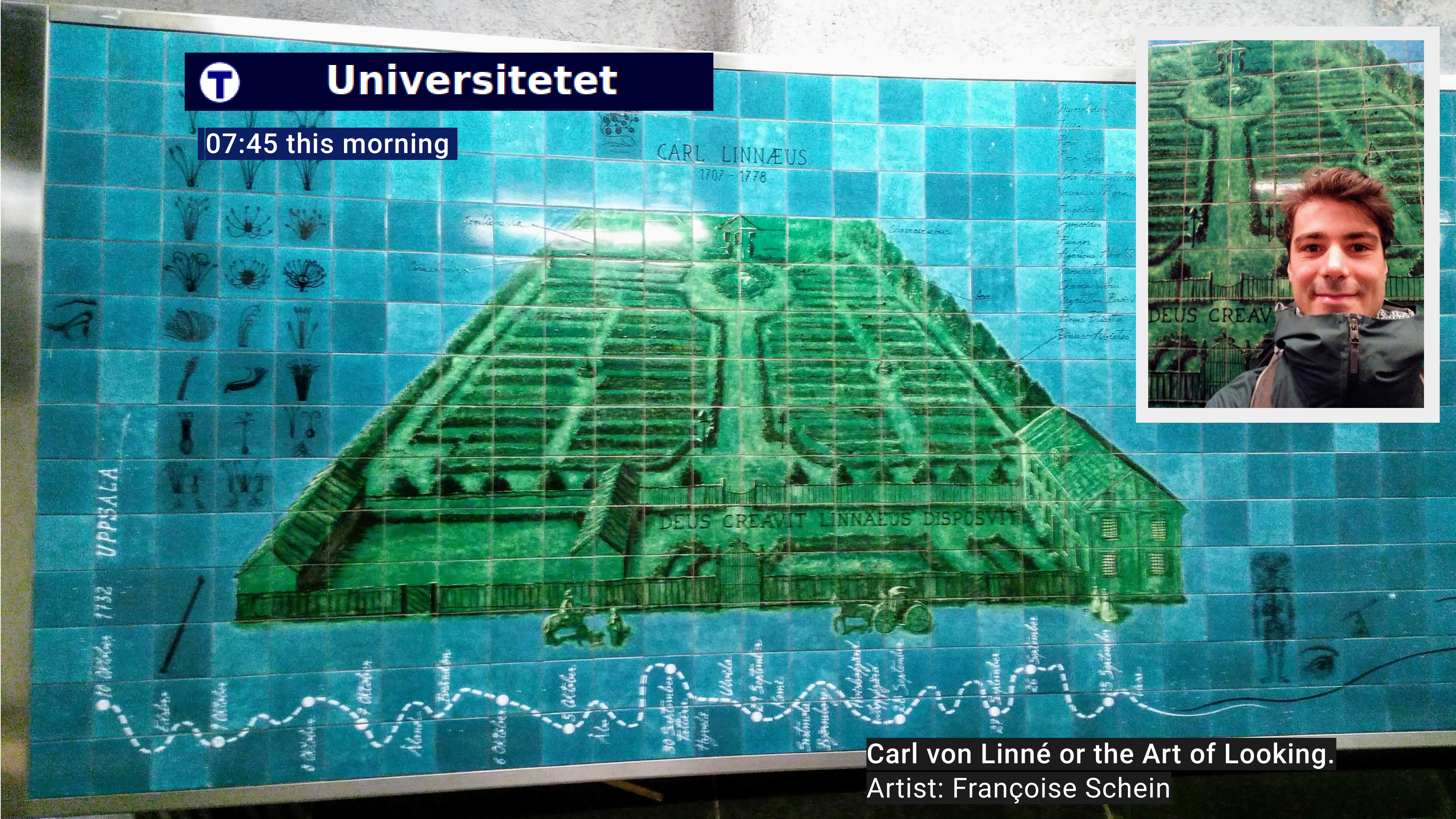


Carl von Linné or the Art of Looking.
Artist: Françoise Schein

Farbstudie - Quadrate und konzentrische Ringe
Wassily Kandinsky, 1913.
Städtische Galerie im Lenbachhaus, München

Studying the atmospheres of exoplanets

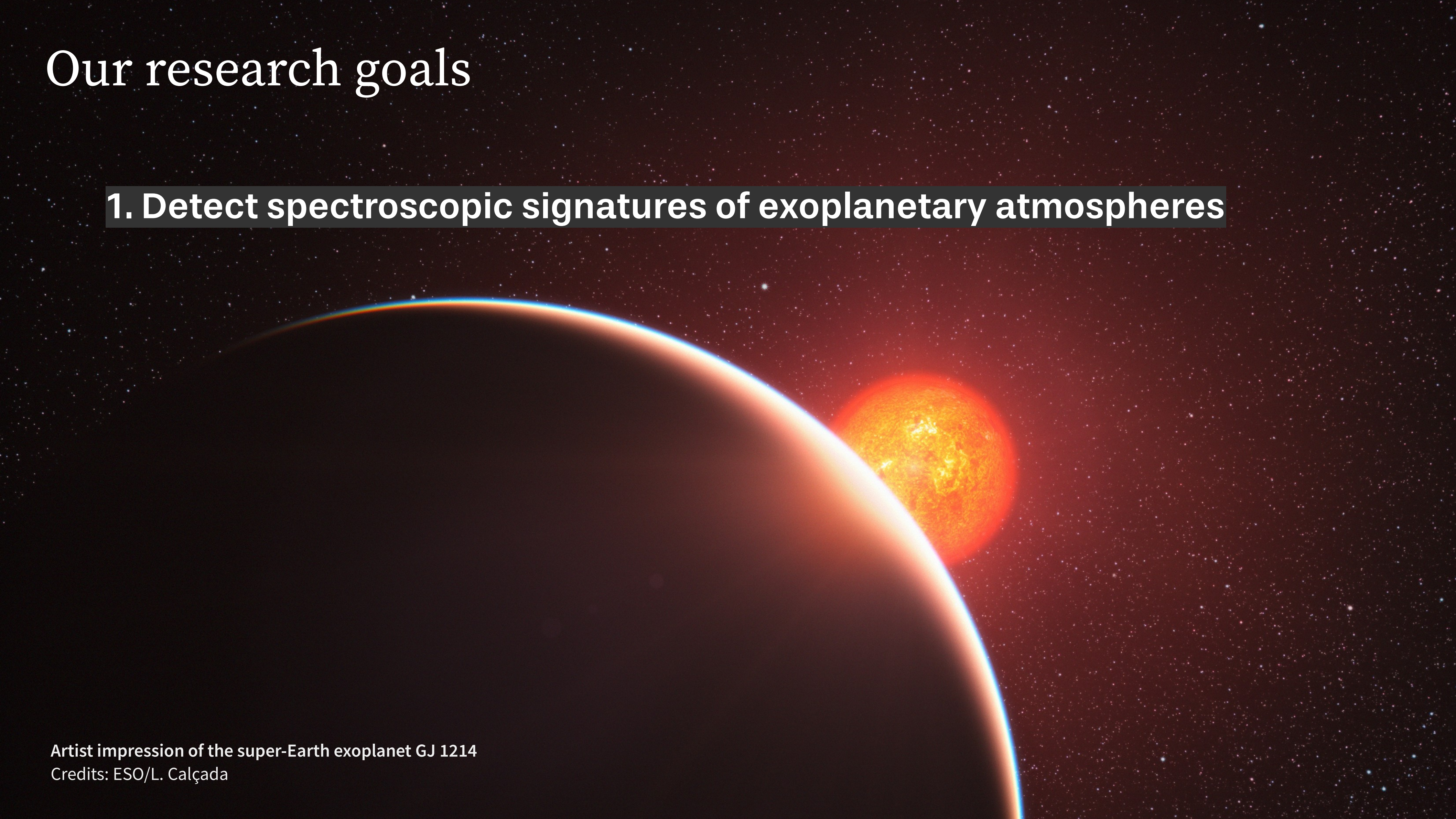
– why and how do we do it?

