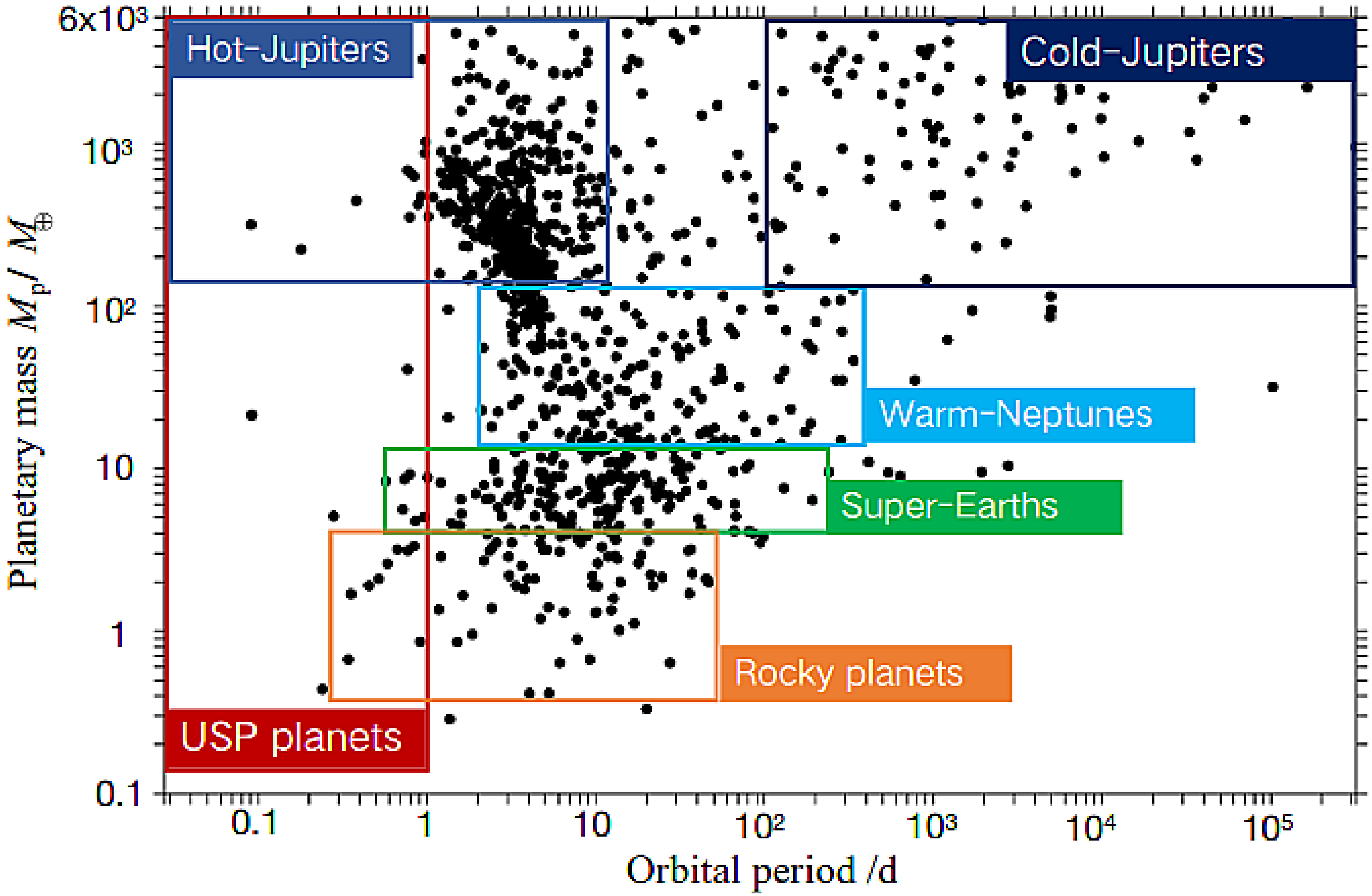
Populações de exoplanetas

Adrián Rodríguez Colucci

Observatório do Valongo
Universidade Federal do Rio de Janeiro

Populações de exoplanetas

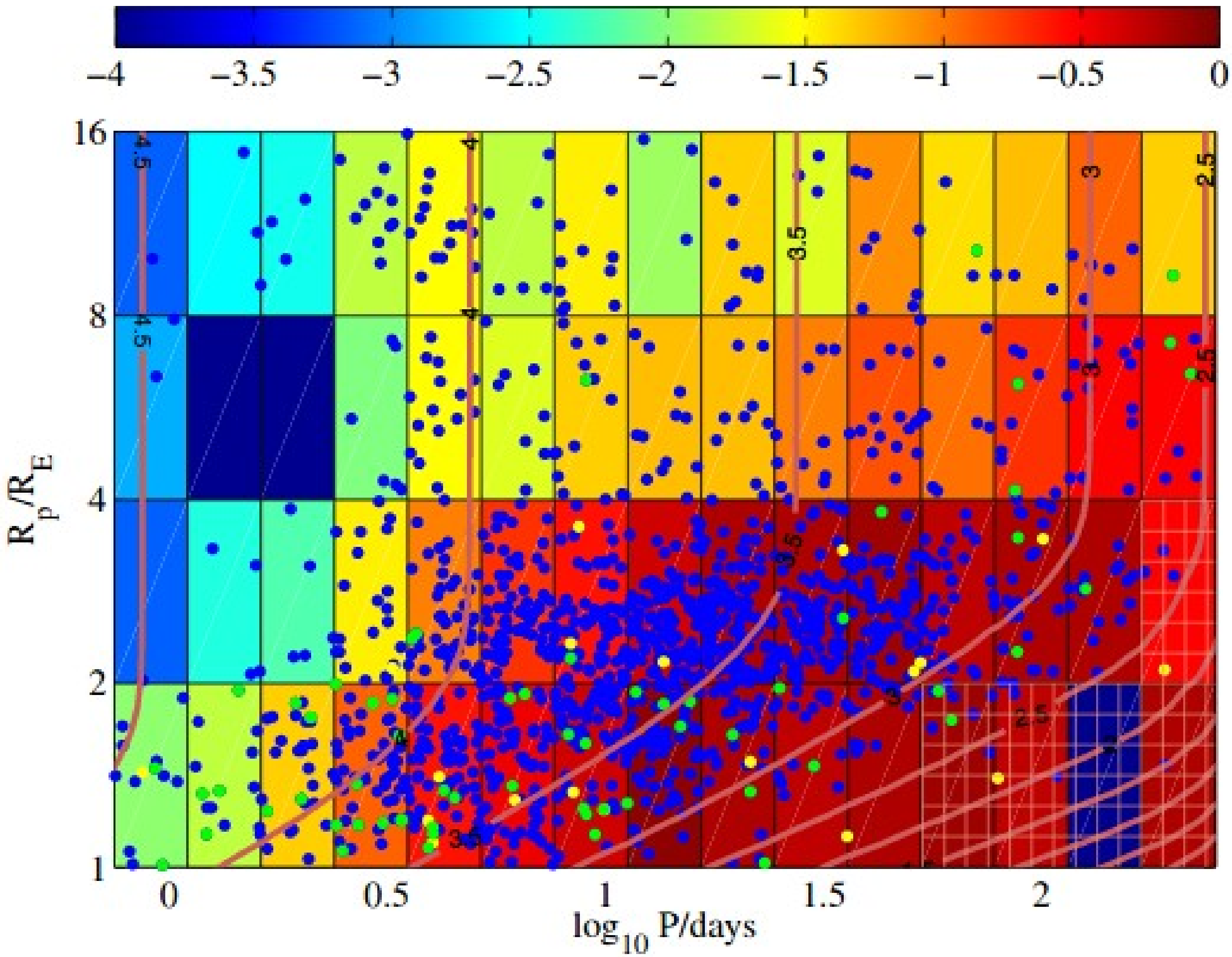
(Liu & Ji, arxiv:2009.02321)



(Ji & Huang, 2020)

- **Planetas pequenos são mais comuns que planetas grandes**
  - Removendo o viés observacional, e para estrelas tipo solar:

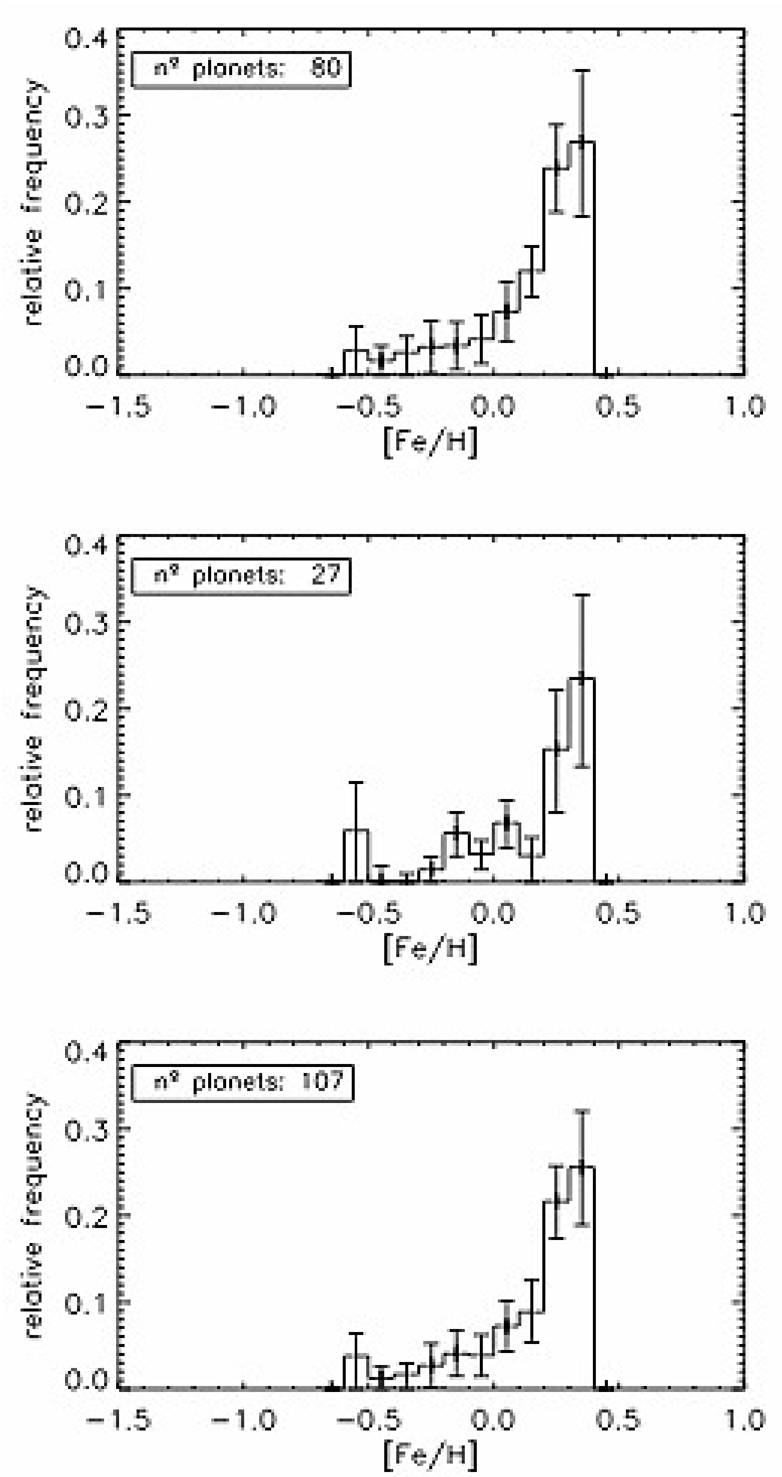
    Hot-Jupiters (HJ) → 1%
    Cold-Jupiters (CJ) → 5 – 10%
    Super-Earths (SE) → 30%



