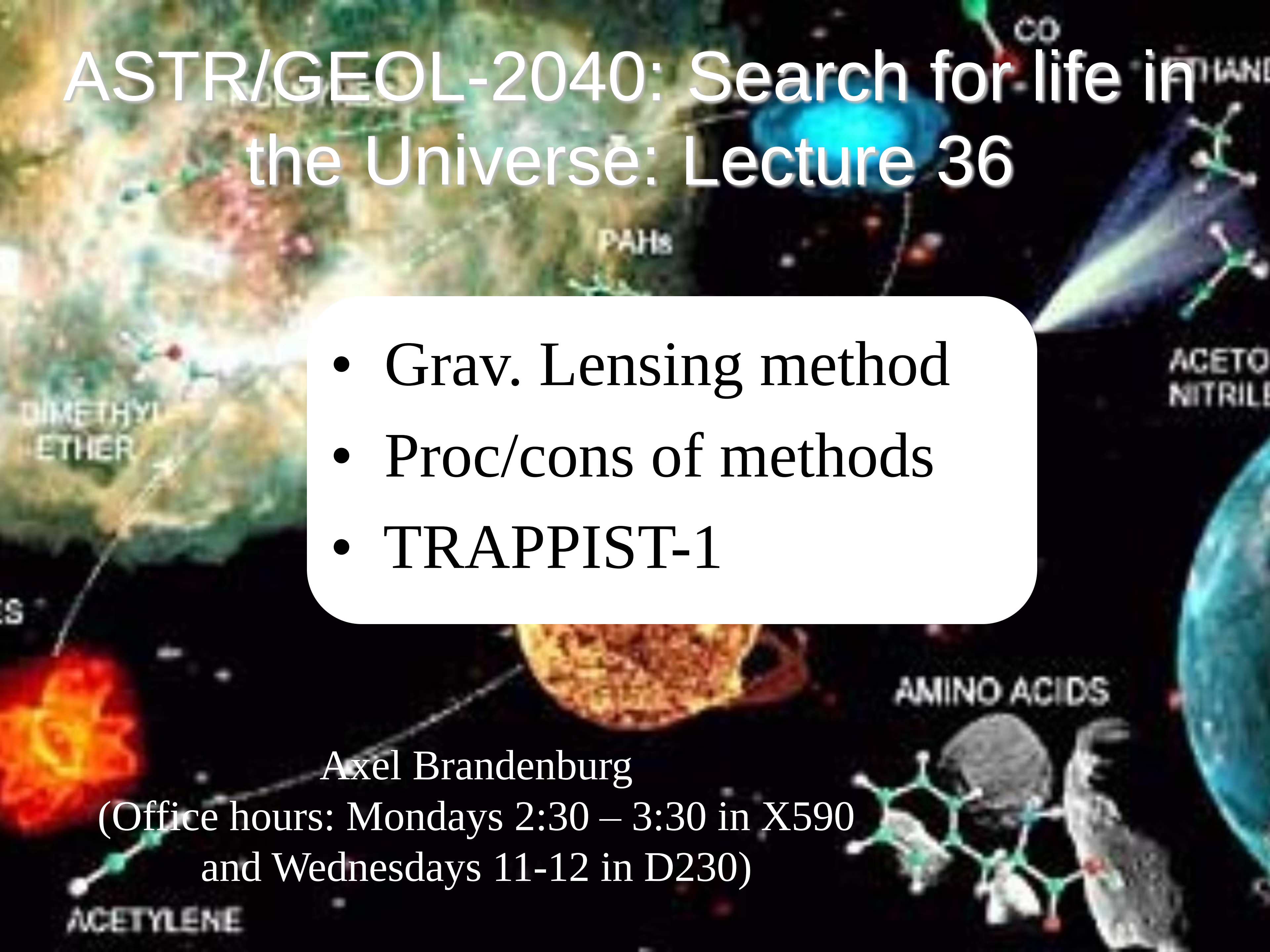
ASTR/GEOL-2040: Search for life in the Universe: Lecture 36

- Grav. Lensing method
- Proc/cons of methods
- TRAPPIST-1

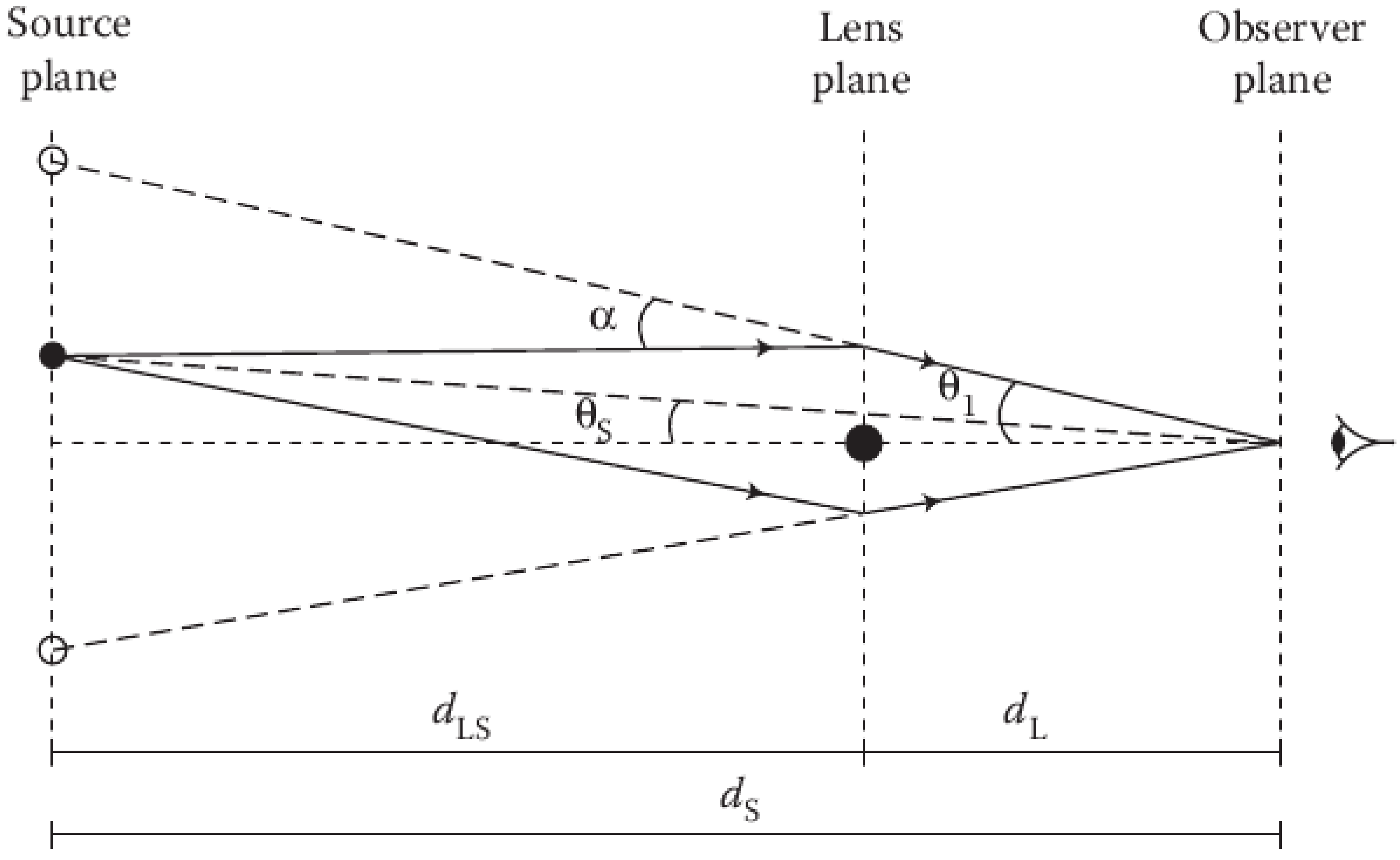
Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590
and Wednesdays 11-12 in D230)



