arXiv.org > astro-ph > arXiv:2002.00231v1

Astrophysics > Earth and Planetary Astrophysics

Water delivery to dry protoplanets by hit-and-run collisions

C. Burger (1 and 2), T. I. Maindl (1), C. M. Schäfer (2) ((1) University of Vienna, Department of Astrophysics, Austria, (2) University of Tübingen, Institute of Astronomy and Astrophysics, Germany)

(Submitted on 1 Feb 2020)

Final water inventories of newly formed terrestrial planets are shaped by their collision history. A setting where volatiles are transported from beyond the snowline to habitable-zone planets suggests collisions of very dry with water-rich bodies. By means of smooth particle hydrodynamics (SPH) simulations we study water delivery in scenarios where a dry target is hit by a water-rich projectile, focusing on hit-and-run encounters with two large surviving bodies, which probably comprise about half of all similar-sized collisions.

Comments: Published as IAU Symposium Proceedings
Subjects: **Earth and Planetary Astrophysics (astro-ph.EP)**
Journal reference: Proceedings IAU Symposium No. 345, Jan 2020, pages 287-288
DOI: 10.1017/S1743921318008621
Cite as: arXiv:2002.00231 [astro-ph.EP]
(or arXiv:2002.00231v1 [astro-ph.EP] for this version)

arXiv.org > astro-ph > arXiv:2002.00405v1

Astrophysics > Earth and Planetary Astrophysics

Accretion disks around young stars: the cradles of planet formation

Dmitry A. Semenov (1,2), Richard. D. Teague (3) ((1) Max Planck Institute for Astronomy, Heidelberg, Germany, (2) Department of Chemistry, Ludwig Maximilian University, Munich, Germany, (3) Center for Astrophysics, Harvard and Smithsonian, Boston, USA)

(Submitted on 2 Feb 2020)

Protoplanetary disks around young stars are the birth sights of planetary systems like our own. Disks represent the gaseous dusty matter left after the formation of their central stars. The mass and luminosity of the star, initial disk mass and angular momentum, and gas viscosity govern disk evolution and accretion. Protoplanetary disks are the cosmic nurseries where microscopic dust grains grow into pebbles, planetesimals, and planets.

Comments: 7 pages, 3 figures, to appear in Europhysics News 51/1
Subjects: **Earth and Planetary Astrophysics (astro-ph.EP)**; Astrophysics of Galaxies (astro-ph.GA); Solar and Stellar Astrophysics (astro-ph.SR)
Cite as: arXiv:2002.00405 [astro-ph.EP]
(or arXiv:2002.00405v1 [astro-ph.EP] for this version)

arXiv.org > astro-ph > arXiv:2001.11045v1

Astrophysics > Earth and Planetary Astrophysics

$M_{\rm dust} - M_\star$ Relation Hints at the Origin of Particle Traps in Protoplanetary Disks

Paola Pinilla, Ilaria Pascucci, Sebastian Marino

(Submitted on 29 Jan 2020)

[abridged] Demographic surveys of protoplanetary disks, mainly with ALMA, have provided access to a large range of disk dust masses ($M_{\rm dust}$) around stars with different stellar types and for different star-forming regions. These surveys found a linear relation in logarithmic scale between $M_{\rm dust}$ and $M_\star$ that steepens with time, but that is flatter for transition disks (TDs). We perform dust evolution models and include perturbations to the gas surface density with different amplitudes to investigate the effect of particle trapping on the $M_{\rm dust} - M_\star$ relation. These perturbations aim to mimic pressure bumps originated by planets. We focus on the effect caused by different stellar and disk masses because exoplanet statistics show a dependence of planet mass with stellar mass and metallicity. We find that models of dust evolution can reproduced the observed $M_{\rm dust} - M_\star$ relation in different star-forming regions when strong pressure bumps are included and when the disk mass scales with stellar mass (case of $M_{\rm disk} = 0.05\,M_\star$ in our models). This result arises from dust trapping and dust growth beyond centimeter-size grains inside pressure bumps. However, the flatter relation of $M_{\rm dust} - M_\star$ for TDs and disks with substructures cannot be reproduced by the models, unless the formation of boulders is inhibited inside pressure bumps. In the context of planets originating pressure bumps, our results agree with the current exoplanet statistics about giant planet occurrence increasing with stellar mass, but we cannot conclude about the type of planets needed in the case of low mass stars. This is because for $M_\star < 1\,M_\odot$, the observed $M_{\rm dust}$ obtained from models is very low due to the efficient growth of dust particles beyond centimeter sizes (boulders) inside pressure bumps.

Comments: Accepted for publication in A&A
Subjects: **Earth and Planetary Astrophysics (astro-ph.EP)**; Solar and Stellar Astrophysics (astro-ph.SR)
Cite as: arXiv:2001.11045 [astro-ph.EP]
(or arXiv:2001.11045v1 [astro-ph.EP] for this version)

arXiv.org > astro-ph > arXiv:2001.11042v1

Astrophysics > Earth and Planetary Astrophysics

Pebble drift and planetesimal formation in protoplanetary discs with embedded planets

Linn E.J. Eriksson, Anders Johansen, Beibei Liu

(Submitted on 29 Jan 2020)

Nearly-axisymmetric gaps and rings are commonly observed in protoplanetary discs. The leading theory regarding the origin of these patterns is that they are due to dust trapping at the edges of gas gaps induced by the gravitational torques from embedded planets. If the concentration of solids at the gap edges becomes high enough, it could potentially result in planetesimal formation by the streaming instability. We test this hypothesis by performing global 1-D simulations of dust evolution and planetesimal formation in a protoplanetary disc that is perturbed by multiple planets. We explore different combinations of particle sizes, disc parameters, and planetary masses, and find that planetesimals form in all these cases. We also compare the spatial distribution of pebbles from our simulations with protoplanetary disc observations. Planets larger than one pebble isolation mass catch drifting pebbles efficiently at the edge of their gas gaps, and depending on the efficiency of planetesimal formation at the gap edges, the protoplanetary disc transforms within a few 100,000 years to either a transition disc with a large inner hole devoid of dust or to a disc with narrow bright rings. For simulations with planetary masses lower than the pebble isolation mass, the outcome is a disc with a series of weak ring patterns but no strong depletion between the rings. Lowering the pebble size artificially to 100 micrometer-sized "silt", we find that regions between planets get depleted of their pebble mass on a longer time-scale of up to 0.5 million years. These simulations also produce fewer planetesimals than in the nominal model with millimeter-sized particles and always have at least two rings of pebbles still visible after 1 Myr.

arXiv.org > astro-ph > arXiv:2001.11040v1

Astrophysics > Earth and Planetary Astrophysics

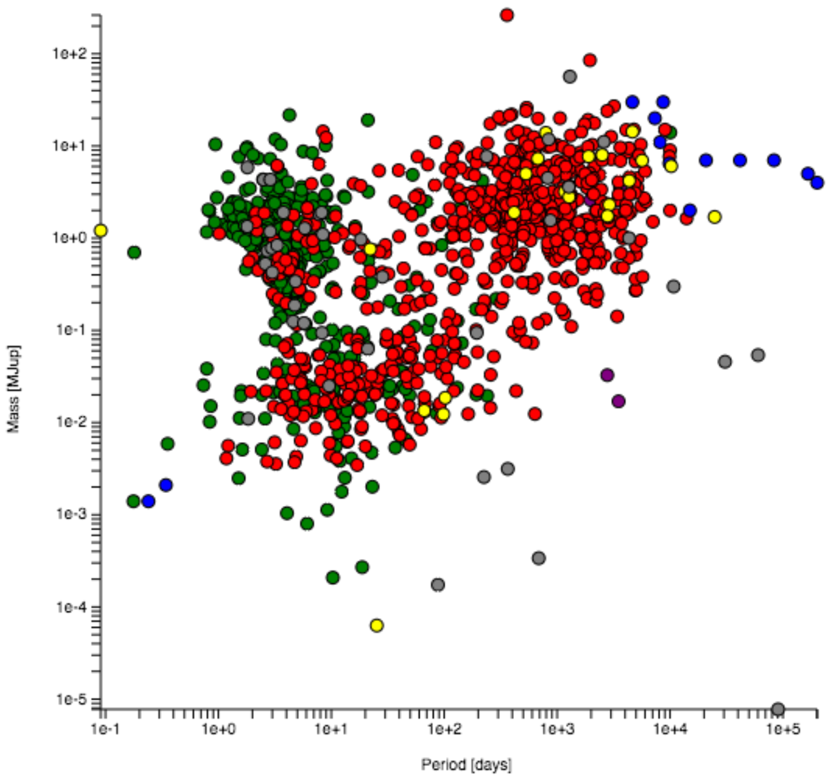
A multi-frequency ALMA characterization of substructures in the GM Aur protoplanetary disk

Jane Huang, Sean M. Andrews, Cornelis P. Dullemond, Karin I. Oberg, Chunhua Qi, Zhaohuan Zhu, Tilman Birnstiel, John M. Carpenter, Andrea Isella, Enrique Macias, Melissa K. McClure, Laura M. Perez, Richard Teague, David J. Wilner, Shangjia Zhang

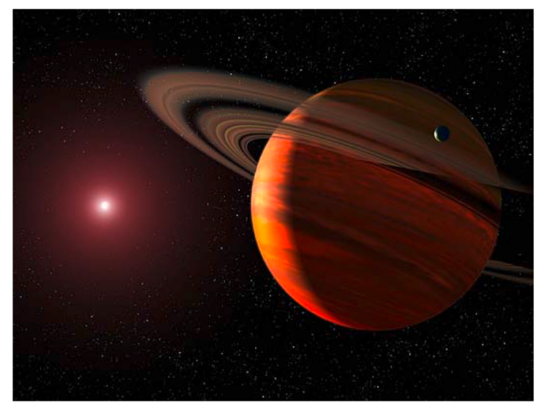
(Submitted on 29 Jan 2020)

The protoplanetary disk around the T Tauri star GM Aur was one of the first hypothesized to be in the midst of being cleared out by a forming planet. As a result, GM Aur has had an outsized influence on our understanding of disk structure and evolution. We present 1.1 and 2.1 mm ALMA continuum observations of the GM Aur disk at a resolution of ~50 mas (~8 au), as well as HCO^+ $J = 3-2$ observations at a resolution of ~100 mas. The dust continuum shows at least three rings atop faint, extended emission. Unresolved emission is detected at the center of the disk cavity at both wavelengths, likely due to a combination of dust and free-free emission. Compared to the 1.1 mm image, the 2.1 mm image shows a more pronounced "shoulder" near R~40 au, highlighting the utility of longer-wavelength observations for characterizing disk substructures. The spectral index α features strong radial variations, with minima near the emission peaks and maxima near the gaps. While low spectral indices have often been ascribed to grain growth and dust trapping, the optical depth of GM Aur's inner two emission rings renders their dust properties ambiguous. The gaps and outer disk ($R > 100$ au) are optically thin at both wavelengths. Meanwhile, the HCO^+ emission indicates that the gas cavity is more compact than the dust cavity traced by the millimeter continuum, similar to other disks traditionally classified as "transitional."