Taxa de ocorrência

(Dong & Zhu, 2013)

● **A ocorrência de planetas gigantes mostra forte dependência com a massa e metalicidade estelar**

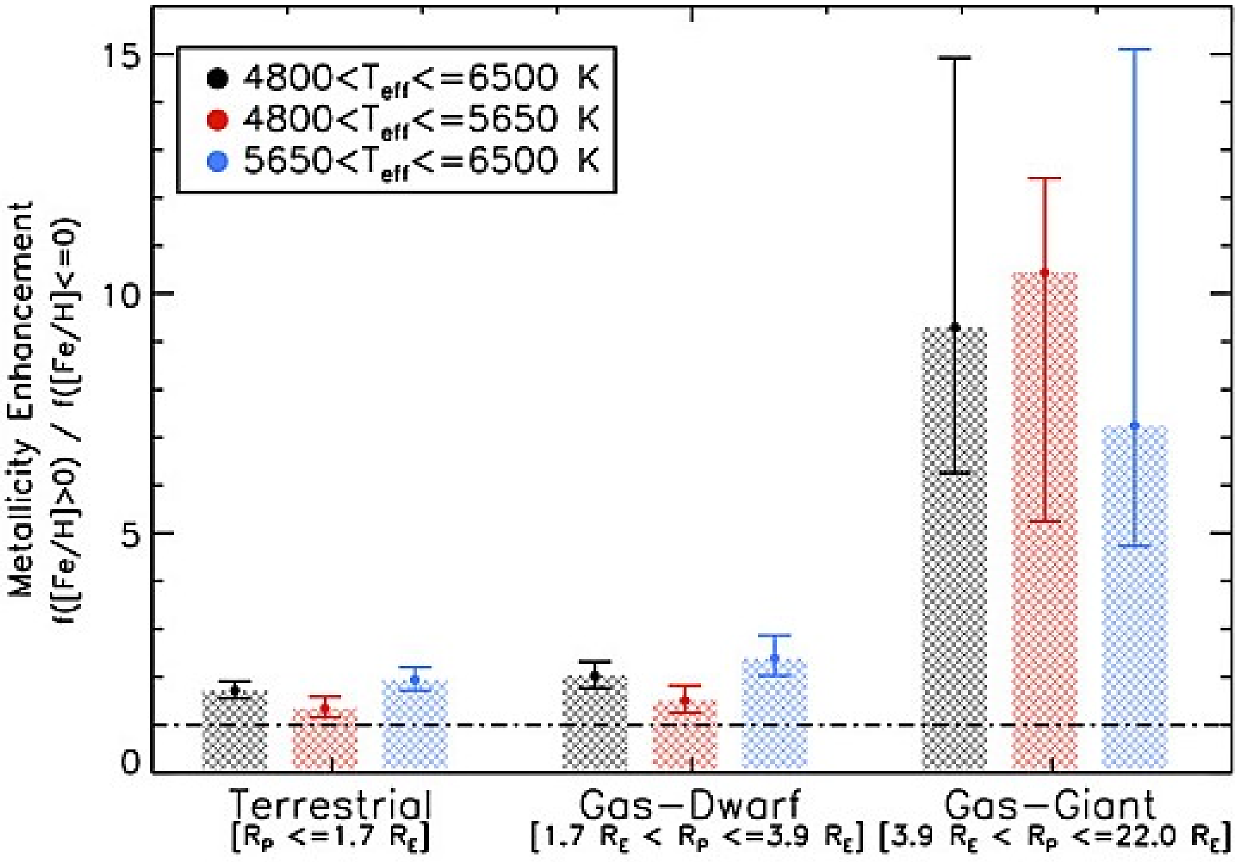


CORALIE

HARPS

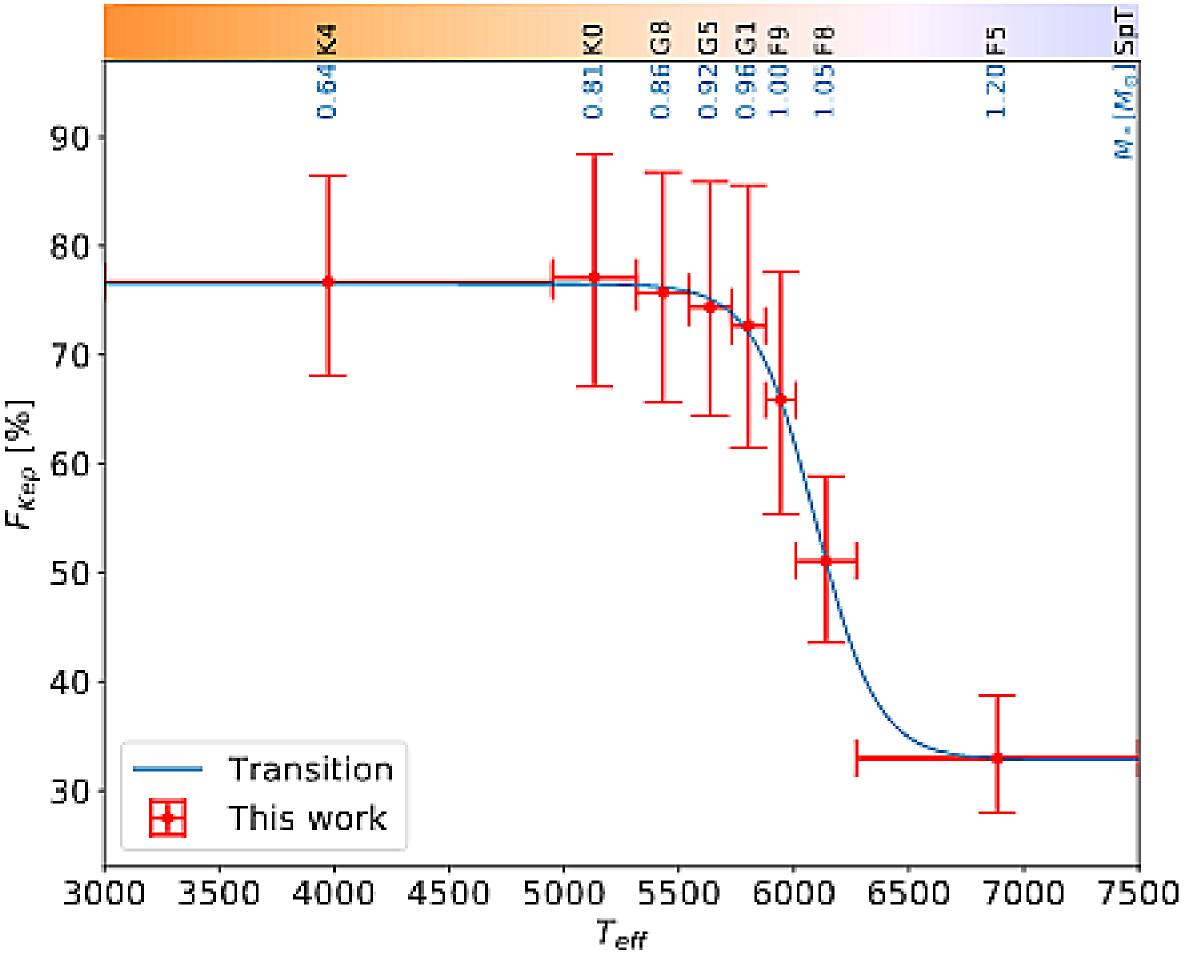
CORALIE + HARPS
(Sousa + 2011)

● **A ocorrência de super-Terras se mostra muito menos dependente da metalicidade estelar**



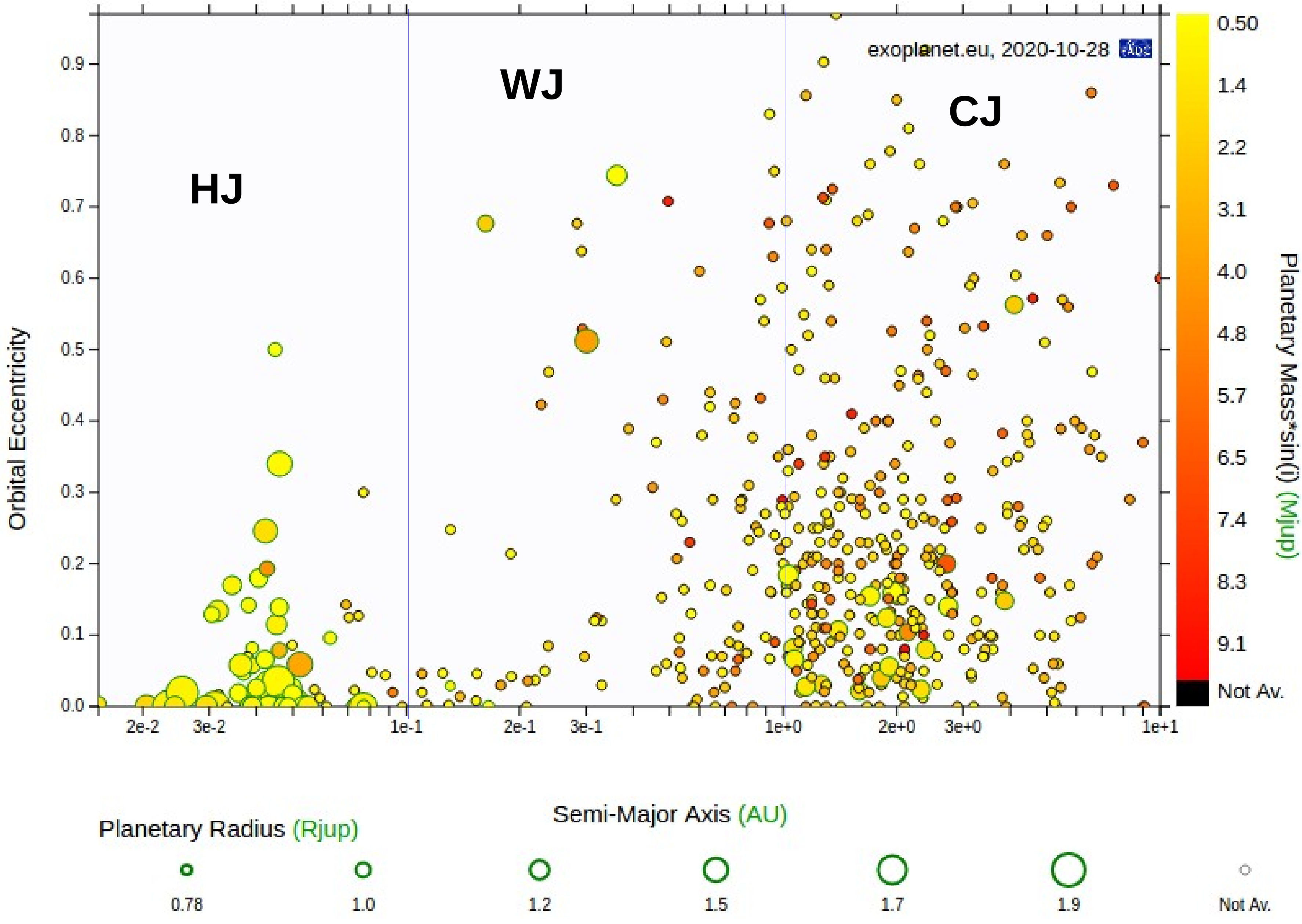
(Wang & Fischer, 2015)

