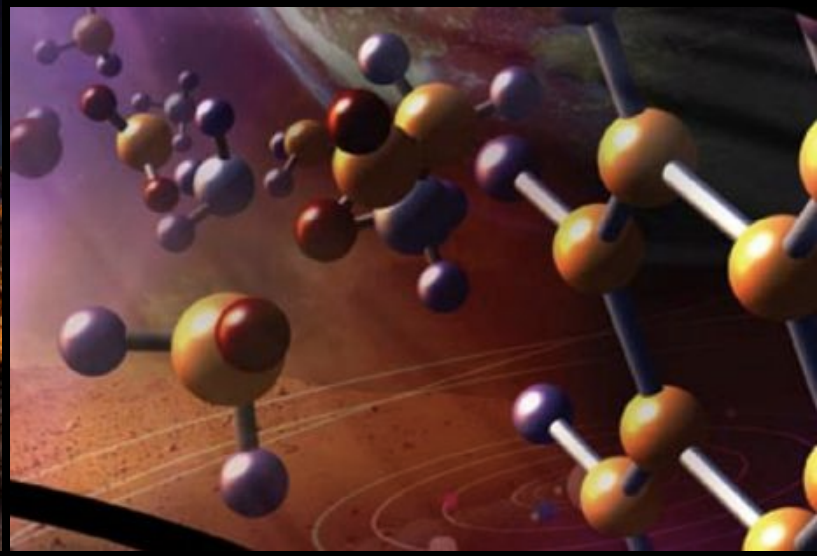
Astrobiologia e Exoplanetas



DrJorgeMelendez

Departamento de Astronomia IAG/USP

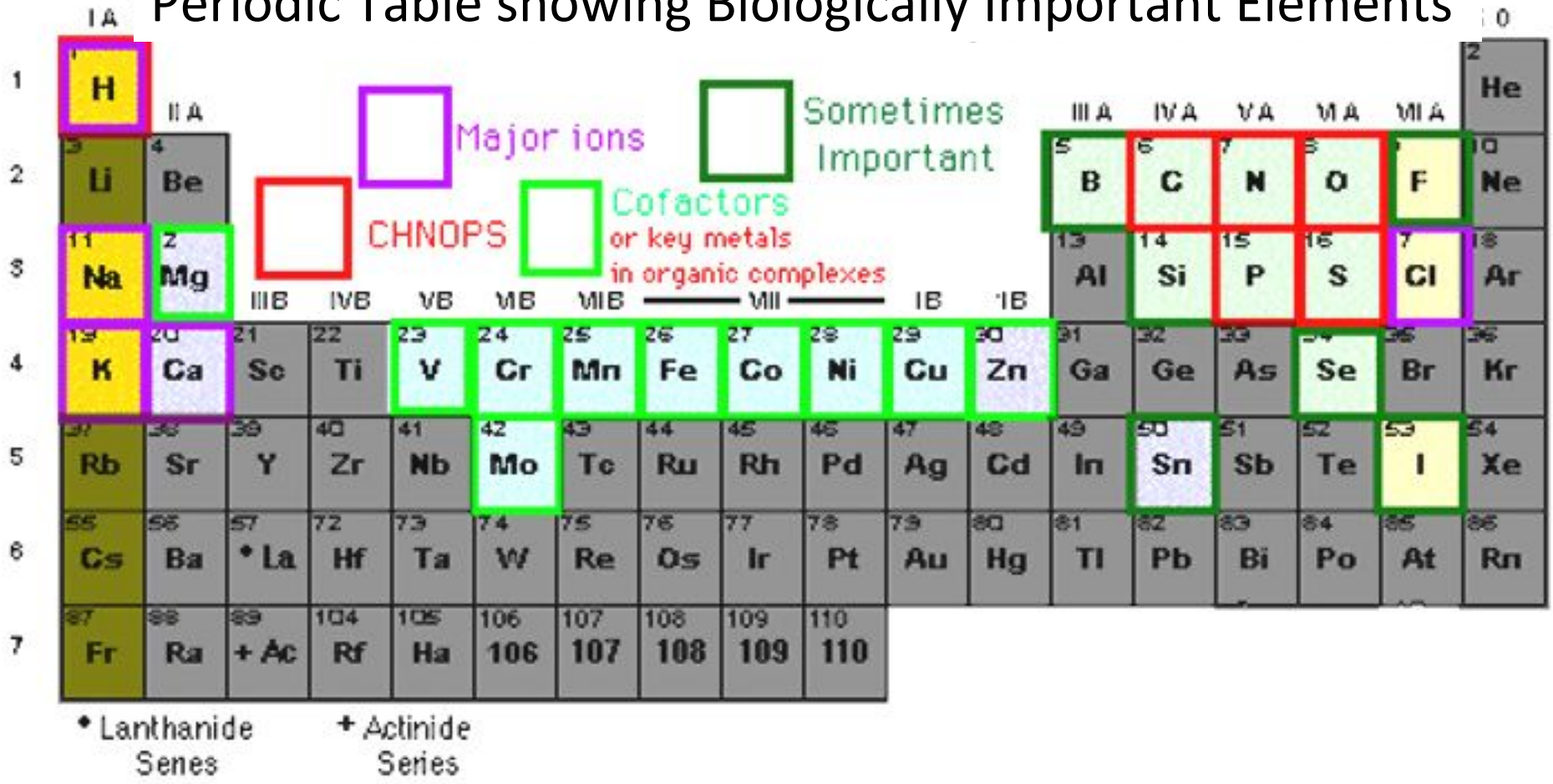
SAMPA
Stellar Atmospheres, Planets and Abundances

https://astrobiology.nasa.gov/

Astrobiology: interdisciplinary science

- Astronomy
- Physics
- Chemistry
- Biology
- Ecology
- Geophysics
- Atmospheric Science
- Engineering

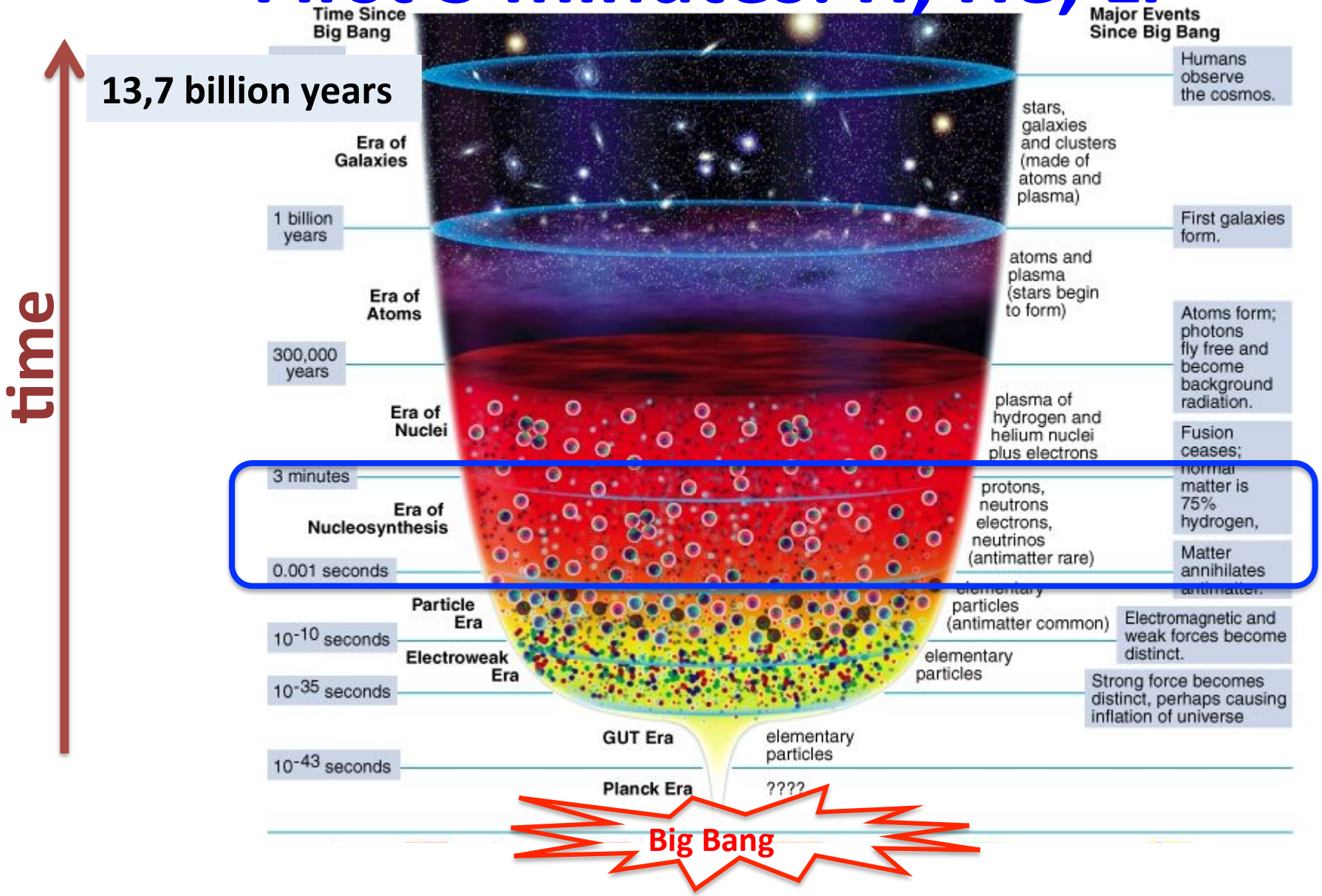
Biogenic elements: CHONPS



http://www.starshipnivan.com/blog/?p=3544

Evolution of our universe

First 3 minutes: H, He, Li



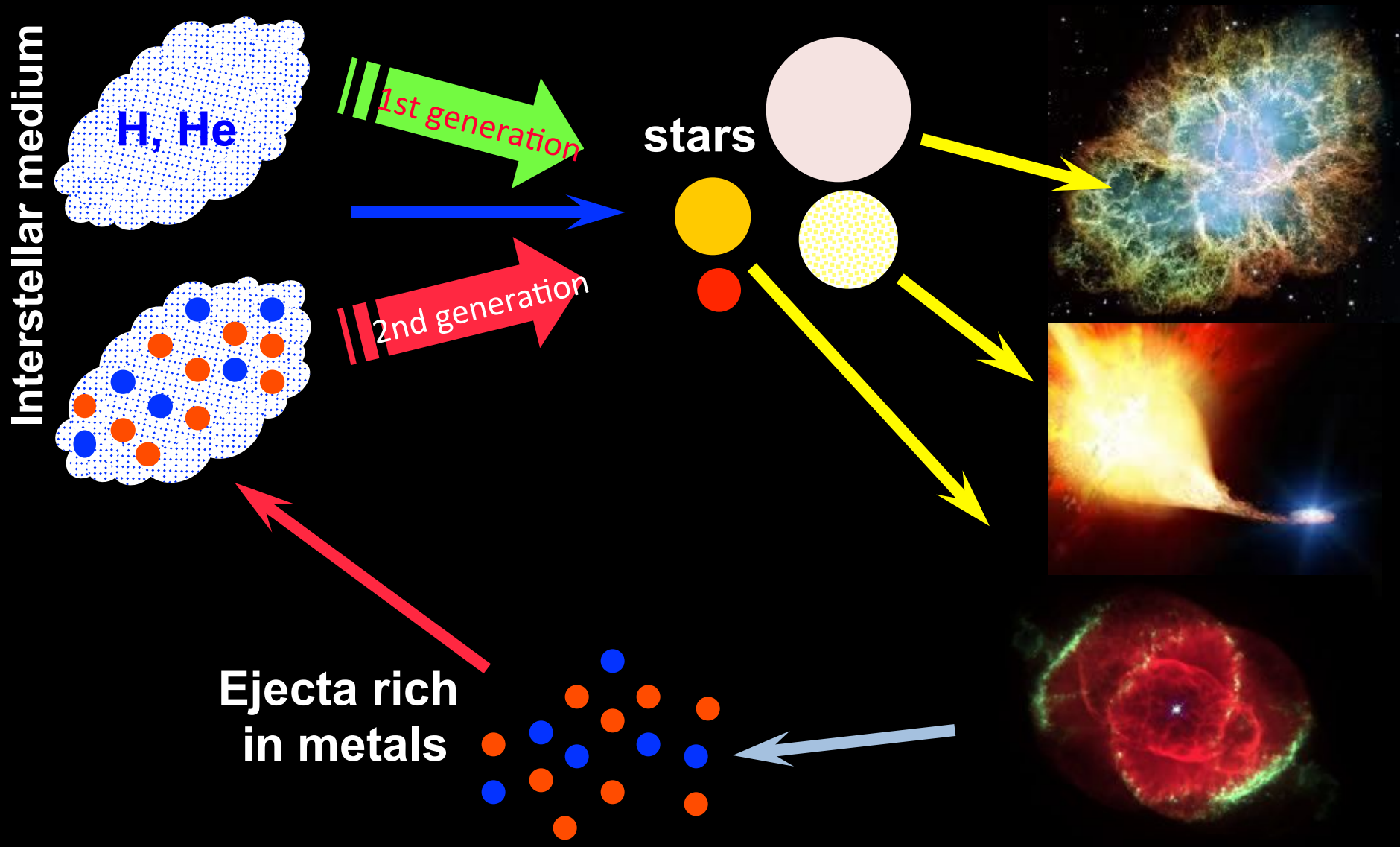
Stellar evolution: building periodic table

Type II Supernova

Planetary Nebula

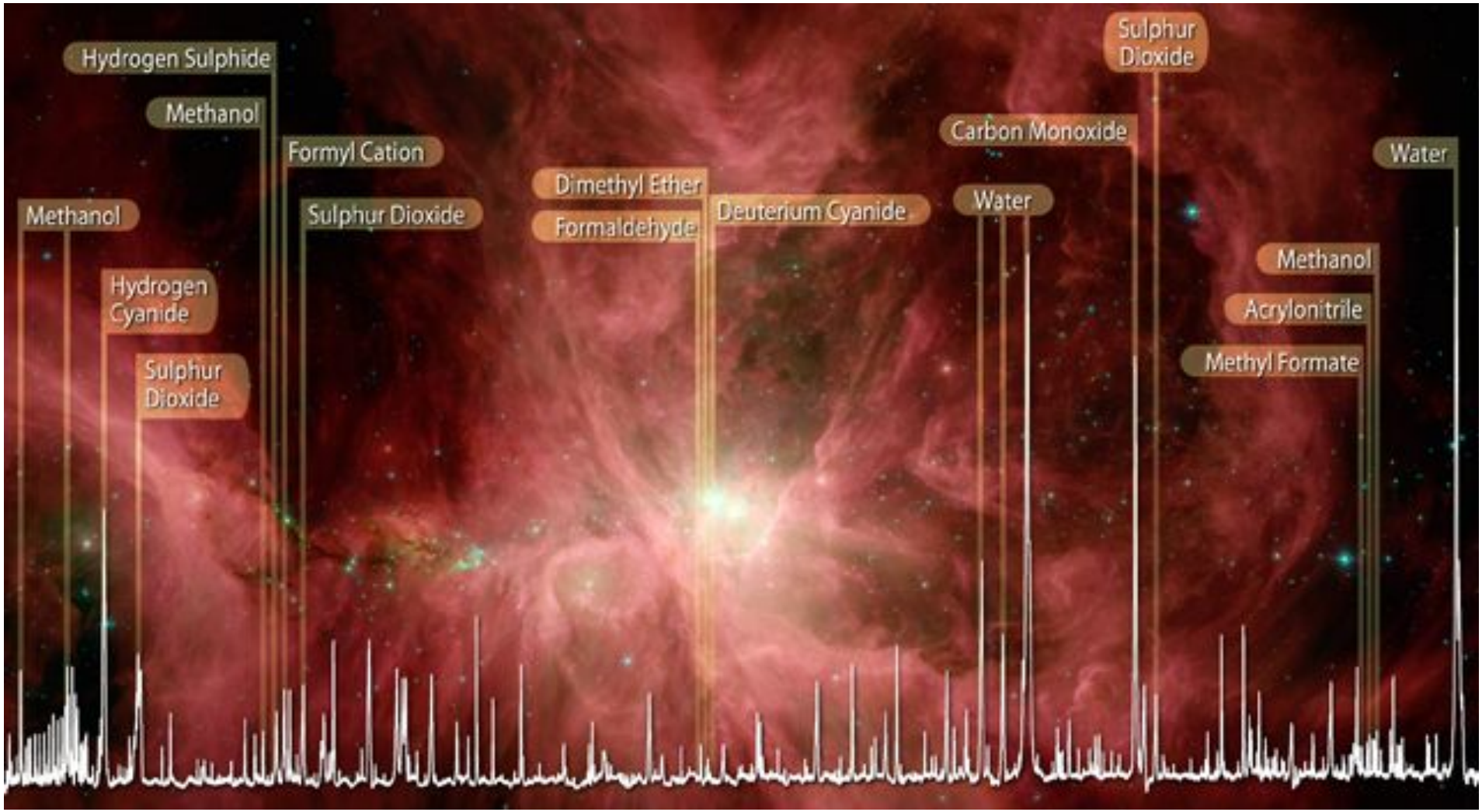
Type Ia Supernova
(artist's concept)

Chemical enrichment in the Galaxy



When we have enough metals in the star-forming cloud, we can build planets

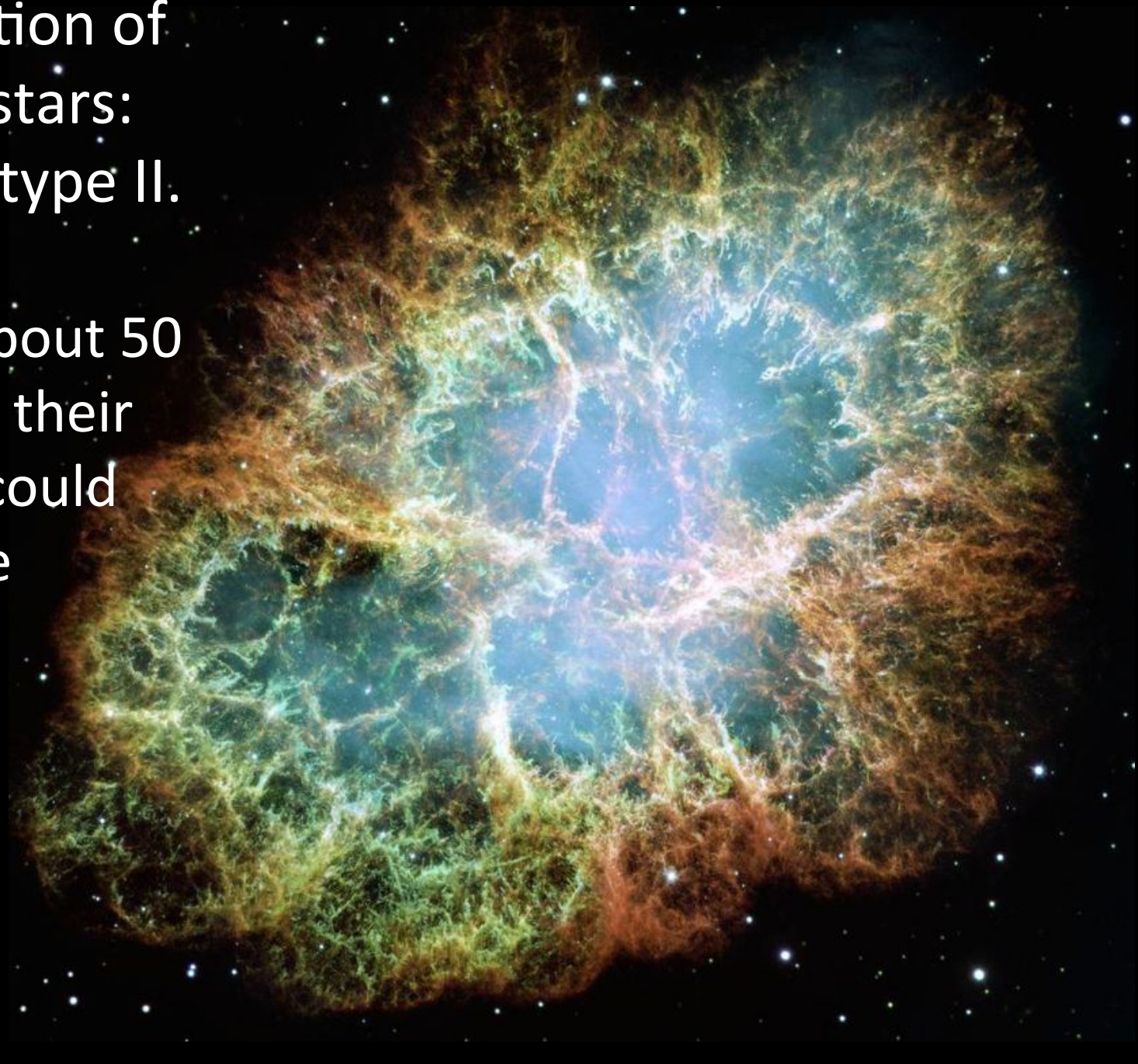
Detection of life-enabling molecules in Orion nebula, by @ESA Herschel



https://www.jpl.nasa.gov/news/news.php?release=2010-077

Final evolution of high-mass stars: supernova type II.

If nearby (about 50 light-years), their explosions could threaten life



Ionizing radiation on planetary atmospheres

Induces chemical reactions producing NO_X which destroy the protective O_3 layer and increase the solar UV flux on surface

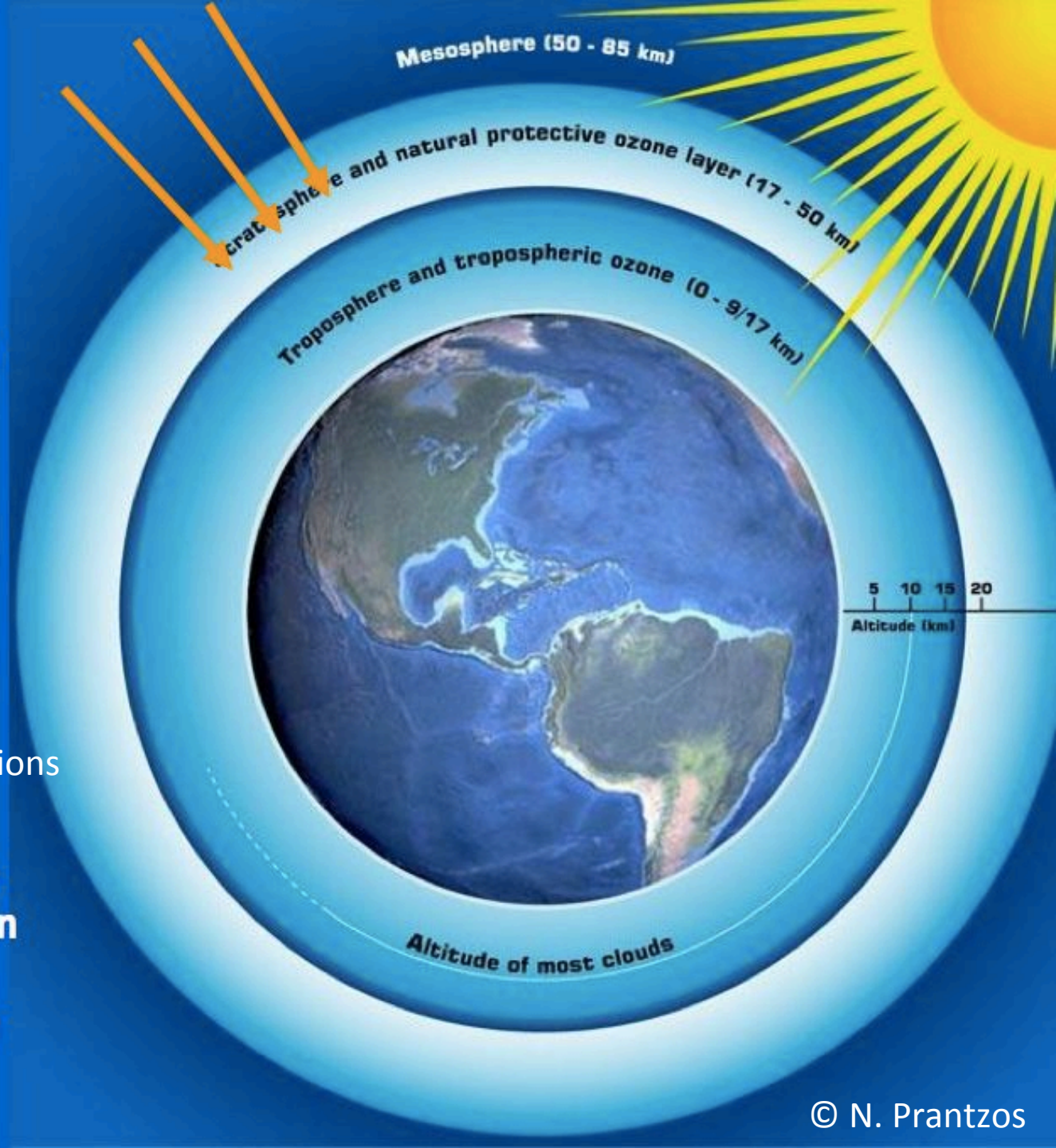
Produces secondary energetic particles and UV reaching the surface

Supernova may cause extinctions

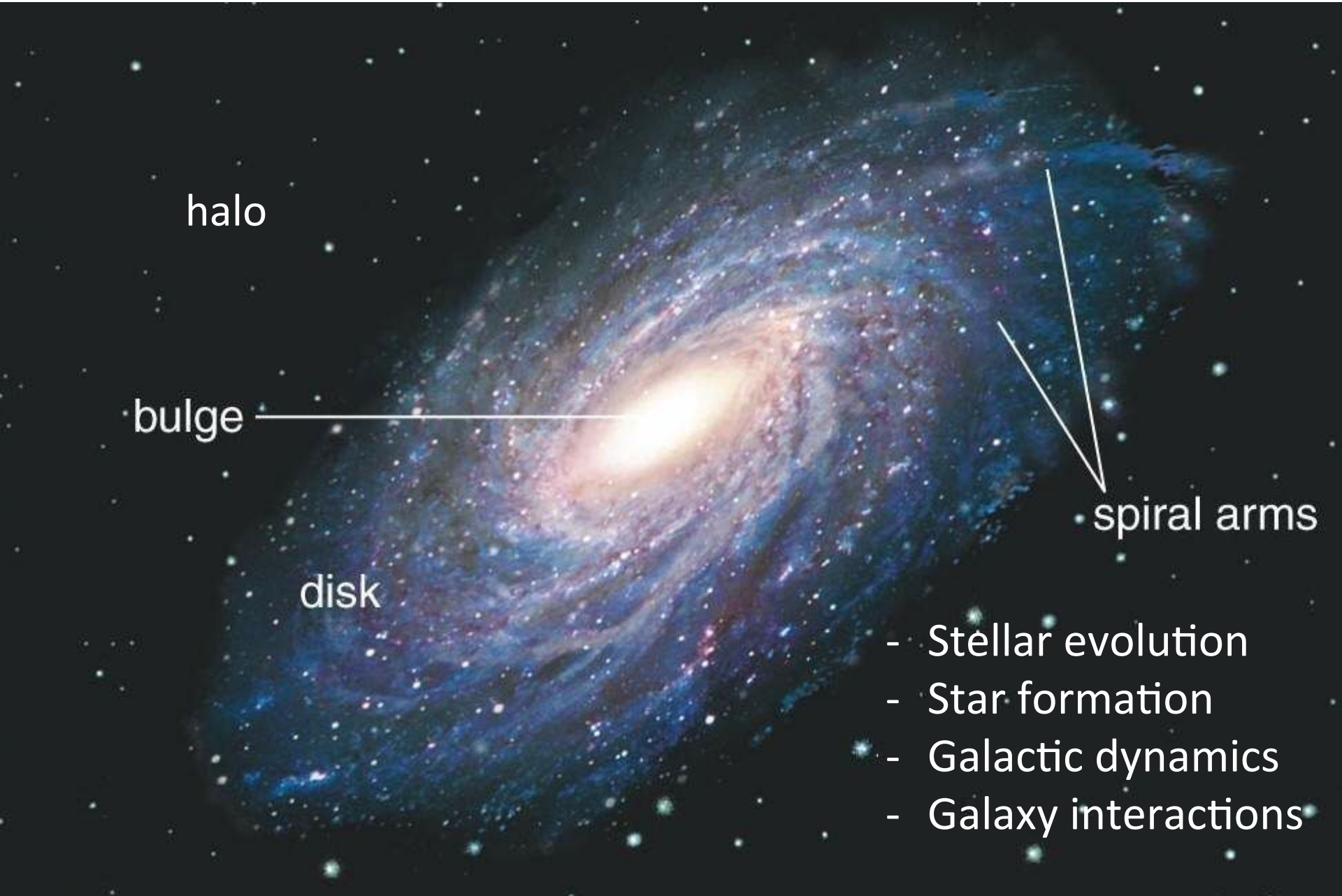
But :

1) Mutations may accelerate and even induce evolution

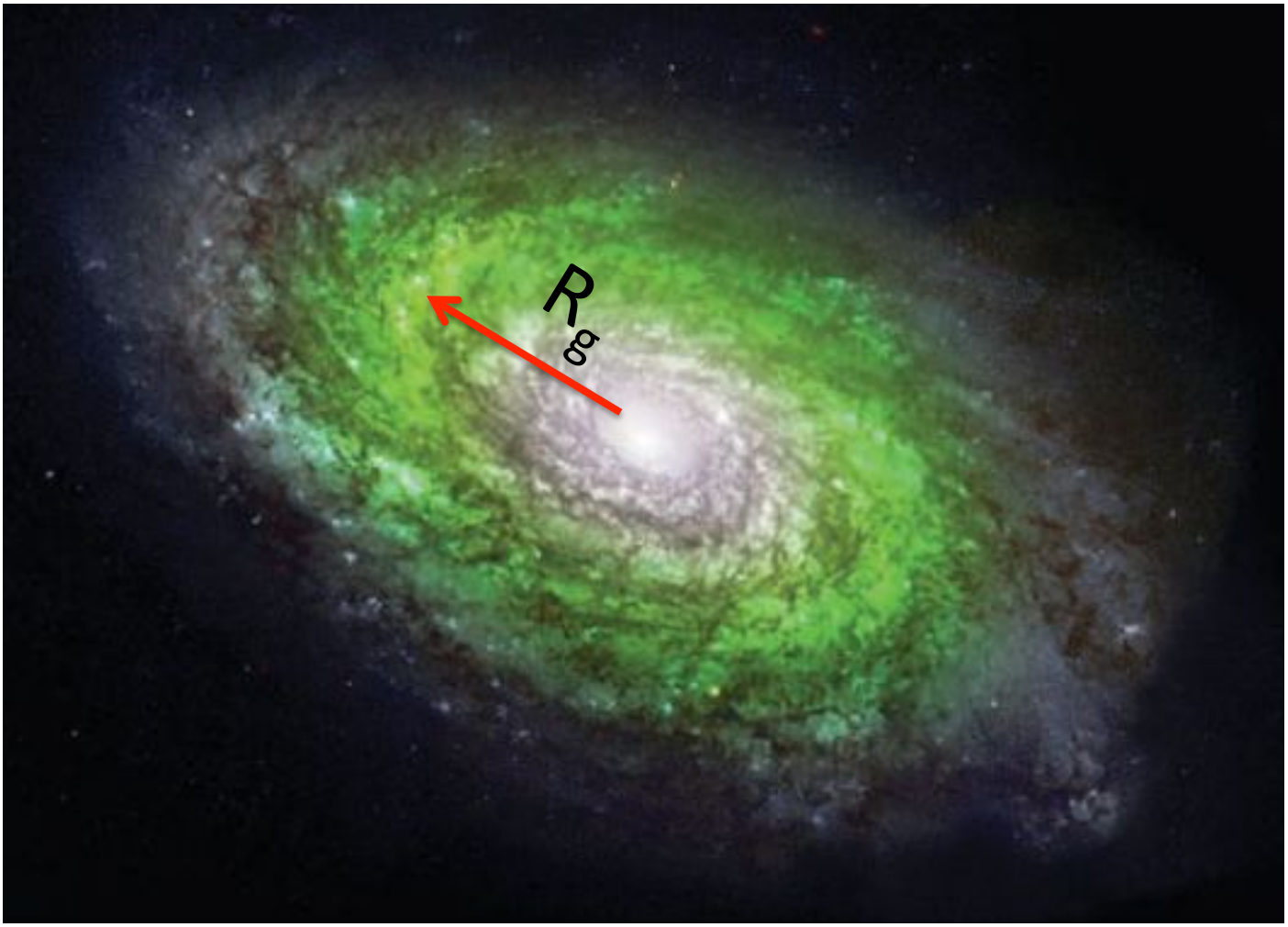
2) Marine life appears rather immune to such events



Galactic habitable zone



Galactic habitable zone. Dependence on R_g?



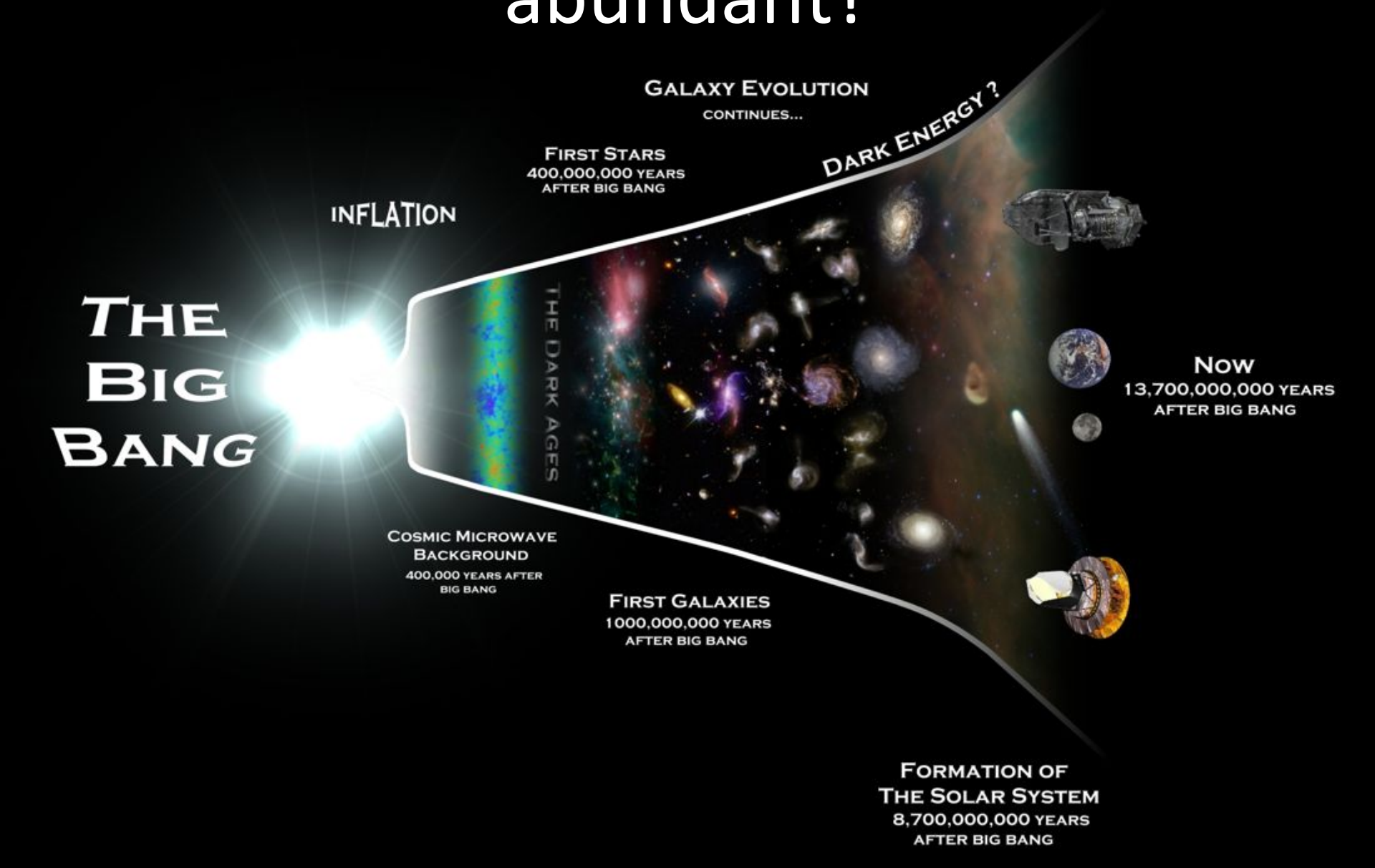
Habitabilidade na Galáxia depende do tempo e raio galactocêntrico R_g, que depende de:

- Metalicidade
- Densidade de estrelas
- Supernovas

Modelo simples, sem considerar migração de estrelas de diferentes R_g na Galáxia

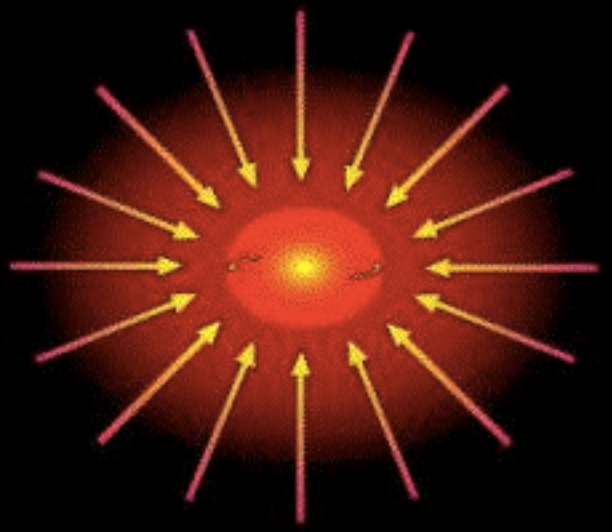
The highlighted green ring in this painting of the Milky Way Galaxy represents what some scientists suspect to be a galactic habitable zone—the only region of the galaxy in which Earth-like planets are likely to be found. However, other scientists think that Earth-like planets could be far more widespread.

