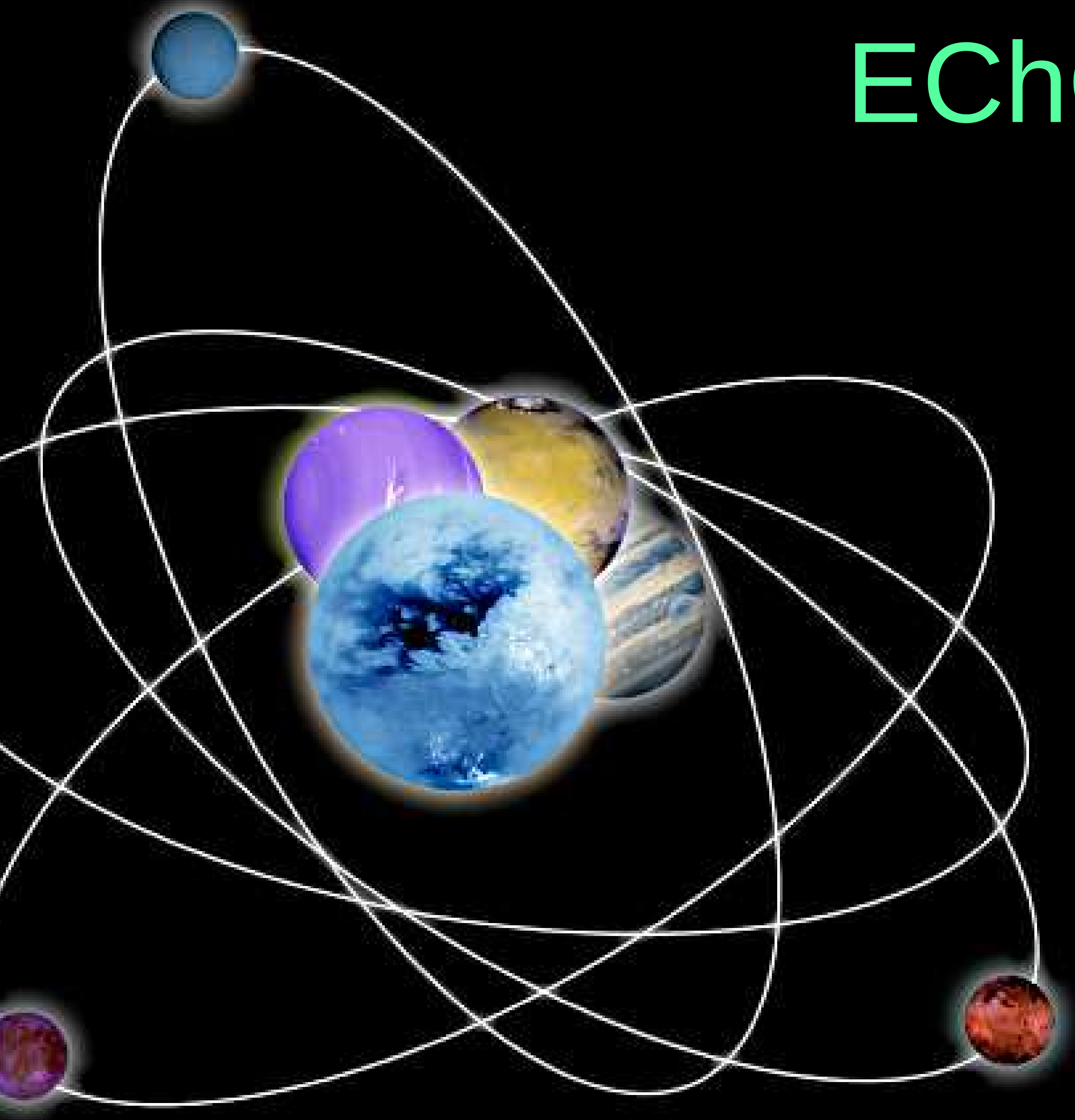
from gas giants to super-Earths

EChO



M. R. Zapatero Osorio (CAB, CSIC-

I. Ribas (ICE)

E. Pallé (IAC)

and the EChO Team

Outline

EChO = Exoplanet Characterization Obs

Scientific objectives

Summary of current knowledge on "exop

Current status of EChO

from gas giants to super-Earths

cientific objectives (all related to giants, Neptune-like and hot super-Earth lanets):

tmospheric composition, temperature, albedo
tmospheric structure (thermochemical equilibrium, photochemistry, dynamics)
lanet-star interaction
nternal structure
lanet formation
xomoons
otential biosignatures

for a launch in 2022

Launch in 2022 following the launch of the first L mission of the Cosmic Vision program. Launch could be brought forward to 2020 if the L mission slip in time.

The M-mission should address the science goals and questions of the Cosmic Vision plan.

The total ceiling cost covered by ESA is 470 M€, which includes the spacecraft, launch services, and mission and science operations.

Payload must be covered by the ESA member states.

The M- (or smaller) mission has to address original and self-standing scientific goals and should not limit itself to technology demonstration, i.e., it must rely on available technology that will be at TRL5 by the end of the Definition Phase prior to the mission being adopted for Implementation.

Deadline for proposal submission: 2010 December 3. Resolution: Jan 2011.

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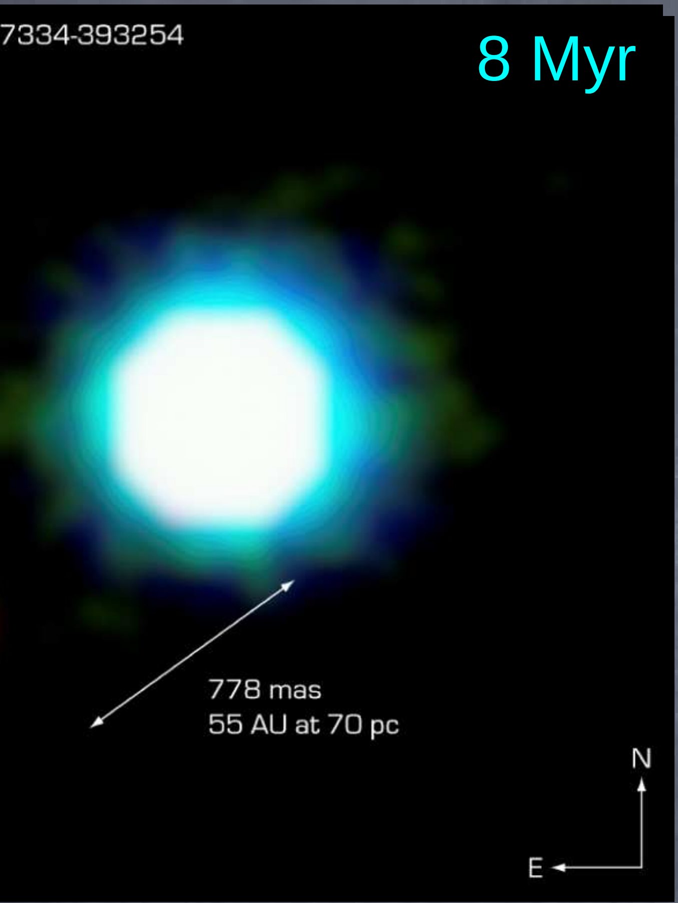
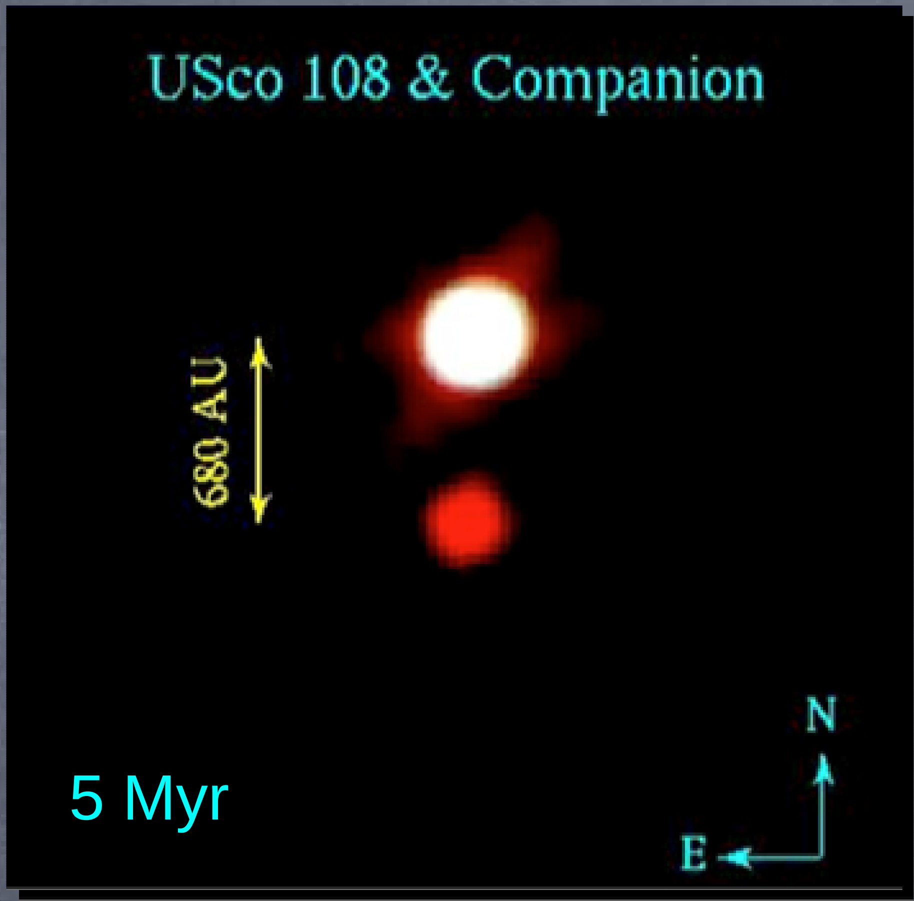


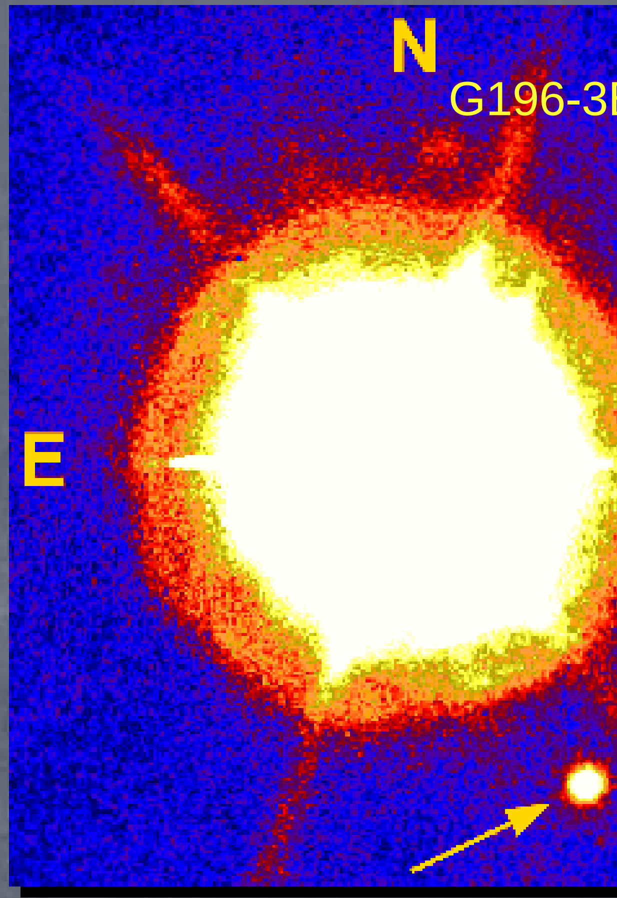
t (5 M_{jup}) around a brown
f (25 M_{jup}) in the TW Hya
ociation (Chauvin et al.
2004).