Alexis Lavail **2020-10-06**

Launch of the Thunberg Fellowship Programme.
The Swedish Collegium for Advanced Study

Our research goals

1. Detect spectroscopic signatures of exoplanetary atmospheres



Artist impression of the super-Earth exoplanet GJ 1214
Credits: ESO/L. Calçada

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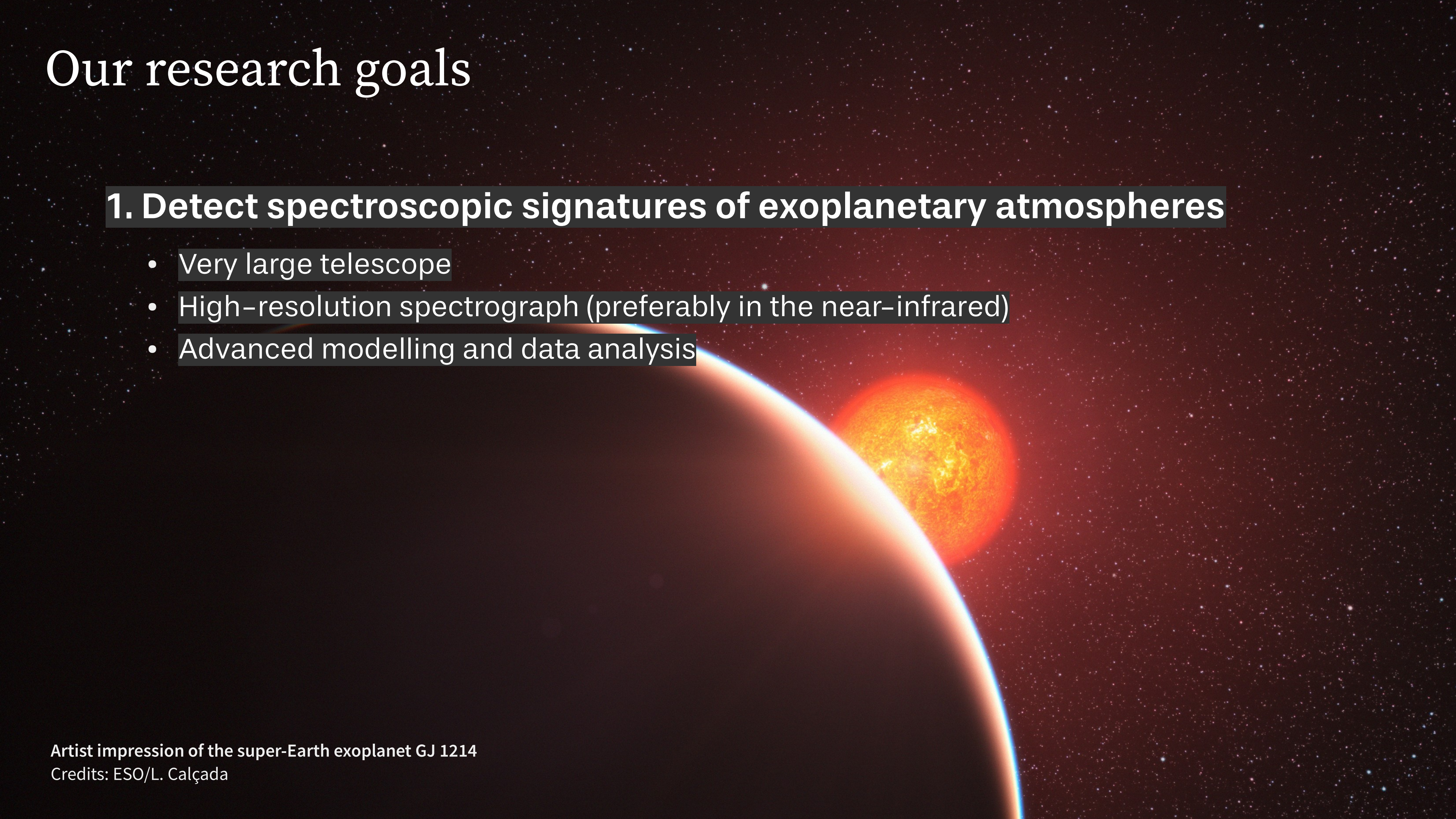
- Very large telescope
- High-resolution spectrograph (preferably in the near-infrared)
- Advanced modelling and data analysis



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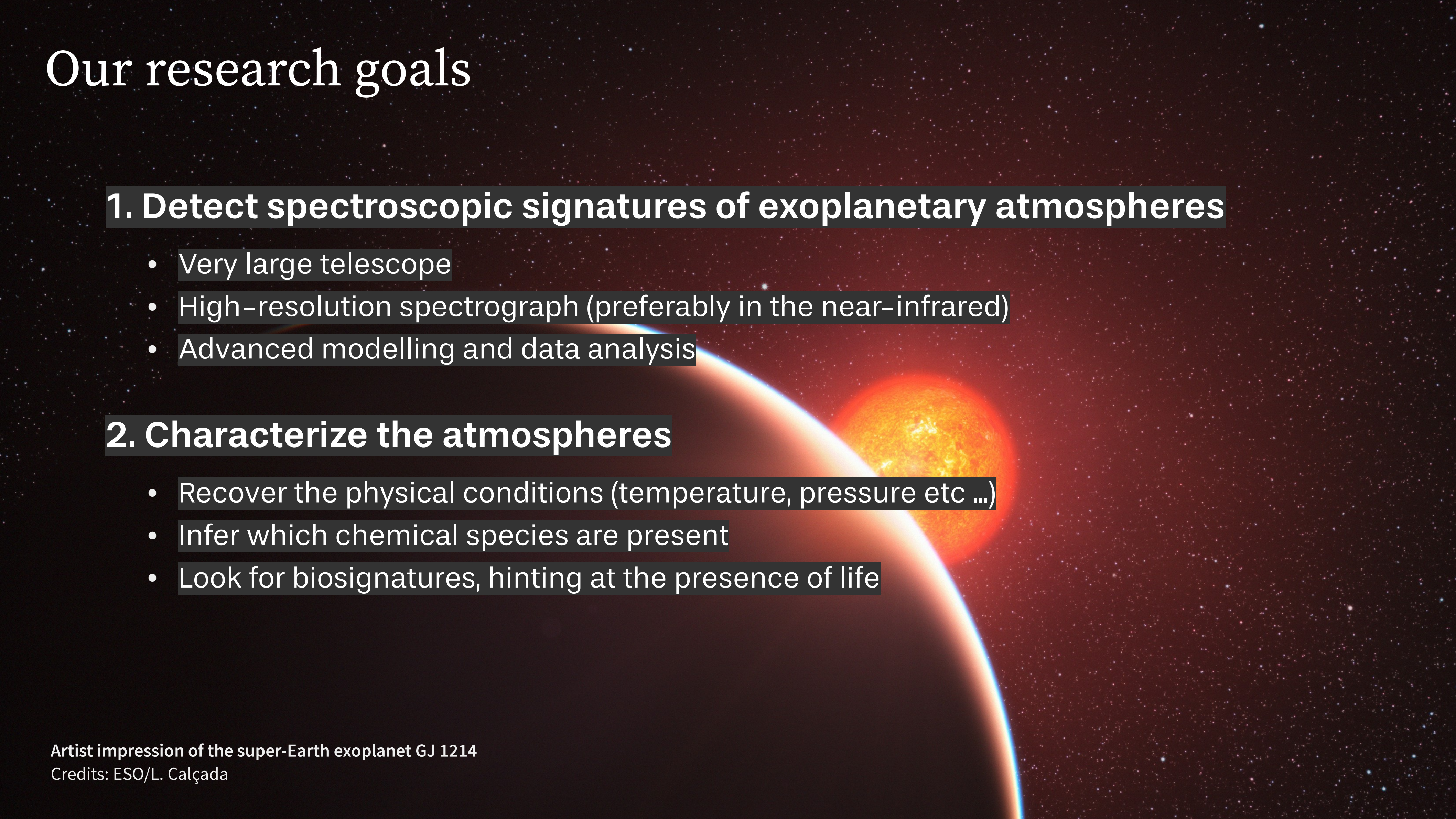