Discovery methods



Transit
Radial Velocity
Microlensing
Direct Imaging
Pulsar Timing
Other Method
(Solar System /
Transit Time Variation)



Pulsar Planets

Pulsar Planets are RARE

List of pulsar planets [edit]

Confirmed planets [edit]

Pulsar	Planetary object	Mass	Semimajor axis (AU)	Orbital period	Discovered
PSR B1620-26	PSR B1620-26 b	2.5 M_J	23	100 years	2003
PSR B1257+12	PSR B1257+12 A	0.020 $M_{\oplus}$	0.19	25.262±0.003 days	1994
	PSR B1257+12 B	4.3 $M_{\oplus}$	0.36	66.5419±0.0001 days	1992
	PSR B1257+12 C	3.90 $M_{\oplus}$	0.46	98.2114±0.0002 days	1992
PSR B0943+10	PSR B0943+10 b	2.8 M_J	1.8	730 days	2014
	PSR B0943+10 c	2.6 M_J	2.9	1460 days	2014
PSR B0329+54	PSR B0329+54 b	1.97 ± 0.19 $M_{\oplus}$	10.26 ± 0.07	27.76 ± 0.03 years	2017

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Astrophysics > High Energy Astrophysical Phenomena

Limits on Planet Formation Around Young Pulsars and Implications for Supernova Fallback Disks

Matthew Kerr, Simon Johnston, George Hobbs, Ryan M. Shannon

(Submitted on 23 Jul 2015)

We have searched a sample of 151 young, energetic pulsars for periodic variation in pulse time-of-arrival arising from the influence of planetary companions. We are sensitive to objects with masses two orders of magnitude lower than those detectable with optical transit timing, but we find no compelling evidence for pulsar planets. For the older pulsars most likely to host planets, we can rule out Mercury analogues in one third of our sample and planets with masses $> 0.4M_{\oplus}$ and periods $P_b < 1$ yr in all but 5% of such systems. If pulsar planets form primarily from supernova fallback disks, these limits imply that such disks do not form, are confined to < 0.1 AU radii, are disrupted, or form planets more slowly (> 2 Myr) than their protoplanetary counterparts.

Comments: 5 pages, 4 figures, accepted to ApJL
Subjects: **High Energy Astrophysical Phenomena (astro-ph.HE)**; Earth and Planetary Astrophysics (astro-ph.EP)
DOI: 10.1088/2041-8205/809/1/L11
Cite as: arXiv:1507.06982 [astro-ph.HE]
(or arXiv:1507.06982v1 [astro-ph.HE] for this version)

Bibliographic data

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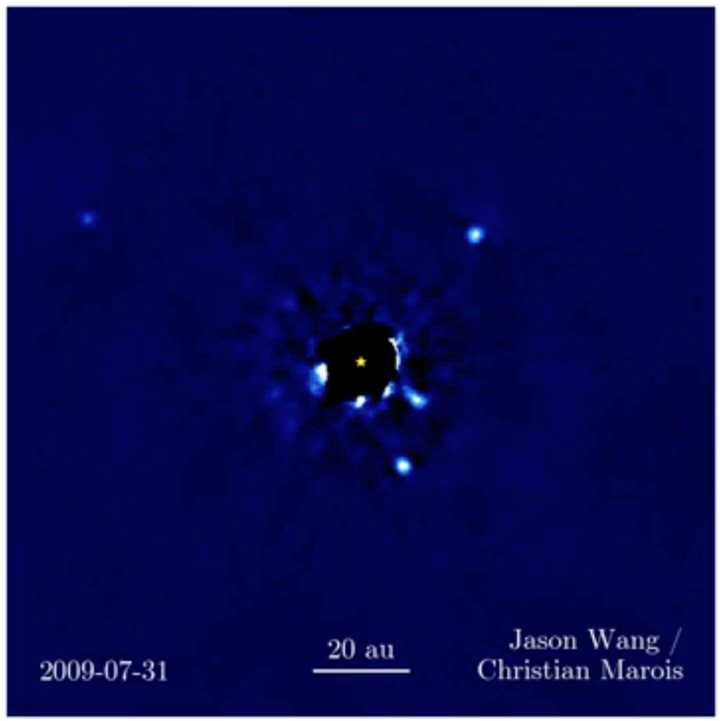
5. SUMMARY AND CONCLUSION

We have searched a large sample of young pulsars for periodic modulation characteristic to planetary companions. Our work is an improvement on previous efforts (Thorsett & Phillips 1992), as our pulsar sample is two orders of magnitude larger and we employ sophisticated methods to mitigate pulsar timing noise and model realistic (noncircular) orbits. Despite the good sensitivity to low-mass planets we find no compelling evidence for such systems. We argue that such companions could have formed in debris disks within the 2 Myr age range spanned by our sample, and their absence implies supernova fallback disks are either rare or confined to small radii.