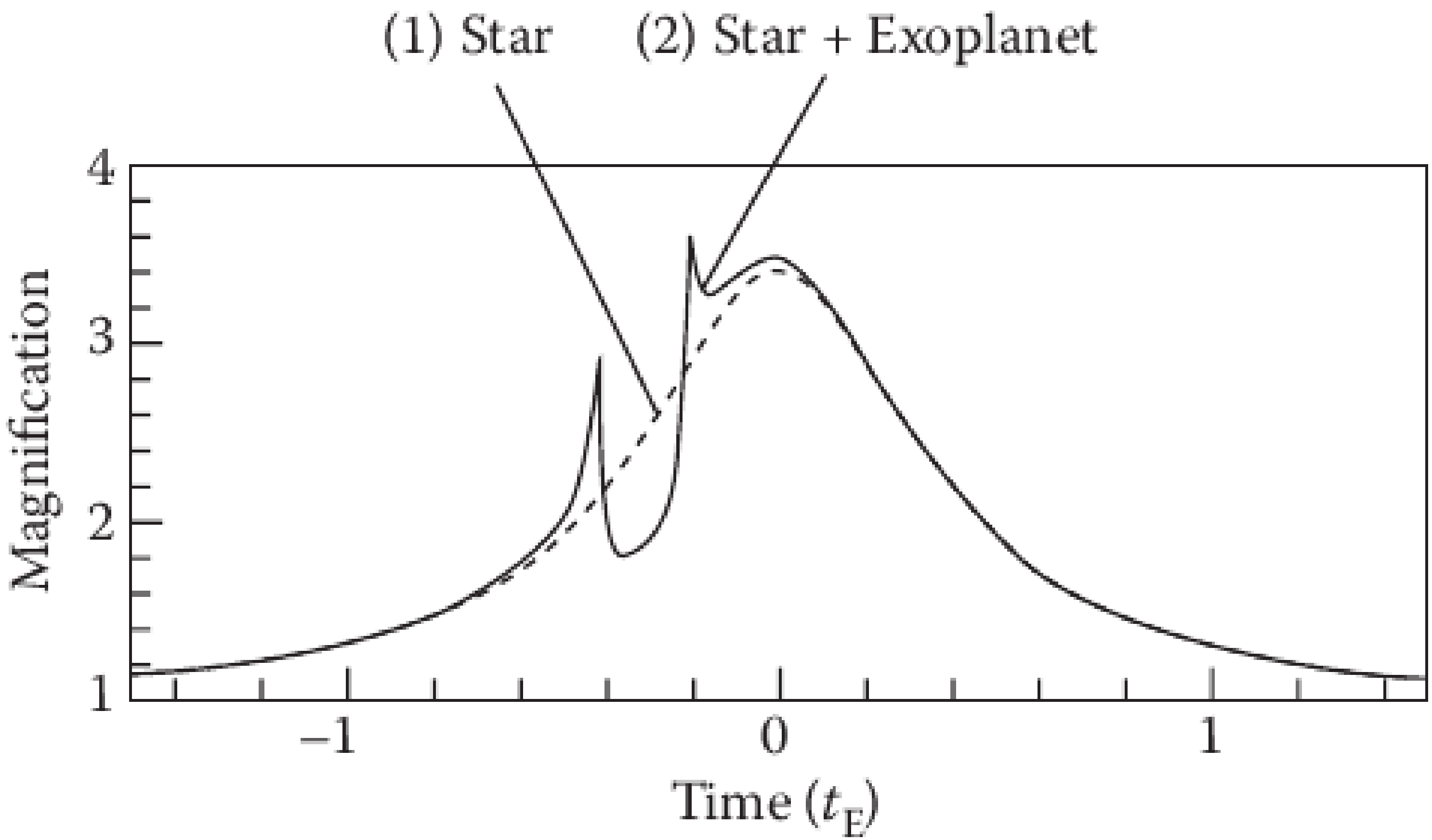
Exoplanet detection methods

- Radial velocity variations
- Astrometry (position in the sky)
- Direct imaging:
- Transit photometry
- Gravitational lensing

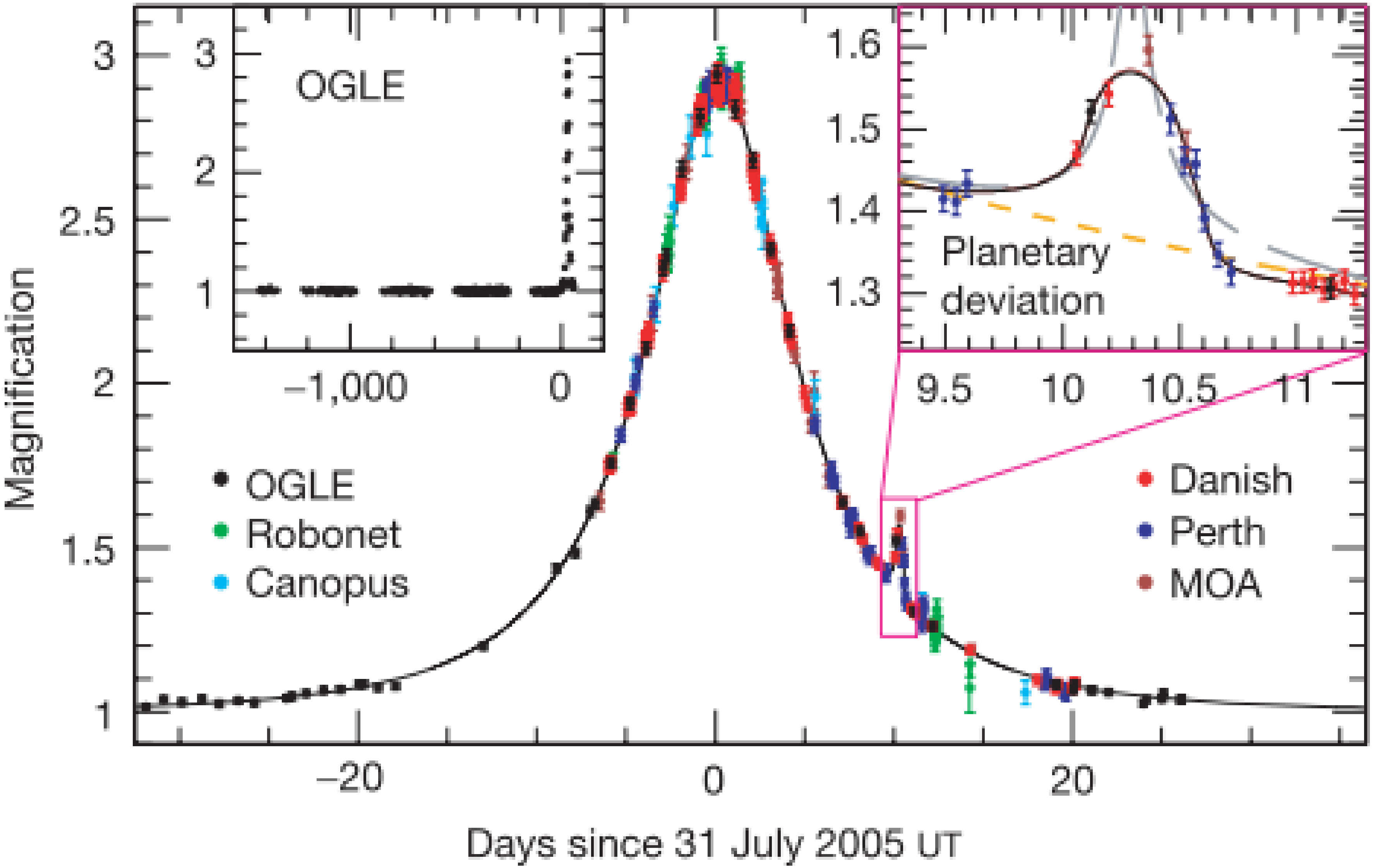
Gravitational (micro) lensing



In theory…



In practice…



OGLE
Planetary deviation
OGLE
Robonet
Canopus
Danish
Perth
MOA
Magnification
Days since 31 July 2005 UT

Discovery of a cool planet of 5.5 Earth masses through gravitational microlensing

J.-P. Beaulieu[1,4], D. P. Bennett[1,3,5], P. Fouqué[1,6], A. Williams[1,7], M. Dominik[1,8], U. G. Jørgensen[1,9], D. Kubas[1,10], A. Cassan[1,4], C. Coutures[1,11], J. Greenhill[1,12], K. Hill[1,12], J. Menzies[1,13], P. D. Sackett[1,14], M. Albrow[1,15], S. Brillant[1,10], J. A. R. Caldwell[1,16], J. J. Calitz[1,17], K. H. Cook[1,18], E. Corrales[1,4], M. Desort[1,4], S. Dieters[1,12], D. Dominis[1,19], J. Donatowicz[1,20], M. Hoffman[1,19], S. Kane[1,21], J.-B. Marquette[1,4], R. Martin[1,7], P. Meintjes[1,17], K. Pollard[1,15], K. Sahu[1,22], C. Vinter[1,9], J. Wambsganss[1,23], K. Woller[1,9], K. Horne[1,8], I. Steele[1,24], D. M. Bramich[1,8,24], M. Burgdorf[1,24], C. Snodgrass[1,25], M. Bode[1,24], A. Udalski[2,26], M. K. Szymański[2,26], M. Kubiak[2,26], T. Więckowski[2,26], G. Pietrzyński[2,26,27], I. Soszyński[2,26,27], O. Szewczyk[2,26], Ł. Wyrzykowski[2,26,28], B. Paczyński[2,29], F. Abe[3,30], I. A. Bond[3,31], T. R. Britton[3,15,32], A. C. Gilmore[3,15], J. B. Hearnshaw[3,15], Y. Itow[3,30], K. Kamiya[3,30], P. M. Kilmartin[3,15], A. V. Korpela[3,33], K. Masuda[3,30], Y. Matsubara[3,30], M. Motomura[3,30], Y. Muraki[3,30], S. Nakamura[3,30], C. Okada[3,30], K. Ohnishi[3,34], N. J. Rattenbury[3,28], T. Sako[3,30], S. Sato[3,35], M. Sasaki[3,30], T. Sekiguchi[3,30], D. J. Sullivan[3,33], P. J. Tristram[3,32], P. C. M. Yock[3,32] & T. Yoshioka[3,30]

