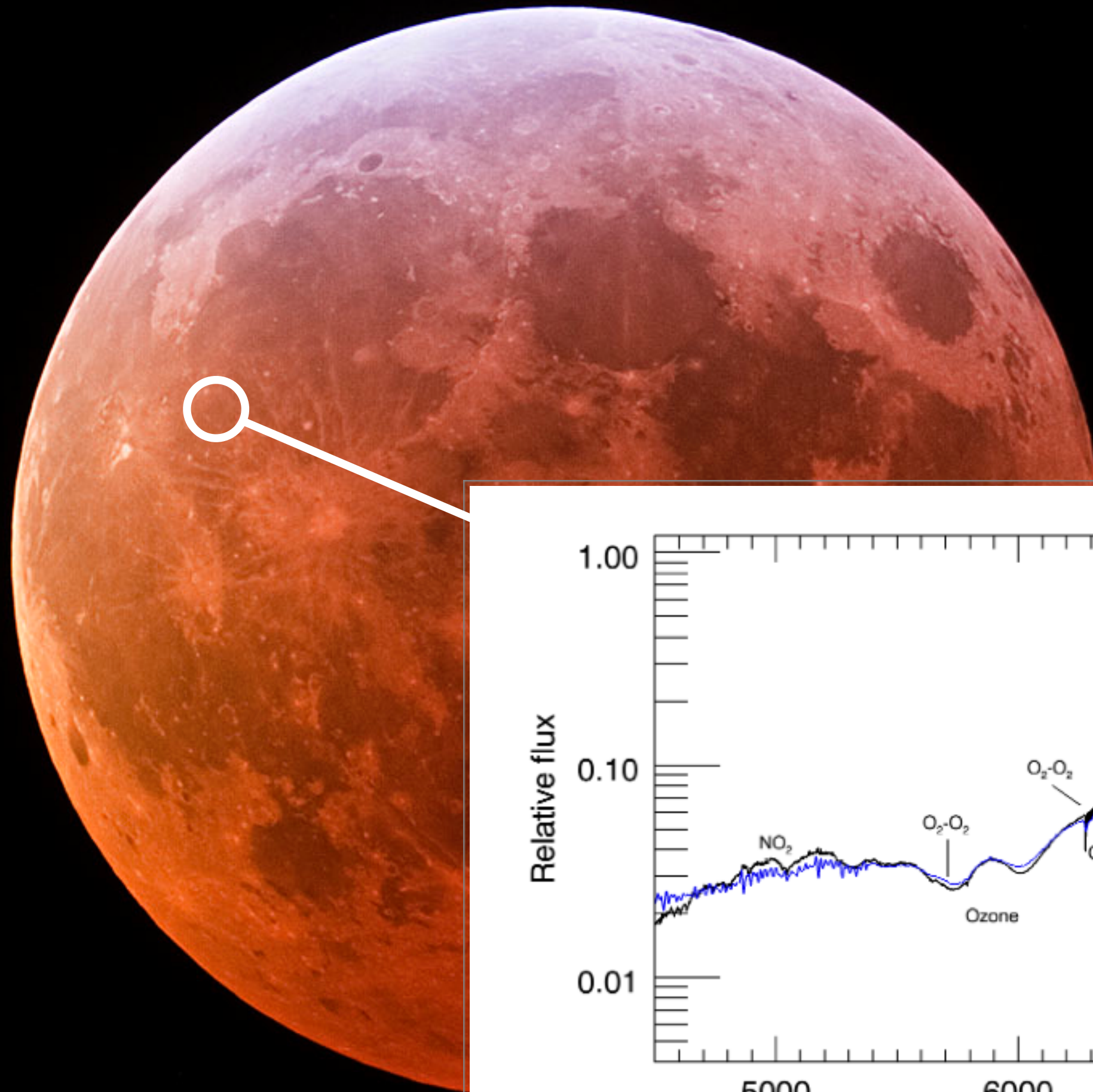
la terre

le soleil.