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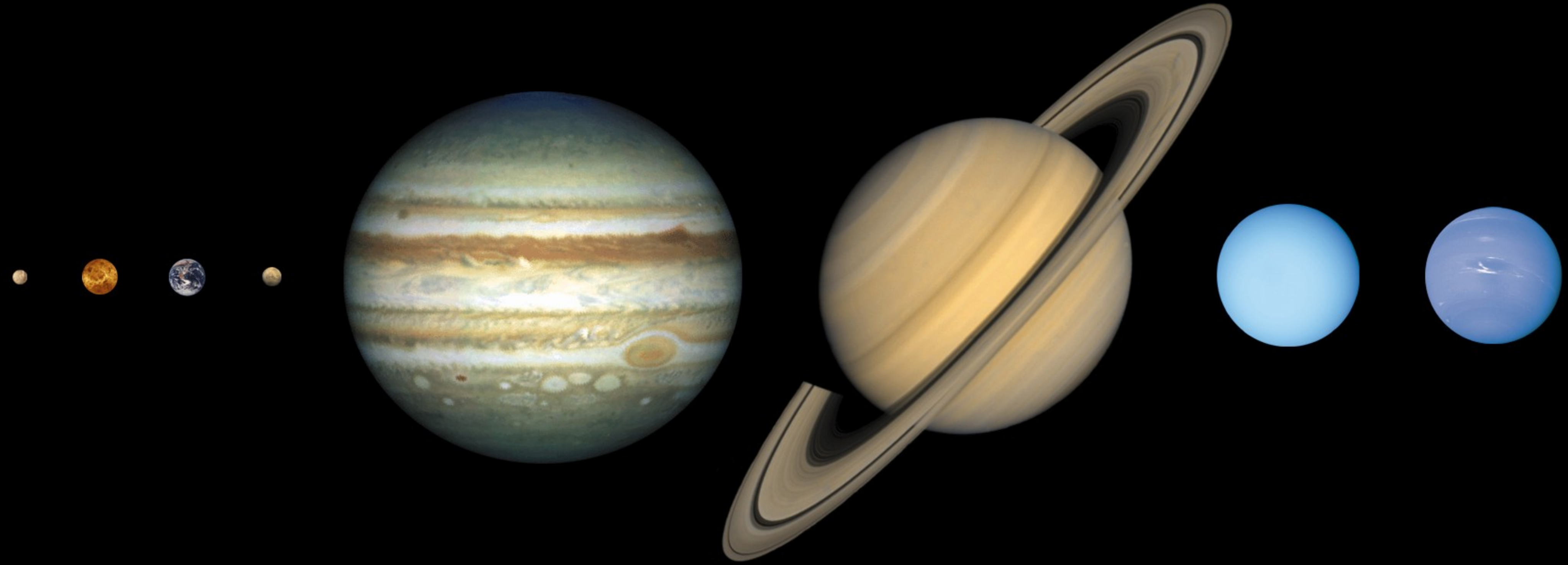
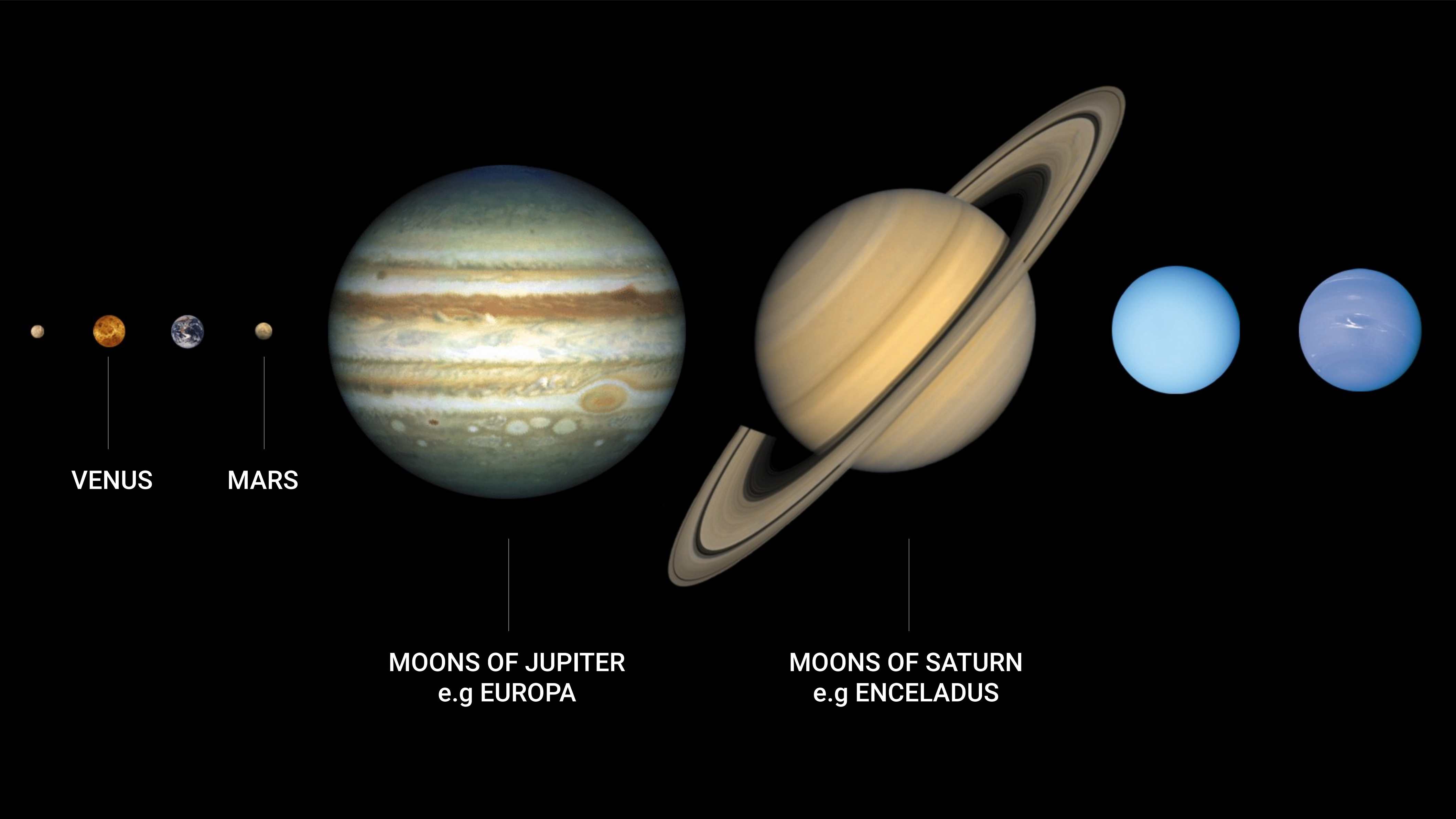
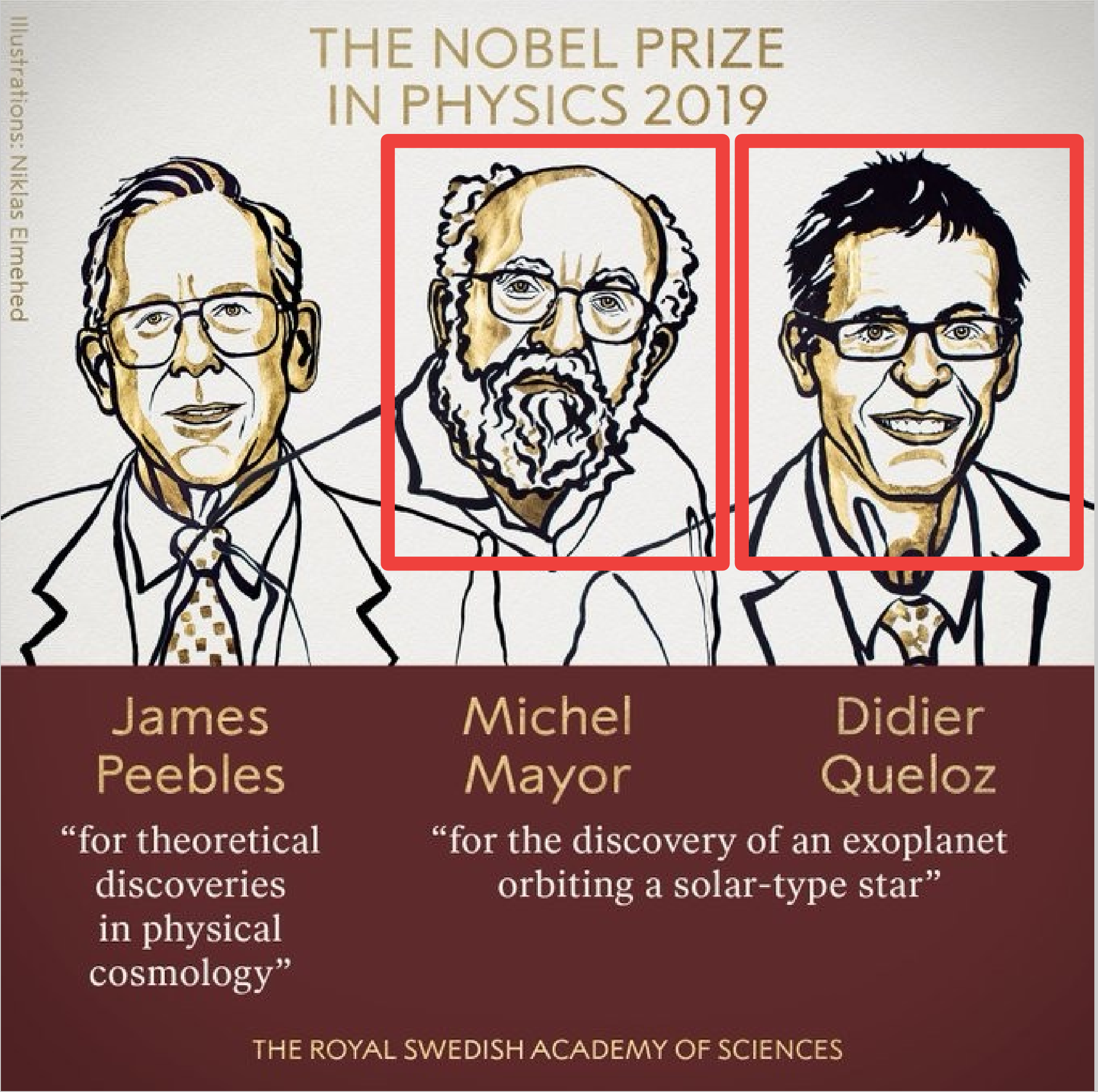
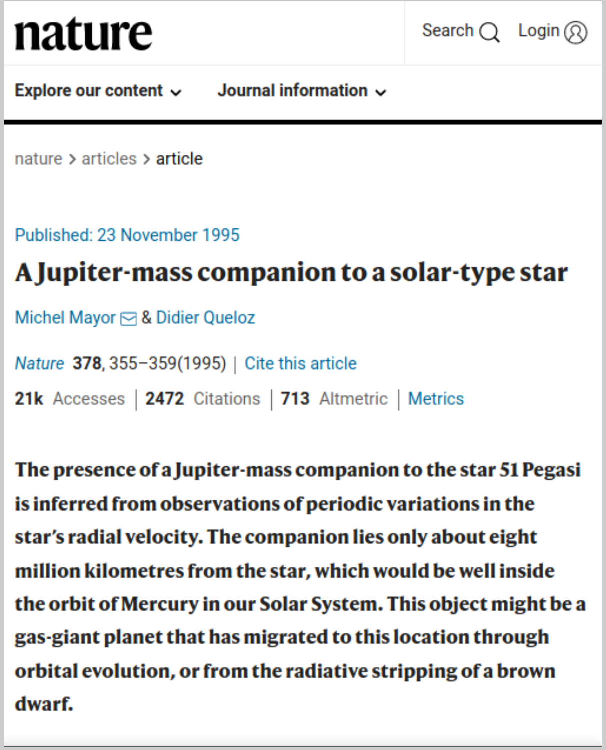