- Once in a lifetime event
- Thus, difficult to confirm
- So far: 19 exoplanets discovered with this

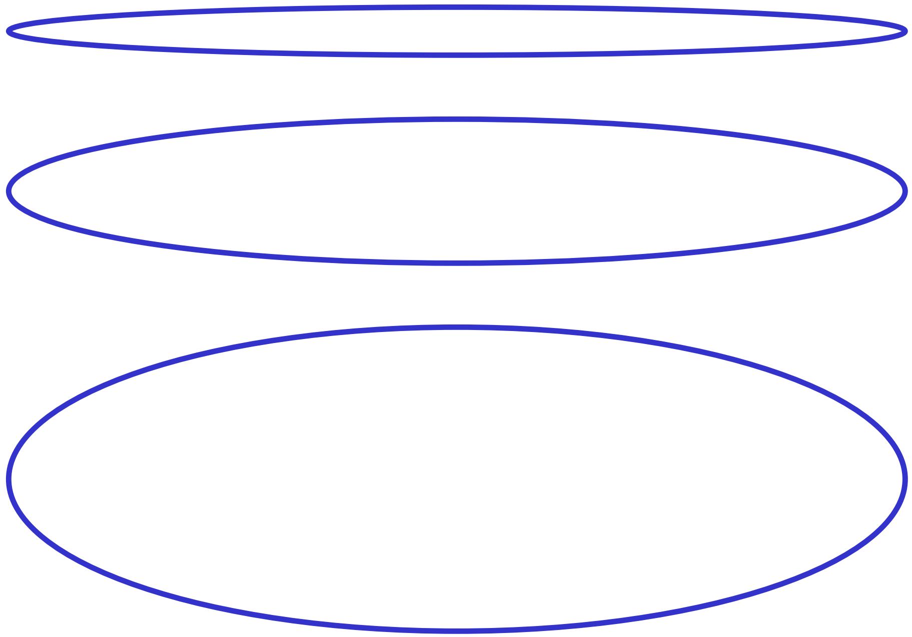
Pros+cons of detection methods

- Radial velocity variations
- Astrometry (position in the sky)
- Direct imaging:
- Transit photometry
- Gravitational lensing

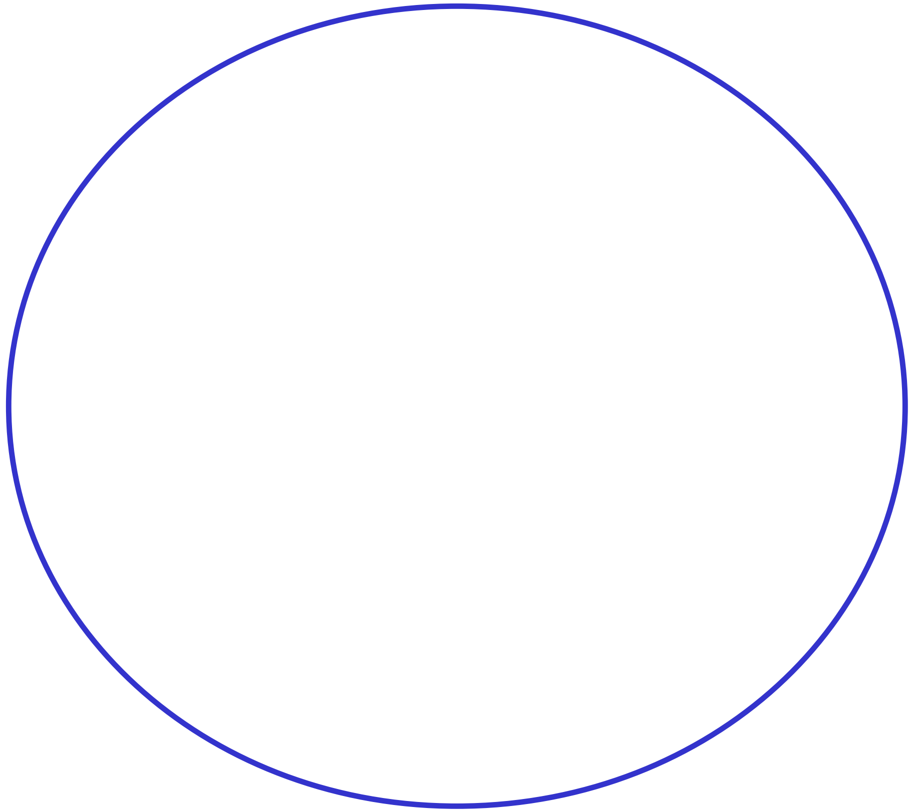
Radial velocity method

A. Can only determine upper limit on its mass
B. Can only determine lower limit on its mass
C. Can only determine upper limit on its radius
D. Can only determine lower limit on its radius
E. Neither of the above

Remember: must be edge-on



Extreme case: face-on



Radial velocity method

A. Can only determine upper limit on its mass
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Radial velocity variations

- Possible from the ground
- Biased toward large planets & close orbits
- Underestimates true motion unless observed edge-on
- Requires accurate spectra
- Large telescopes
- Long observing times (if dim)

Astrometric method

- Now possible with GAIA space craft
- Detects planets in all orbital orientations
- Edge-on perhaps tricky
- Only for nearby stars
- Biased toward massive stars far from host
- Requires long observations

Direct imaging

- The only method that allows study of planet itself!
- Requires large telescopes and means of blocking light of host star
- Worked just with a few
- Will become important in future
- Google for Web Cash

Axel Brandenburg Thu Apr 20, 11:21 PM

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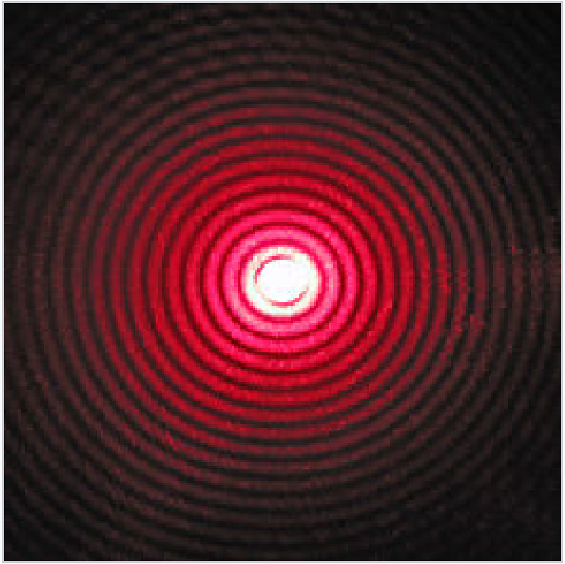
Diffraction

From Wikipedia, the free encyclopedia

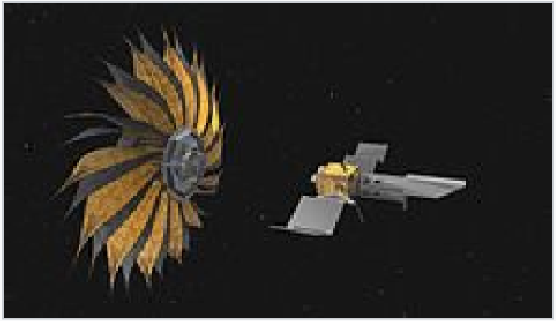
Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit. It is defined as the bending of light around the corners of an obstacle or aperture into the region of geometrical shadow of the obstacle. In classical physics, the diffraction phenomenon is described as the interference of waves according to the Huygens–Fresnel principle. These characteristic behaviors are exhibited when a wave encounters an obstacle or a slit that is comparable in size to its wavelength. Similar effects occur when a light wave travels through a medium with a varying refractive index, or when a sound wave travels through a medium with varying acoustic impedance. Diffraction occurs with all waves, including sound waves, water waves, and electromagnetic waves such as visible light, X-rays and radio waves.



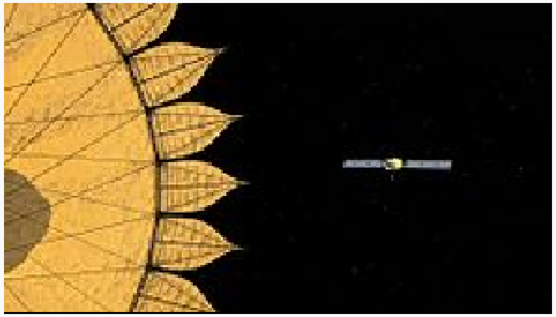
Diffraction pattern of red laser beam made on a plate after passing a small circular hole in another plate

Previous Next Highlight all Match case

The **New Worlds Mission** is a proposed project comprising a large occulter in space designed to block the light of nearby stars in order to observe their orbiting exoplanets. The observations could be taken with an existing space telescope, possibly the James Webb Space Telescope when it launches, or a dedicated visible light optical telescope optimally designed for the task of finding exoplanets. A preliminary research project was funded from 2005[1] through 2008 by NASA Institute for Advanced Concepts (NIAC) and headed by Webster Cash of the University of Colorado at Boulder in conjunction with Ball Aerospace & Technologies Corp., Northrop Grumman, Southwest Research Institute and others. Since 2010 the project has been looking for additional financing from NASA and other sources in the amount of roughly US$3 billion including its own four-meter telescope,[2] or $750 million for one starshade to be used with the James Webb Space Telescope.[3] If financed and launched, it would last five years.