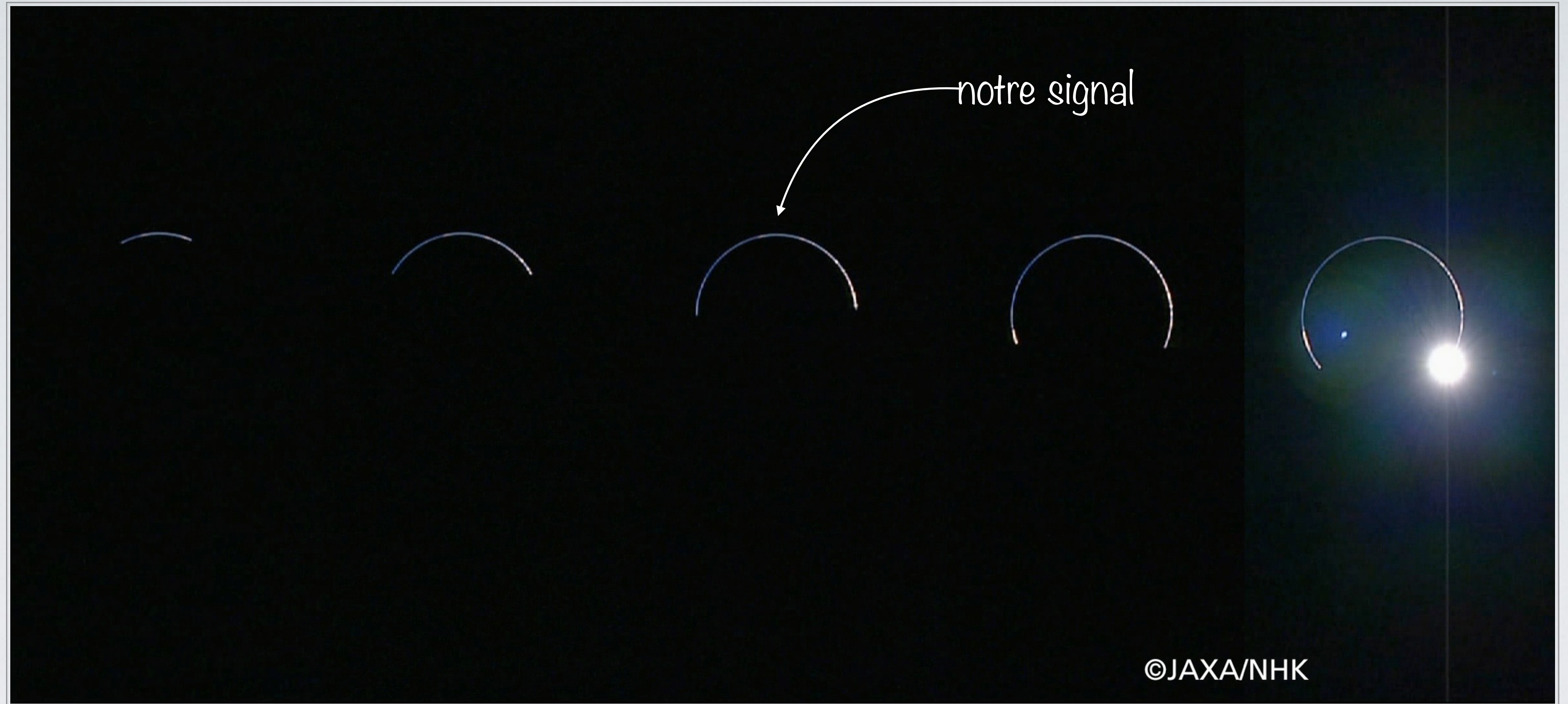




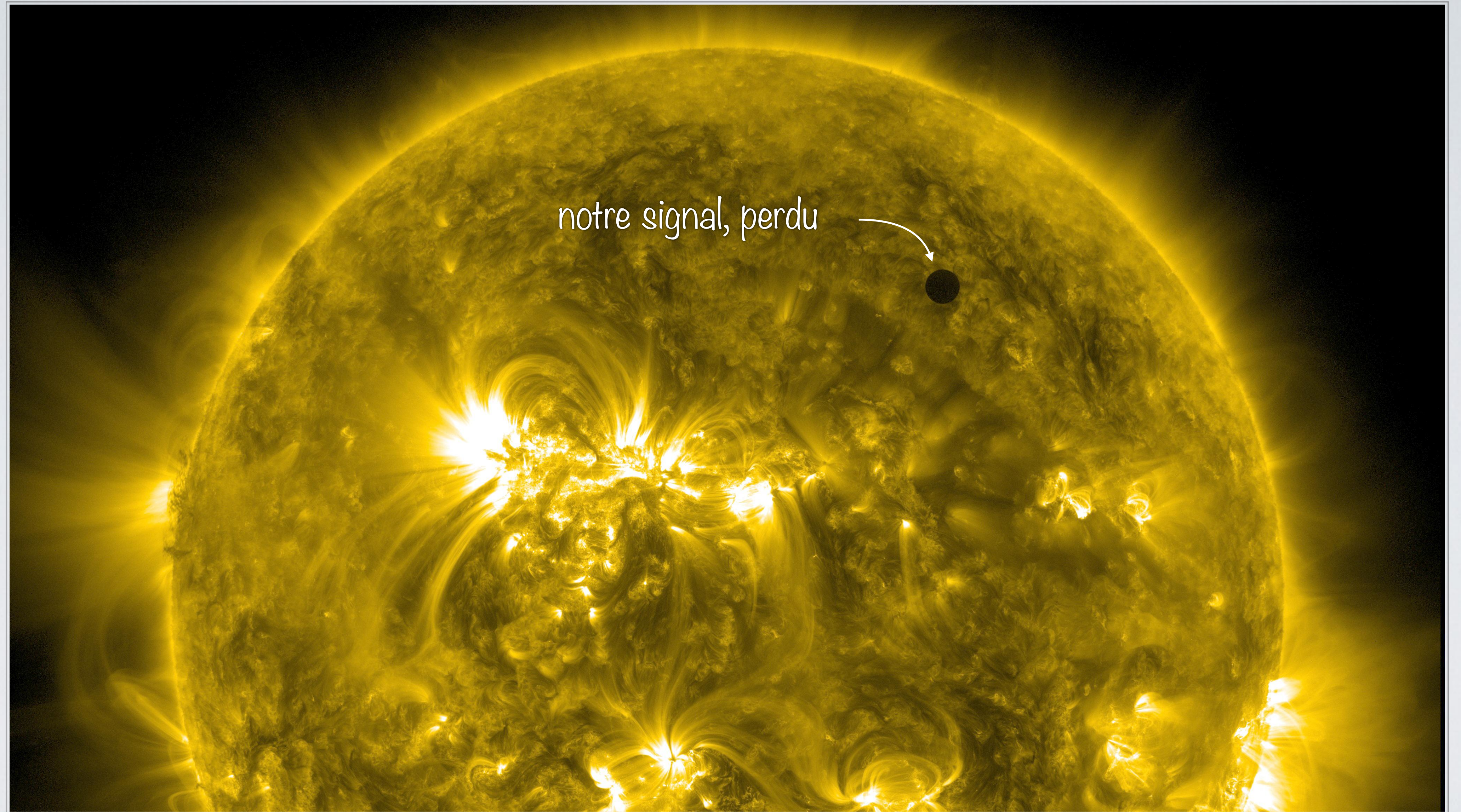
Eclipse de Lune, depuis la Lune



spectroscopie de transmission

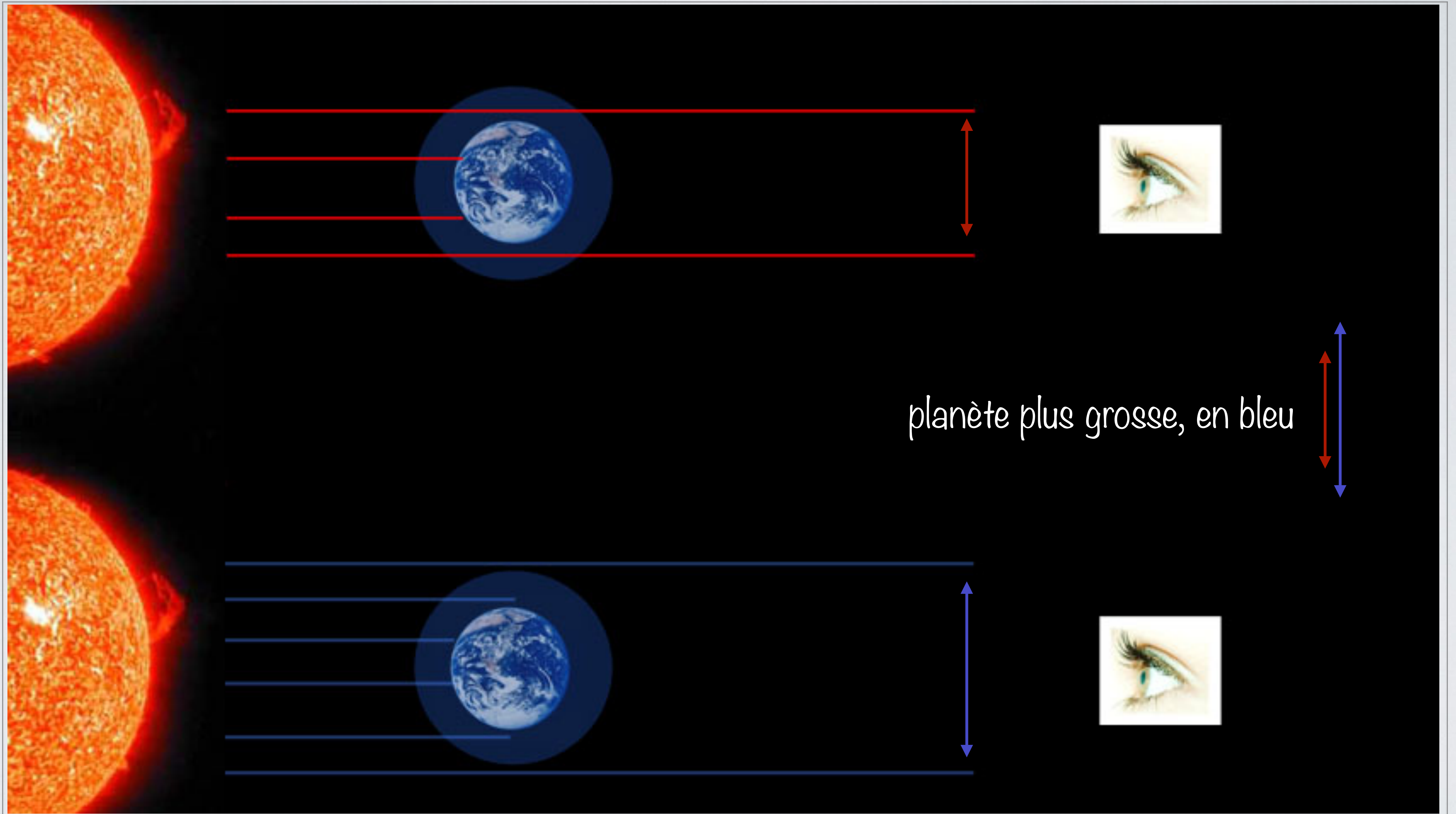


spectroscopie de transmission

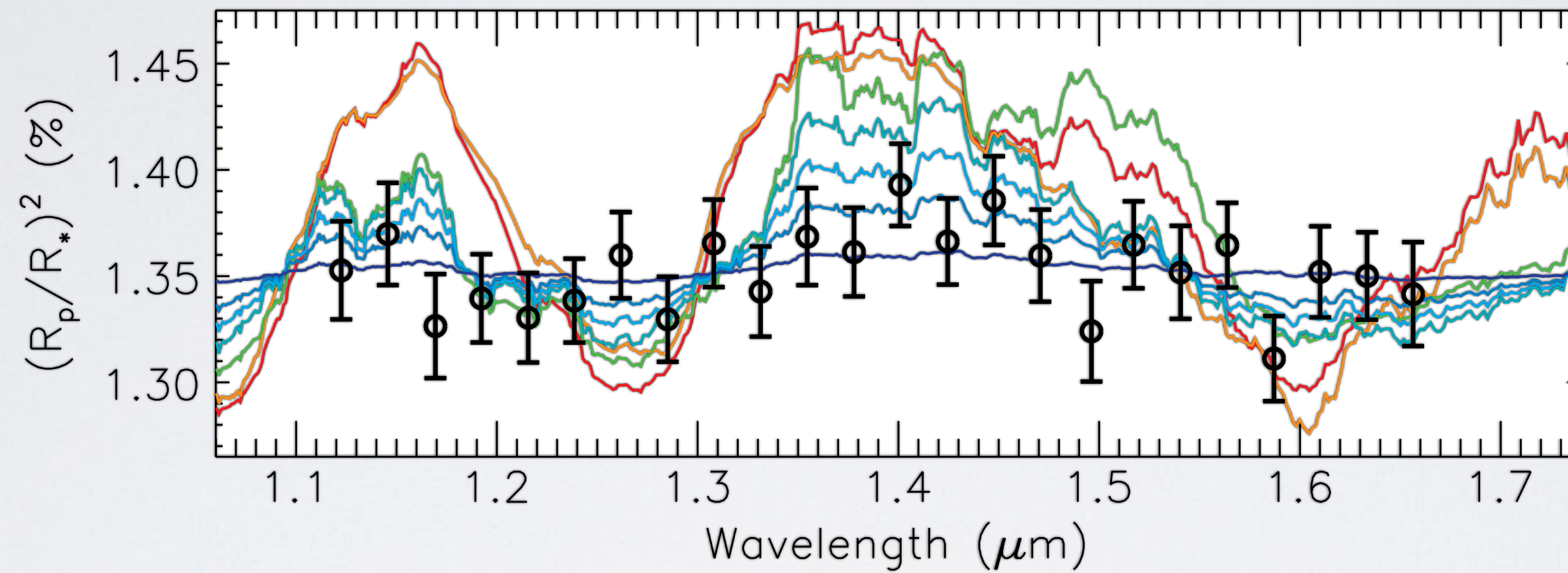


le transit de Vénus

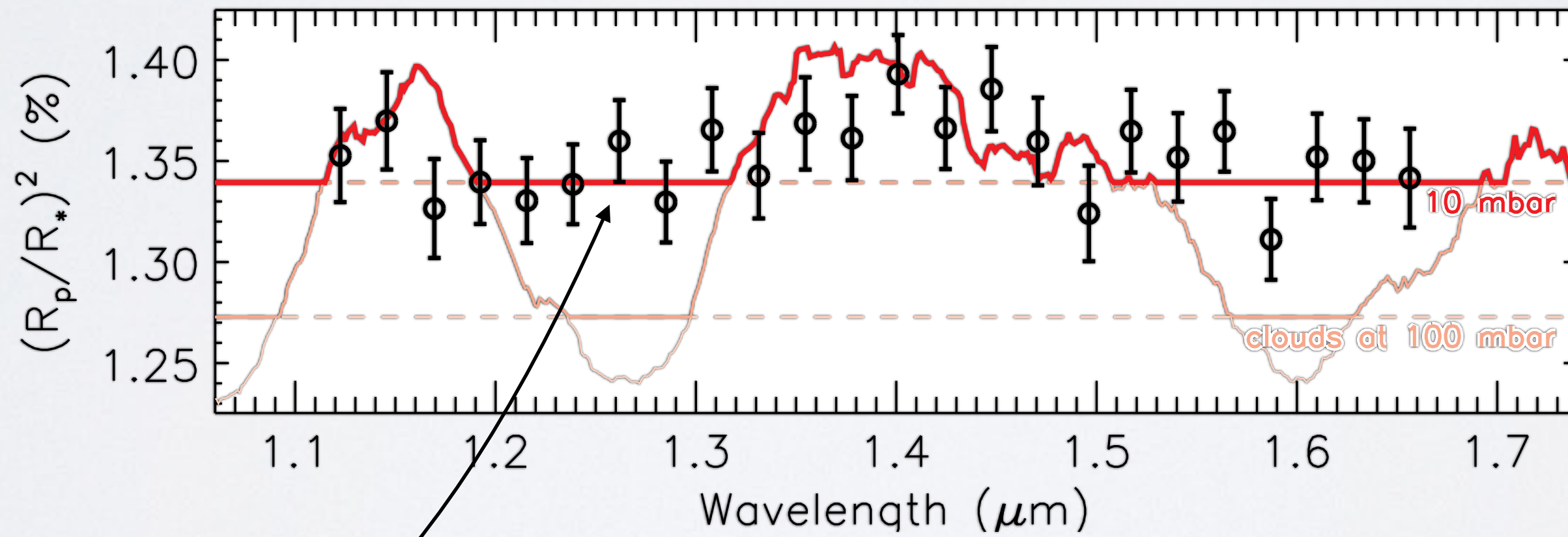
spectroscopie de transmission



spectroscopie de transmission



- solar: $\chi^2=126.2$
- solar with 50X metals: $\chi^2=113.2$
- solar with no CH_4 : $\chi^2=88.9$
- 10% H_2O : $\chi^2=47.8$
- 20% H_2O : $\chi^2=25.5$
- 40% H_2O : $\chi^2=15.3$
- 100% H_2O : $\chi^2=16.7$

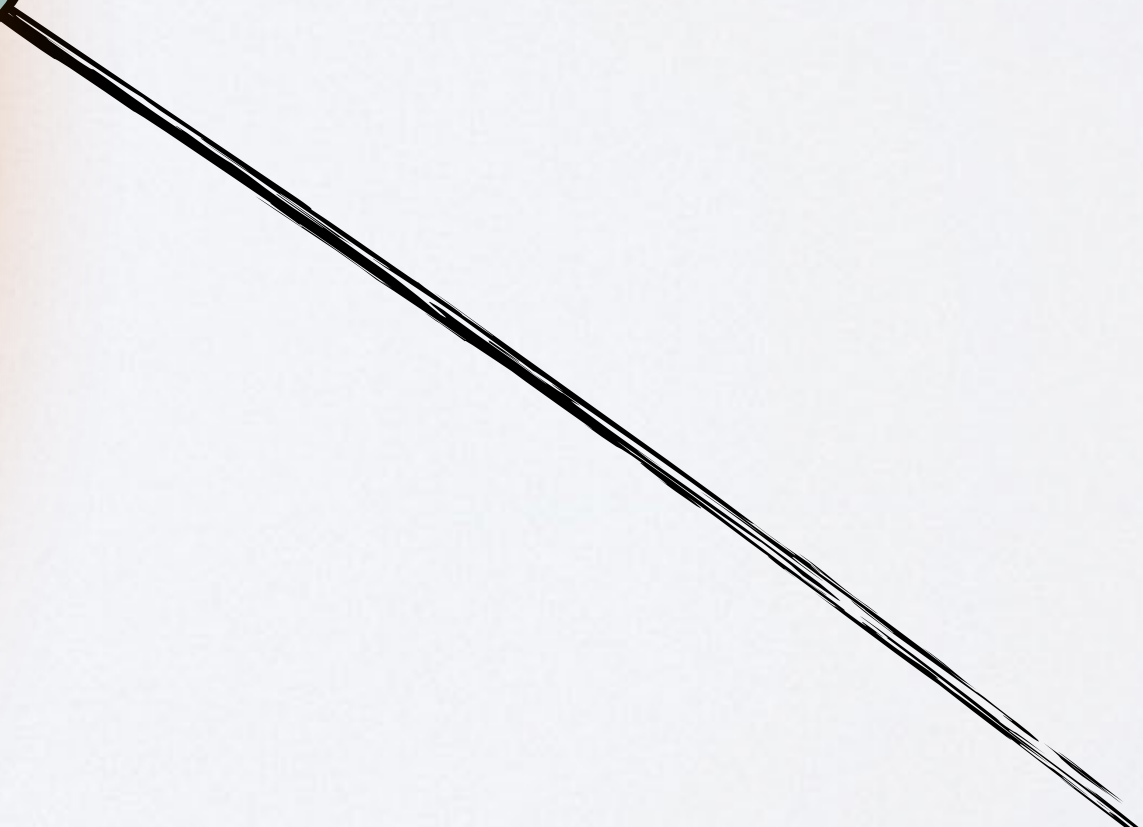
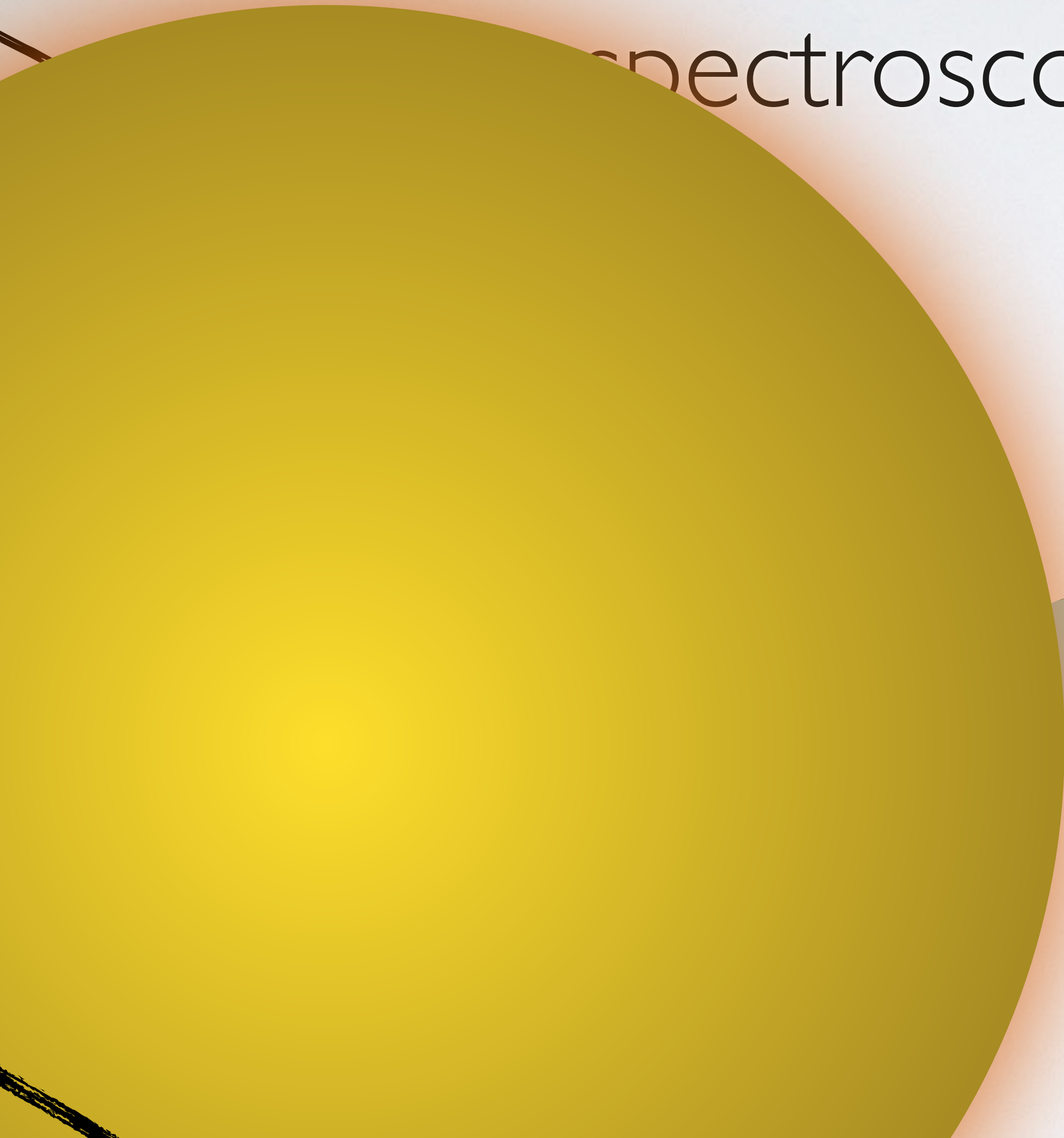


