The local universe, the search for life, and the Physics Nobel Prize 2019

to J. Peebles, and M. Mayor & D. Queloz

"for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos"

Ansgar Reiners

Georg-August-Universität Göttingen

Institut für Astrophysik Göttingen

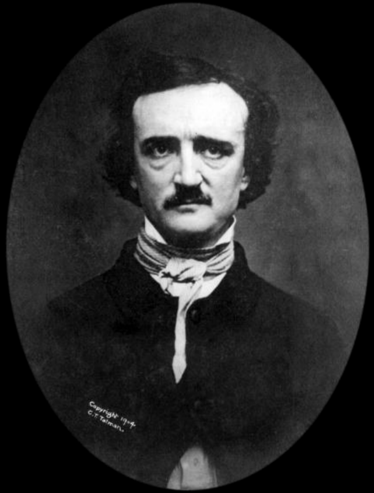
DESY Colloquium

NASA, Apollo 4, Nov 9, 1967

NASA, Apollo 8, Dec 24, 1968

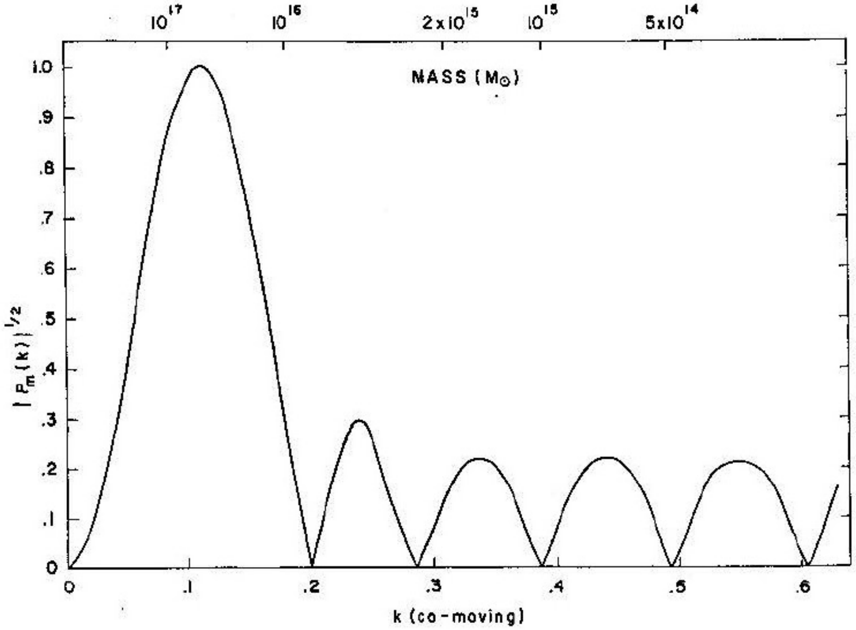
NASA, Apollo 8, Dec 24, 1968

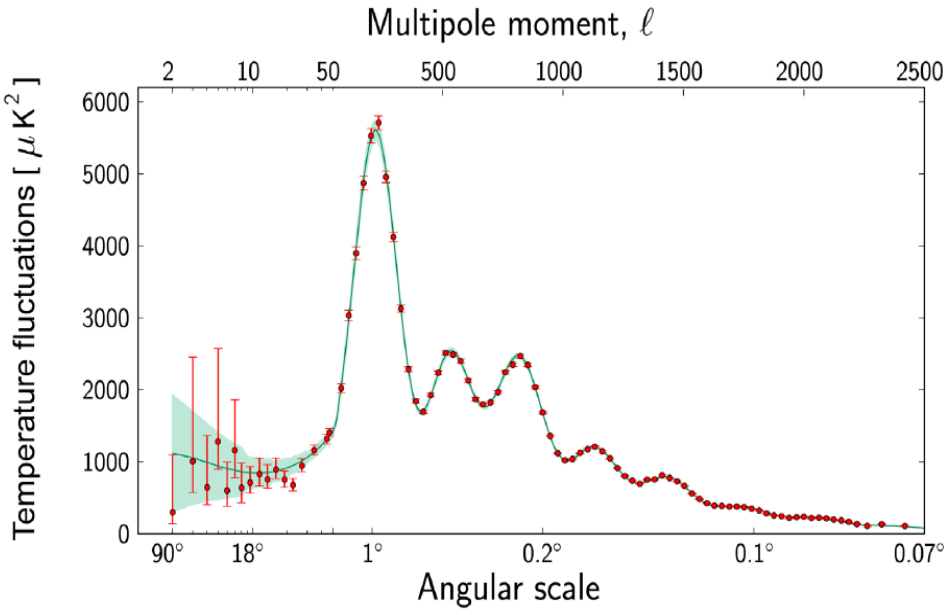
Edgar Allan Poe, *Eureka – A Prose Poem*, 1848:



Let us now endeavor to conceive what Matter must be, when, or if, in its absolute extreme of Simplicity. Here the Reason flies at once to Imparticularity – to a particle – to one particle – a particle of one kind – of one character – of one nature – of one size – of one form –a particle, therefore, "without form and void" – a particle positively a particle at all points – a particle absolutely unique, individual, undivided, and not indivisible […]

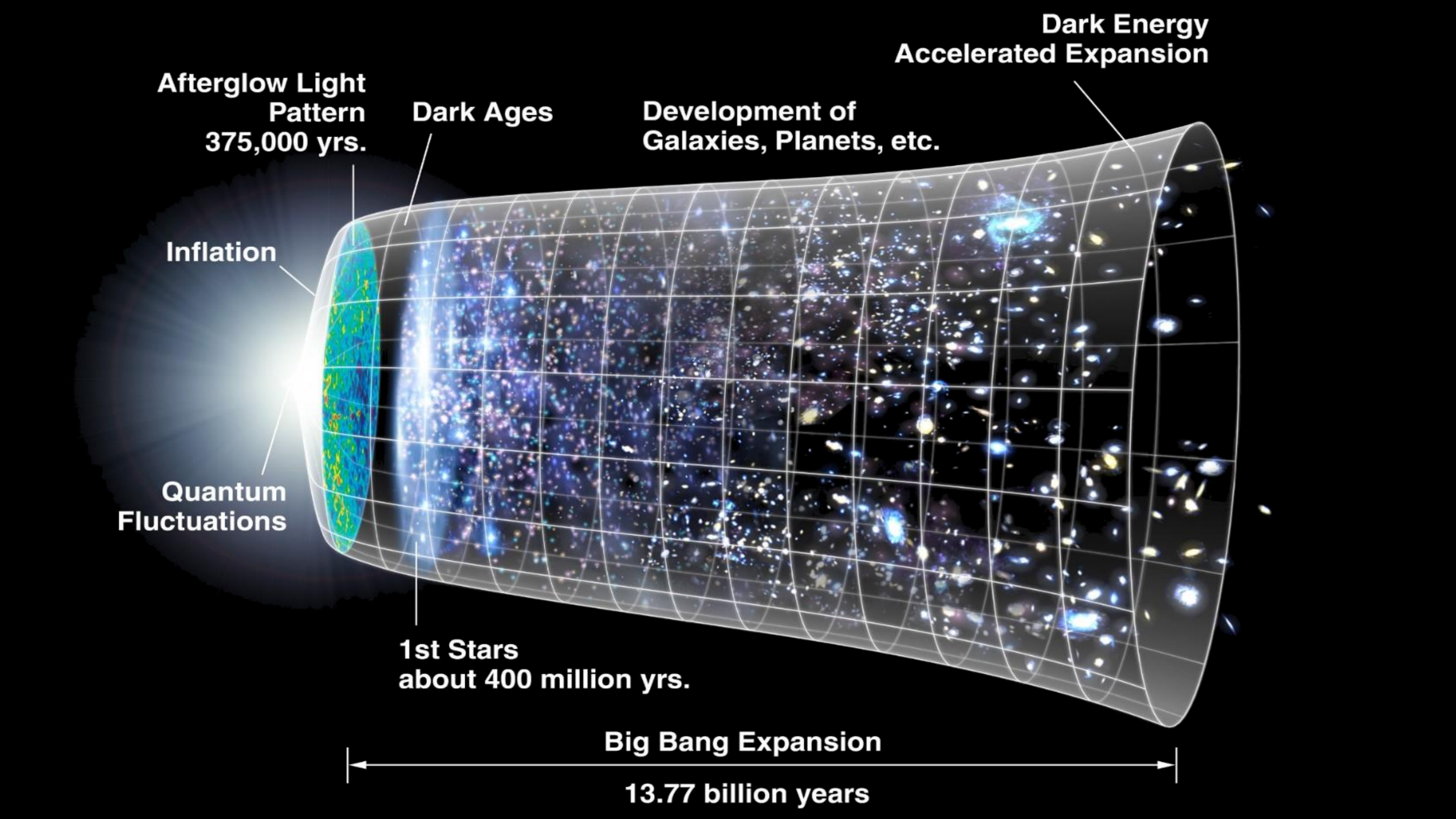
The Primordial Particle

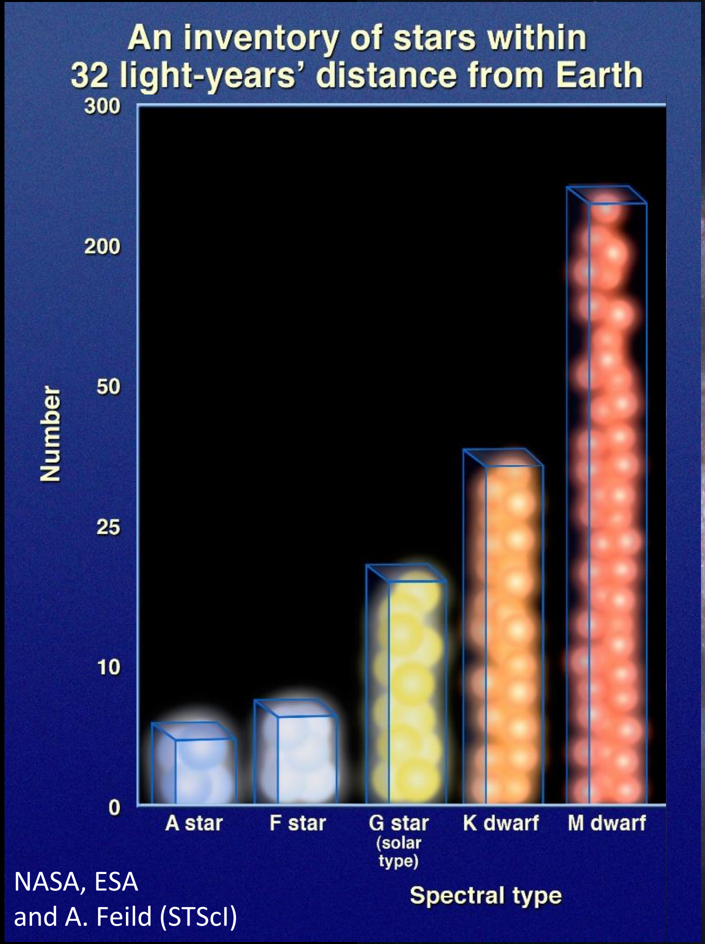




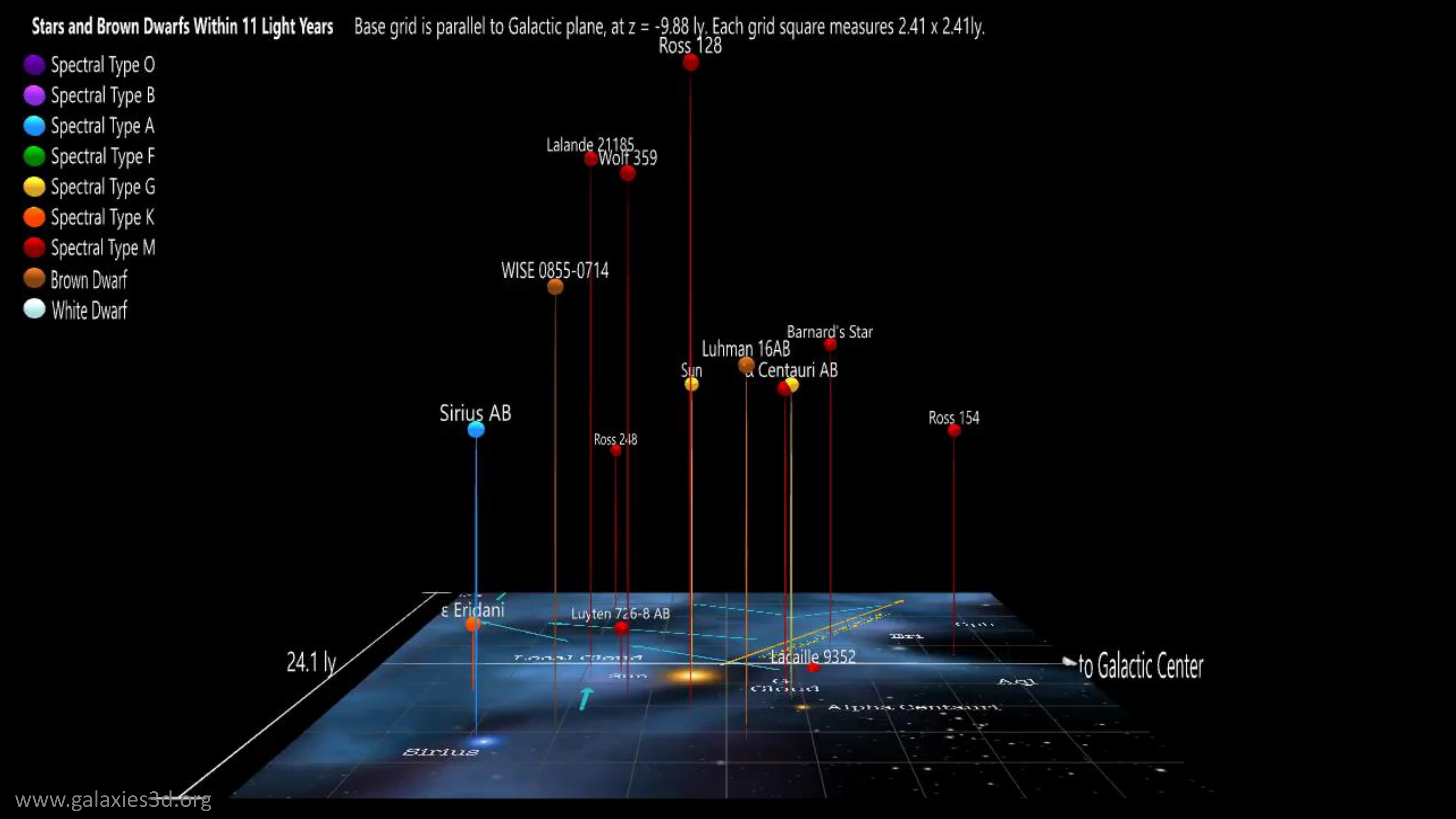
Peebles & Yu, 1970

Planck collaboration, 2018


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
375,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.77 billion years