- **Super-Terras são mais abundantes ao redor de estrelas anãs**



(Yang + 2020)

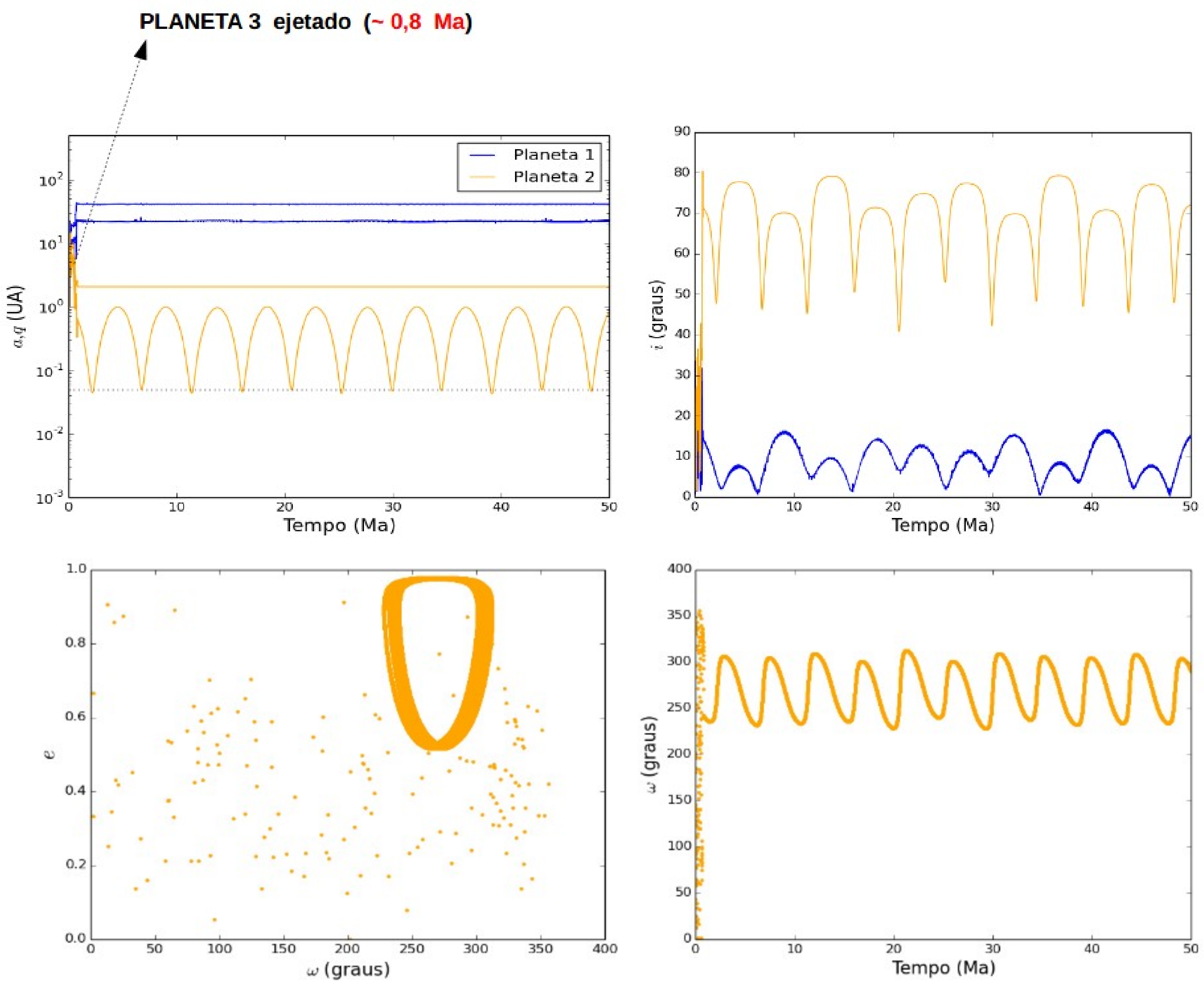
- **HJs possuem órbitas mais circulares do que os WJs e CJs**



Exoplanet.eu

● **Altas excentricidades e inclinações orbitais de planetas gigantes podem ser causadas pelo efeito Lidov – Kozai (companheiro distante) ou por outros mecanismos como o scattering planetário.**

♦ Inclinação = inclinação mútua (entre planeta e compaheiro).

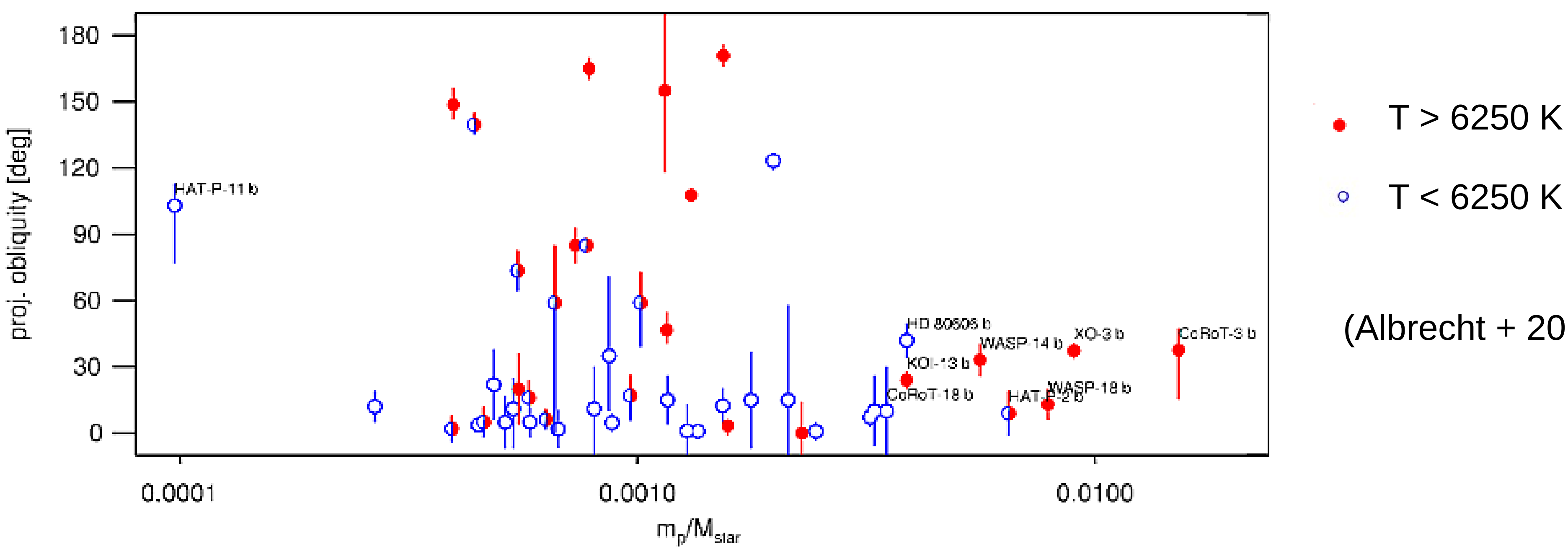


● Muitos HJs possuem grandes obliquidades, incluindo órbitas polares e retrógradas

♦ Obliquidade = ângulo entre o spin da estrela e o momento angular orbital do planeta.

♦ Lidov – Kozai e scattering podem explicar as grandes obliquidades (Naoz + 2011, 2013; Chatterjee + 2008).

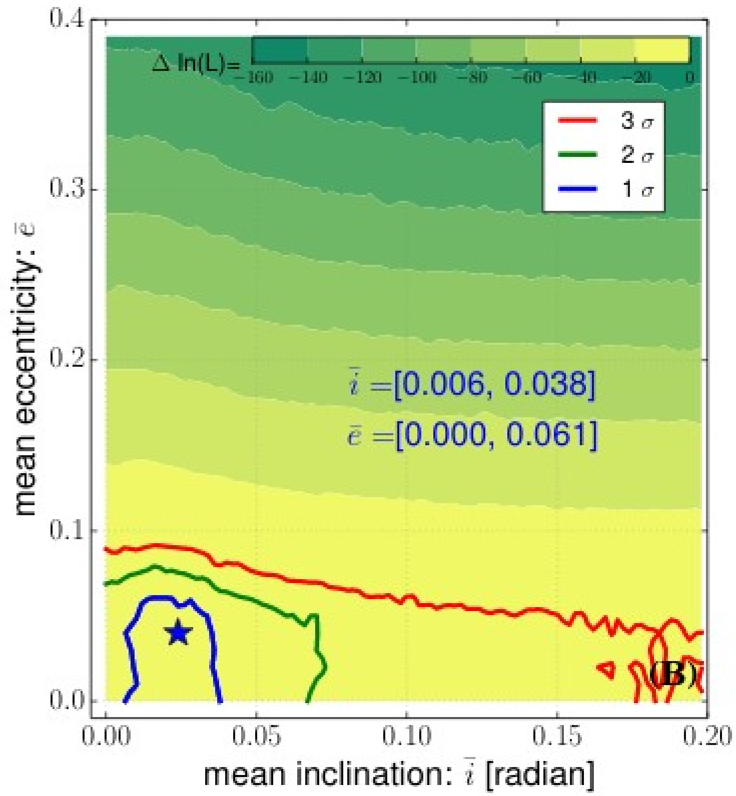
♦ Outros mecanismos podem ser: reorientação do spin estelar devido a processos internos; inclinação do disco protoplanetário devido à interação com estrela companheira (Lai, 2012; Zanazzi & Lai, 2018).