The diversity of planets in our own solar system.

Source: NASA/Lunar and Planetary Institute


VENUS
MARS
MOONS OF JUPITER
e.g EUROPA
MOONS OF SATURN
e.g ENCELADUS





nature

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Published: 23 November 1995

A Jupiter-mass companion to a solar-type star

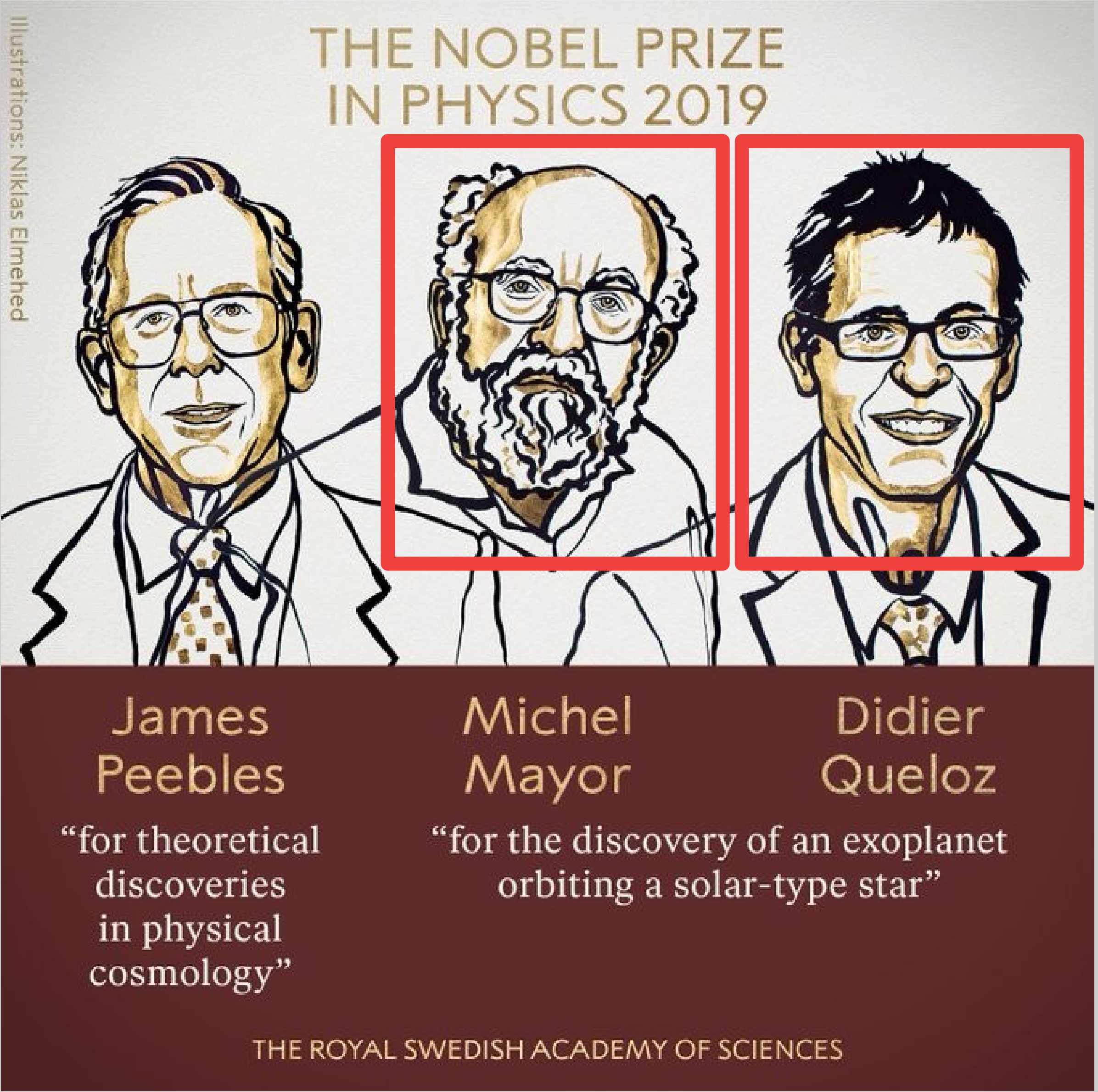
Michel Mayor & Didier Queloz

Nature **378**, 355–359(1995) | Cite this article

21k Accesses | **2472** Citations | **713** Altmetric | Metrics

The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.

The Nobel Prize in Physics 2019 was awarded "for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos"