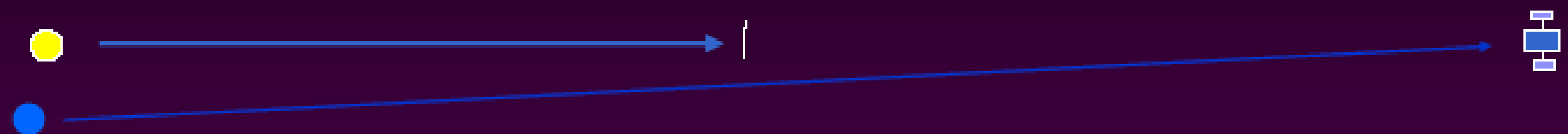
Starshade with space observatory during deployment



Play media

Video demonstration of the starshade

Contents



Transit method

A. Can only determine upper limit on its mass
B. Can only determine lower limit on its mass
C. Can only determine upper limit on its radius
D. Can only determine lower limit on its radius
E. Neither of the above

Transit method

- Allows many stars to be observed at once
- Can detect very small planets
- Feasible with small telescopes
- Can provide atmospheric data in cases of measurable eclipses
- But only if edge-on
- For small planets: sensitivity only from space

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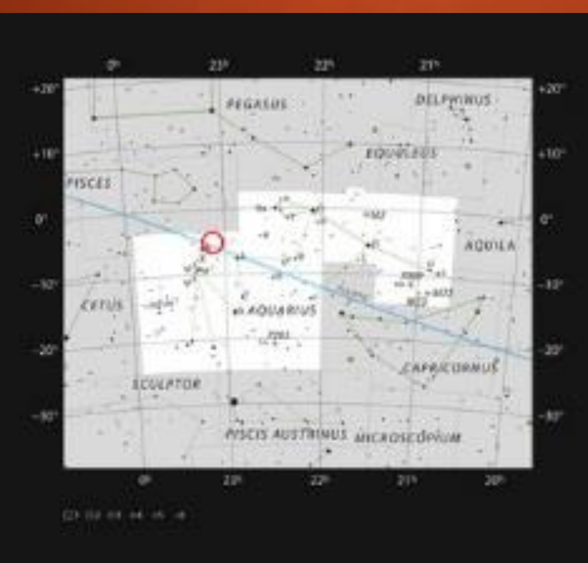
As of 2011

- 10% of all exoplanets are giant planets < 4AU
- High metallicity
- Only a few Earth-like planets
- In 2011: no planet with < Earth's mass
- Beginning to find super-Earth…
- Now in 2017: the picture changes