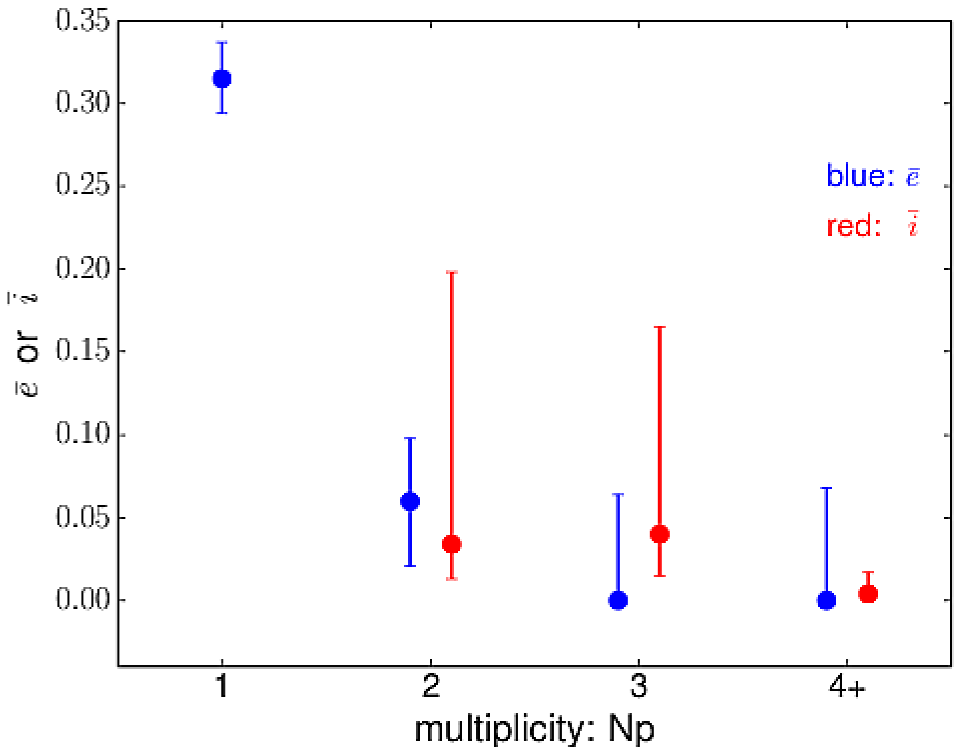


(Albrecht + 2012)

- **Dados do KEPLER revelam:**

  - Sistemas multi-planetários têm excentricidades e inclinações relativamente baixas.
  - Sistemas de um planeta exibem altas excentricidades e inclinações.
  - Sistemas de um planeta → pertenciam a sistemas multi-planetários e tiveram suas órbitas excitadas devido a interações planeta-planeta de longo período ou por companheiros externos. Assim, eles aparecem como planetas "isolados" nos levantamentos.



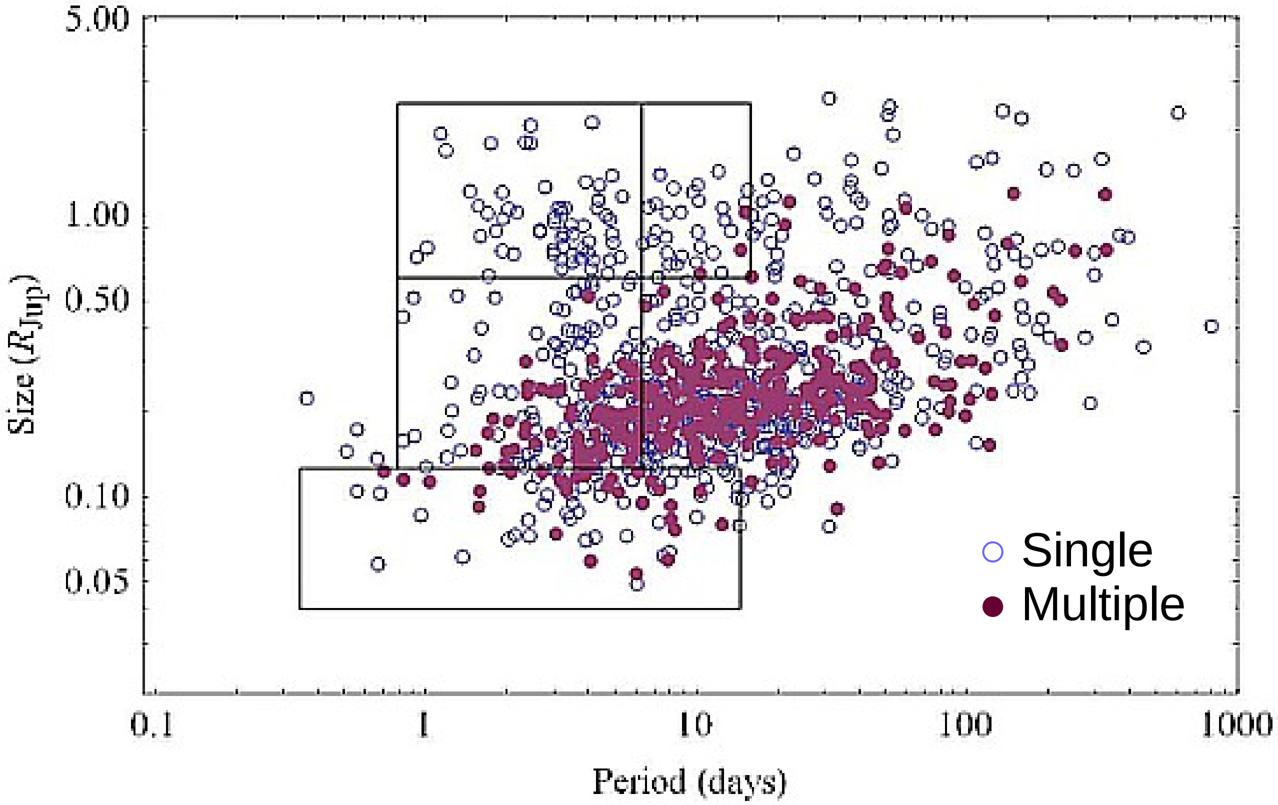


(Xie + 2016)

- **HJs raramente possuem companheiros externos até poucas UAs**

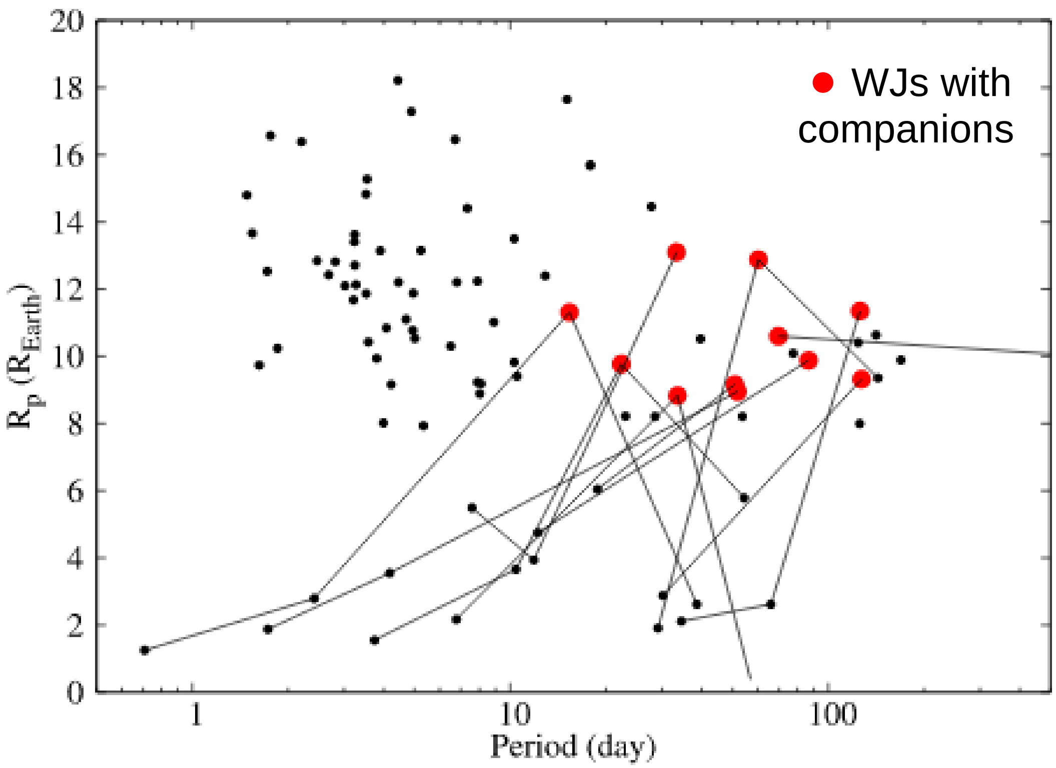
  - ♦ Consistente com cenários de mecanismos Lidov – Kozai e scattering (Mustill + 2018).

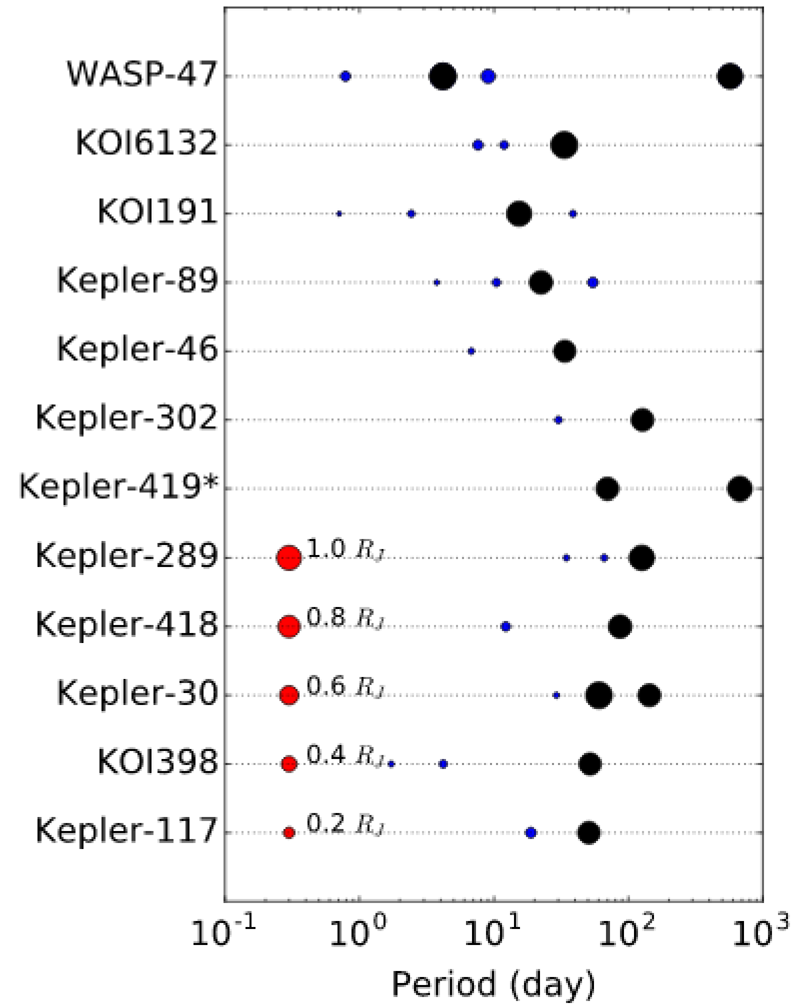
  - ♦ HNs predominam em sistemas de um planeta (Dong + 2018).