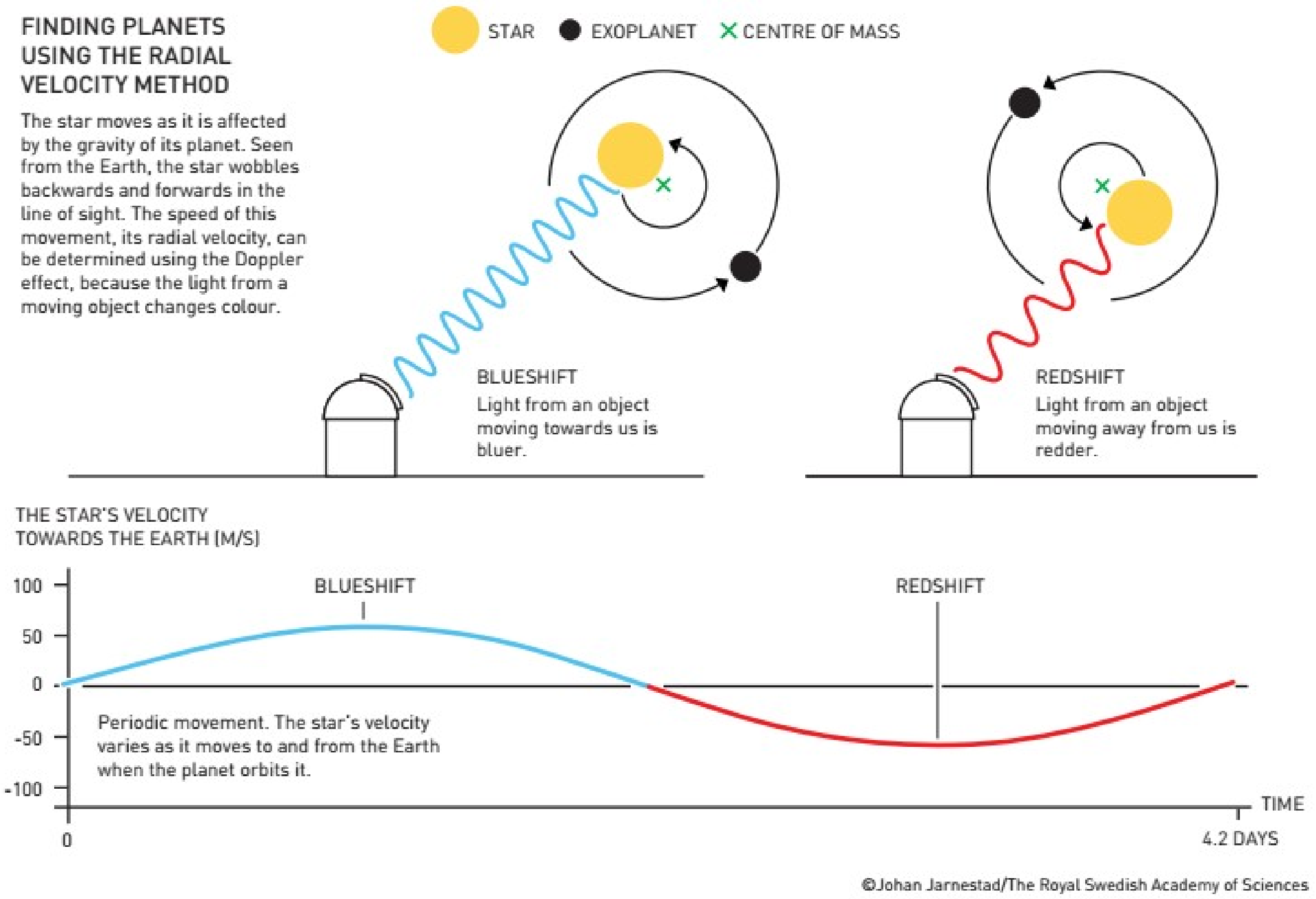


4358 planets in 3221 planetary systems confirmed as per today

http://exoplanet.eu

Detecting an exoplanet.

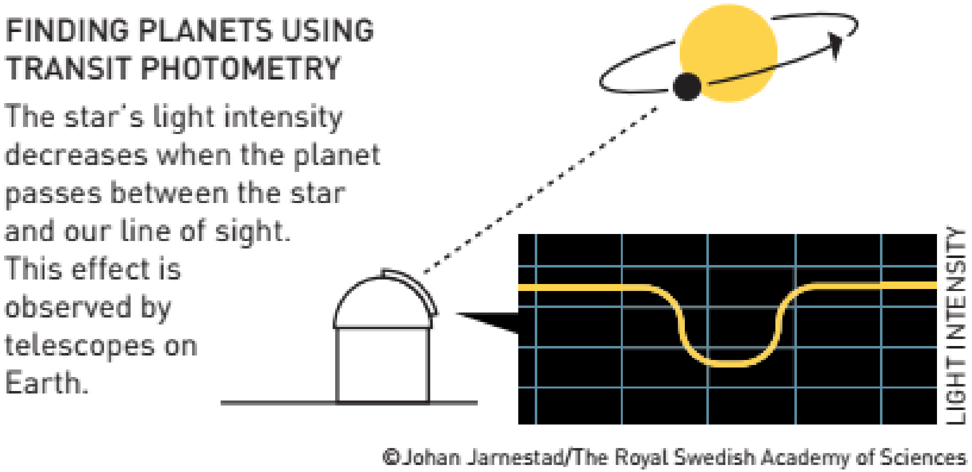
The radial velocity method.



This method uses **extremely stable spectrographs** at **ground-based telescopes.**

Detecting an exoplanet.

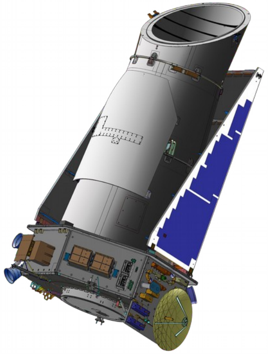
The transit photometry method.



This method makes full use of **space telescopes**.

CoRoT
launched 2006

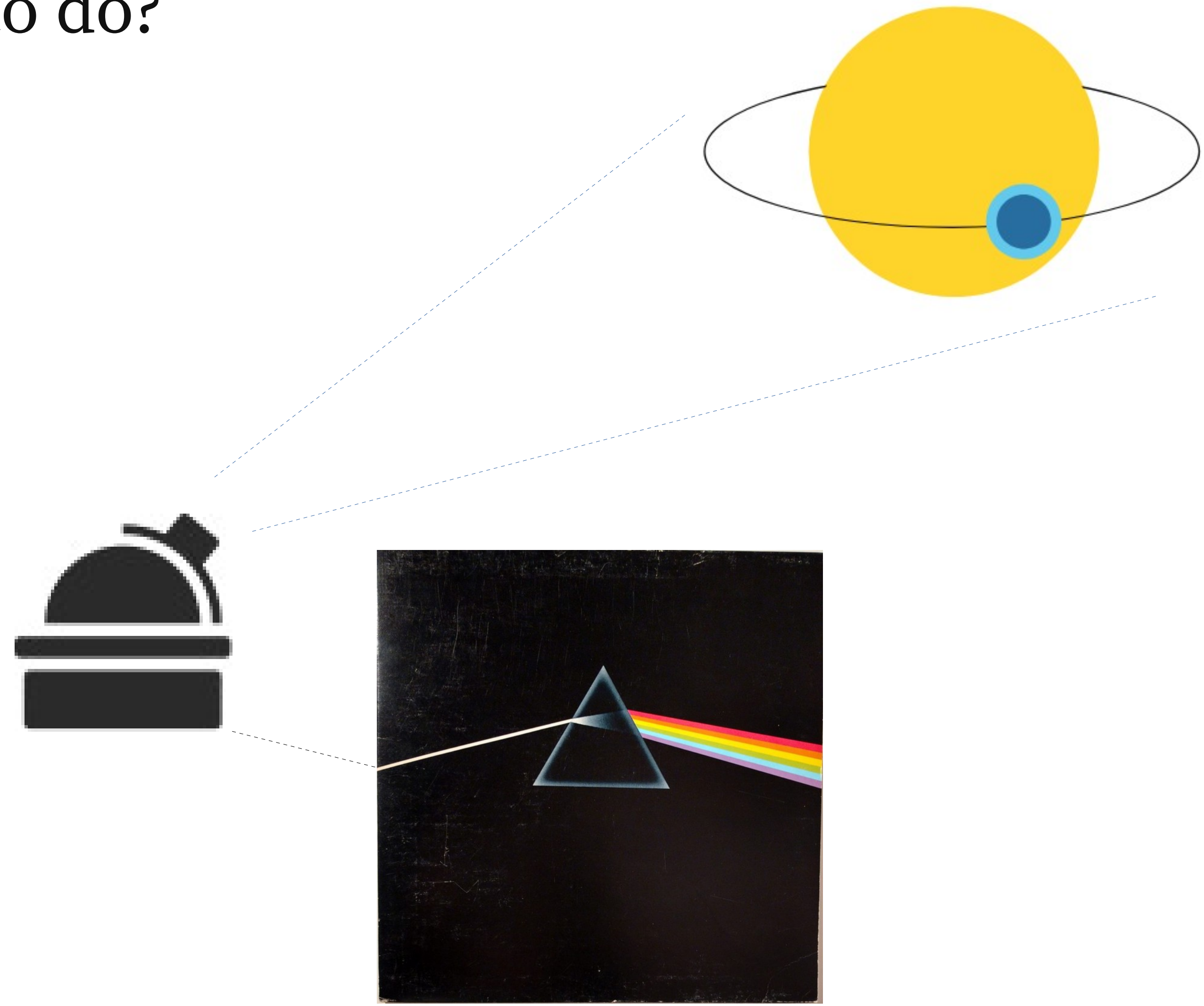
Kepler
launched 2009



TESS
launched 2018

What do we want to do?

Transit spectroscopy



What do we want to do?