p\$\$#&*g de nuages

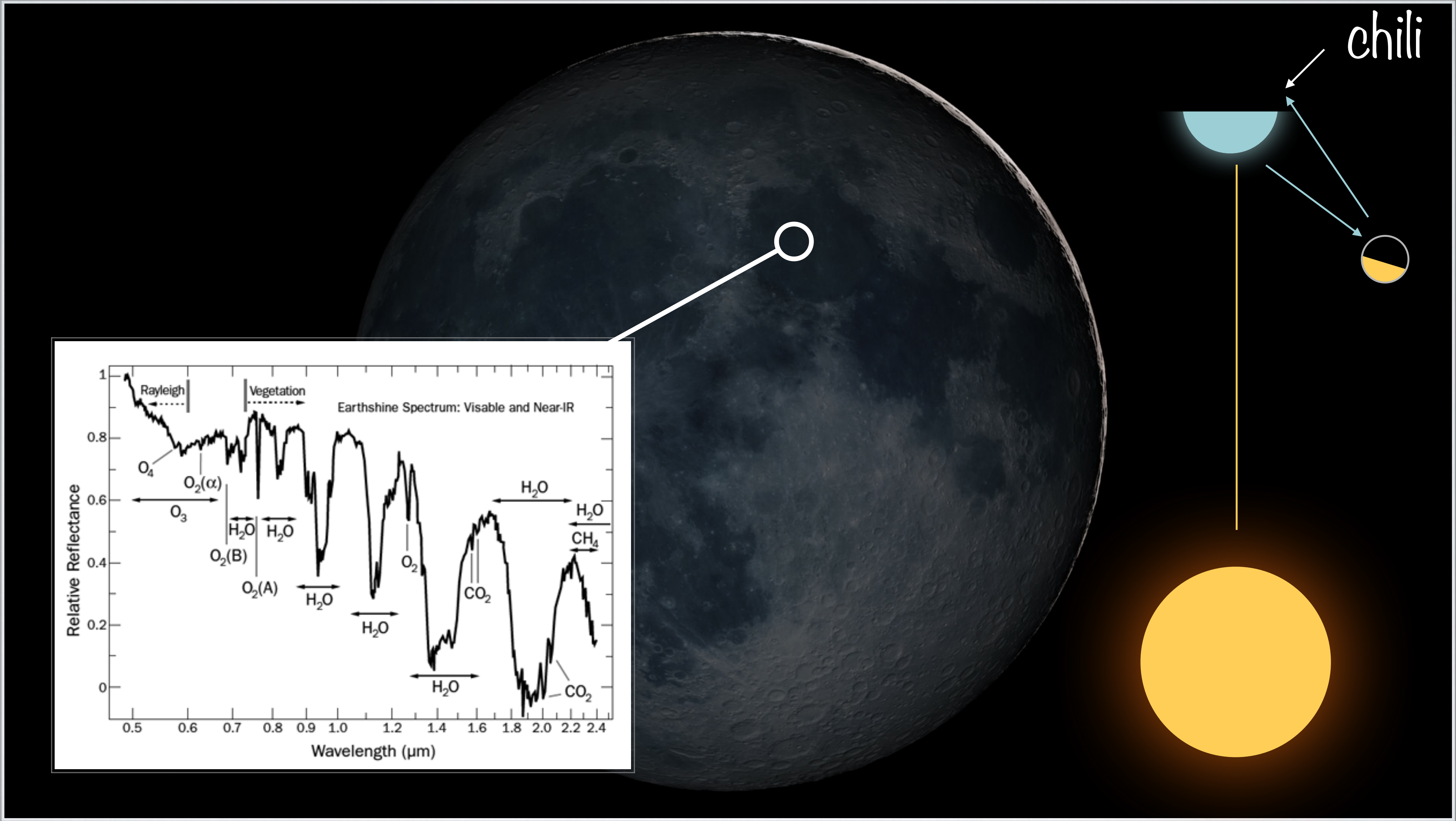
GJ 1214b

Berta et al. 2012

spectroscopie d'émission



spectroscopie d'émission

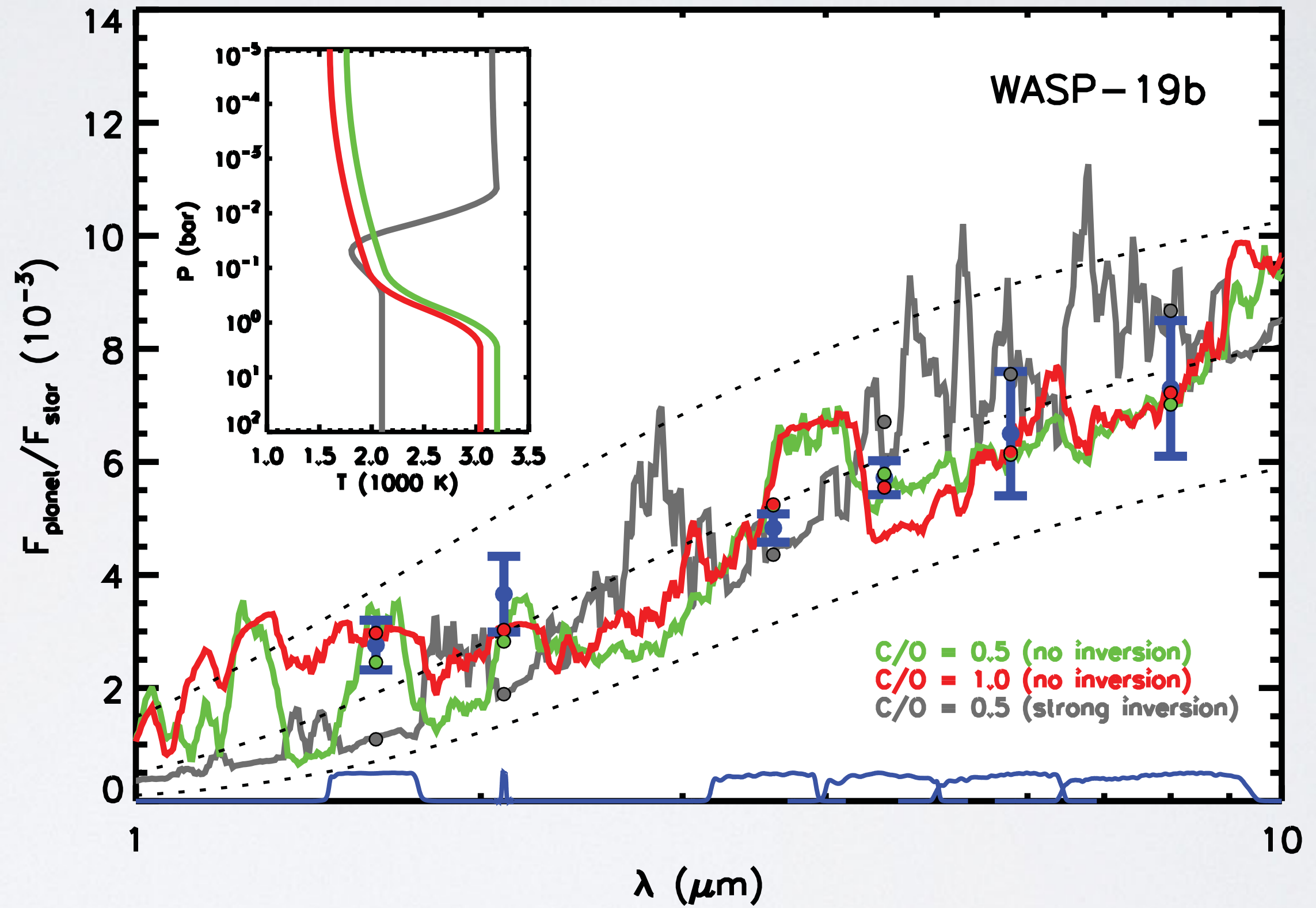
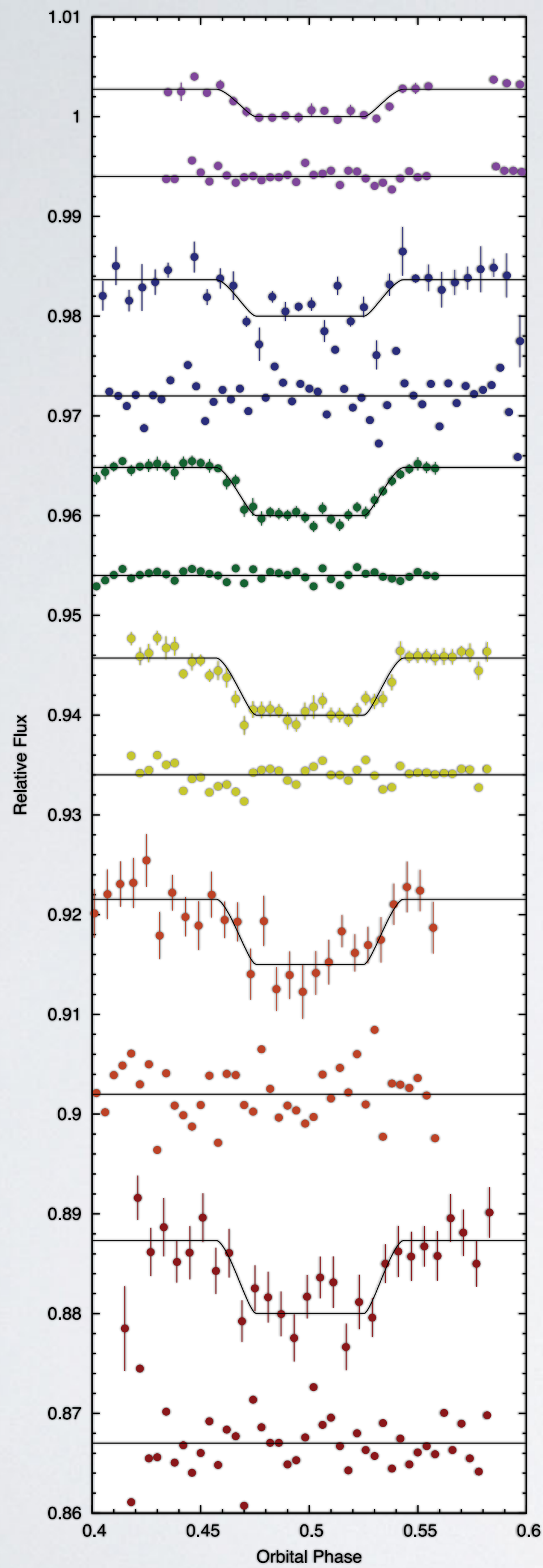