At which cosmic time is life more abundant?



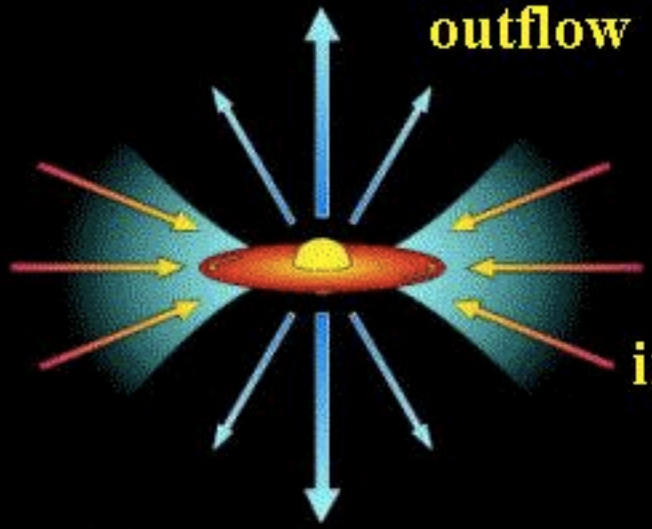
Star and Planet formation

How are single stars born?



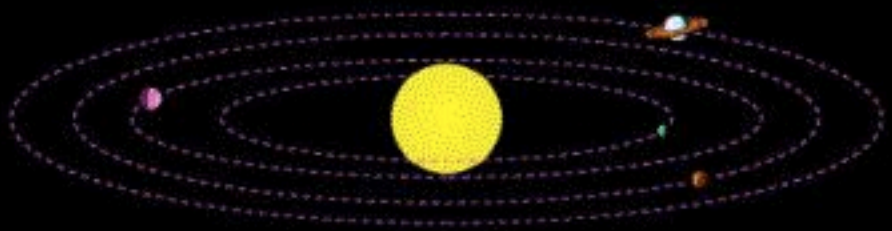
Cloud collapse

x1000
in scale



Rotating disk

Planet formation



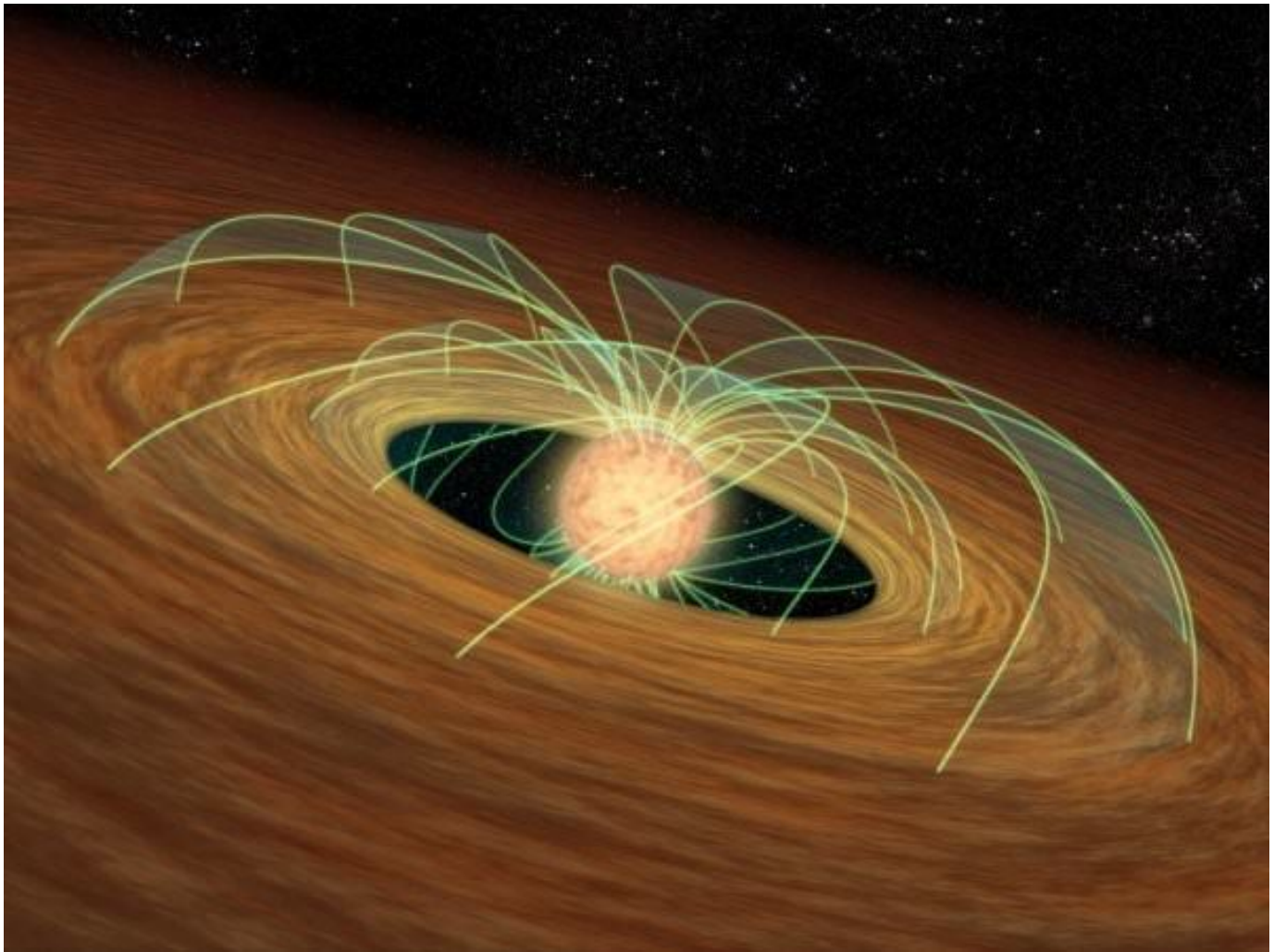
Mature solar system

Scenario largely from indirect tracers.

http://web.gps.caltech.edu/~gab/astrophysics/astrophysics.html

Fig. by McCaughrean

Precisamos conhecer melhor a interação entre o disco estelar e o campo magnético, para conhecer melhor as fases finais de formação da estrela e a evolução do disco proto-planetário



Condensation of solids in the solar nebula → Rocky planet? Giant planet?

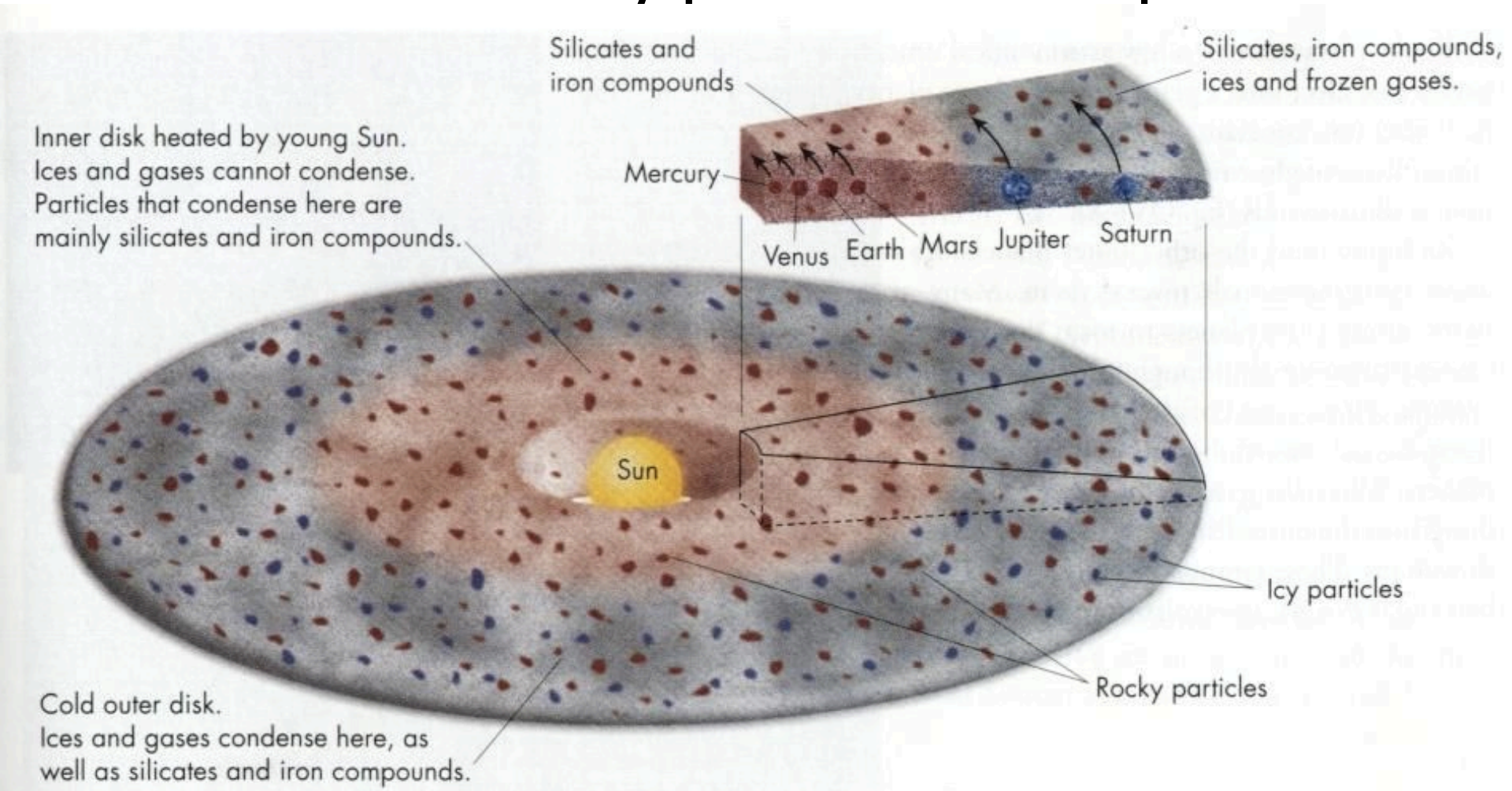
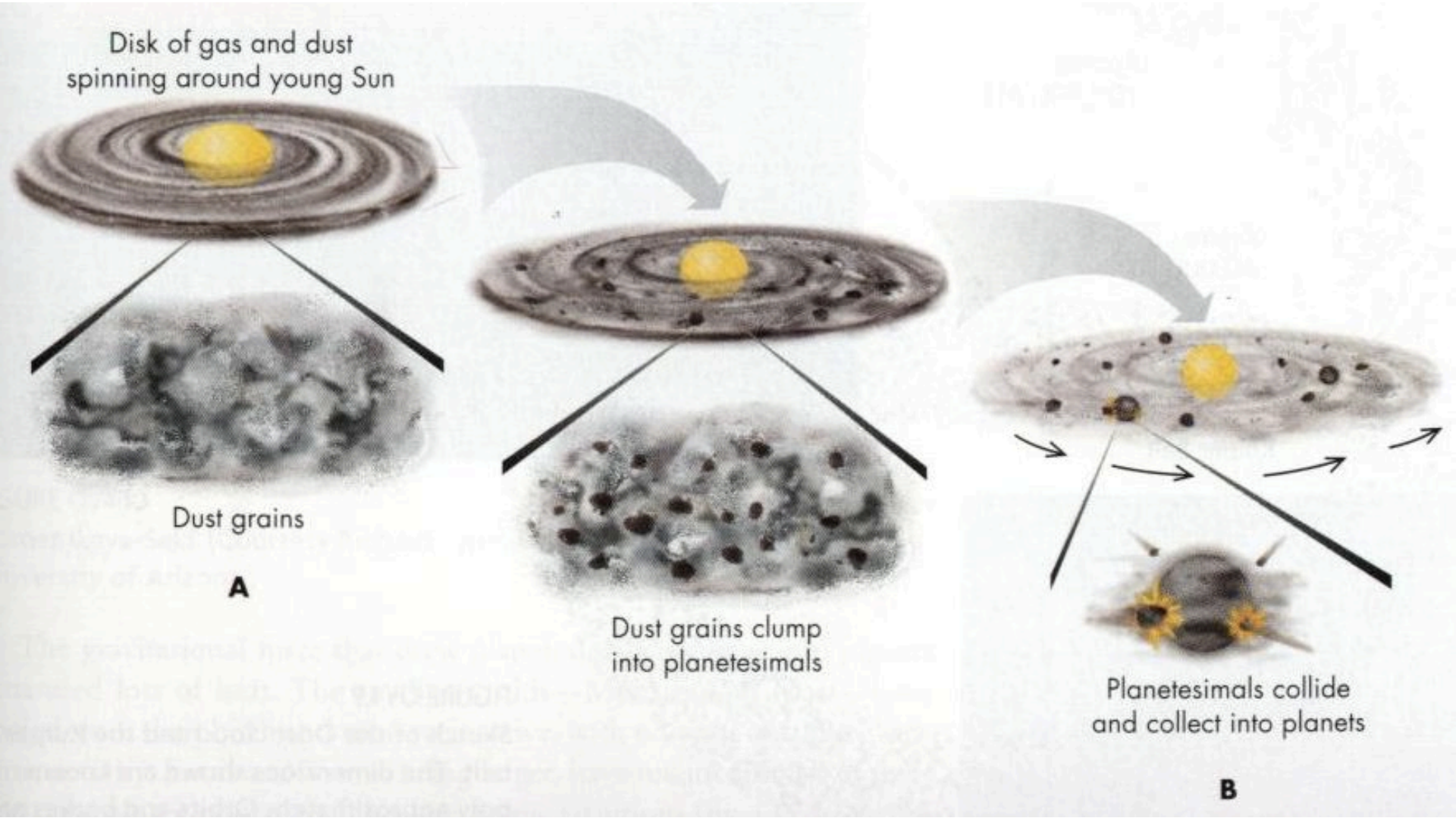


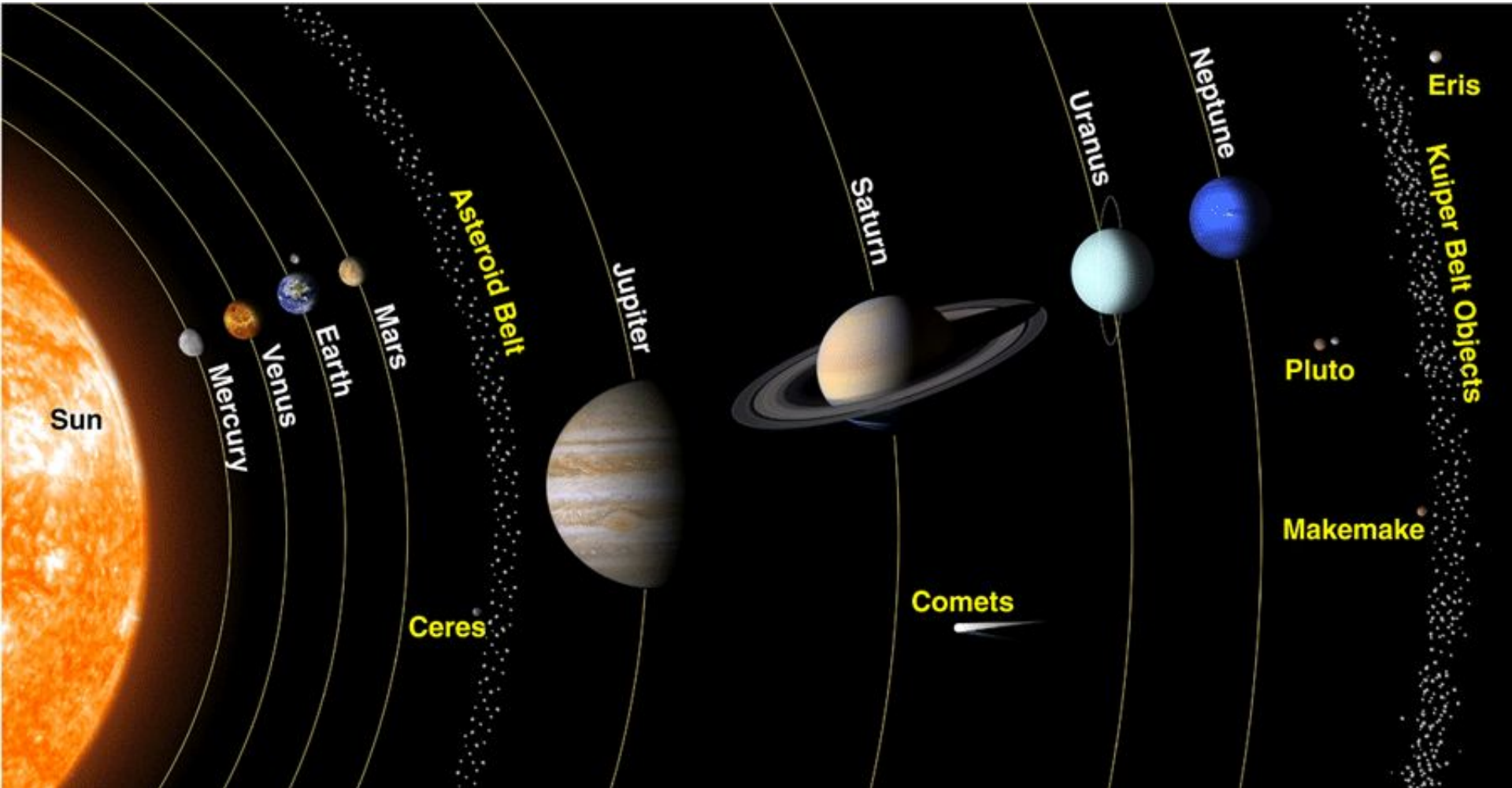
FIGURE OV4.6
Heat from the young Sun prevented ice from condensing in the inner parts of the Solar Nebula. The planetesimals—and ultimately the planets—that formed there are therefore composed mainly of rock and iron.

From dust grains to planets



Solar system:

- High spatial resolution observations
- Direct exploration with space probes
- Rich information on solar system dynamics



Origin of water in the inner Solar System: planetesimals scattered inward during Jupiter and Saturn's rapid gas accretion

Sean N. Raymond[a] & Andre Izidoro[a,b]

Abstract

There is a long-standing debate regarding the origin of the terrestrial planets' water as well as the hydrated C-type asteroids. Here we show that the inner Solar System's water is a simple byproduct of the giant planets' formation. Giant planet cores accrete gas slowly until the conditions are met for a rapid phase of runaway growth. As a gas giant's mass rapidly increases, the orbits of nearby planetesimals are destabilized and gravitationally scattered in all directions. Under the action of aerodynamic gas drag, a fraction of scattered planetesimals are deposited onto stable orbits interior to Jupiter's. This process is effective in populating the outer main belt with C-type asteroids that originated from a broad (5-20 AU-wide) region of the disk. As the disk starts to dissipate, scattered planetesimals reach sufficiently eccentric orbits to cross the terrestrial planet region and deliver water to the growing Earth. This mechanism does not depend strongly on the giant planets' orbital migration history and is generic: whenever a giant planet forms it invariably pollutes its inner planetary system with water-rich bodies.

Simulations of Water Delivery to Earth's region during grow of Jupiter & Saturn

Raymond & Izidoro (2017)

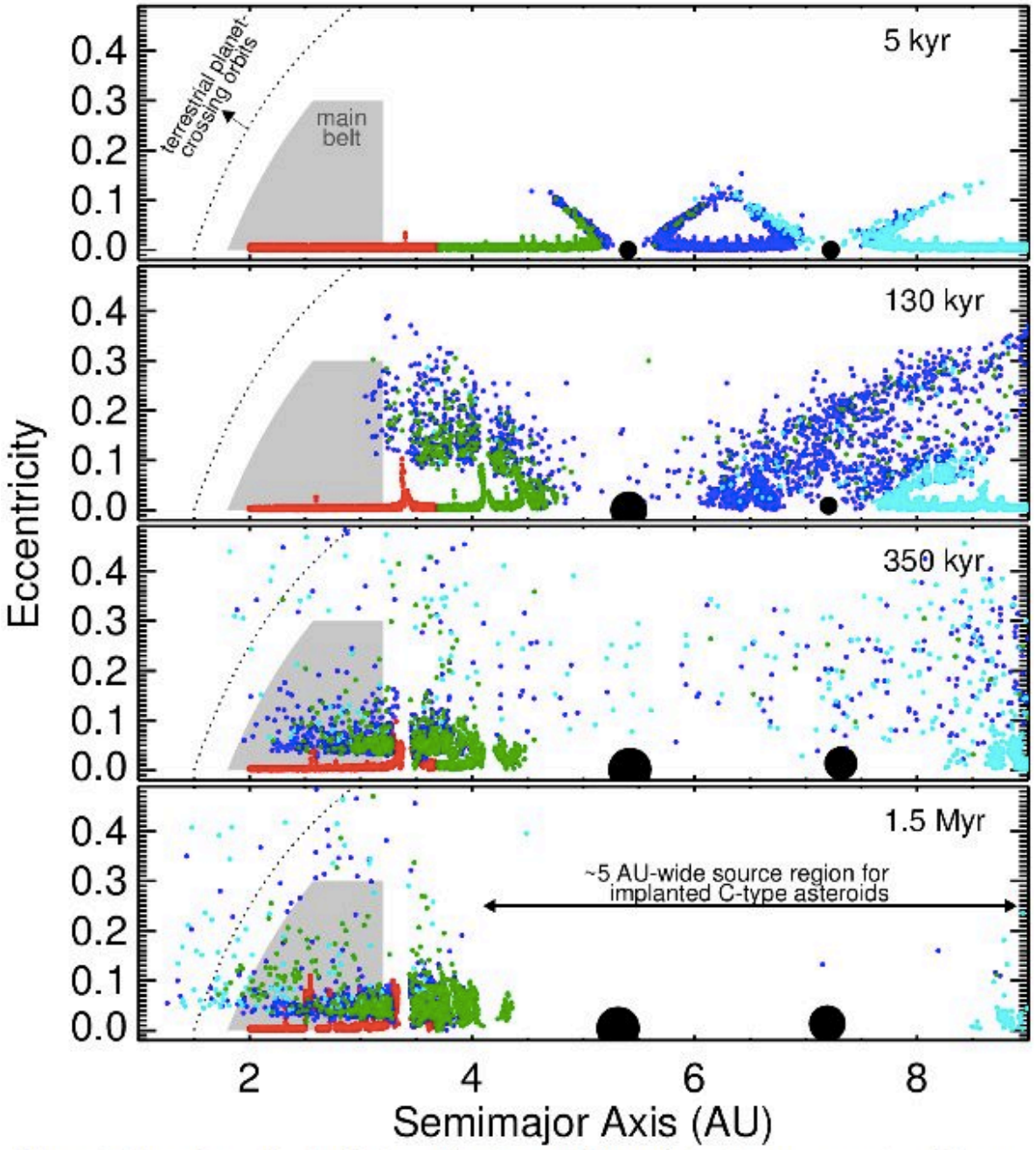
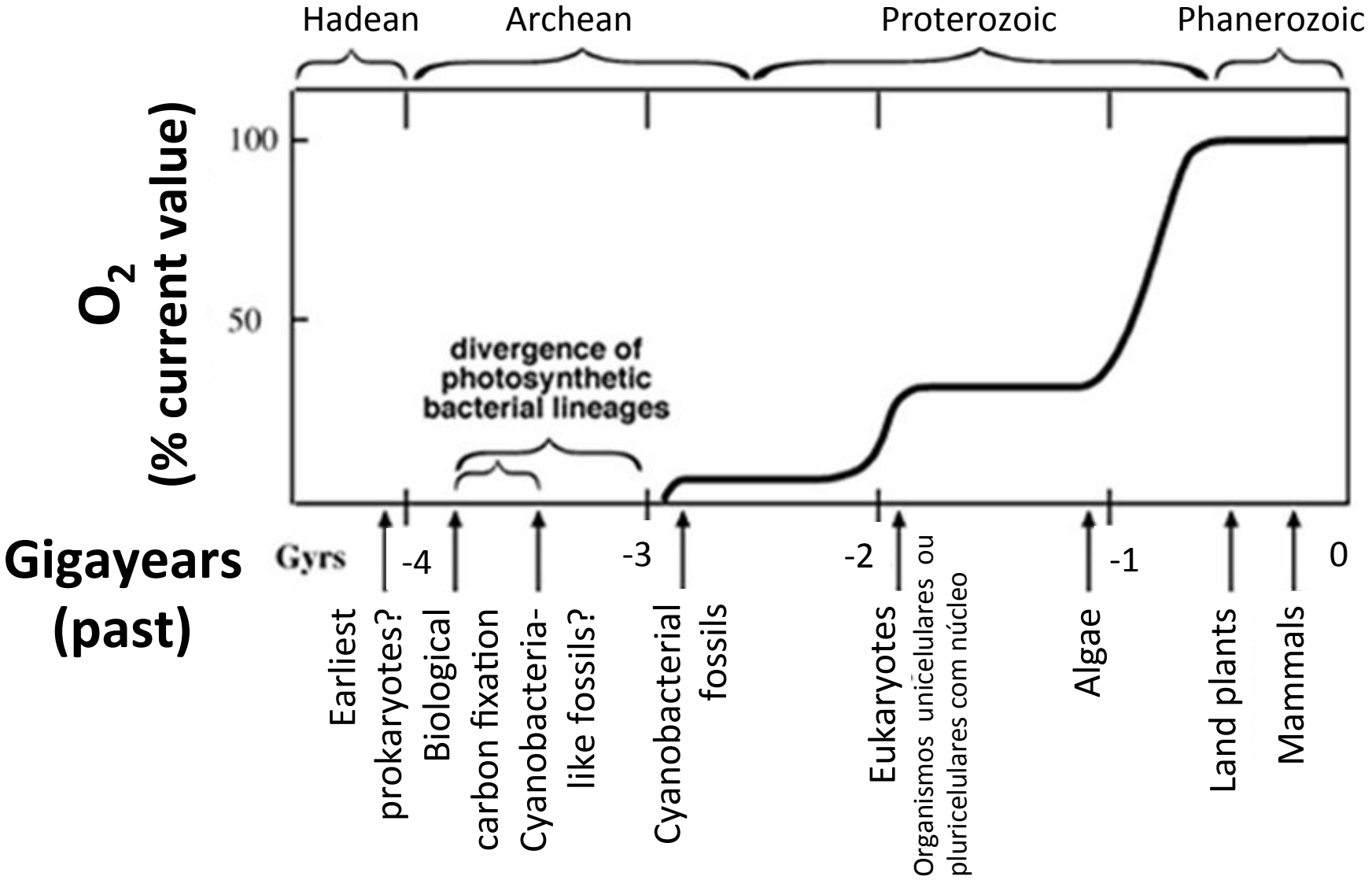
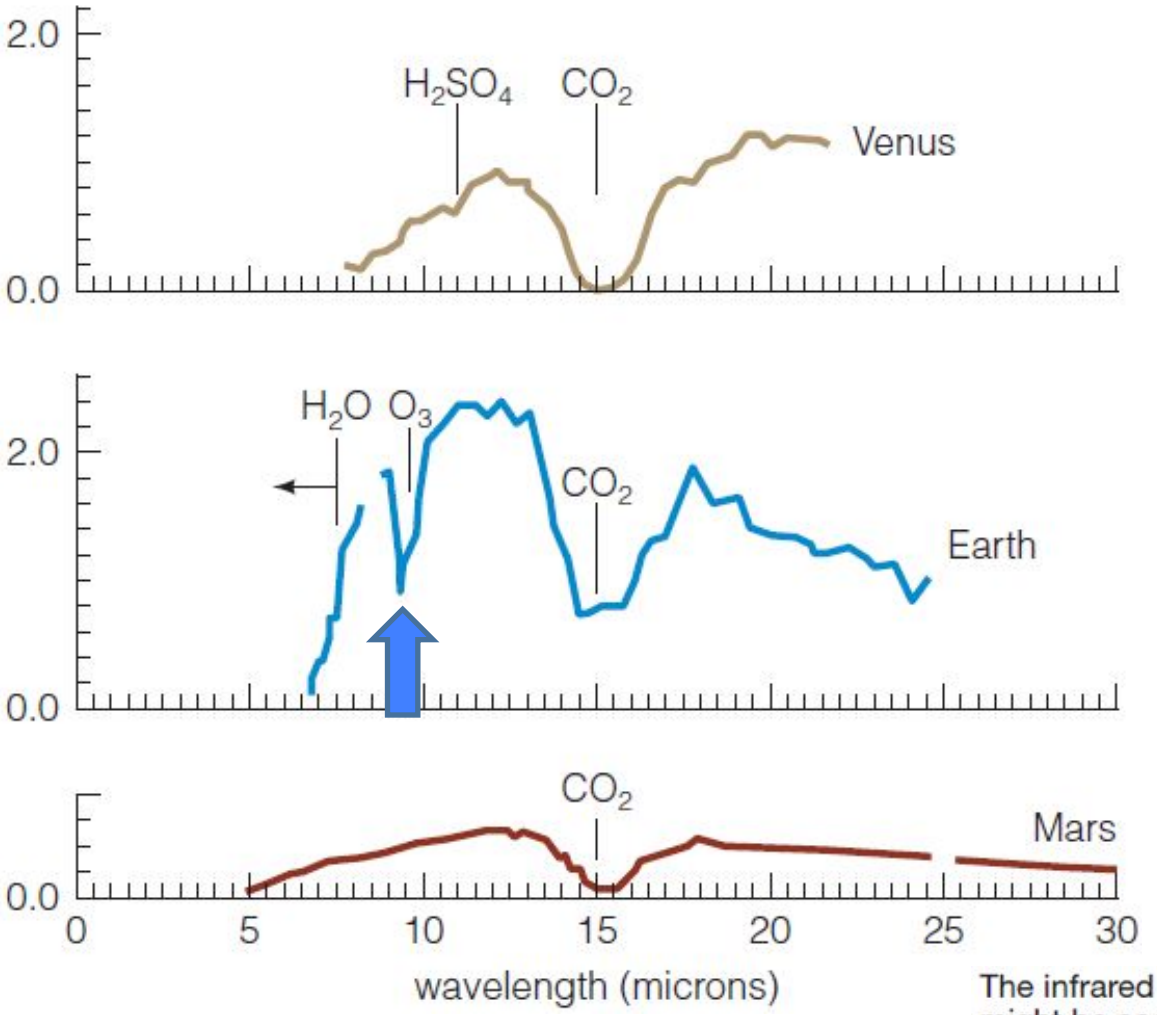


Figure 2: Snapshots of a simulation of Jupiter and Saturn's in-situ gas accretion. Planetesimals are color-coded simply by their starting orbital radius. Here Jupiter's grew linearly from a $3\,M_\oplus$ core to its full mass from 100-200 kyr and Saturn from 300-400 kyr. The

Cyanobacteria produced the oxygen in the early Earth's atmosphere



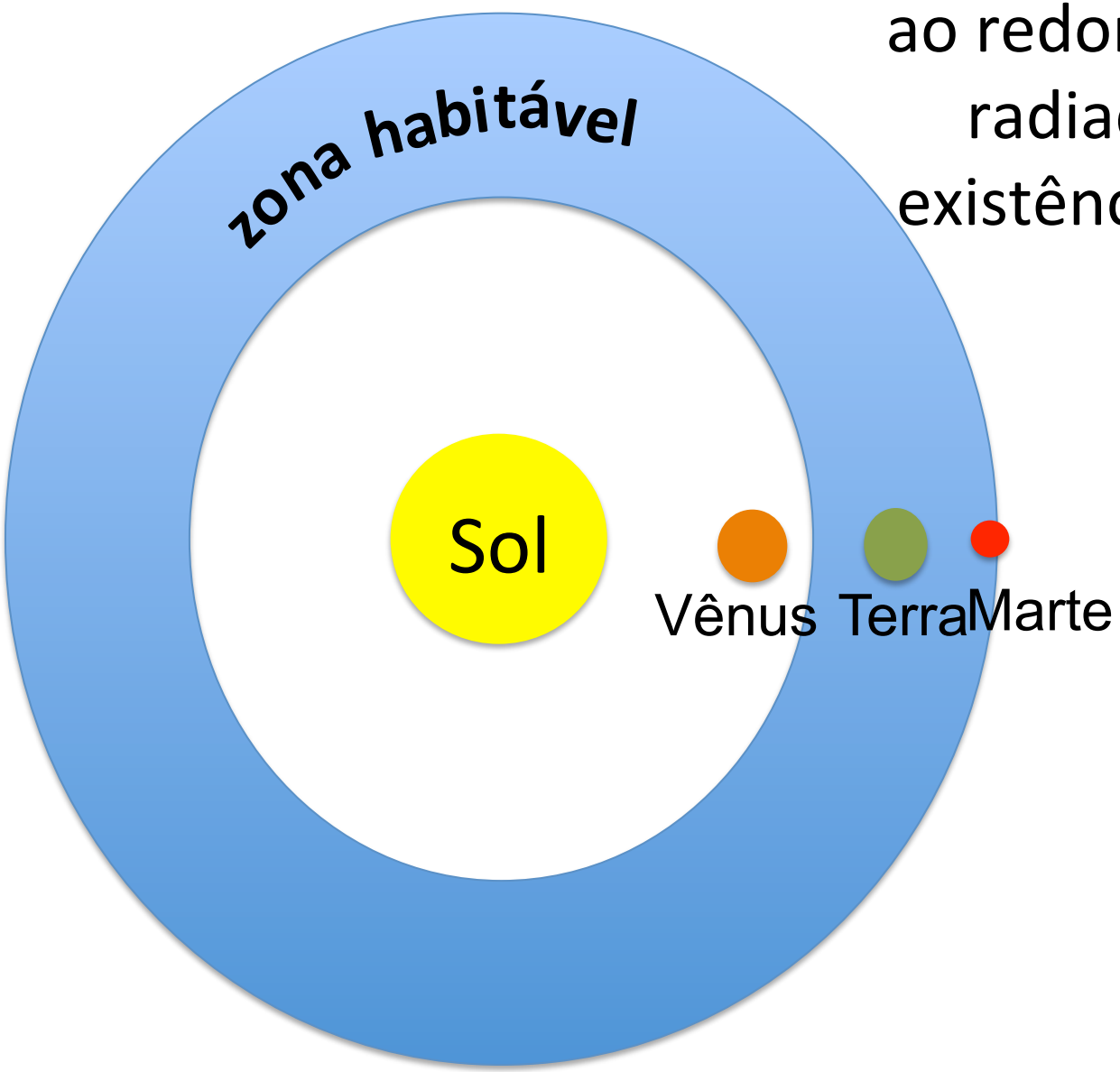
Signatures of life in an Earth-like planet



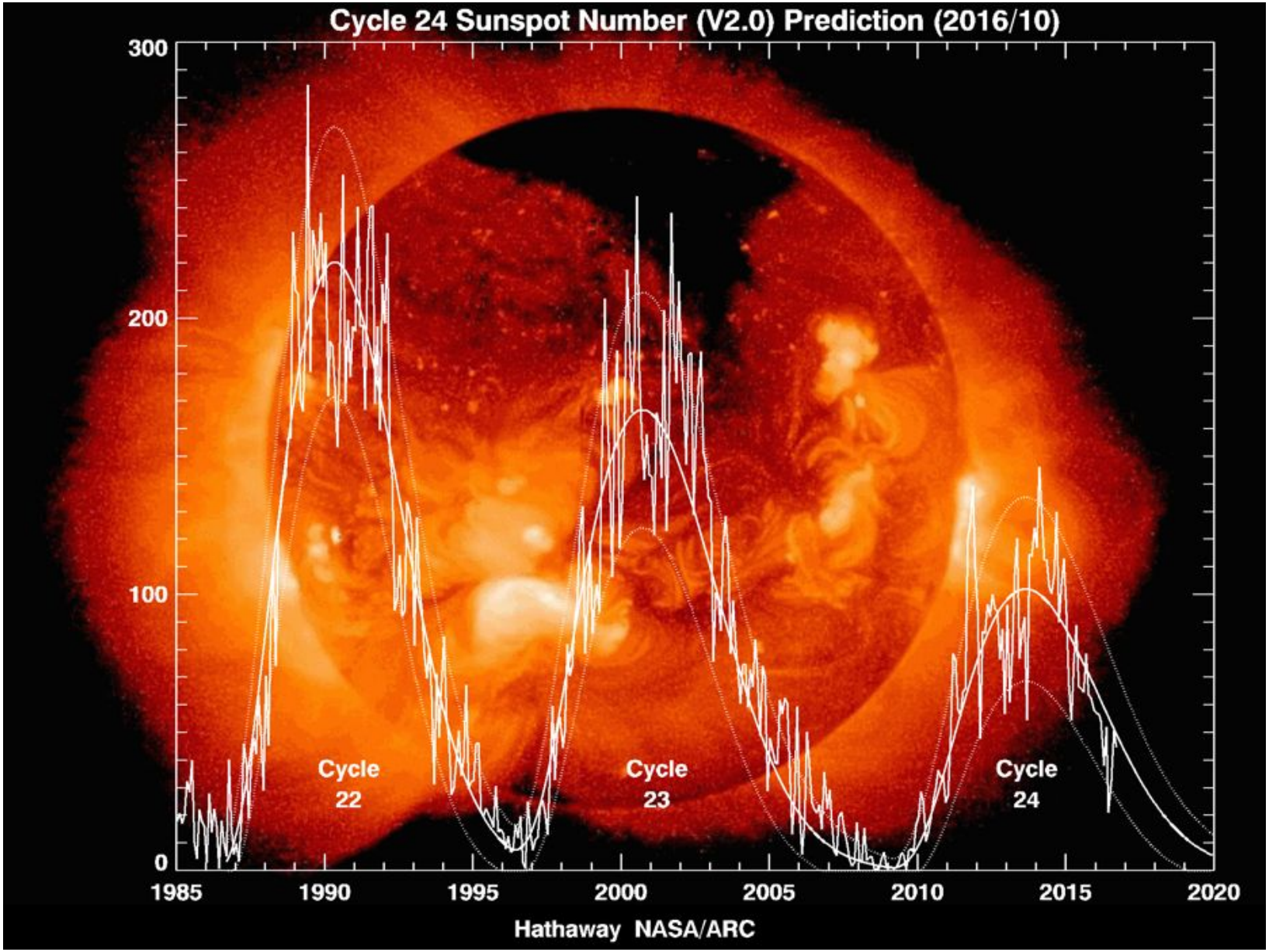
O_3: life indicator?