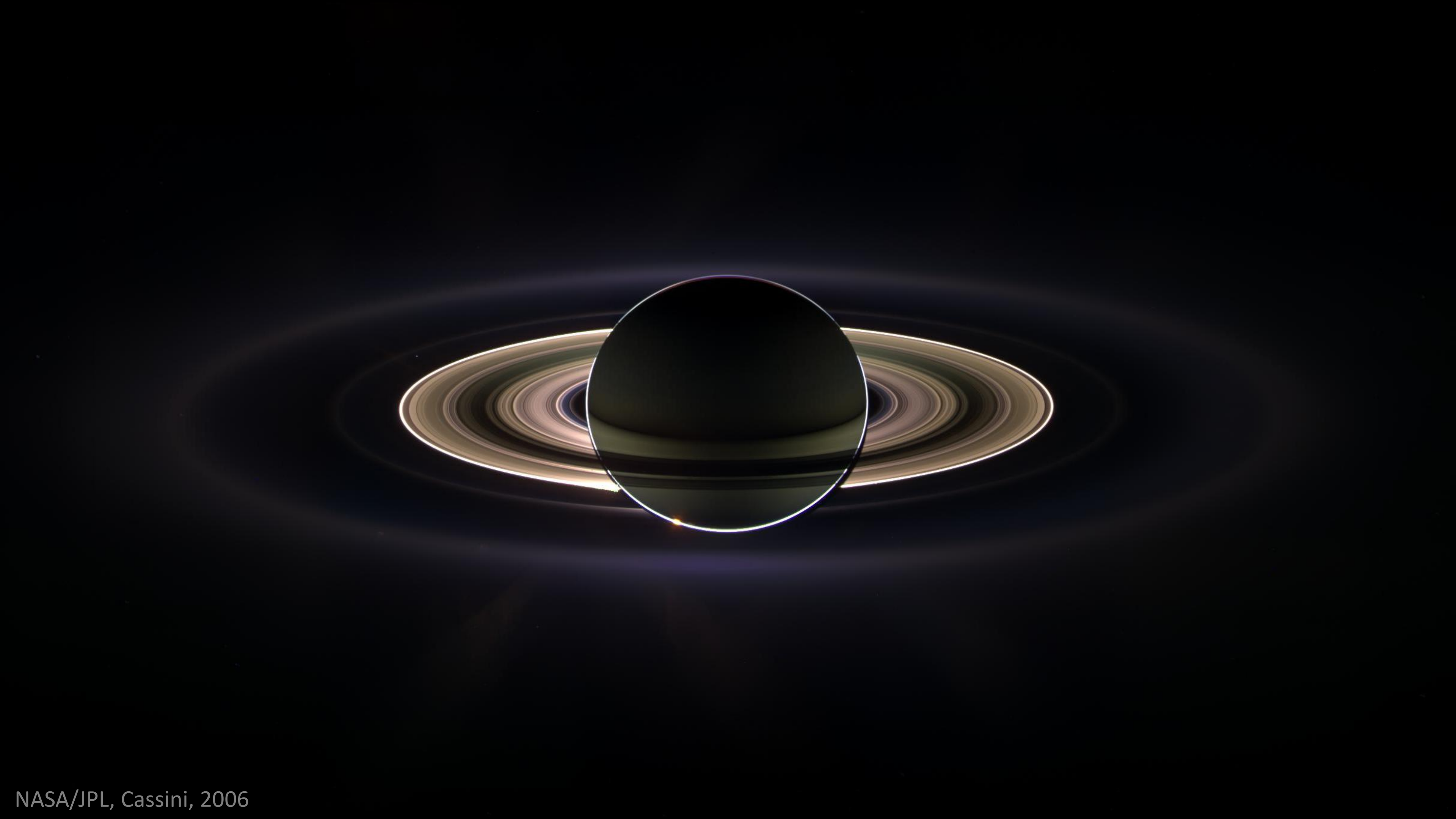

An inventory of stars within
32 light-years' distance from Earth
300
200
50
25
10
0
Number
A star
F star
G star
(solar
type)
K dwarf
M dwarf
Spectral type
NASA, ESA
and A. Feild (STScI)


You are here



Stars and Brown Dwarfs Within 11 Light Years
Base grid is parallel to Galactic plane, at z = -9.88 ly. Each grid square measures 2.41 x 2.41ly.
Spectral Type O
Spectral Type B
Spectral Type A
Spectral Type F
Spectral Type G
Spectral Type K
Spectral Type M
Brown Dwarf
White Dwarf
Ross 128
Lalande 21185
Wolf 359
WISE 0855-0714
Barnard's Star
Luhman 16AB
Sun
α Centauri AB
Sirius AB
Ross 248
Ross 154
ε Eridani
Luyten 726-8 AB
Lacaille 9352
24.1 ly
to Galactic Center
Sirius

NASA, Voyager 1, Feb 4, 1990



NASA/JPL, Cassini, 2006

SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†
Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation; (2) origin of life; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be?

The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-

* Now on leave at CERN, Geneva.

† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

A search for life on Earth from the Galileo spacecraft

Carl Sagan*, W. Reid Thompson*, Robert Carlson†, Donald Gurnett‡ & Charles Hord§

* Laboratory for Planetary Studies, Cornell University, Ithaca, New York 14853, USA
† Atmospheric and Cometary Sciences Section, Jet Propulsion Laboratory, Pasadena, California 91109, USA
‡ Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242-1479, USA
§ Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, Colorado 80309, USA

In its December 1990 fly-by of Earth, the Galileo spacecraft found evidence of abundant gaseous oxygen, a widely distributed surface pigment with a sharp absorption edge in the red part of the visible spectrum, and atmospheric methane in extreme thermodynamic disequilibrium; together, these are strongly suggestive of life on Earth. Moreover, the presence of narrow-band, pulsed, amplitude-modulated radio transmission seems uniquely attributable to intellig-ence. These observations constitute a control experiment for the search for extraterrestrial life by modern interplanetary spacecraft.

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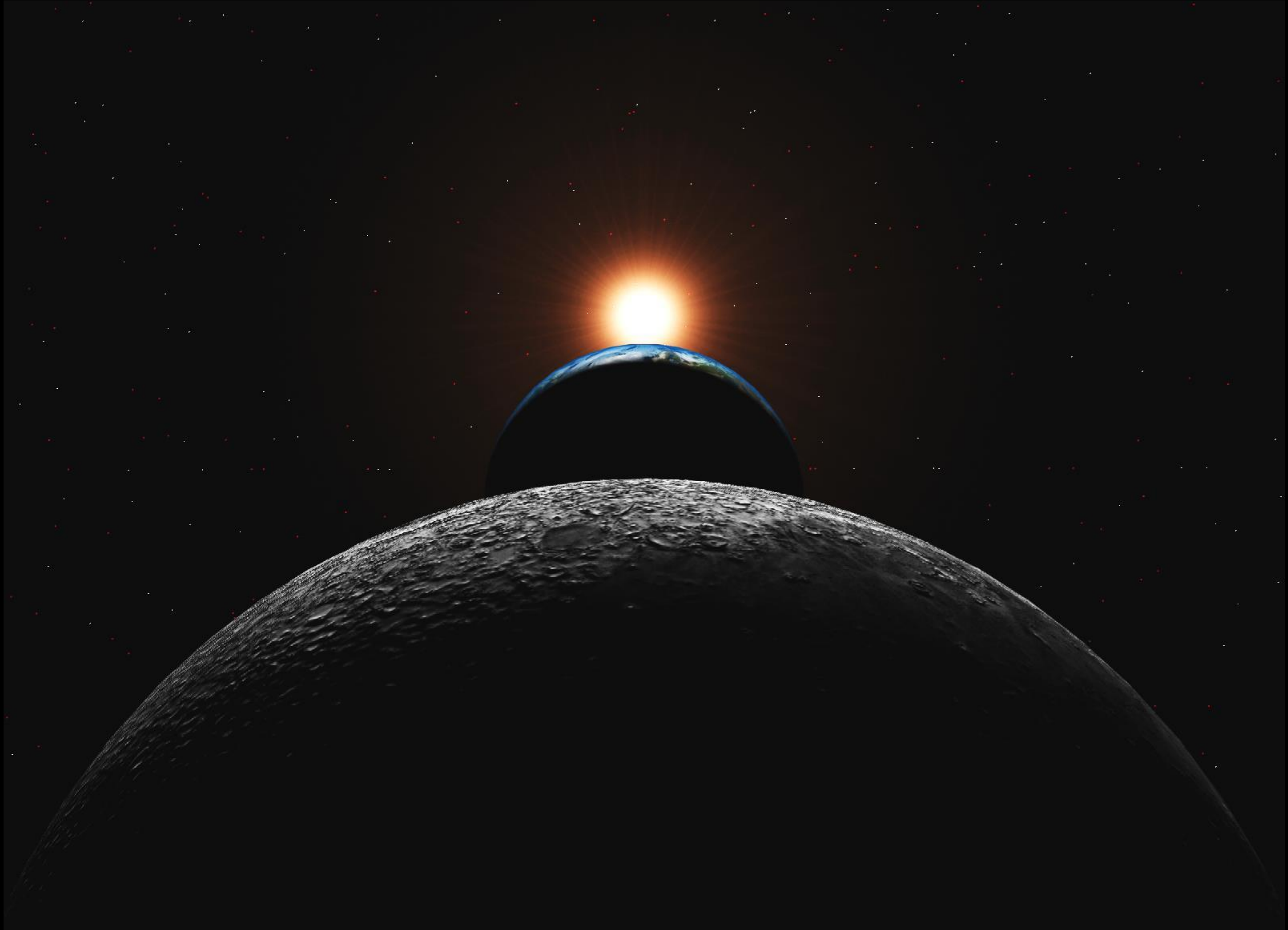
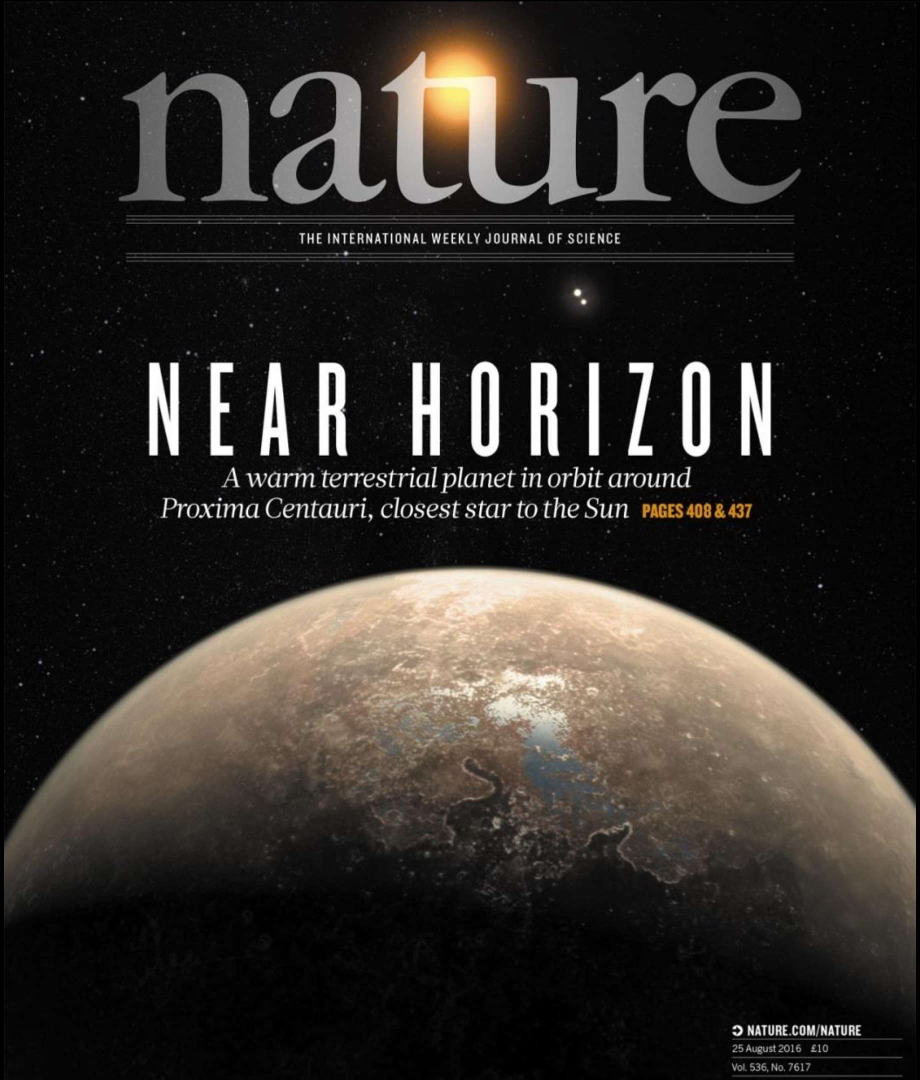
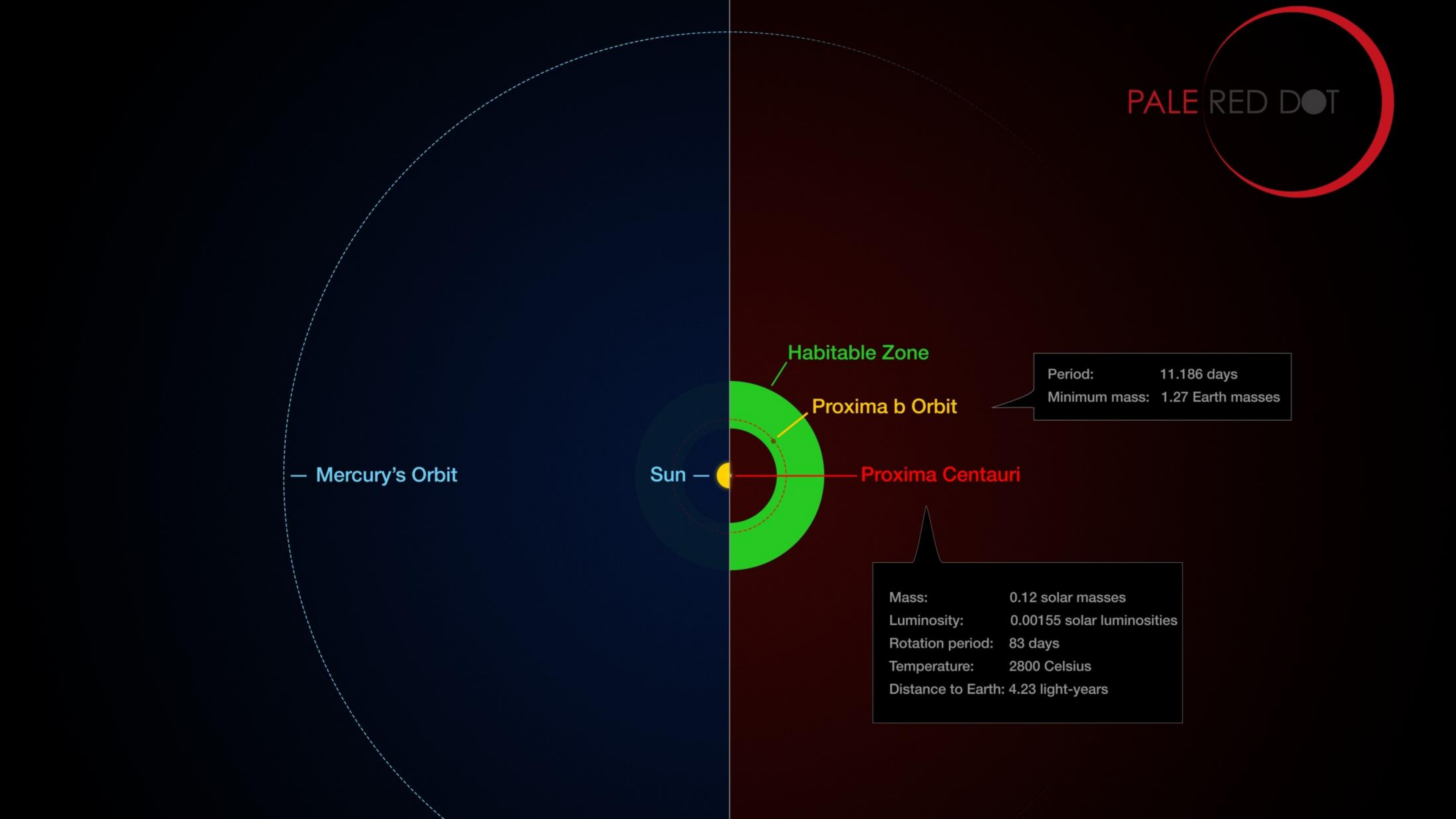
JPL, Galileo, Dec 11, 1990



2001 – Space Odyssey


nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
NEAR HORIZON
A warm terrestrial planet in orbit around
Proxima Centauri, closest star to the Sun PAGES 408 & 437
NATURE.COM/NATURE
25 August 2016 £10
Vol. 536, No. 7617


PALE RED DOT
Habitable Zone
Proxima b Orbit
Period: 11.186 days
Minimum mass: 1.27 Earth masses
Mercury's Orbit
Sun
Proxima Centauri
Mass: 0.12 solar masses
Luminosity: 0.00155 solar luminosities
Rotation period: 83 days
Temperature: 2800 Celsius
Distance to Earth: 4.23 light-years

New Scientist

WEEKLY August 27 - September 2, 2016

SHADOW WORLD
The untouchable layer of reality all around us

GENETIC RECODE
Blueprint of life gets a total rewrite

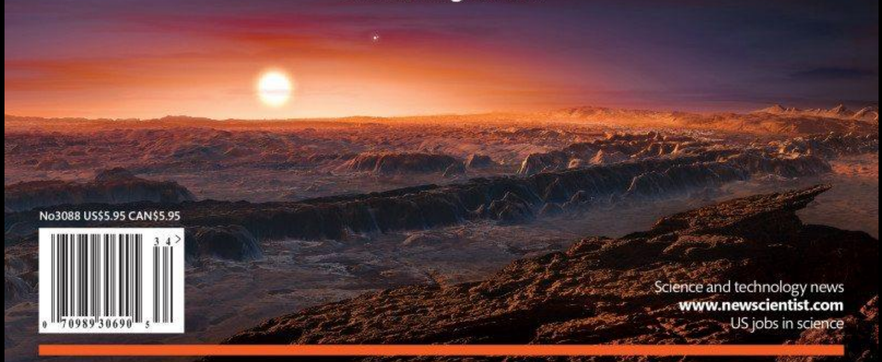
TIME TWISTER
Quantum trick reverses cause and effect

BAD MEDICINE Why so much health advice turns out to be wrong

SPECIAL REPORT: PROXIMA B

WE'VE FOUND AN EARTH-LIKE PLANET AROUND OUR NEAREST STAR

Should we go there?