Transit spectroscopy

Telescope

We will use the **8-metre Very Large Telescope** of the **European Southern Observatory** in Paranal, Chile.

Photo: ESO/S. Brunier

What do we want to do?

Transit spectroscopy

Spectrograph

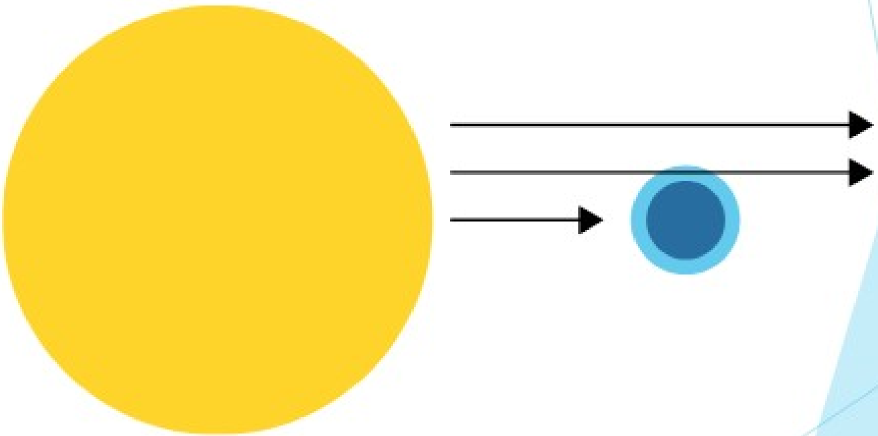
We have built a high-resolution near-infrared spectrograph: **CRIRES+**

Photo: CRIRES+ consortium

Transit Spectroscopy

$$Obs = (F - A_{C+A}\, F(x_{C+A}) + A_A\, F(x_A)\, P)\, T$$

- Obs: Observation
- P: Planet atmosphere
- F: total stellar Flux
- $F(x)$: average stellar Flux blocked by the planet and/or atmosphere at x
- T: Telluric absorption
- A_{C+A}: Relative area of the planet core and atmosphere
- A_A: Relative area of the atmosphere



Slide from Ansgar Wehrhahn, *Uppsala University*.

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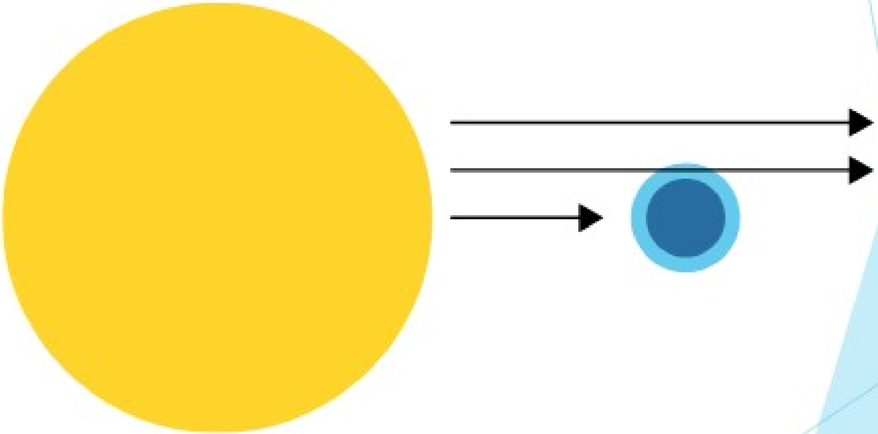

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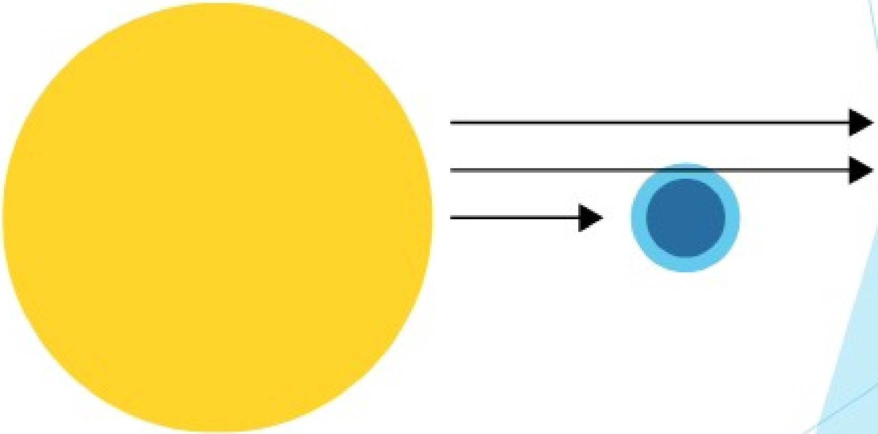

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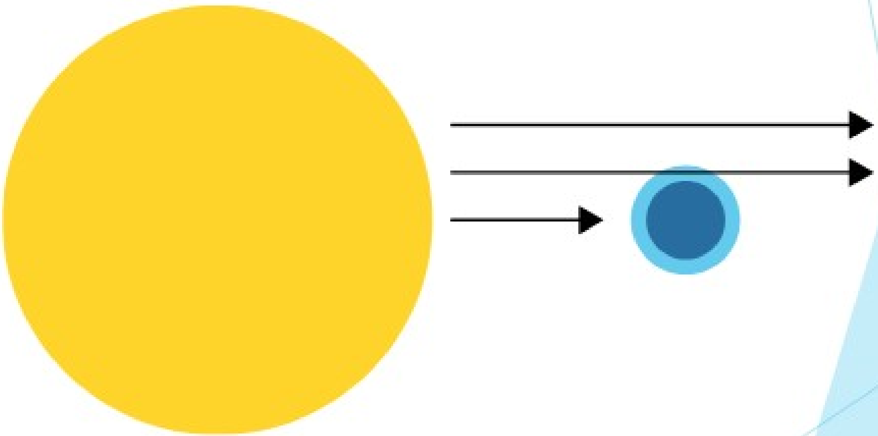

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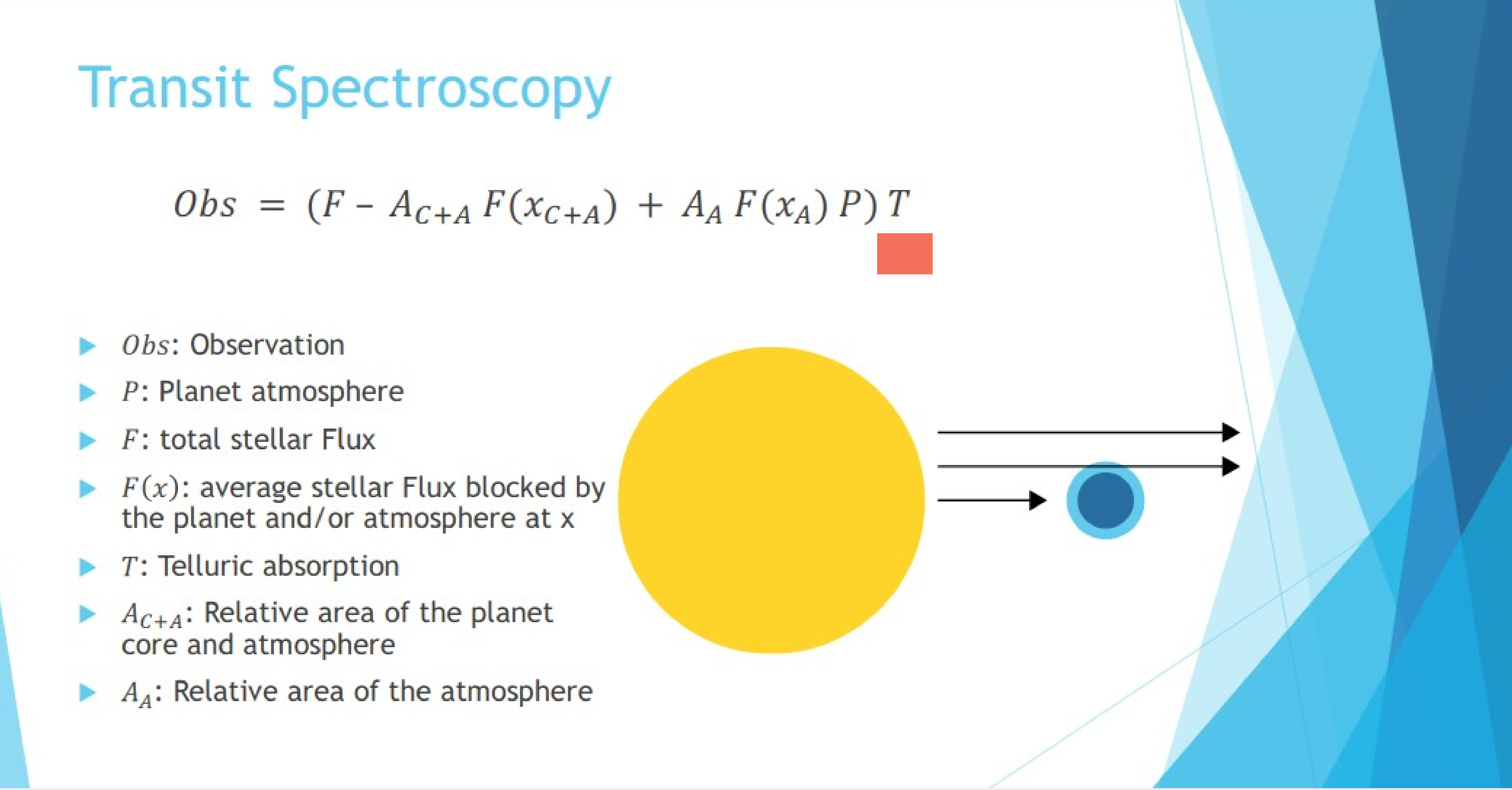