The infrared spectra of Venus, Earth, and Mars, as they might be seen from afar, showing absorption features that point to the presence of carbon dioxide (CO_2), ozone (O_3), and sulfuric acid (H_2SO_4) in their atmospheres. While carbon dioxide is present in all three spectra, only our own planet has appreciable oxygen (and hence ozone)—a product of photosynthesis. If we could make similar spectral analyses of distant planets, we might detect atmospheric gases that would indicate life.

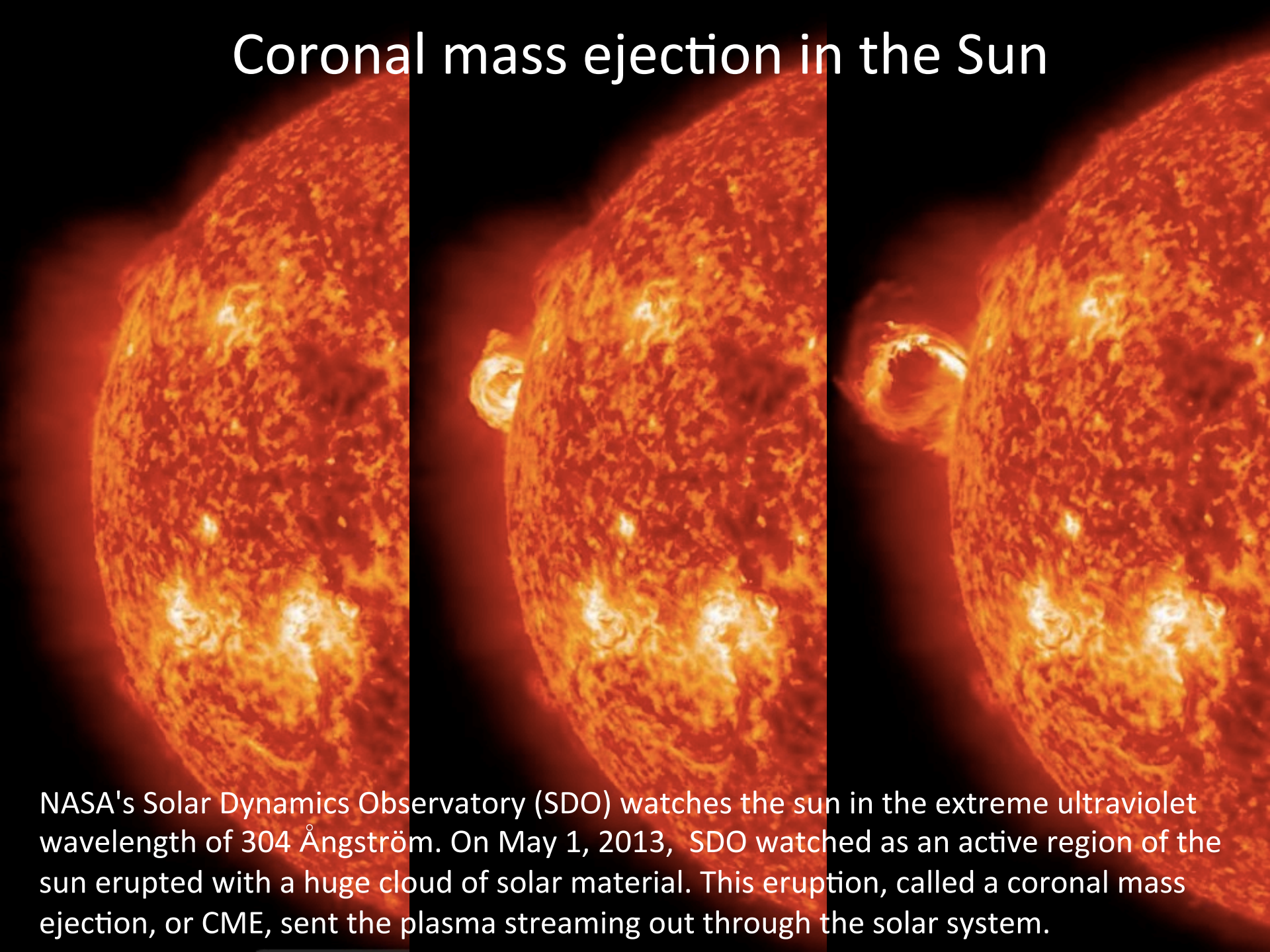
A **zona habitável** é uma região ao redor da estrela onde a radiação dela permite a existência de **água líquida**



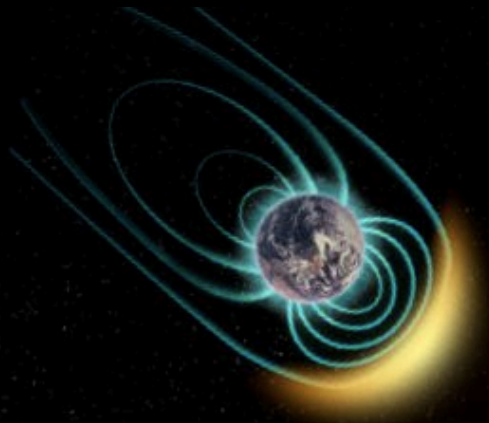
Conditions for habitability beyond water



Coronal mass ejection in the Sun



NASA's Solar Dynamics Observatory (SDO) watches the sun in the extreme ultraviolet wavelength of 304 Ångström. On May 1, 2013, SDO watched as an active region of the sun erupted with a huge cloud of solar material. This eruption, called a coronal mass ejection, or CME, sent the plasma streaming out through the solar system.



Stellar magnetic activity and their effects on planets

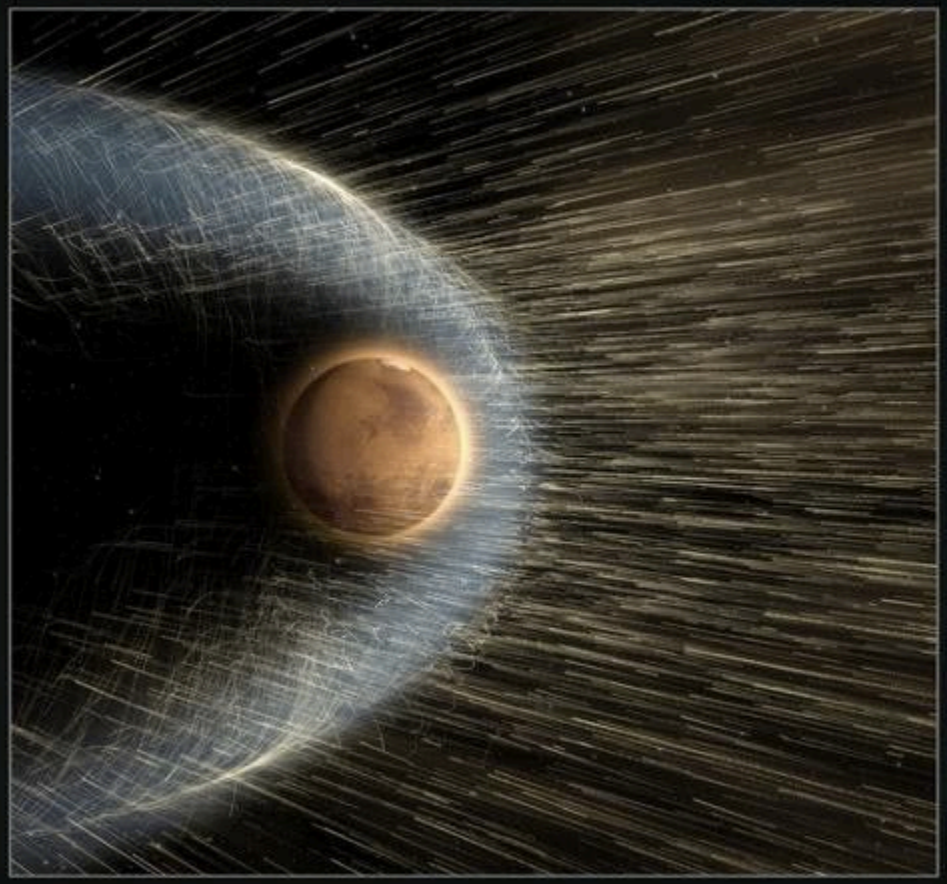
Aline Vidotto

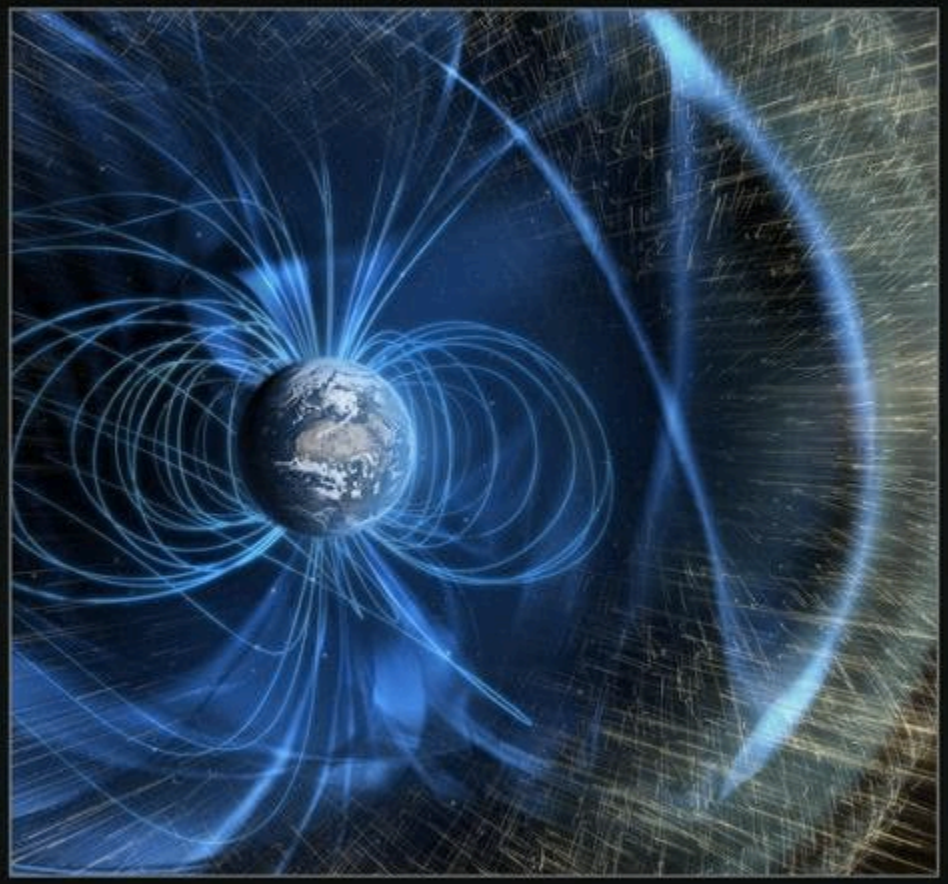
Trinity College Dublin
The University of Dublin

Is Mars suitable for life?

HST

Mars has lost most of its atmosphere
(due to its low mass but also due to solar wind)





NASA

POR **CESAR BAIMA** **22/2/2017**

CIÊNCIA

Trappist-1

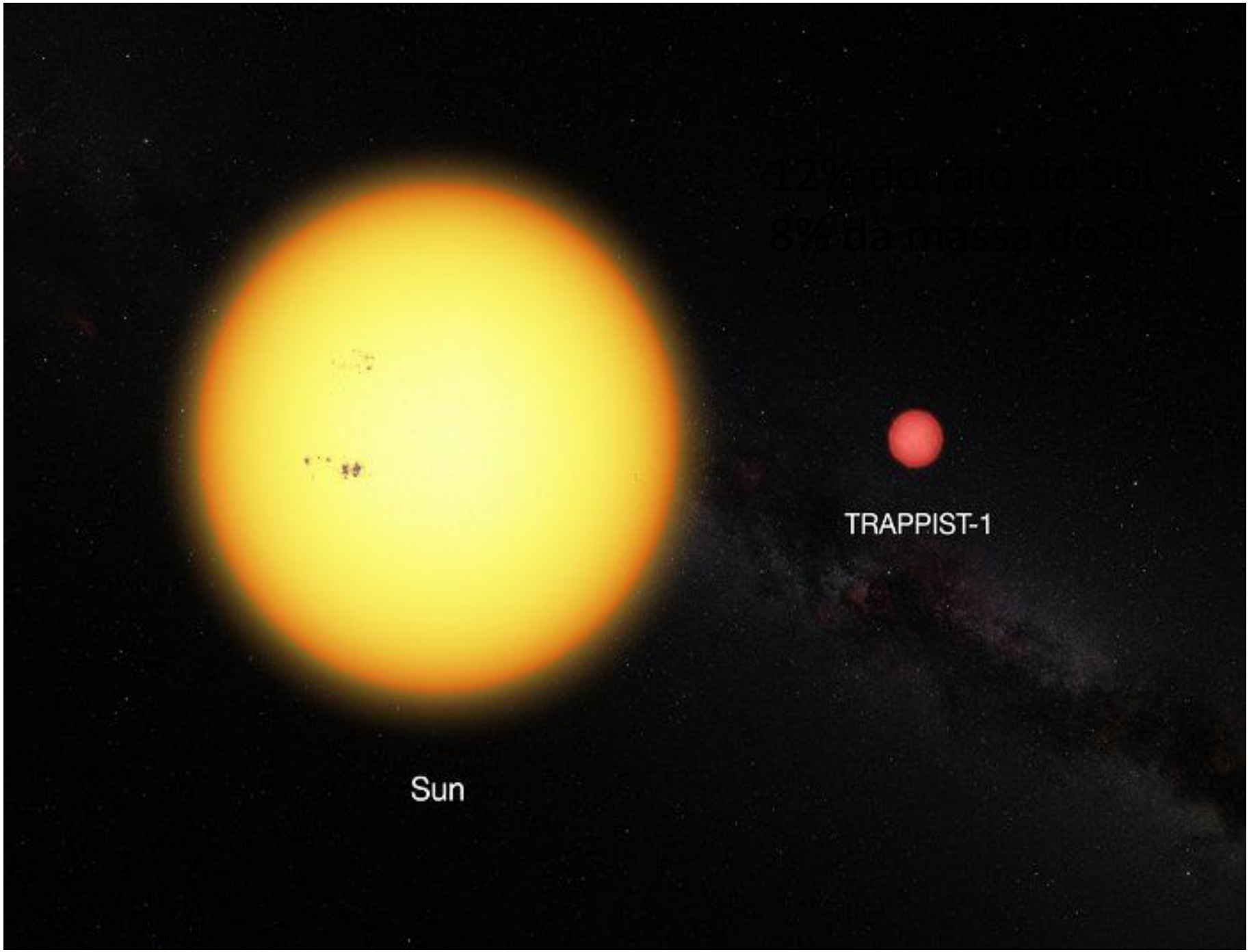
DESCOBERTO SISTEMA COM SETE PLANETAS SIMILARES À TERRA

Objetos orbitam estrela anã a distâncias que permitiram existência de água em estado líquido na sua superfície, condição para abrigar vida como conhecemos

NASA

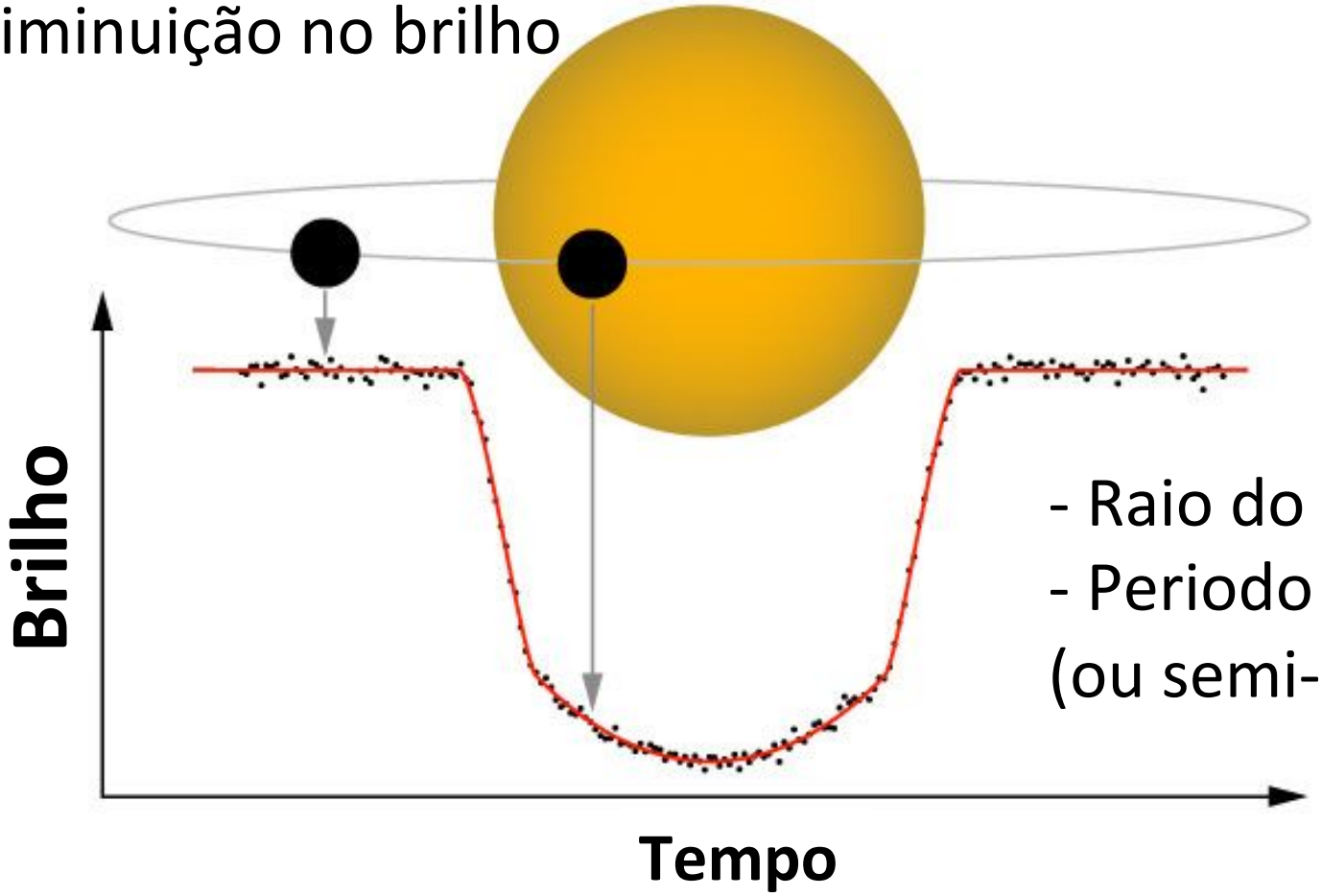
TRAPPIST:
TRAnsiting Planets
& PlanetesImals
Small Telescope–
South

Telescópio Trappist
(60 cm) no
Observatório
La Silla do ESO


12% do raio do sol
8% da massa do sol
TRAPPIST-1
Sun

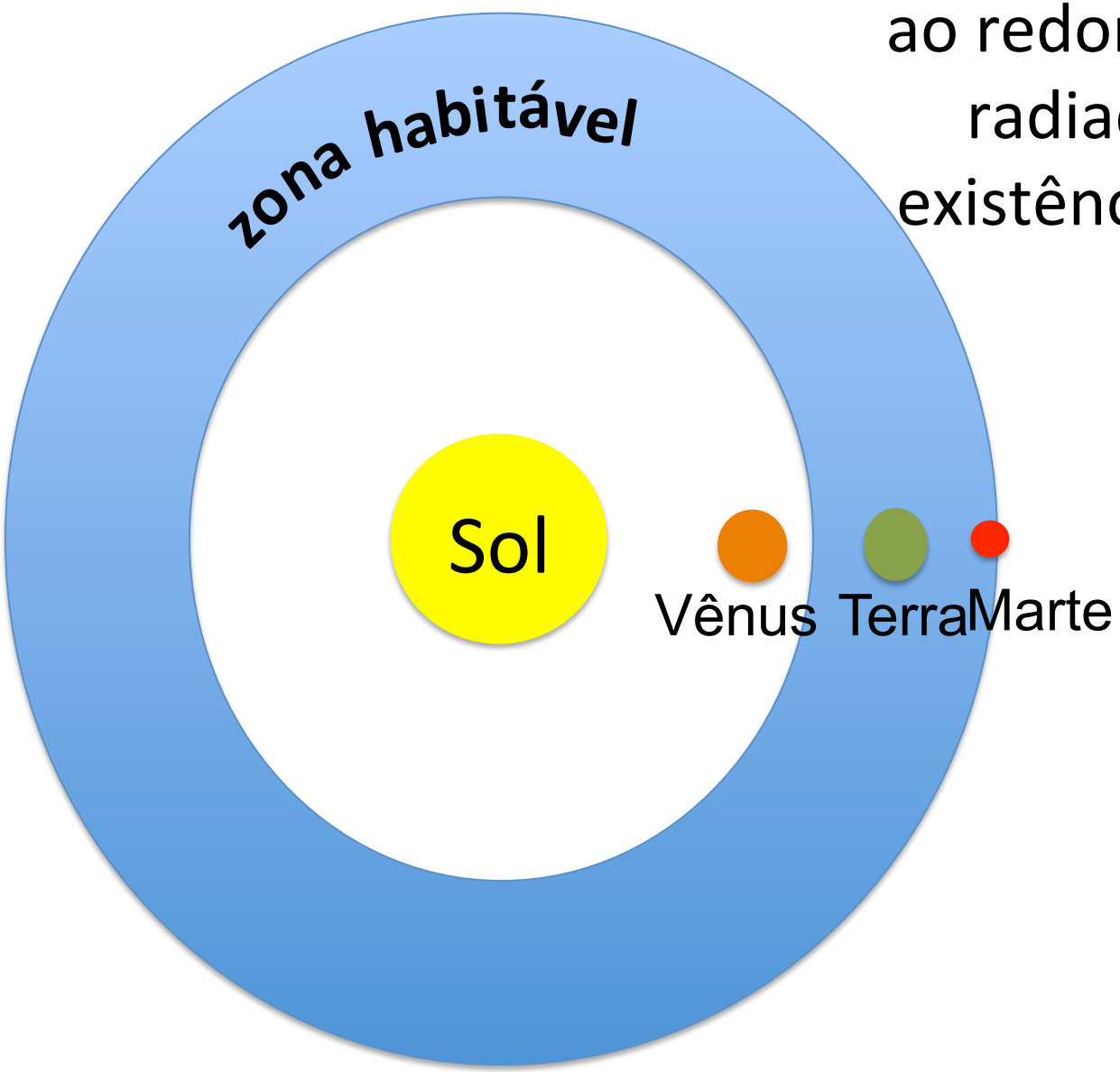
Detecção de planetas: método de trânsito

Exoplaneta pode ser detectado pelo bloqueio da luz da estrela na sua passagem diante desta, causando uma diminuição no brilho

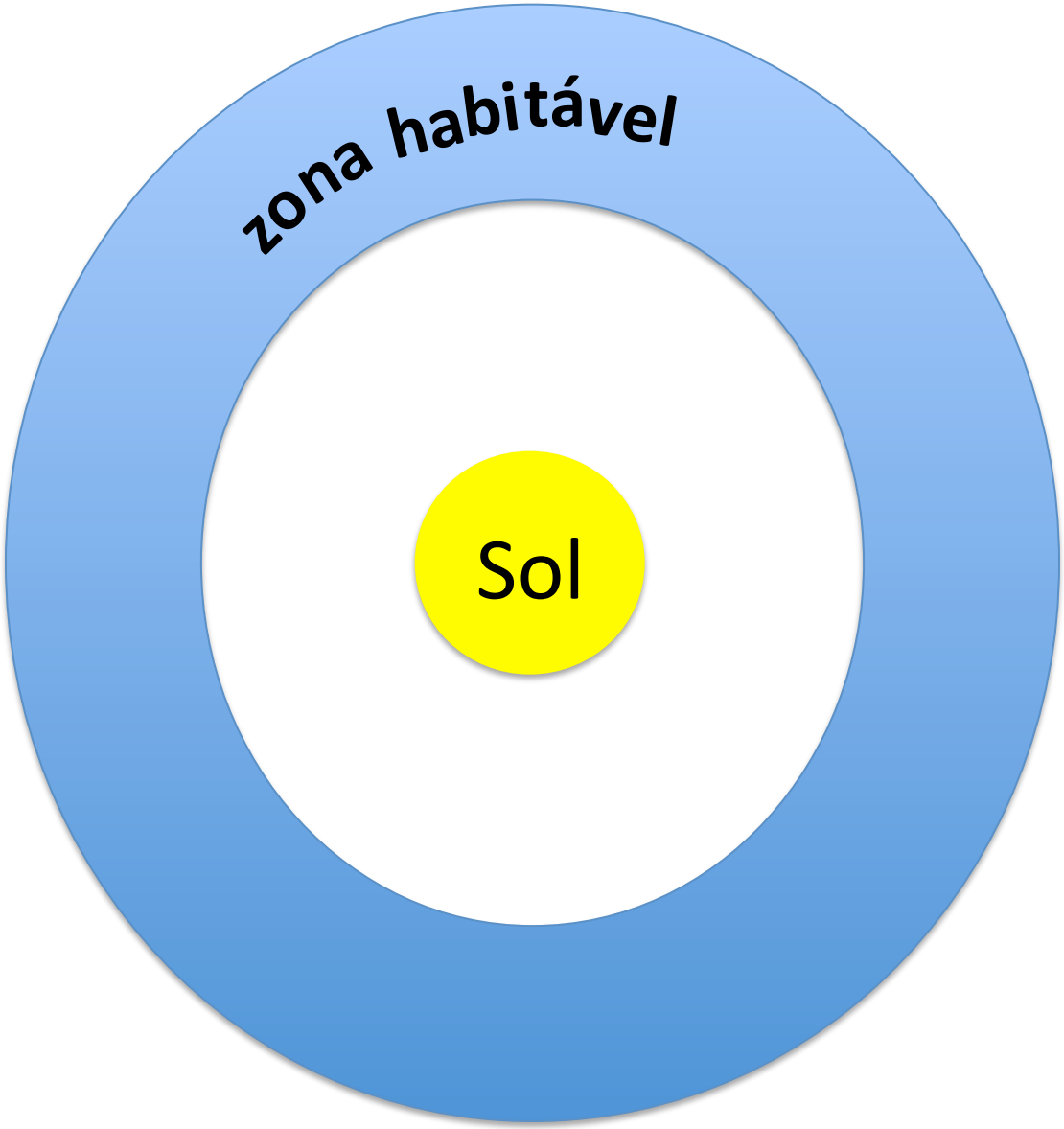


- Raio do exoplaneta
- Periodo orbital
(ou semi-eixo maior)

A **zona habitável** é uma região ao redor da estrela onde a radiação dela permite a existência de **água líquida**



Sistema Solar



Estrelas menores tem uma zona habitável menor

Trappist-1

POR **CESAR BAIMA**

22/02/2017

CIÊNCIA

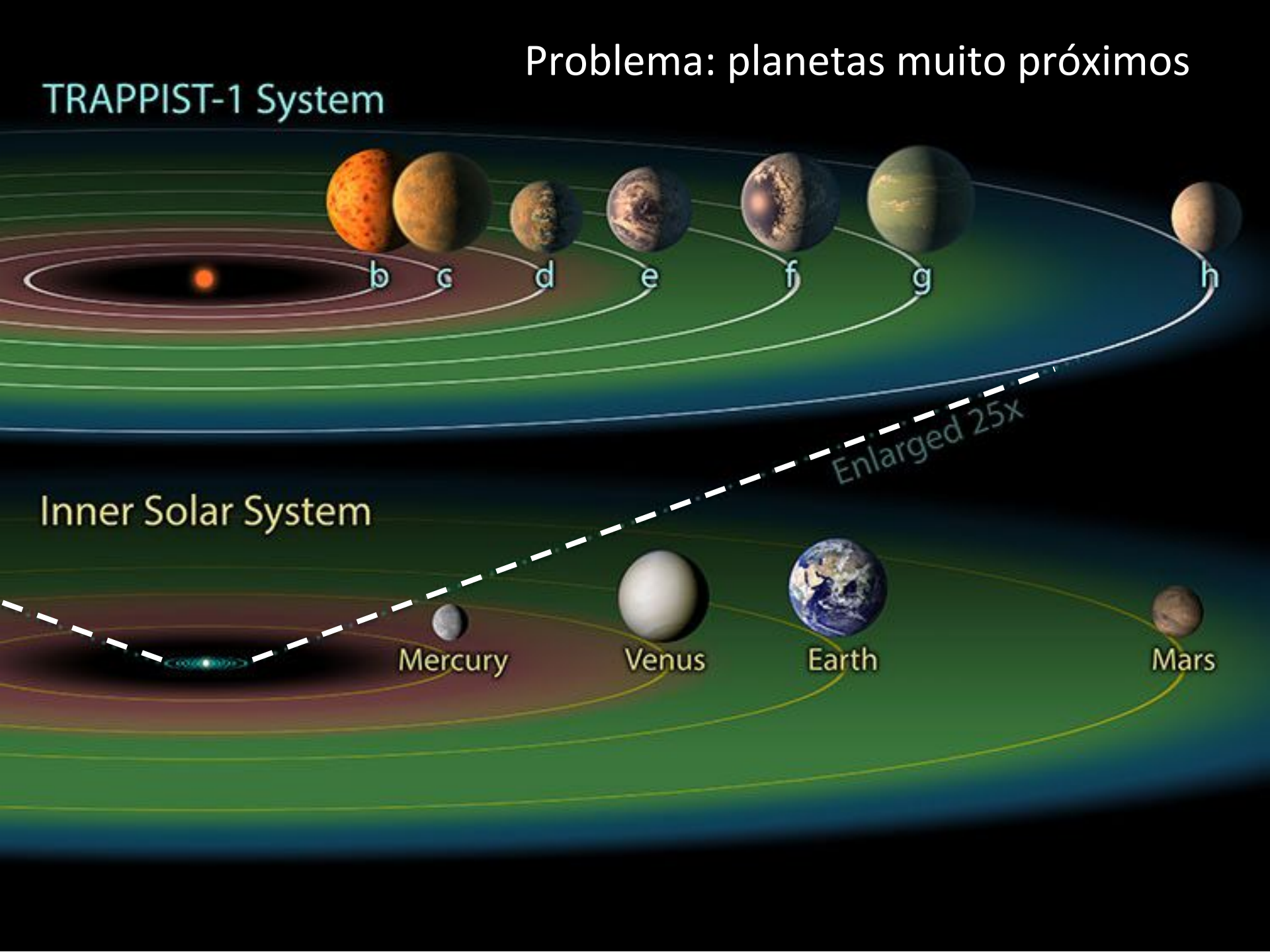
DESCOBERTO SISTEMA COM SETE PLANETAS SIMILARES À TERRA

Objetos orbitam estrela anã a distâncias que permitiram existência de água em estado líquido na sua superfície, condição para abrigar vida como conhecemos