chili



la lueur cendrée

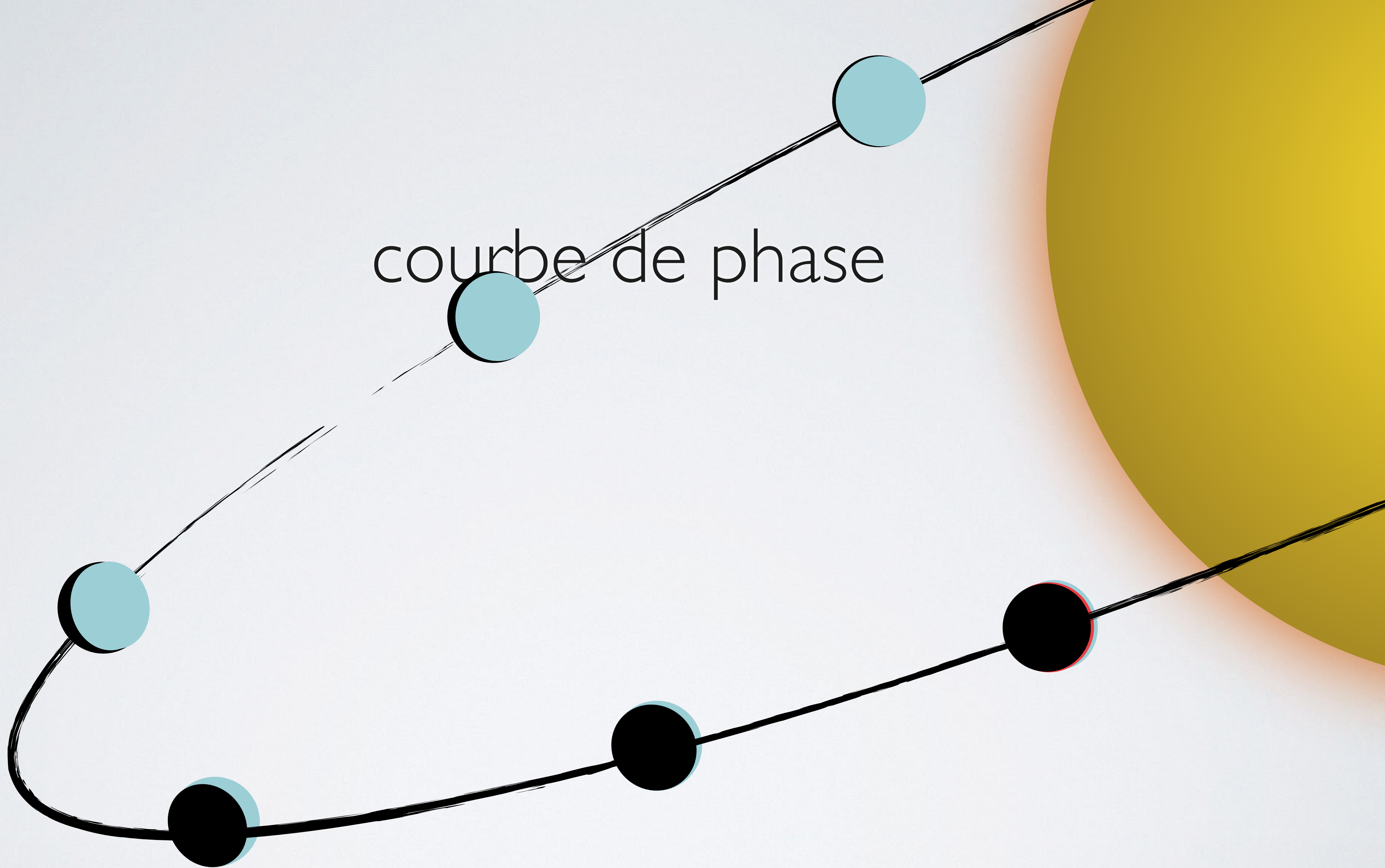
spectroscopie d'émission



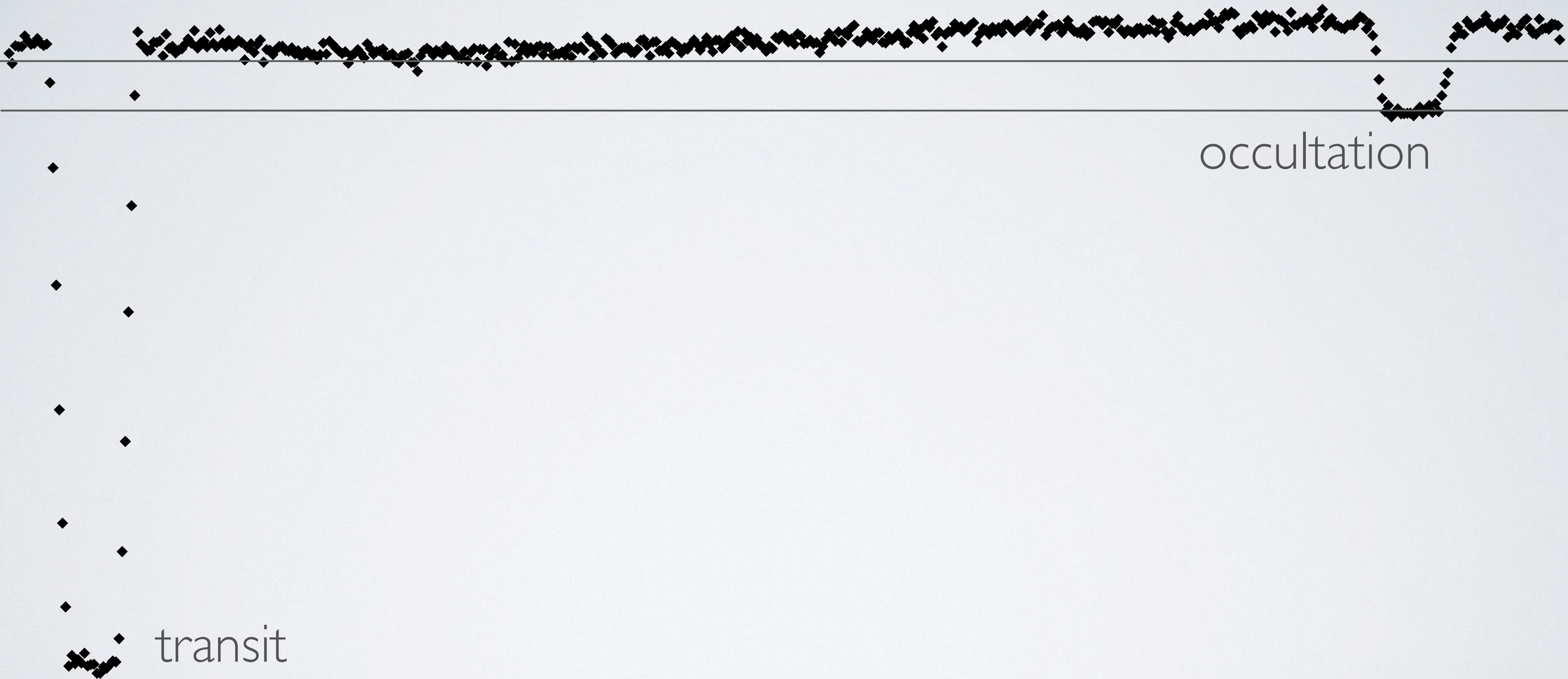
WASP-19b

Anderson et al. 2013

courbe de phase



courbe de phase



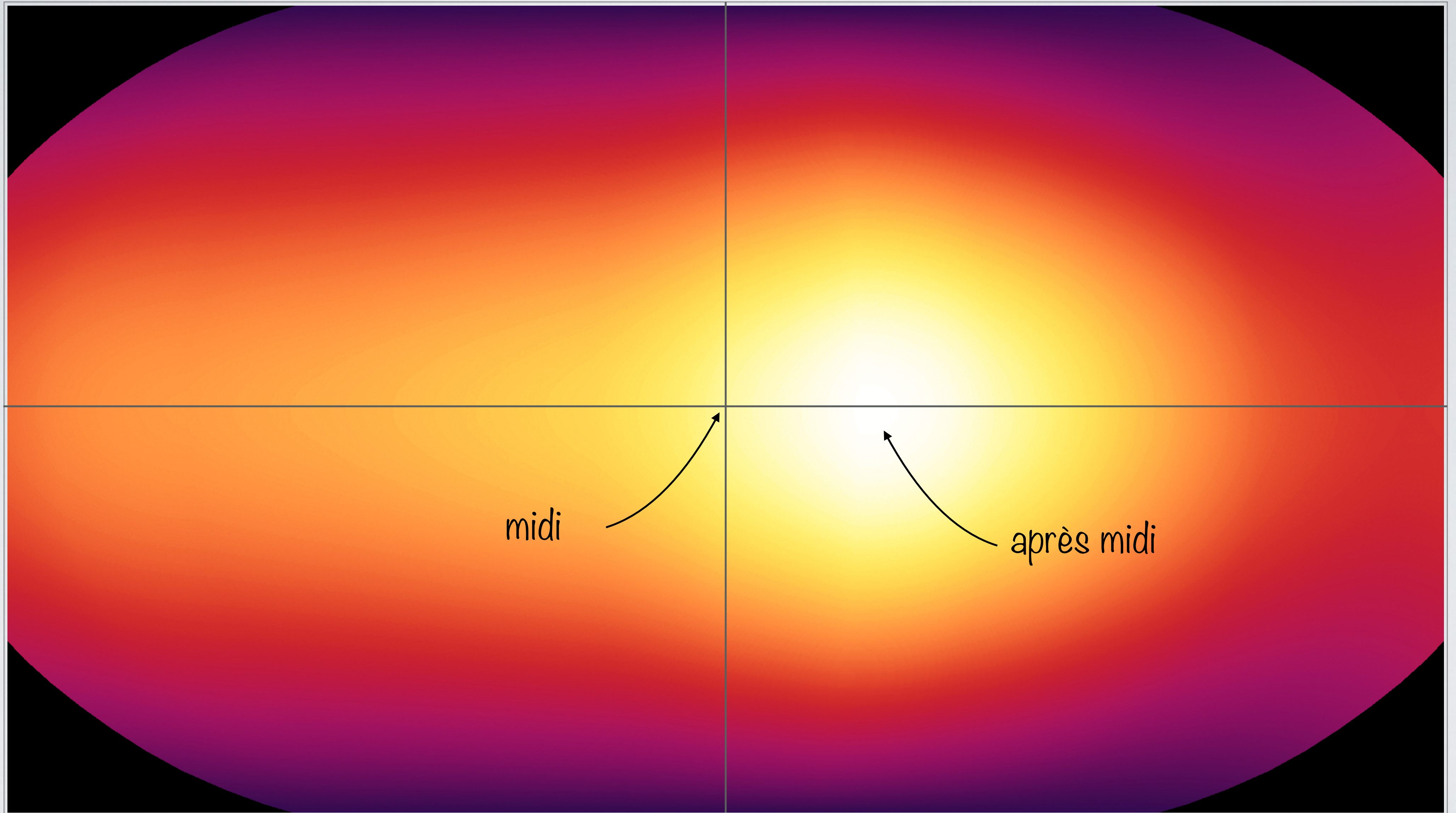
transit

occultation

donnés réelles

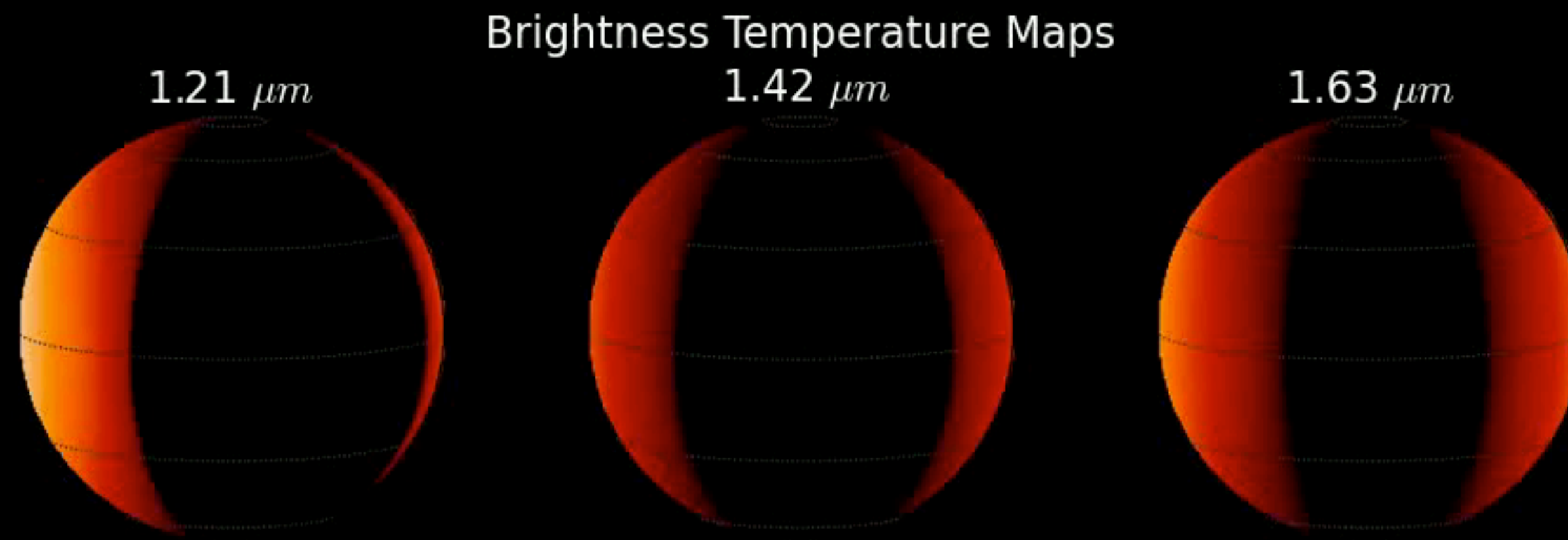
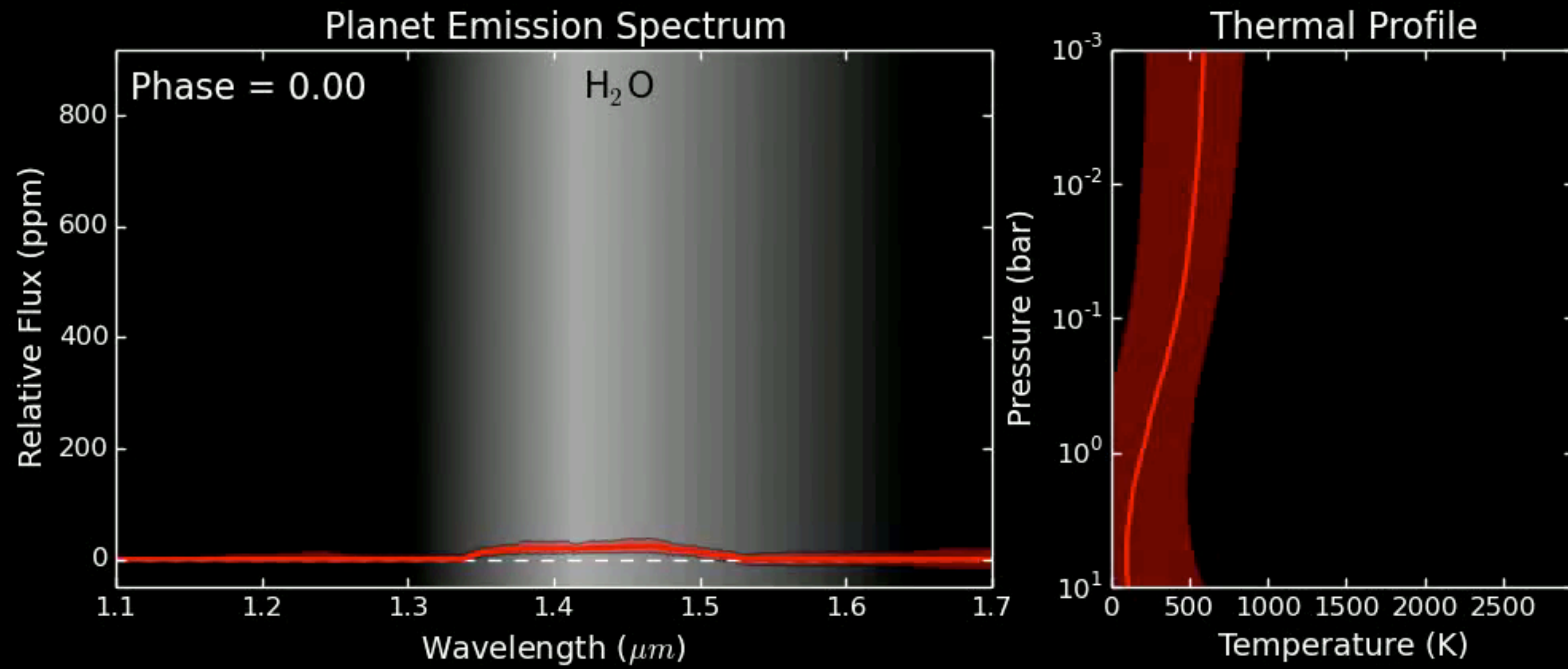
Knutson et al. 2012

carte en 1D



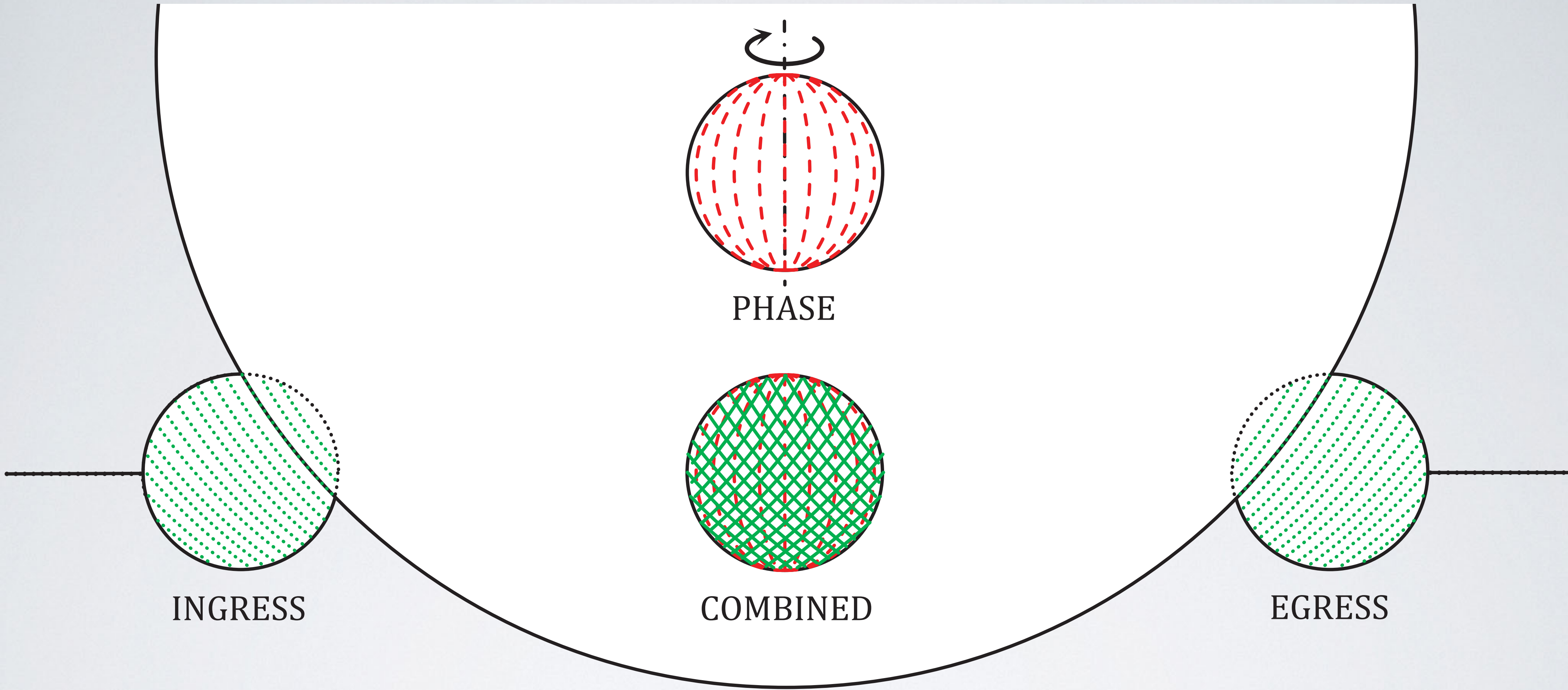