USCO 108

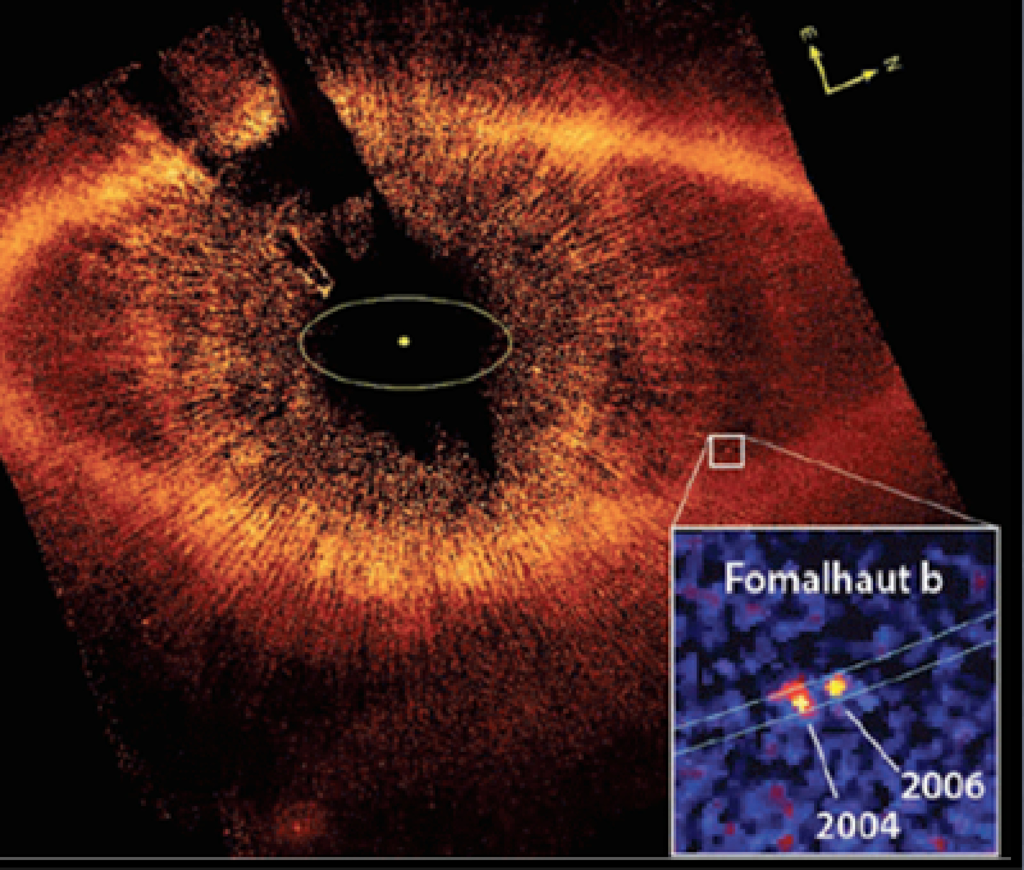


Planet (13 M_{jup}) around a brown dwarf (50 M_{jup}) in the Upper Sco association (Béjar, Zapatero Osorio, et al. 2008).

G 196-3B



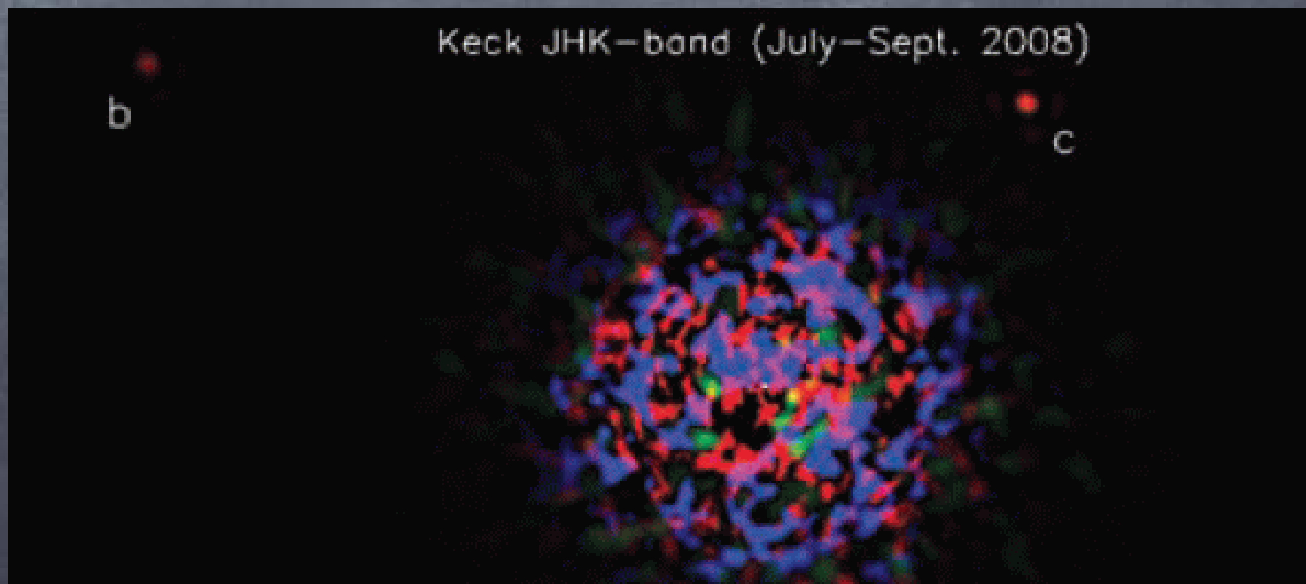
Brown dwarf (10-25 M_{jup}
a low-mass star (0.4 M_{s}
field, orbital separation
AU (Rebolo, Zapatero O
al. 1998).

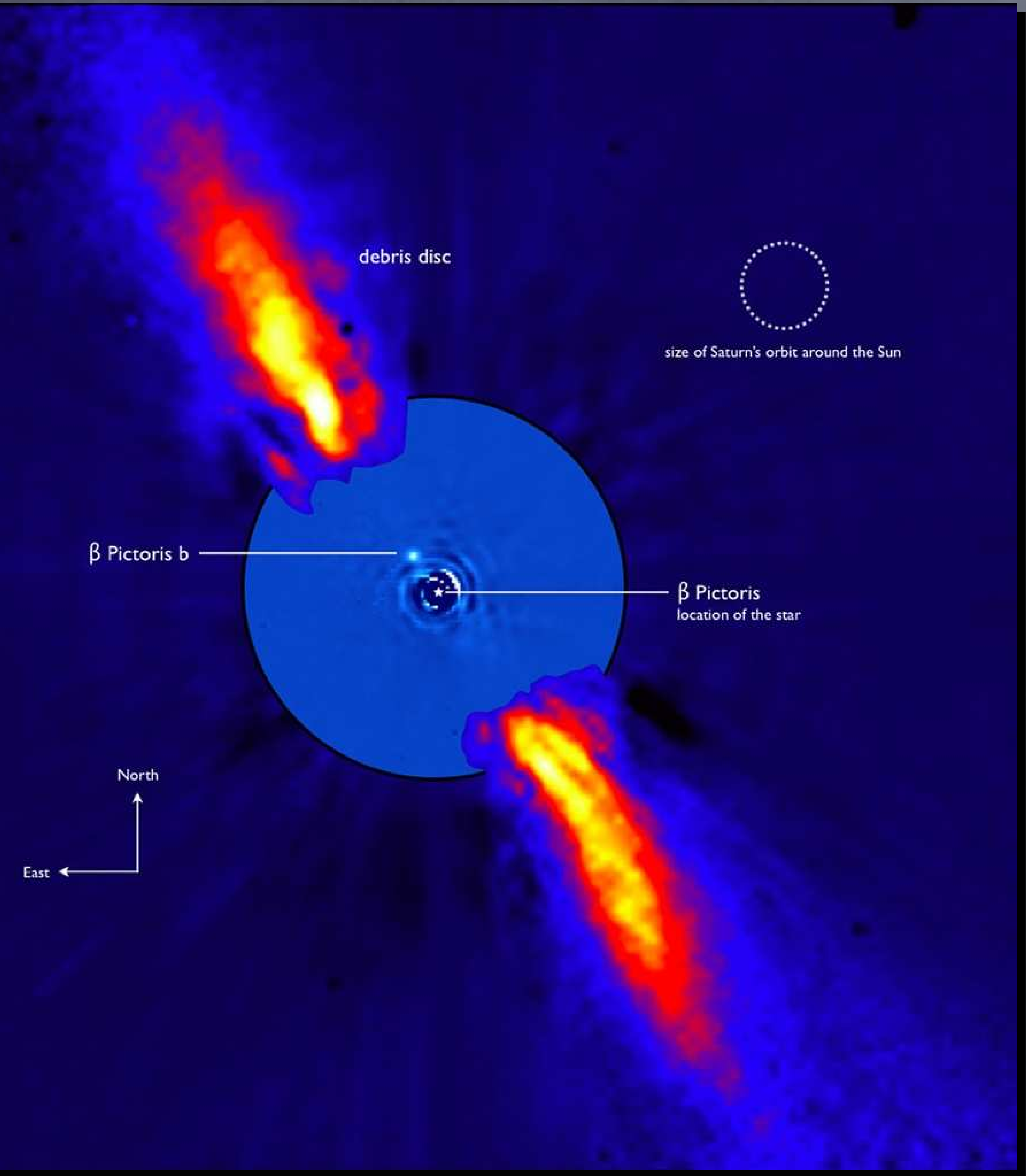


A planet (Fomalhaut b) orbiting at 115 AU from
A3V-type star Fomalhaut, which has an age of 10
Myr. The orbital motion of the planet was detected
comparing the 2004 and 2006 epochs shown in
inset (Kalas et al. 2008). The estimated mass o
planet is below 10 M_{jup}.