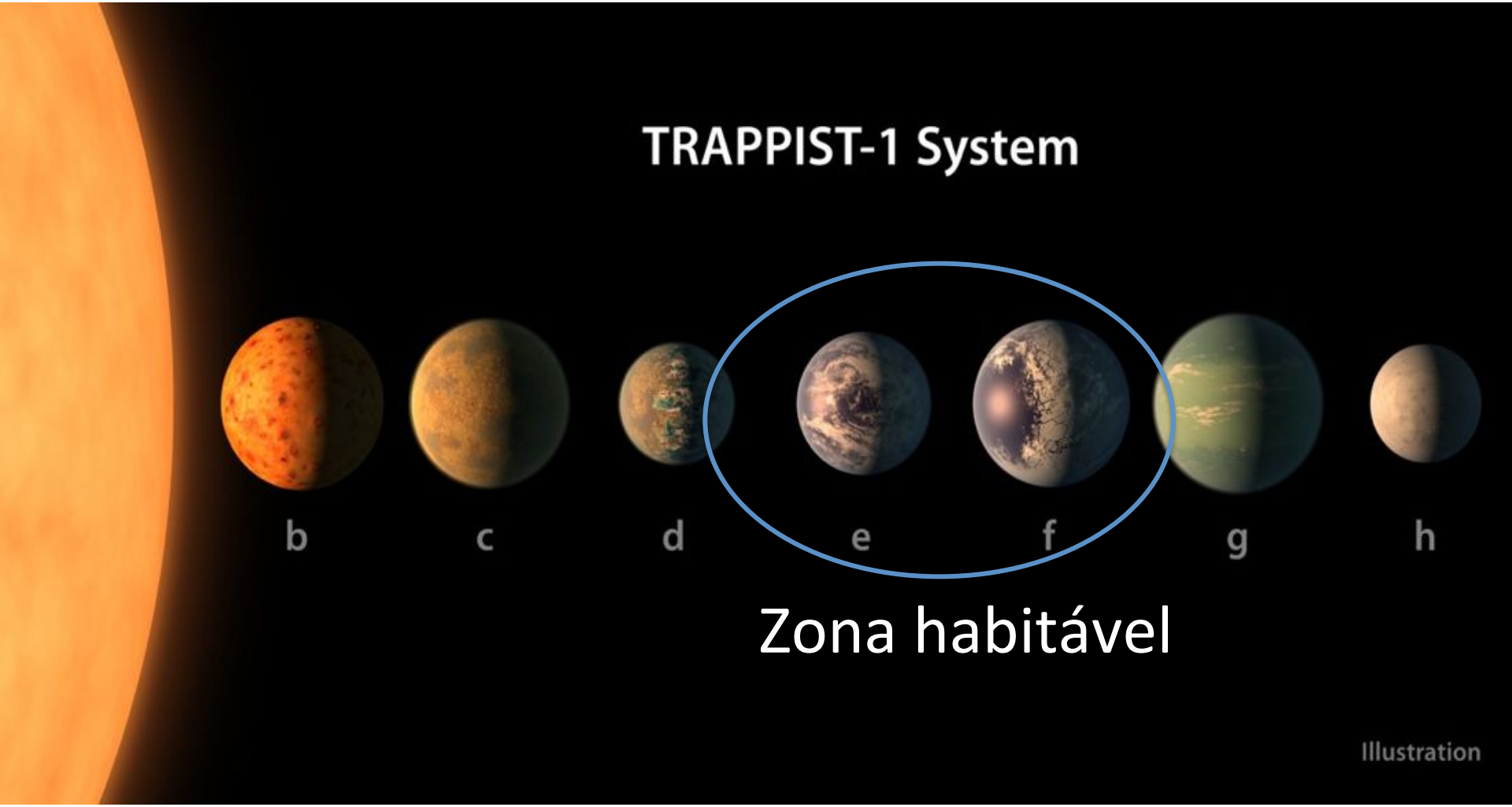
NASA Spitzer

ESO Trappist VLT + outros telescópios

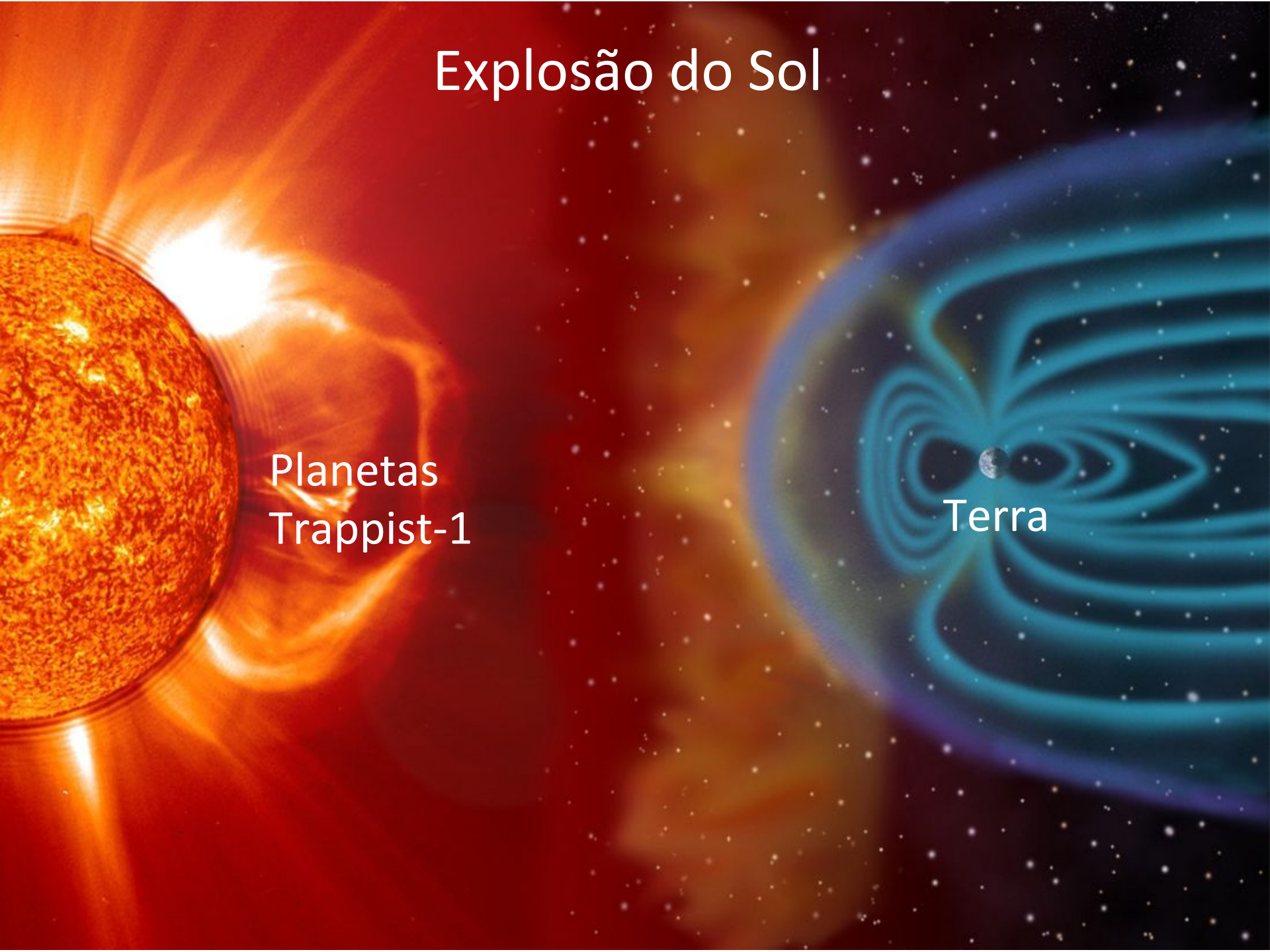
Problema: planetas muito próximos



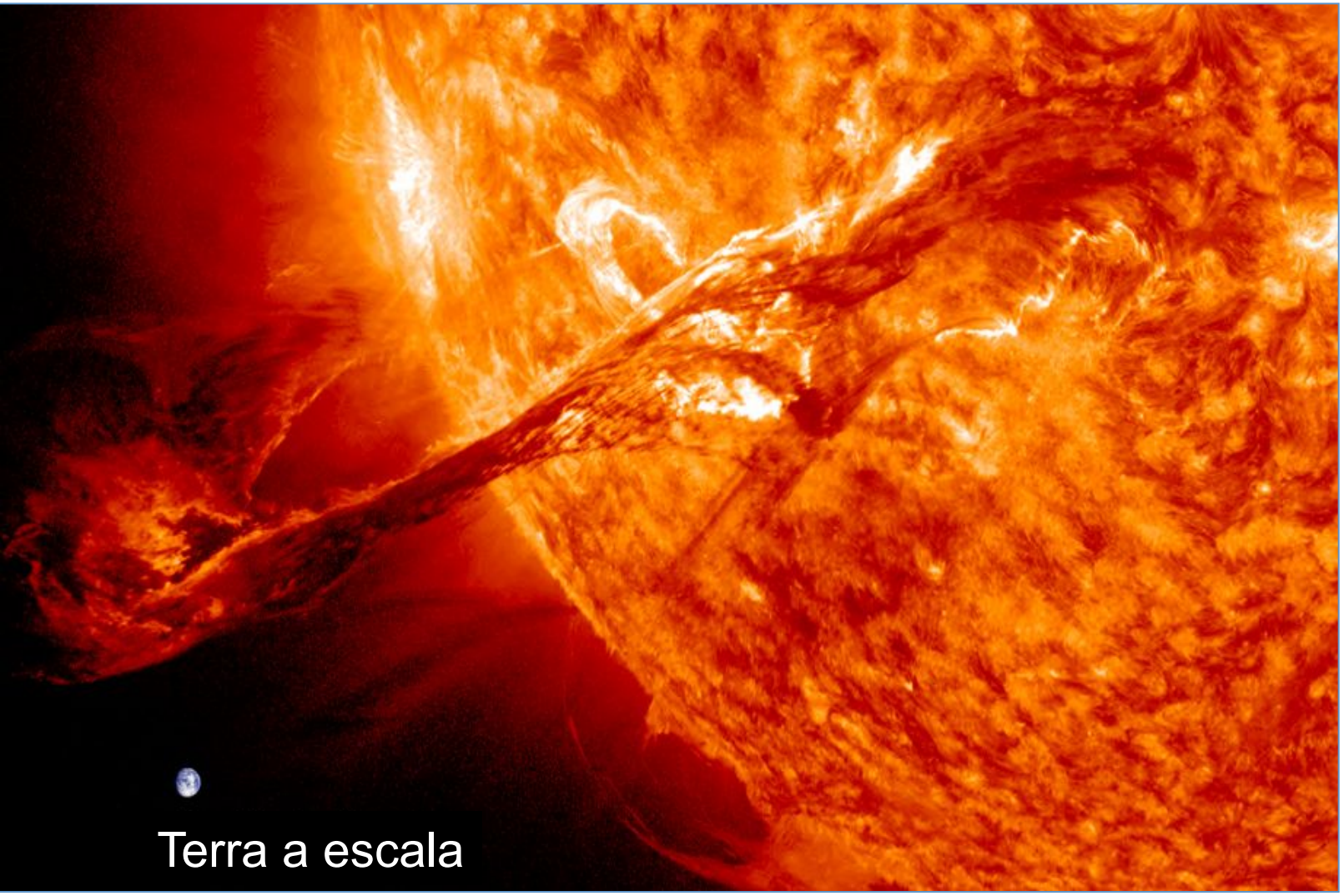
Afetados por forças de maré, planetas de Trappist-1 apresentam sempre a mesma face à estrela → forte contraste de temperatura



Explosão do Sol

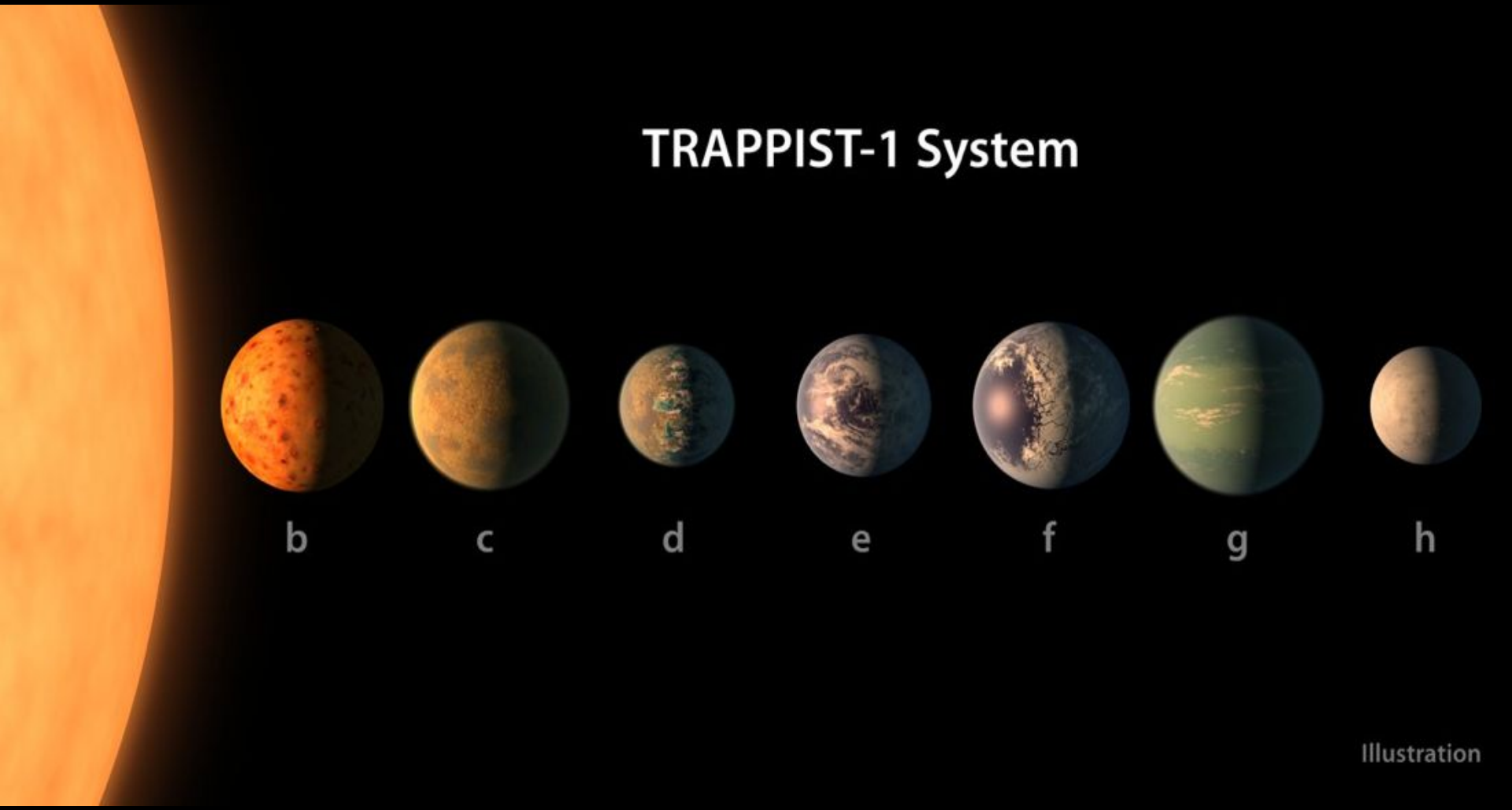


Trappist-1 tem super explosões, 100 X maiores que no Sol



Sol no 31/8/2012

Conclusão: poucas chances para a vida em planetas da Trappist-1



Outros fatores que podem afetar a vida: asteroides

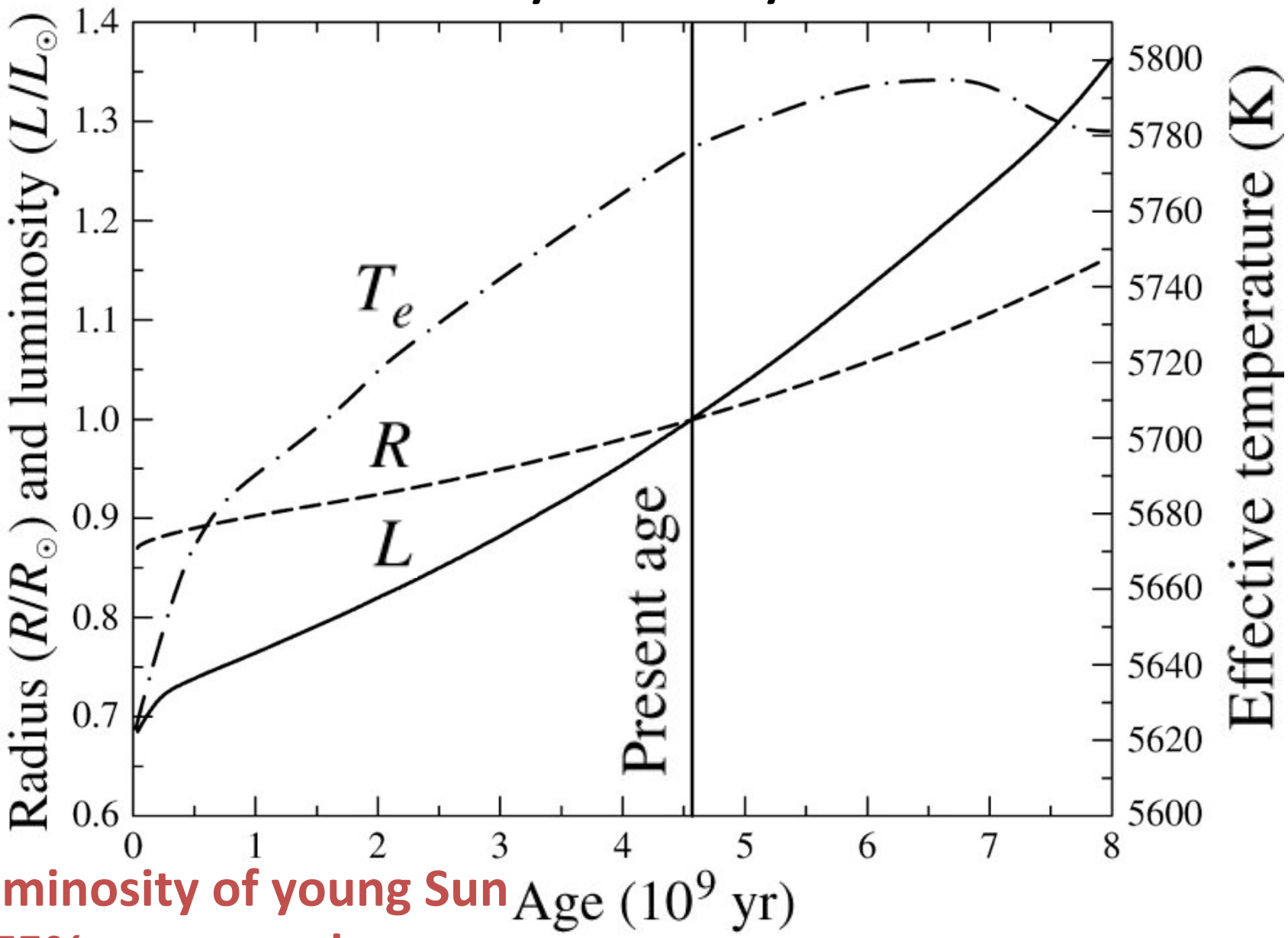
Asteroids can affect the evolution of life, like for the extinction of the dinosaurs

How the evolution of the Sun + climate on Earth (and life) affects habitability?

Terra *snowball*

Terra aquecida pelo efeito estufa do metano

Evolutionary history of the Sun

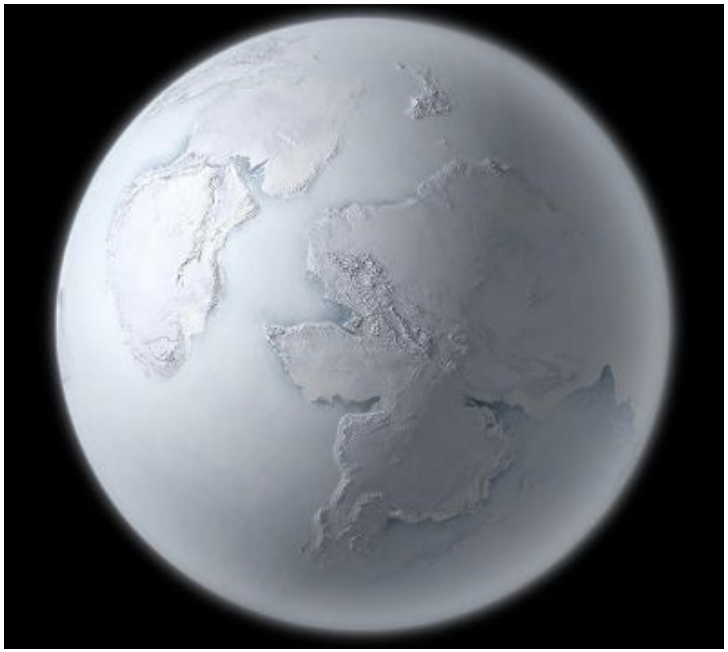


Luminosity of young Sun ~ 75% current value

Faint young Sun paradox

Paradoxo do jovem Sol fraco

O problema do jovem Sol fraco é a contradição aparente entre observações de água líquida no início da história da Terra, e a predição de que o brilho do Sol na época era de apenas 75% em relação ao presente, insuficiente para manter água no estado líquido



SNOWBALL: a Terra nos seus primórdios?

JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118, 1–18, doi:10.1002/jgrd.50808, 2013

Exploring the faint young Sun problem and the possible climates of the Archean Earth with a 3-D GCM

B. Charnay,[1] F. Forget,[1] R. Wordsworth,[2] J. Leconte,[1] E. Millour,[1]
F. Codron,[1] and A. Spiga[1]

[9] Methane has been suggested as an important complement to CO_2 to warm the early Earth [*Kiehl and Dickinson*, 1987]. It can absorb thermal radiation at 7–8 μm, thus at the edge of the atmospheric window (8–12 μm), where CO_2 cannot. It can therefore produce an efficient warming. In an anoxic atmosphere, the lifetime of methane is 1000 times higher than today [*Zahnle*, 1986; *Kasting and Howard*, 2006]. During the Archean, methane would have been released by methanogenic bacteria through the reaction:

$$CO_2 + 4H_2 \Rightarrow CH_4 + 2H_2O \qquad (1)$$

where H_2 comes from hydrothermal sources and volcanoes, or from the primitive atmosphere [*Tian et al.*, 2005].

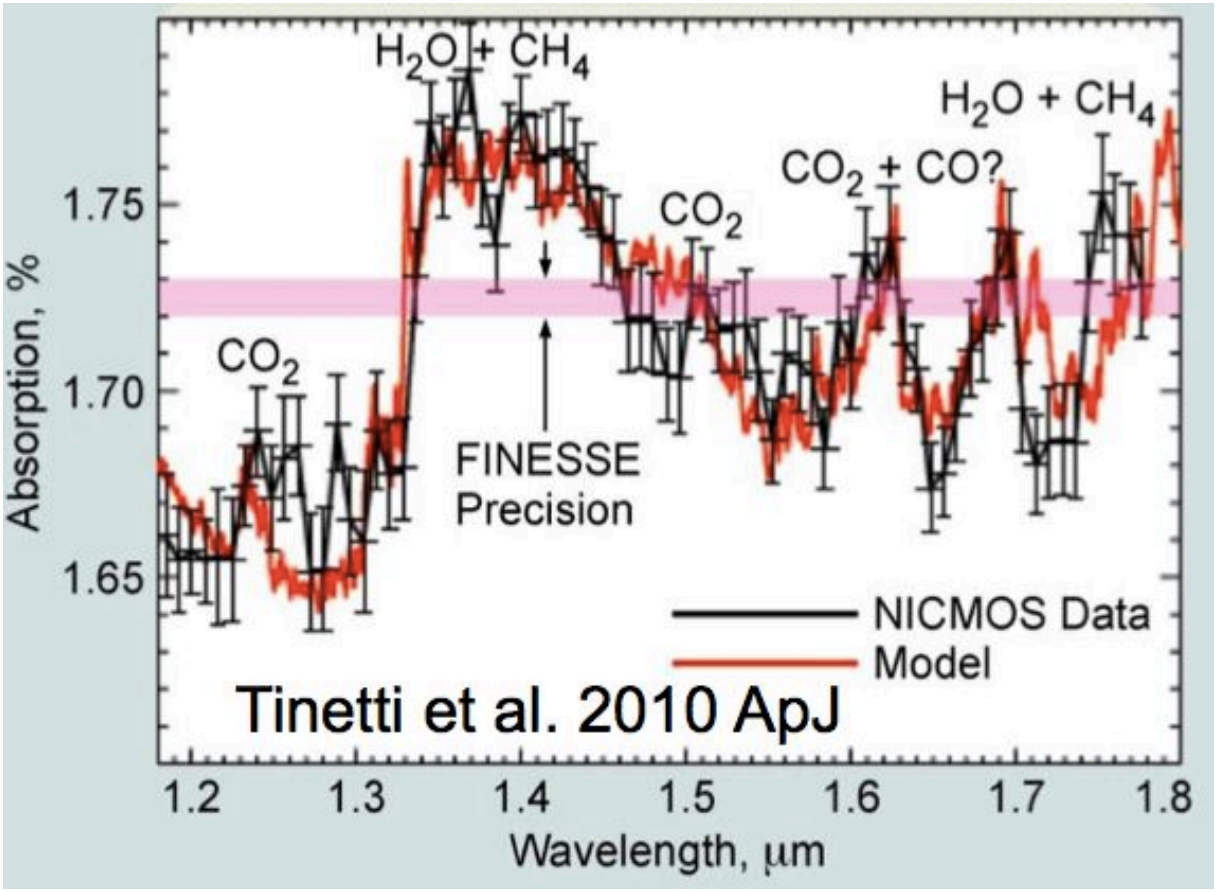
Evolution of our own Sun:
end of oceans on Earth (1 Gyr from now)

In 5 Gyr the Sun will be a red giant: end of Earth

Astronomical Instrumentation.

ARIEL: exploração da atmosfera de exoplanetas

Com participação da NASA (via CASE)



S E T I

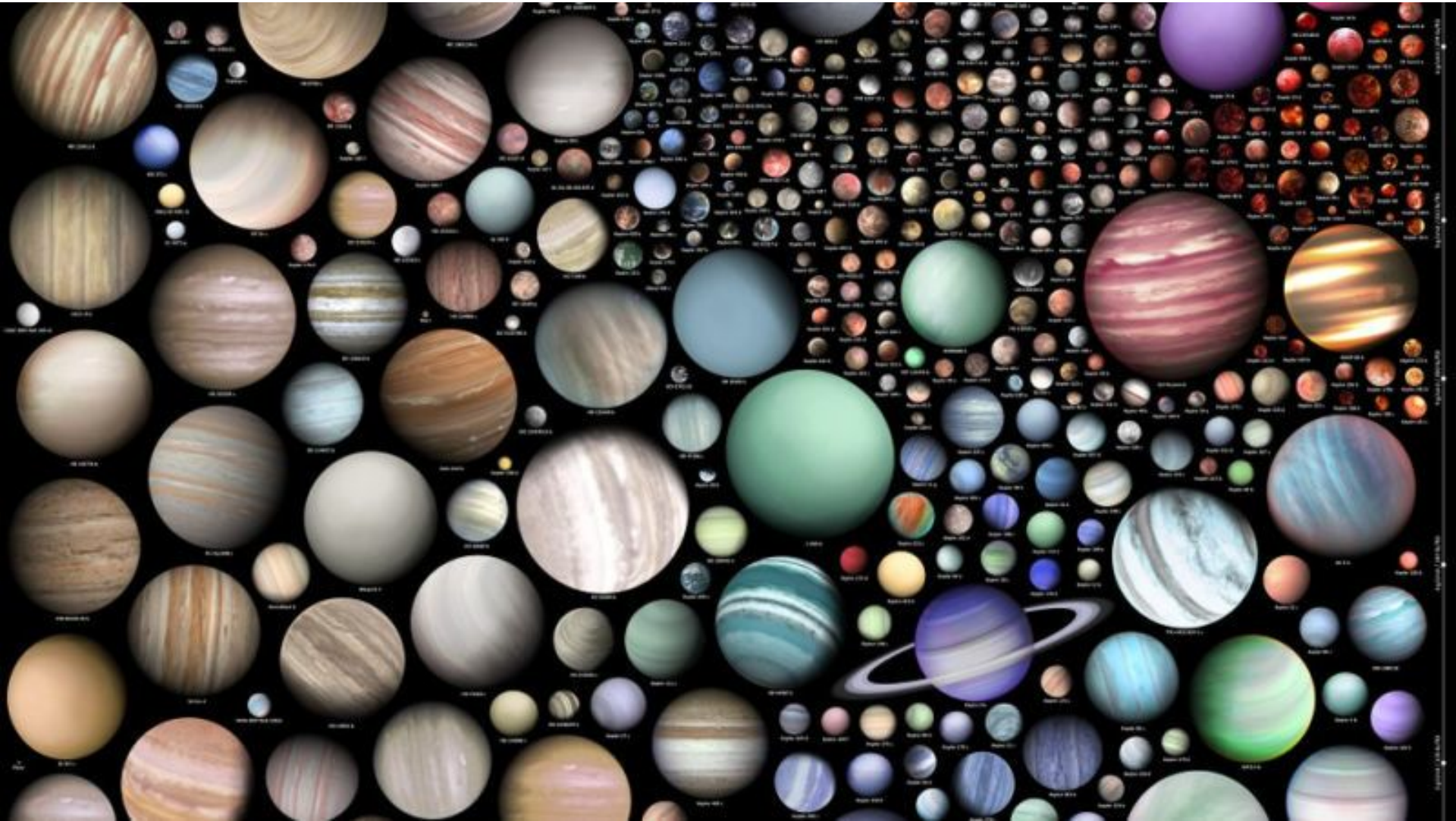
Search for Extraterrestrial Intelligence

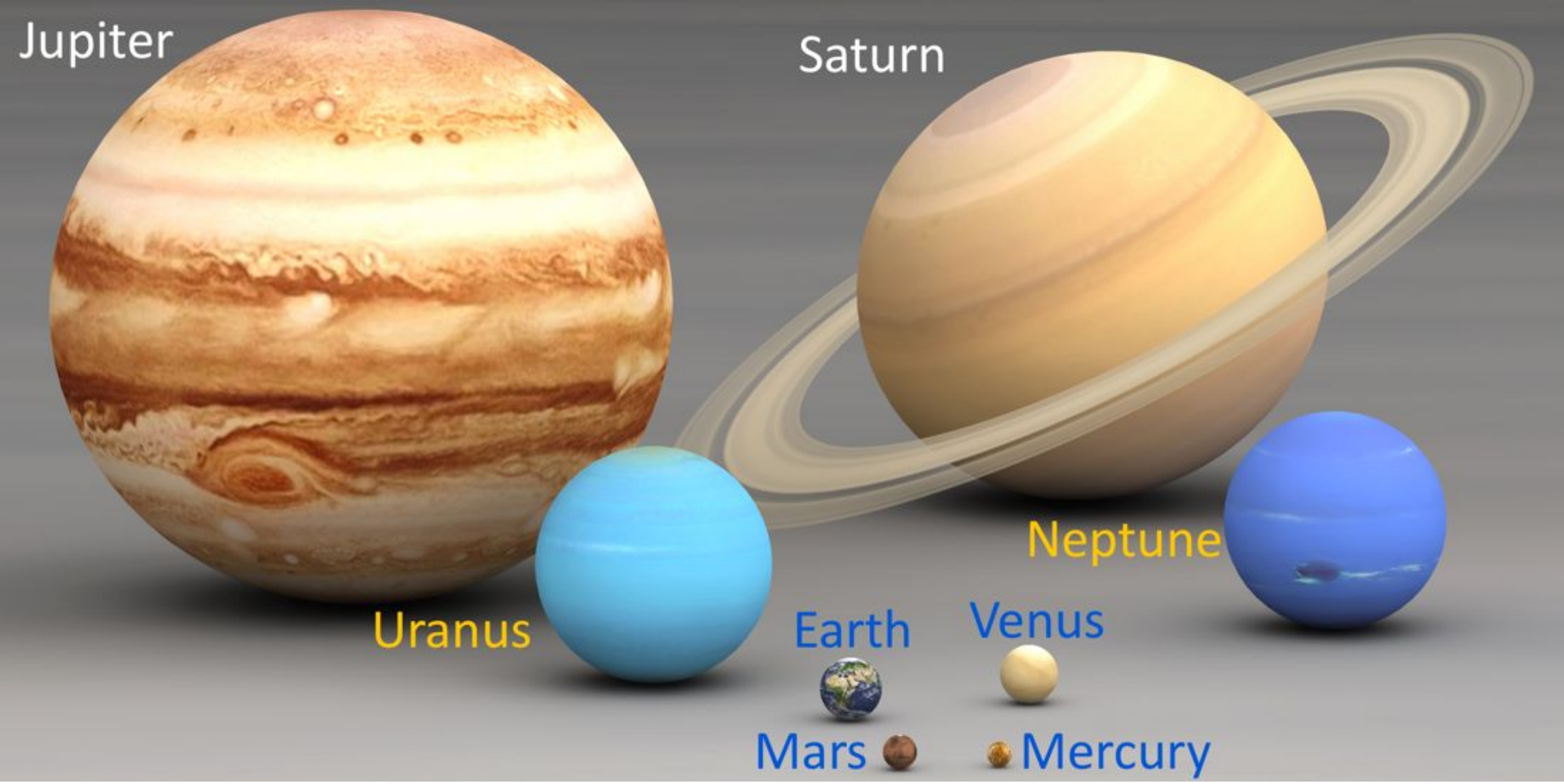
- Passive SETI: detect signals sent by other civilizations
- Active SETI: send messages to other civilizations

- How many planets out there?
- How many rocky planets?
- How many are habitable?
- How many civilizations?

Exoplanets

Planets outside the Solar System

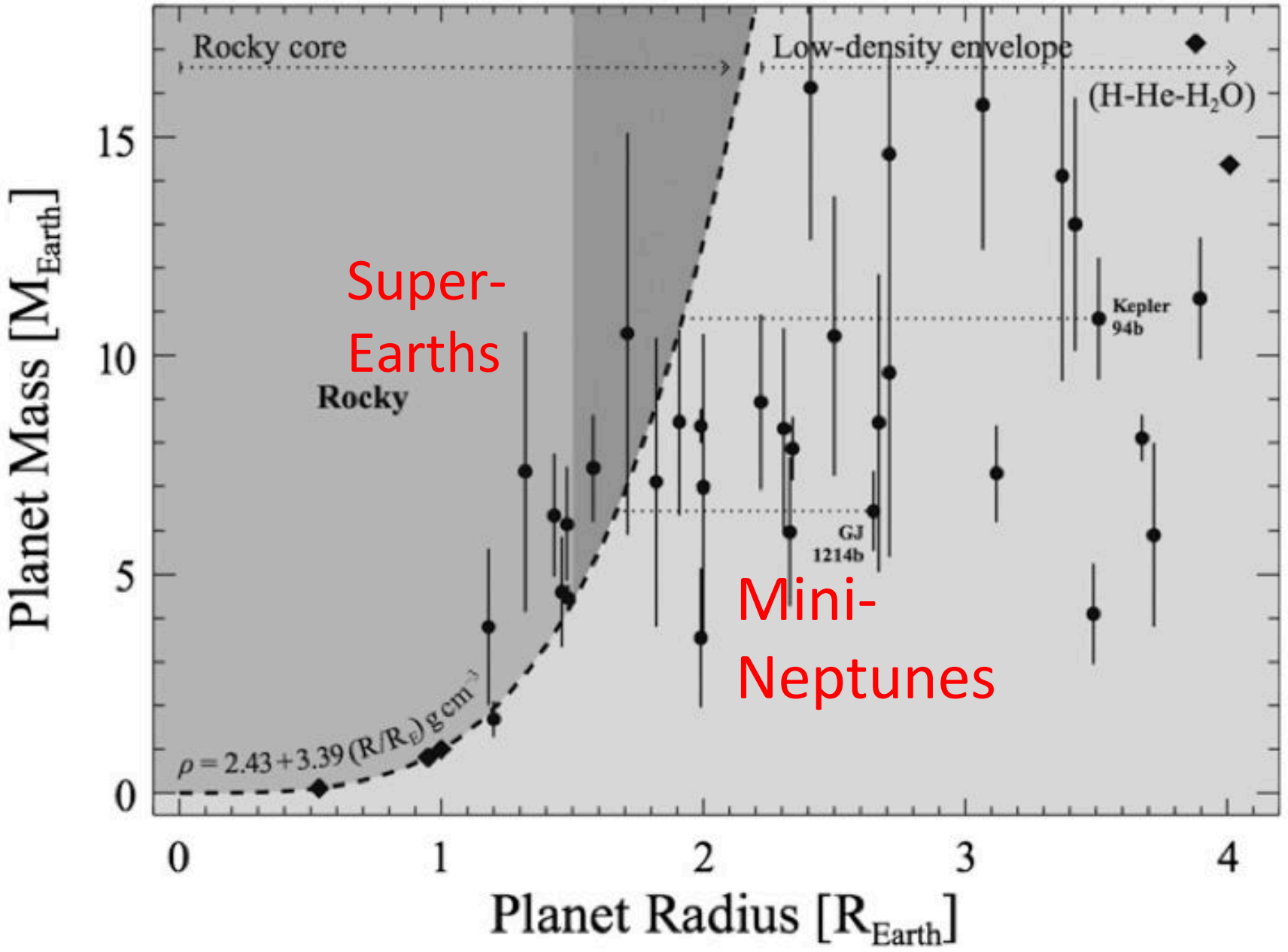




Solar system:
- Jupiters
- Neptunes
- Earths

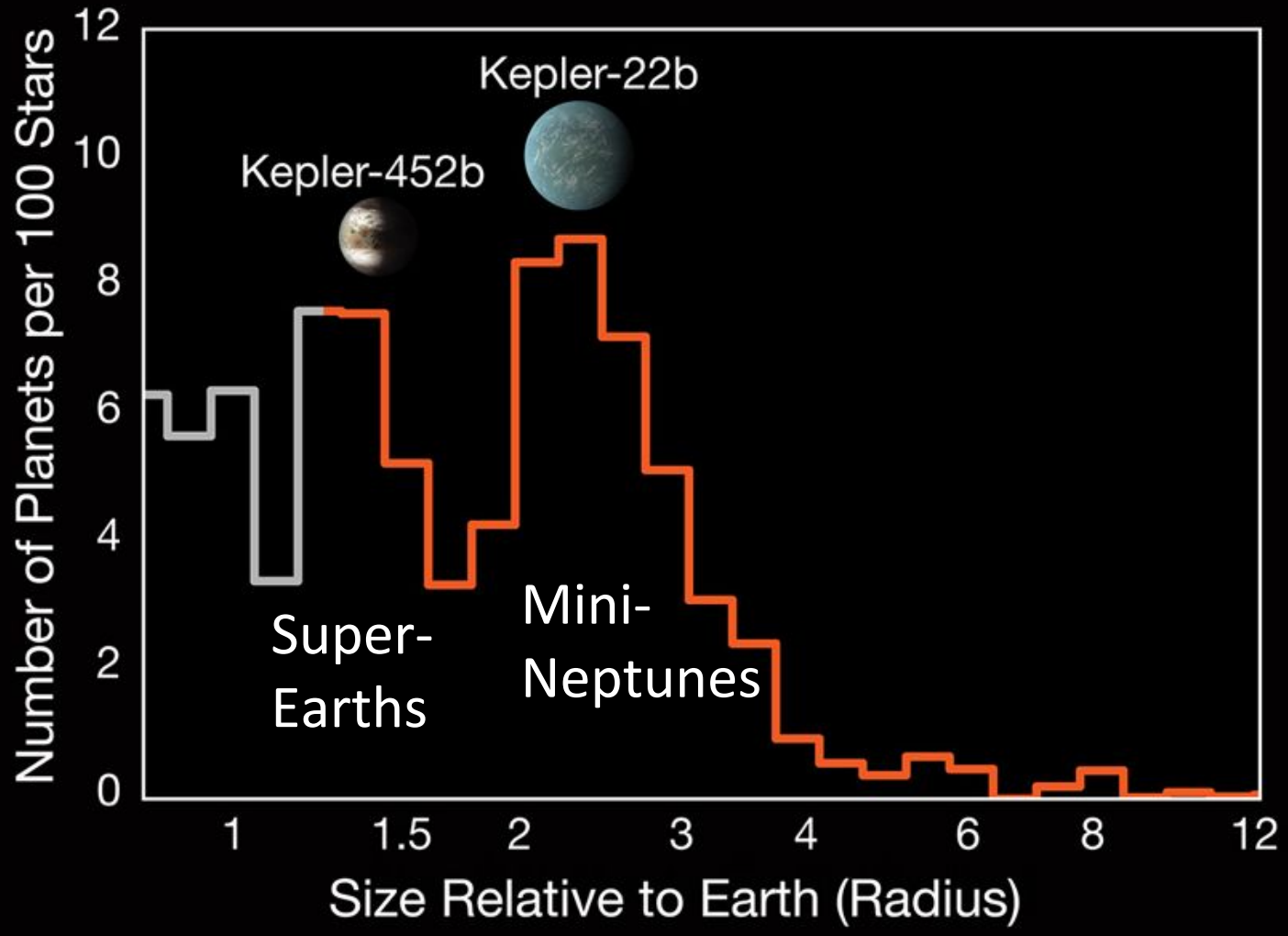
Other systems may host:
- Hot-Jupiters
- Mini-Neptunes
- Super-Earths