(Steffen + 2012)

● ~ metade dos Jupiteres mornos coexistem com planetas de baixa massa

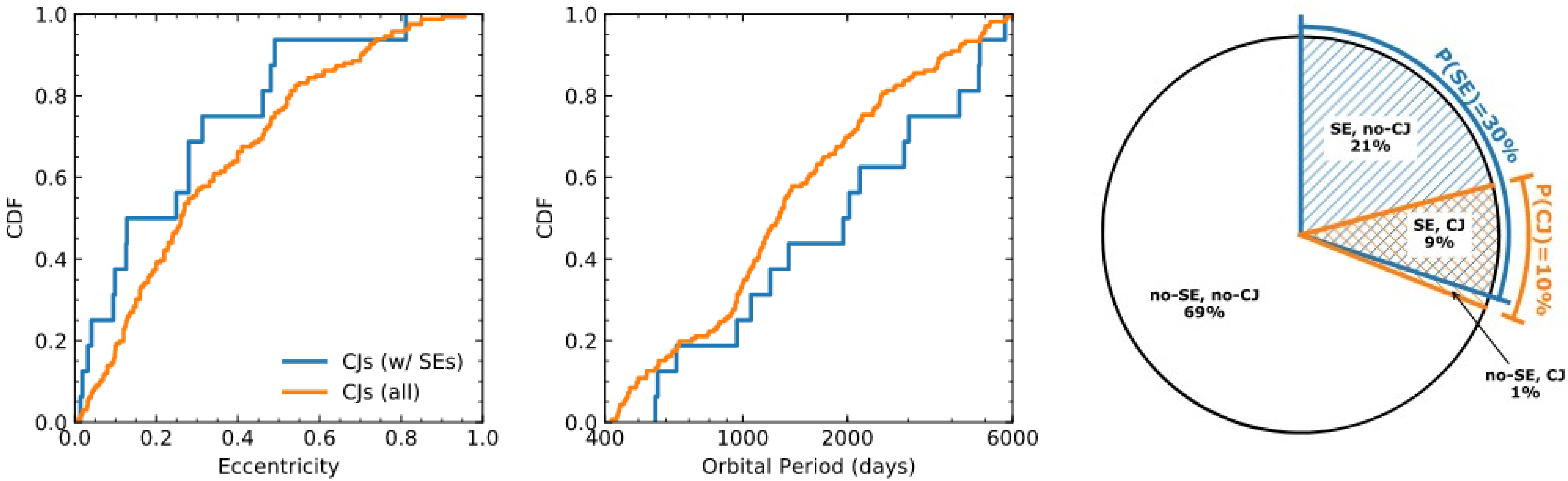




(Huang + 2016)

● **Jupiteres frios tendem a estar acompanhados por super-Terras quentes**

♦ 25 – 30% dos sistemas contendo Jupiteres frios são também habitados por outros planetas gigantes (Wittenmyer + 2020).

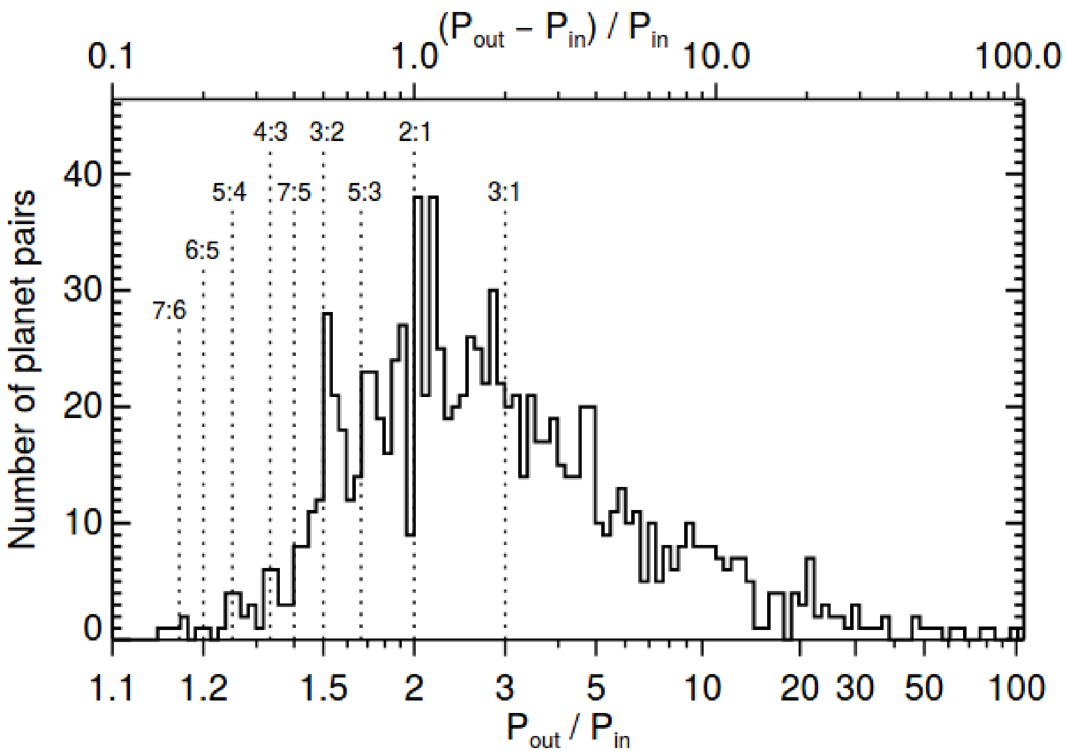


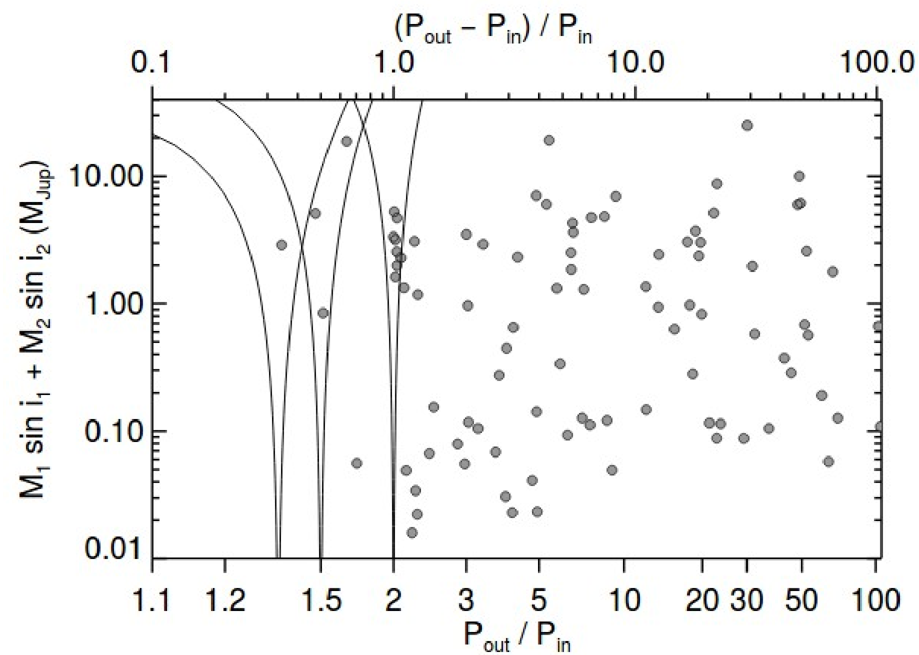
(Zhu & Wu, 2018)

● **A razão de períodos de planetas adjacentes não mostra concentração em MMR nem distribuição aleatória**

♦ Distribuição assimétrica ao redor das 2/1 e 3/2 MMRs.

♦ Alguns mecanismos: maré; interação com planetésimos; migração em discos altamente turbulentos; instabilidades dinâmicas em sistemas compactos (Delisle & Laskar 2014; Chatterjee & Ford 205; Batygin & Adams 2017).

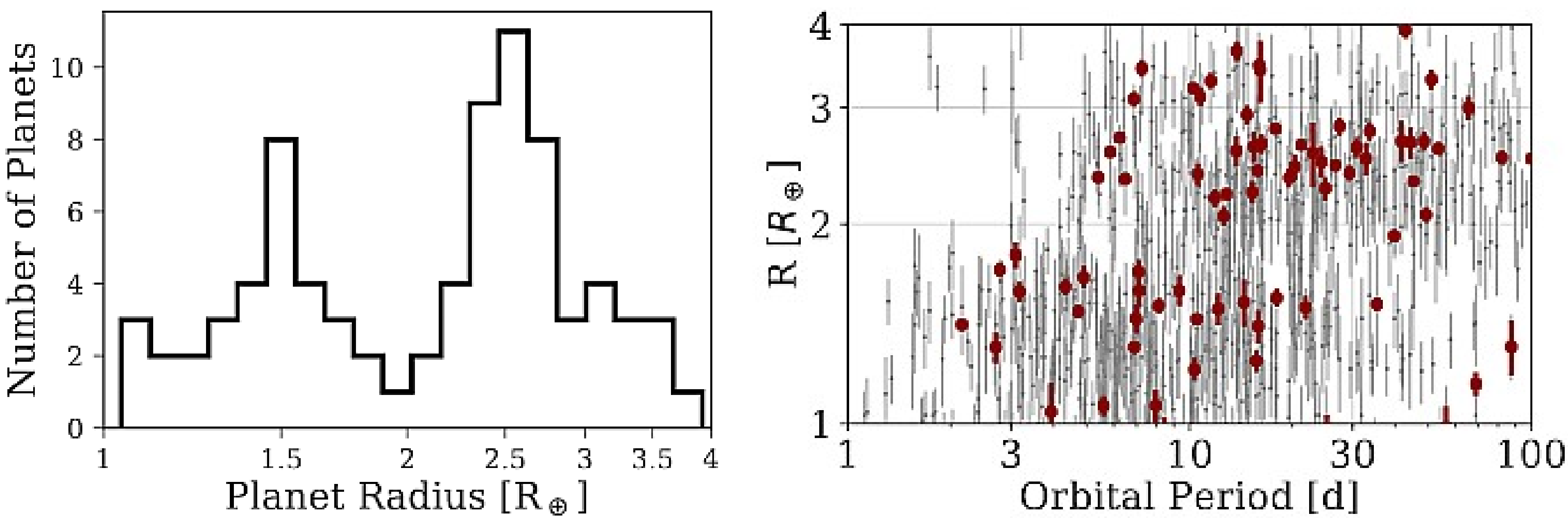




(Winn & Fabrycky, 2015)

● A taxa de ocorrência de super-Terras quentes tem uma distribuição de raio bimodal, com um fator de queda entre Rp ~ 1,5 – 2R⊕

- ♦ Vale do raio ou deserto sub-Netuniano.
- ♦ Transição na composição de planetas rochosos sem envelope gasoso de H/He para planetas com envelopes de gás de alguns % da massa do planeta (Lopez & Fortney, 2013).
- ♦ Mecanismos: perda de gás por fotoevaporação (Owen & Wu, 2017); impactos que removem atmosferas primordiais (Liu + 2015).