The debris disk of the star is seen through the sca
light in visible wavelengths.

ee planets (HR 8799 b,c,d) around the
M_{sol} star HR 8799, which has an age of
-160 Myr in counter clockwise orbits
(Marois et al. 2008):
b = 7 M_{jup}, 68 AU
c = 10 M_{jup}, 38 AU

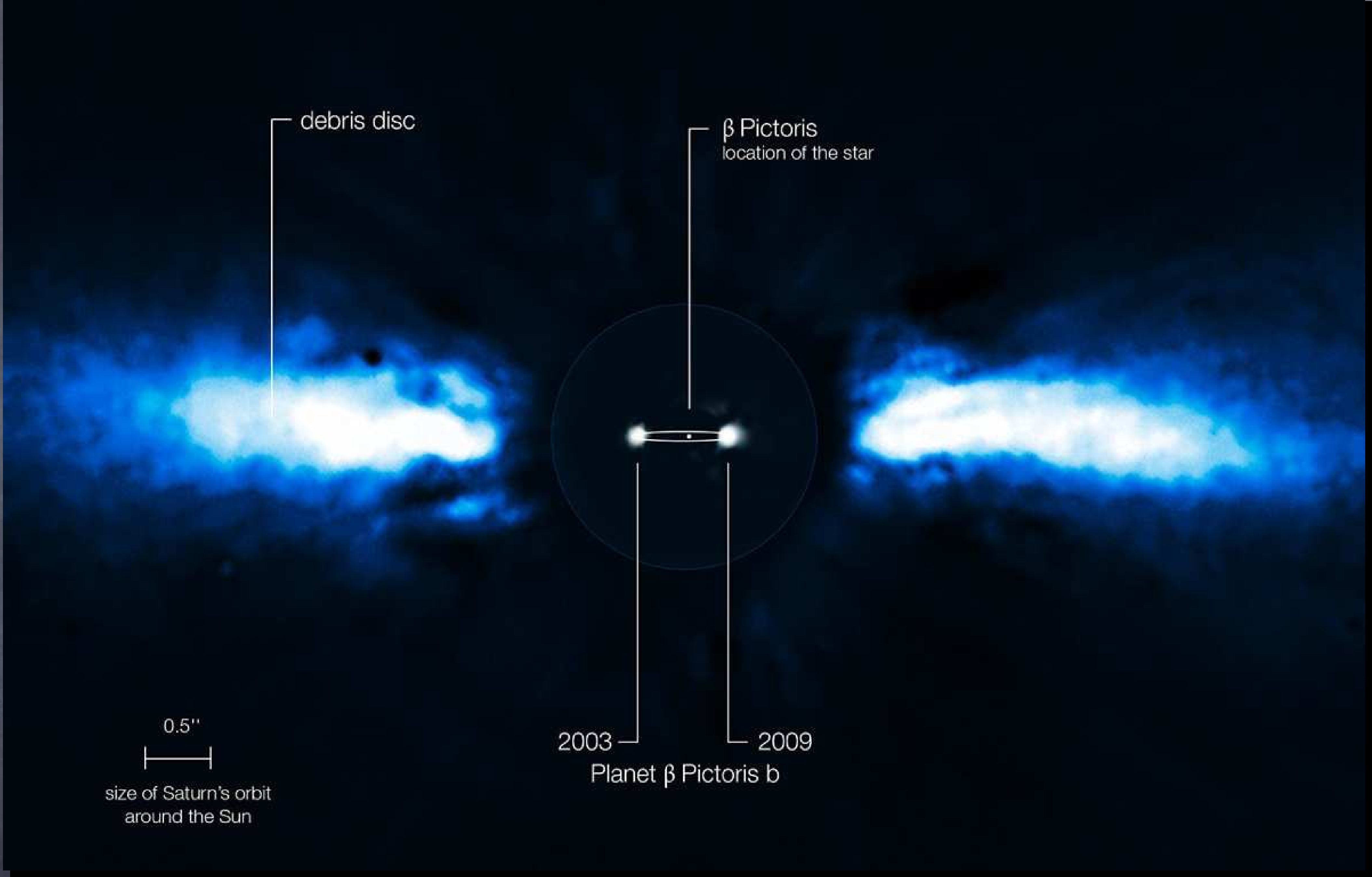




Planet ß Pictoris b orbiting the 1.75-M
ß Pictoris, which has an age of 12 M
one of the largest debris disks ever
(1100 AU).

The planet has an estimated mass o
M_{jup} and it is located at about 10 AU
parent star.

The young age of this planetary syst
Myr) proves that giant gas planets ca
in a few Myr.



nce discovery, ß Pictoris b was reobserved twice in the last few years. The planet has moved fro
e side of the star in 2003 to the other side in 2009 (Lagrange et al. 2010), suggesting that ß Picto

QuickTime™ and a
GIF decompressor
are needed to see this picture.

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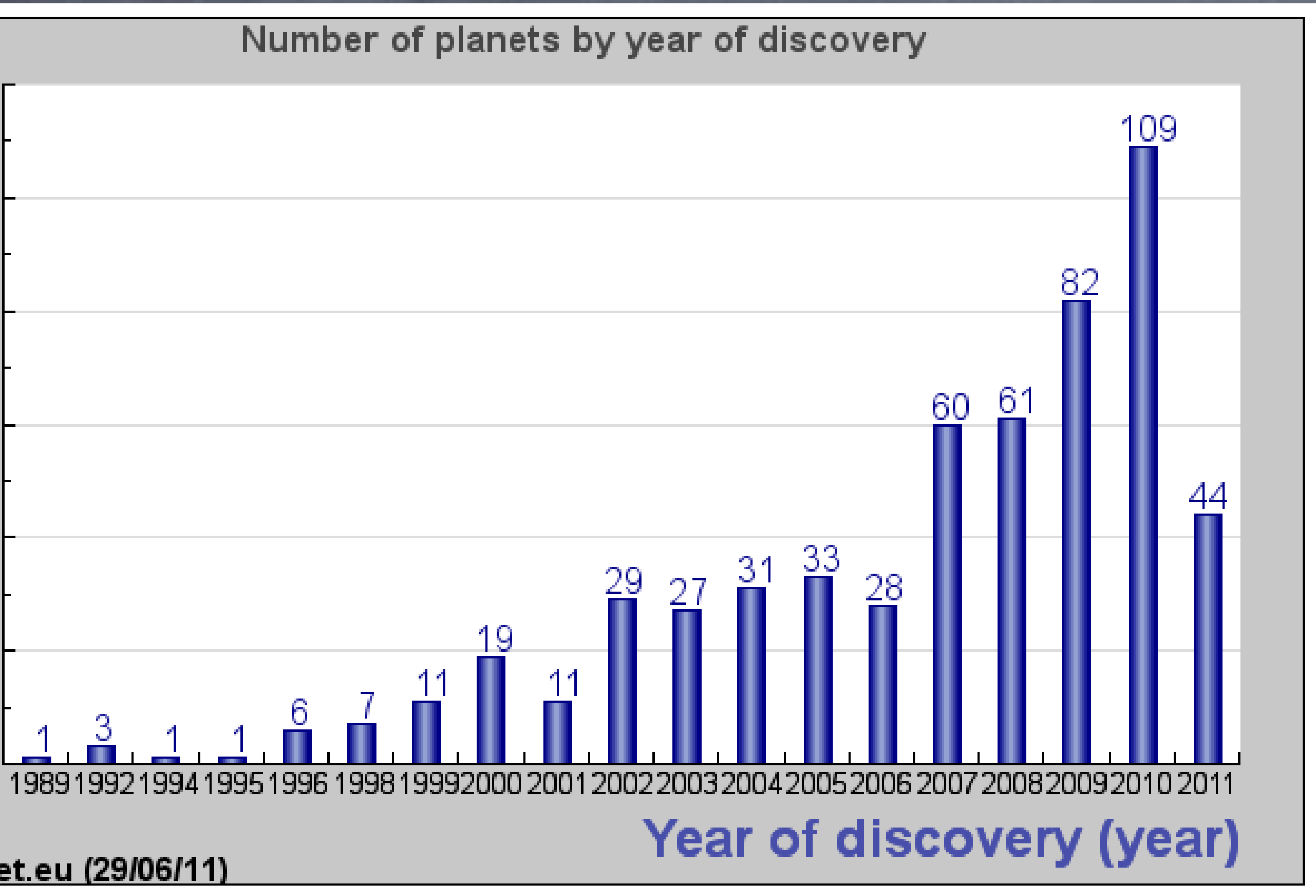
GIF decompressor
are needed to see this picture.

h planet and star move around the center of
vity of the system (cross symbol). We cannot
close-in planets directly, but we can measure
elocity and/or positional displacement induced
on the star by the presence of the planets.

e “radial velocity” spectroscopic technique is
y efficient detecting giant planets in close-in
ts. This technique requires very high spectral
ution, high precision, and stable instruments.

In addition to the “radial velocity” technique
“transit” photometric method is also qui
successful. It is based on the observation
star’s small drop in brightness that occurs wh
orbit of one of the star’s planets passes (“tra
in front of the star.

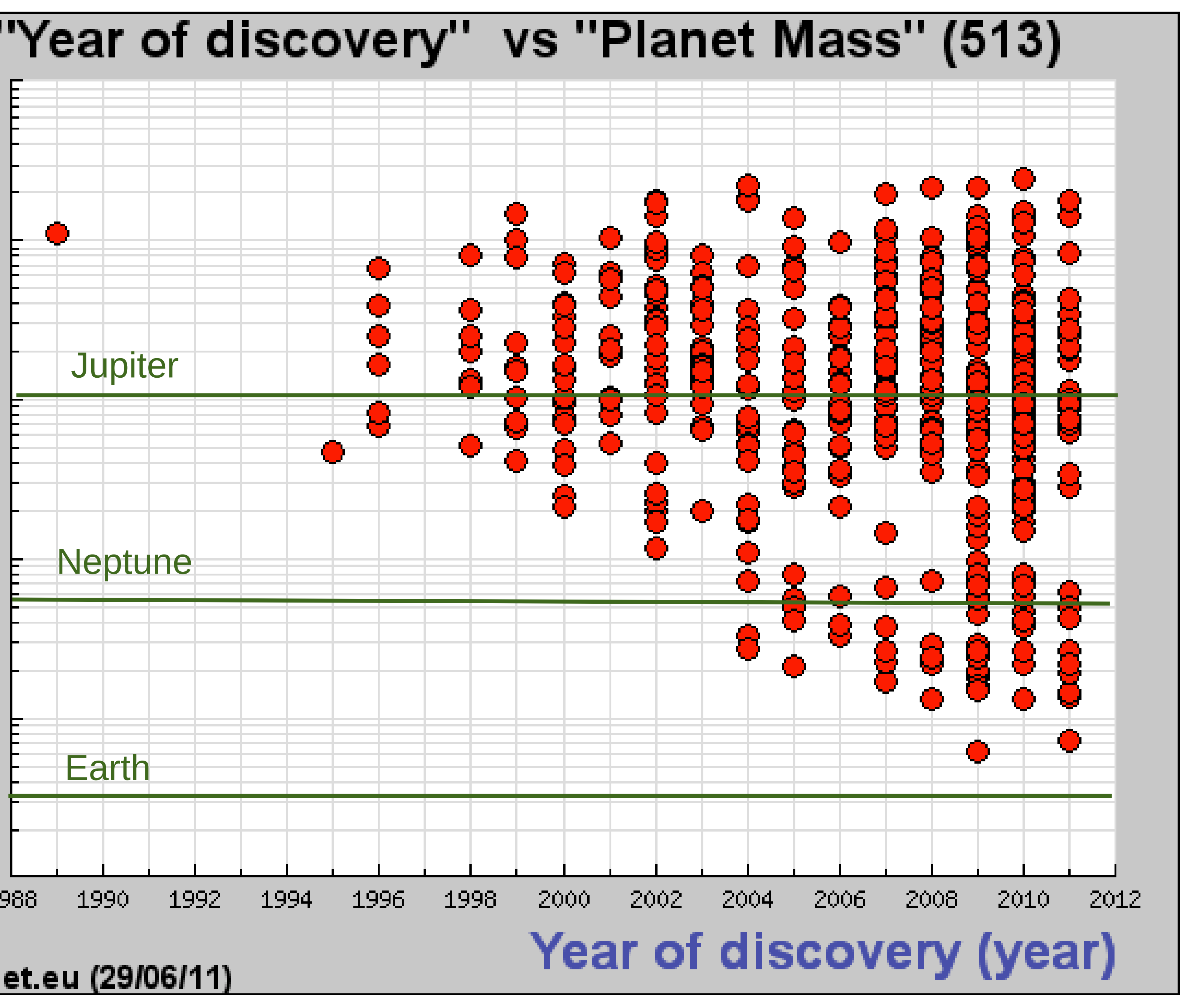
The combination of “radial velocity” and “tr
observations for a particular planet allows
determination of the planet absolute mass ar



~ 560 planets of stars found
planetary systems.