http://www.lesud.com/lesud-astronomy_pageid81.html



Marcy et al. 2014 PNAS

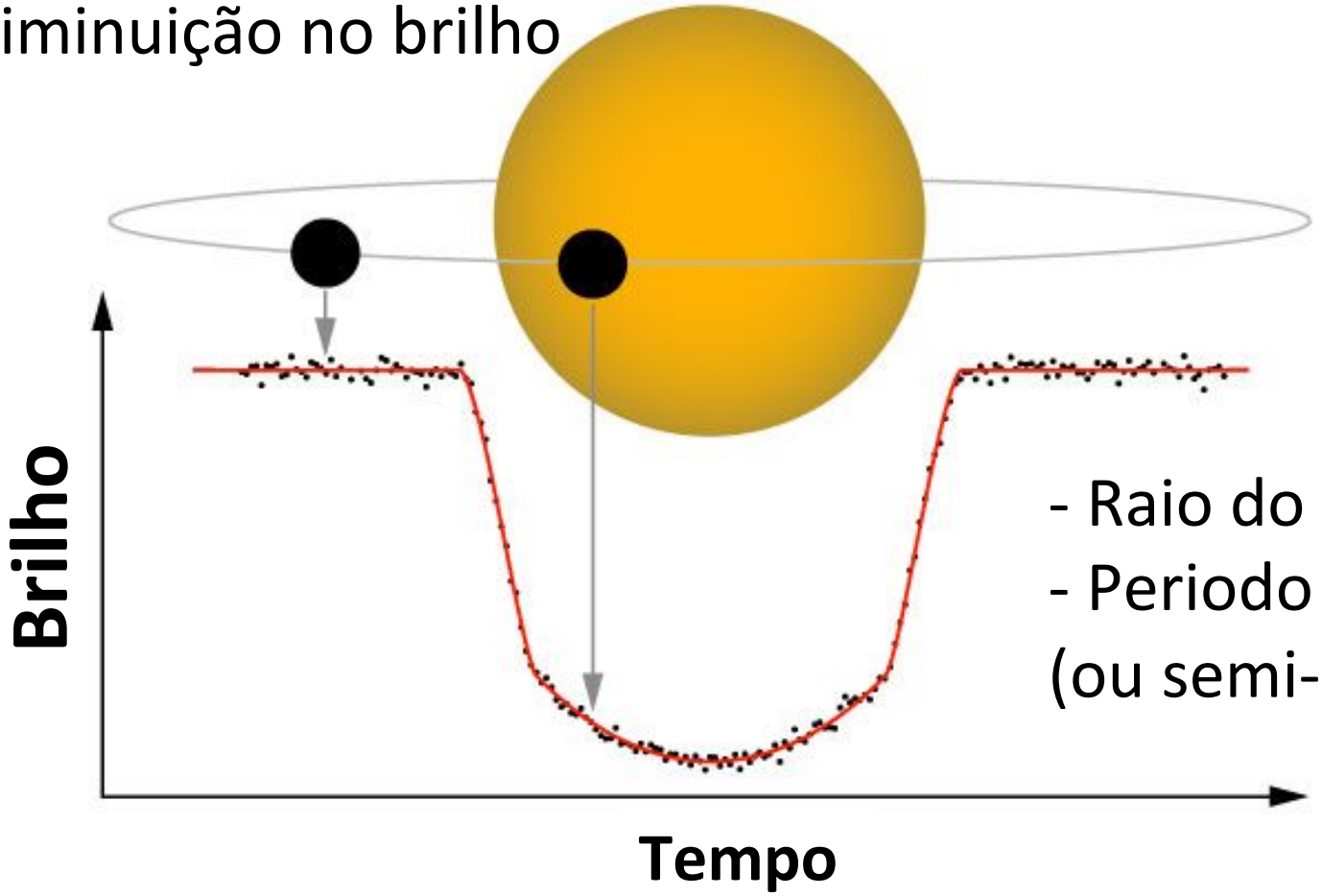
Small Planets Come in Two Sizes



Benjamin Fulton et al. 2017

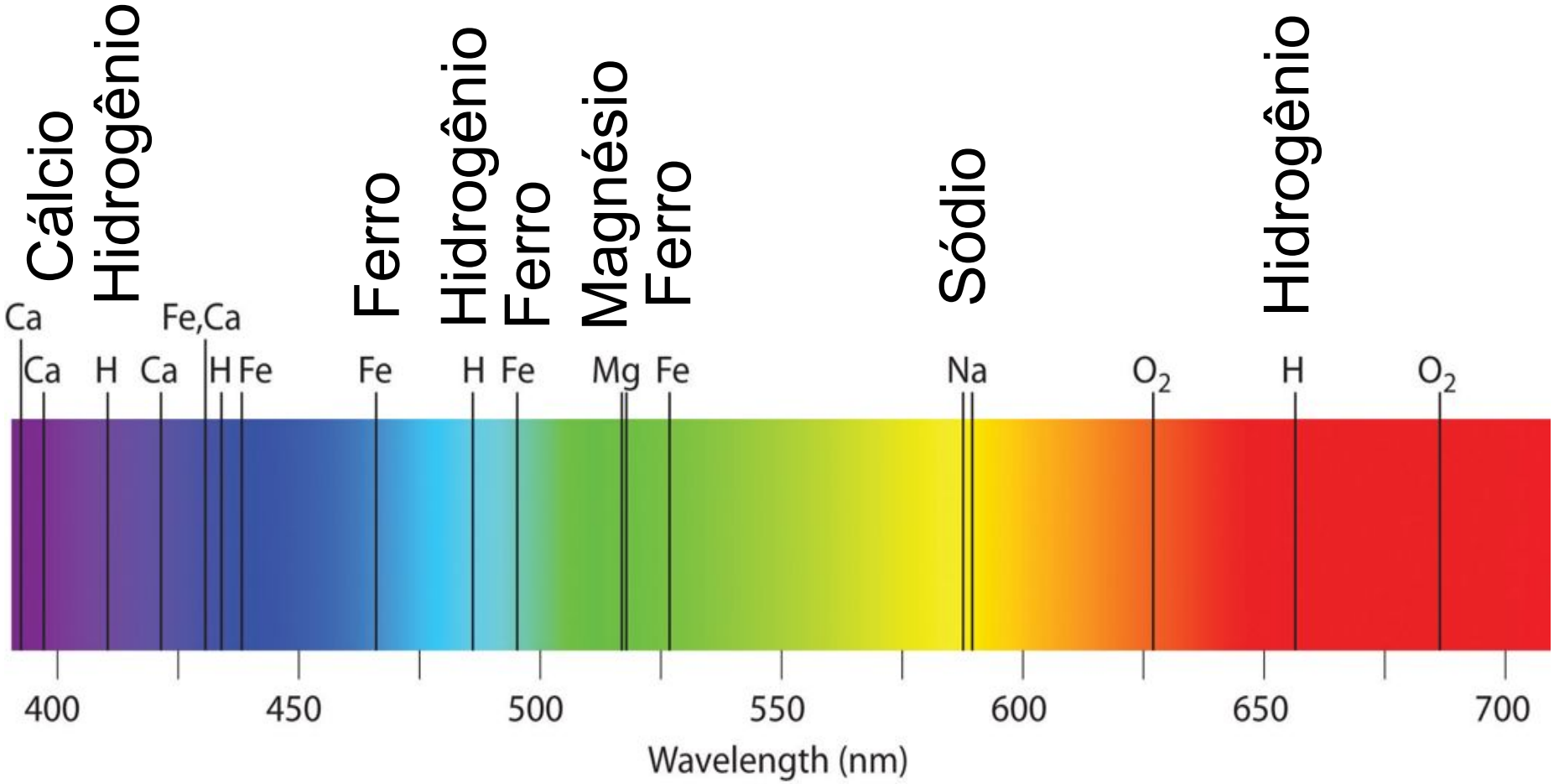
Detecção de planetas: método de trânsito

Exoplaneta pode ser detectado pelo bloqueio da luz da estrela na sua passagem diante desta, causando uma diminuição no brilho



- Raio do exoplaneta
- Periodo orbital
(ou semi-eixo maior)

Outro método de detecção de exoplanetas: usando linhas do espectro

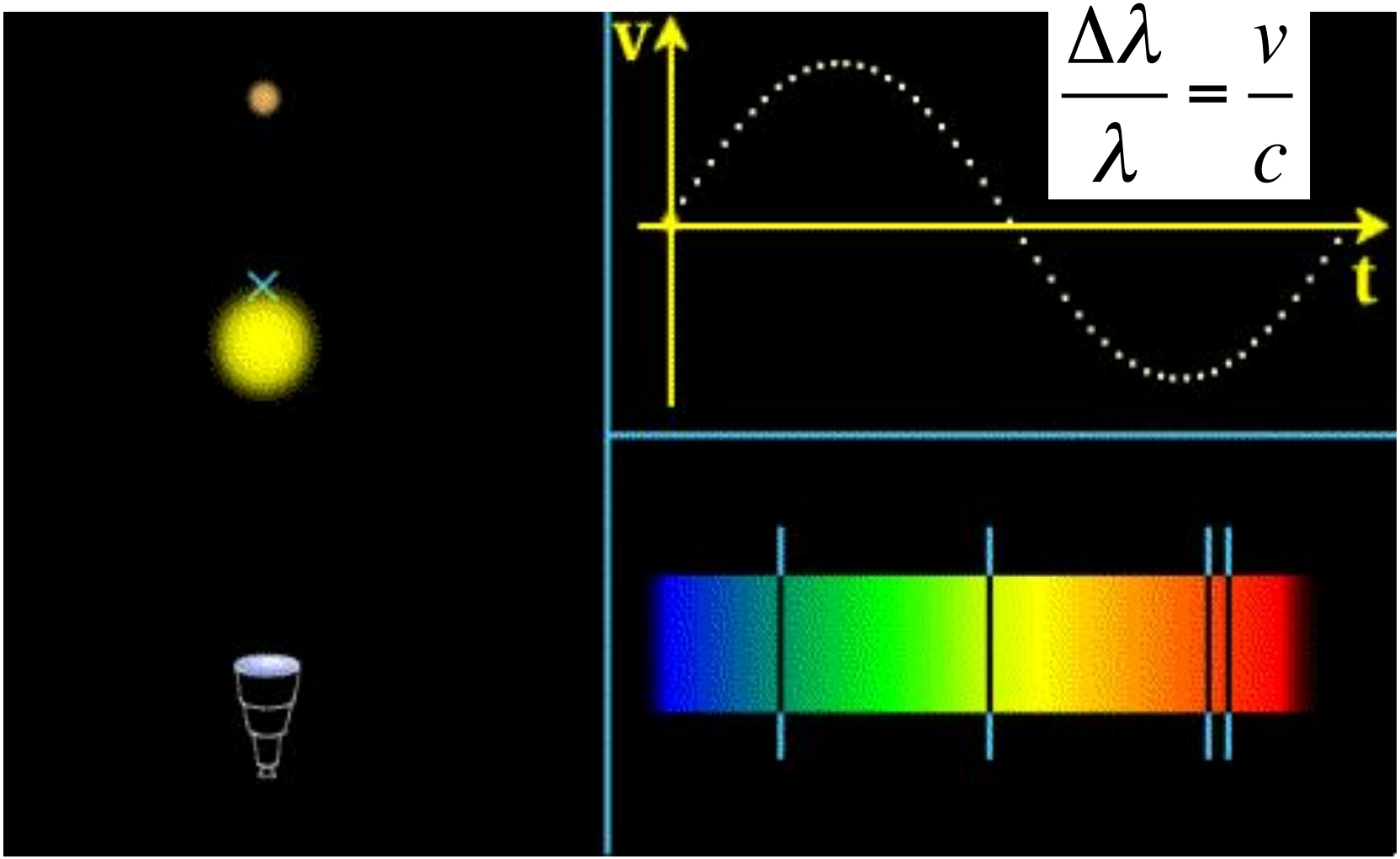


Efeito Doppler

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

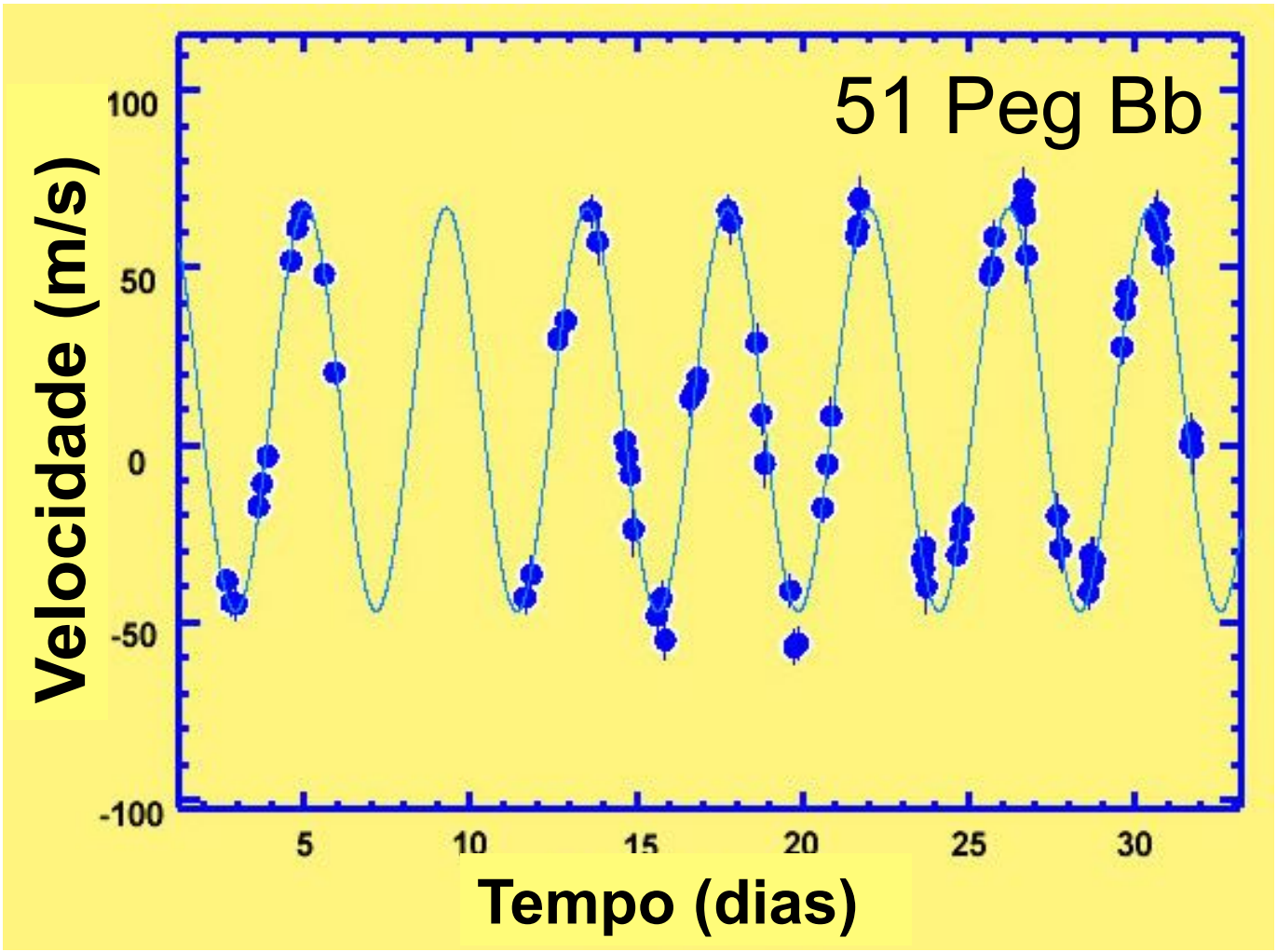
Estrela se afasta

Estrela se aproxima



https://media4.obspm.fr/exoplanetes/pages_exopl-methodes/images/images/spectro.gif

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$



- Massa do exoplaneta
- Periodo orbital (ou semi-eixo maior)

http://www.kcvs.ca/martin/astro/au/unit7/164/chp16_4.html

Ano 1995:

51 Peg

Primeiro exoplaneta em estrela de tipo solar

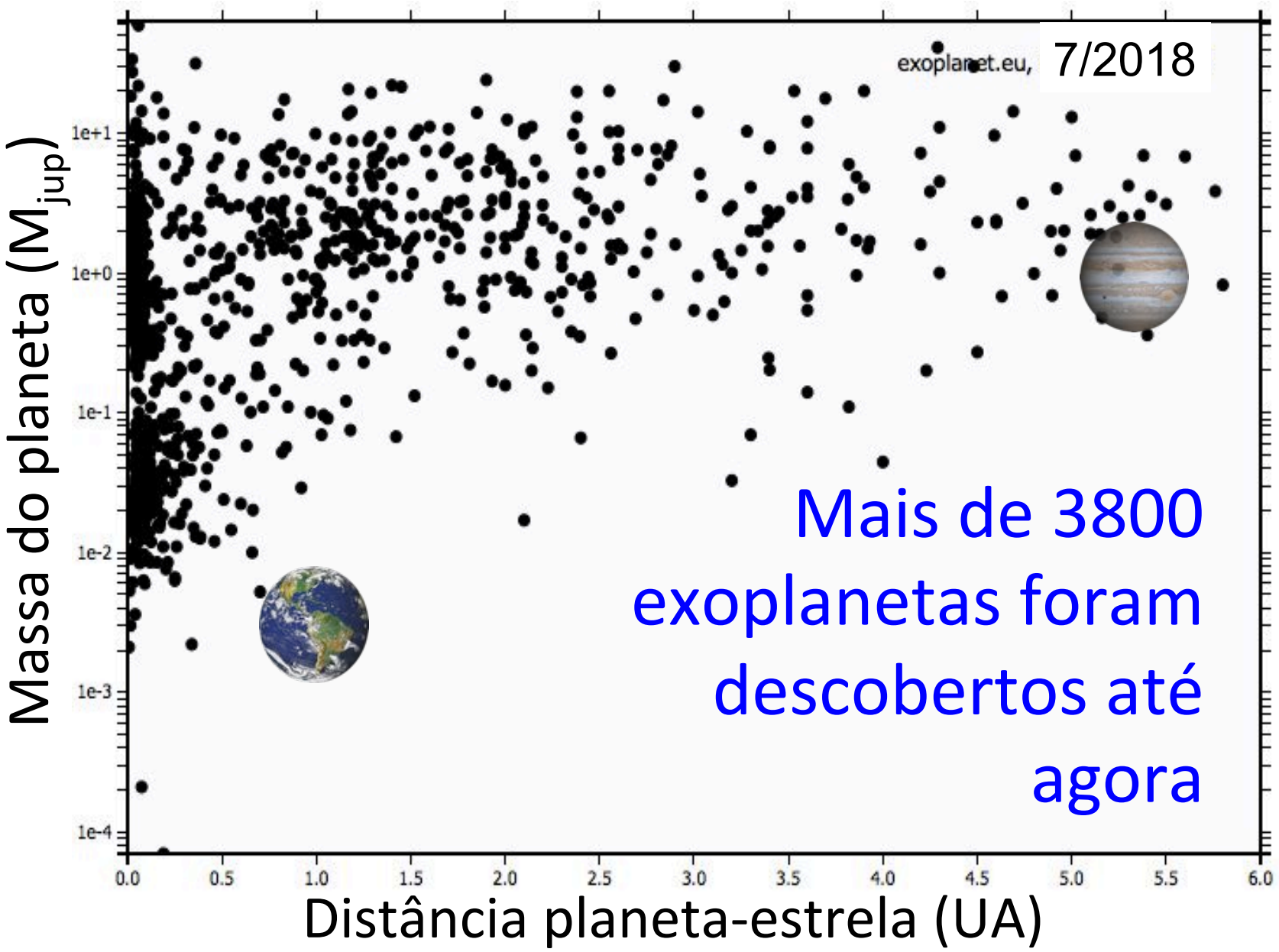
Mercúrio
Vênus
Terra
Marte

Sistema Planetário Solar

Júpiter

Sistema Planetário 51 Peg

51 Peg b


exoplanet.eu, 7/2018
Massa do planeta (M_{jup})
1e+1
1e+0
1e-1
1e-2
1e-3
1e-4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Distância planeta-estrela (UA)
Mais de 3800 exoplanetas foram descobertos até agora

Mercúrio
Vênus
Terra
Marte

Sistema Planetário Solar

Júpiter

Sistema Planetário 23 Librae

23 Lib b

23 Lib c

Sistema Planetário Solar

Mercúrio
Vênus
Terra
Marte

Júpiter

Sistema Planetário Upsilon Andromedae

Ups And c

Ups And b

Ups And d

Ups And e

Sol

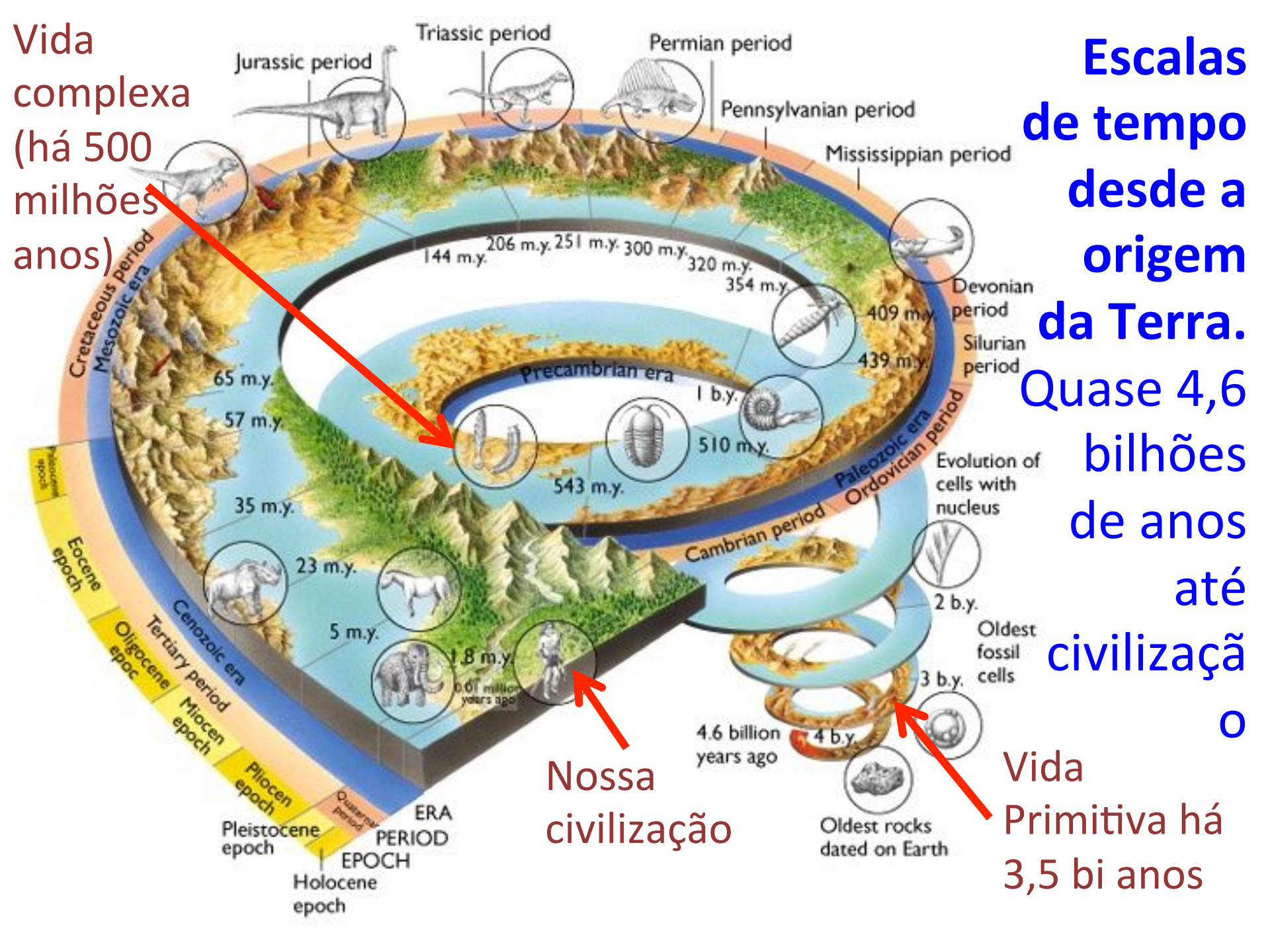
Idade: 4,6 bilhões anos

Vida total: 10 bilhões anos

Ups And

Idade: 3 bilhões anos

Vida total: 4,5 bilhões anos

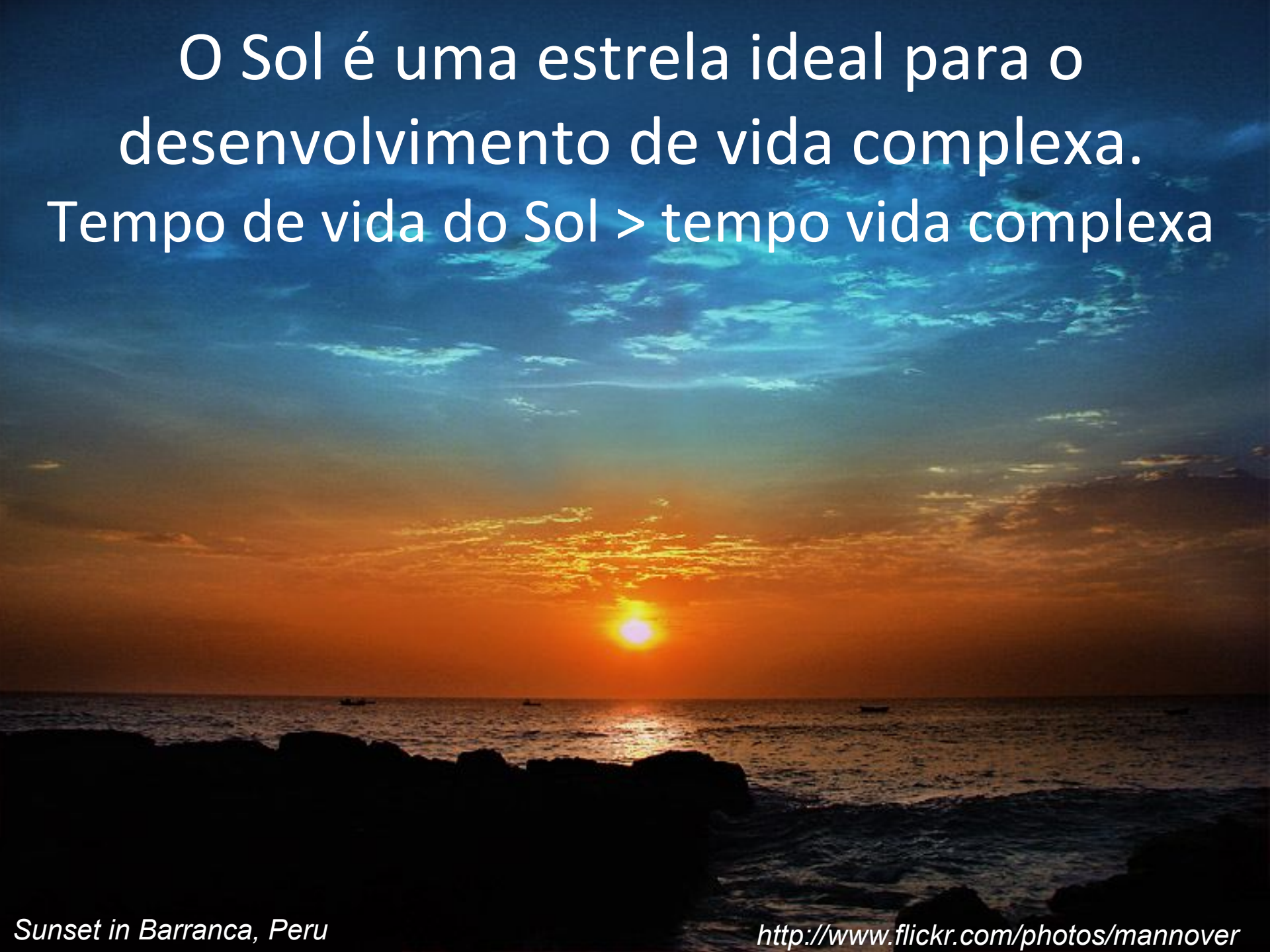


Escalas de tempo desde a origem da Terra.

Quase 4,6 bilhões de anos até civilizaçã o

O Sol é uma estrela ideal para o desenvolvimento de vida complexa.

Tempo de vida do Sol > tempo vida complexa



Sunset in Barranca, Peru

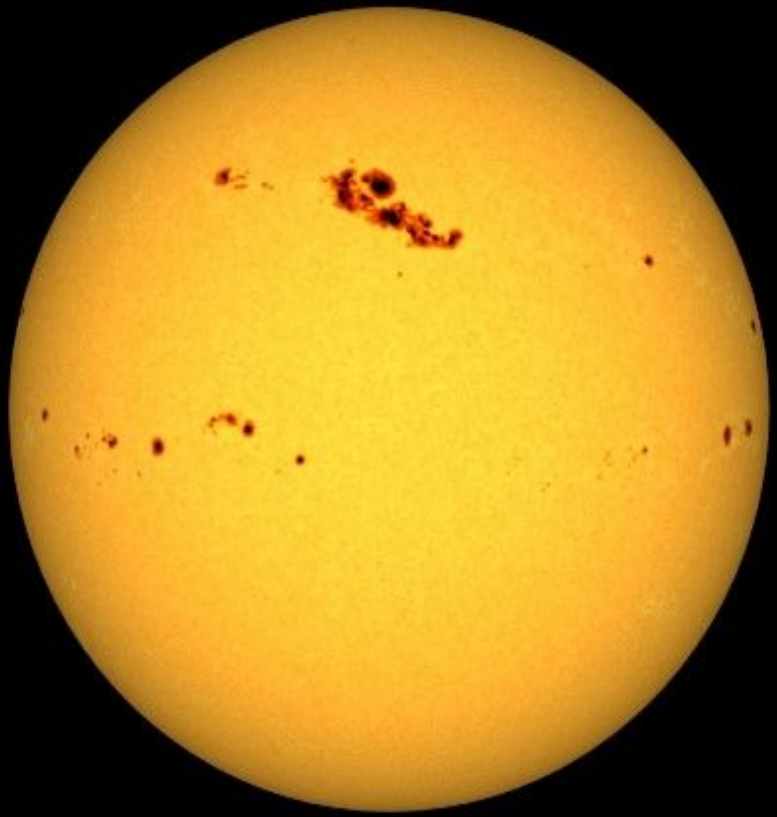
http://www.flickr.com/photos/mannover

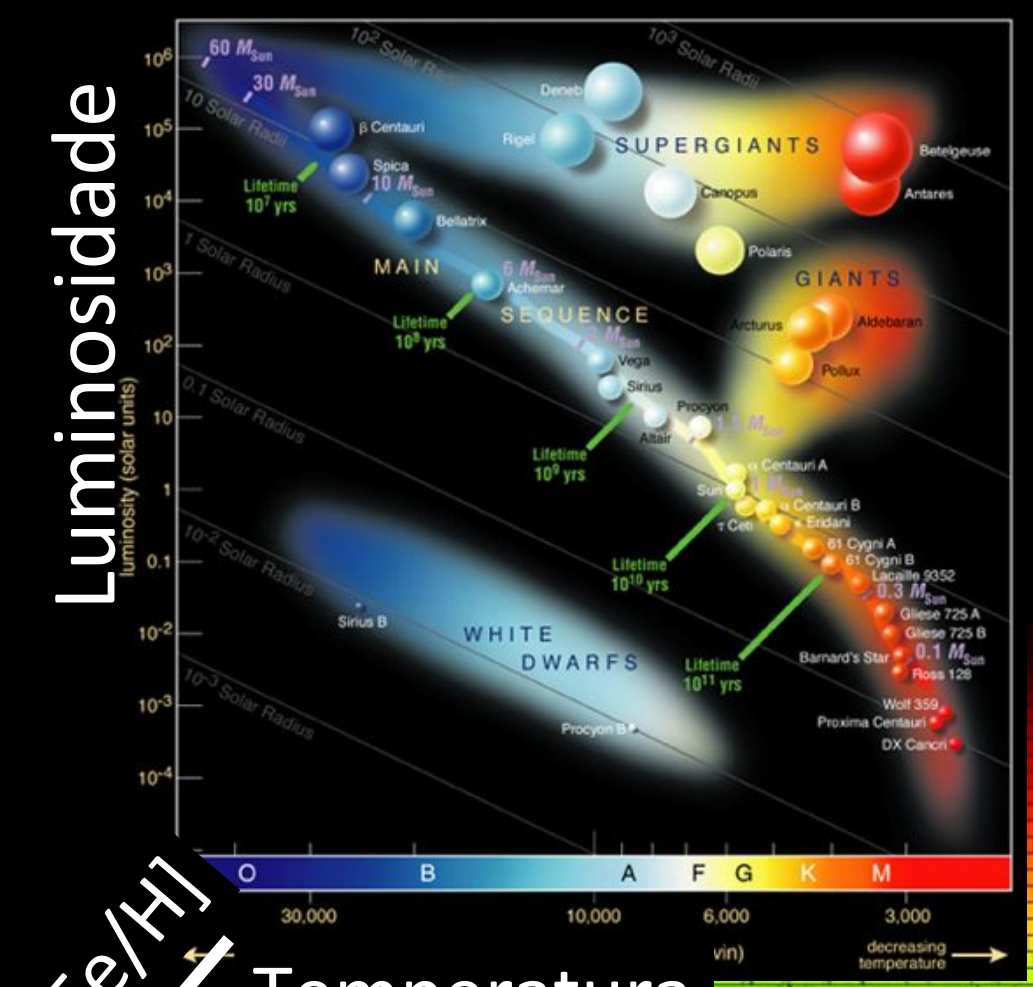
Como encontrar gêmeo do Sistema Solar?