(Van Eylen + 2018)

● Planetas interestelares

♦ Formalmente não são planetas (definição IAU).

♦ Detectados através de micro-lenteamento (https://youtu.be/6vVetE5cEMA).

♦ Origem:

- planetas ejetados de sistemas planetários jovens (van Elteren + 2019, A&A, 624) ou velhos (Zink + 2020, arXiv:2009.07296).

- formação in-situ em regiões de formação estelar (sub-brown dwarfs, ex: OTS 44).

♦ Número de planetas interestelares pode superar ao de estrelas na Via Láctea.

♦ Candidatos existem em outras galáxias (RXJ 1131-1231, Dai & Guerras 2018, ApJL, 853)

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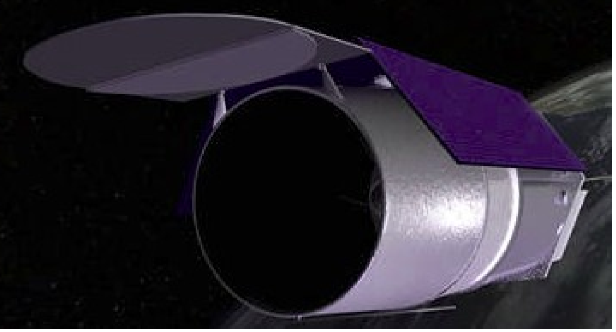

Nancy Grace Roman Space Telescope

About the Roman Space Telescope

The Nancy Grace Roman Space Telescope (formerly known as WFIRST, the Wide Field Infrared Survey Telescope) – a mission concept to answer vital questions in both exoplanet detection and dark energy research.

The powerful role that spaceborne telescopes can play in the future was underscored by a seminal study in 2010 called *New Worlds, New Horizons in Astronomy and Astrophysics*, written by the U.S. National Research Council. That study, which laid out a blueprint for ground- and space-based astronomy and astrophysics for the decade of the 2010s, rated the Roman Space Telescope (then called WFIRST) as the top-priority large-scale mission.

Illustration of Nancy Grace Roman Space Telescope
Credits: NASA

- A previsão é de detectar **~ 250 planetas interestelares** com massas mínimas similares à massa de Marte (Johnson + 2020, AJ, 160).
- Lançamento dentro dos próximos 5 anos.

The Great Inequality and the Dynamical Disintegration of the Outer Solar System

Jon K. Zink,[1] Konstantin Batygin,[2] and Fred C. Adams[3,4]

[1] *Department of Physics and Astronomy, University of California, Los Angeles, CA 90095, USA*
[2] *Division of Geological and Planetary Sciences California Institute of Technology, Pasadena, CA 91125, USA*
[3] *Physics Department, University of Michigan, Ann Arbor, MI 48109, USA*
[4] *Astronomy Department, University of Michigan, Ann Arbor, MI 48109*

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ABSTRACT

Using an ensemble of N-body simulations, this paper considers the fate of the outer gas giants (Jupiter, Saturn, Uranus, and Neptune) after the Sun leaves the main sequence and completes its stellar evolution. Due to solar mass-loss – which is expected to remove roughly half of the star's mass – the orbits of the giant planets expand. This adiabatic process maintains the orbital period ratios, but the mutual interactions between planets and the width of mean-motion resonances (MMR) increase, leading to the capture of Jupiter and Saturn into a stable 5:2 resonant configuration. The expanded orbits, coupled with the large-amplitude librations of the critical MMR angle, make the system more susceptible to perturbations from stellar flyby interactions. Accordingly, within about 30 Gyr, stellar encounters perturb the planets onto the chaotic sub-domain of the 5:2 resonance, triggering a large-scale instability, which culminates in the ejections of all but one planet over the subsequent $\sim$ 10 Gyr. After an additional $\sim$ 50 Gyr, a close stellar encounter (with a perihelion distance less than $\sim$ 200 AU) liberates the final planet. Through this sequence of events, the characteristic timescale over which the solar system will be completely dissolved is roughly 100 Gyr. Our analysis thus indicates that the expected dynamical lifetime of the solar system is much longer than the current age of the universe, but is significantly shorter than previous estimates.

Planetas orbitando estrelas evoluidas

Gigantes vermelhas

Compilation of Discoveries of Substellar Companions around Giant Stars

This is, to the best of my knowledge, a list of all credible planets orbiting giant stars. Typically, only refereed publications are considered.
Planets orbiting subgiant stars are not included.

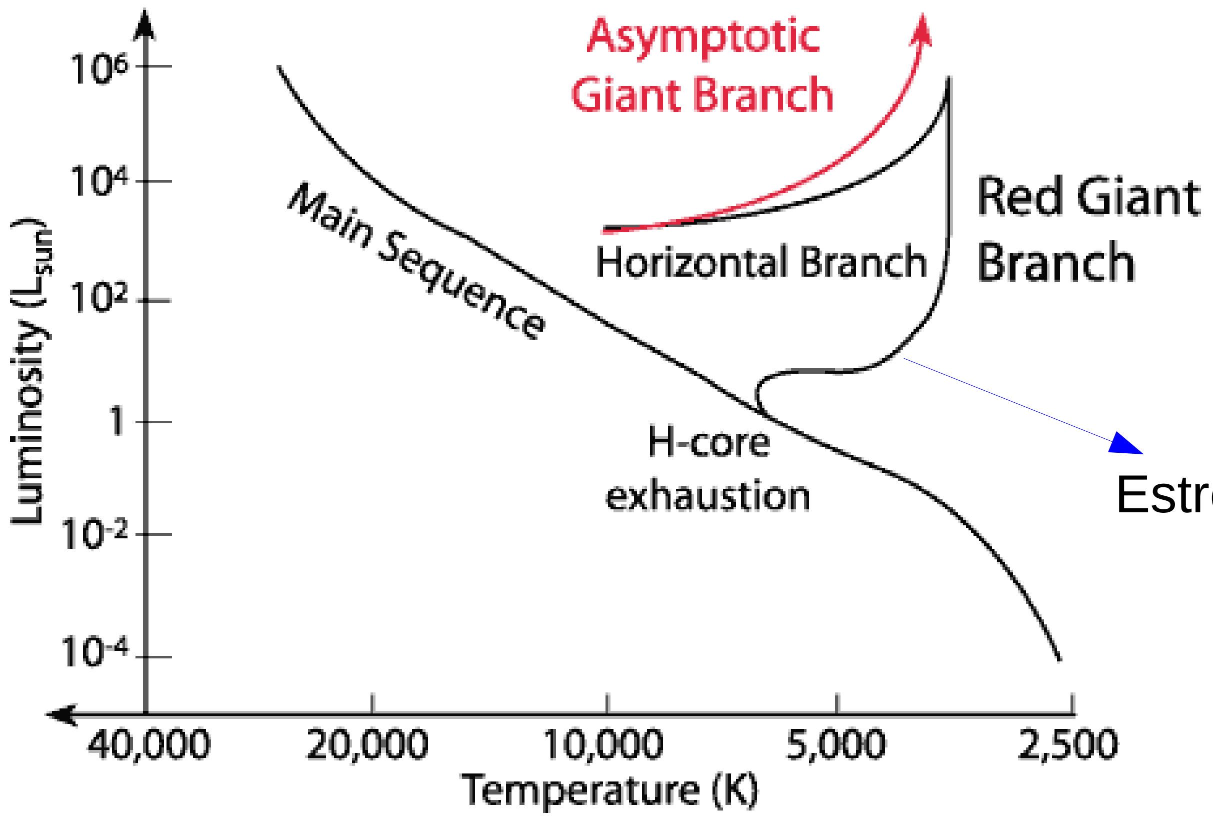
The table is now sortable (click on the column headers) and downloadable in cvs format!

112 substellar companions in 102 systems
click here to download data in cvs format

#	name	hip	V [mag]	-	+	K [mag]	-	+	sptype	feh	-	+	mstar [M_Sun]	-
1	iota Dra b	75458	3.29			0.671			K2 III	0.11			1.05	0.36
2	Pollux b	37826	1.16			-0.936			K0 IIIb	0.07			1.86	
3	HD 11977 b	8928	4.68			2.590			G5 III	-0.16			2.31	
4	HD 47536 b	31688	5.25			2.383			K1 III	-0.65	0.04	0.04	0.98	0.08
5	HD 13189 b	10085	7.57			3.997			K2 II				4.5	2.5
6	epsilon Tau b	20889	3.53			1.422			K0 III	0.17	0.04	0.04	2.7	0.1

https://www.lsw.uni-heidelberg.de/users/sreffert/giantplanets/giantplanets.php

$L = 4\pi^2\sigma T^2 R^4$ → ao longo da fase RGB, **o raio estelar cresce dramaticamente.**



Estrelas evoluidas

Planetas orbitando estrelas evoluidas

Gigantes vermelhas

- Estrelas gigantes vermelhas **perdem massa** de forma significativa.