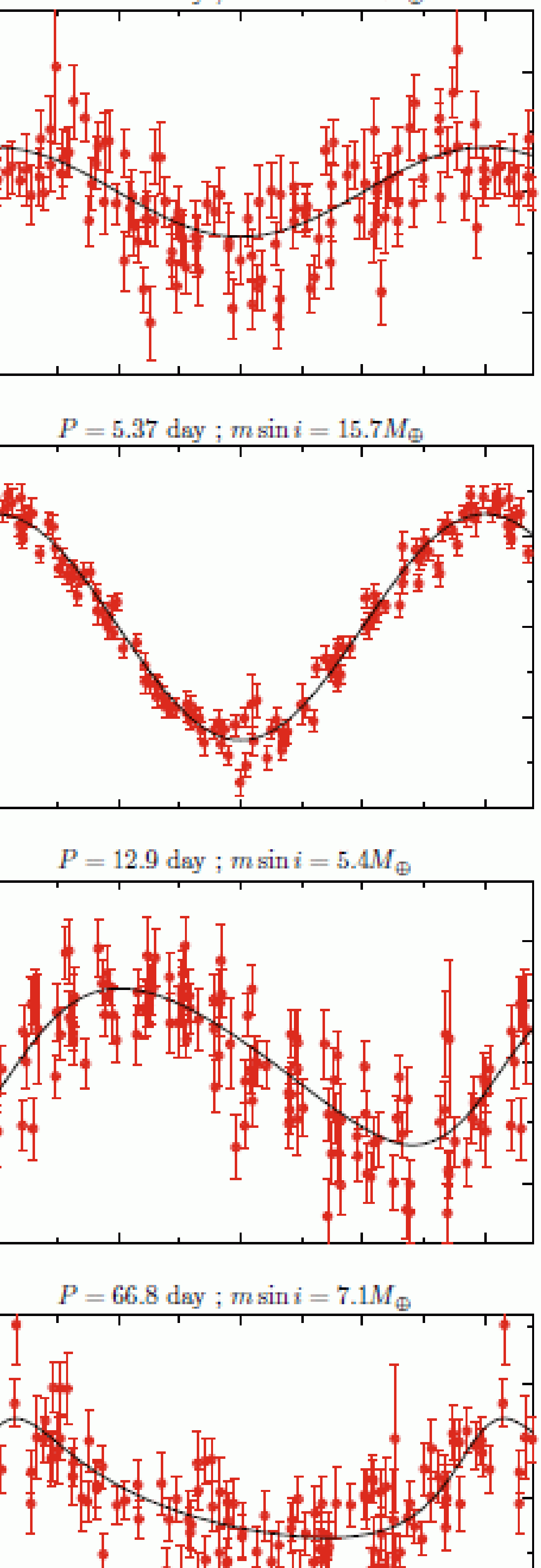
~130 transiting planets

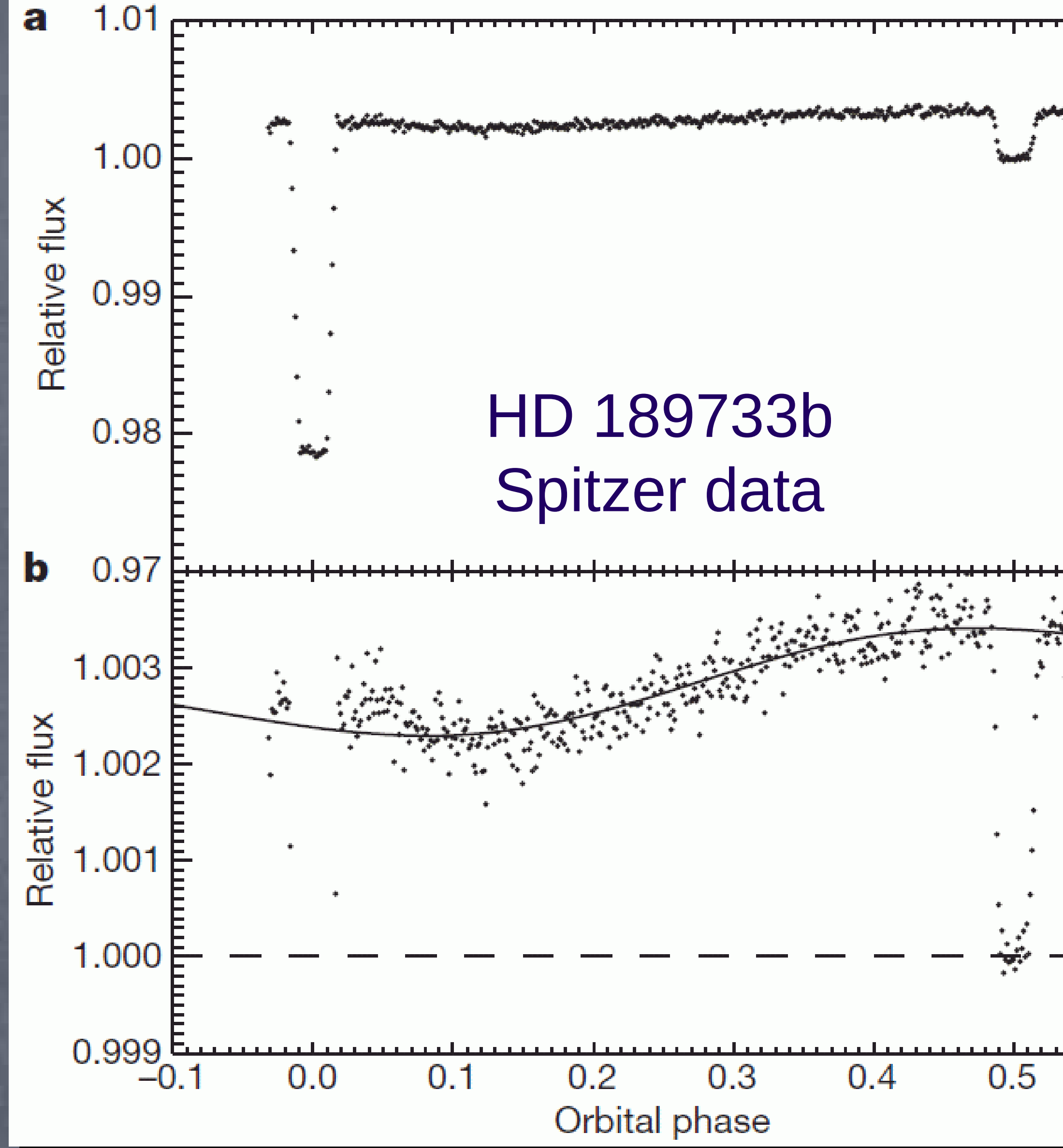
Radial velocity and tran
explorations account for 95%
discoveries.



The "easiest" planets to de
the massive ones ("super-J
in close-in (e.g., less thar
orbits.

The combination of the pho
transit method and th
spectroscopic radial ve
method has allowed the de
of the first "super-Earths" (
of mass) around main-sec
stars.