TRAPPIST-1

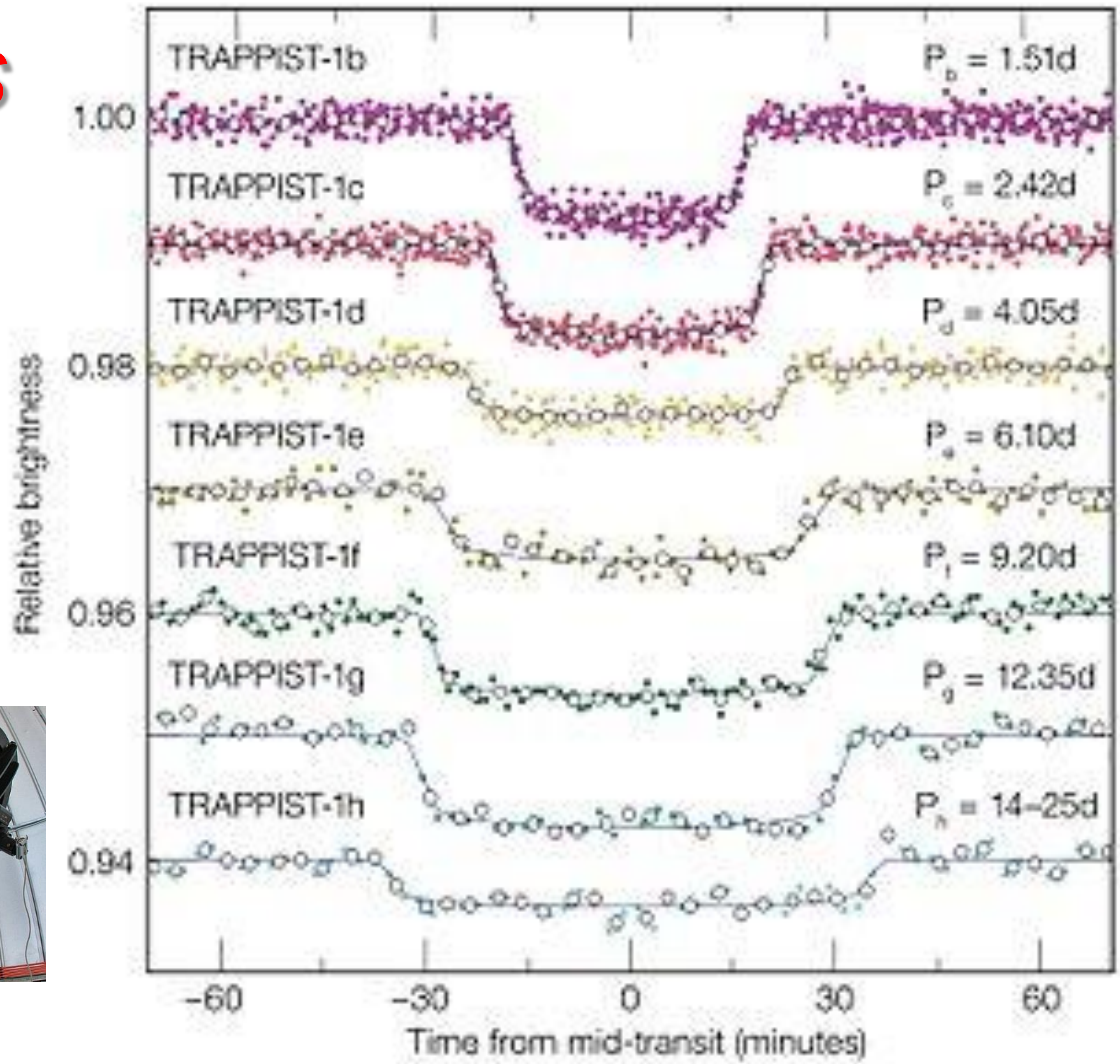
- M8 star
- 7 terrestrial planets

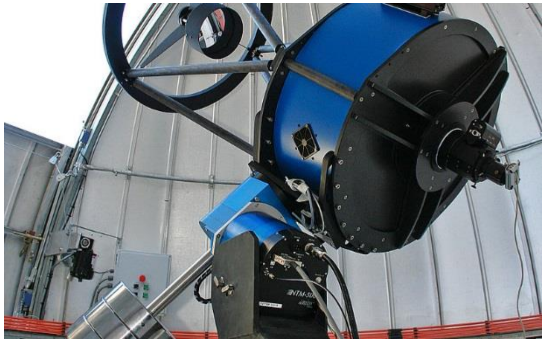


m=18.8, 12 pc = 39 ly

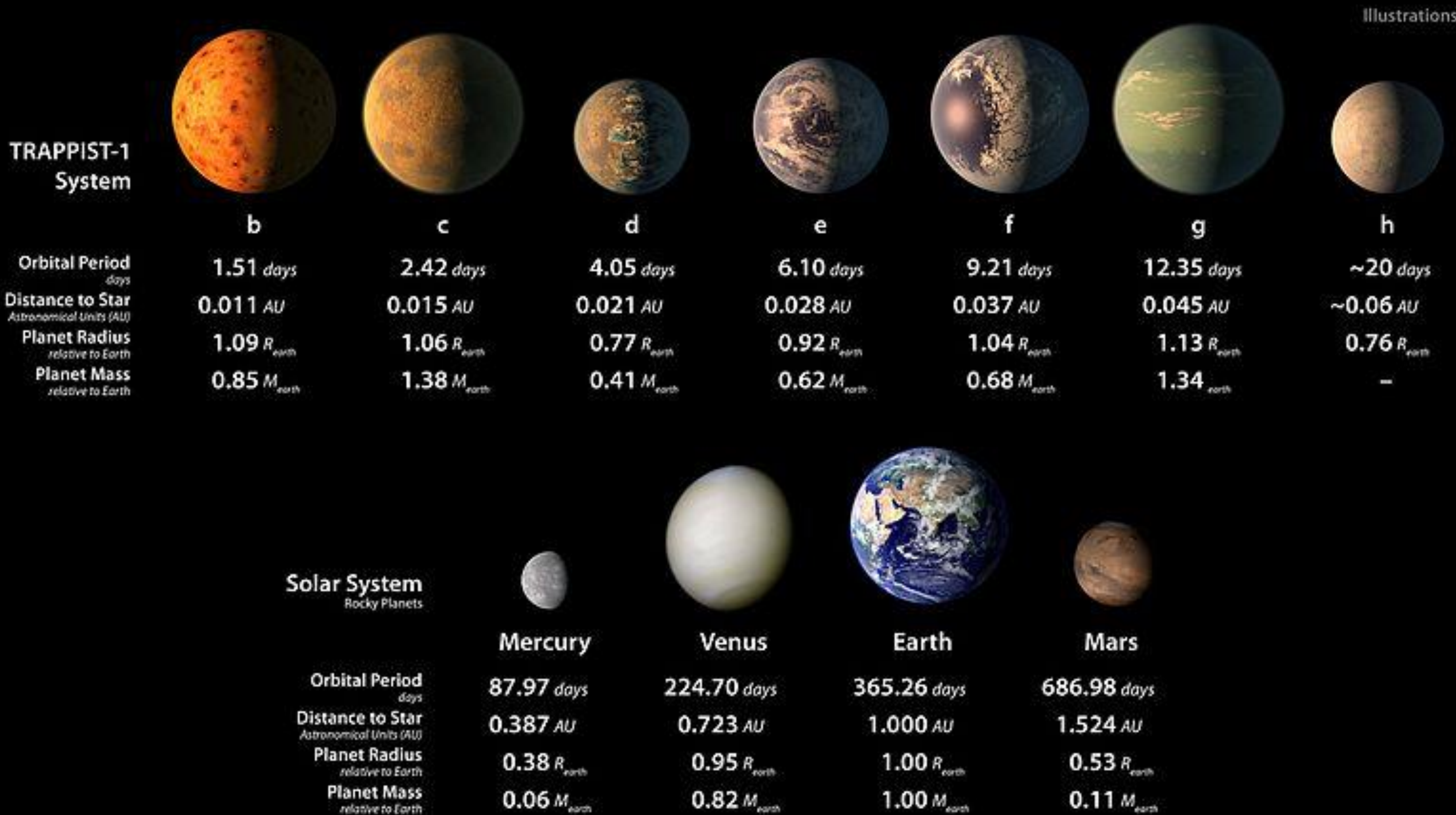
Transits

- Orbits: 1.5-20d
- Orb perts → mass





TRAPPIS-1 vs Sun

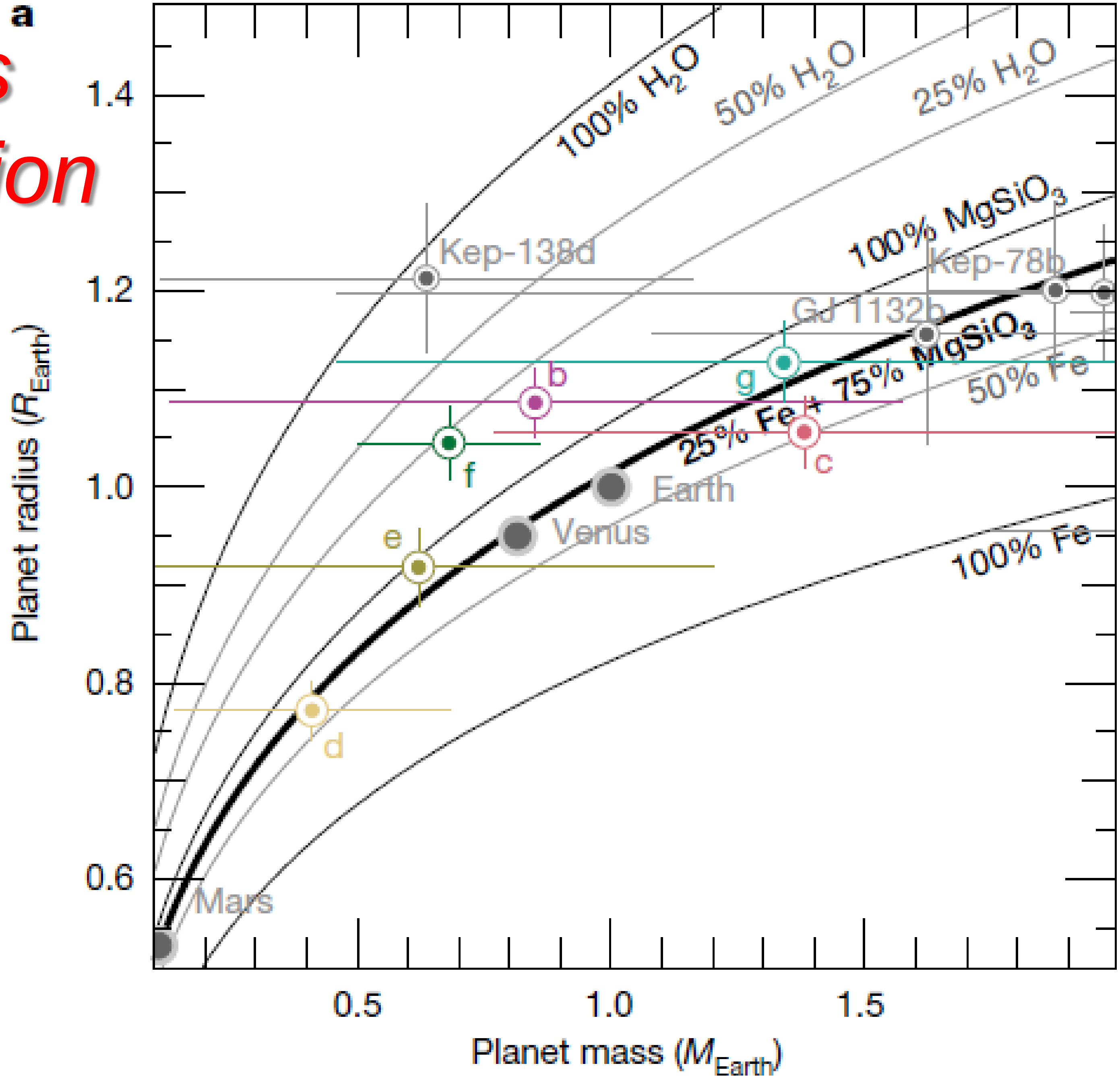


Host star

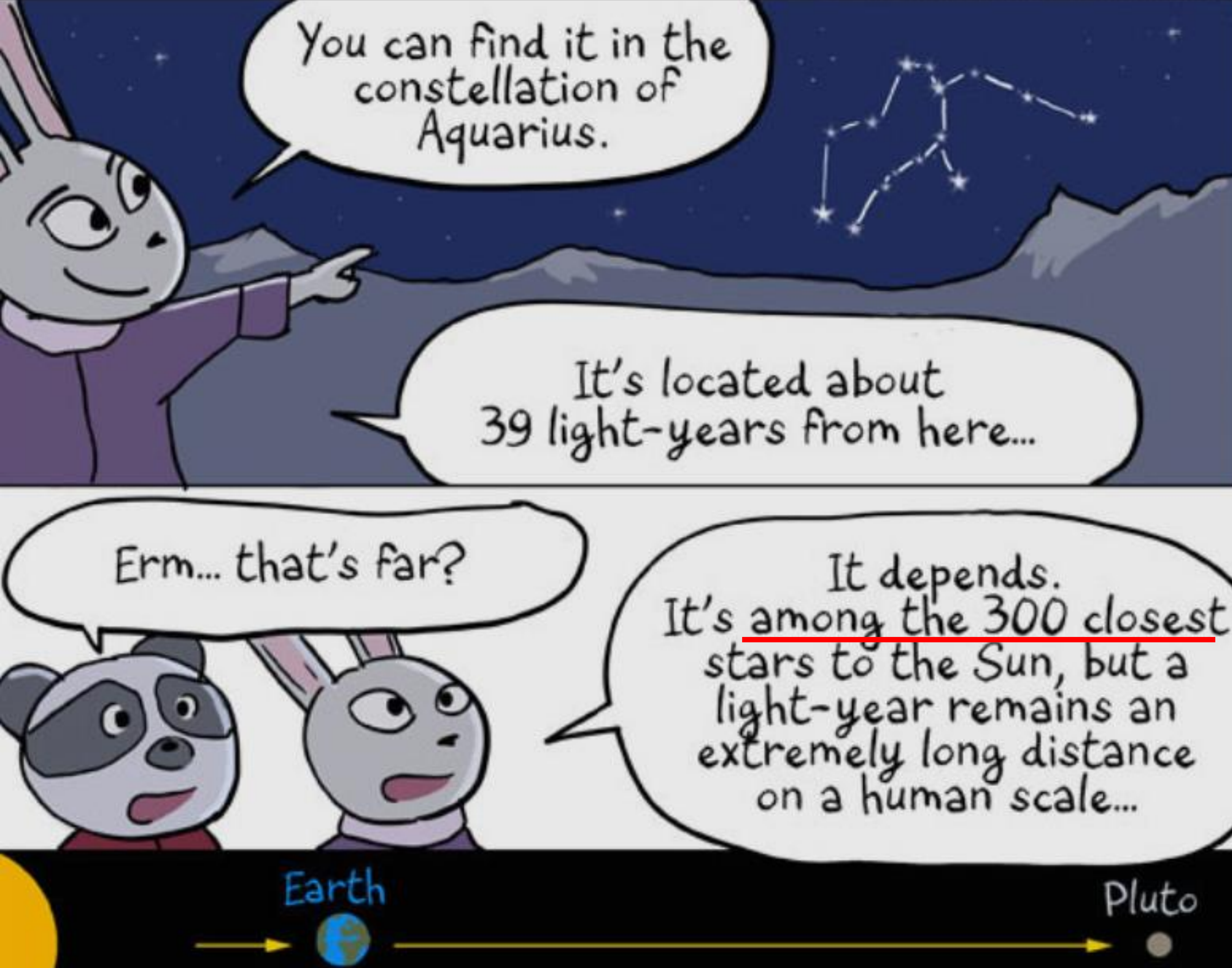
- Mass: 0.08 M_S = 80 M_J
  - Ultracool dwarf
- Radius: 0.114 R_S = 1.11 R_J
- Age: > 1Gyr
  - Not too many flares