No3088 US$5.95 CAN$5.95

Science and technology news
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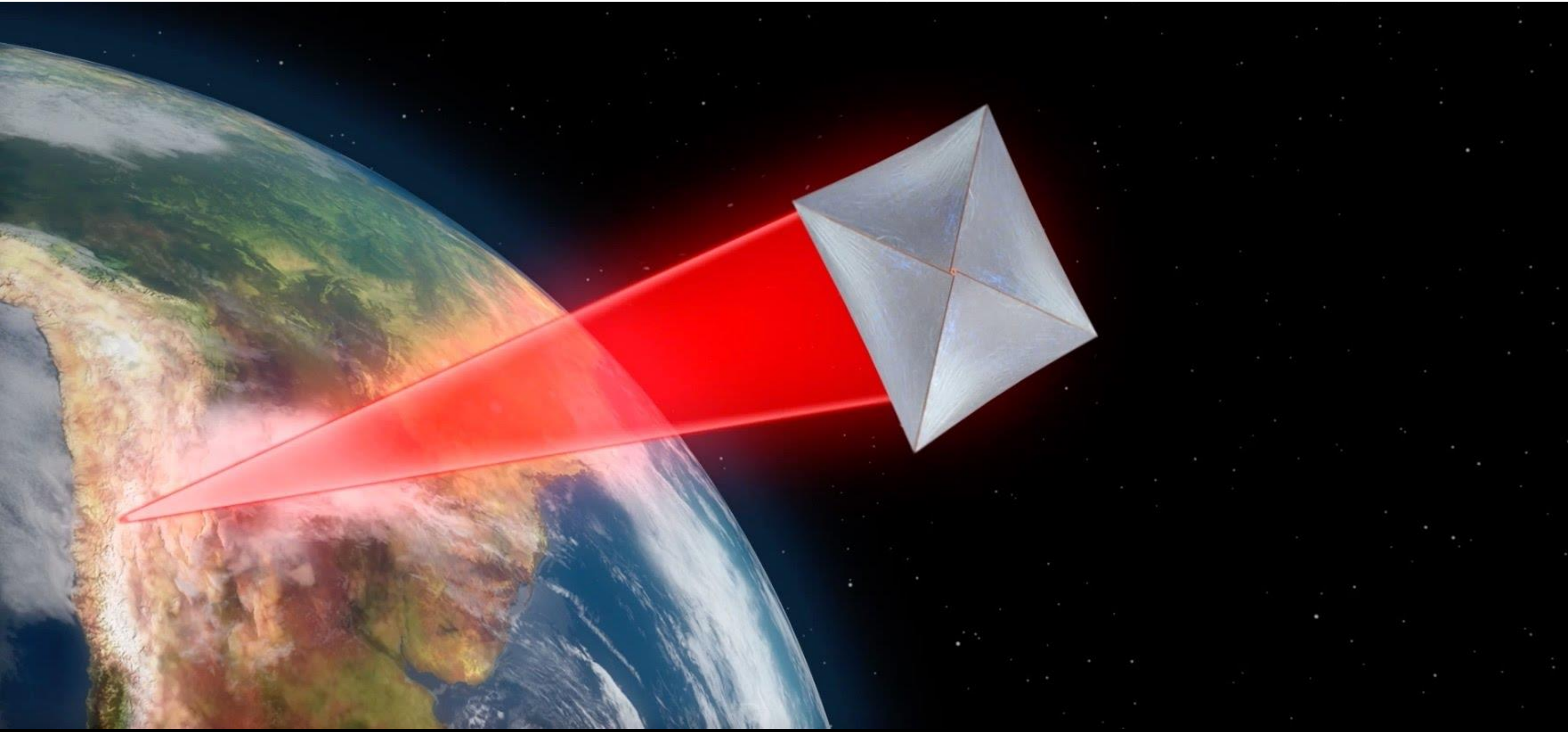
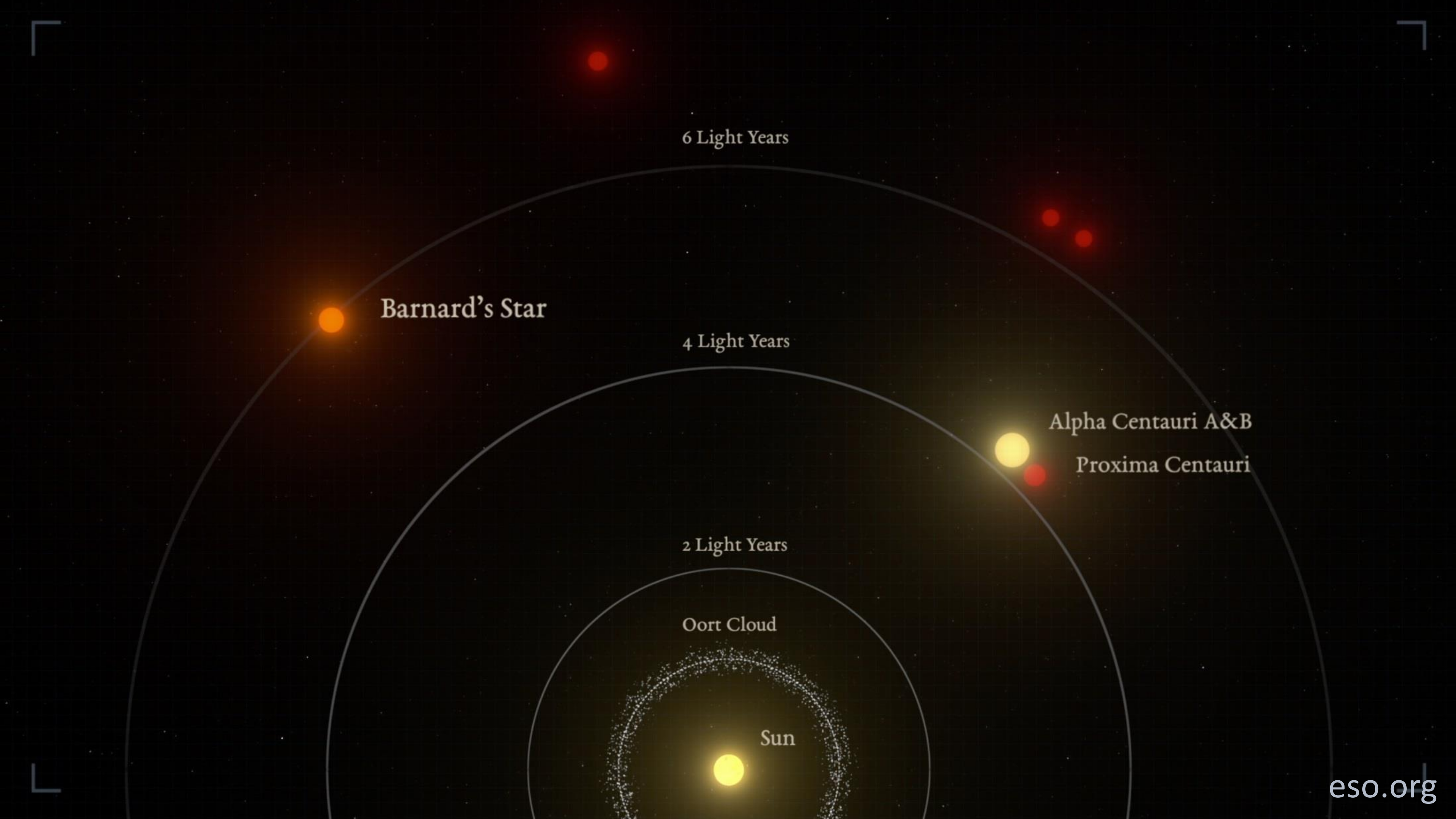
US jobs in science