Knutson et al. 2012

carte spectrale



K. B. Stevenson (2014)

carte en 2D



INGRESS

PHASE

COMBINED

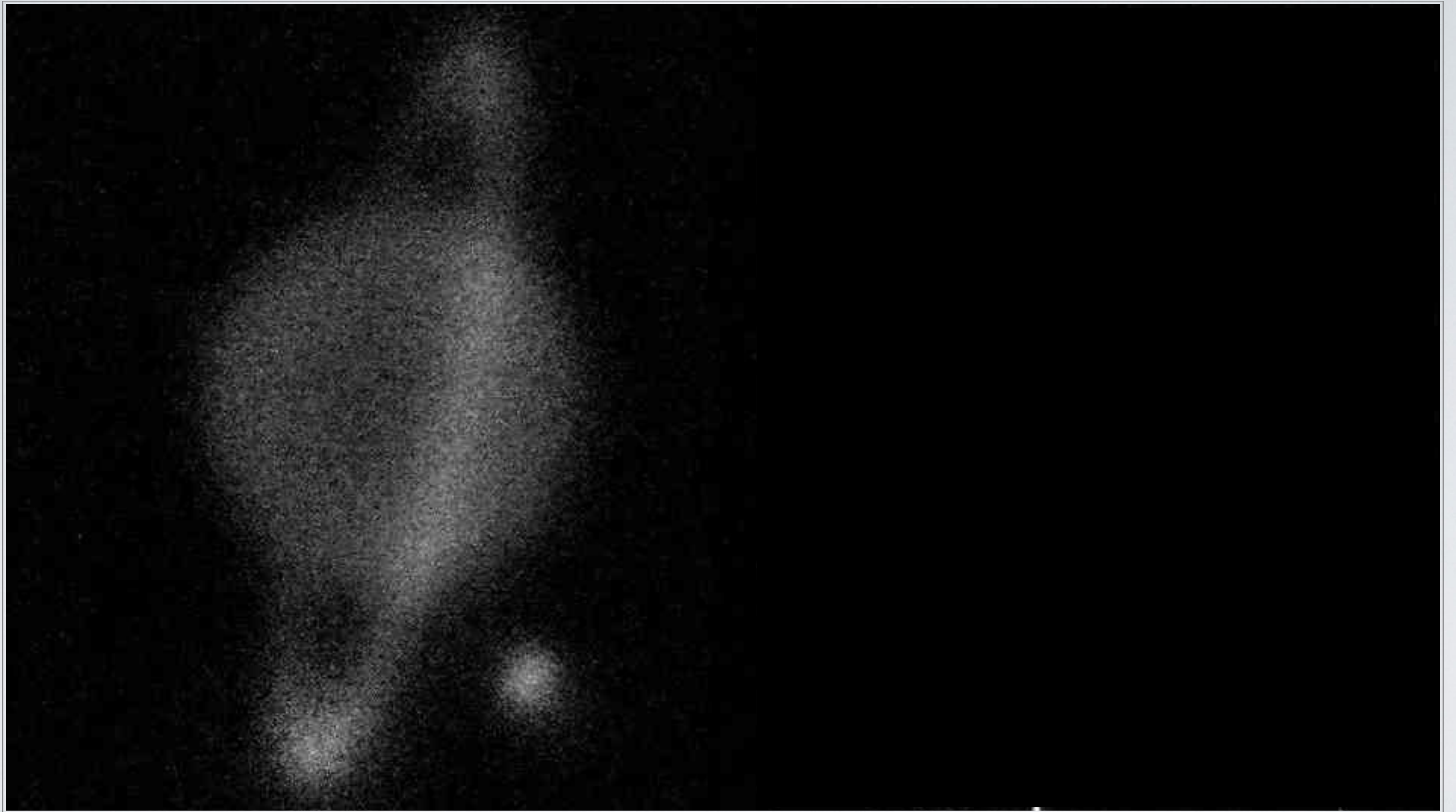
EGRESS

A deep-field astronomical image showing a vast field of stars. Several stars are highlighted with a bright blue circular glow, indicating direct detections. The background is a dense field of smaller, fainter stars. The text "quelques détections directes" is overlaid in the center in a white, sans-serif font.