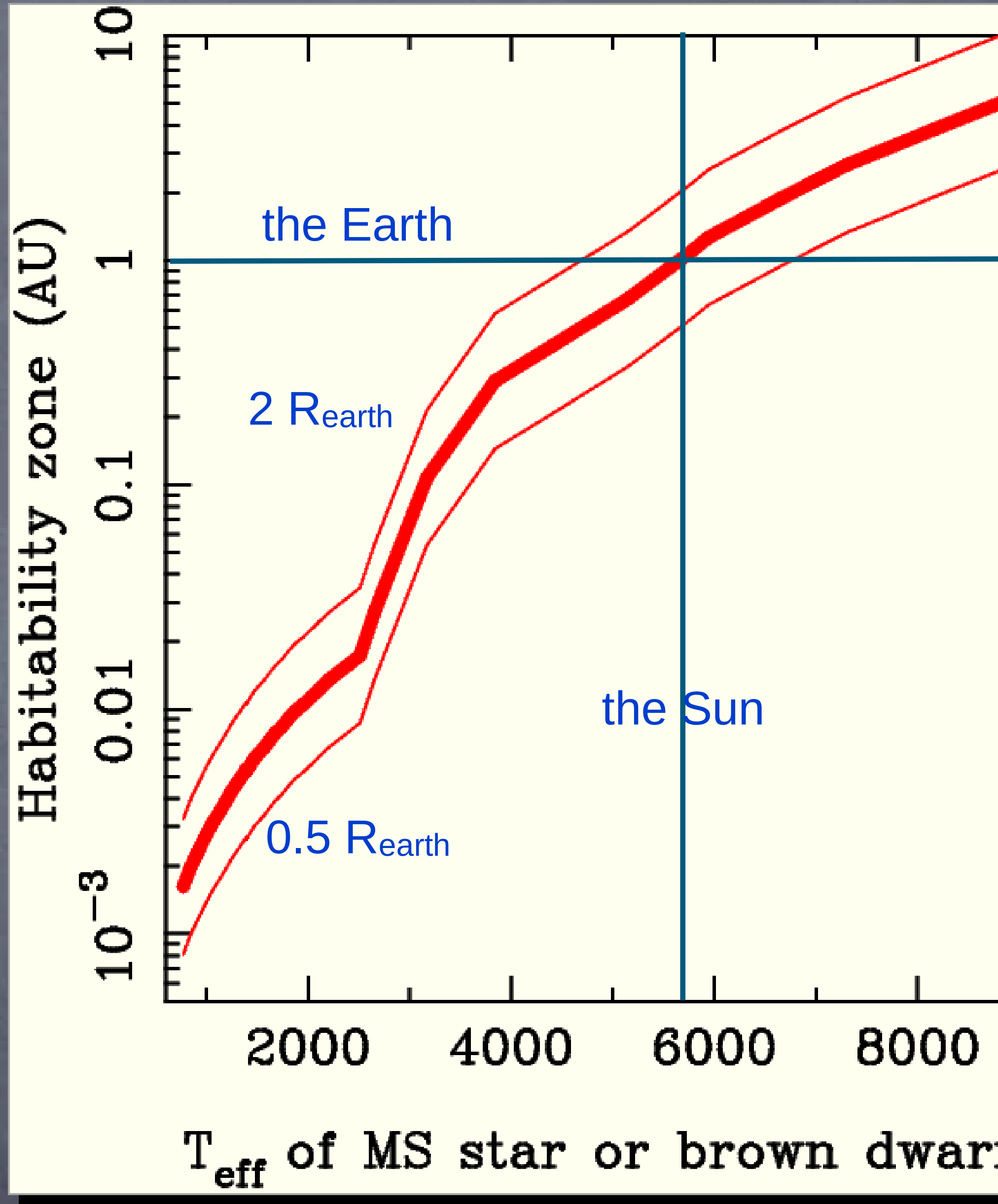


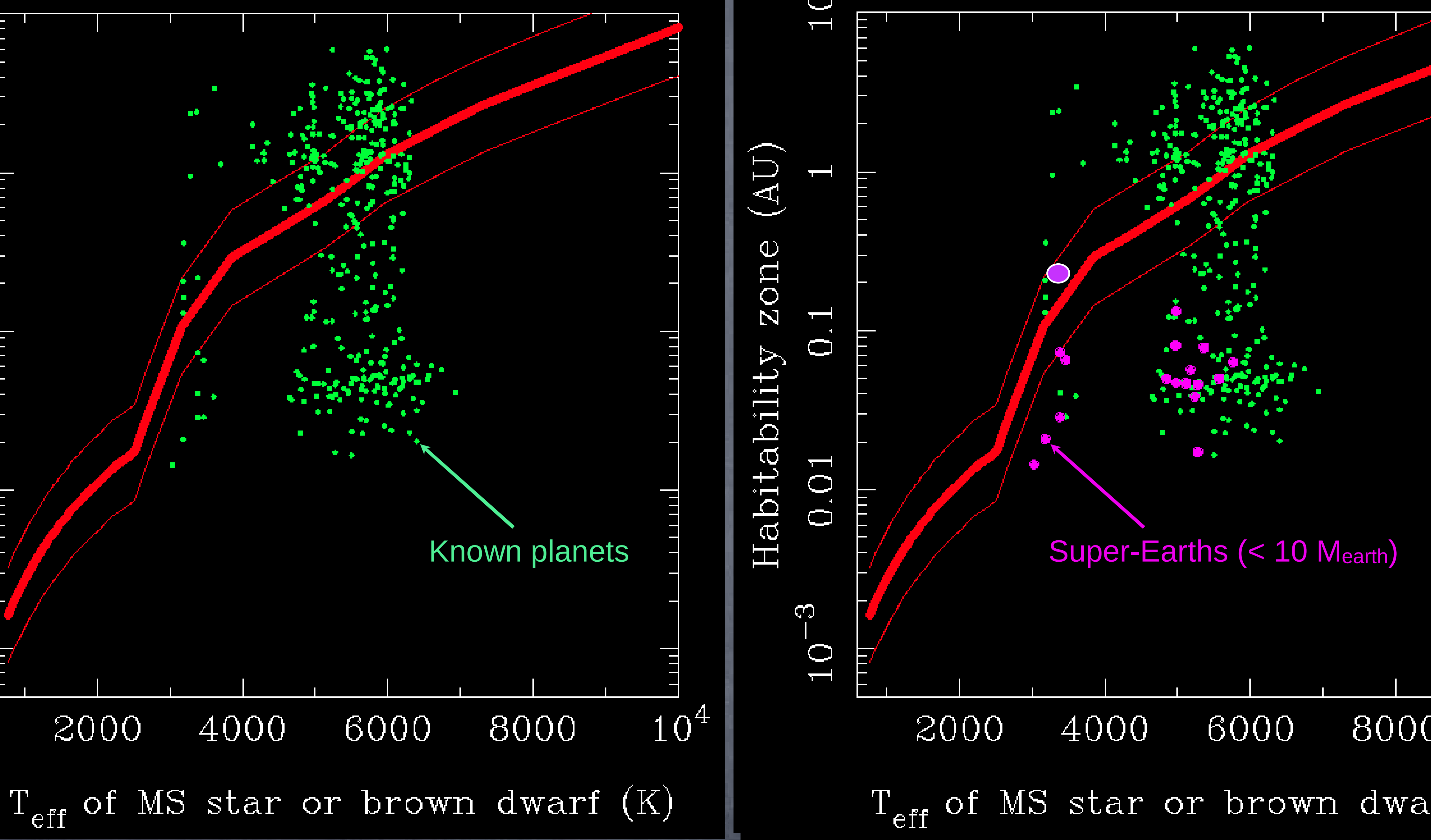


Four planets around the M3-type star GJ 581 in rather close-in orbits. The minimum mass of the smallest planet is 1.94 times that of Earth!

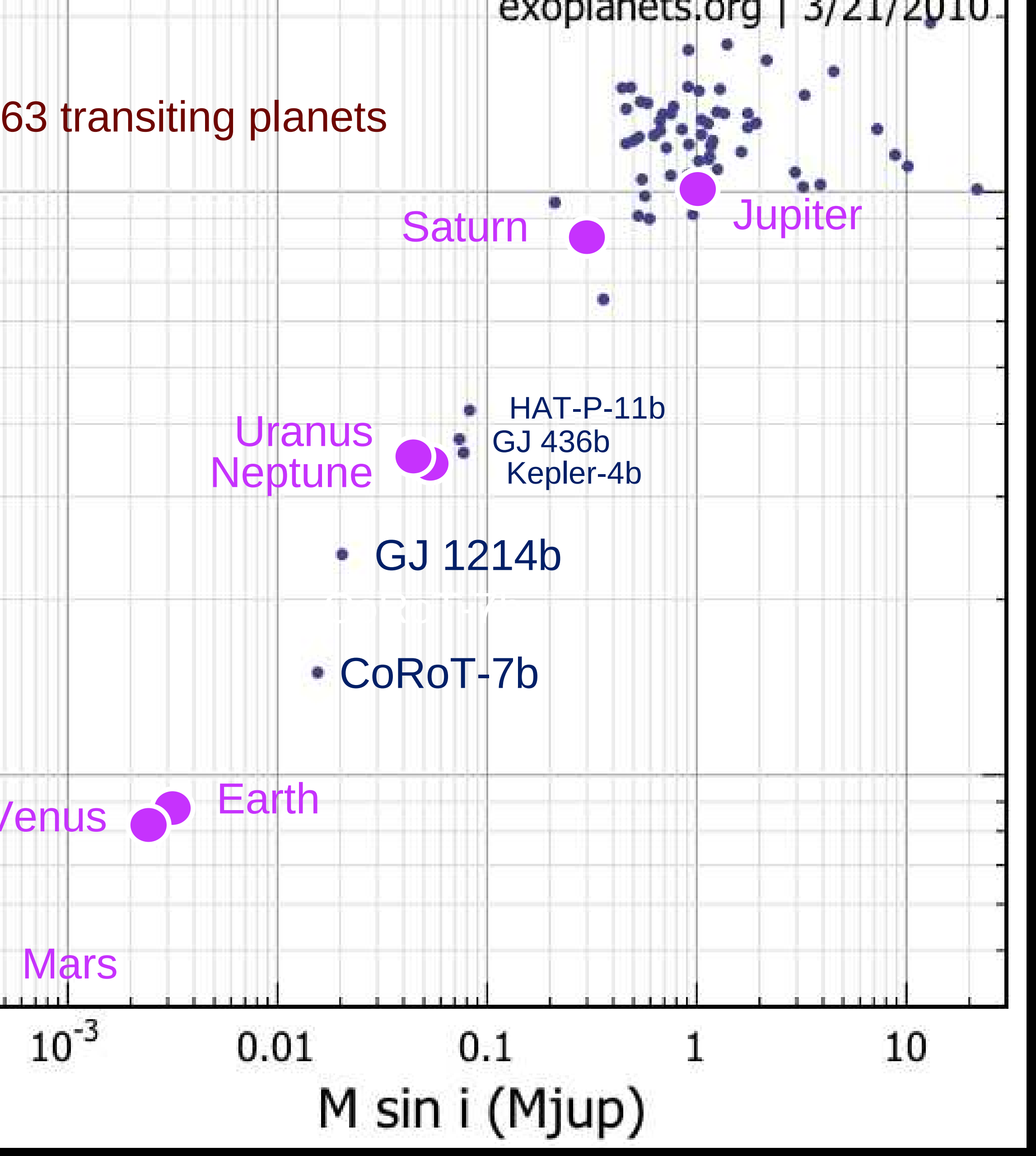
Primary and secondary transit warm (~1000 K), gas giant (1.13 planet in a close-in orbit (0.03 around the solar-type star HI 189733 (Knutson et al. 2007 astrophysical considerations, working definition of ability zone (HZ) of stars: orbits where Earth-twin nets can maintain liquid water on its surface and Earth-twin life.