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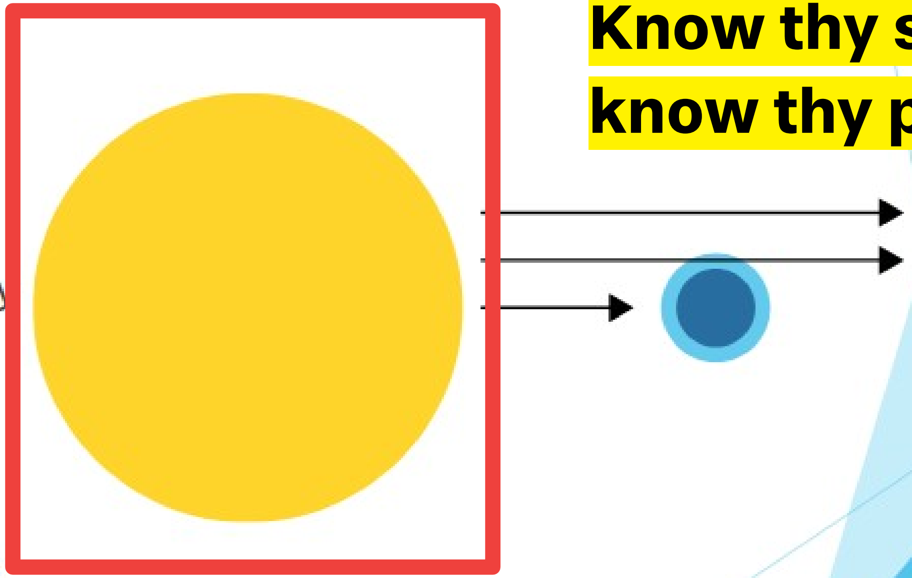
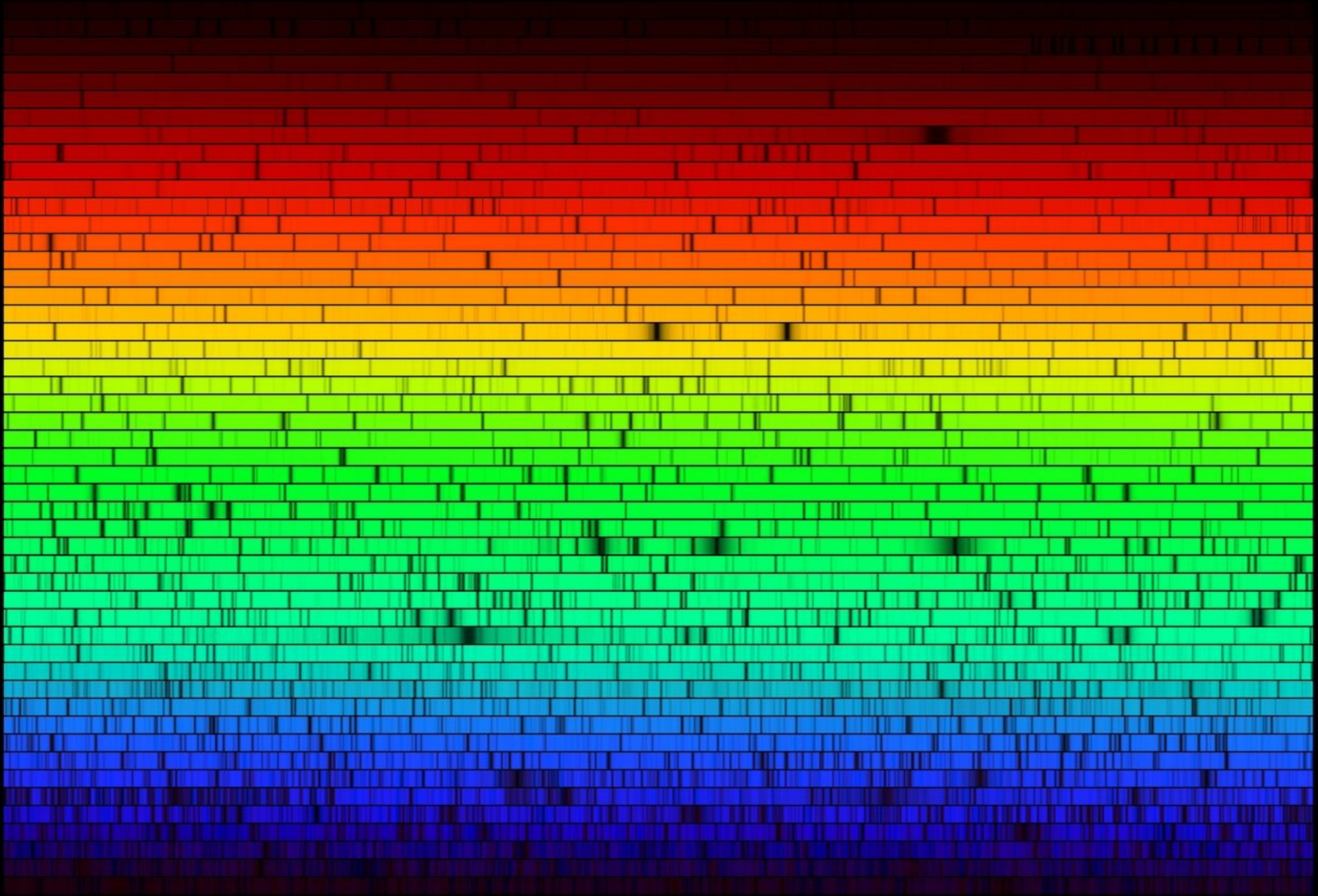