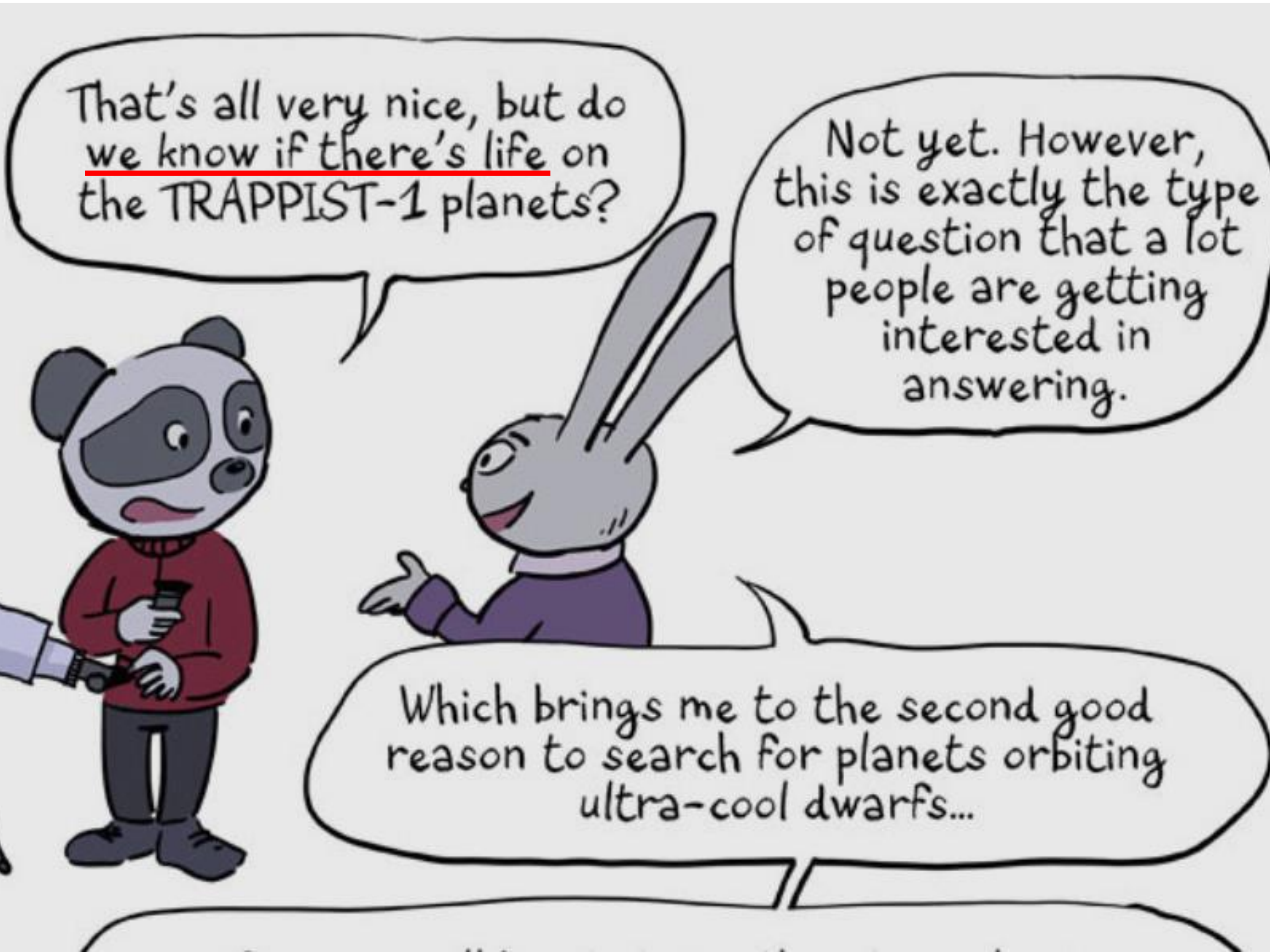
Planets composition

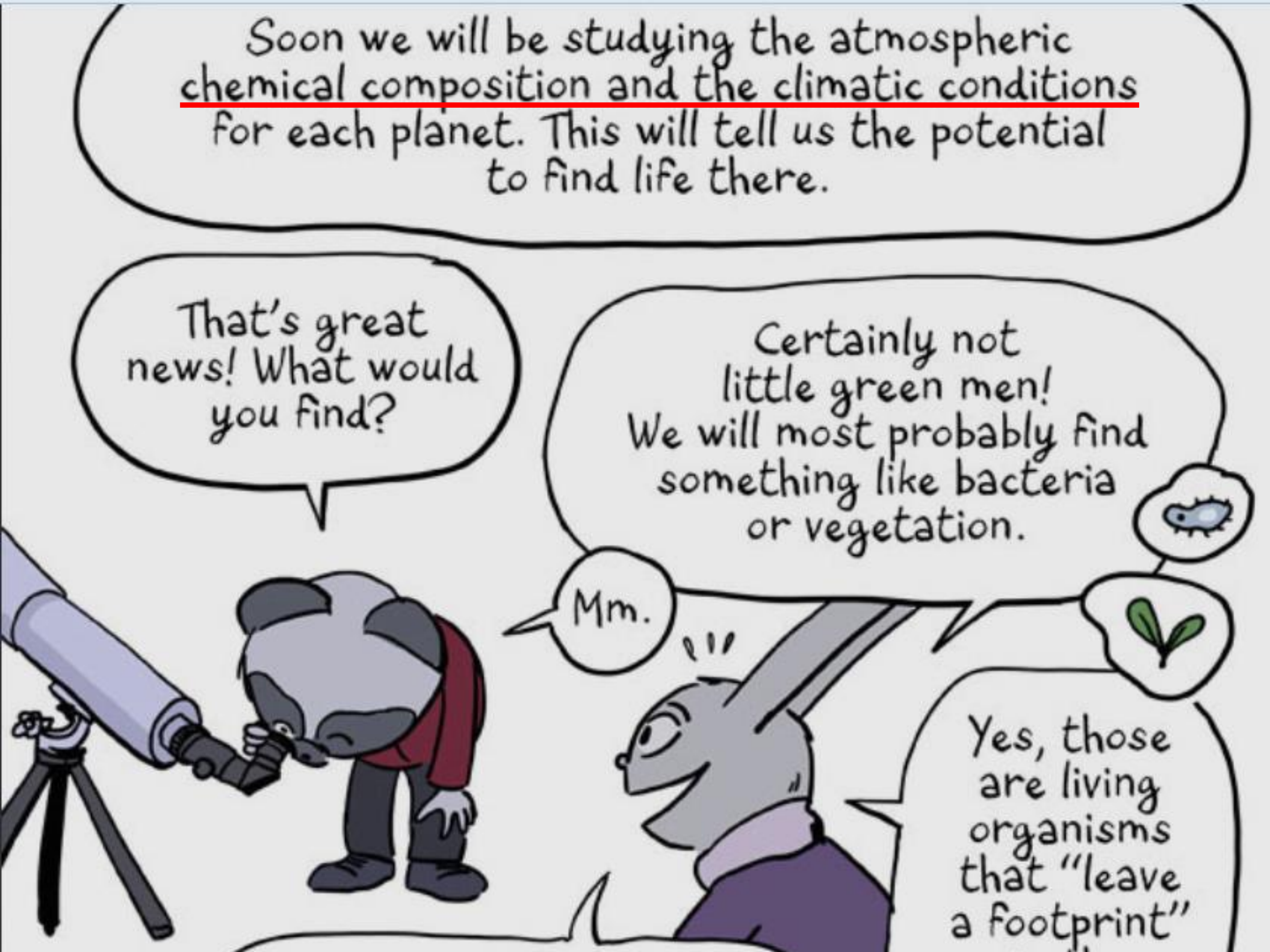
- Real terrestrial planets!
- Similar to Earth!