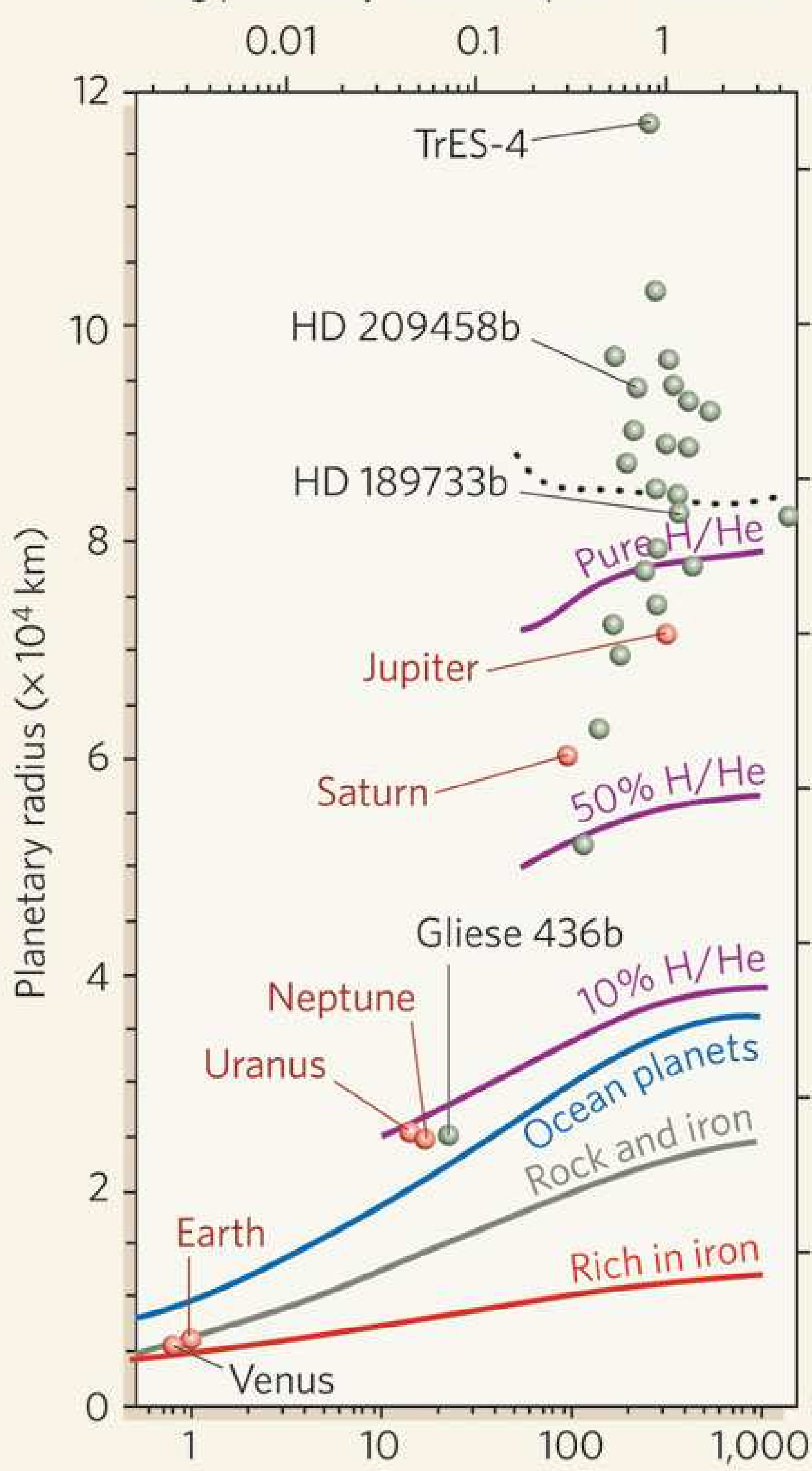
s implies a stellar light insolation identical to that received by the Earth from the Sun. HZs are portional to the size of the rocky or liquid planets and to the square root of the star luminosities.





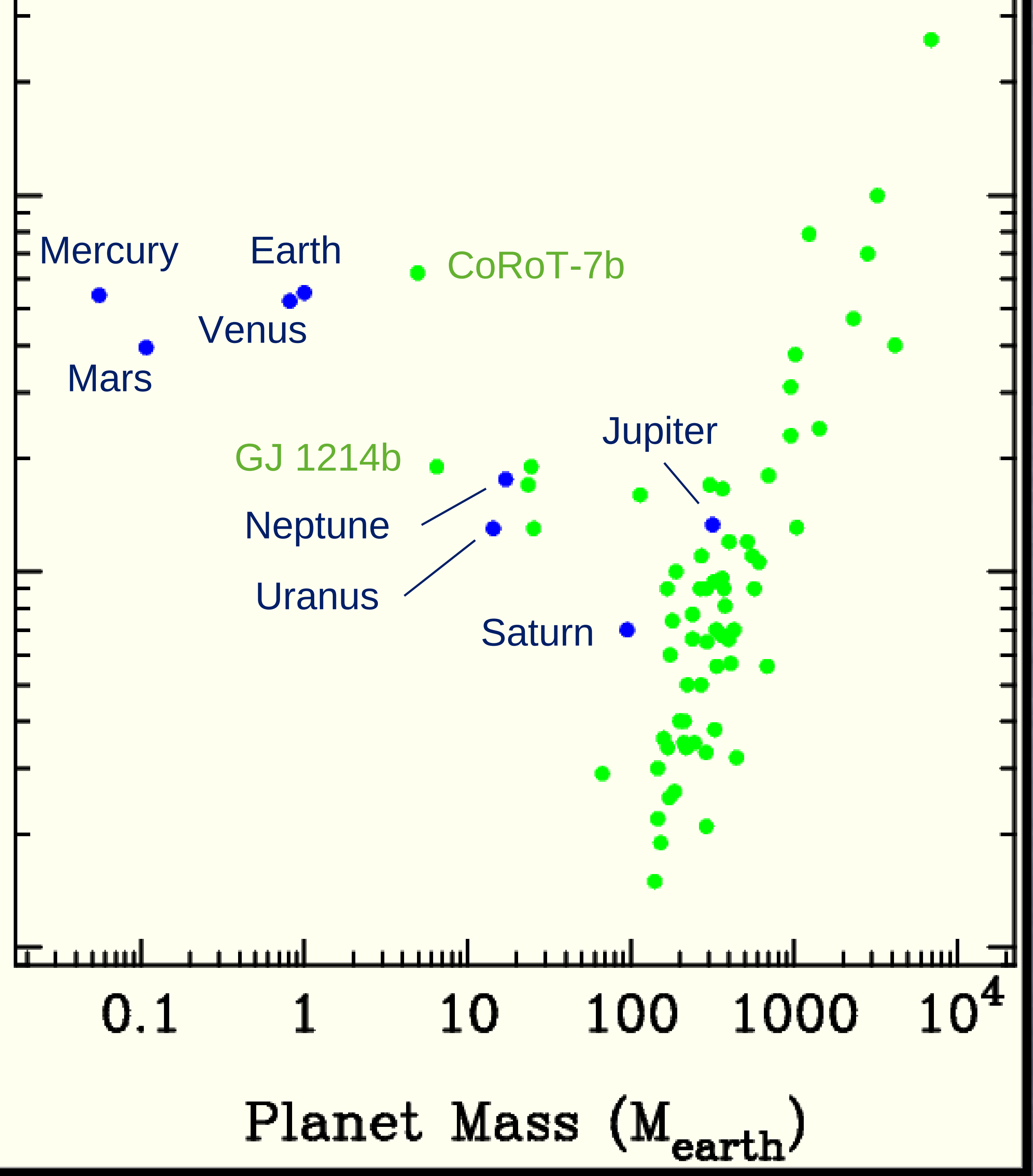
of the super-Earth planets lie in the habitable zone of their parent stars, with the possible excep
GJ 581 d. The mass of this planet is still uncertain, and its radius (size) is unknown.