- A perda de massa tem **impacto na evolução do semi-eixo** dos planetas**:**

$$\left\langle \left(\frac{\mathrm{d}a}{\mathrm{d}t} \right)_{\mathrm{ml}} \right\rangle = -\frac{a}{M+m} \frac{\mathrm{d}M}{\mathrm{d}t},$$

Veras + (2015)

$$\left\langle \left(\frac{\mathrm{d}e}{\mathrm{d}t} \right)_{\mathrm{ml}} \right\rangle = \left\langle \left(\frac{\mathrm{d}\omega}{\mathrm{d}t} \right)_{\mathrm{ml}} \right\rangle = 0.$$

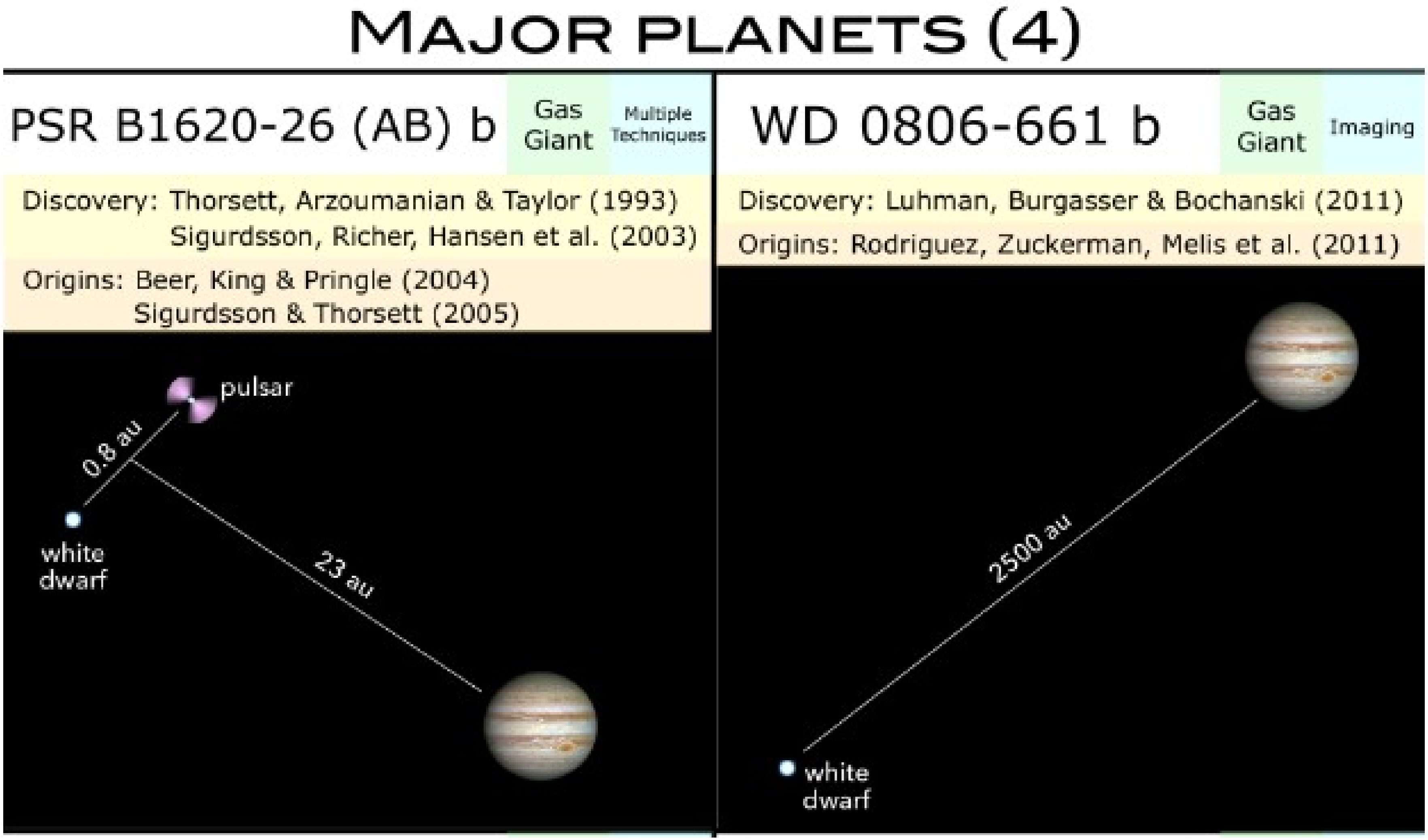
$$\dot{M}_\star = -4 \times 10^{-13} \eta \left(\frac{L_\star}{L_\odot} \right) \left(\frac{R_\star}{R_\odot} \right) \left(\frac{M_\star}{M_\odot} \right)^{-1} M_\odot \,\mathrm{yr}^{-1},$$

Reimers (1975)

- da/dt > 0 → **planetas se afastam da estrela**

Planetas orbitando estrelas evoluidas

Anãs brancas

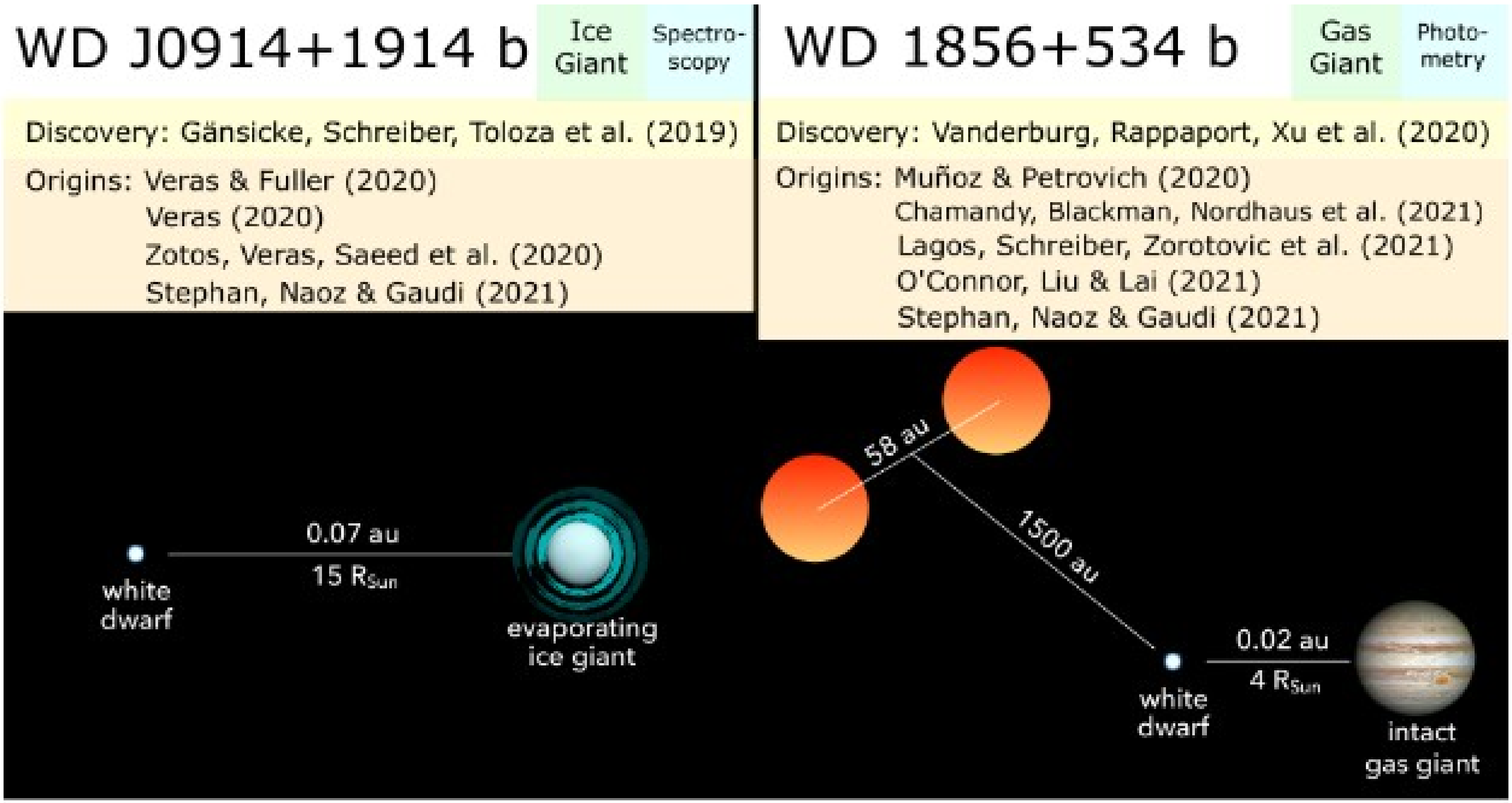


Veras (2021)

● Planetas orbitando estrelas evoluidas

♦ Anãs brancas

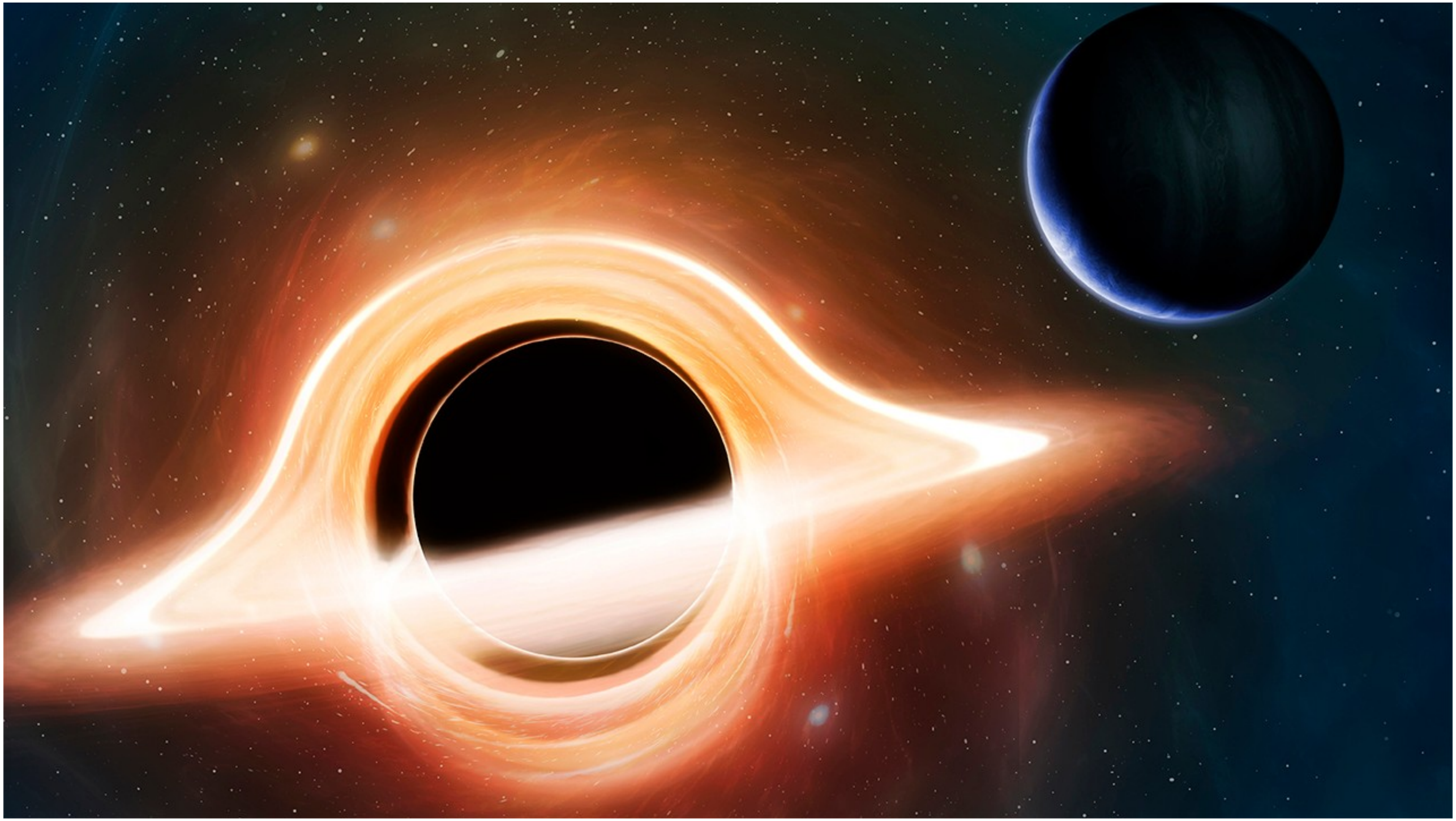
Os 4 planetas descobertos são **gigantes** e se localizam a **distâncias muito pequenas ou grandes** da anã, revelando efeitos de **viés observacional**.