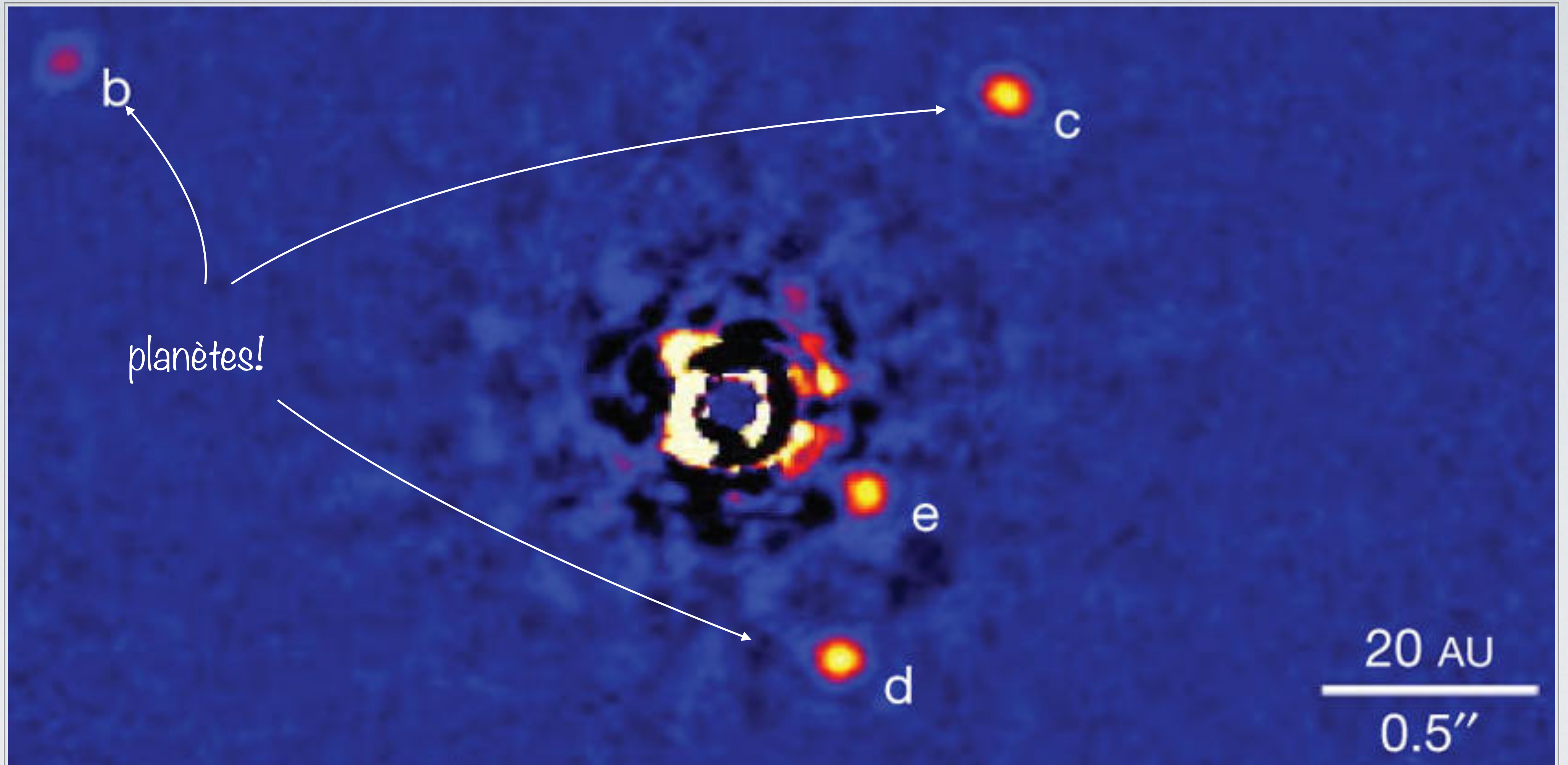
quelques détections directes



une nuit normale, Cerro Paranal, Chili



Keck, Hawai'i

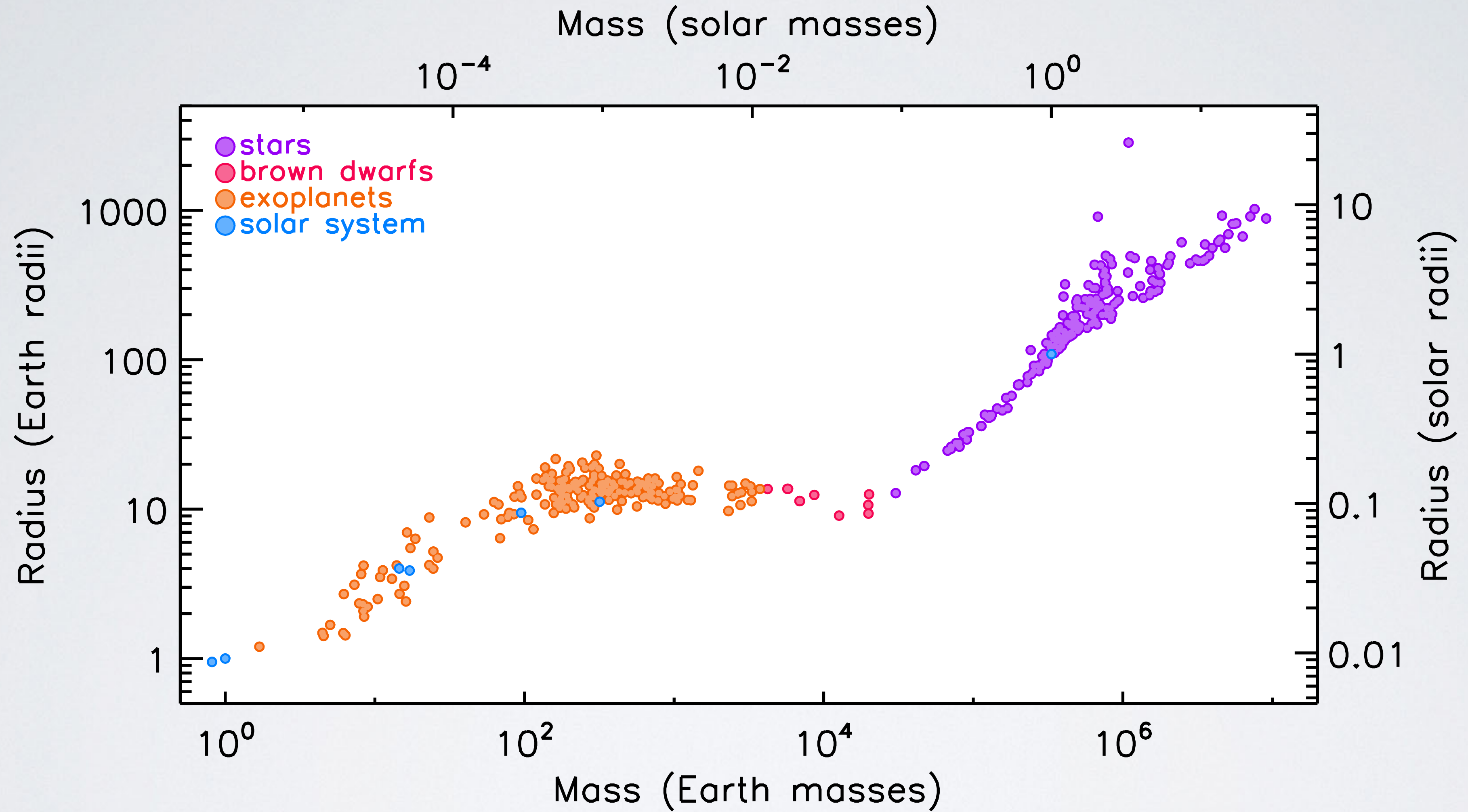


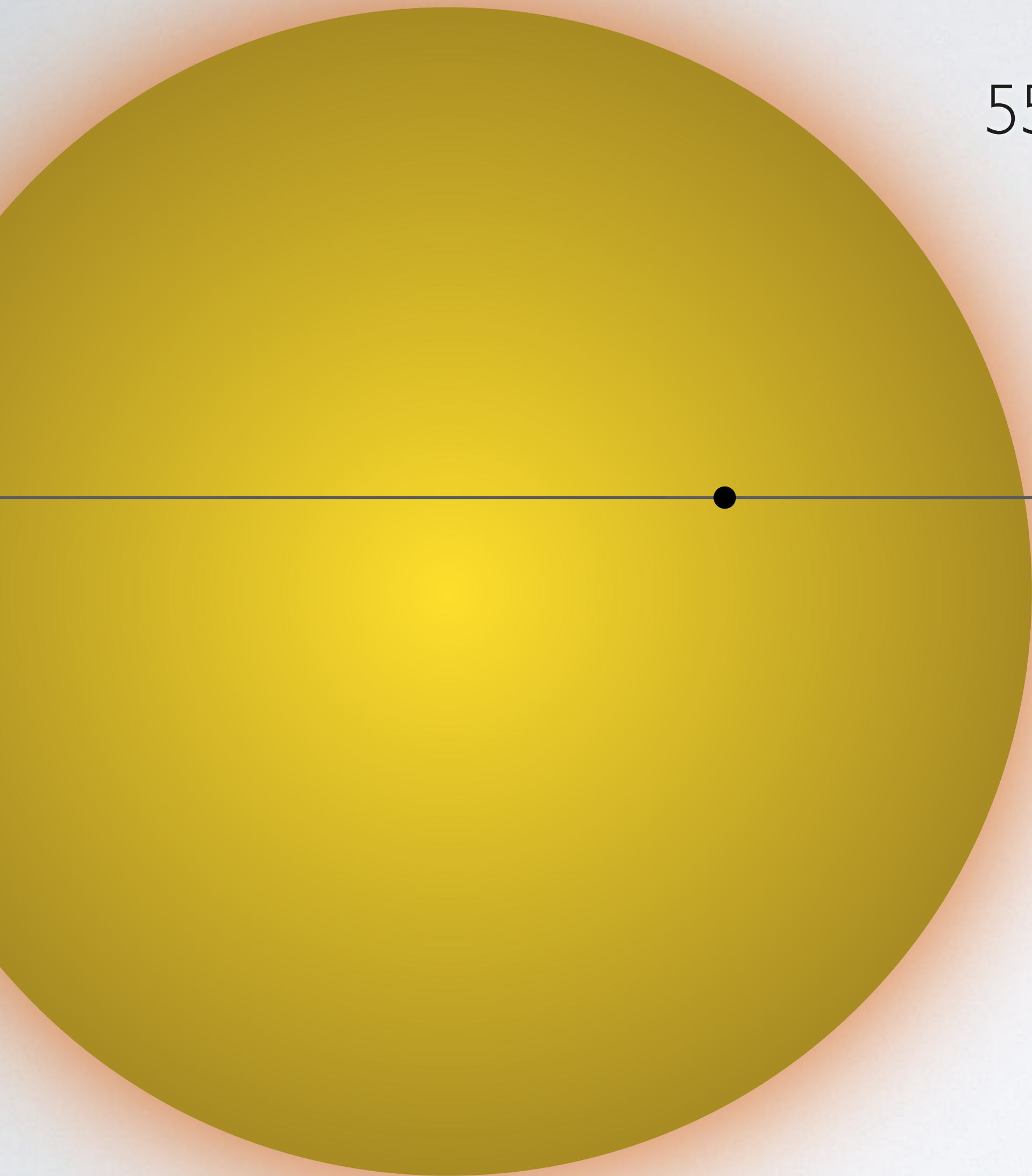
Marois et al. 2010

A deep space photograph of a starry field. The background is a dense field of small, distant stars. Several prominent stars are highlighted with a bright blue glow and a white crosshair. In the upper left and center, there are faint, wispy orange and red nebulae. The overall scene is dark and rich with celestial detail.