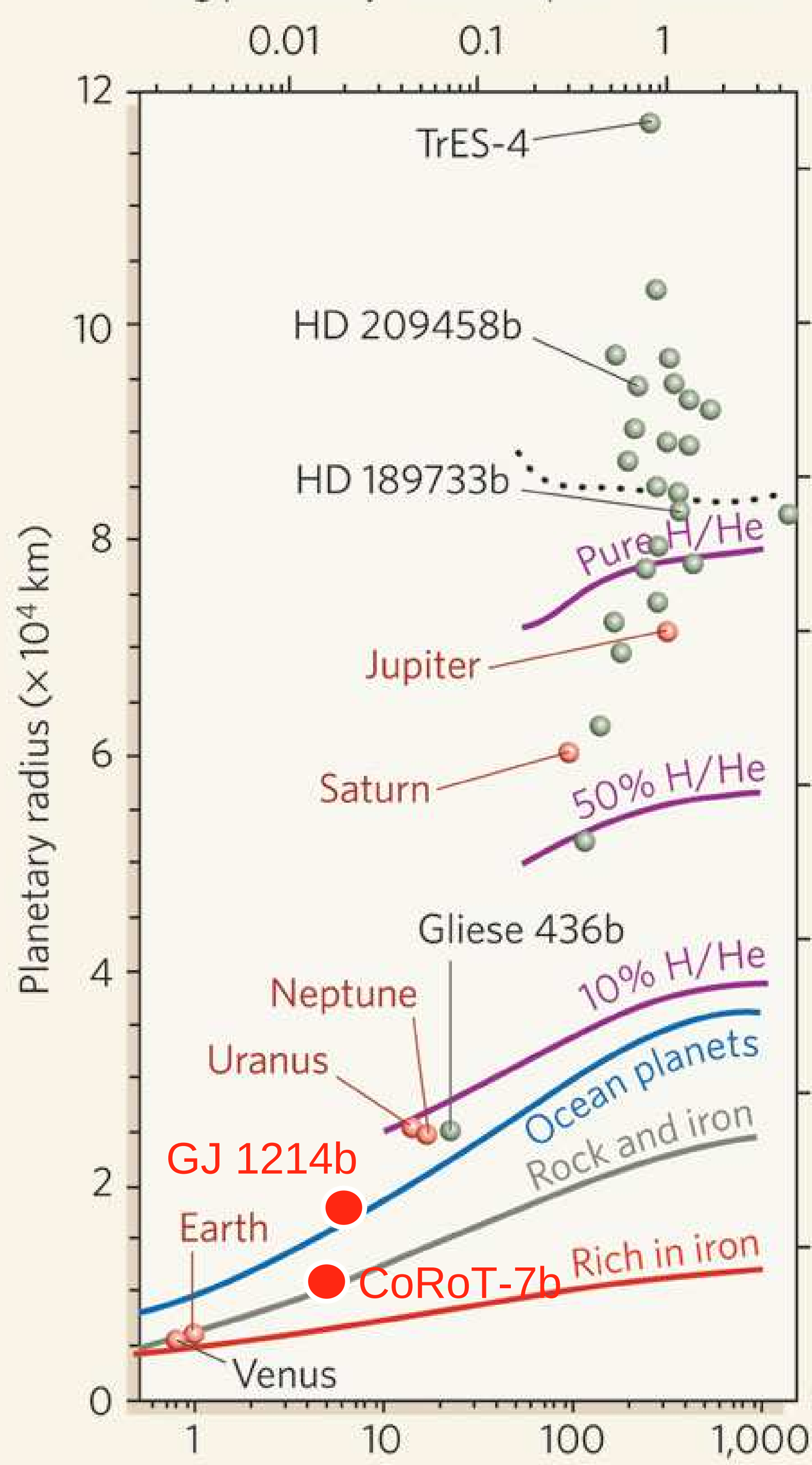




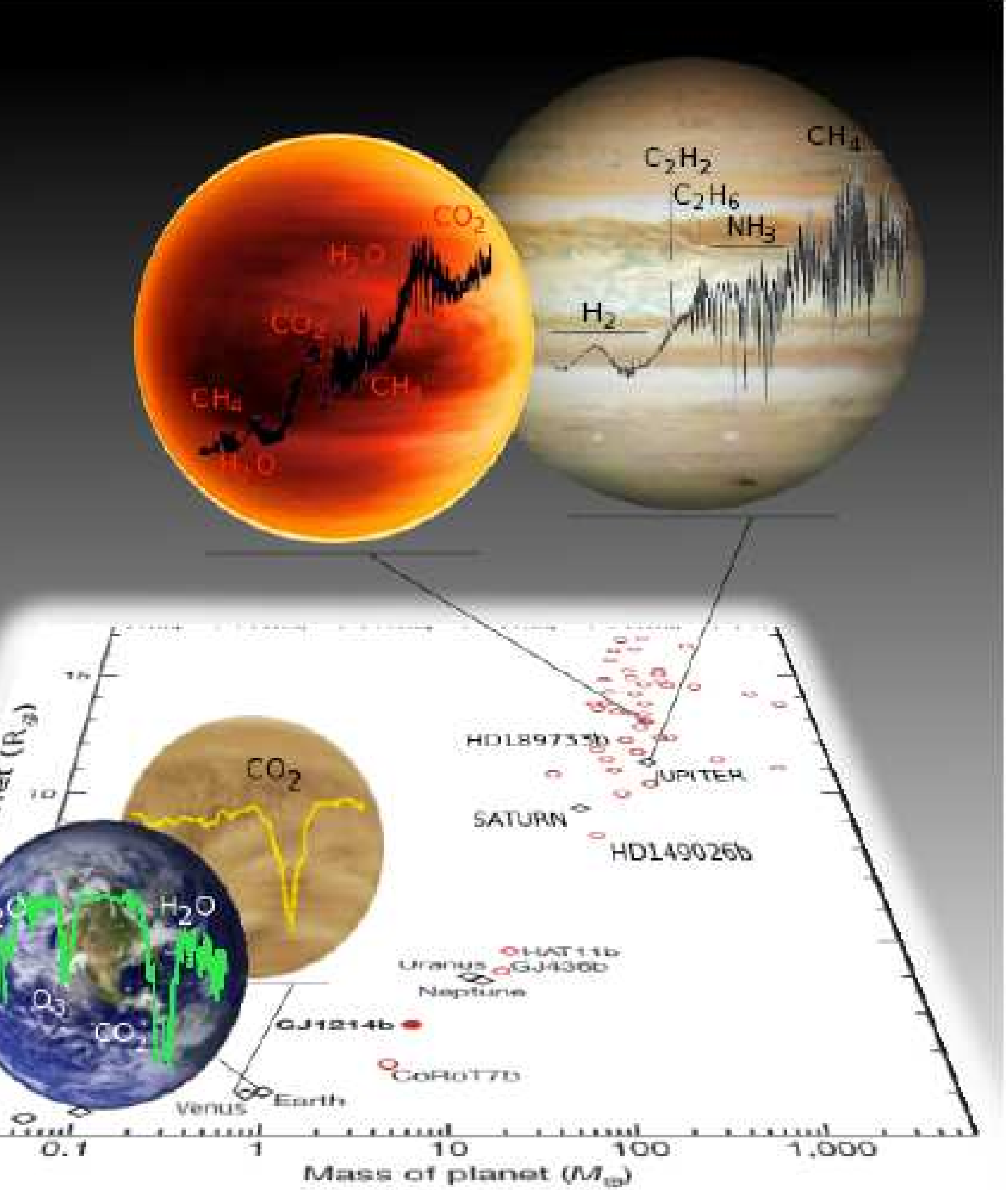
f stars appear to show a similar mass-radius relation than solar system planets.

upiter"-like planets, dispersion is large likely due to different ounts of stellar light insolation and metallic composition.



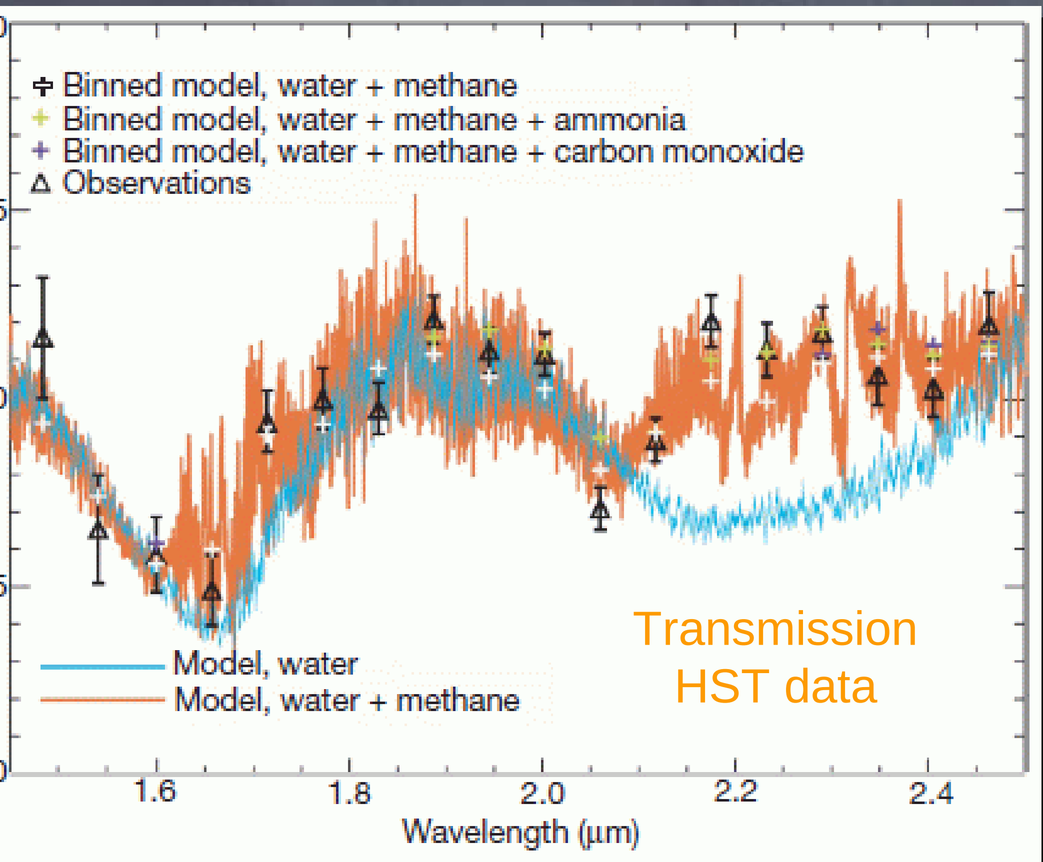


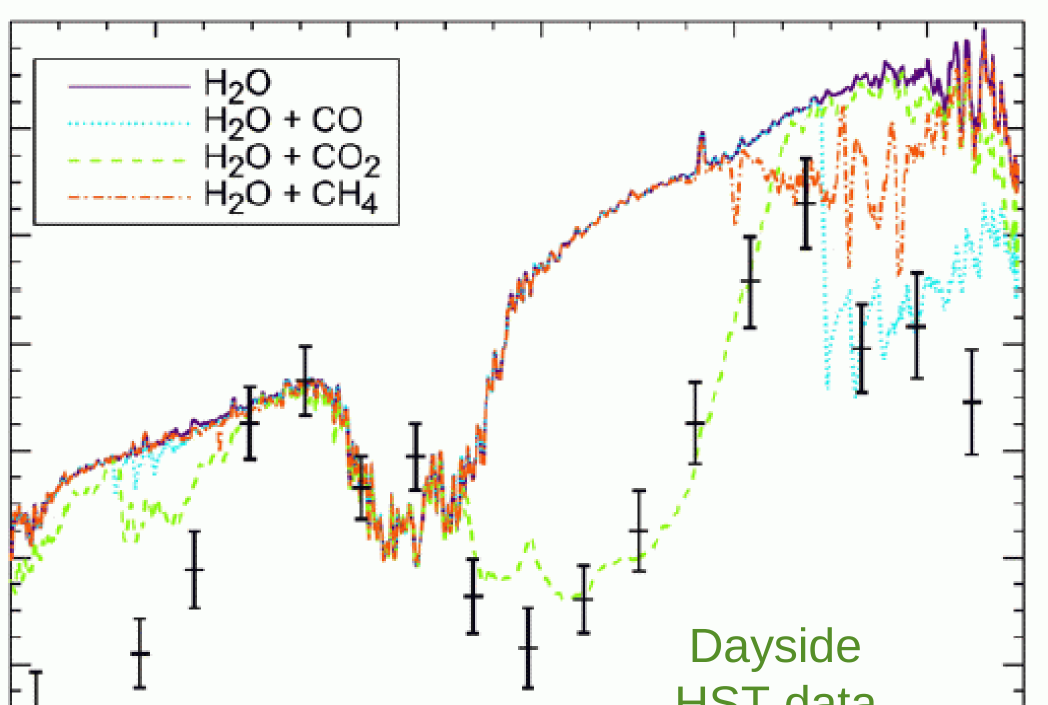
NOT in the habitable zones of their parent stars, CoRoT-7b (5

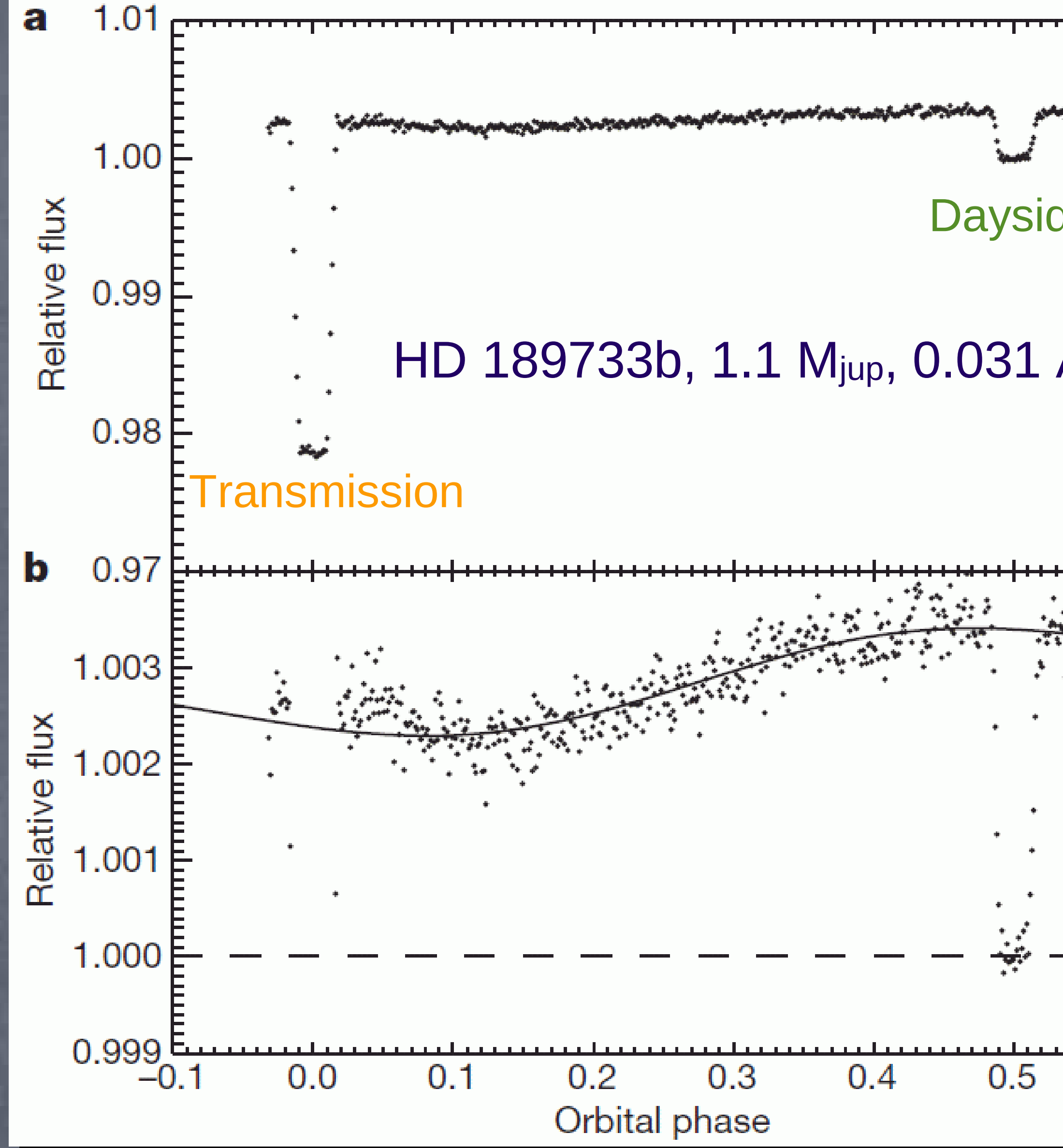


Planets can be very similar in mass and radius and yet ifferent worlds, as demonstrated by these two pairs of ex- A spectroscopic analysis of the atmospheres is needed to ir physical and chemical identities.