Veras (2021)

- **Planetas orbitando estrelas evoluidas**

♦ **Buracos negros? → *Blanets***



● Planetas orbitando estrelas evoluidas

♦ Buracos negros? → *Blanets*

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https://doi.org/10.3847/1538-4357/ab4cf0

Planet Formation around Supermassive Black Holes in the Active Galactic Nuclei

Keiichi Wada[1,2,3], Yusuke Tsukamoto[1], and Eiichiro Kokubo[4]
[1] Kagoshima University, Graduate School of Science and Engineering, Kagoshima 890-0065, Japan; wada@astrophysics.jp
[2] Ehime University, Research Center for Space and Cosmic Evolution, Matsuyama 790-8577, Japan
[3] Hokkaido University, Faculty of Science, Sapporo 060-0810, Japan
[4] National Astronomical Observatory of Japan, Mitaka 181-8588, Japan
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Abstract

As a natural consequence of the elementary processes of dust growth, we discovered that a new class of planets can be formed around supermassive black holes (SMBHs). We investigated a growth path from submicron sized icy dust monomers to Earth-sized bodies outside the "snow line," located several parsecs from SMBHs in low luminosity active galactic nuclei (AGNs). In contrast to protoplanetary disks, the "radial drift barrier" does not prevent the formation of planetesimals. In the early phase of the evolution, low collision velocity between dust particles promotes sticking; therefore, the internal density of the dust aggregates decreases with growth. When the porous aggregate's size reaches 0.1–1 cm, the collisional compression becomes effective, and the decrease in internal density stops. Once 10–100 m sized aggregates are formed, they are decoupled from gas turbulence, and the aggregate layer becomes gravitationally unstable, leading to the formation of planets by the fragmentation of the layer, with 10 times the mass of the Earth. The growth timescale depends on the turbulent strength of the circumnuclear disk and the black hole mass $M_{\rm BH}$, and it is comparable to the AGN's lifetime ($\sim 10^8$ yr) for low mass ($M_{\rm BH} \sim 10^6 M_\odot$) SMBHs.

Planetas em outras Galáxias ?

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Article | Published: 25 October 2021

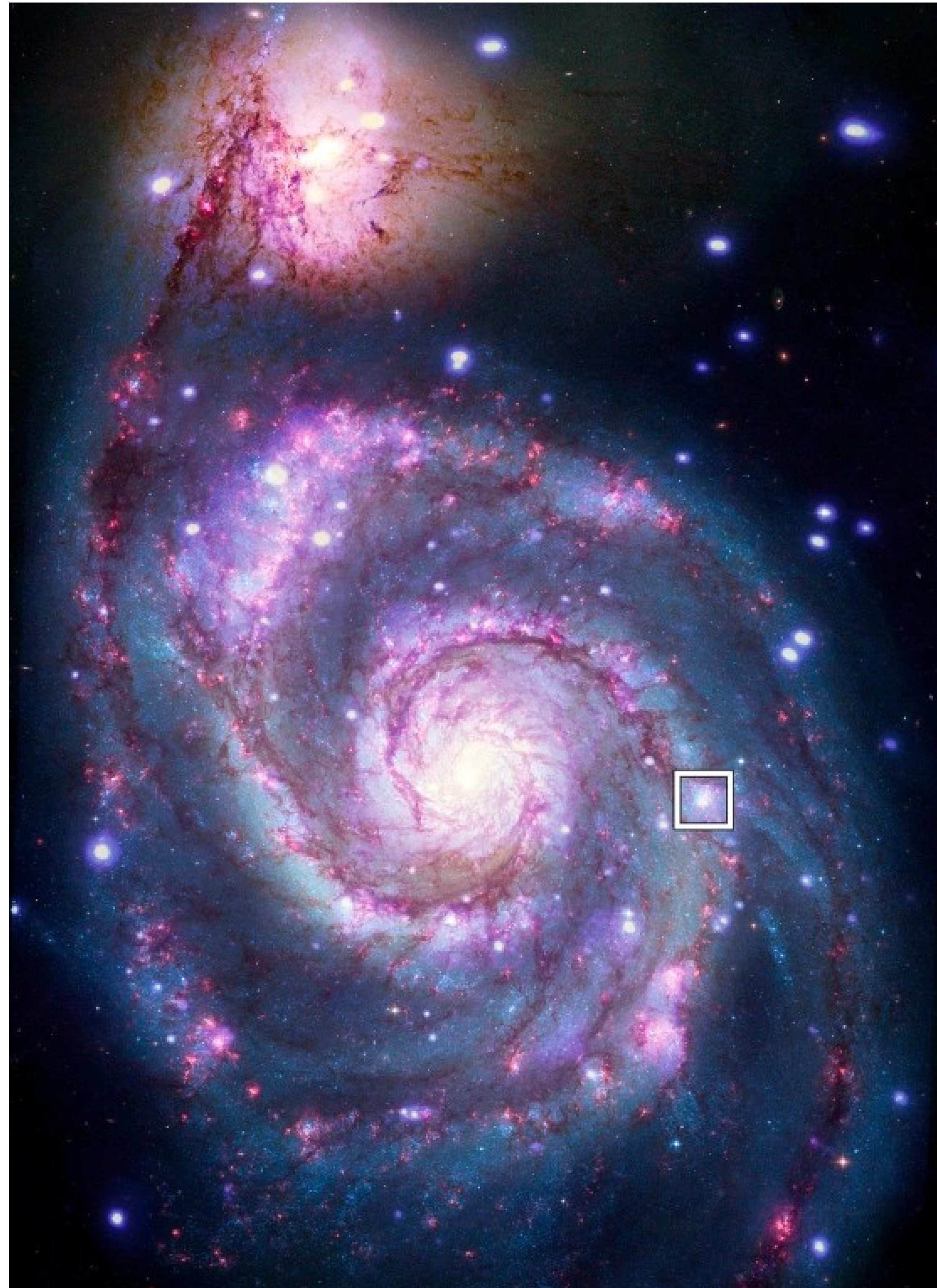
A possible planet candidate in an external galaxy detected through X-ray transit

Rosanne Di Stefano, Julia Berndtsson, Ryan Urquhart, Roberto Soria, Vinay L. Kashyap, Theron W. Carmichael & Nia Imara

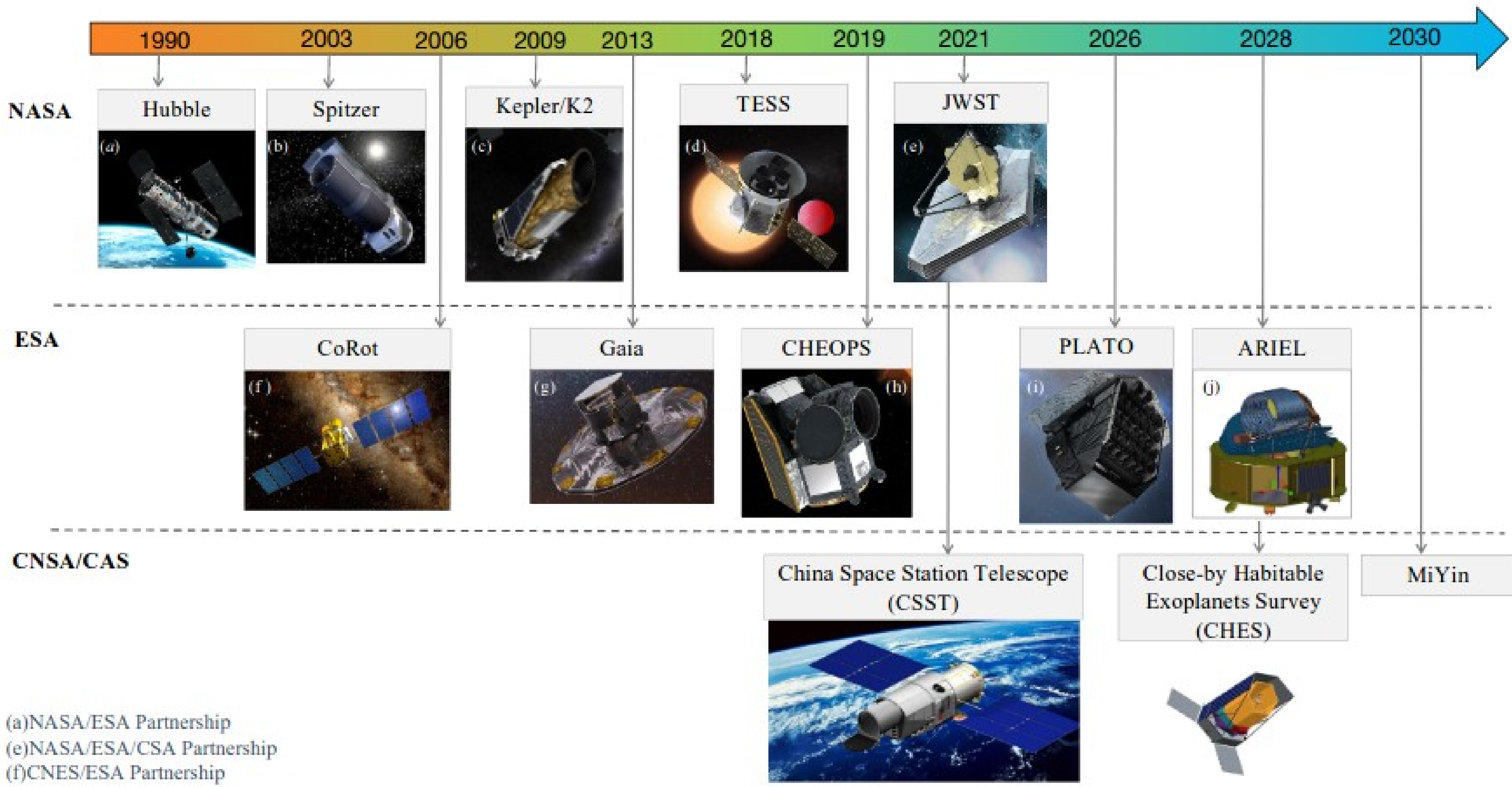
– **Trânsito** de ~3h em uma **binária de raios X** indica a presença de um planeta na **galáxia Messier 51** (23 Mlyr).

– Planeta do tamanho de Saturno.

– Período orbital ~ 70 anos.



● Exploração



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