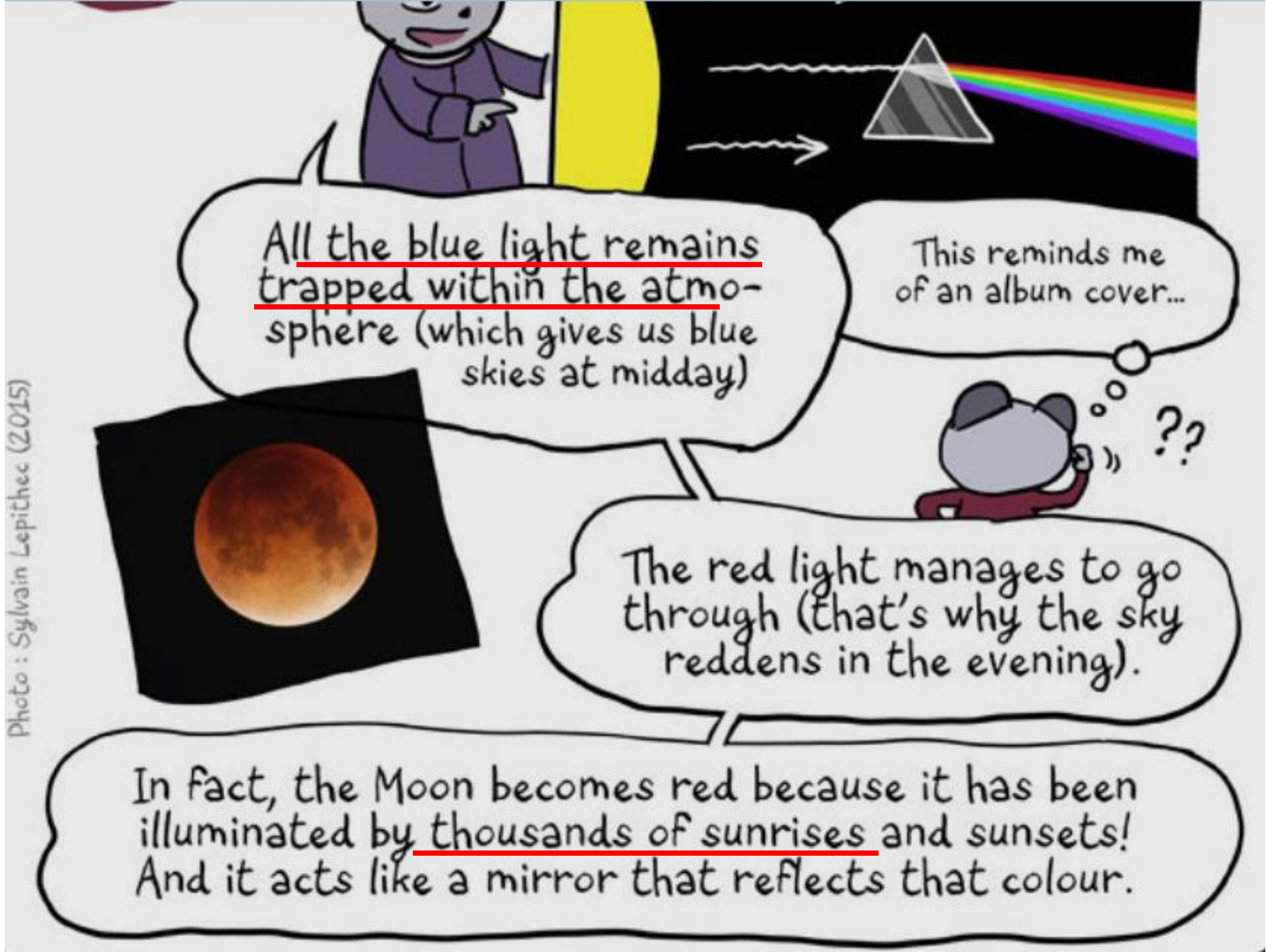


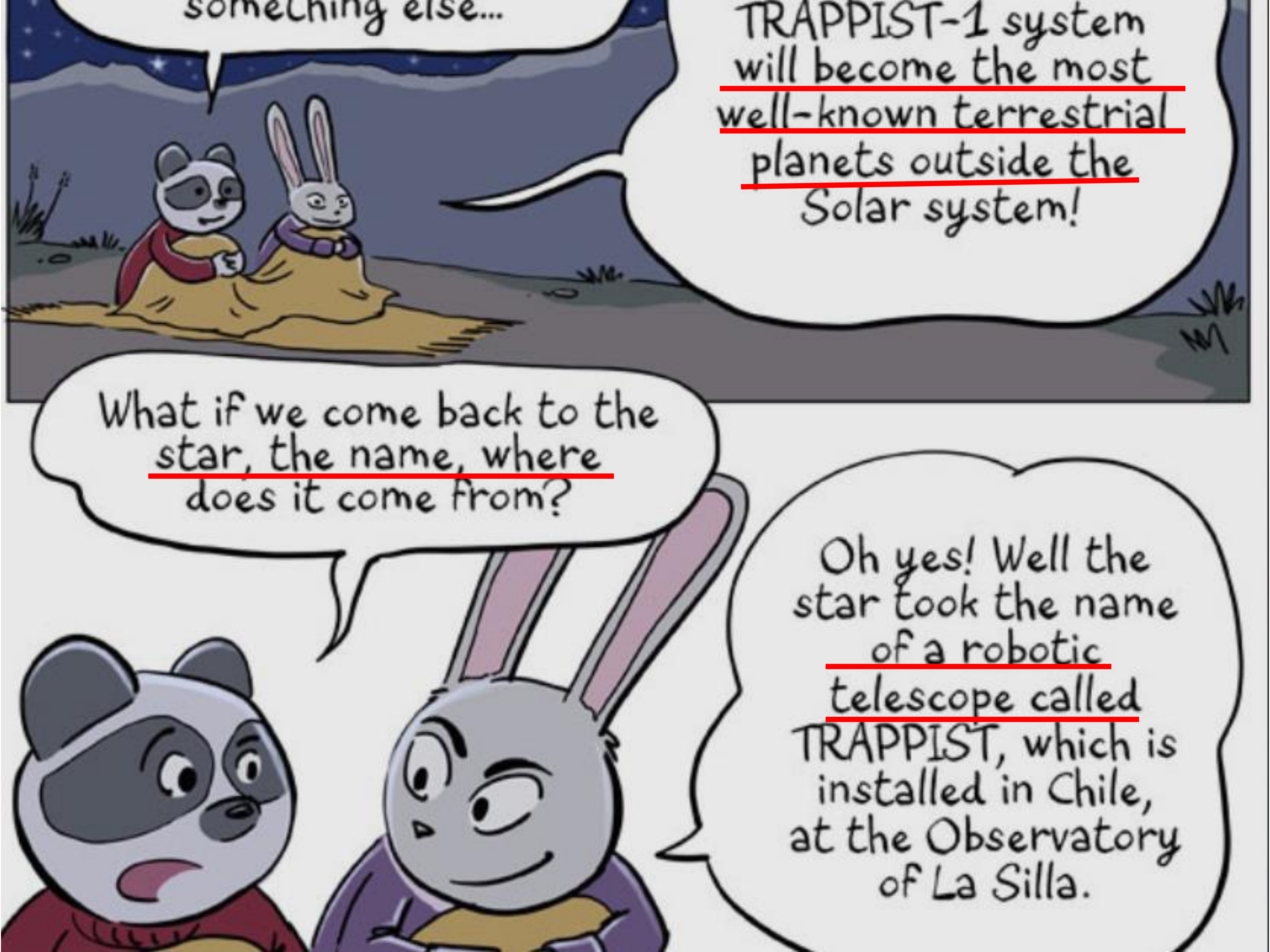

Why the strange name?
I'll tell you later.
You know, it's an important star.
Really? What's so special about it?