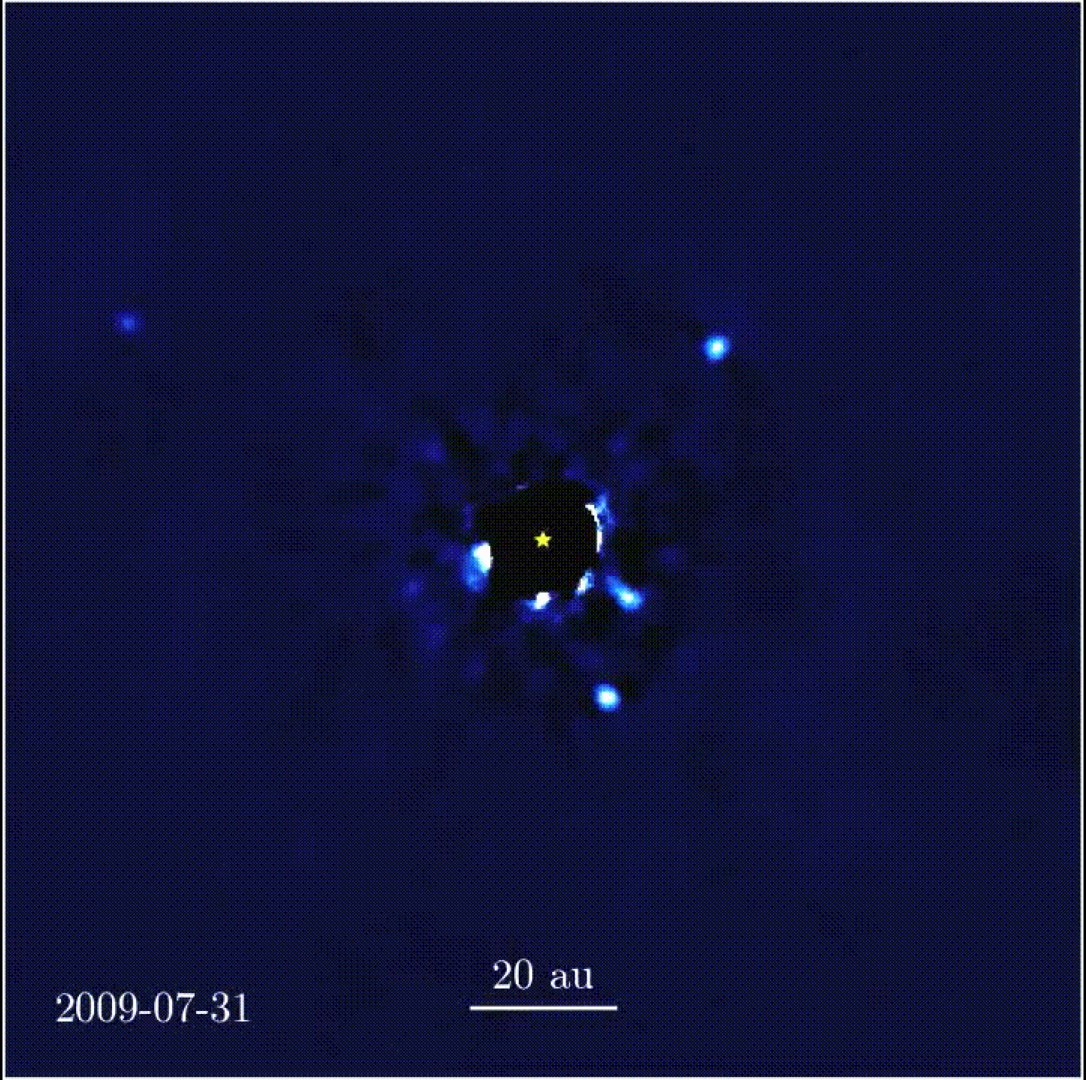

SpaceX

BREAKTHROUGH
STARSHOT

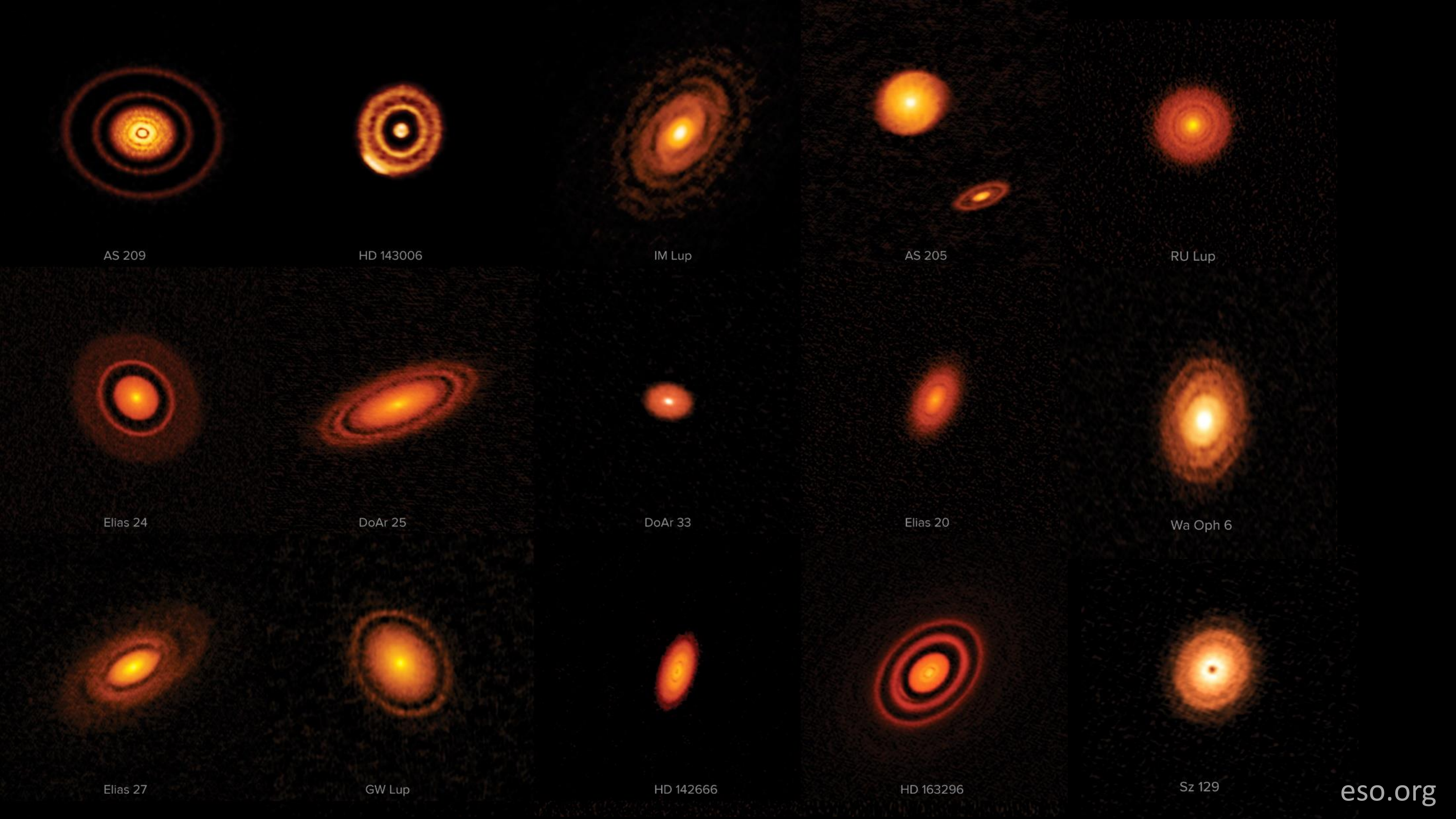


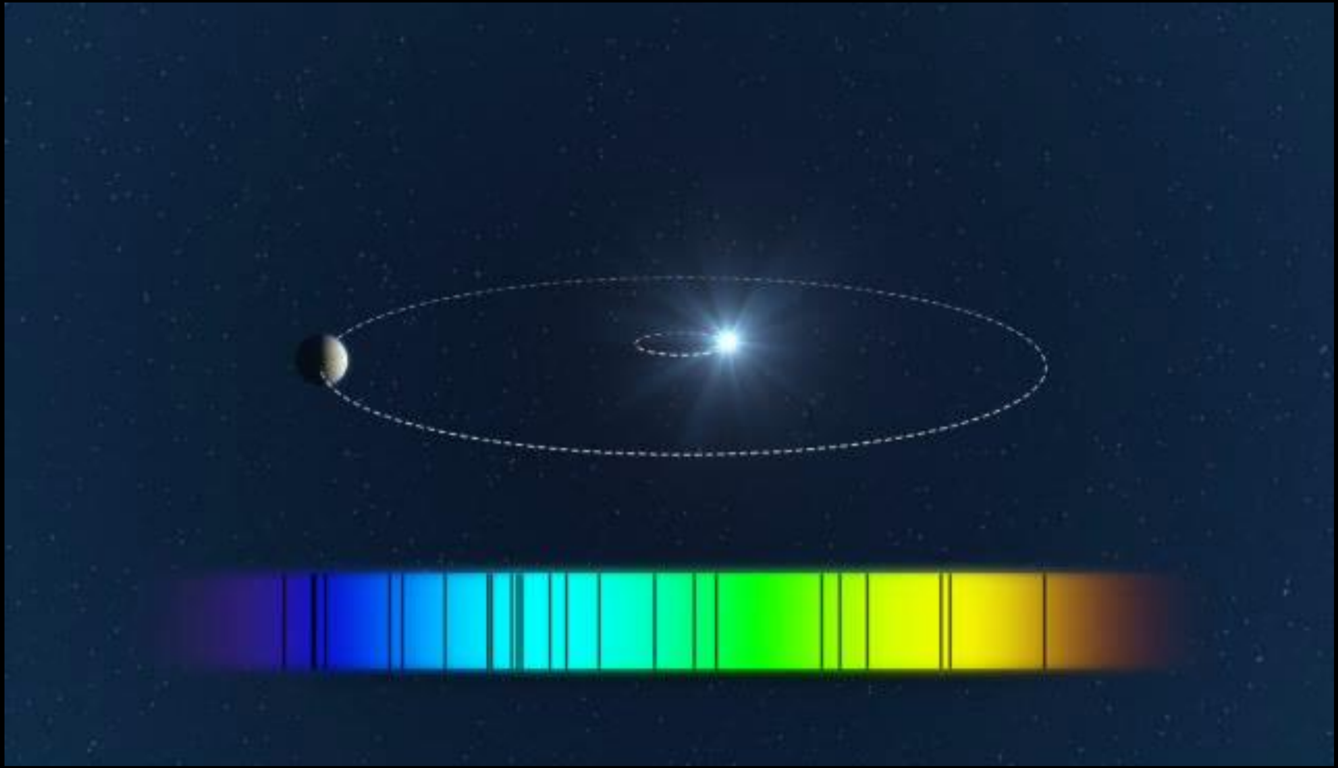

6 Light Years
Barnard's Star
4 Light Years
Alpha Centauri A&B
Proxima Centauri
2 Light Years
Oort Cloud
Sun
eso.org


eso.org

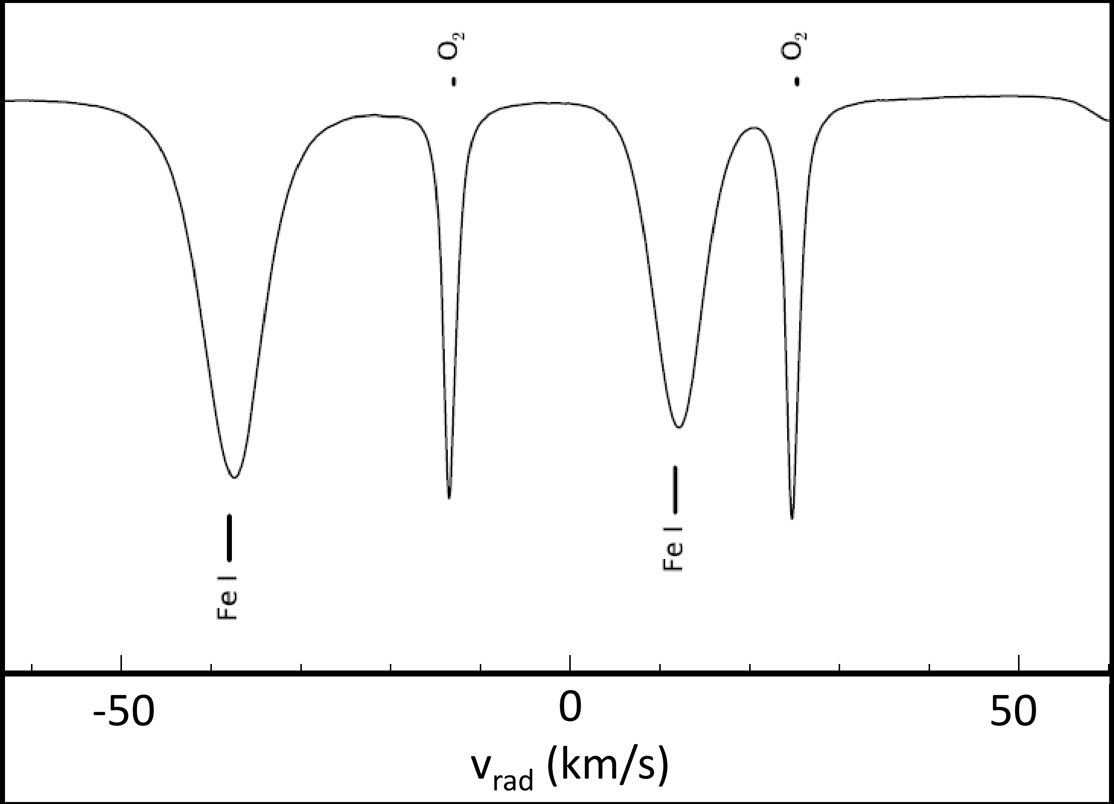


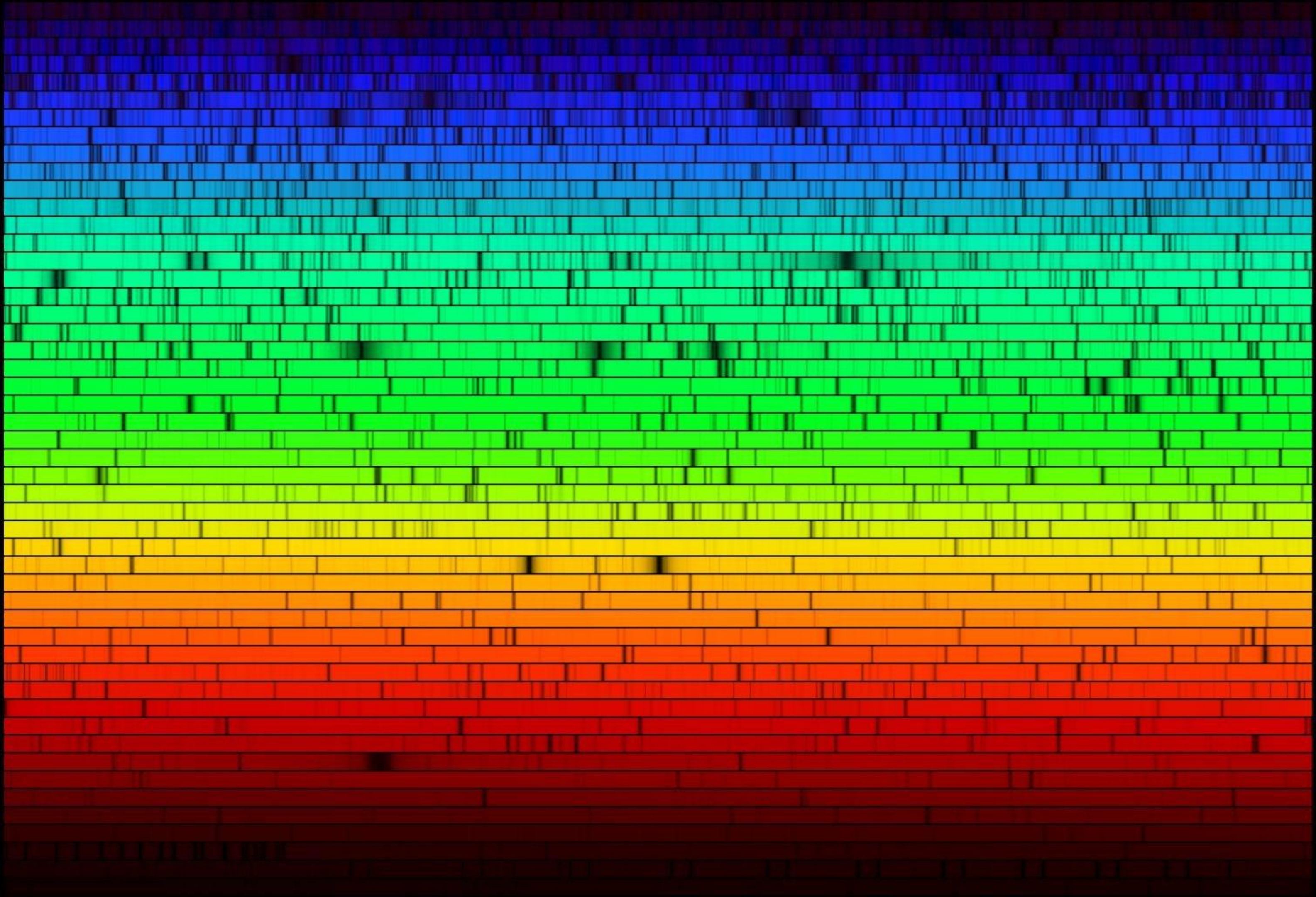
J. Wang, C. Marois

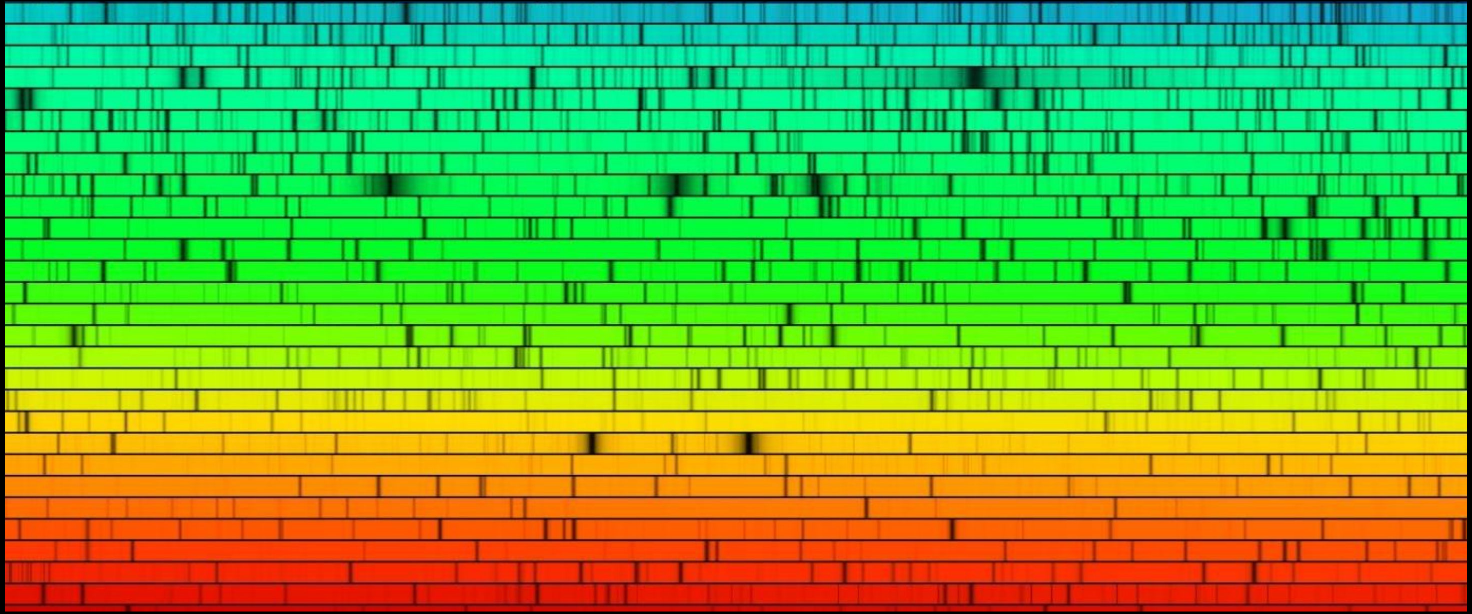

AS 209
HD 143006
IM Lup
AS 205
RU Lup
Elias 24
DoAr 25
DoAr 33
Elias 20
Wa Oph 6
Elias 27
GW Lup
HD 142666
HD 163296
Sz 129
eso.org