Primeiro encontrar gêmeo do Sol

Credits: Nasa

Gêmeas do Sol: estrelas com propiedades similares ao Sol (temperatura, luminosidade, composição química)

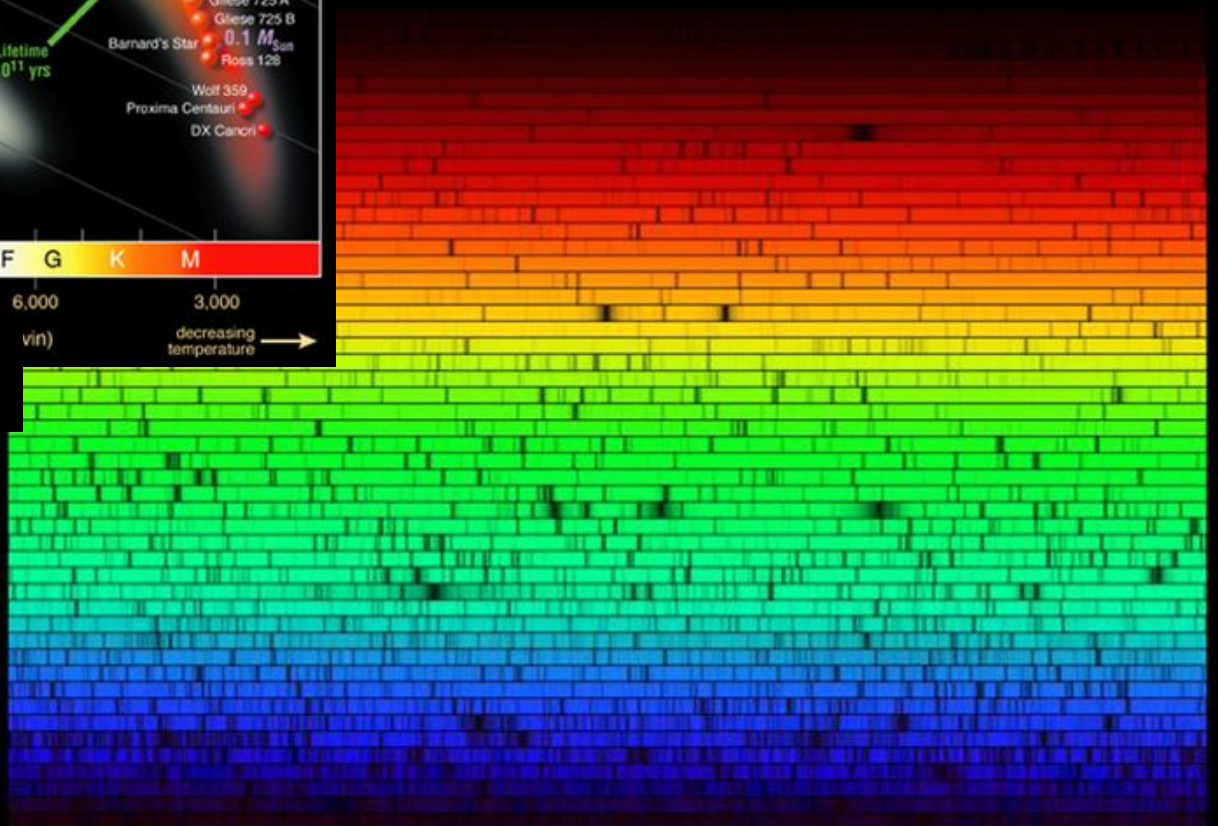




$T_{eff}=T_{Sol} \pm 100$ K,

$\log g = \log g_{Sol} \pm 0.1$ dex,

[Fe/H] = 0.0 ± 0.1dex



Espectro: temperatura, luminosidade, composição química, rotação, exoplanetas ☺

A primeira gêmea solar foi descoberta em 1997 por astrônomos brasileiros: **18 Sco**

THE ASTROPHYSICAL JOURNAL, 482:L89–L92, 1997 June 10

HR 6060: THE CLOSEST EVER SOLAR TWIN?[1]

G. F. PORTO DE MELLO[2,3] AND L. DA SILVA[3]

[2] Universidade Federal do Rio de Janeiro, Departamento de Astronomia, Observatório do Valongo, Ladeira do Pedro Antônio, 43, CEP 20080-090 Saude, Rio de Janeiro, Brazil; gustavo@ov.ufrj.br.

[3] CNPq/Observatório Nacional, Departamento de Astronomia, Rua General José Cristino 77, 20921-400 São Cristovão, Rio de Janeiro, Brazil; licio@on.br.

Parameter	Sun	HR 2290	**18 Sco** HR 6060	16 Cyg A	16 Cyg B
$\Delta T_{\rm eff}$ (K)	0	0	12 ± 30	8 ± 25	−17 ± 20
$\Delta \log g$	0	0.07 ± 0.20	0.05 ± 0.12	−0.16 ± 0.07	−0.09 ± 0.07
$L/L_\odot$	1.00	1.05 ± 0.27	1.05 ± 0.02	1.63 ± 0.03	1.28 ± 0.02
[Fe/H]	0	0.13 ± 0.04	0.05 ± 0.06	0.06 ± 0.04	0.02 ± 0.04
$(B-V)$	0.648	0.66	0.65	0.64	0.66
$(U-B)$	0.178	0.20	0.17	0.19	0.20
Spectral type	G2 V	G3 V	G2 Va	G1.5 V	G2.5 V

Segunda gêmea solar identificada em 2006: HD 98618

THE ASTROPHYSICAL JOURNAL, 641:L133–L136, 2006 April 20

HD 98618: A STAR CLOSELY RESEMBLING OUR SUN[1]

JORGE MELÉNDEZ,[2] KATIE DODDS-EDEN, AND JOSÉ A. ROBLES
Research School of Astronomy and Astrophysics, Mount Stromlo Observatory.

Projeto iniciação científica de Katie Dodds-Eden, usando dados do Keck

nature International weekly journal of science

Published online 24 March 2006 | Nature | doi:10.1038/news060320-11

News

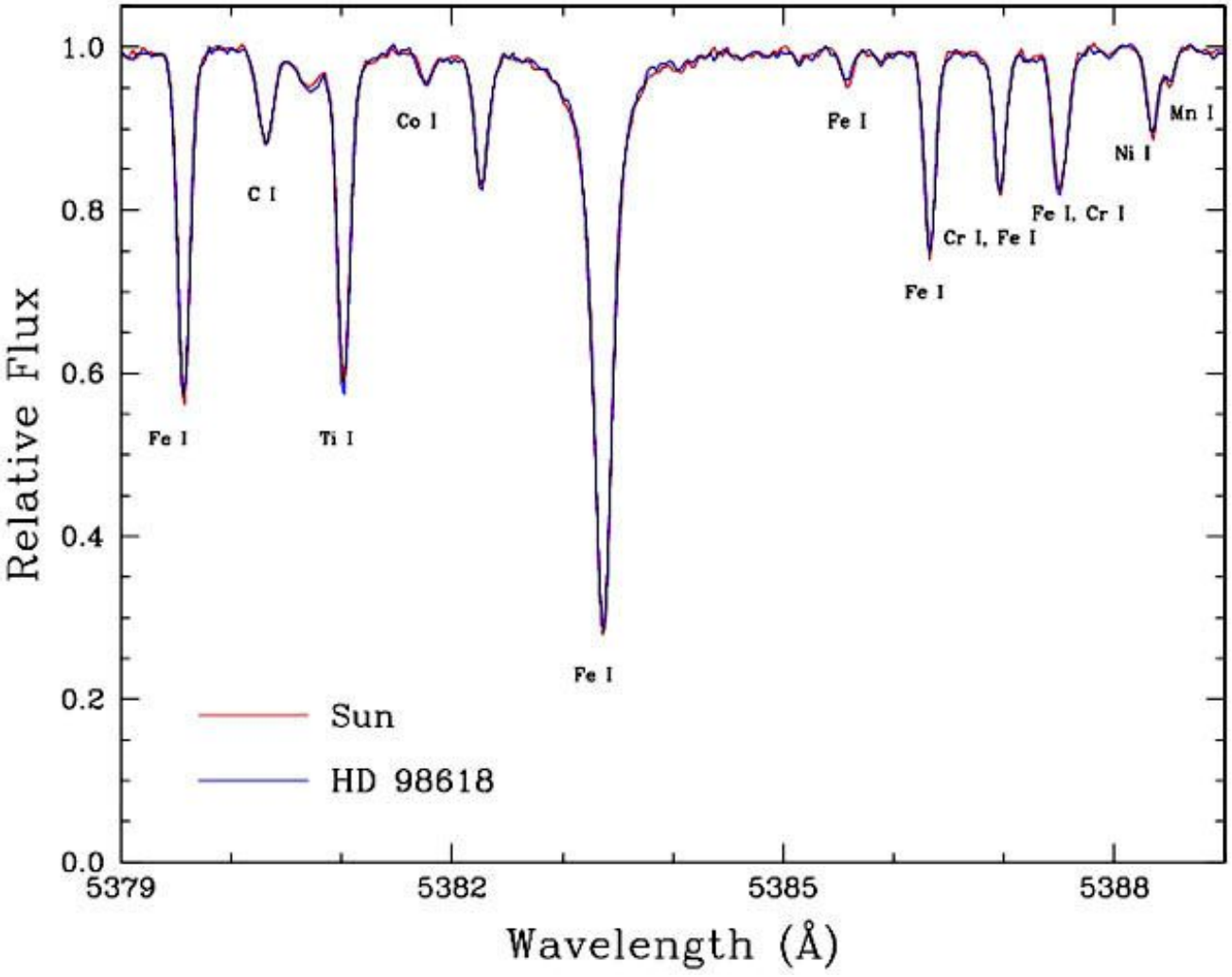
Bright future for Sun's twin

Homely stars make perf

Mark Peplow

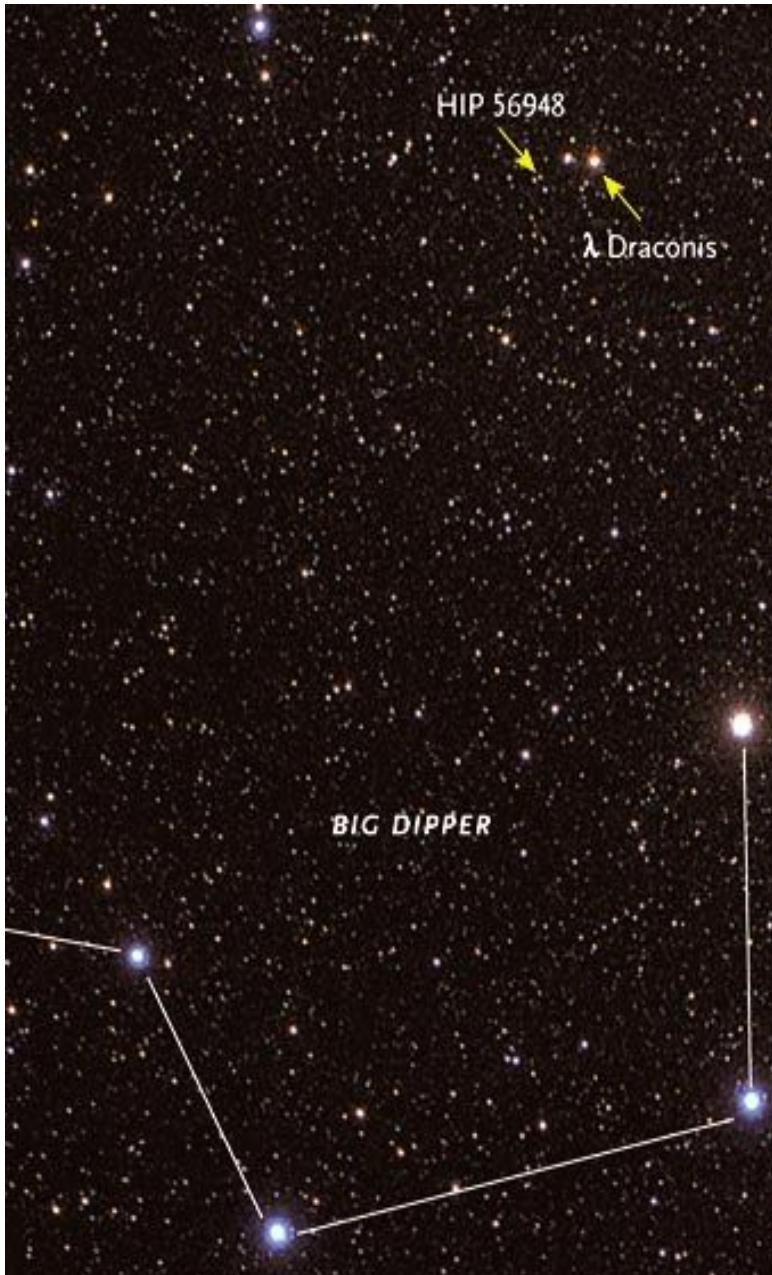
It looks like a home away
Astronomers trawling thro
catalogue of known stars h
one that is nearly identical
and they say it's an ideal p
looking for small blue-gree
that could host alien life.

The solar twin, called HD 9
about 126 light years from
bright enough to be seen f
Northern Hemisphere usin



Terceira gêmea solar em 2007: HIP 56948

Iván Ramírez



nature

Work by Peter Hänggi of the University of Augsburg in Germany and his collaborators contradicts those early calculations. The group's one-dimensional models of particles in a gas show that the same temperature will be observed regardless of the observer's speed. The team admits, however, that this may not be true of two- or three-dimensional gases, and believes that further study is needed.

CLIMATE CHANGE

Irreducible sensitivity

Science **318**, 629–632; 582–583 (2007)

PLANETARY SCIENCE

Identical twins

Astrophys J. **669**, L89–L92 (2007)

Astronomers have identified a star that is in many ways indistinguishable from the Sun.

Peruvian astronomers Jorge Meléndez of the Australian National University, and Iván Ramírez at the McDonald Observatory of the University of Texas in Austin report that the parameters of HIP 56948, one of four 'solar twins' they have been studying, are exactly the same as the Sun's, within the constraints of observational a
solar twins, this s

Medicine, California, USA

A systems biologist encourages modelling by the millions.

In a typical modelling study, we write down equations, solve them, and see whether they account for known data. If they do, we claim to understand some bit of biology. One huge caveat is that many other models might have matched the data just as well.

Researchers from Peking

Our Sun's Twin

By: **Kelly Beatty** | November 14, 2007

elmundo.es Ciencia y ecología

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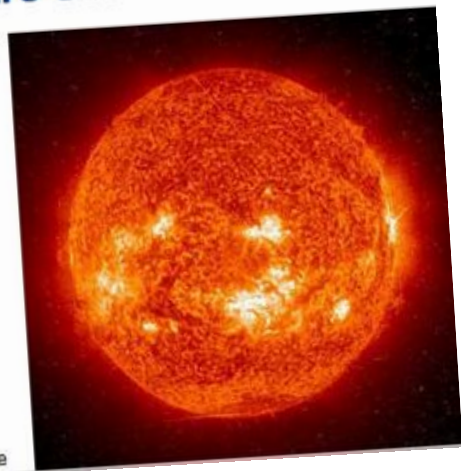
POR MASA, TAMAÑO, TEMPERATURA Y COMPOSICIÓN QUÍMICA

Expertos peruanos en EEUU descubren una estrella 'gemela' de nuestro Sol

Actualizado jueves 04/10/2007 10:44 (CET)

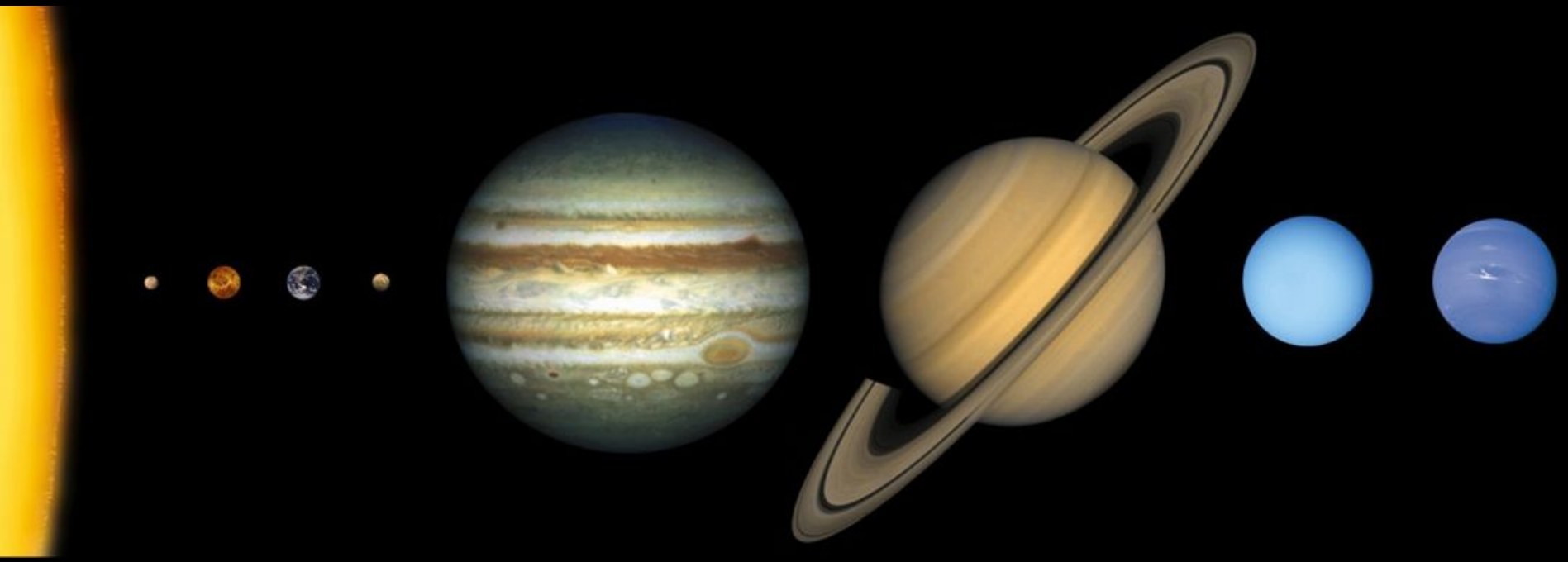


ÁNGEL DÍAZ

MADRID.- A medida que se construyen mayores telescopios y se crean mejores sistemas de observación, los científicos siguen afanados en hallar, en algún recóndito rincón del cosmos, un espejo perfecto de nuestro mundo, cuya lejana luz pueda mostrarnos que no estamos tan solos como parece. Como no habría vida sin planetas como la Tierra, ni planetas como la Tierra sin su Sol, el **hallazgo de una estrella idéntica a la nuestra**, llamada HIP 56498, podría suponer un gran avance en esta dirección.

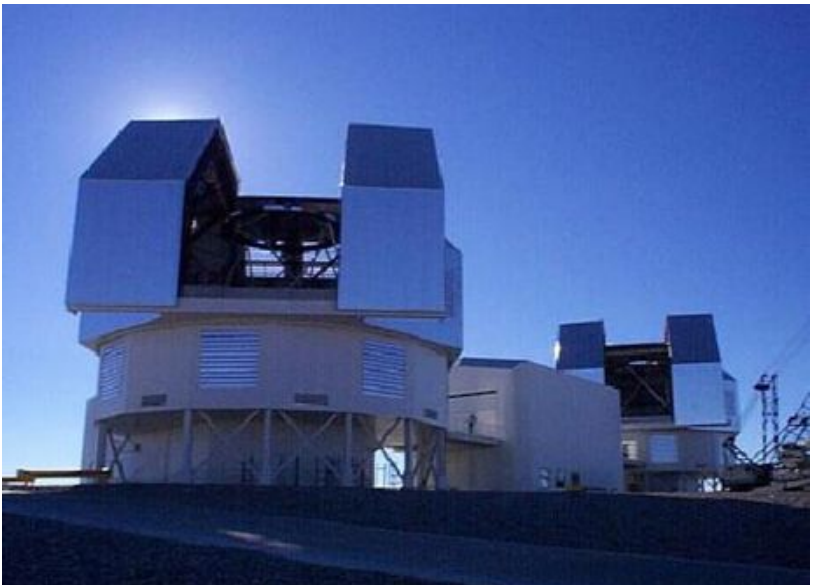
encuentra a 200 años luz de

Quão comum é o nosso Sol?
O nosso sistema solar é especial?

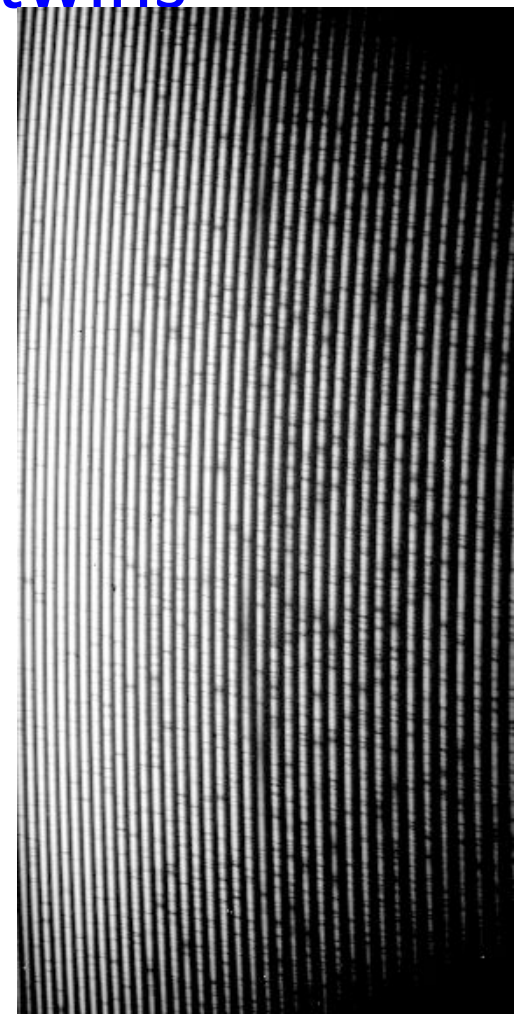


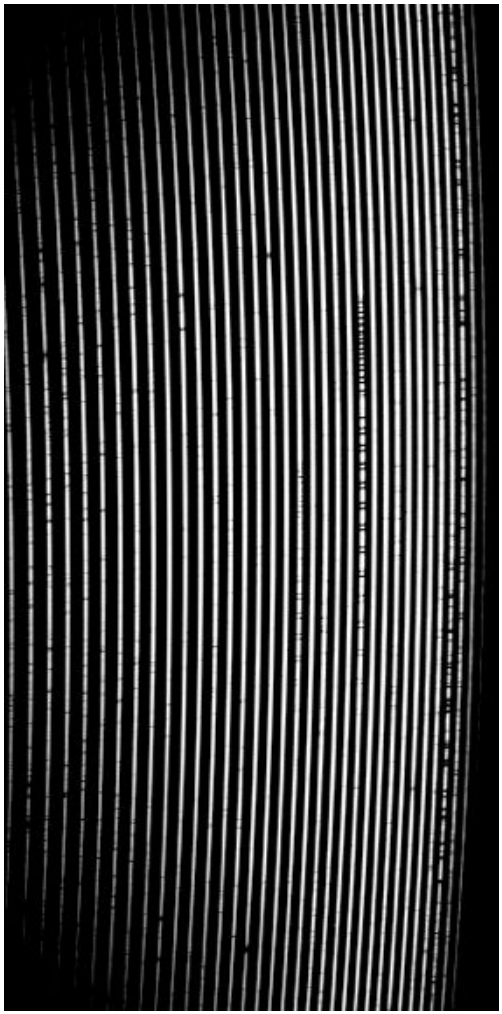
Experiment on how common is the Sun relative to 11 solar twins

- Magellan 6.5m Telescope & Mike spectrometer
- R = 65,000
- S/N = 450 per pixel
- coverage 340 – 1000 nm
- Solar spectrum: Vesta
- 3 nights of observations



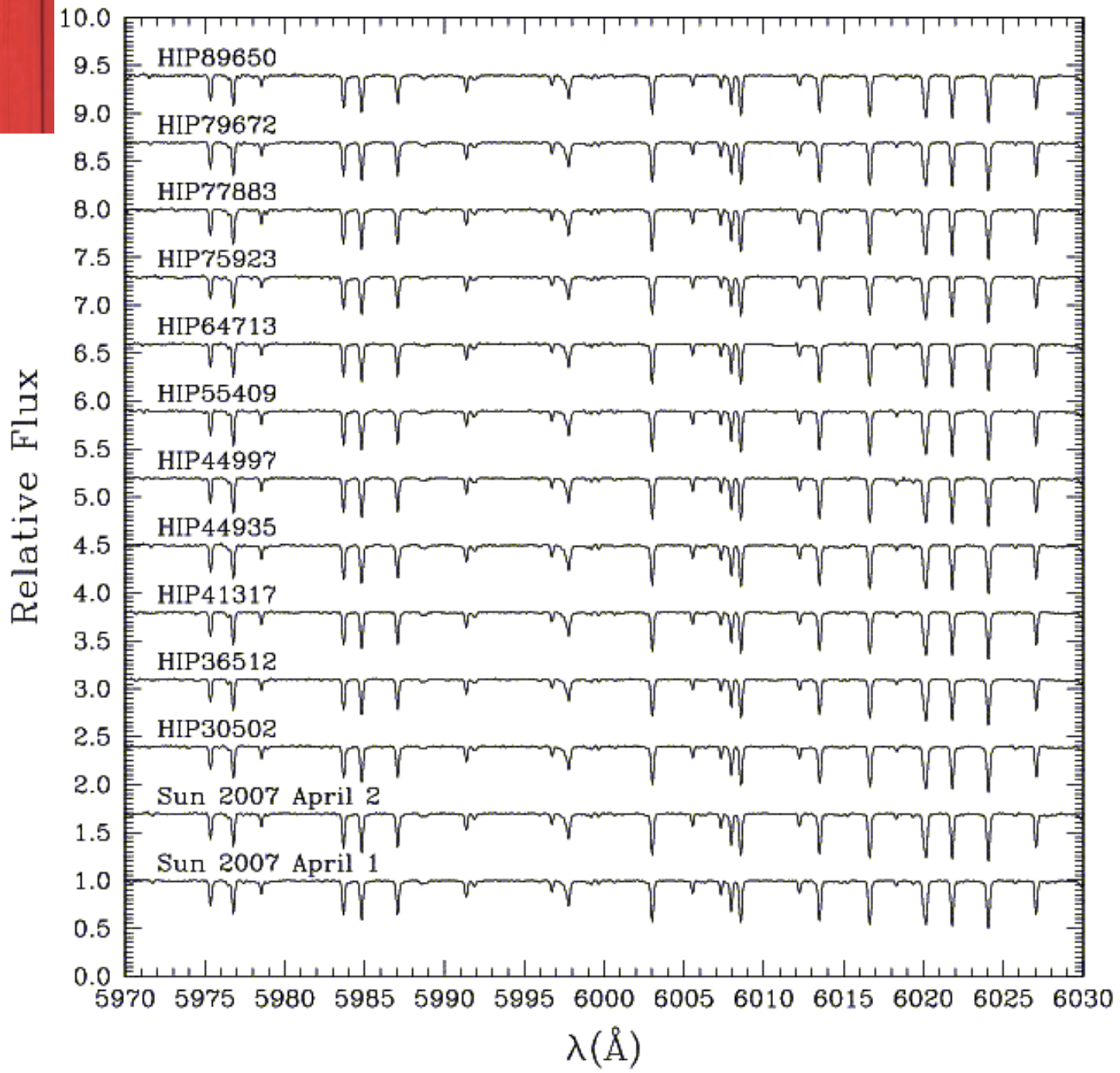
Observations of the solar twin 18 Sco





BLUE frame **RED frame**

Exemplo de espectros de 11 gêmeas solares e o Sol, para estudo da composição química do Sol vs. gêmeas solares

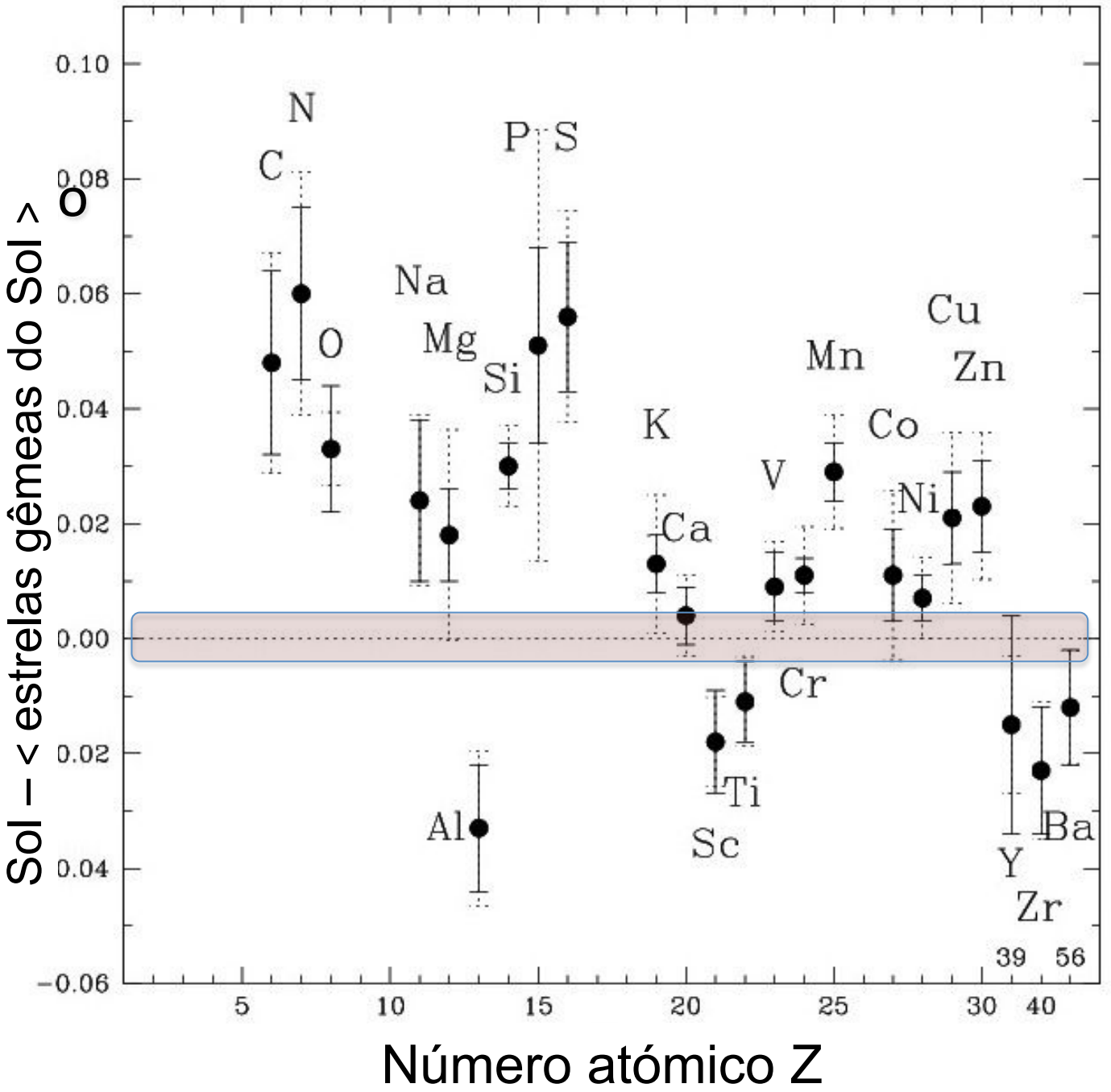


Meléndez et al. 2009, ApJ, 704, L66

Δ abundância:
Sol - <gêmeas>
vs. Número atómico Z

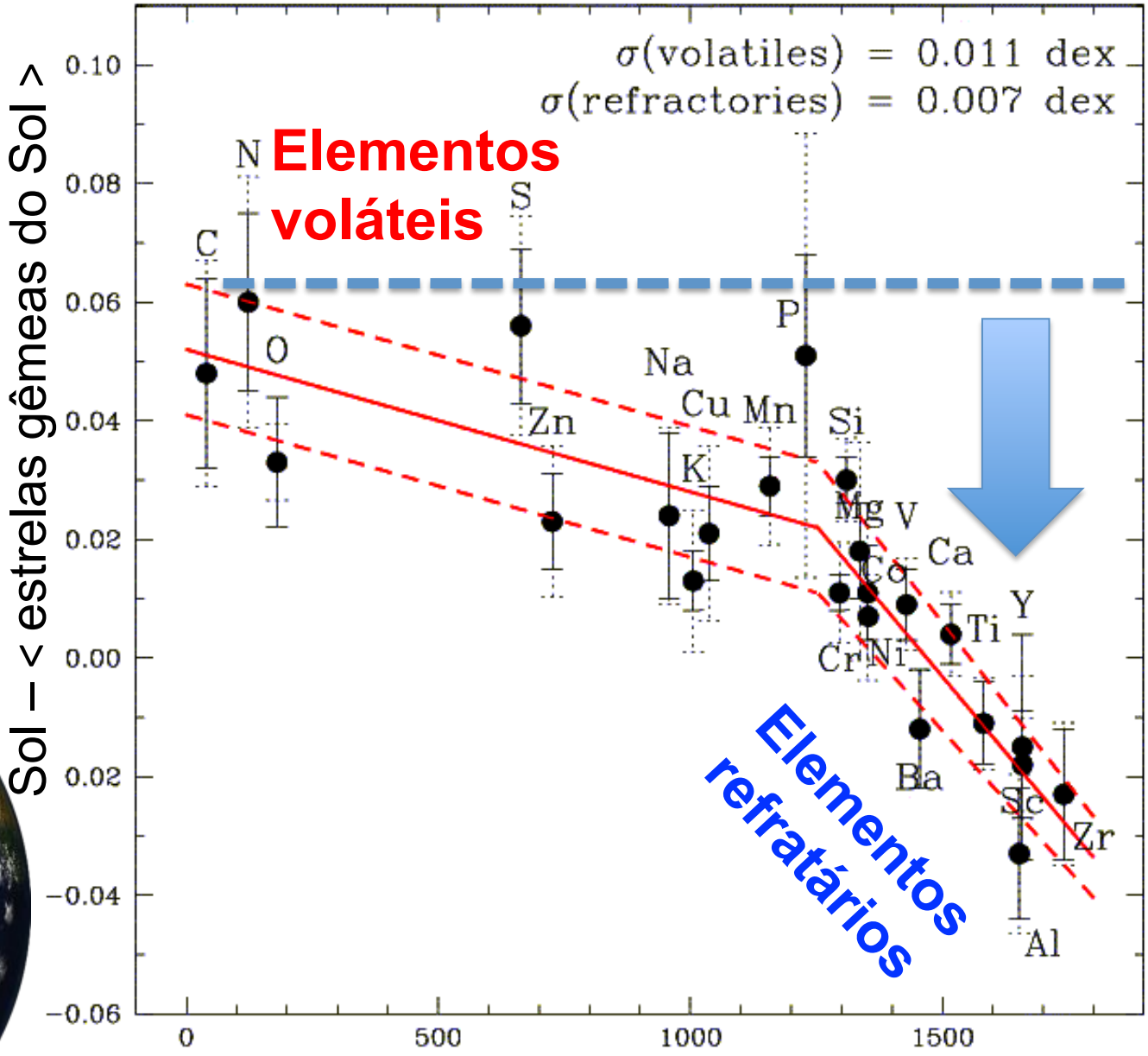
Sol normal :
Δ = 0
Sol anormal:
Δ ≠ 0

Nossa estrela mãe é anómala



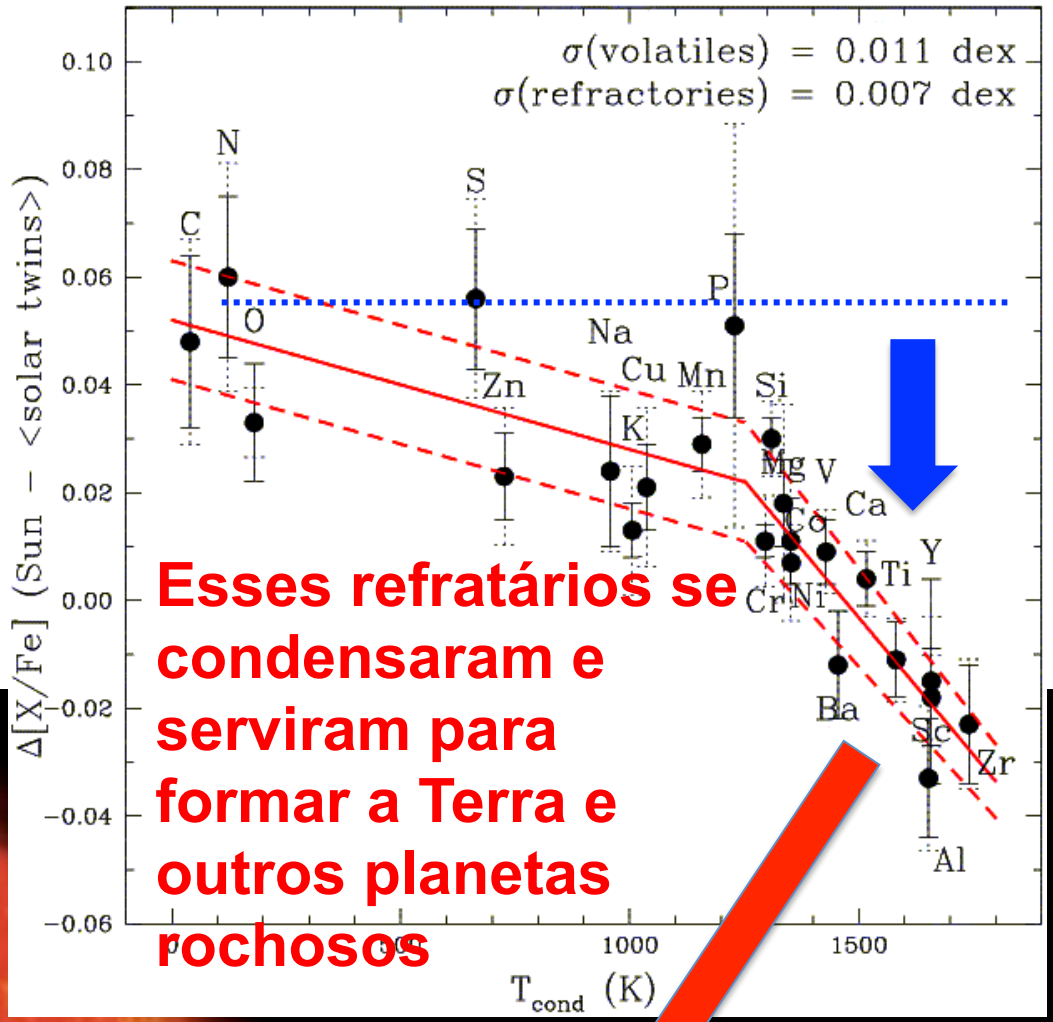
Meléndez et al. 2009

Elementos químicos que formam a Terra são mais deficientes no Sol !!!