Know thy star, know thy planet

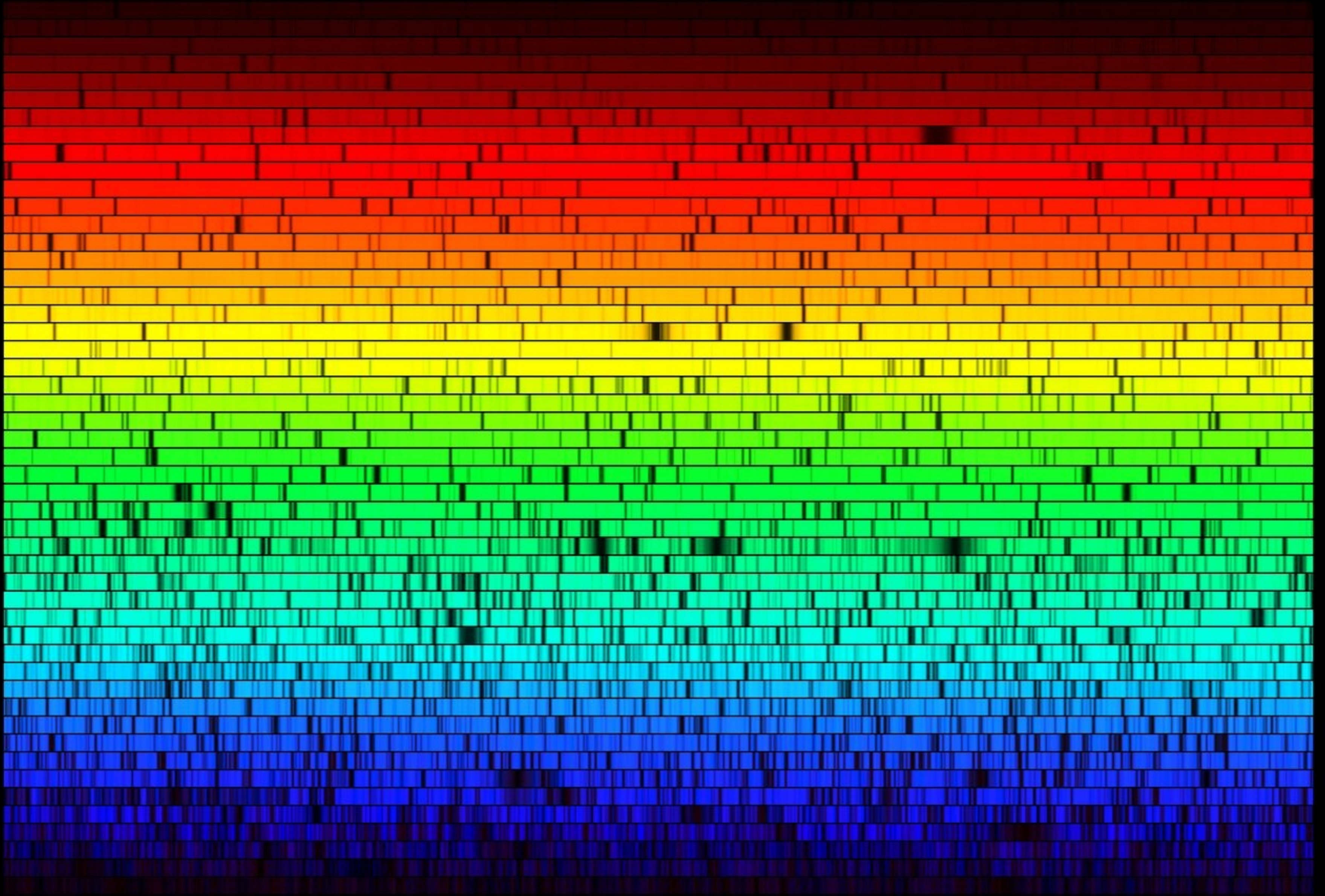
Slide from Ansgar Wehrhahn, *Uppsala University*.

The Sun

Source: N.A.Sharp, NOIRLab/NSF/AURA

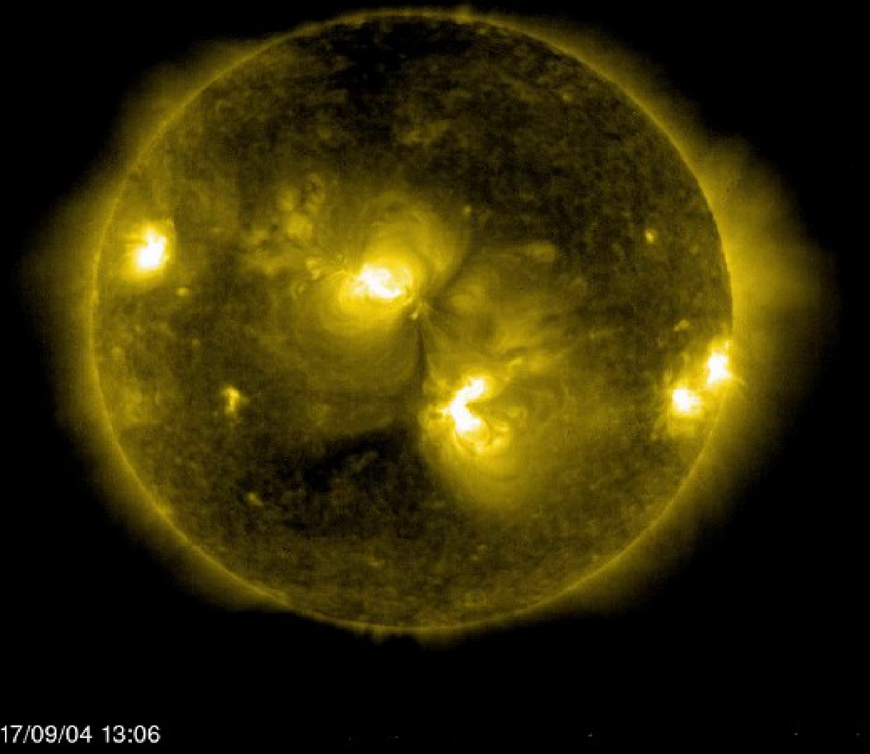


Arcturus



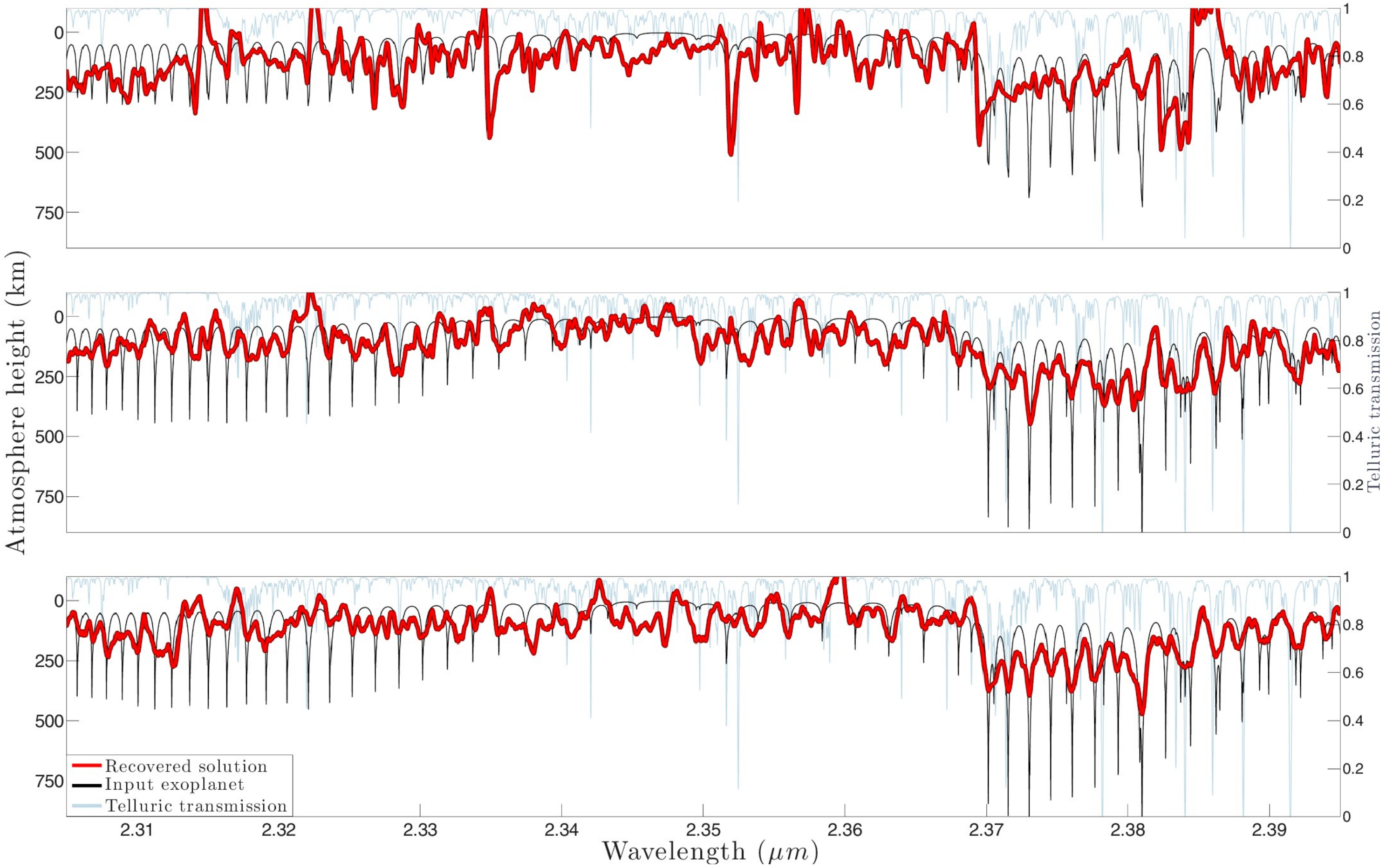
Source: N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NS

ON SEPTEMBER 6, THE SUN EJECTED TWO MASSIVE SOLAR FLARES.



If everything works:

We recover exoplanet atmospheres spectra



Recovered exoplanetary transmission spectra from simulated transit observations of a hot-Jupiter transiting a G2 star

Aronson et al. 2015. A&A 578, A133

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