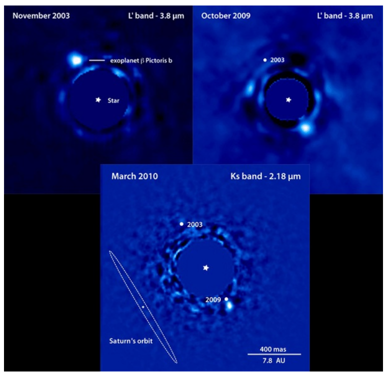
Extrasolar planets – Direct Imaging

Four planets around HR 8799

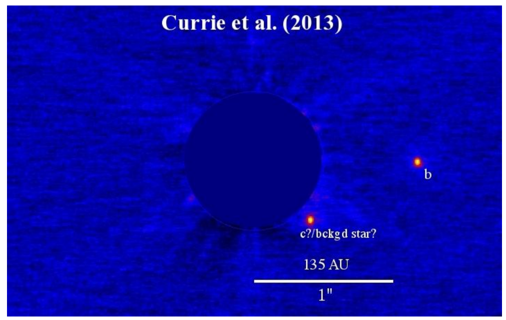


Extrasolar planets – Direct Imaging

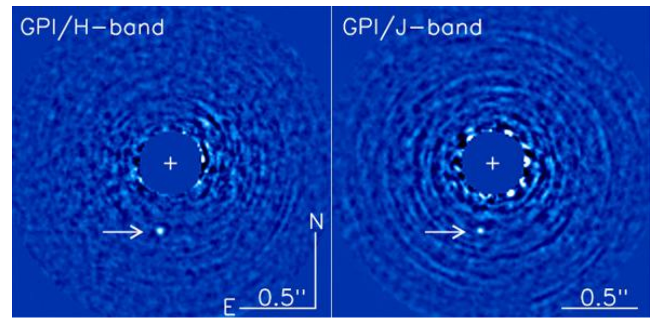
Beta Pictoris b

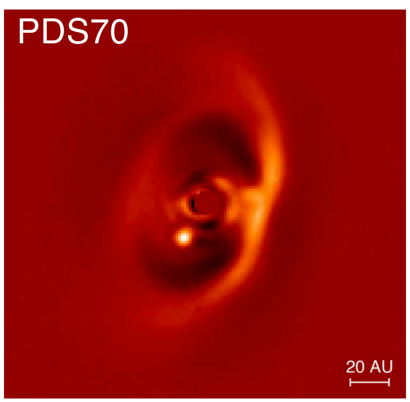


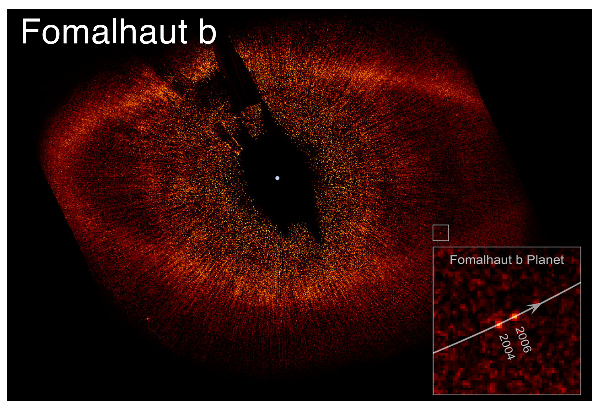
ROXs 42Bb

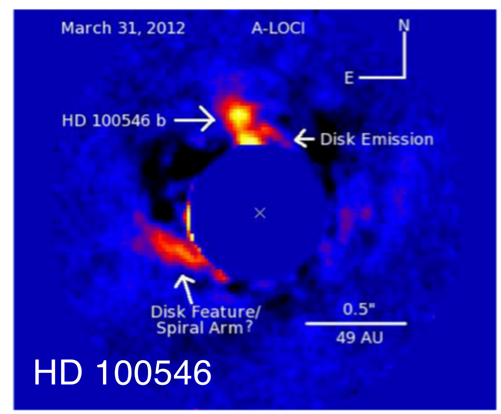


51 Eridani b



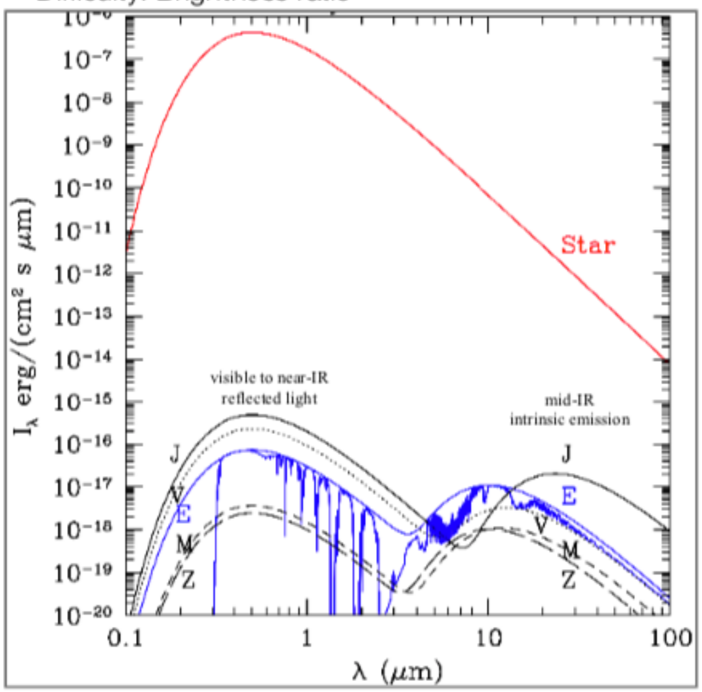






Contrast

Difficulty: Brightness ratio



Typical numbers:

visible: Fplanet / Fstar ≈ 10^{-9}

infrared: Fplanet / Fstar ≈ 10^{-6}

Favorable cases:

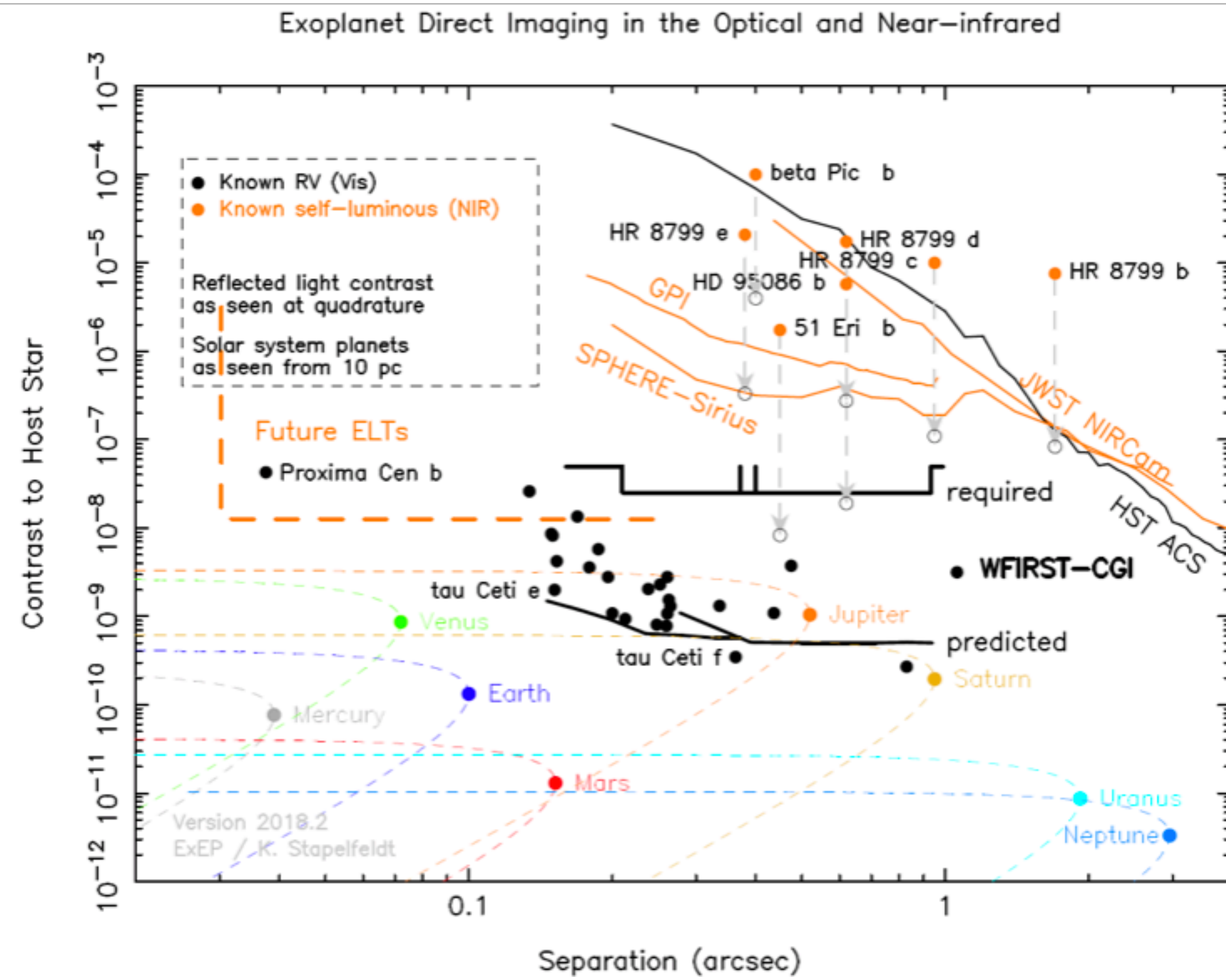
infrared observations

planets orbiting less luminous stars

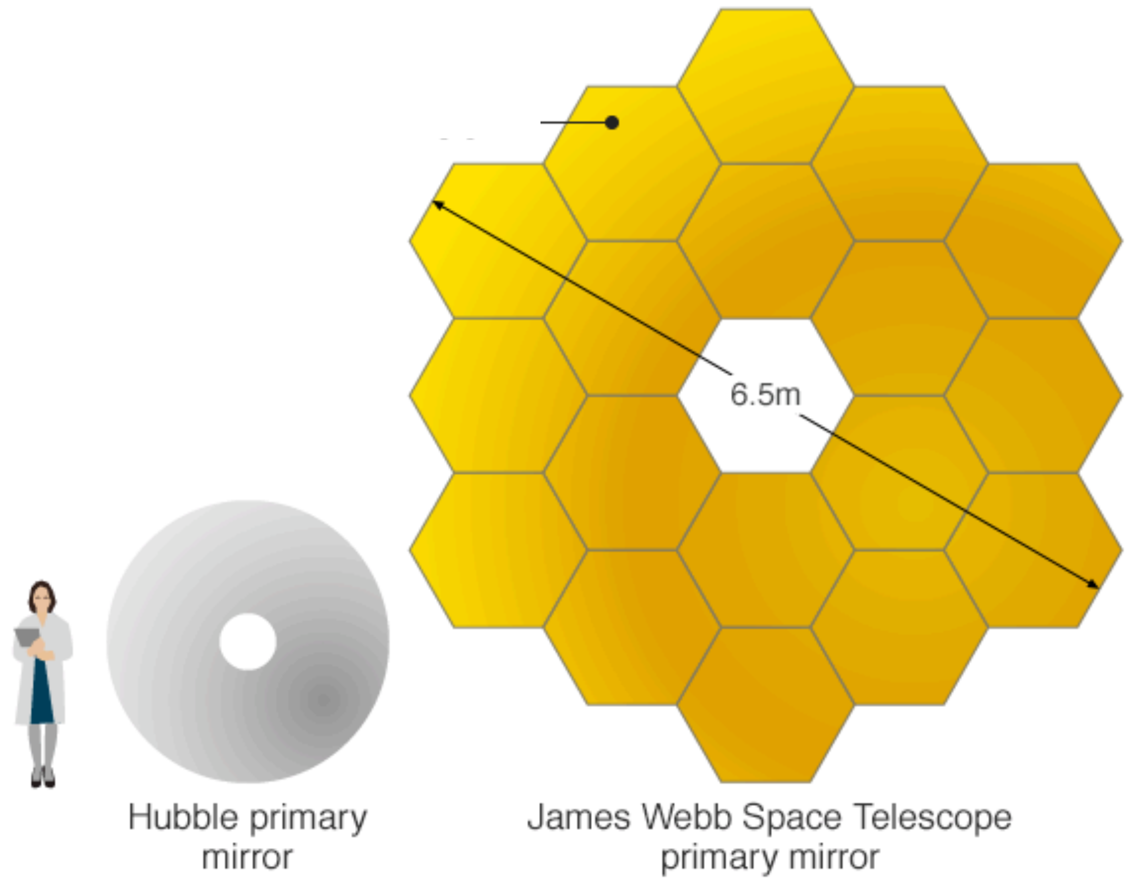
→ M dwarfs

young planets

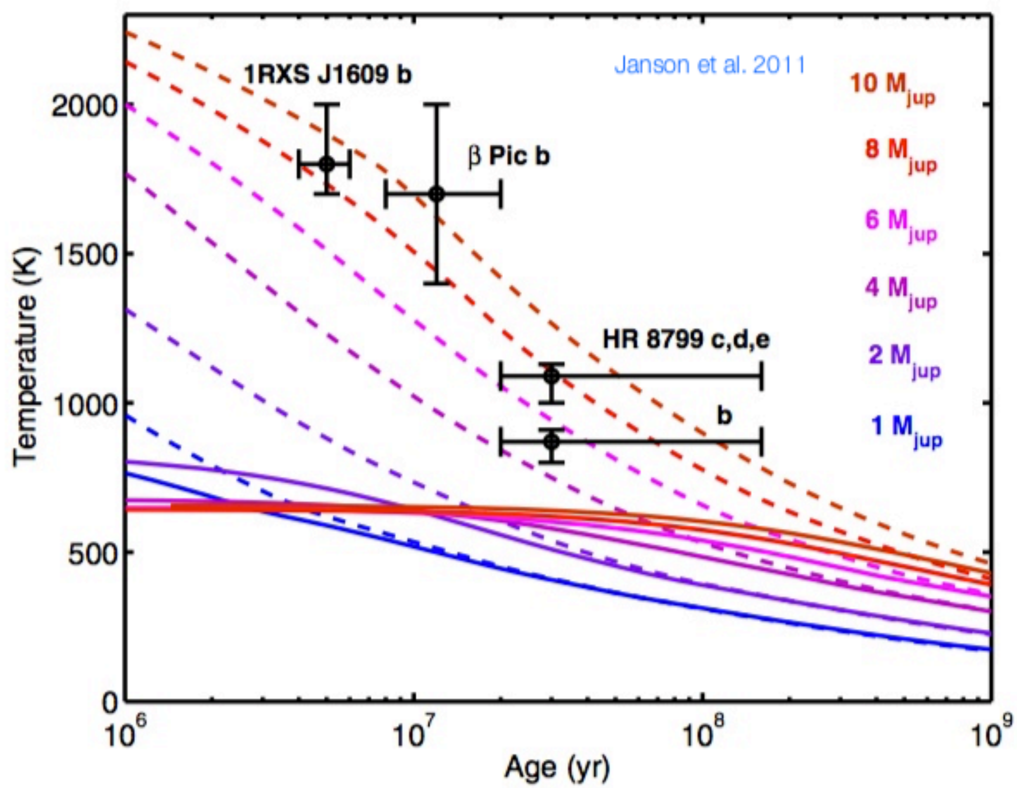
→ planet formation



Exoplanet Direct Imaging in the Optical and Near−infrared
Contrast to Host Star
Separation (arcsec)
Known RV (Vis)
Known self−luminous (NIR)
Reflected light contrast
as seen at quadrature
Solar system planets
as seen from 10 pc
Future ELTs
Proxima Cen b
beta Pic b
HR 8799 e
HR 8799 d
HR 8799 c
HR 8799 b
HD 95086 b
51 Eri b
GPI
SPHERE−Sirius
JWST NIRCam
HST ACS
required
WFIRST−CGI
predicted
tau Ceti e
tau Ceti f
Venus
Jupiter
Saturn
Earth
Mercury
Mars
Uranus
Neptune
Version 2018.2
ExEP / K. Stapelfeldt
0.1
1


6.5m
Hubble primary mirror
James Webb Space Telescope primary mirror

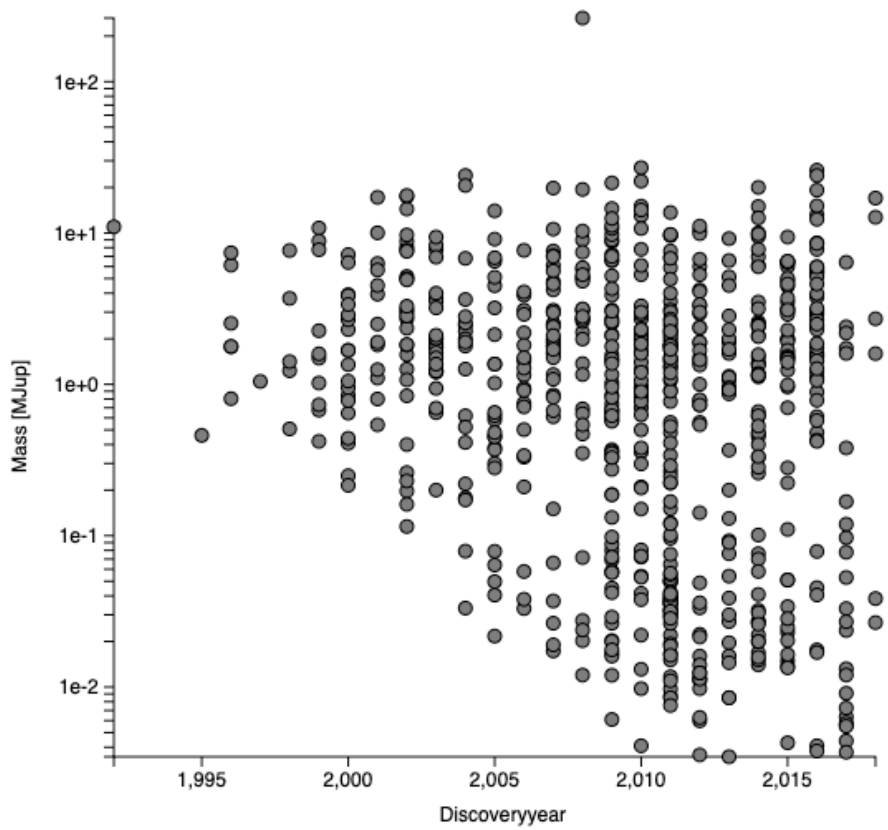
Easier to find when young



Direct Imaging

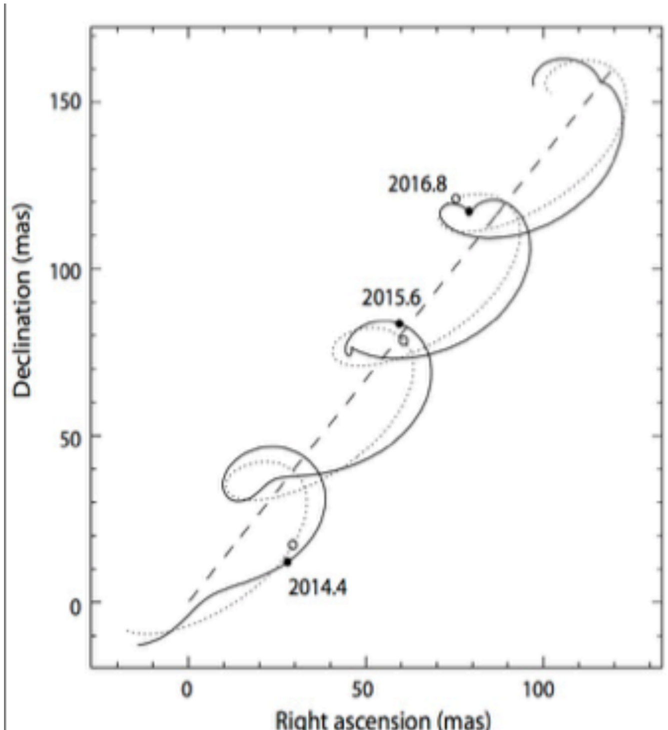
- Advantages
  - Allows physical characterization: Temperature, log g, chemical composition
  - Direct detection, no other explanations possible (must exclude background star chance alignment.)
- Disadvantages
  - Very difficult, only young objects. Huge brightness contrast, tiny projected separation.
  - Measures intrinsic (or reflected) luminosity L. Not mass M. L-M relation is model dependent and very uncertain.

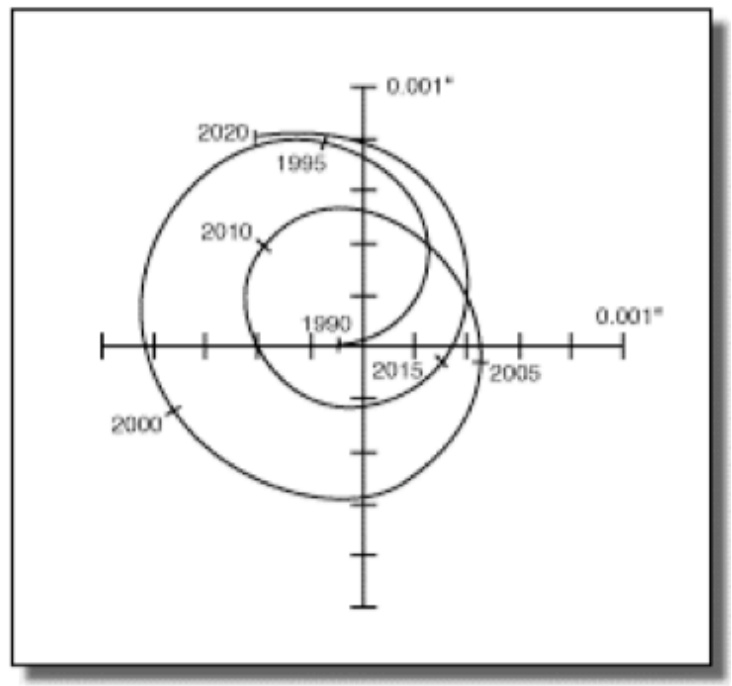
Radial Velocity vs Time



Astrometry – Gaia

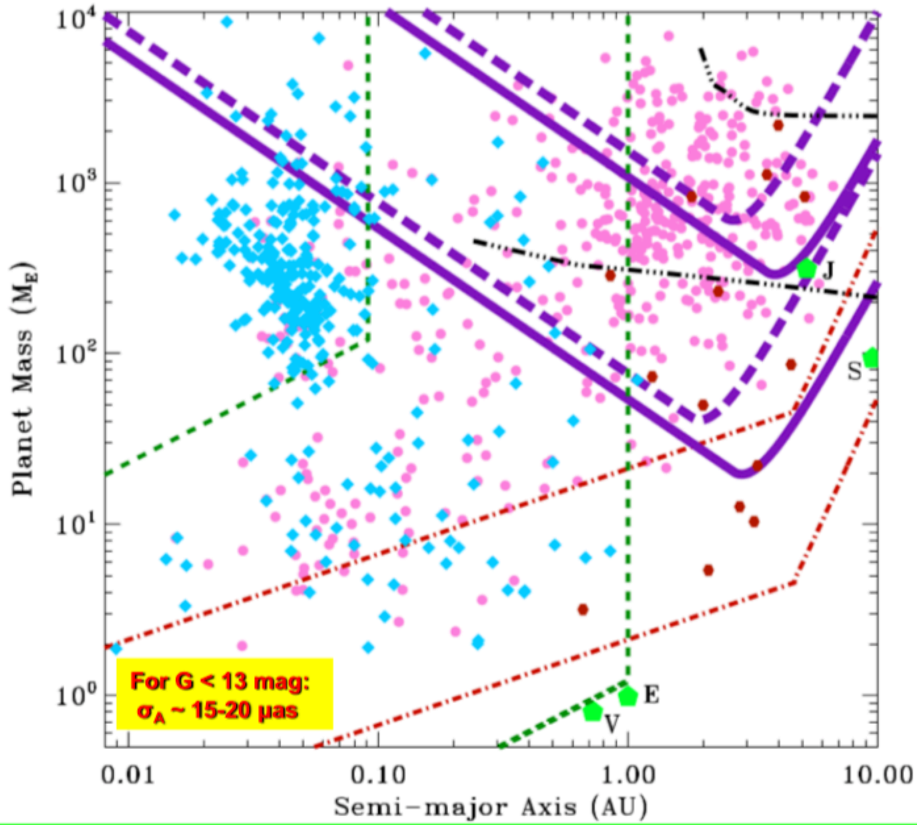
It's that simple…





Astrometric displacement of the Sun due to Jupiter as seen from 10 parsecs.