Meléndez, Asplund, Gustafsson, Yong 2009, ApJ Letters

Meléndez et al. 2009

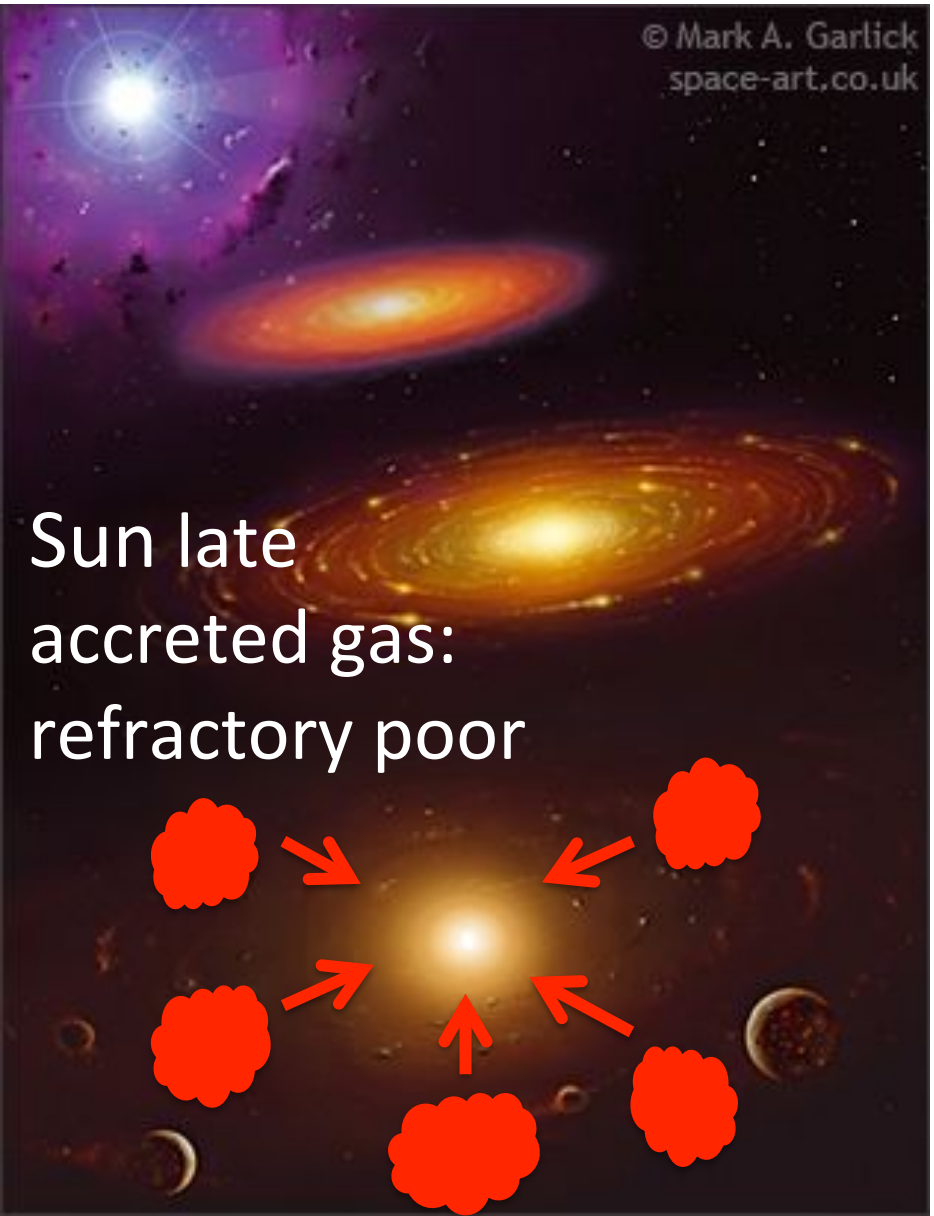


Esses refratários se condensaram e serviram para formar a Terra e outros planetas rochosos

Na região interna do Sistema Solar a temperatura é muito alta, permitindo a condensação de apenas elementos refratários

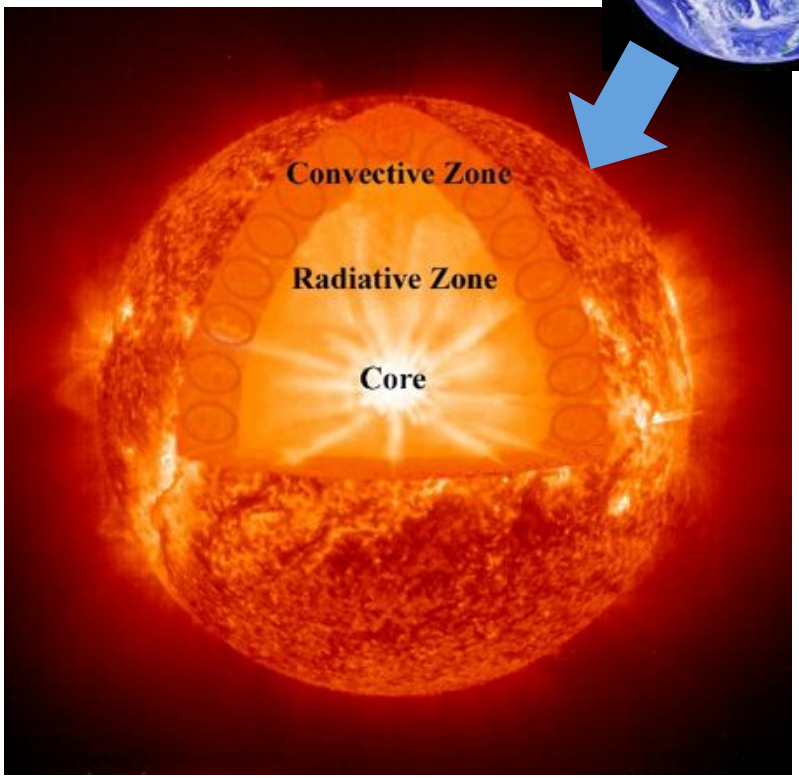
Chemical Signatures of planets

1. Dust removed: refractory poor

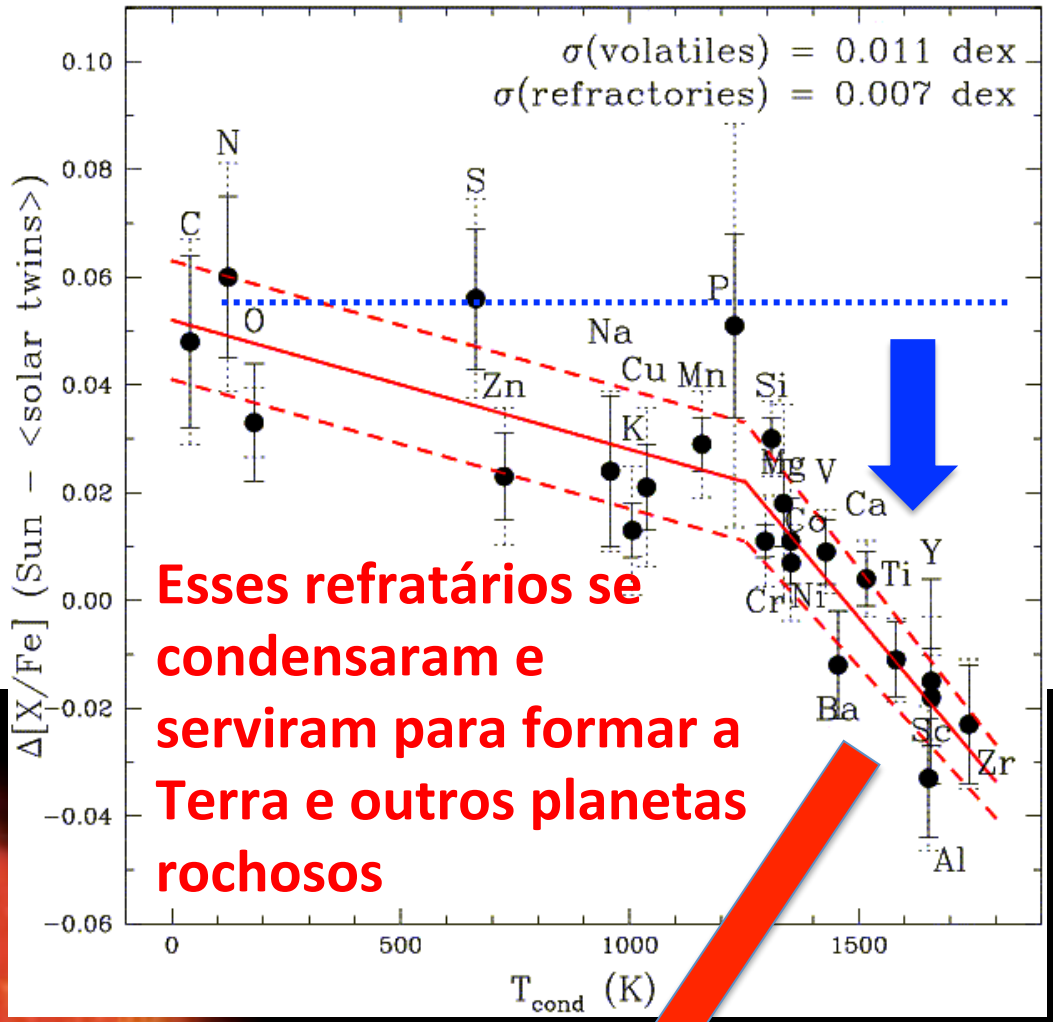


2. Planet accretion: refractory rich

Planet engulfment



Meléndez et al. 2009



Esses refratários se condensaram e serviram para formar a Terra e outros planetas rochosos

The late accreted gas in the convection zone was deficient in refractories

Signature of planet engulfment: binary 16 Cyg

The Astrophysical Journal, 740:76 (15pp), 2011 October 20 doi:10.1088/0004-637X/740/2/76

ELEMENTAL ABUNDANCE DIFFERENCES IN THE 16 CYGNI BINARY SYSTEM: A SIGNATURE OF GAS GIANT PLANET FORMATION?

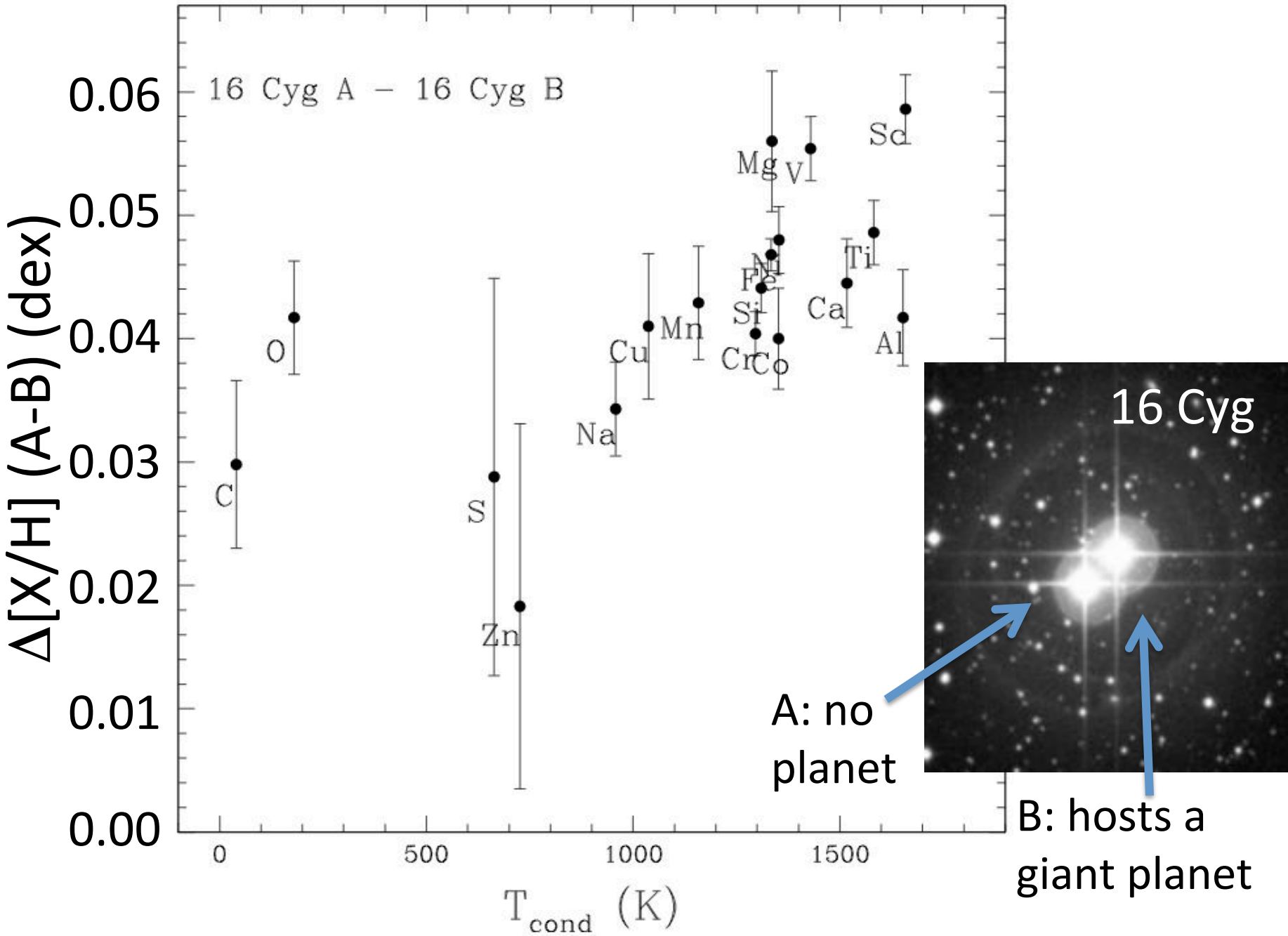
I. Ramírez[1], J. Meléndez[2], D. Cornejo[3], I. U. Roederer[1], and J. R. Fish[1,4]

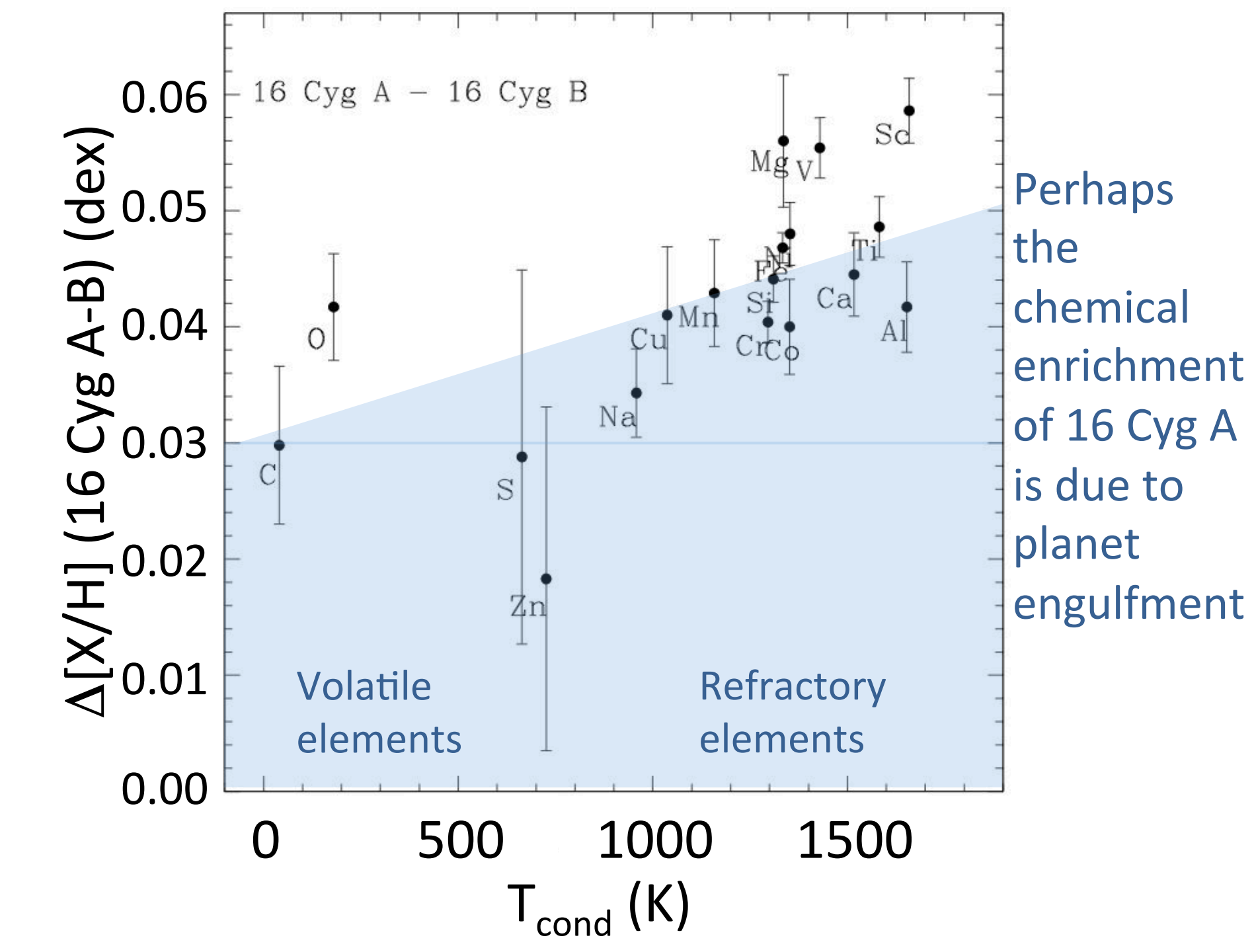
16 Cyg: widely separated pair of solar twins

16 Cyg A : no planets

16 Cyg B : giant planet

(~ 2 M_J)


16 Cyg A – 16 Cyg B
Δ[X/H] (A-B) (dex)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
500
1000
1500
T cond (K)
C
O
S
Zn
Na
Cu
Mn
Mg
V
Sc
Ni
Fe
Si
Cr
Co
Ca
Ti
Al
16 Cyg
A: no planet
B: hosts a giant planet

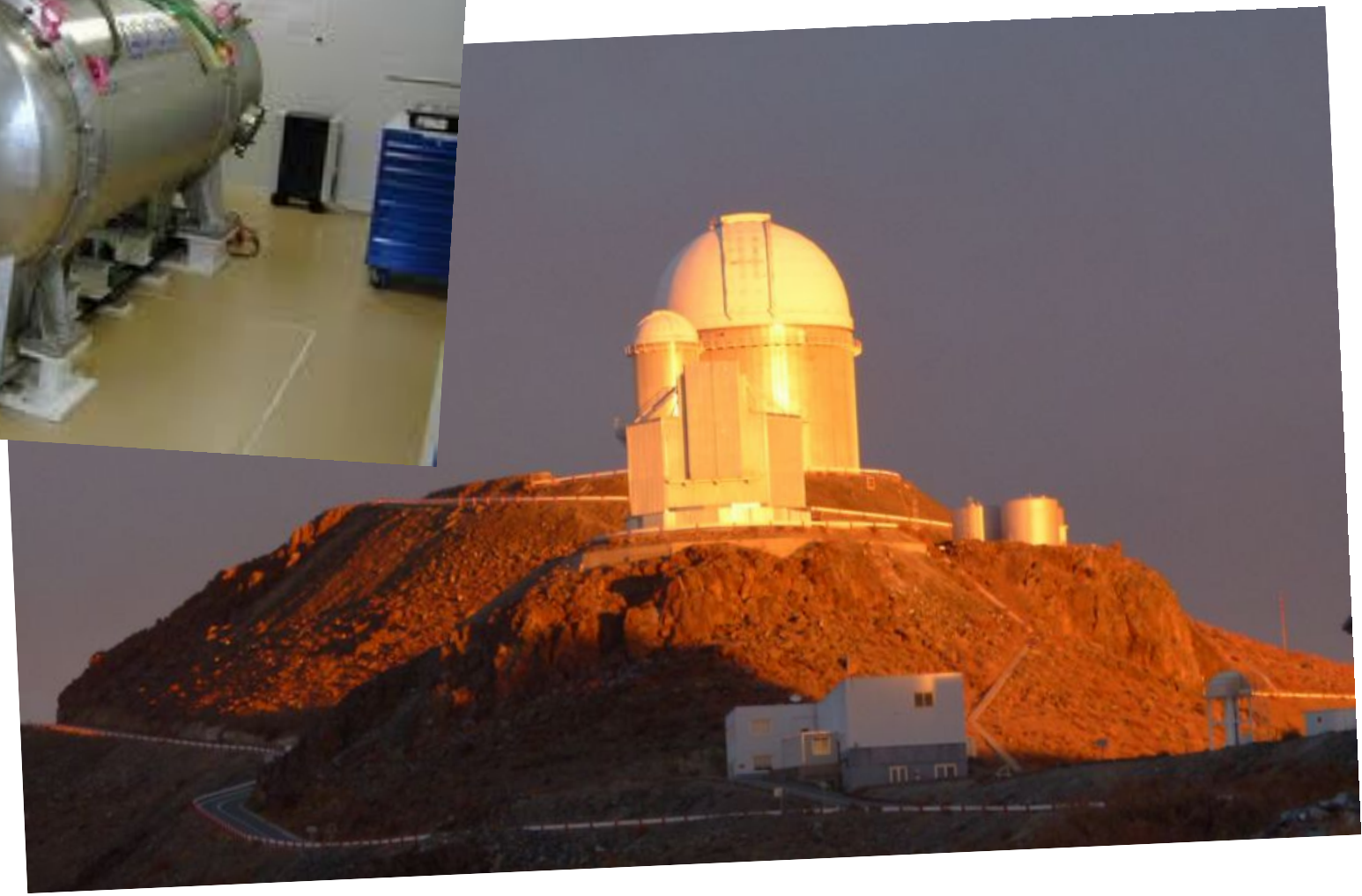

16 Cyg A – 16 Cyg B
Δ[X/H] (16 Cyg A-B) (dex)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
500
1000
1500
T cond (K)
C
O
S
Zn
Na
Cu
Mn
Mg
V
Sc
Ni
Fe
Si
Cr
Co
Ti
Ca
Al
Volatile elements
Refractory elements
Perhaps the chemical enrichment of 16 Cyg A is due to planet engulfment

Procura de planetas em gêmeas do Sol, no Observatório **ESO La Silla: 100 noites**

Projeto internacional liderado pela USP (Prof. Jorge Melendez).

Brasil, EUA, Alemanha, Austrália

Usamos o telescópio de 3,6m com o HARPS, o instrumento mais preciso do mundo para procurar por outros planetas. Precisão de 1m/s



A&A 581, A34 (2015)
DOI: 10.1051/0004-6361/201525748

Astronomy & Astrophysics

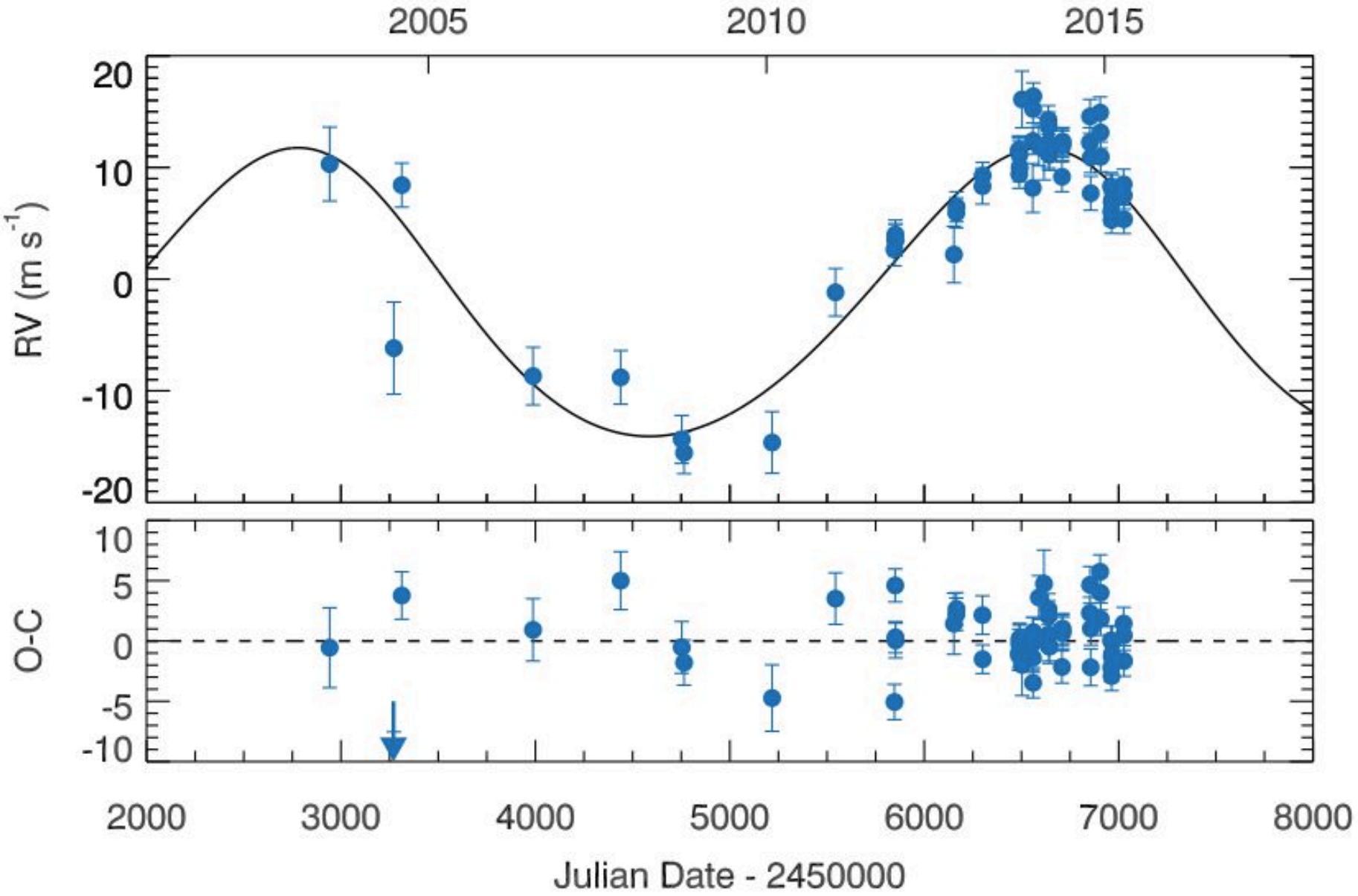
The Solar Twin Planet Search

II. A Jupiter twin around a solar twin⋆

M. Bedell[1,⋆⋆], J. Meléndez[2], J. L. Bean[1], I. Ramírez[3], M. Asplund[4], A. Alves-Brito[5], L. Casagrande[4], S. Dreizler[6], T. Monroe[2], L. Spina[2], and M. Tucci Maia[2]

[1] Department of Astronomy and Astrophysics, University of Chicago, 5640 S. Ellis Ave, Chicago, IL 60637, USA
e-mail: mbedell@oddjob.uchicago.edu
[2] Departamento de Astronomia do IAG/USP, Universidade de São Paulo, Rua do Matão 1226, Cidade Universitária, 05508-900 São Paulo, SP, Brazil
[3] McDonald Observatory and Department of Astronomy, University of Texas at Austin, USA
[4] Research School of Astronomy and Astrophysics, The Australian National University, Cotter Road, Weston, ACT 2611, Australia
[5] Instituto de Fisica, Universidade Federal do Rio Grande do Sul, Av. Bento Goncalves 9500, Porto Alegre, RS, Brazil
[6] Institut für Astrophysik, University of Göttingen, Germany

Received 26 January 2015 / Accepted 27 June 2015



Bedell, Meléndez, Bean et al. 2015

Mercúrio
Vênus
Terra
Marte

Sistema Solar

Júpiter

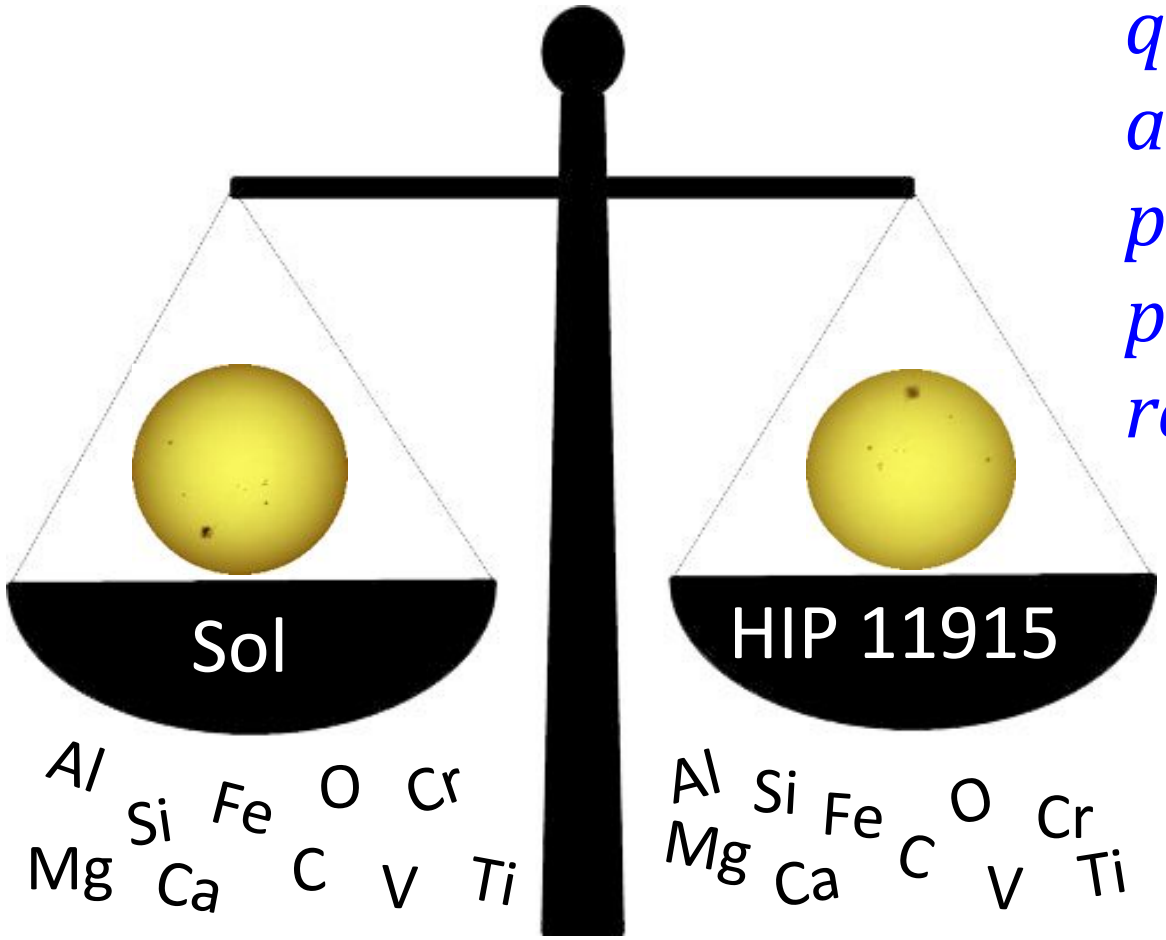
Sistema planetário HIP 11915

HIP11915b

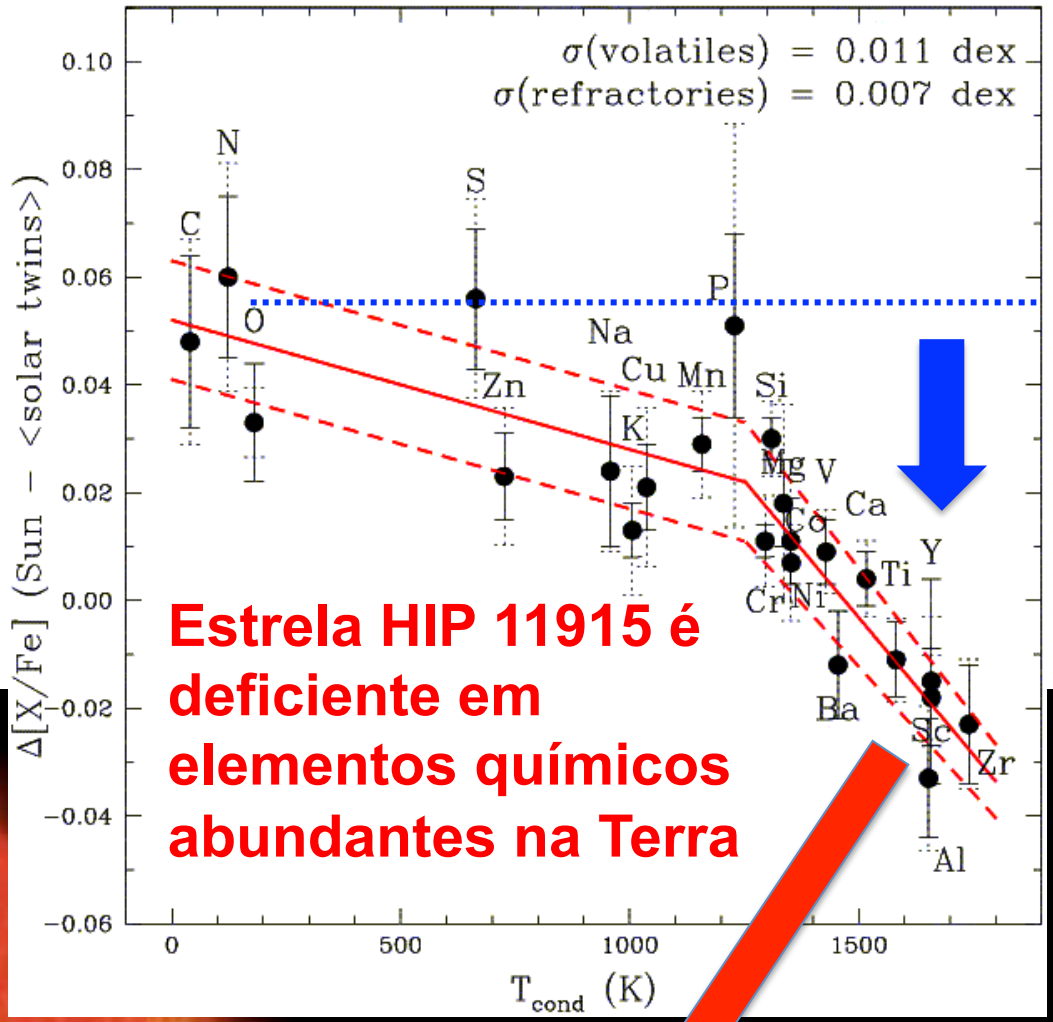
Primeiro planeta “brasileiro”

HIP 11915

Estrela muito similar ao Sol



Composição química adequada para formar planetas rochosos



HIP 11915 pode ter planetas rochosos devido *à composição similar ao Sol*

HIP 11915: candidato a sistema solar gêmeo

?