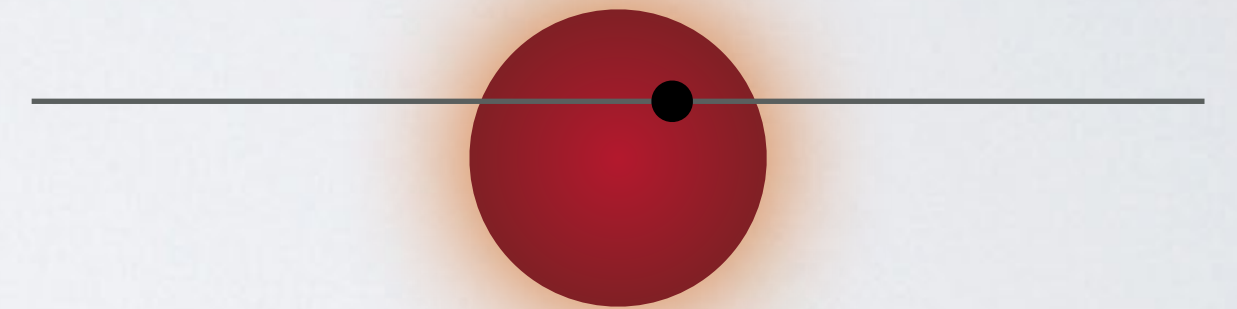
découvertes prochaines

diagramme mass/rayon



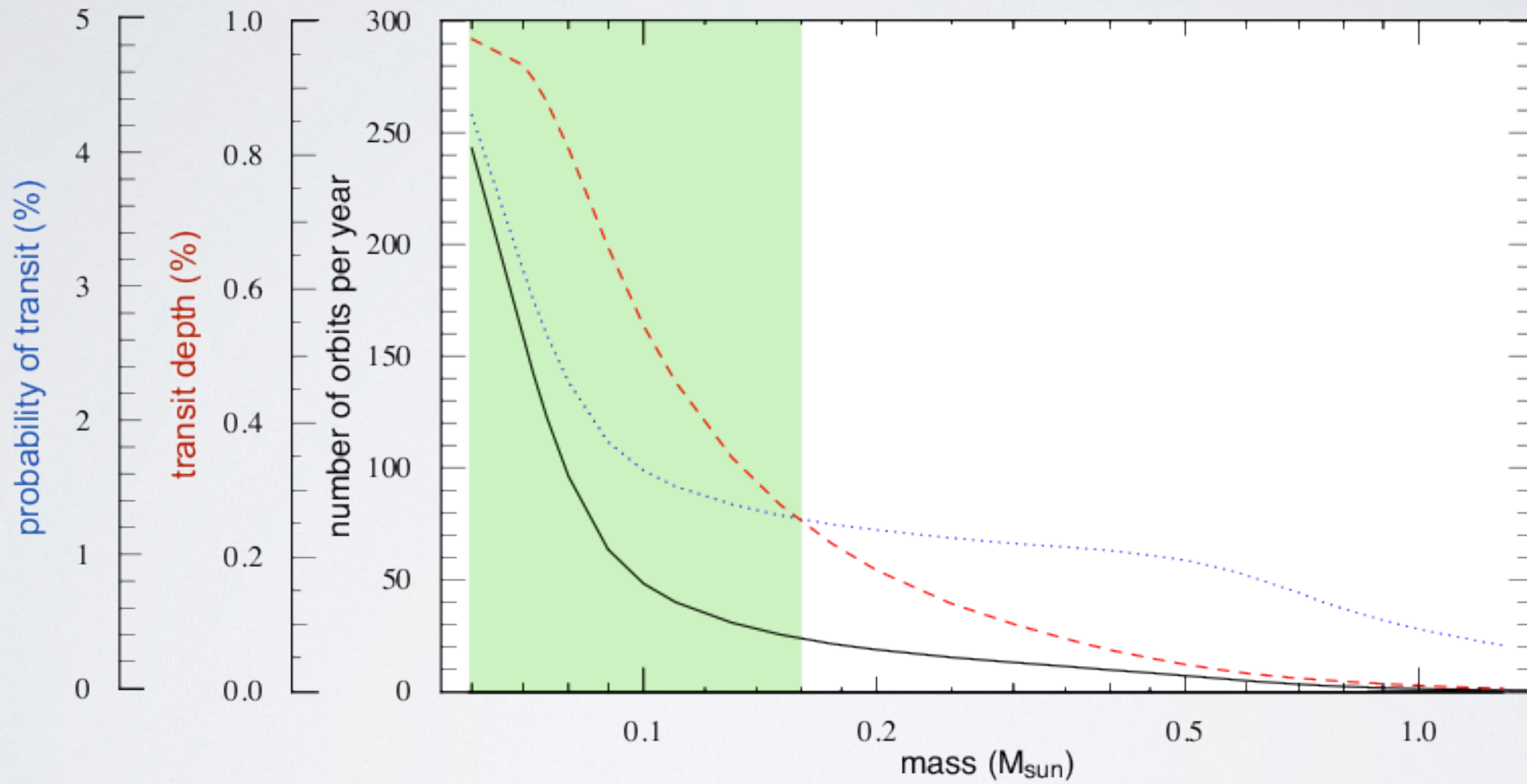


5500 K



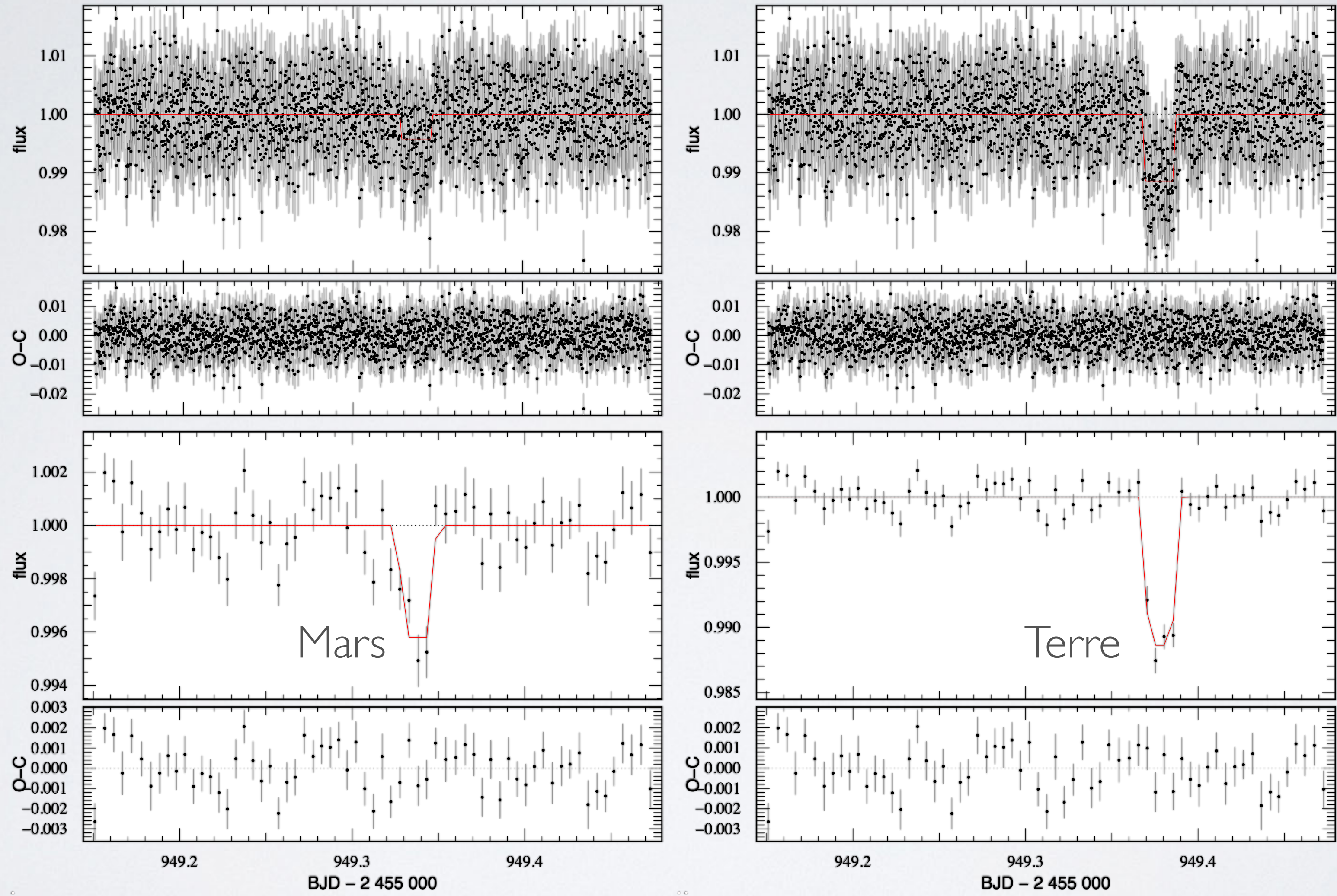
1500 K

la taille compte!



adapted from Triaud et al. 2013c

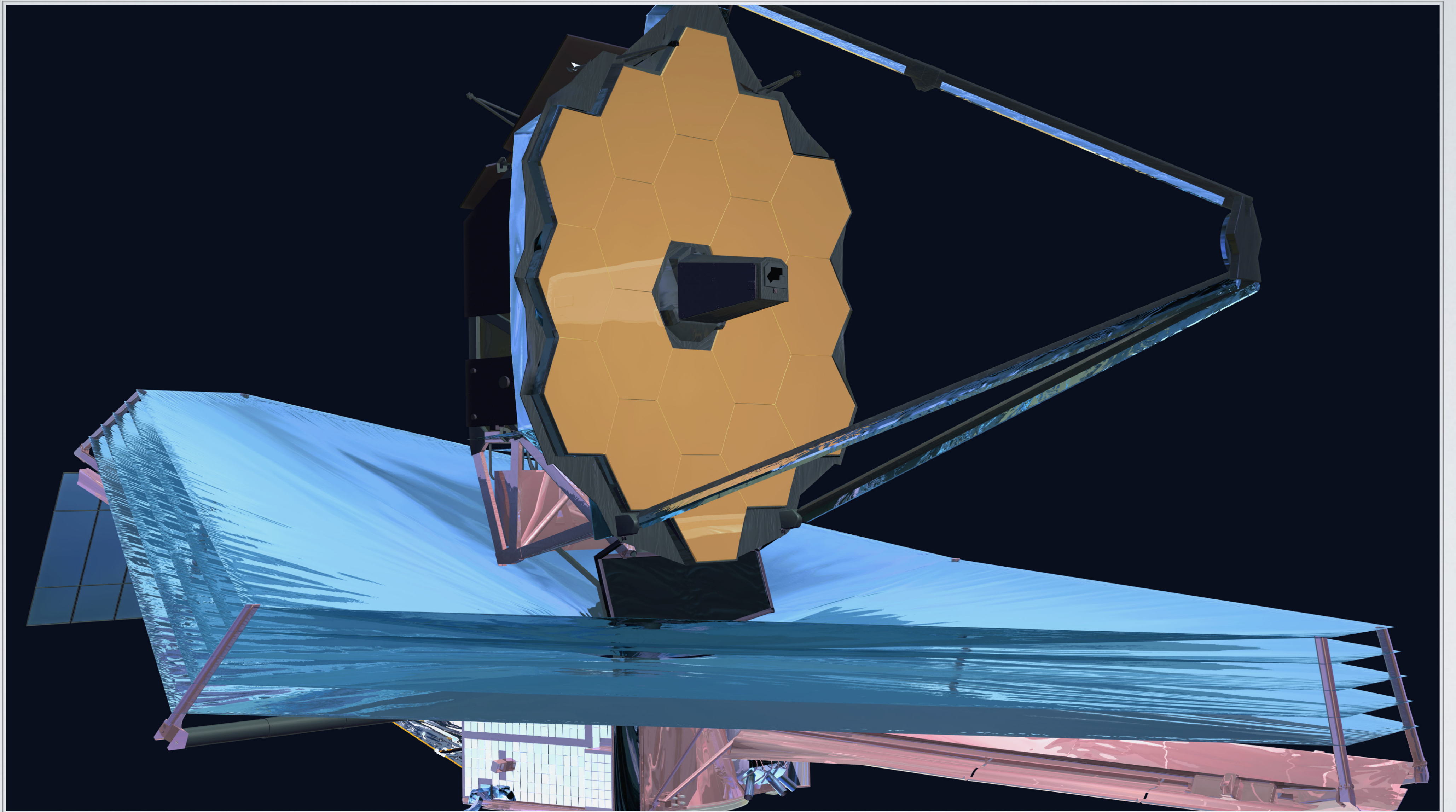
à la recherche de planète transitant des naines brunes