Gaia Discovery Space



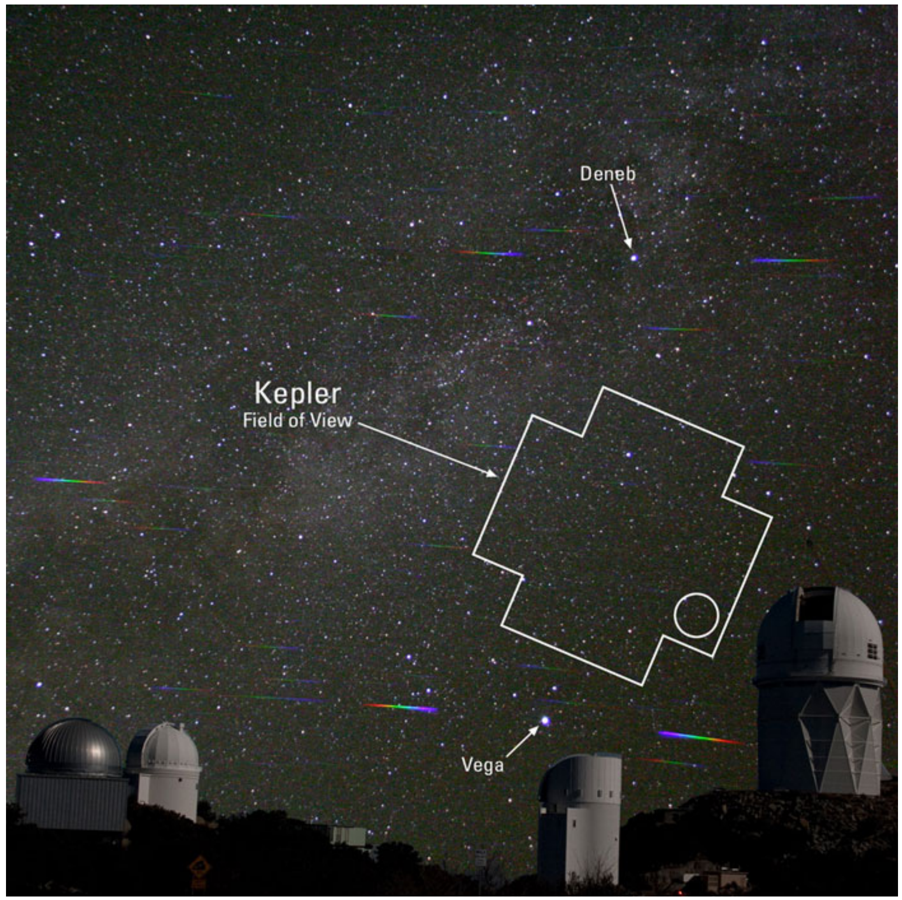
Unbiased, magnitude-limited planet census of maybe 10^6-10^7 stars

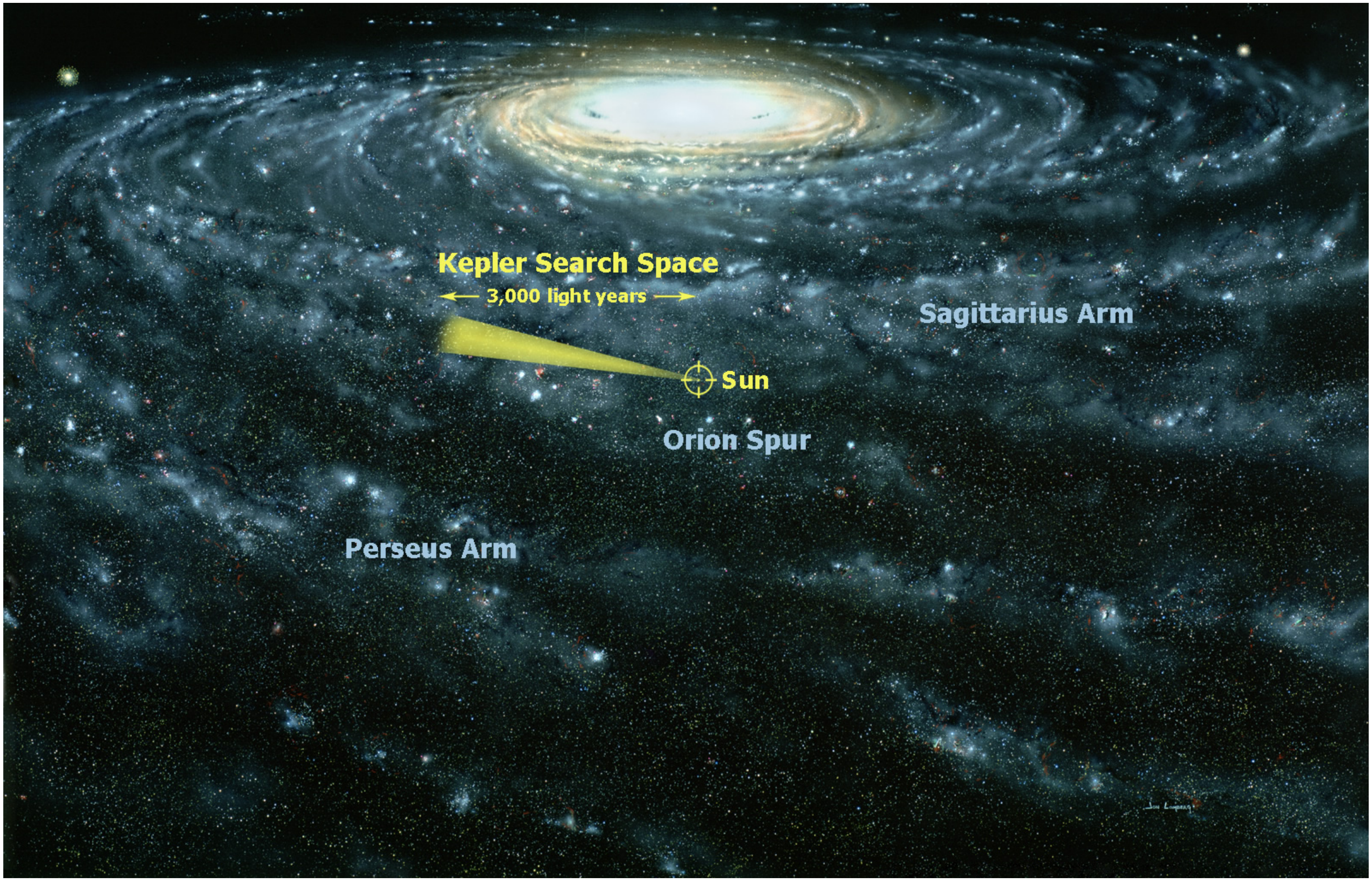
>10^4 NEW gas giants ($<$ 15 M_{JUP}) around A through M dwarfs Numbers might as much as triple for a 10-yr mission