Vida complexa

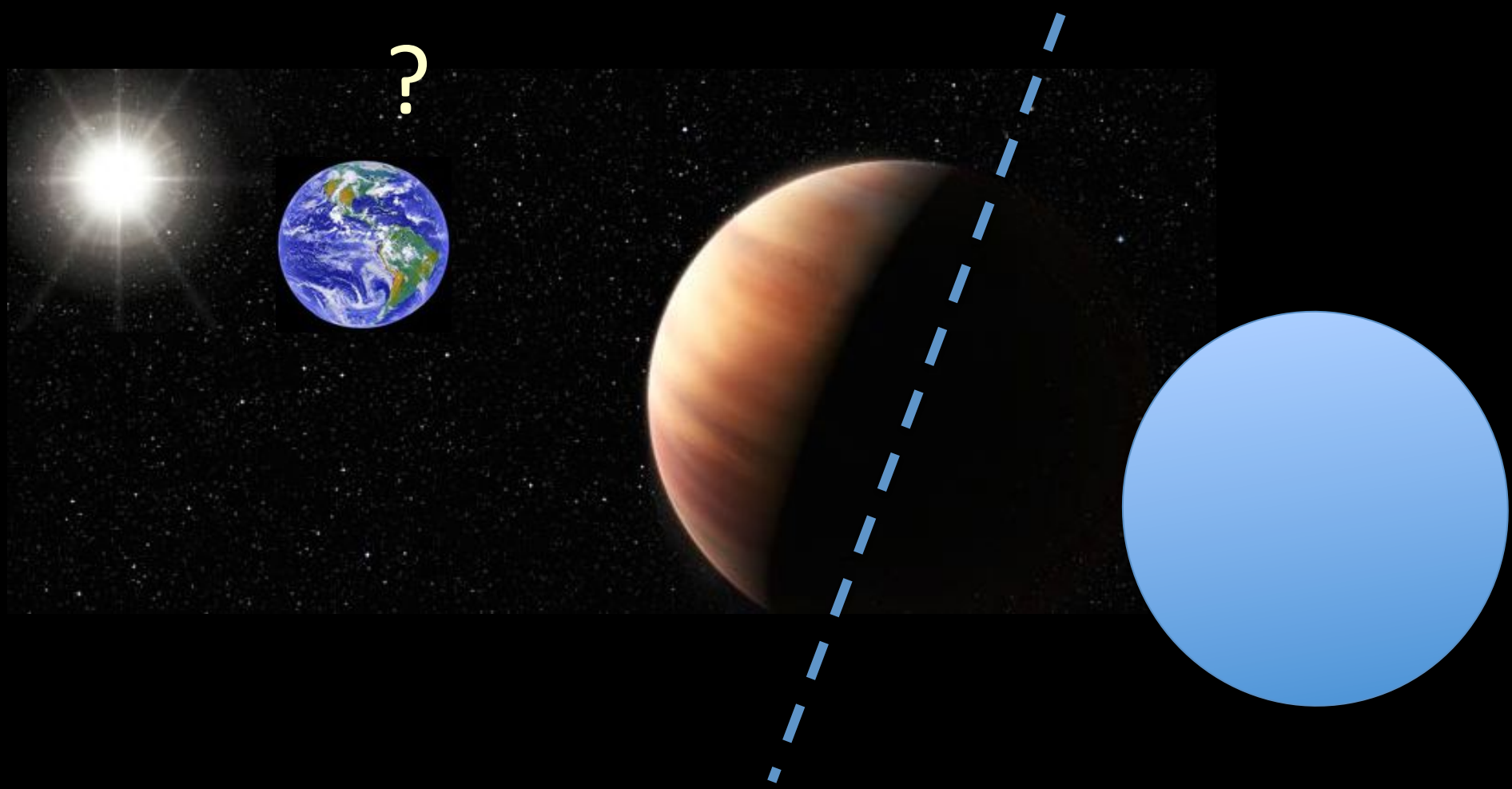
Júpiter é fundamental para manter a configuração do Sistema Solar

André Izidoro
UNESP

Planetas rochosos na região interna

Planetas gigantes na região externa

HIP 11915: candidato a sistema solar gêmeo



Divulgação do Júpiter gêmeo em HIP 11915

Jornal Nacional: 67000*3*24 pontos = 4,8 mi grande São Paulo

Divulgação do Júpiter gêmeo

FOLHA DE S.PAULO

Mensageiro Sideral

De onde viemos, onde estamos e para onde vamos

O primeiro exoplaneta brasileiro

POR SALVADOR NOGUEIRA

15/07/15 ⊙ 15:23 Compartilhar 471 OUVIR O TEXTO

O ESO (Observatório Europeu do Sul) escolheu o dia seguinte à passagem da primeira espaçonave enviada da Terra por Plutão para anunciar a descoberta do primeiro exoplaneta brasileiro. Parabéns.

GALILEU

Astrônomos brasileiros descobrem gêmeo de Júpiter orbitando gêmea do Sol

Busca por um Sistema Solar 2.0 acaba de ganhar um de seus mais promissores candidatos

16/07/2015 - 08H07/ ATUALIZADO 08H0707 / POR ANDRÉ JORGE DE OLIVEIRA

@grupofolha.com

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ESTADÃO

Ciência

'Novo Júpiter' dá pista para Terra 2.0

O GLOBO

Descoberto planeta extrassolar 'gêmeo' de Júpiter

Na busca por uma 'Terra 2', equipe liderada por brasileiro identificou objeto na órbita de estrela parecida com nosso Sol

POR CESAR BAIMA

15/07/2015 11:00 / ATUALIZADO 15/07/2015 13:11

GIOVANA GIRARDI - O ESTADO DE S. PAULO

15 Julho 2015 | 12h 36

Gêmeo do gigante do Sistema Solar orbita estrela parecida com o Sol, o que sugere a existência de um planetinha como o nosso

Divulgação do Júpiter gêmeo na imprensa internacional

CNN

Newly discovered Jupiter twin hints at new solar system similar to Earth's

By Ben Brumfield, CNN
Updated 1434 GMT (2134 HKT) July 16, 2015

Jupiter's 'Twin' Found: Is This Solar System 2.0?

SPACE.COM

by Elizabeth Howell, Space.com Contributor | July 16, 2015 08:35am ET

muy INTERESANTE

Encuentran gemelos de Júpiter y del Sol

Las posibilidades de encontrar un sistema planetario como el nuestro parecen cada vez más cercanas.

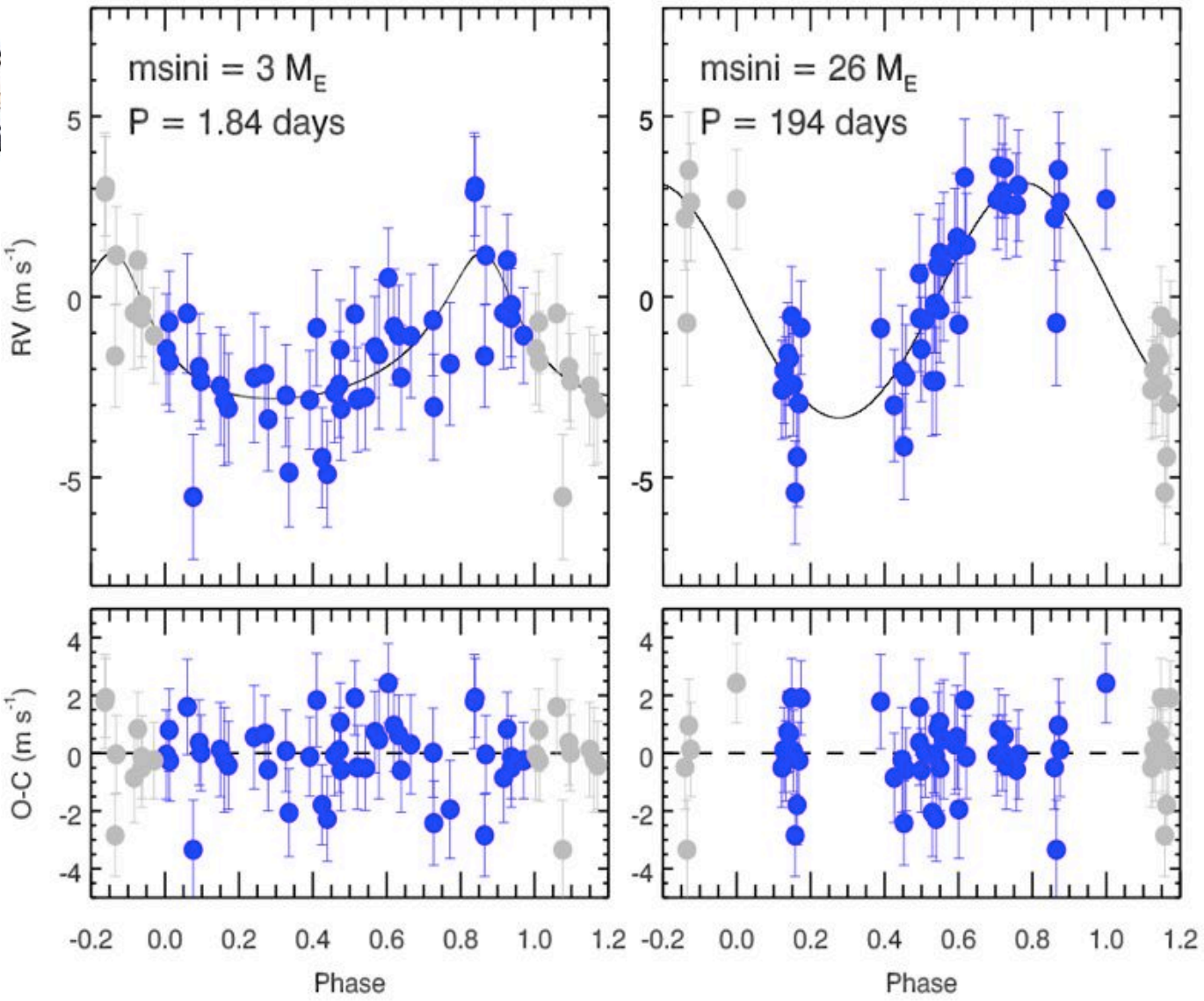
Scoperto un gemello di Giove che ruota attorno al sosia del sole

16/07/2015 - 15:35 - Un gemello di Giove orbita attorno a una stella simile al nostro sole. A scoprilo è stato un team internazionale di astronomi utilizzando il telescopio da 3,6 metri dell'Eso. L'esopianeta si trova a una distanza dalla sua stella (HIP 11915) simile a ...

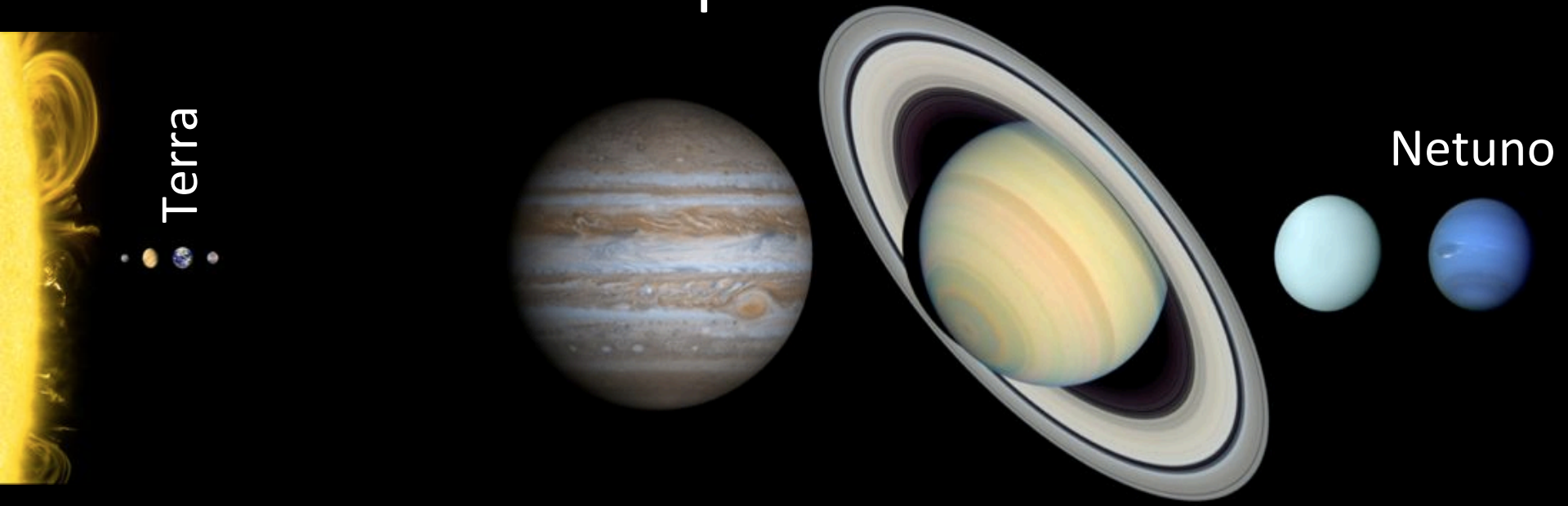
The Solar Twin Planet Search

V. Close-in, low-mass planet candidates and evidence of planet accretion in the solar twin HIP 68468

Jorge Meléndez[1], Megan Be
Yan[6], Jian-Rong Shi[6], Karin L
Marcelo Tucci



Sistema planetário solar



Sistema planetário HIP 68468

Universidade de São Paulo

Planeta devorado por estrela

Estrela HIP 68468 apresenta exceso de lítio

Também excesso de elementos abundantes na Terra

Universidade de São Paulo

Astrônomos brasileiros descobrem dois planetas em estrela gêmea do Sol

POR **SÉRGIO MATSUURA**

04/11/2016 9:58 / atualizado 04/11/2016 10:42

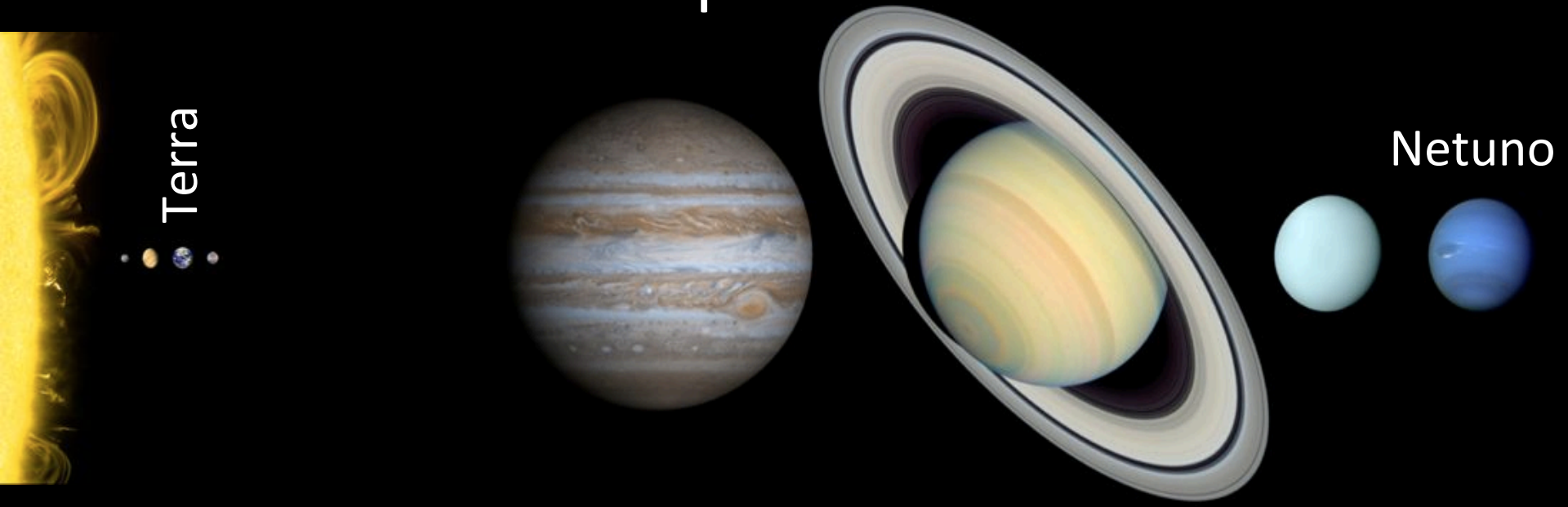
GALILEU

Astrônomos da USP descobrem dois novos planetas

E eles revelam a trágica histórica de um terceiro planeta

04/11/2016 - 11H11/ ATUALIZADO 11H1111 / POR BRUN

Sistema planetário solar

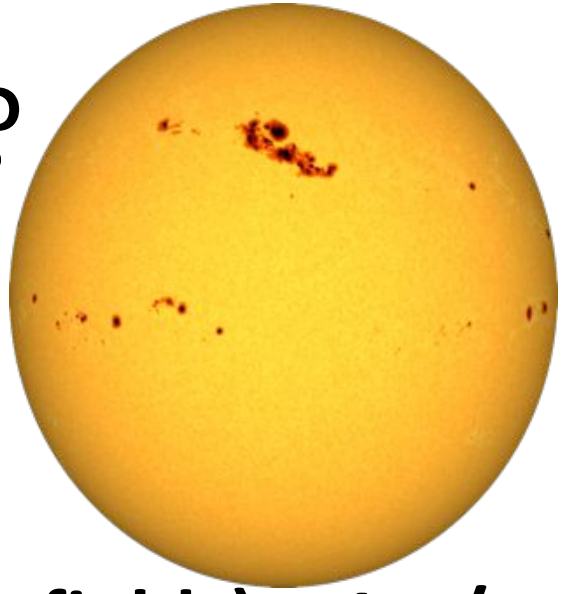


Como encontrar um Sistema Solar 2.0?

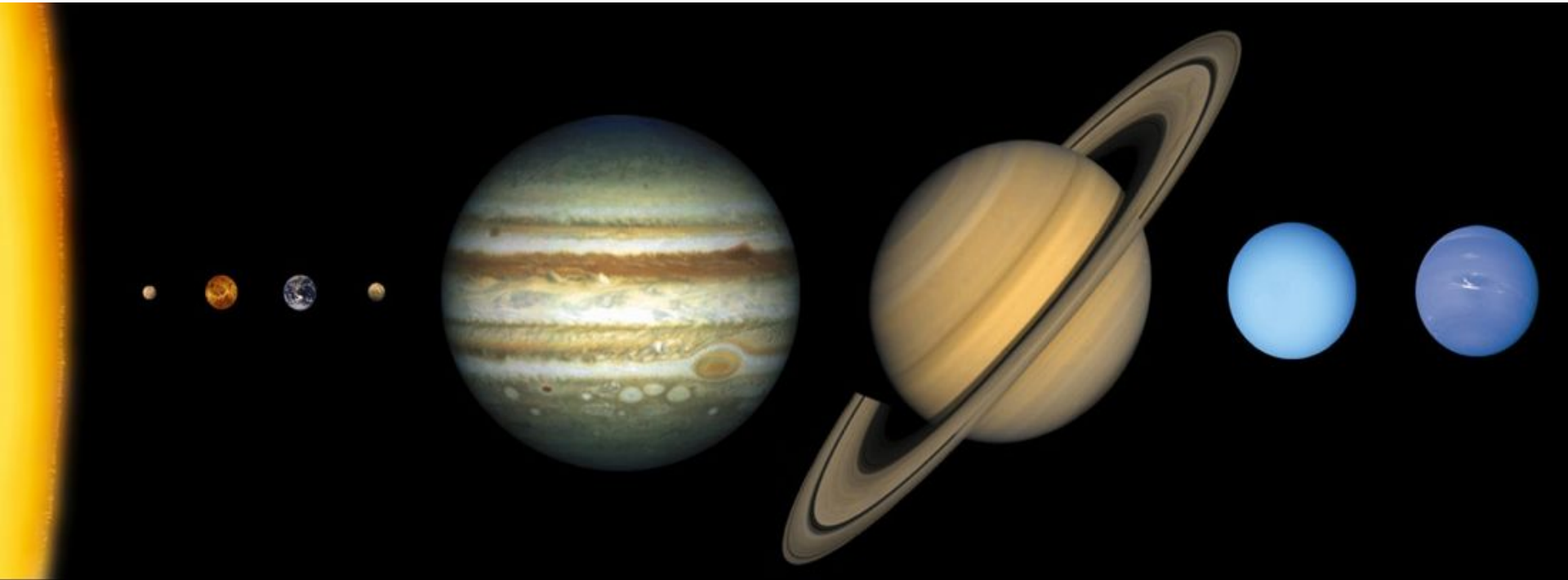
- Estrela gêmea do Sol

- Gêmeo de Júpiter (sem Júpiter, a Terra pode ser destruída)

Como detectar a Terra 2,0?



- Atual instrumentação: 1m/s
- Efeito da Terra 9 cm/s
- **Challenges: stellar noise (magnetic fields) ~ 1m/s**



Convection

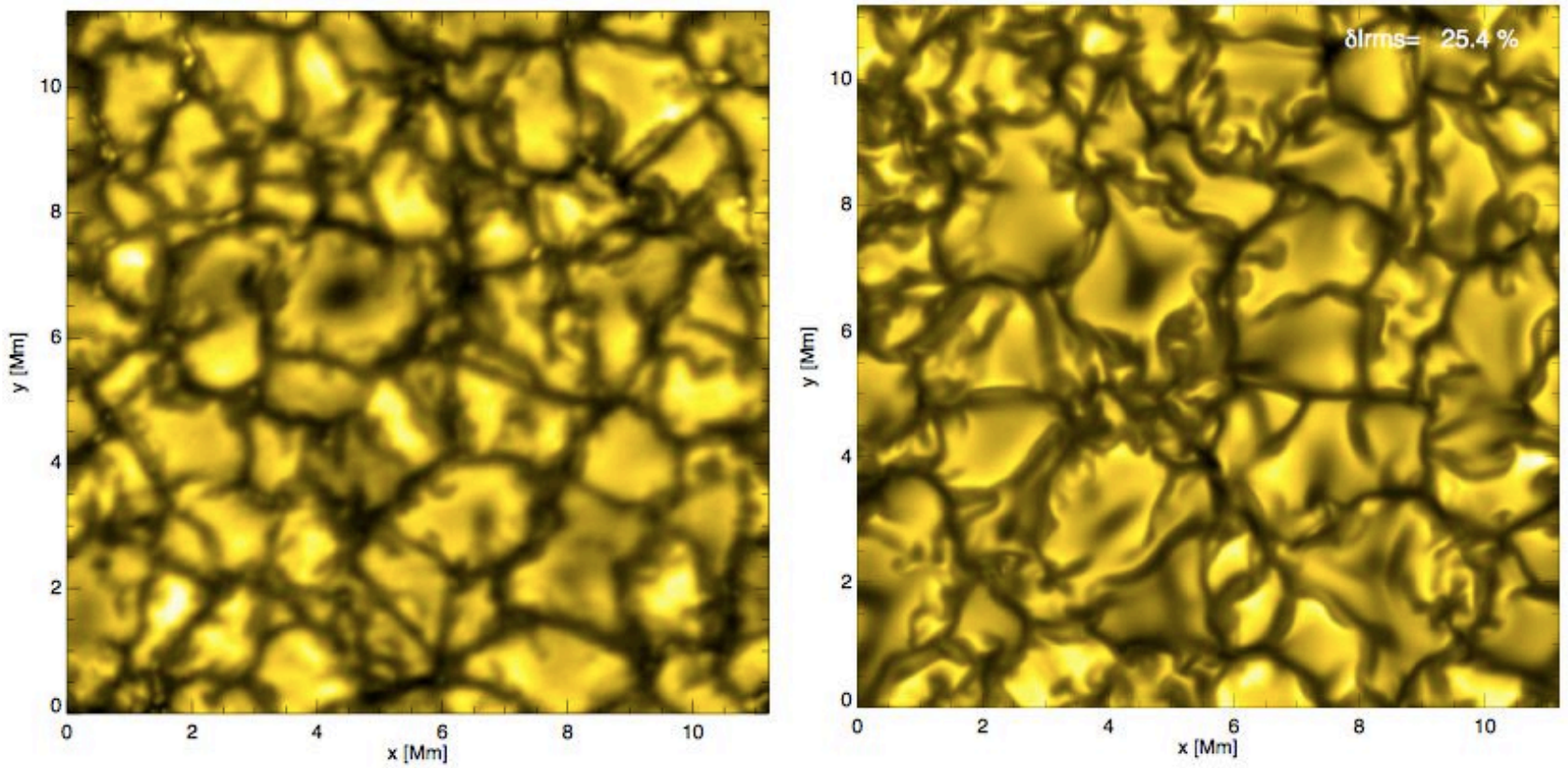
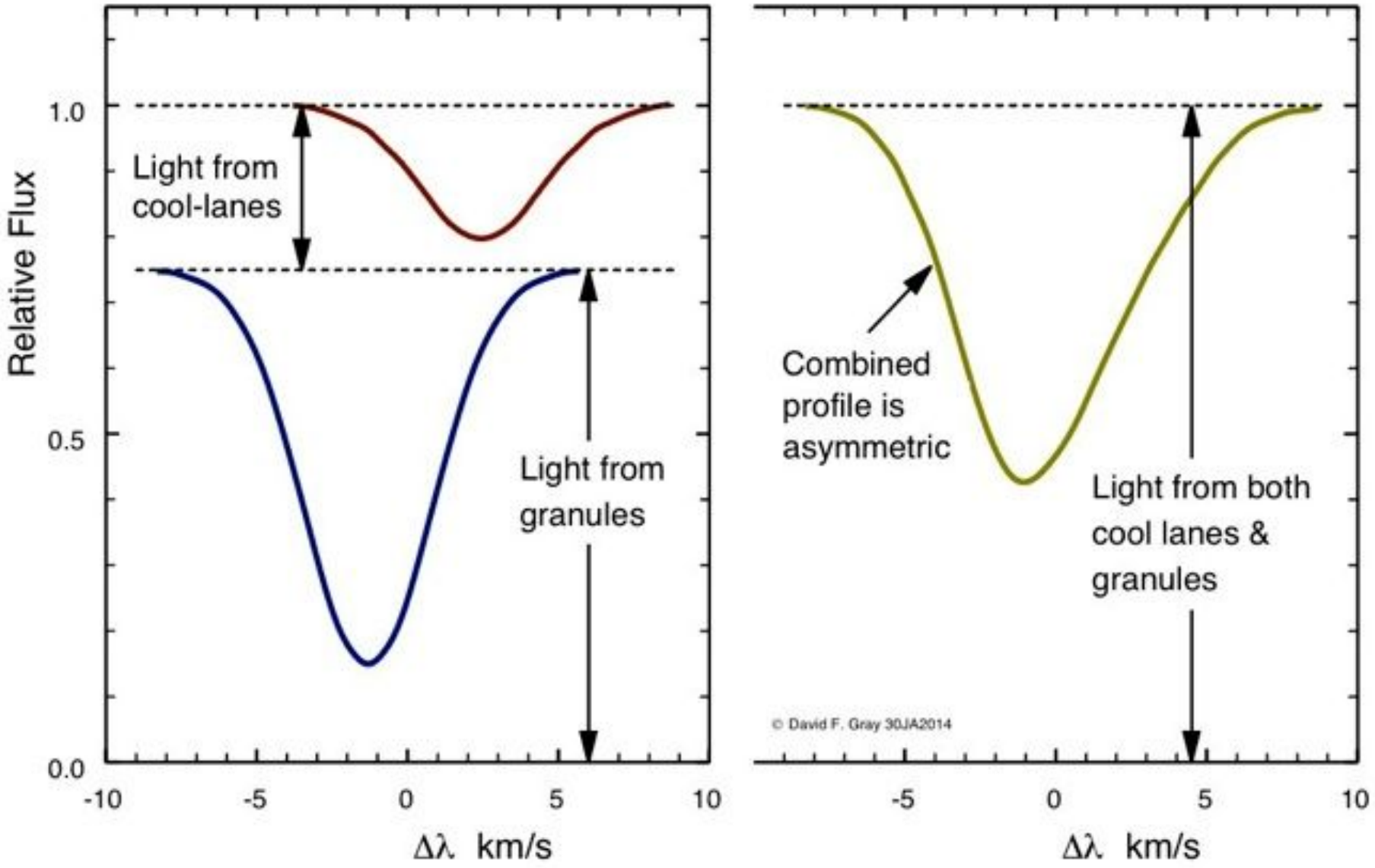


Figure 1: **Left:** Quiet solar granulation as observed with the 1m Swedish Solar Telescope (courtesy Mats Carlsson 2004). **Right:** High-resolution CO^{5}BOLD simulation of solar surface convection. Both images show the emergent continuum intensity (using identical scaling) at λ 4364 Å in a field measuring $15'' \times 15''$ (11×11 Mm).

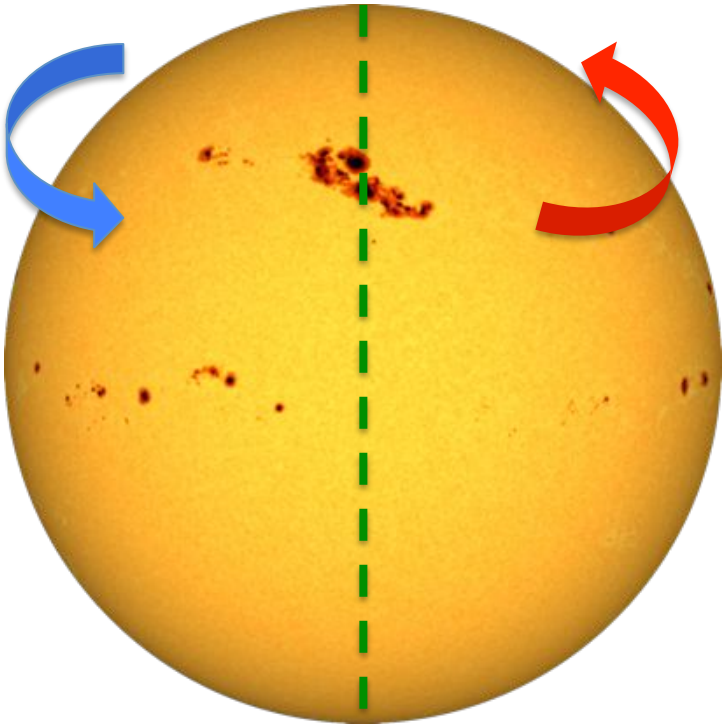
The Solar Photospheric Nitrogen Abundance.
Determination with 3D and 1D model atmospheres.

E.Maiorca[A], *E.Caffau*[B], *P.Bonifacio*[C,B,D], *M.Busso*[A,H], *R.Faraggiana*[E], *M.Steffen*[F], *H.-G.Ludwig*[C,B], *I.Kamp*[G]

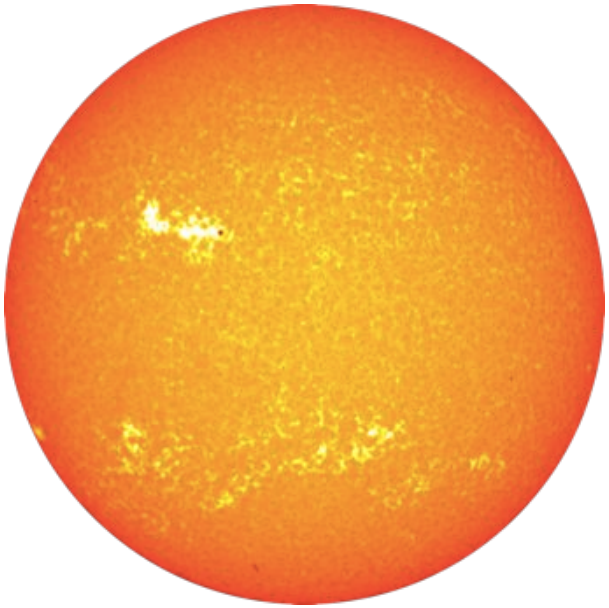


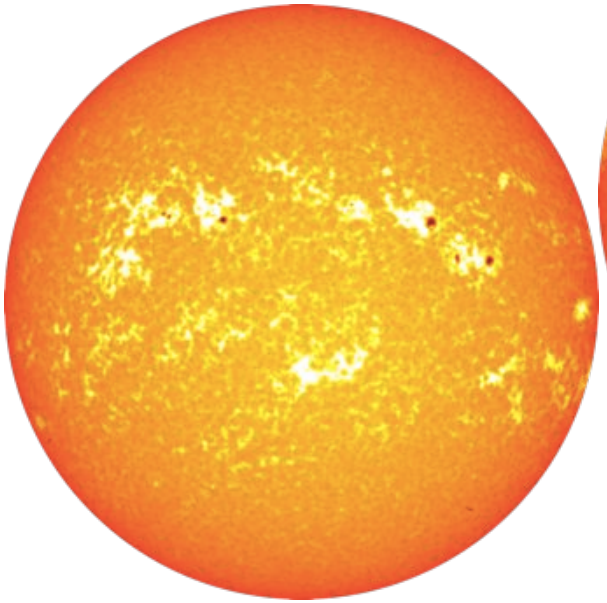
Stellar lines have an asymmetric profile due to convection

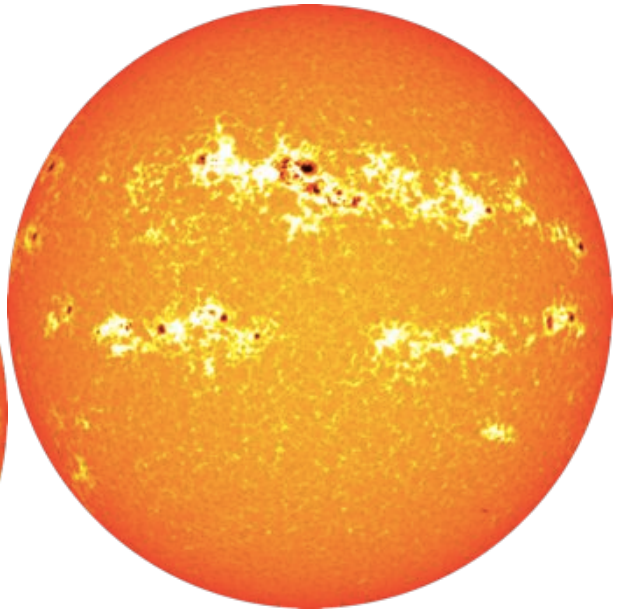
http://astro.uwo.ca/~dfgray/Granulation.html



Sunspots and *plages* can distort the line profile → mimic radial velocity variations (m/s)



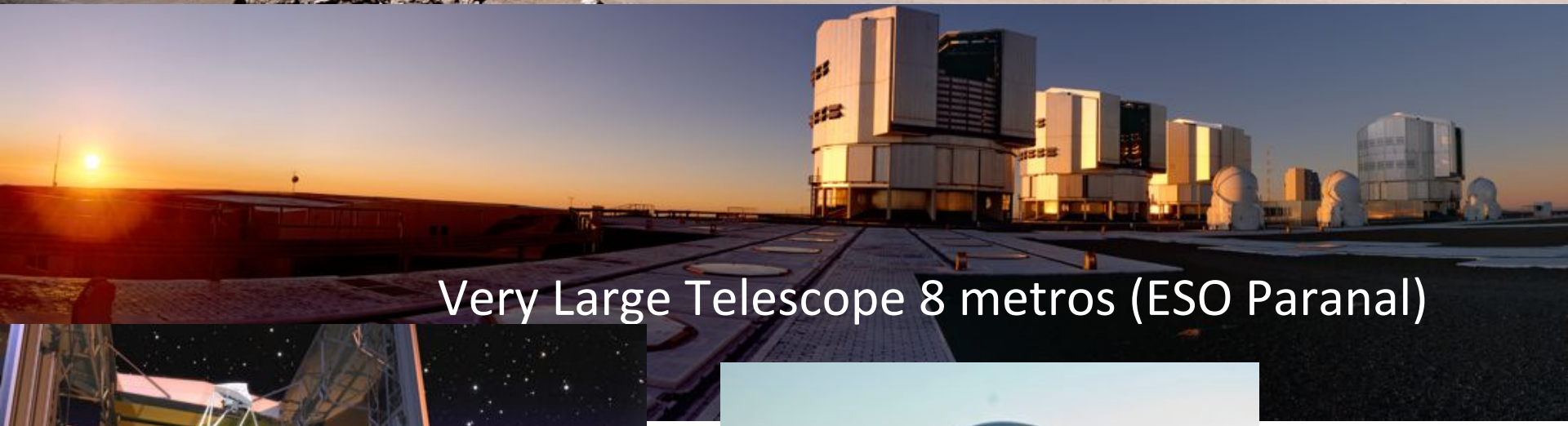




Futuro promissor para detectar a Terra 2.0

2 – 25 cm/s

ELT 39 m (ESO)



Very Large Telescope 8 metros (ESO Paranal)

GMT 24 m
(Las Campanas)

SOAR 4 m
(Chile)

Final remarks

- Astrobiologia e Exoplanetas são áreas muito amplas e em crescimento na Astronomia

- Vagas disponíveis (IC, mestrado, doutorado, pós-doutorado) no meu grupo SAMPA para estudos de Astrofísica Estelar e Exoplanetas

- Disponível hoje no horário do almoço e até 19:00 na minha sala (G-203, acima do auditório)

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