données réelles, plantes simulées

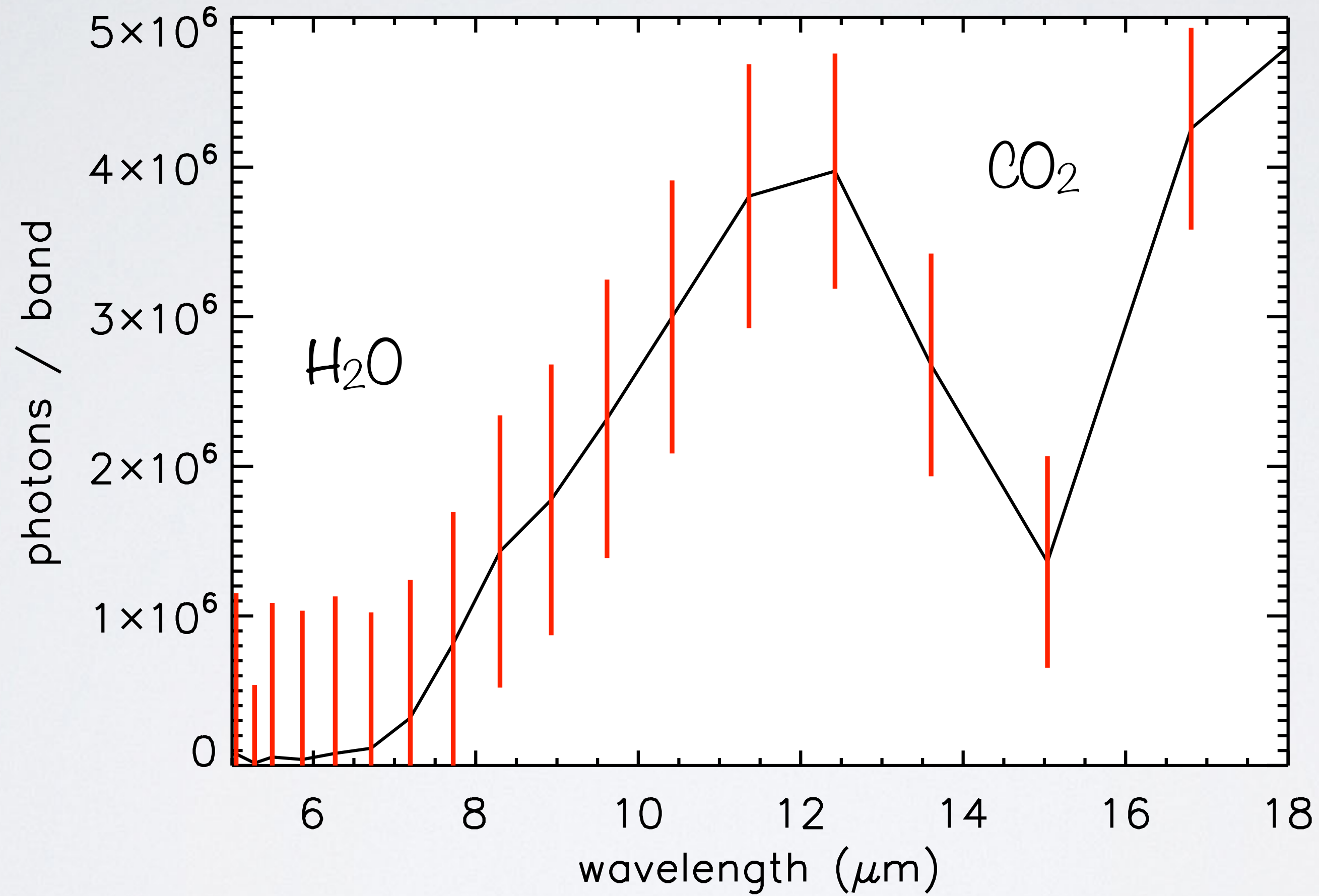
observations proposées pour *Spitzer*

Triaud et al. 2013c

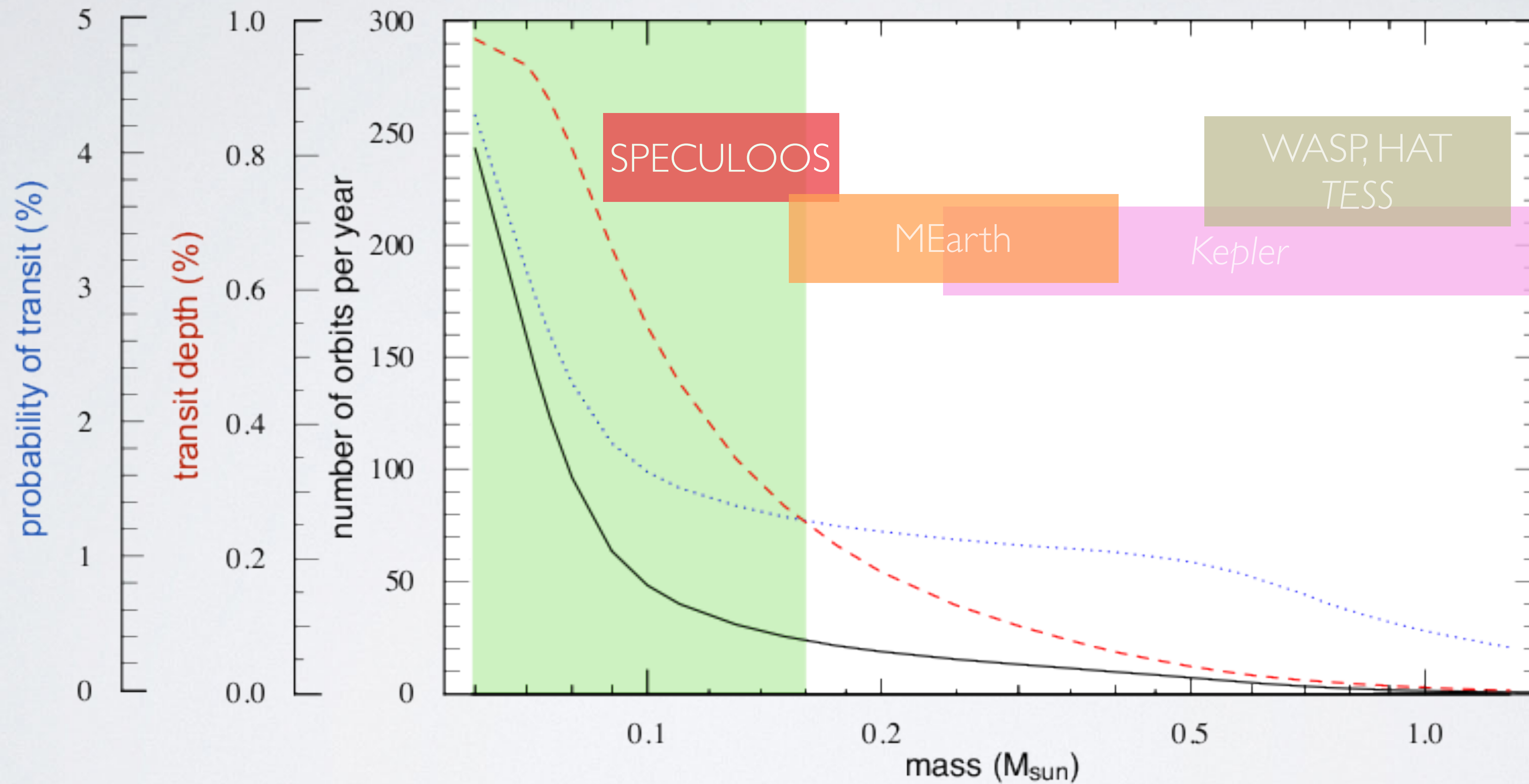


le télescope spatial *James Webb*

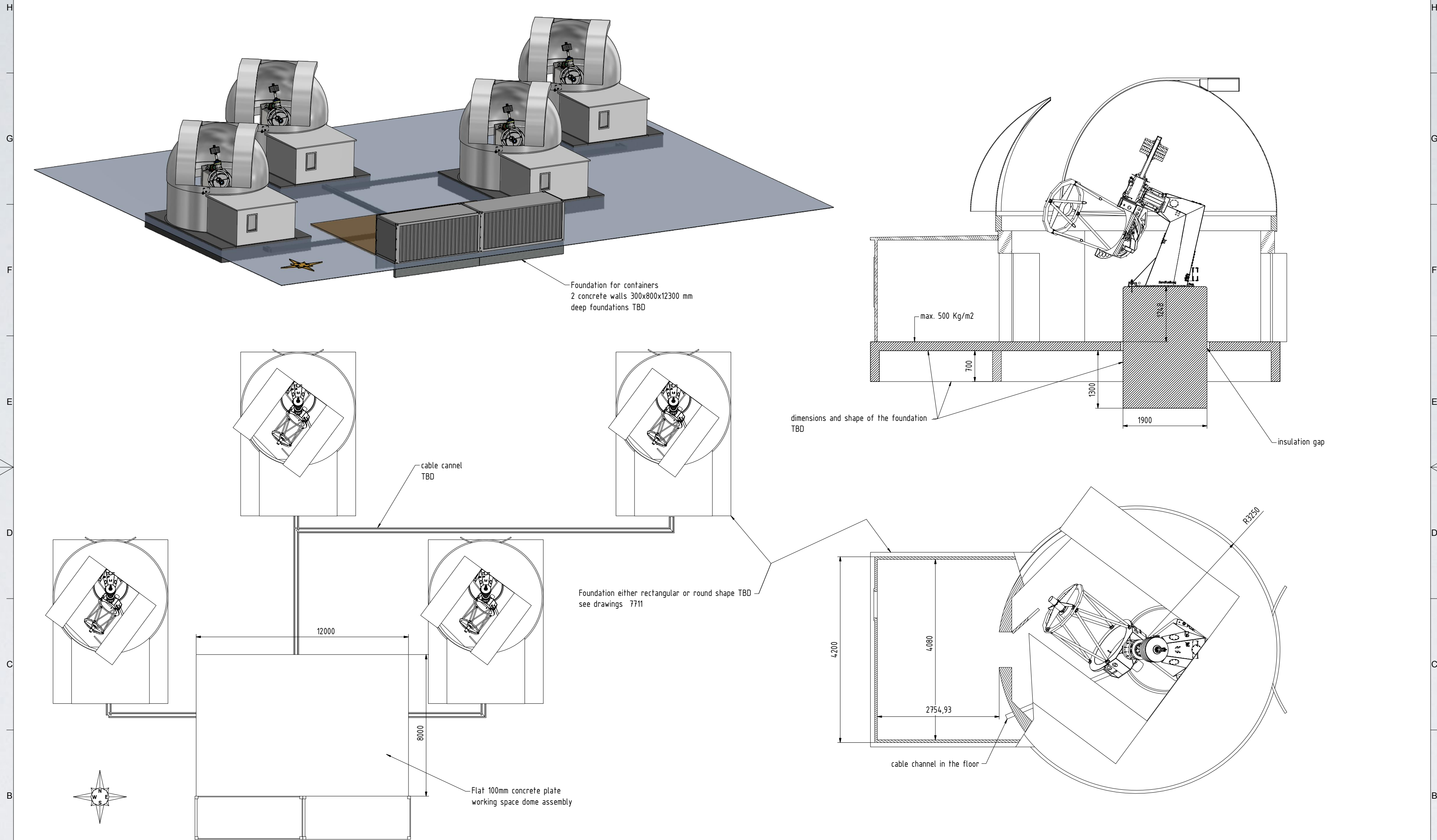
signal atmospherique d'une Terre orbitant une naine brune



notre seule chance de découvrir un environnement habitable, cette décade



12 11 10 9 8 7 6 5 4 3 2 1



en cours d'installation

<p>ISO 13715</p> <p>ISO 2768 - mK</p> <p>First angle projection Projektion Deutsch</p> <p>Gebrauch, Reproduktion, Vervielfältigung oder Speicherung dieser Zeichnung nur mit schriftlicher Genehmigung von Astelco Systems GmbH</p>	<p>Werkstückkanten ISO 13715</p> <p>Datum 10.09.2015</p> <p>Mass: N/A Volumen: N/A</p> <p>ASTELCO Systems</p>	<p>Ra3.2</p> <p>Material: Oberfläche: Farbe:</p> <p>7714 Speculoos Site</p>	<p>1 of 1</p>
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12 11 10 9 8 7 6 5 4 3 2 1

plus de 1000 naines froides sont connues dans le voisinage solaire

600 d'entre elles seront observées par SPECULOOS

le satellite *Kepler* a observé ~ 90 systèmes $< 0.13 M_{\text{sol}}$
et a identifié 5 planètes dans 2 systèmes

On s'attend de découvrir 10+ systèmes planétaires dont les planètes rocheuses
seront étudiées en détails par le *JWST* et les ELTs

SPECULOOS

des environnements, différents du nôtre

un mode différent de formation planétaire

une irradiation différentes, plus dans l'infrarouge et l'UV

des planètes synchrones?



des planètes aux paramètres optimaux pour des investigations atmosphériques

l'opportunité d'étudier l'habitabilité dans des conditions non-terrestre

en résumé



L. Rudaux, 1937

les exoplanètes montrent une grande variété

la plupart des systèmes sont différents du notre

les modèles peinent à former des planètes alors la Nature
nous dit que c'est simple

on pourra bientôt étudier la composition atmosphérique
de planètes similaires à la Terre.

WASP-Genève collaboration

Gillon, Pollacco, Collier-Cameron,
Queloz, Hellier, Smalley, Maxted, West,
Ségransan, Hebb, Anderson, Jehin,
Simpson, Brown, Lendl, Udry, Mayor...

friends & competitors

Winn, Narita, Johnson, Bouchy,
Hébrard, Moutou, Hirano, Albrecht

David V. Martin

the brown dwarf connection

Selsis, Gillon, Winn, Artigau, Delorme, Helling, Radigan, Doyon, Laughlin,
Raymond, Seager, Demory, Littlefair, Bolmont, Forveille, Leconte, Albert

SPECULOOS

Gillon, Queloz, Almlécky, Jehin, Demory, Van Grootel