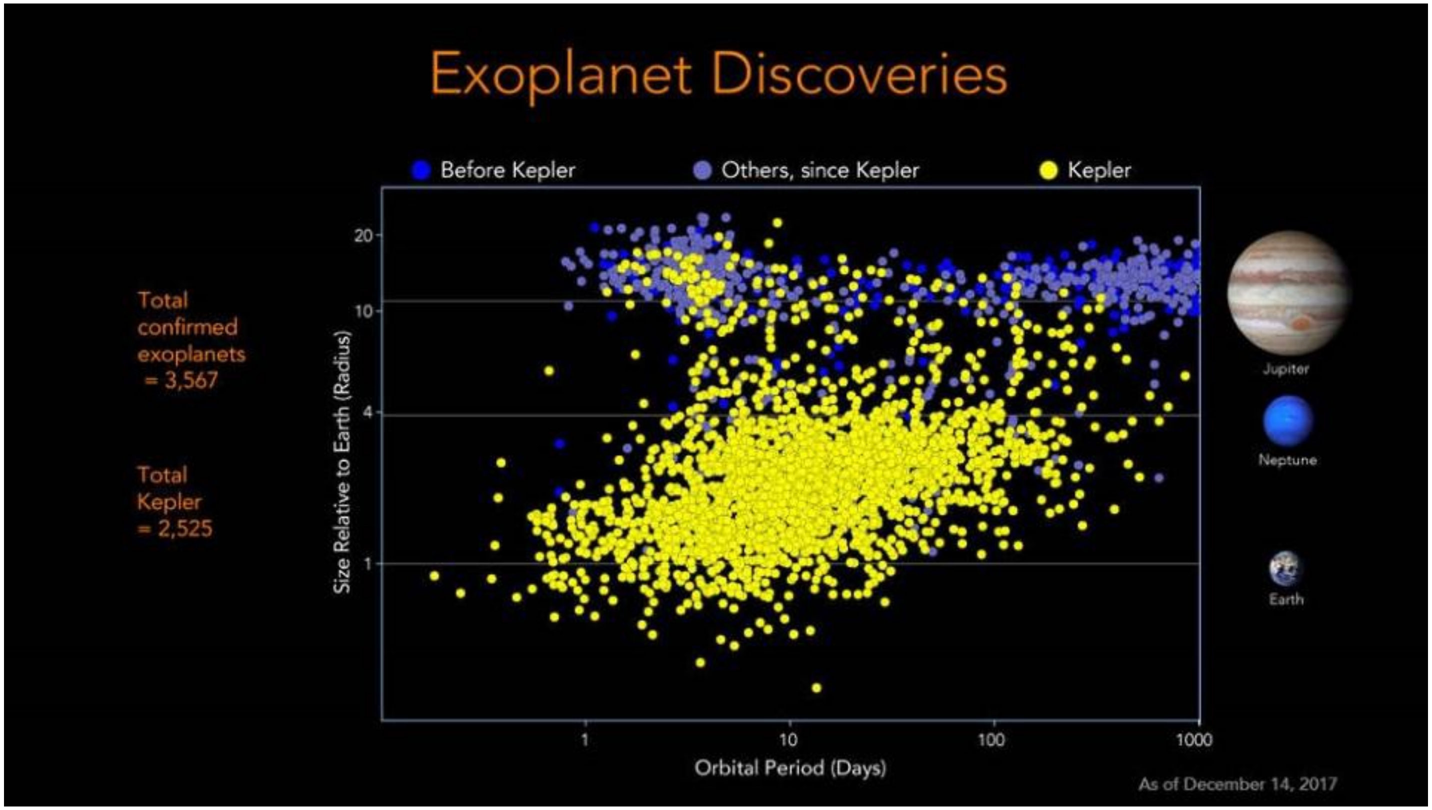
Lattanzi et al. 2000,
Sozzetti et al.2001
Casertano et al. 2008
Perryman et al. 2014
Sozzetti et al. 2014
Sahlmann et al. 2014

Gaia will test the fine structure of GP parameters distributions and frequencies (including the GP/BD transition), and investigate their changes as a function of stellar mass, metallicity, age, and multiplicity with unprecedented resolution

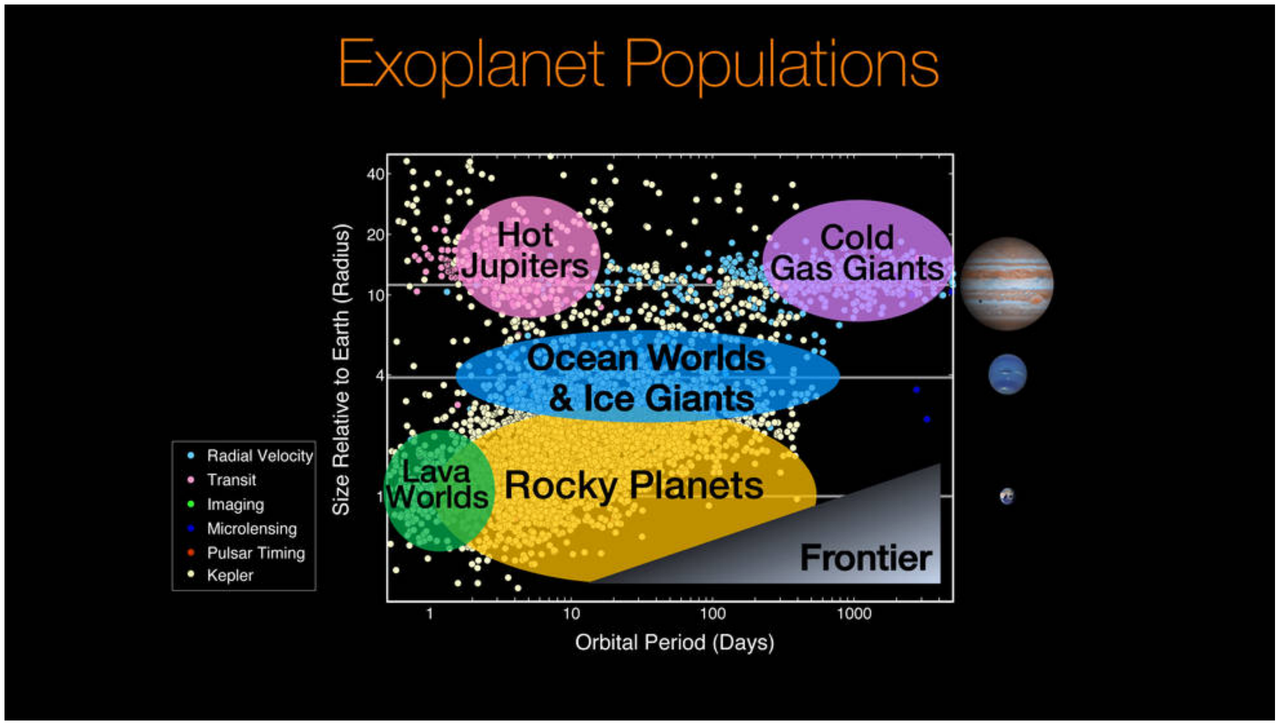
Game Changer – The *Kepler* mission



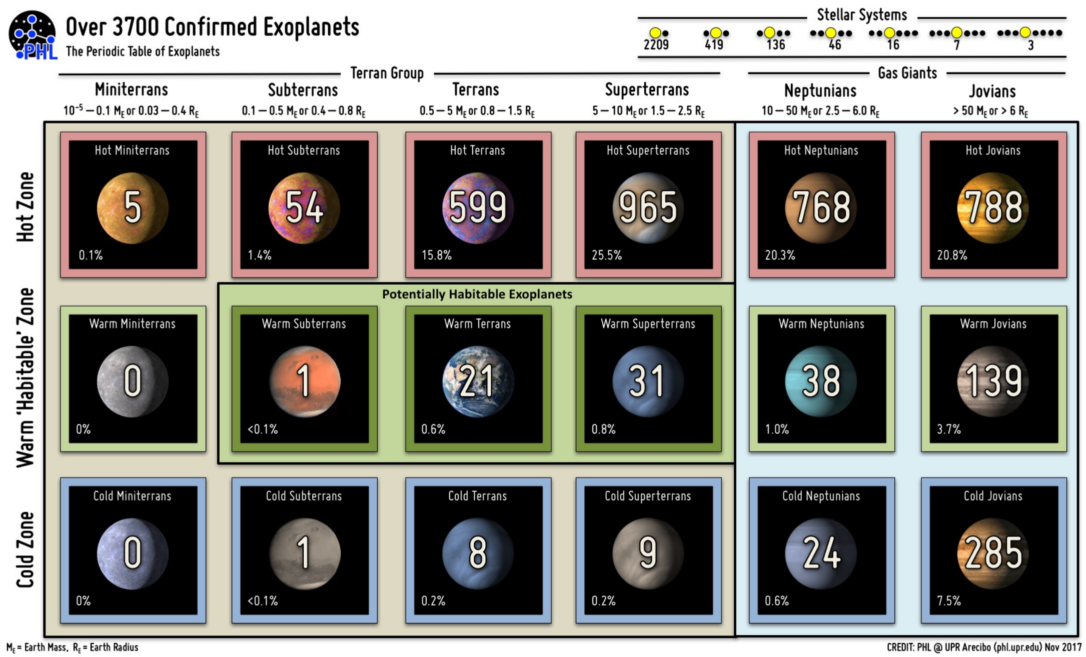

Kepler Search Space
3,000 light years
Sun
Sagittarius Arm
Orion Spur
Perseus Arm

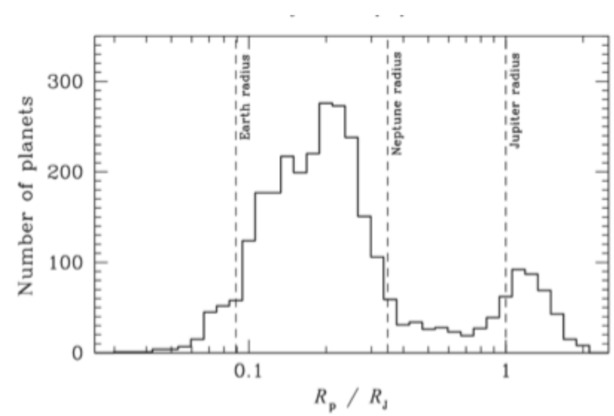

Exoplanet Discoveries
Before Kepler
Others, since Kepler
Kepler
Total confirmed exoplanets = 3,567
Total Kepler = 2,525
Size Relative to Earth (Radius)
20
10
4
1
1
10
100
1000
Orbital Period (Days)
Jupiter
Neptune
Earth
As of December 14, 2017