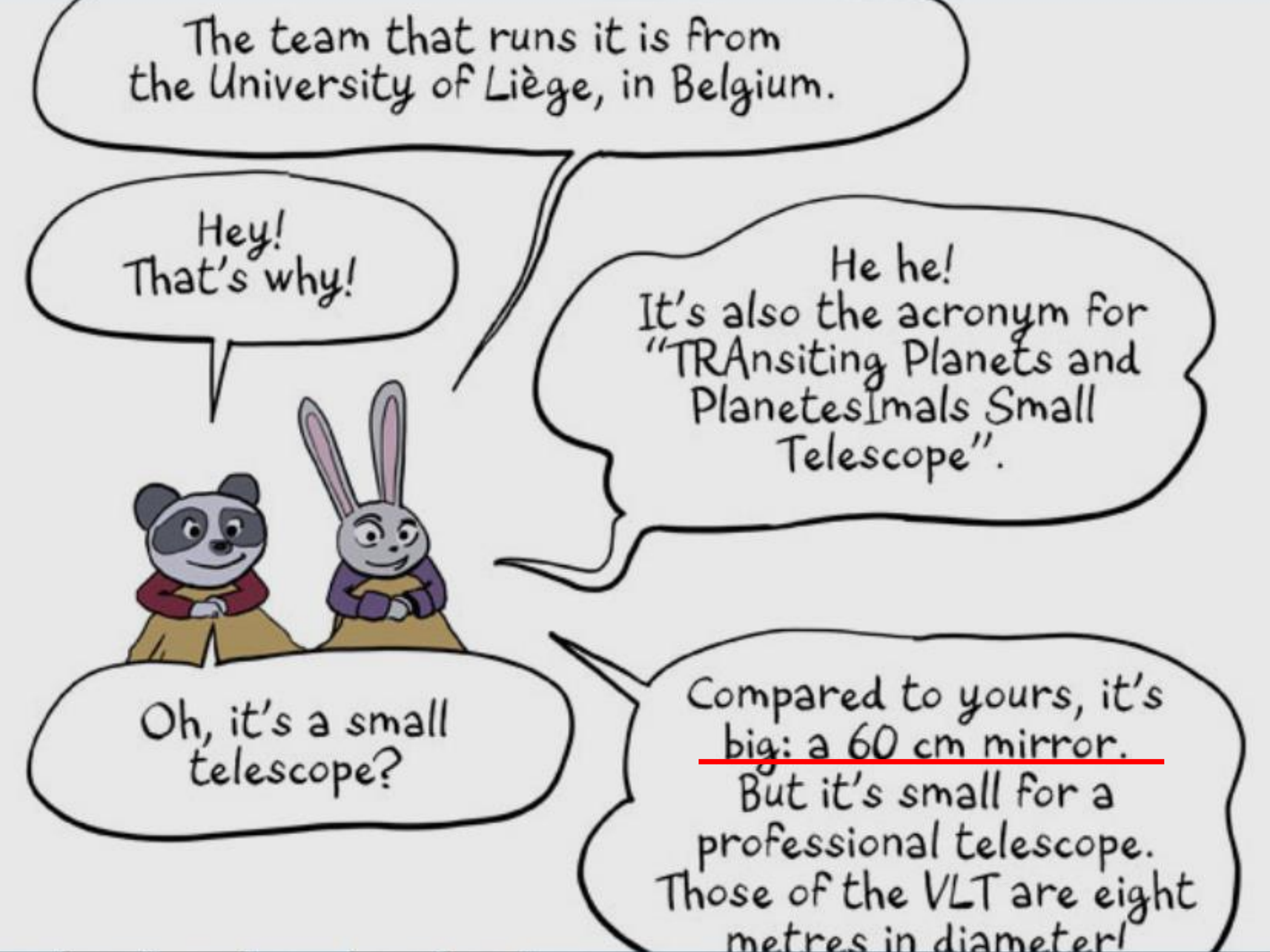

You can find it in the constellation of Aquarius.
It's located about 39 light-years from here...
Erm... that's far?
It depends. It's among the 300 closest stars to the Sun, but a light-year remains an extremely long distance on a human scale...
Earth
Pluto


That's all very nice, but do we know if there's life on the TRAPPIST-1 planets?
Not yet. However, this is exactly the type of question that a lot people are getting interested in answering.
Which brings me to the second good reason to search for planets orbiting ultra-cool dwarfs...


Soon we will be studying the atmospheric chemical composition and the climatic conditions for each planet. This will tell us the potential to find life there.
That's great news! What would you find?
Certainly not little green men! We will most probably find something like bacteria or vegetation.
Mm.
Yes, those are living organisms that "leave a footprint"


All the blue light remains trapped within the atmo- sphere (which gives us blue skies at midday)
This reminds me of an album cover...
??
The red light manages to go through (that's why the sky reddens in the evening).
In fact, the Moon becomes red because it has been illuminated by thousands of sunrises and sunsets! And it acts like a mirror that reflects that colour.
Photo : Sylvain Lepithec (2015)


something else...
TRAPPIST-1 system will become the most well-known terrestrial planets outside the Solar system!
What if we come back to the star, the name, where does it come from?
Oh yes! Well the star took the name of a robotic telescope called TRAPPIST, which is installed in Chile, at the Observatory of La Silla.

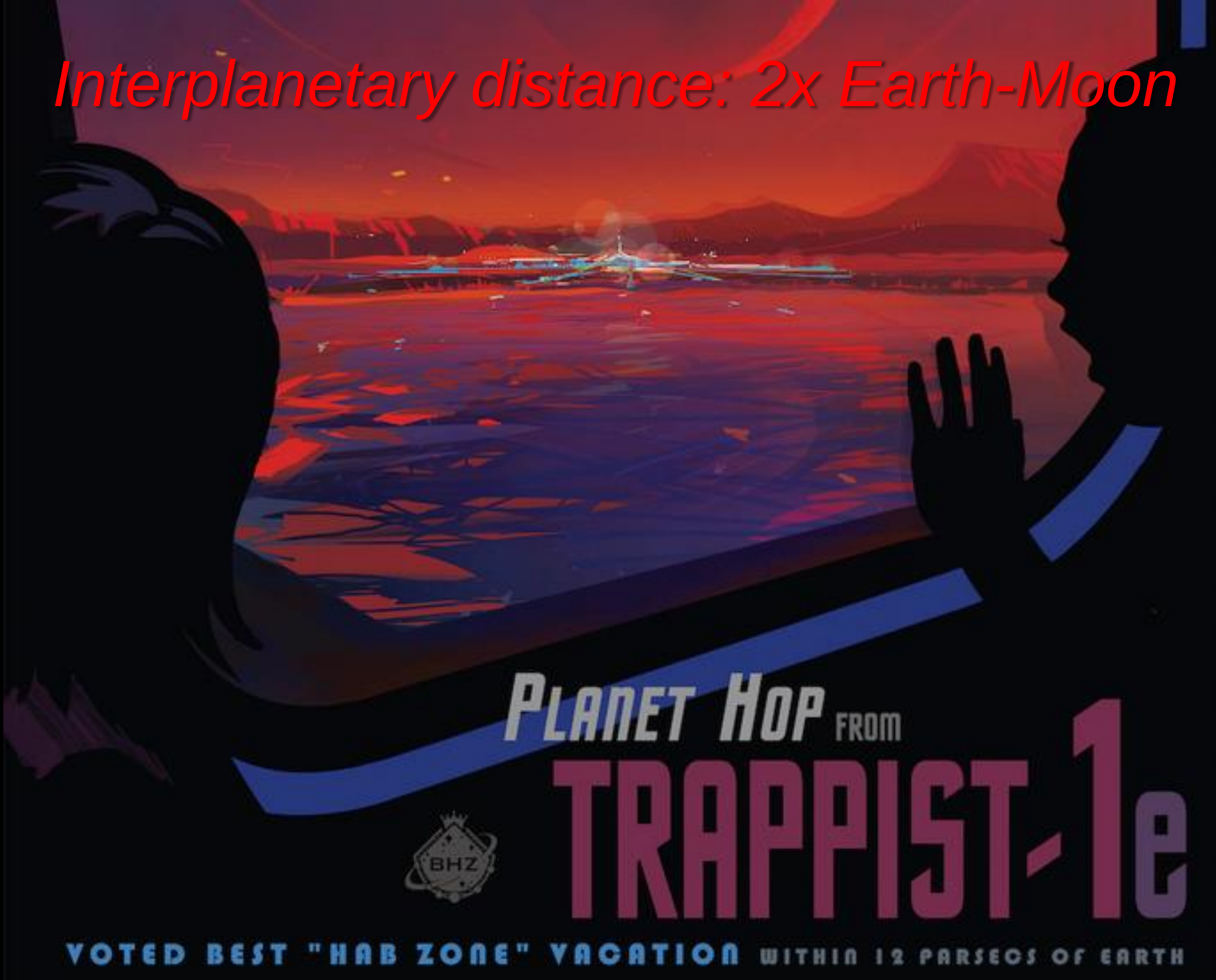

The team that runs it is from the University of Liège, in Belgium.
Hey! That's why!
He he! It's also the acronym for "TRAnsiting Planets and PlanetesImals Small Telescope".
Oh, it's a small telescope?
Compared to yours, it's big: a 60 cm mirror. But it's small for a professional telescope. Those of the VLT are eight metres in diameter!

TRAnsiting Planets & PlanetesImals Small Telecope

- Belgium robotic, La Silla
- Named after Trappists breweries

La Trappe Abbey or **La Grande Trappe** is a monastery in Soligny-la-Trappe, Orne, France, and the house of origin of the **Order of Cistercians of the Strict Observance** (O.C.S.O.: Ordo Cisterciensis Strictioris Observantiae), Reformed Cistercians or Trappists, to whom it gave its name.

Interplanetary distance: 2x Earth-Moon



Where to go from here

- James Webb (JWST) → atmosph.
- Search for Planets EClipsing ULtracOOL stars → SPECULOOS
- Target for many planetary studes
- And certainly SciFi

Problems with M dwarfs

(Dwarf = main sequence stars)

- M dwarfs have frequent flares
  - At least in their first 1 Gyr
- Closer planet: synchronous rotation
- What does this mean for life?

- (and what about effect of atmosphere)

Next time

- Starshot
- Breakthrough message
- etc

- RGS pp 281 – 295