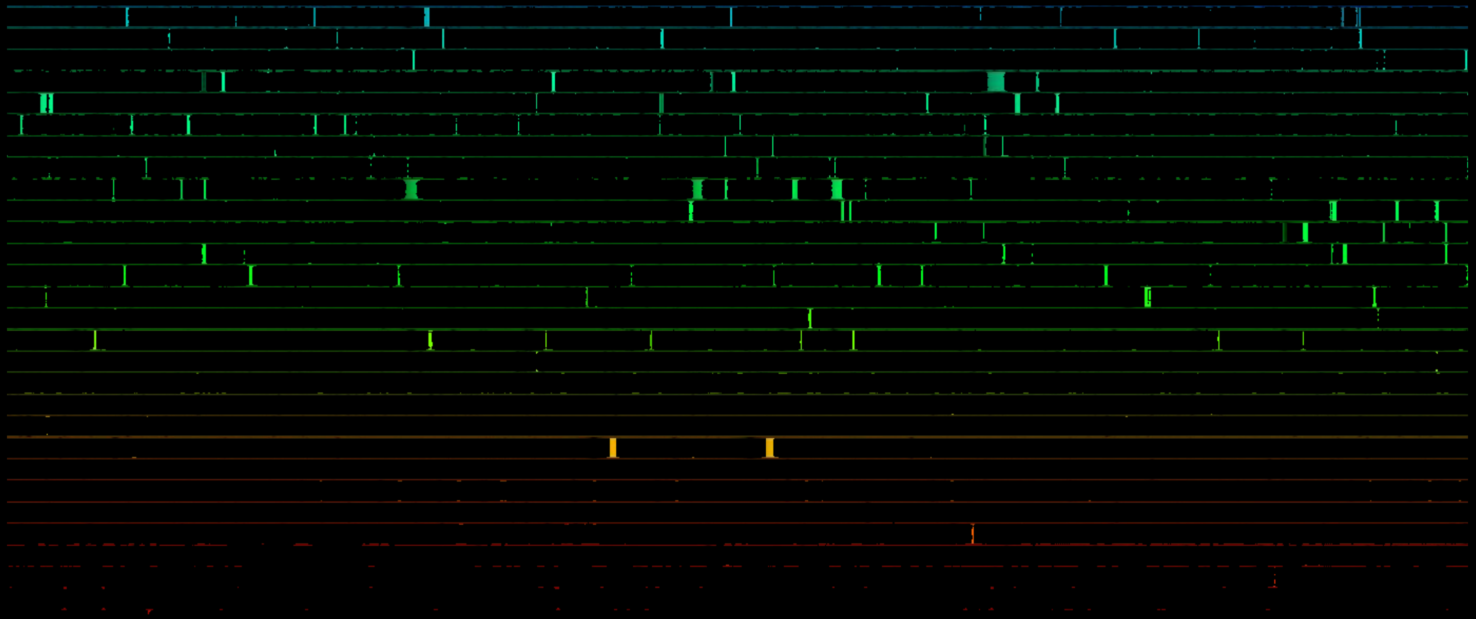


A stellar spectral line is a few km/s wide









produced by γ-ray photon–photon scattering in a hot, dense accretion disk from which some positrons escape to annihilate

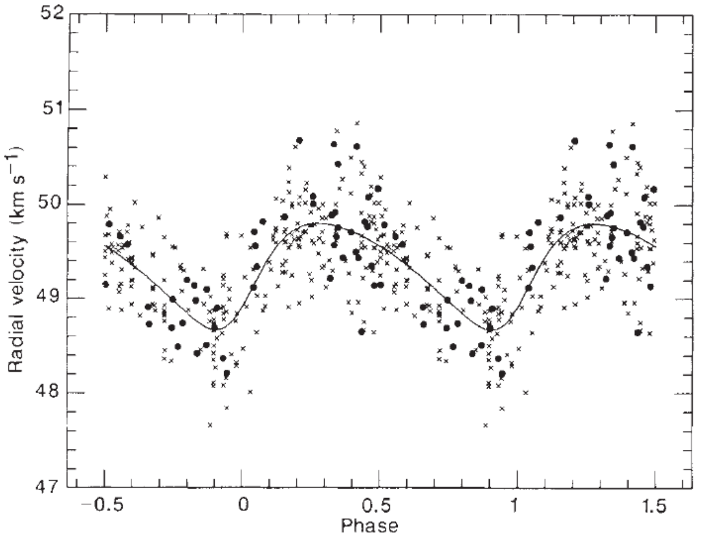


FIG. 2 The orbital solution for the combined data set. The continuous line is the orbital solution with the parameters of Table 1. The CfA velocities are denoted by crosses, the CORAVEL velocities by filled circles.

(the orbital period of GX1+4 is unknown) or from an episodic ejection of mass from the M giant, smothering the X-ray source[26]. The GRIS data are being searched for the characteristic 2-min pulsation period of such a source.

The unseen companion of HD114762: a probable brown dwarf

David W. Latham*, Tsevi Mazeh†, Robert P. Stefanik*, Michel Mayor‡ & Gilbert Burki‡

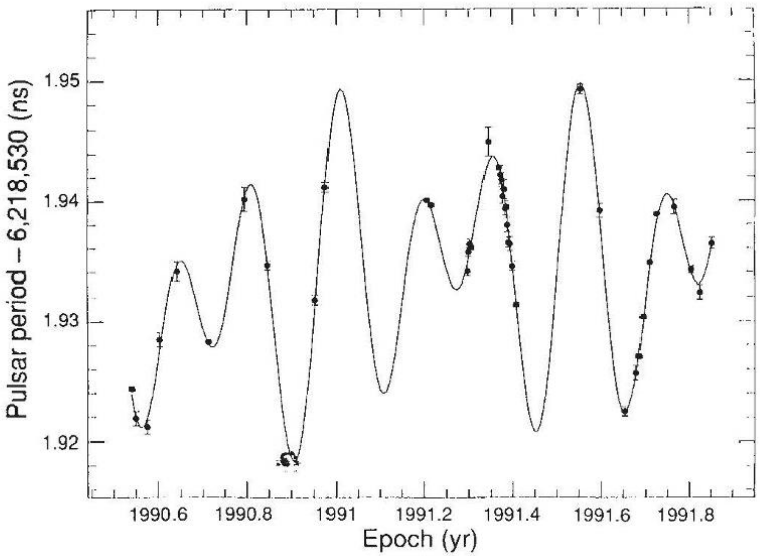
* Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, Massachusetts 02138, USA
† School of Physics and Astronomy, Raymond and Beverly Sackler Faculty of Exact Science, Tel Aviv University, Tel Aviv 69978, Israel
‡ Observatoire de Genève, Chemin des Maillettes 51, Ch-1290 Sauverny, Switzerland

BROWN dwarfs are substellar objects with too little mass to ignite hydrogen in their cores. Despite considerable effort to detect brown dwarfs astrometrically[1–4], photometrically[4–9], and spectroscopically[10–12], only a few good candidates have been discovered. Here we present spectroscopic evidence for a probable brown-dwarf companion to the solar-type star HD114762. This star undergoes periodic variations in radial velocity which we attribute to orbital motion resulting from the presence of an unseen companion. The rather short period of 84 days places the companion in an orbit similar to that of Mercury around the Sun, whereas the rather

A planetary system around the millisecond pulsar PSR1257+12

A. Wolszczan* & D. A. Frail†

* National Astronomy and Ionosphere Center, Arecibo Observatory, Arecibo, Puerto Rico 00613, USA
† National Radio Astronomy Observatory, Socorro, New Mexico 87801, USA



scope at a frequency of 430 MHz (ref. 2). The characteristics of this survey and the details of data analysis are described else-

one as a post-fit residual, implying that the pulse arrival time of PSR1257+12 are indeed affected by two independent peri odicities. Further detailed analysis has shown that th periodicities are independent of radio frequency and that othe millisecond pulsars routinely observed at Arecibo with the sam data acquisition equipment show no such effect in their timin residuals.

Millisecond pulsars are extremely stable rotators. Systemati timing observations of objects like the 1.5-ms pulsar 1937+2 (ref. 6) have not revealed any timing noise, quasiperiodic TO variations or 'glitches' at the level often found in the populatio of younger pulsars and believed to be related to neutron sta seismology[7]. The frequency independence of the amplitude o

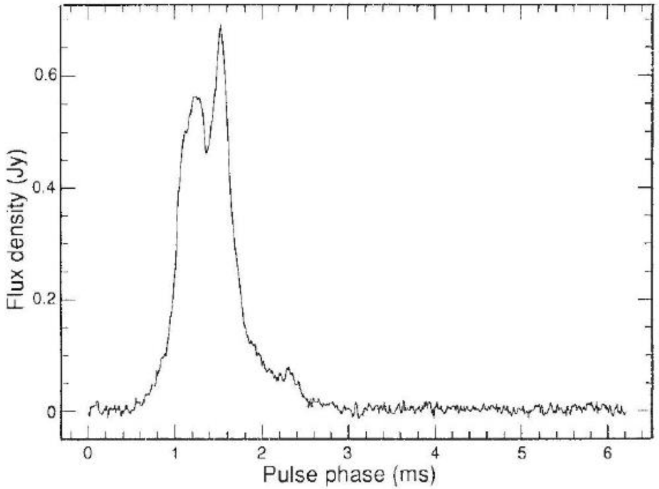
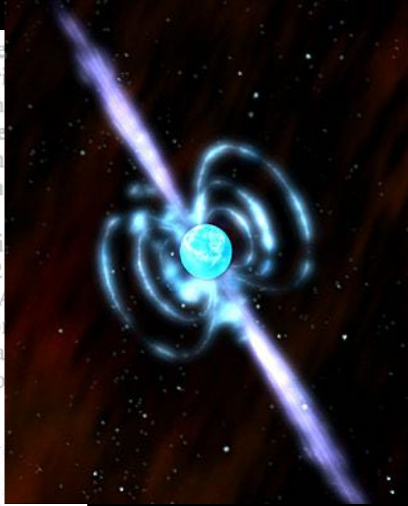
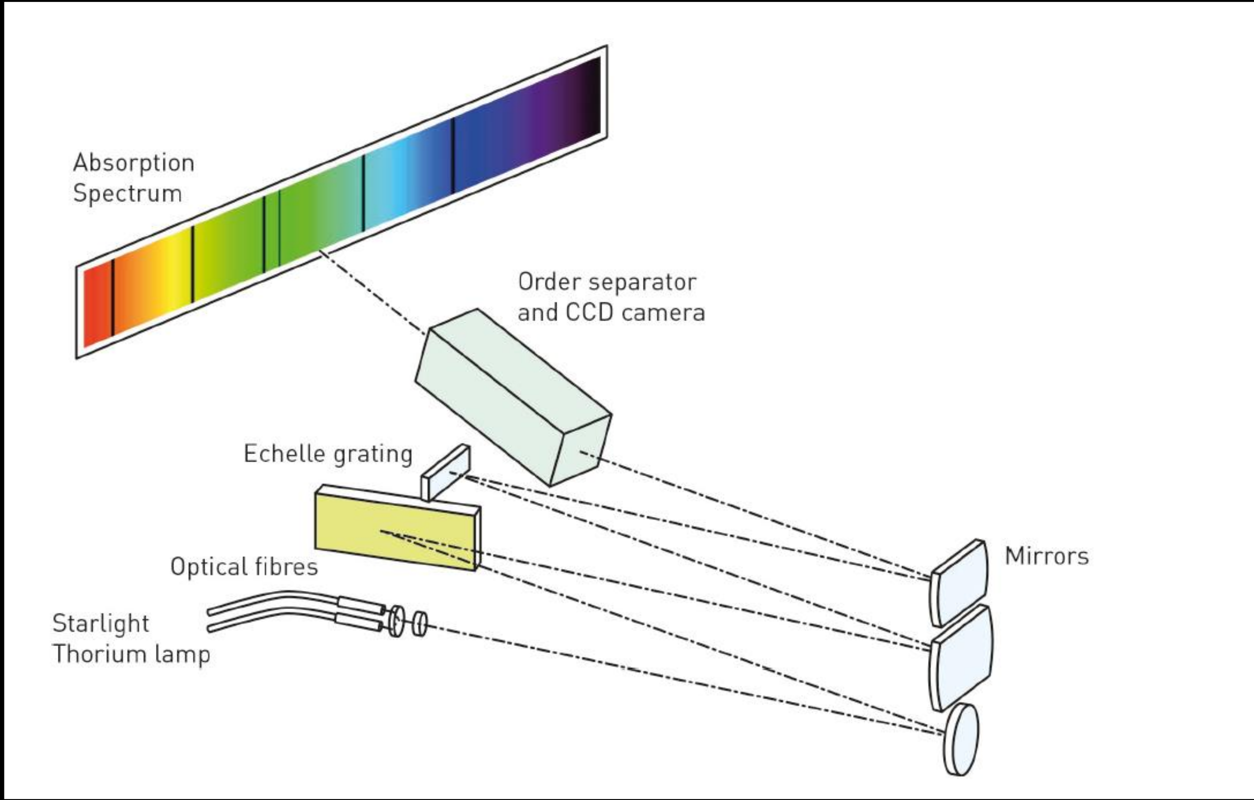


FIG. 1. The average pulse profile of PSR1257+12 at 430 MHz. The effective time resolution is ~12 µs.





adapted from Baranne et al., 1996

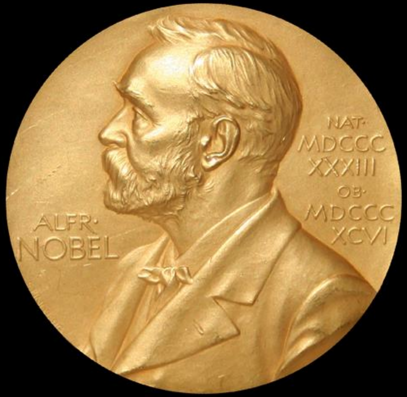
A Jupiter-mass companion to a solar-type star

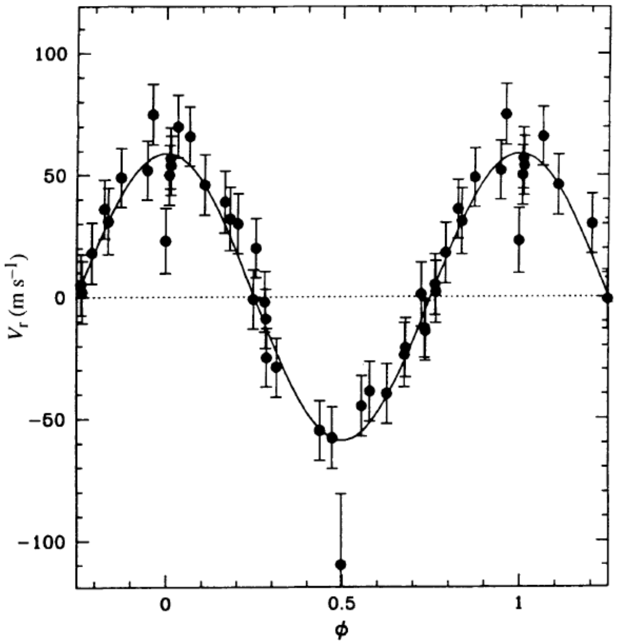
Michel Mayor & Didier Queloz

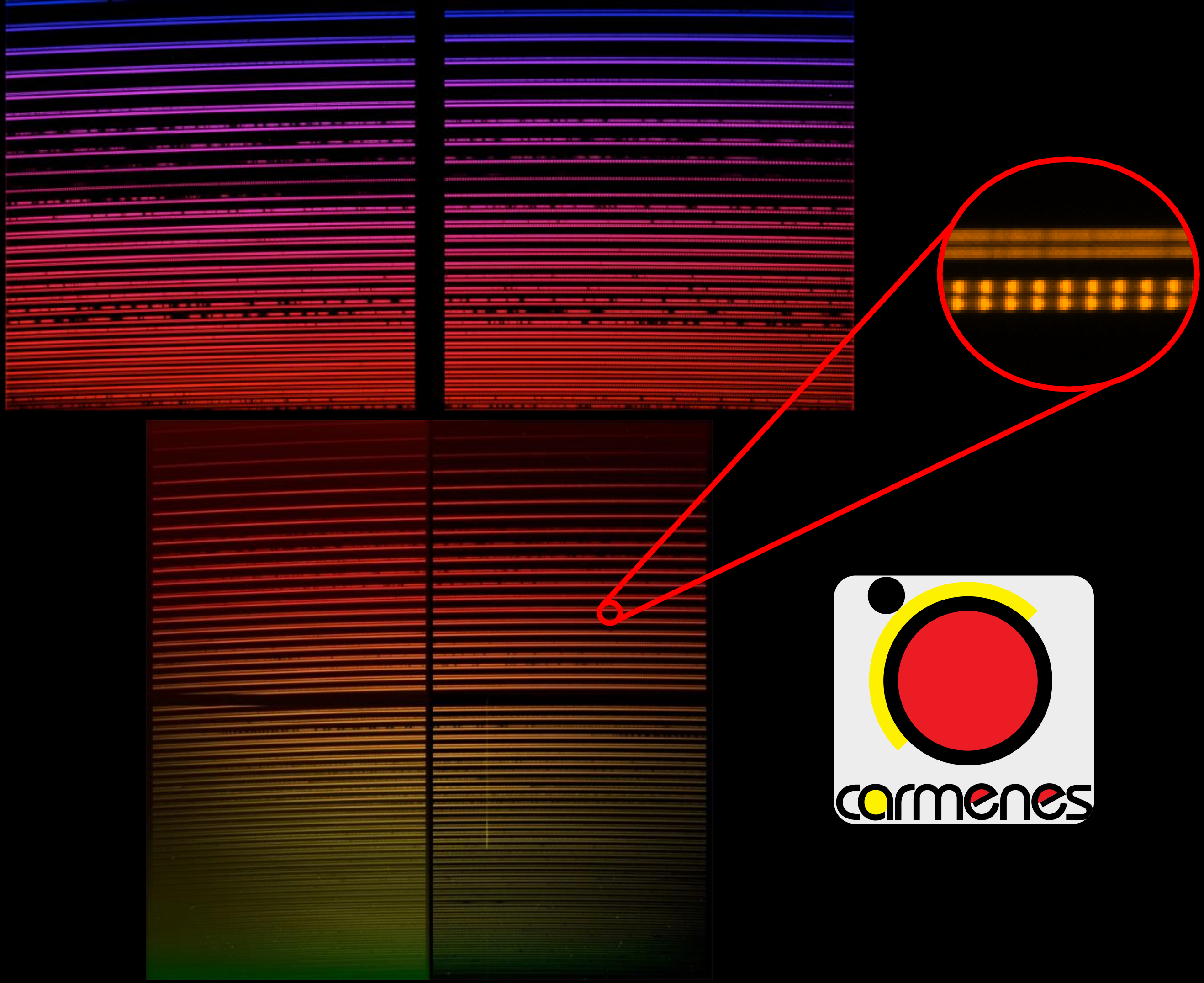
Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