New types of planets

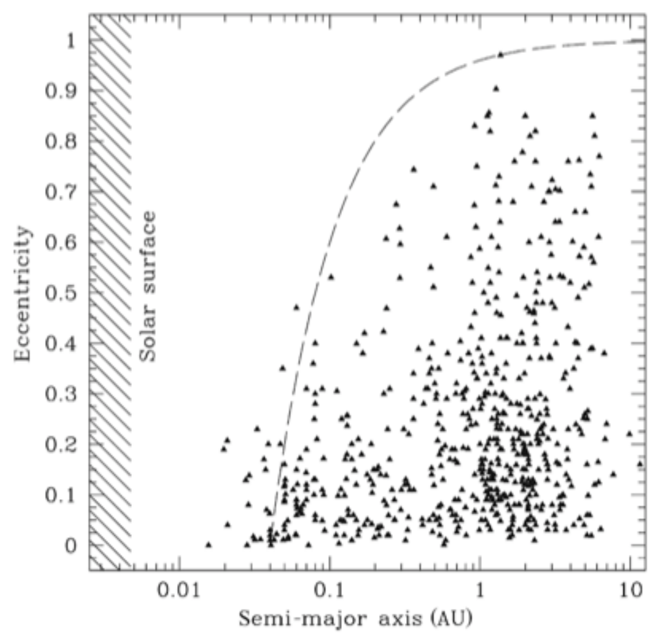


Super-Earths
are the most common type of planet

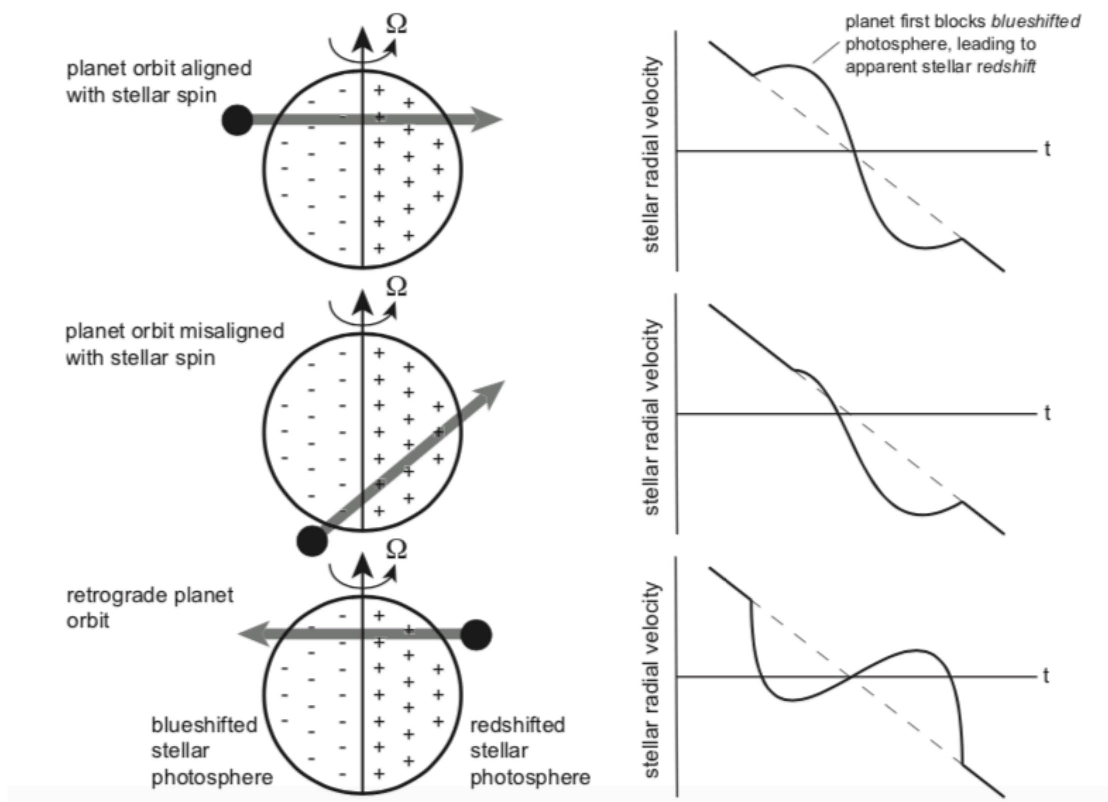




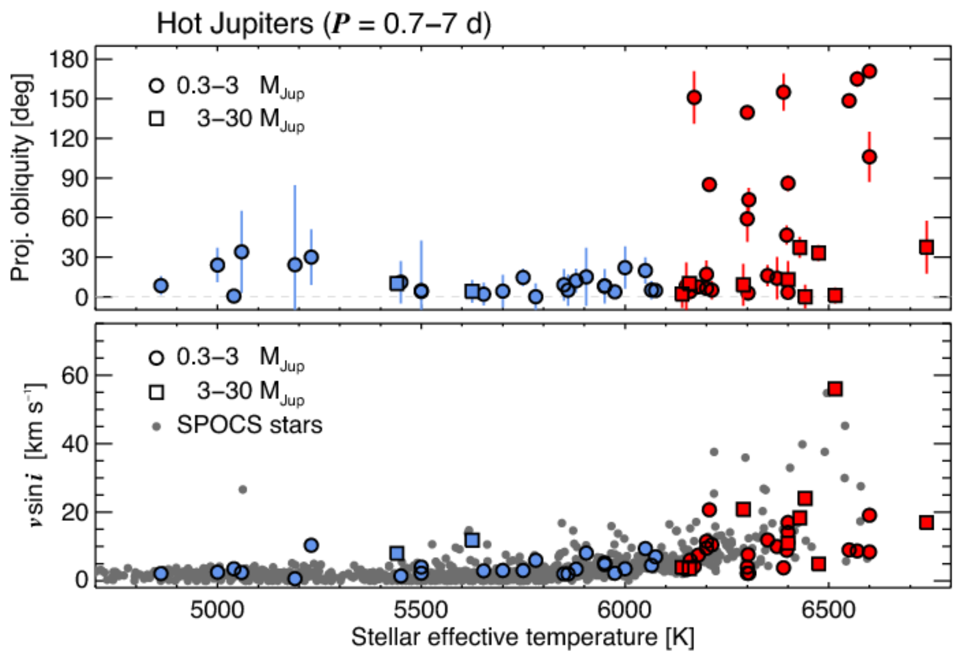
Orbital Properties: Eccentricity



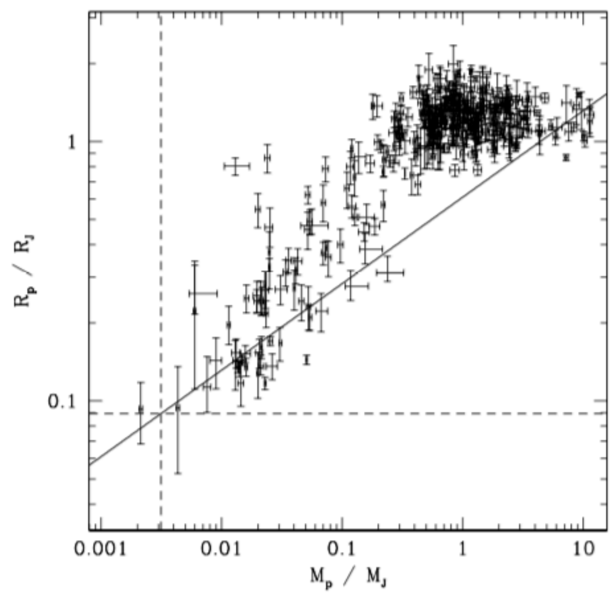
Rossiter-McLaughlin effect



Inclination
Shift at the radiative/convective transition

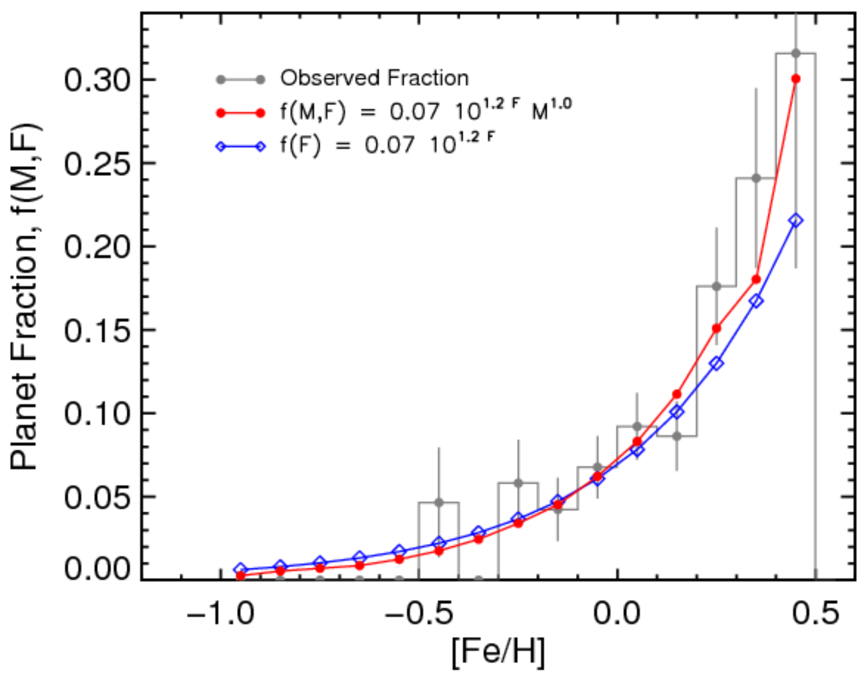


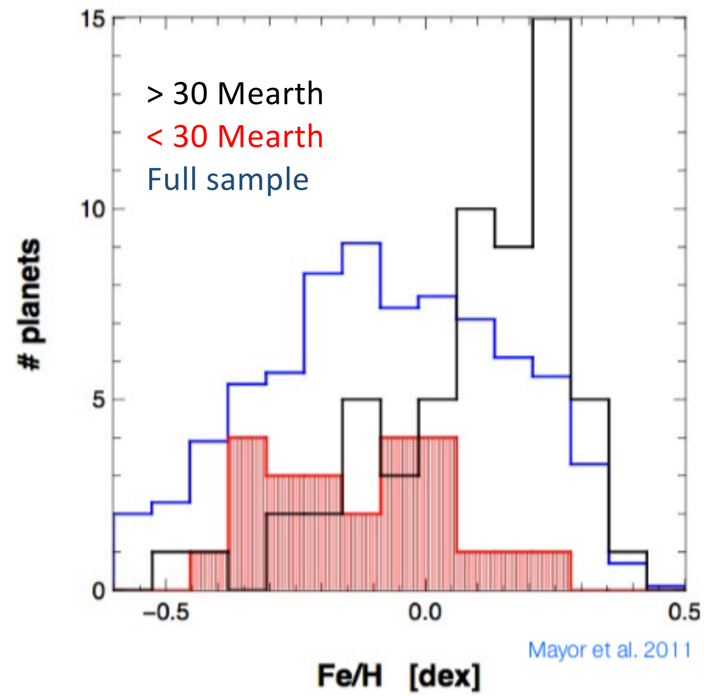
Physical Properties: Radius



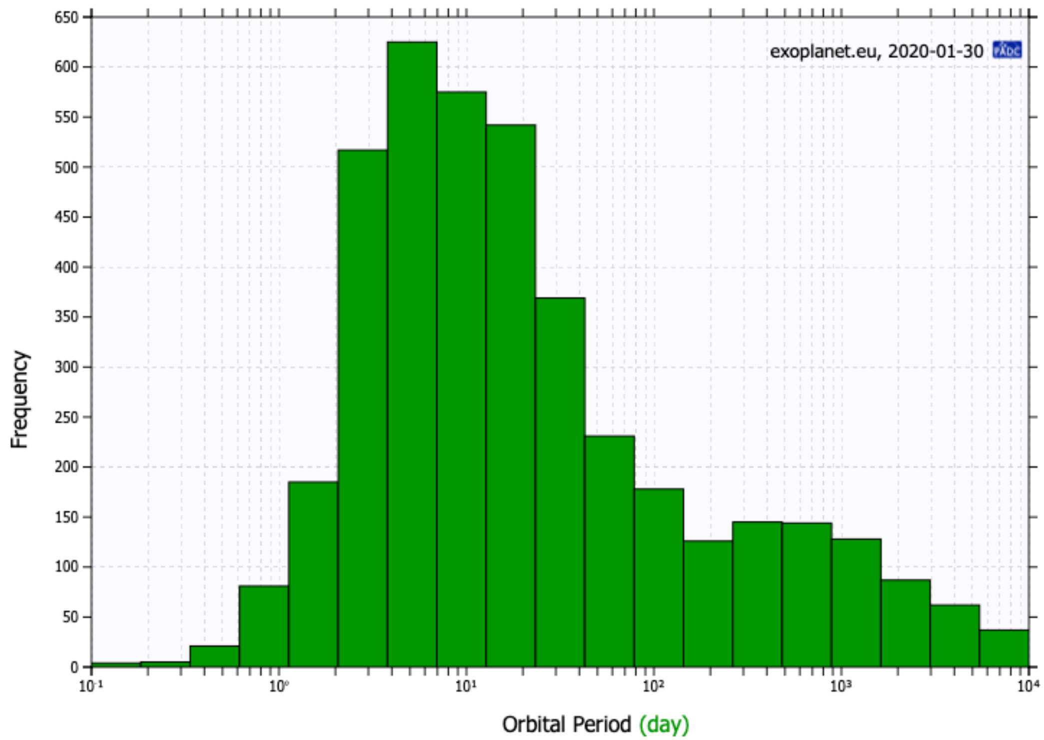
Metallicity matters for giant planets

Giant planet occurance

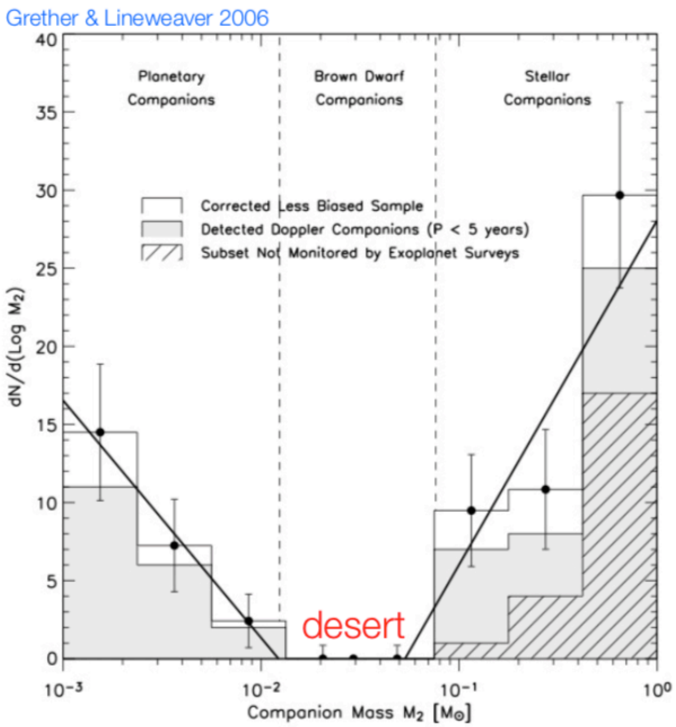




3-day pile-up


exoplanet.eu, 2020-01-30
Frequency
Orbital Period (day)