*H_2O	0.51, 0.57, 0.65, 0.72, 0.82, 0.94	1.13, 1.38, 1.9, **2.69**	6.2	[illegible]
*CO_2	-	1.21, 1.57, 1.6, 2.03, **4.25**	-	1
C_2H_2	-	1.52, **3.0**	7.53	1
HCN	-	**3.0**	-	1
C_2H_6	-	3.4	-	1
O_3	0.45-0.75 (the Chappuis band)	4.7	9.1, **9.6**	1
HDO	-	2.7,3.67	7.13	-
*CO	-	1.57, 2.35, **4.7**	-	-
O_2	0.58, 0.69, 0.76, 1.27	-	-	-
NH_3	0.55, 0.65, 0.93	1.5, 2, 2.25, 2.9, **3.0**	6.1, **10.5**	-
PH_3	-	4.3	8.9, 10.1	-
*CH_4	0.48, 0.57. 0.6, 0.7, 0.79, 0.86,	1.65, 2.2, 2.31, 2.37, **3.3**	6.5, **7.7**	-
CH_3D	?	3.34, **4.5**	6.8, 7.7, **8.6**	-
C_2H_4	-	**3.22**, 3.34	6.9, **10.5**	-
H_2S	-	2.5, 3.8 ...	7	-
SO_2	-	4	**7.3**, 8.8	-
N_2O	-	2.8, 3.9, **4.5**	7.7, 8.5	-
NO_2	-	3.4	**6.2**, 7.7	1
H_2	-	2.12	-	-
H_3^+	-	2.0, 3-4.5	-	-
He	-	1.083	-	-
*Na	0.589	1.2	-	-
*K	0.76	-	-	-
TiO	0.4-1	1-3.5	-	-
VO	0.4-1	1-2.5	-	-
FeH	0.6-1	1-2	-	-
TiH	0.4-1	1-1.6	-	-
Rayleigh	0.4-1	-	-	-
Cloud/haze	yes	possible	silicates, etc.	[illegible]



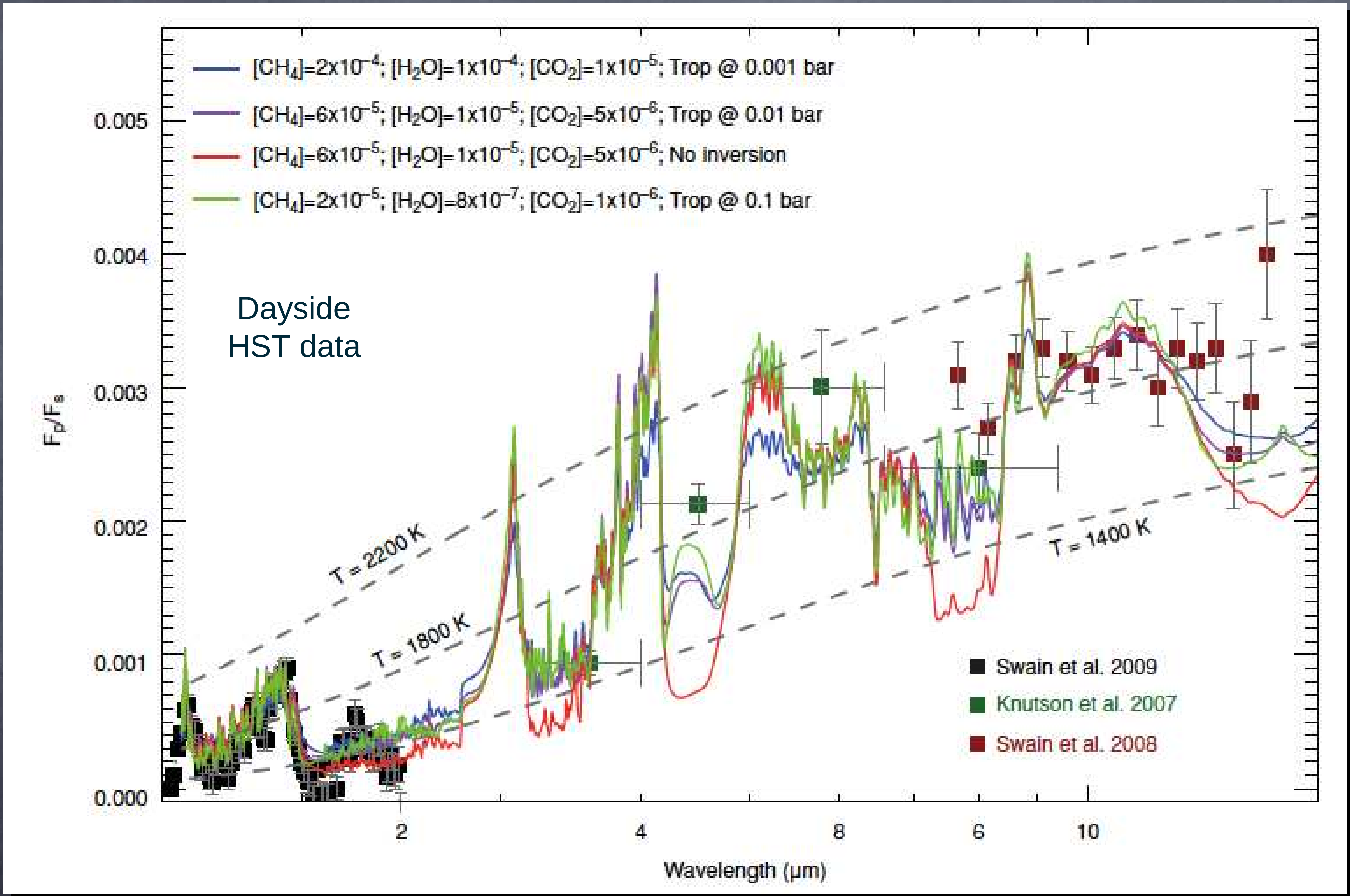




Transmission spectrum of HD 189733b
explained by the presence of water vapor
methane (Swain et al. 2008).

Dayside spectrum is explained by the pres

HD 209458b, 0.69 M_{jup}, 0.047 AU



Water vapor, carbon dioxide, and methane present in the dayside spectrum of planet

ESA internal EChO team:

Study manager: Ludovic Puig

Study scientist: Kate Isaak

Payload managers: Didier Martin supported by Pierre-Elie Crouzet

+ support from technical experts at ESTEC.

Study Science Team: Giovanna Tinetti (UK), Pierre Drossart (FR), Oliver Krause (DE), Christophe Lovas (FR), Marc Ollivier (FR), Ignasi Ribas (ES), Ignas Snellen (NL), Bruce Swinyard (UK)

Aim of assessment study:

to define the mission to a level at which scientific value and feasibility (technical/programmatic) can be assessed.

Output:

Assessment study report includes science objectives, SCIENCE REQUIREMENTS, payload, mission design and operations (ground sgment + science operations), mission management (+ procurement approach)

Exoplanet Characterization Observatory

The ECHO mission will be able to characterize the atmospheres of exoplanets down to Super-Earth size in the habitable zone of late-type stars, using VIS+NIR+MIR transit/occultation spectroscopy.

Current scientific requirements and other details:

1.2-m telescope with passive cooling.

Soyuz launcher from Kourou to L2 orbit (1293 kg injected mass).

5 yr mission lifetime.

Continuous spectroscopy from 0.6 to 11 (16 goal) μm. Three channels (VIS, NIR, MIR) with wavelength overlap.

Photometric stability of better than 10^4 across the observing band during 2 days.

Spectral resolution: ~1000 (VIS), >300 (NIR), >30 (MIR).

Exoplanet Characterization Observatory

The ECHO mission will be able to characterize the atmospheres of exoplanets down to Super-Earth size in the habitable zone of late-type stars, using VIS+NIR+MIR transit/occultation spectroscopy.

Proposed Spanish contribution:

Mid-infrared channel(s): optical and optomechanical design, optics procurement, validation testing (CAB, INTA).

On-board and ground-segment data processing and calibration software (ICE, possible contribution of CAB-INTA).

Electronics, including signal processing and data processing units, instrument control unit, and power supply unit (IAC, ICE).

Exoplanet Characterization Observatory

Schedule

Start of EChO assessment study - May 2011

Completion of 1st phase study (internal) - Sep 2011

Start of industrial studies - beginning of 2012

End of industrial studies - end of 2012

Completion of assessment study - end of 2012

Yellow Book - end of 2012 or early 2013

Internal independent ESA review - early 2013

Down-selection of candidate missions (2) for definition phase - mid-2013

Summary of the ESA short study
(2010 March 26)

Mission feasible within requirements and constraints: mass OK, power OK, telemetry OK, …

Ample heritage from other missions.

Risk areas:

AOCS (altitude and orbit control system, pointing stability) technical development.

5-16 μm channel challenging: cryogenics. Detector development.

Insufficient number of science targets.

Kepler, CoRoT

Gaia

HAT

Espresso, Carmenes

Sphere

Radial Velocity Surveys (HARPS, Keck, UVES, ...)

Transit Surveys (WAPS & SuperWAPS, ...)

JWST, Plato

Board:

J.-P. Beaulieu (Inst. Astrop. Paris), M. Güdel (Univ. Viena), Th. Henning (MPIA), G. Micela (INAF), M. Meyer (ETH Zurich), I. Ribas (ICE), D. Stam (SRON Netherlands Inst. Space Research), G. Tinetti (Univ. College London).

Science Working Group ("Tiger team")

Ignas Snellen (Leiden Univ.)
Alan Aylward (Univ. College London)
Angioletta Coradini (INAF)
Roy van Boekel (MPIA)
Therese Encrenaz (Obs. Paris)
María Rosa Zapatero Osorio (CAB), Enric Pallé (IAC)

Instrument Working Group ("Tiger team")

Marc Ollivier (Institut d'Astrophysique Spatiale d'Orsay)
Oliver Krause (MPIA)
Bruce Swinyard (RAL)
Emanuele Pace (Univ. Firenze)
Spanish rep. TBD

In Spain: IAC, IAA, UPV, ICE, CAB