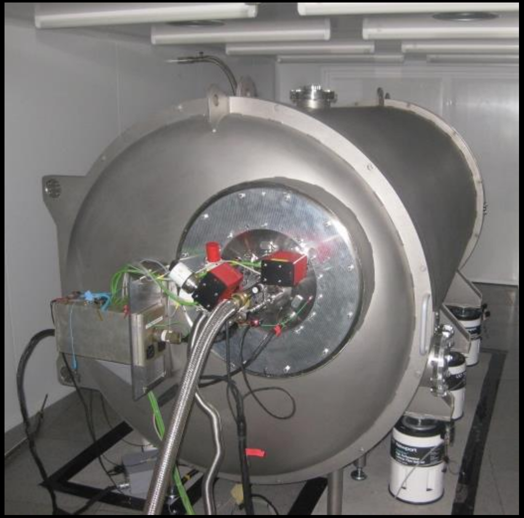
The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might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

NATURE · VOL 378 · 23 NOVEMBER 1995

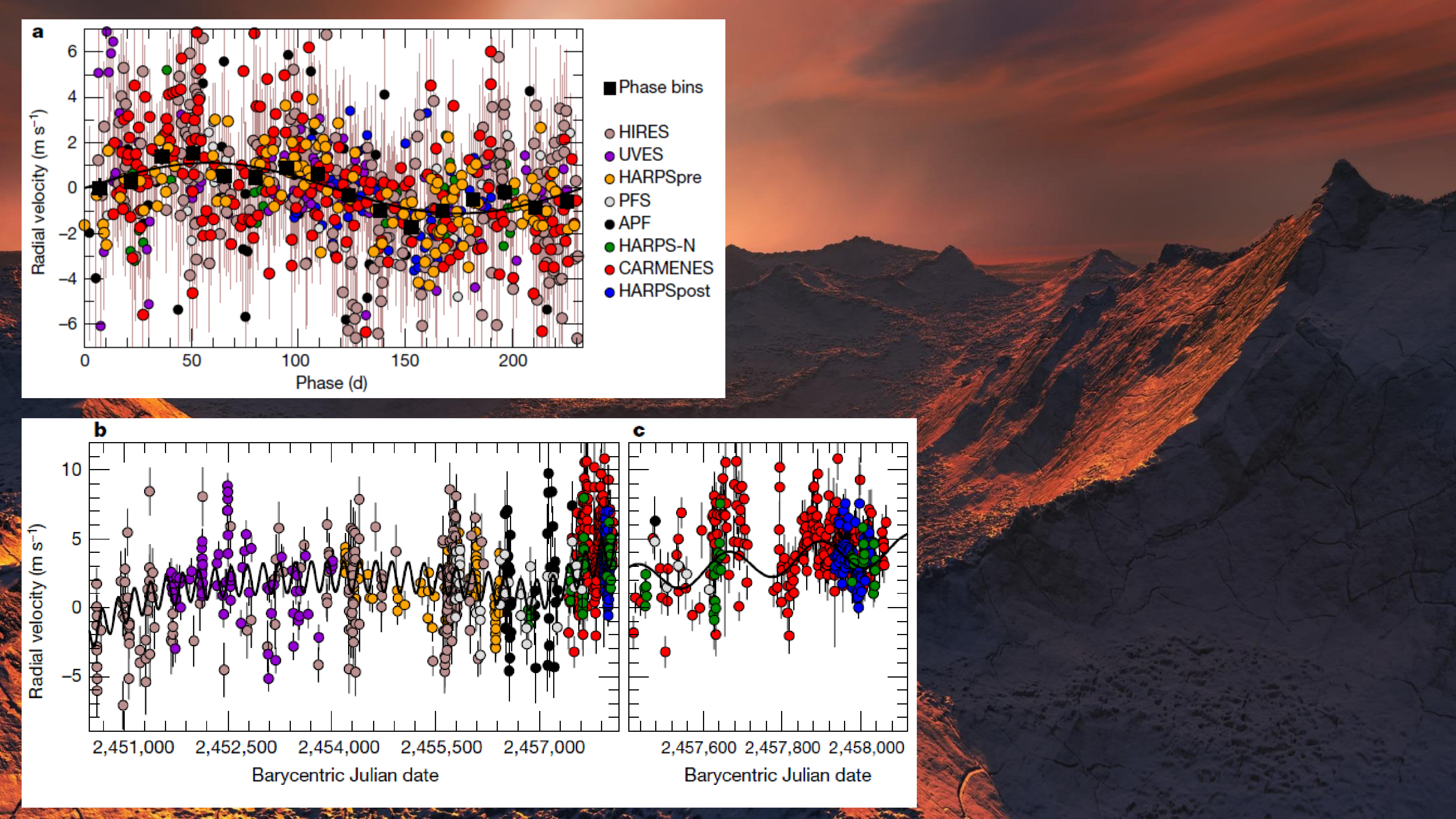




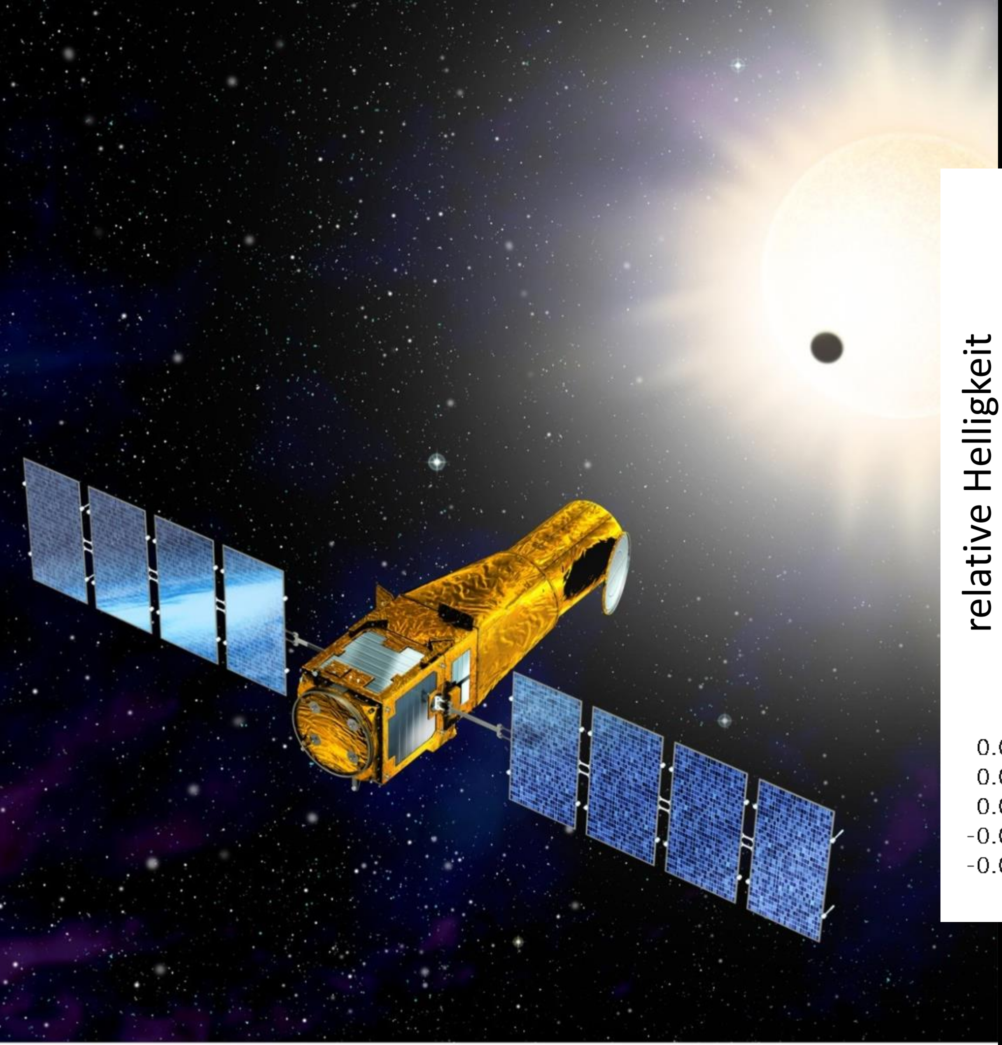




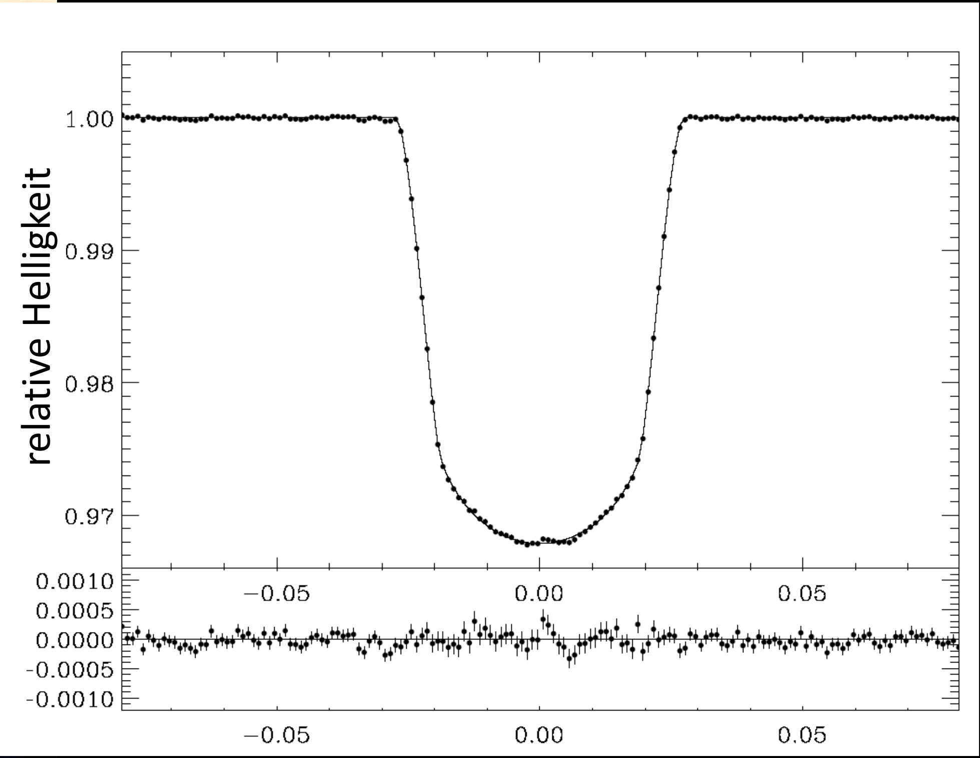
carmenes


a
Radial velocity (m s⁻¹)
Phase (d)
Phase bins
HIRES
UVES
HARPSpre
PFS
APF
HARPS-N
CARMENES
HARPSpost
b
Radial velocity (m s⁻¹)
2,451,000
2,452,500
2,454,000
2,455,500
2,457,000
Barycentric Julian date
c
2,457,600
2,457,800
2,458,000
Barycentric Julian date

Blue Planets
around
Red Stars

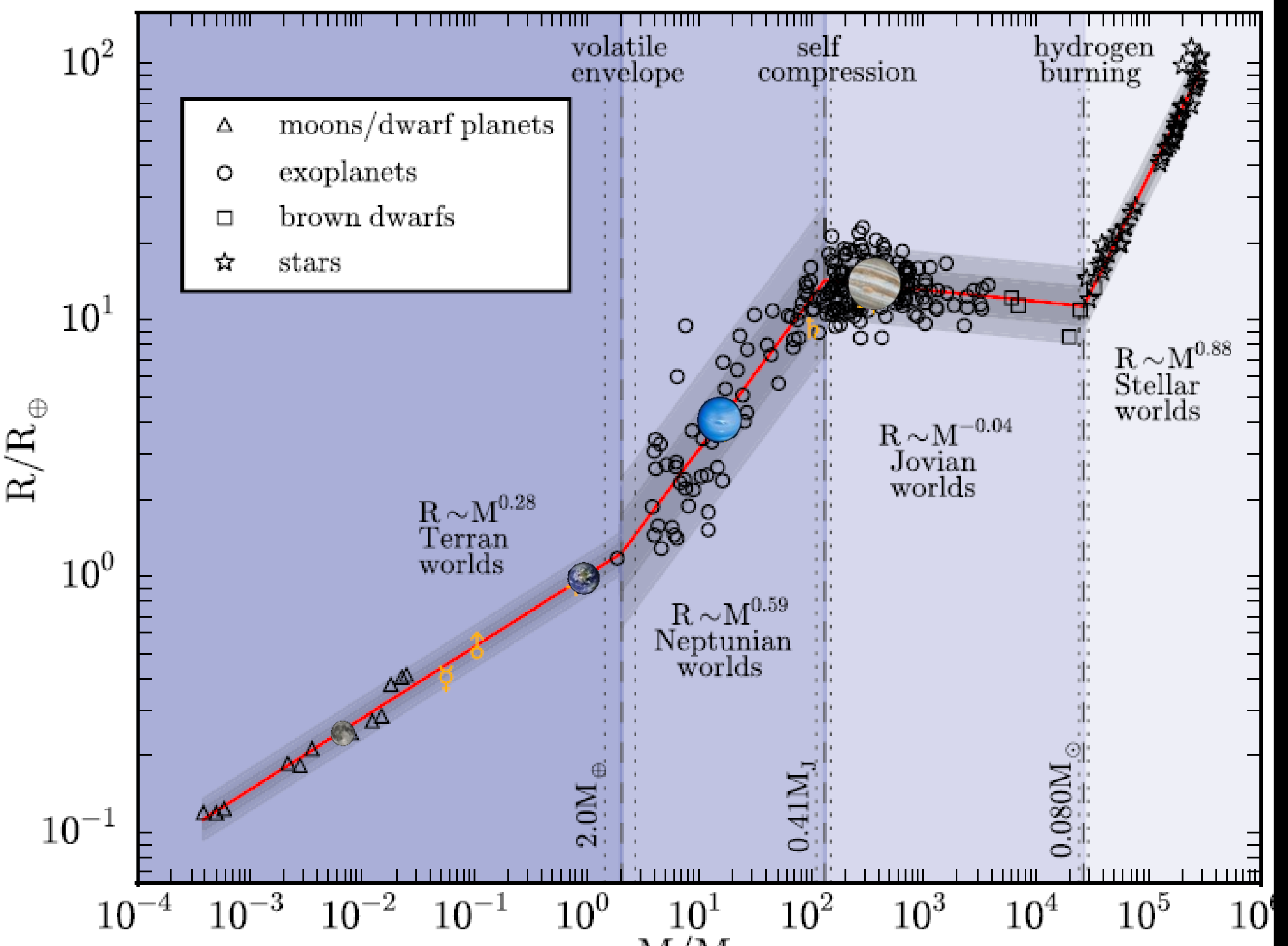


CNES - Mai 2004/Illus. D. Ducros

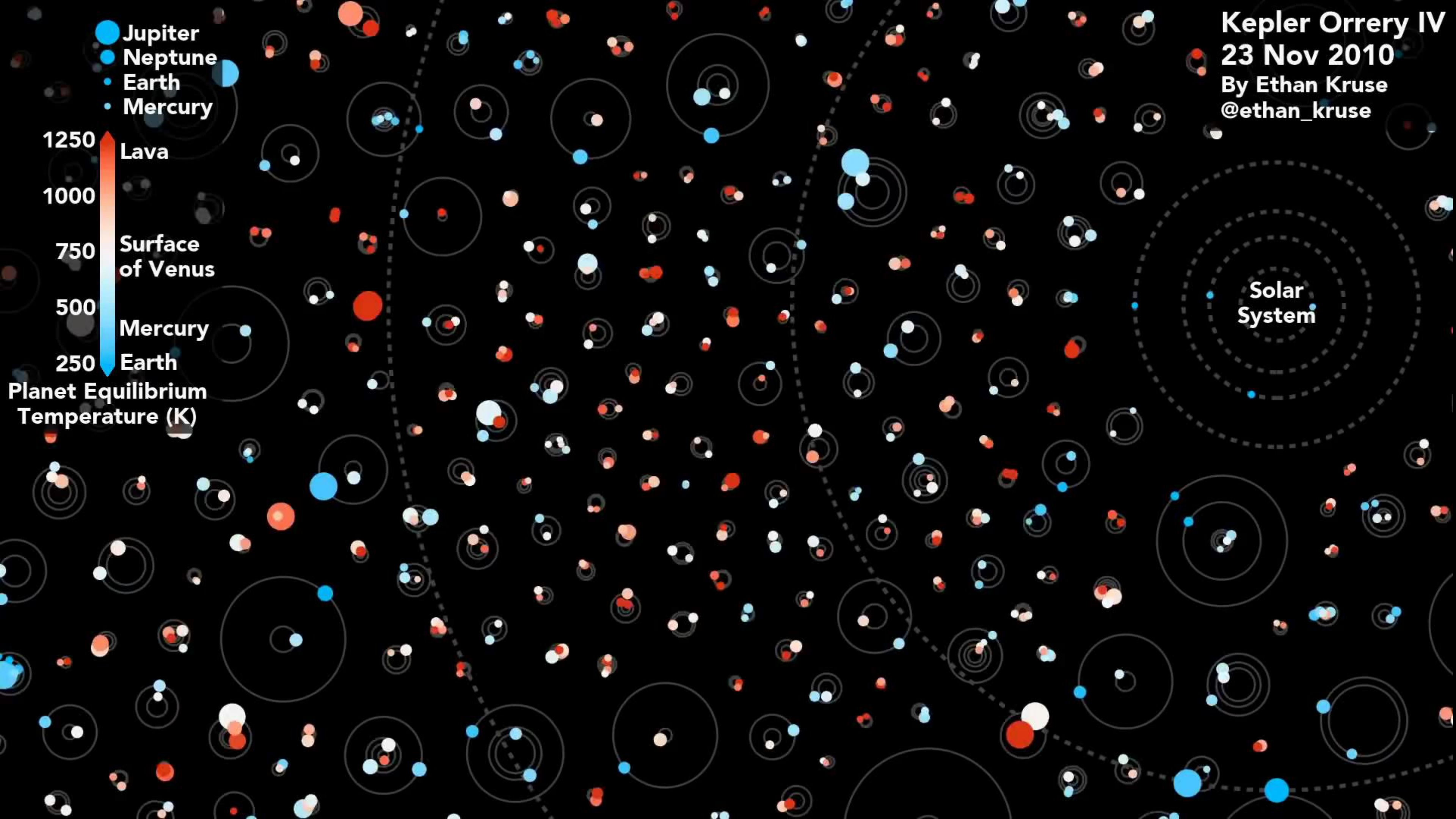


Alonso et al., 2008

With mass and radius known, we begin to understand the physics

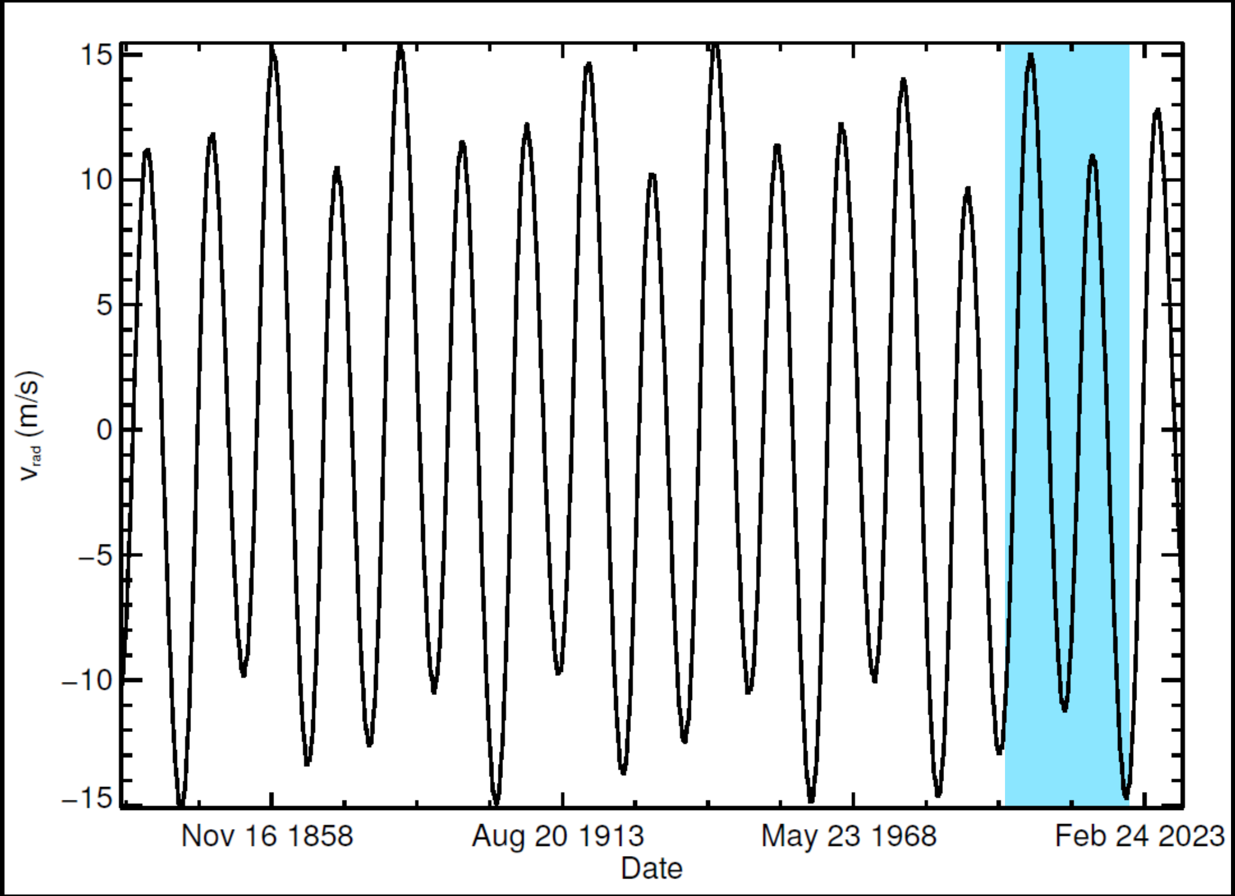


adapted from Chen & Kipping, 2017



Kepler Orrery IV
23 Nov 2010
By Ethan Kruse
@ethan_kruse
Jupiter
Neptune
Earth
Mercury
1250
1000
750
500
250
Lava
Surface of Venus
Mercury
Earth
Planet Equilibrium Temperature (K)
Solar System

The solar system is a challenging one

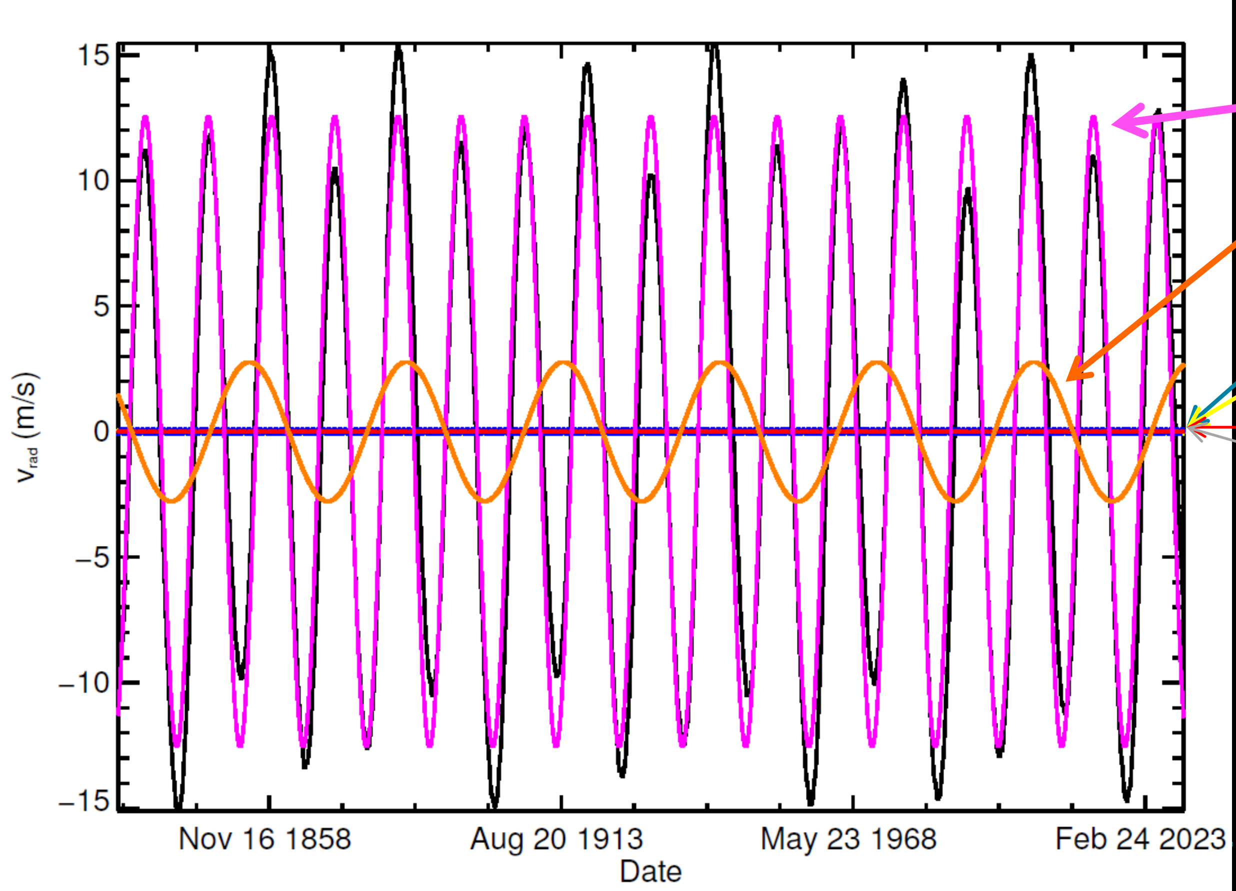


Velocities of the Sun relative to Solar System barycenter

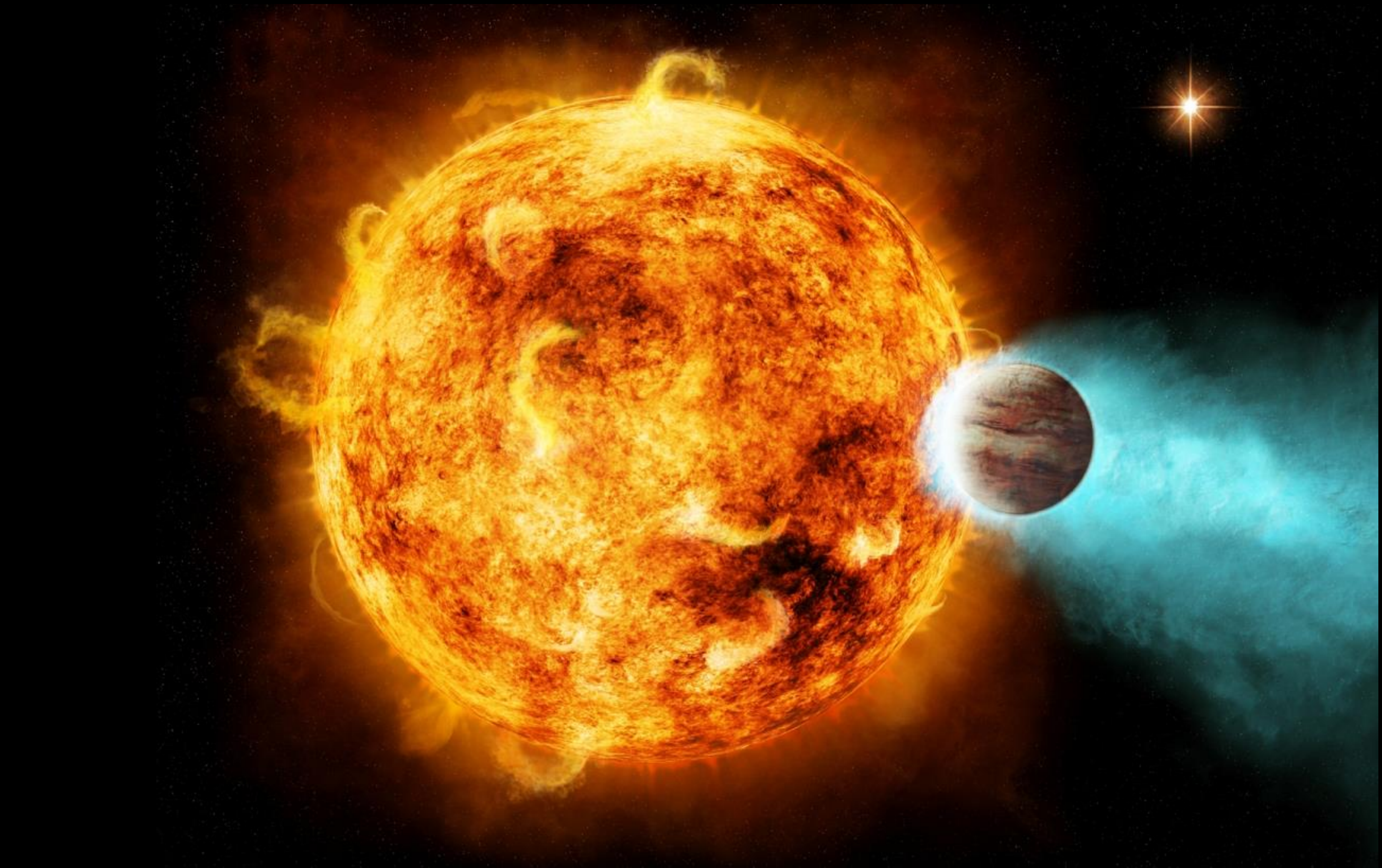
data from JPL/Horizons

„planet hunting epoch"

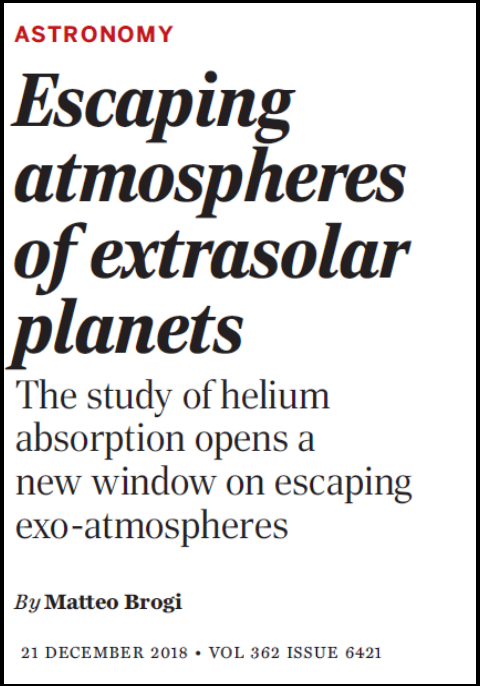
The solar system is a challenging one



Jupiter	12 m/s
Saturn	2.5 m/s
Earth	9 cm/s
Venus	8.5 cm/s
Mars	8 mm/s
Mercury	8 mm/s



Molecules in planetary atmospheres

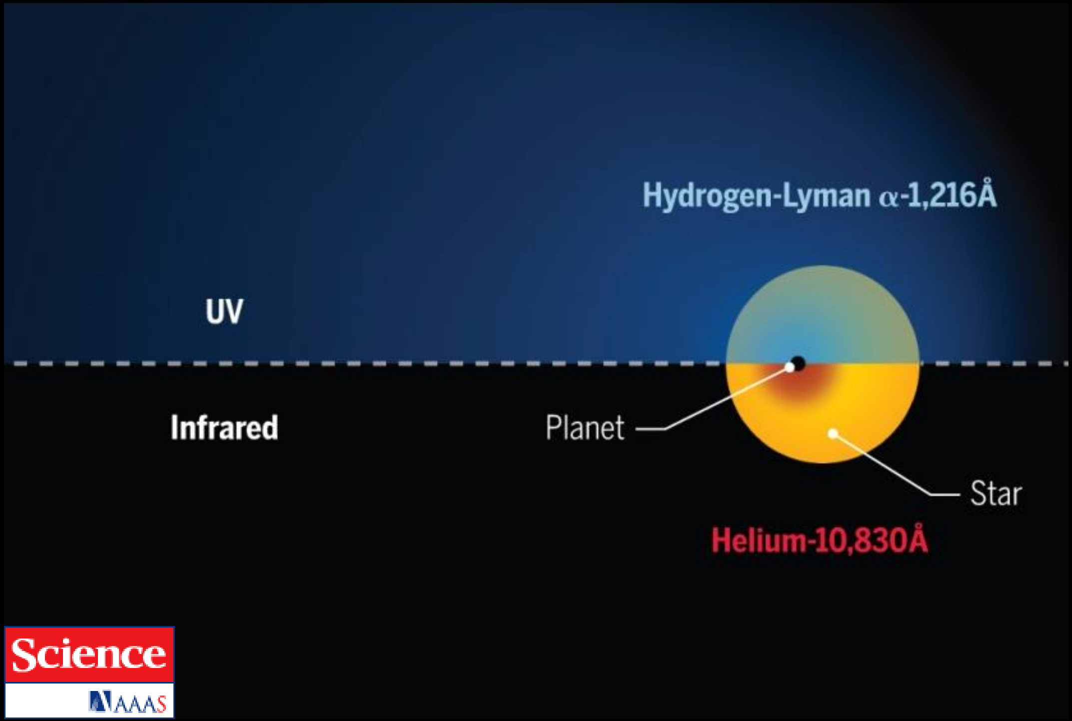

ASTRONOMY

Escaping atmospheres of extrasolar planets

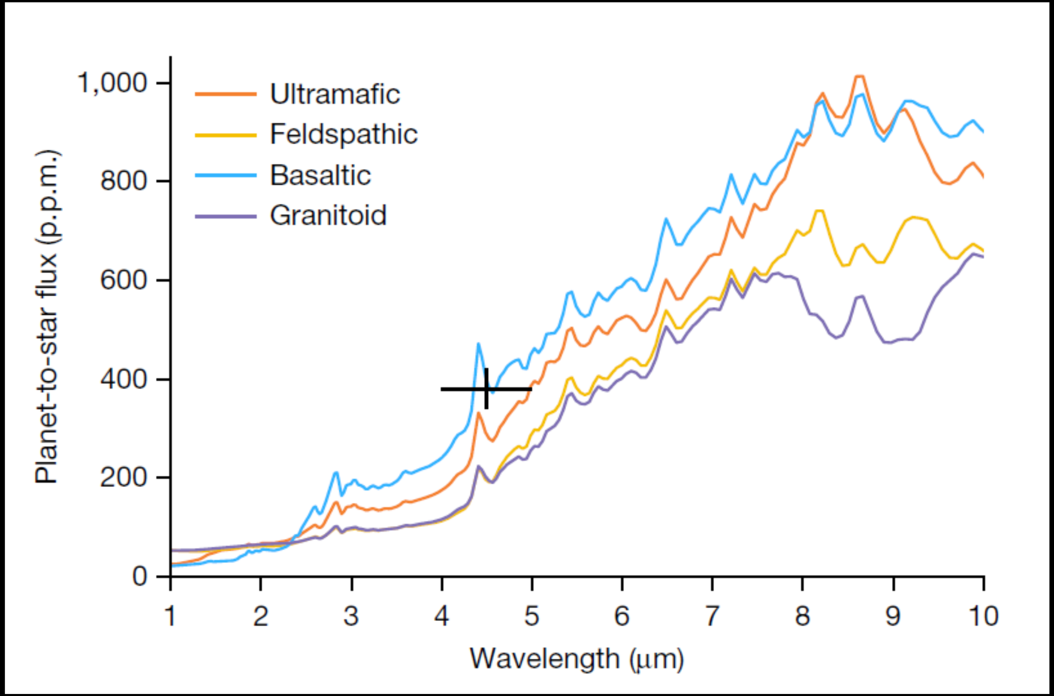
The study of helium absorption opens a new window on escaping exo-atmospheres

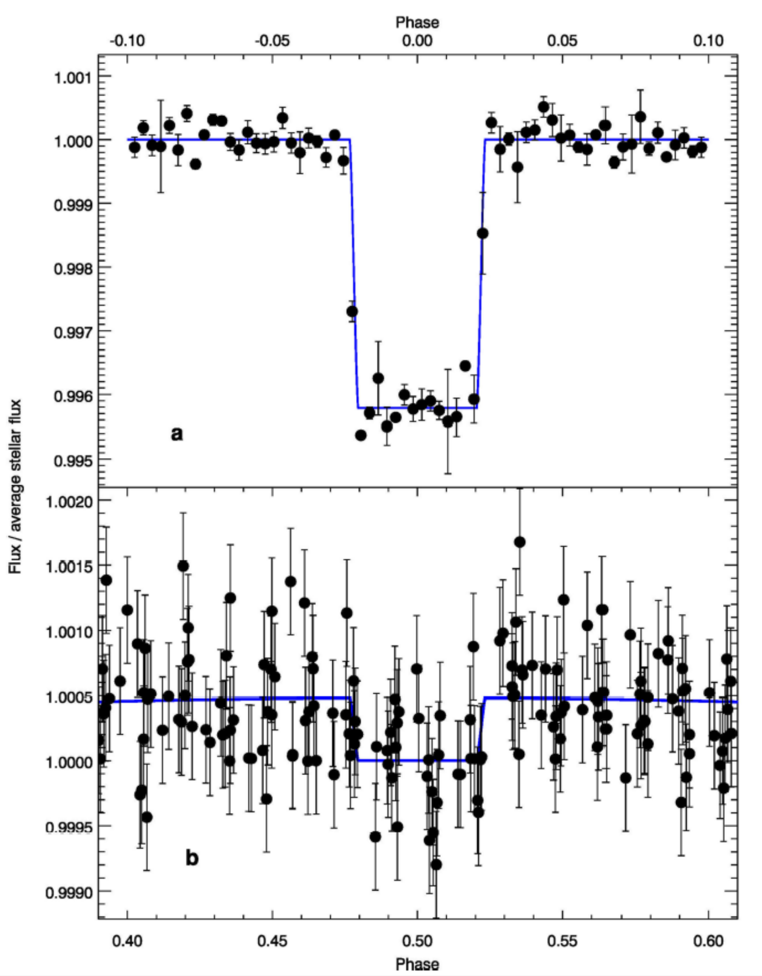
By **Matteo Brogi**

21 DECEMBER 2018 • VOL 362 ISSUE 6421



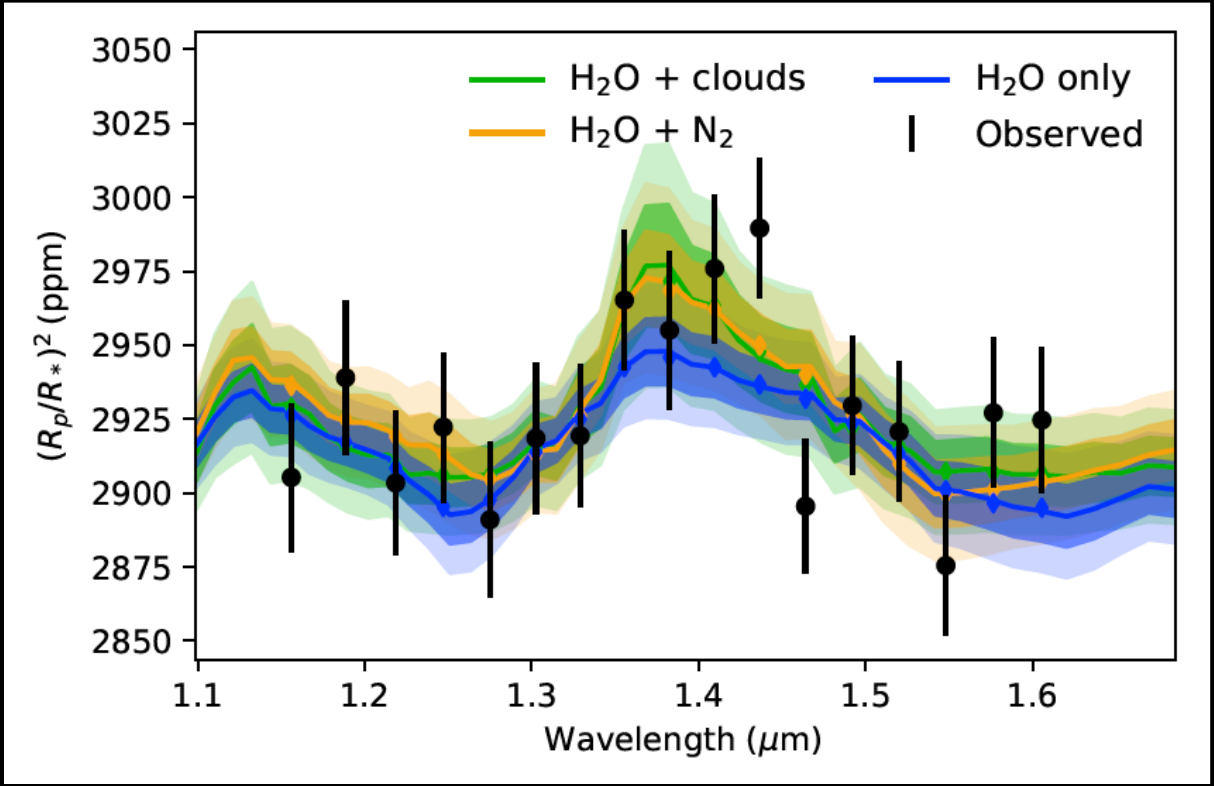
Super-Earth transit spectroscopy
(no thick clouds)





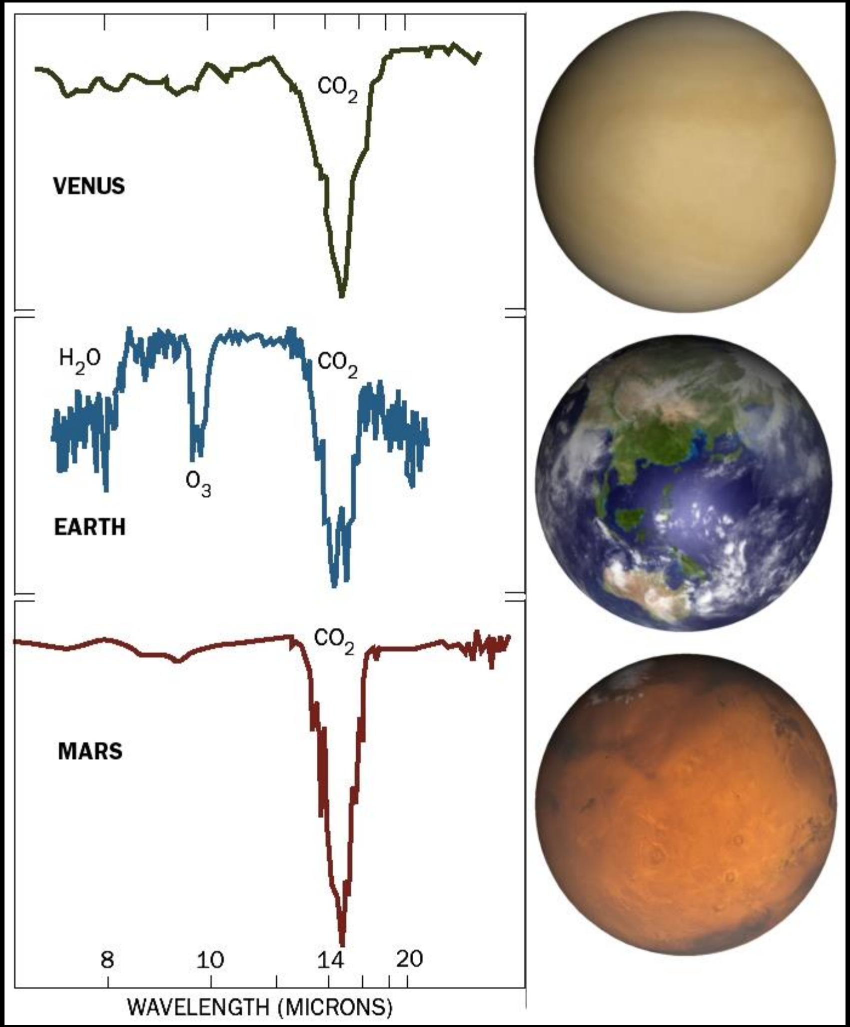
Kreidberg, et al. (2019)

Water in Super-Earth atmosphere



Tsiaras, et al. (2019)

Fingerprint of life?



Our place in the universe

1. **Begin to see local universe planet population**
2. **Many stars and planets very different from solar system**
3. **So far, no Earth 2.0 – but many surprises**