650
600
550
500
450
400
350
300
250
200
150
100
50
0
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

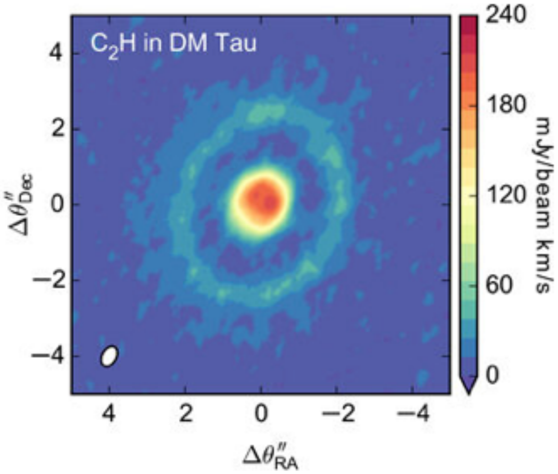
Brown Dwarf desert



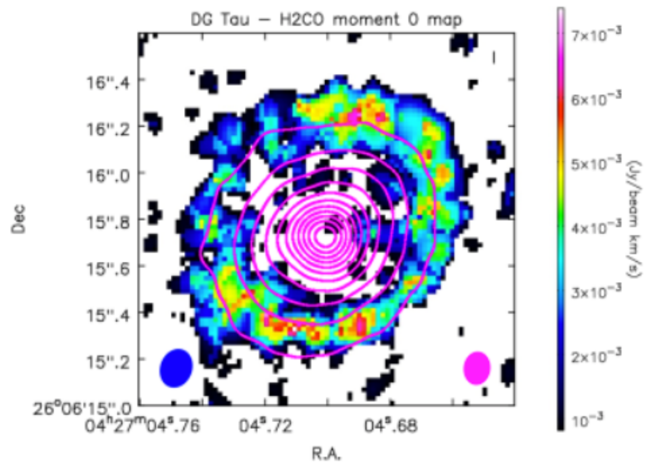
- less than 0.6 % of Sun-like stars have a brown-dwarf companion: so called "Brown dwarf desert"
- mass distribution function shows a lack of objects between 25-45 M_J. Upper end of planet mass distribution?
- Nothing particular is seen at 13 M_J (D-burning limit).

Other icelines

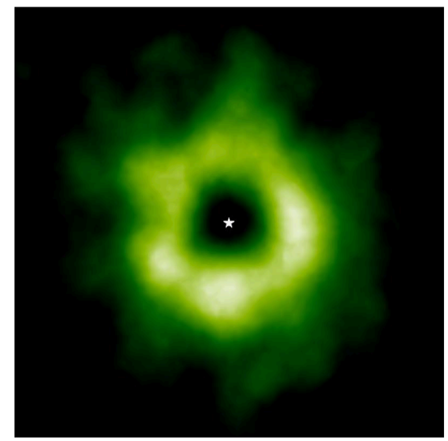
C_2O iceline
DM Tau



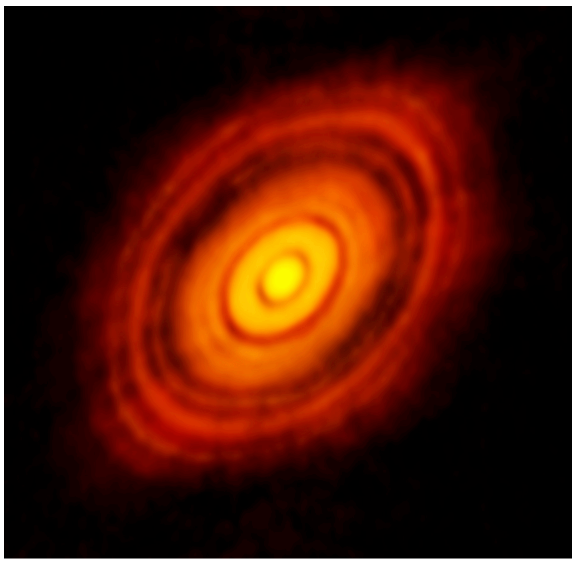
H_2CO iceline
DG Tau

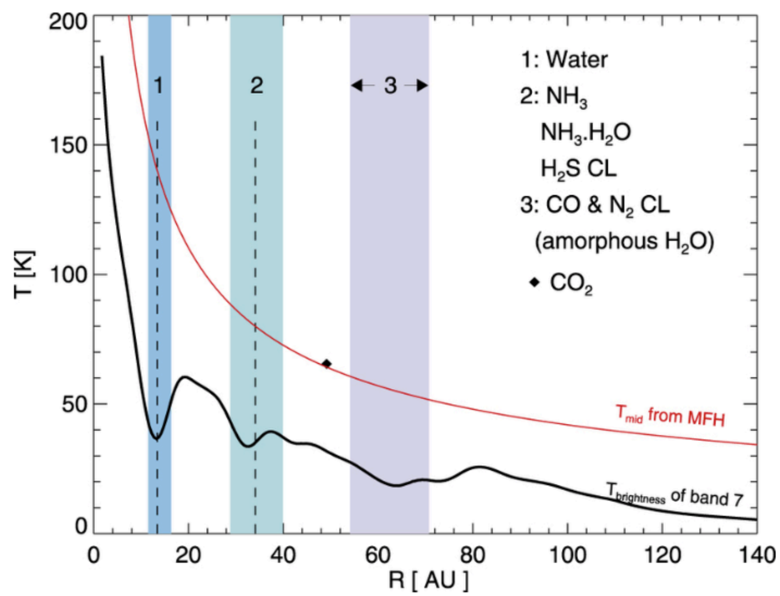


CO iceline
TW Hya



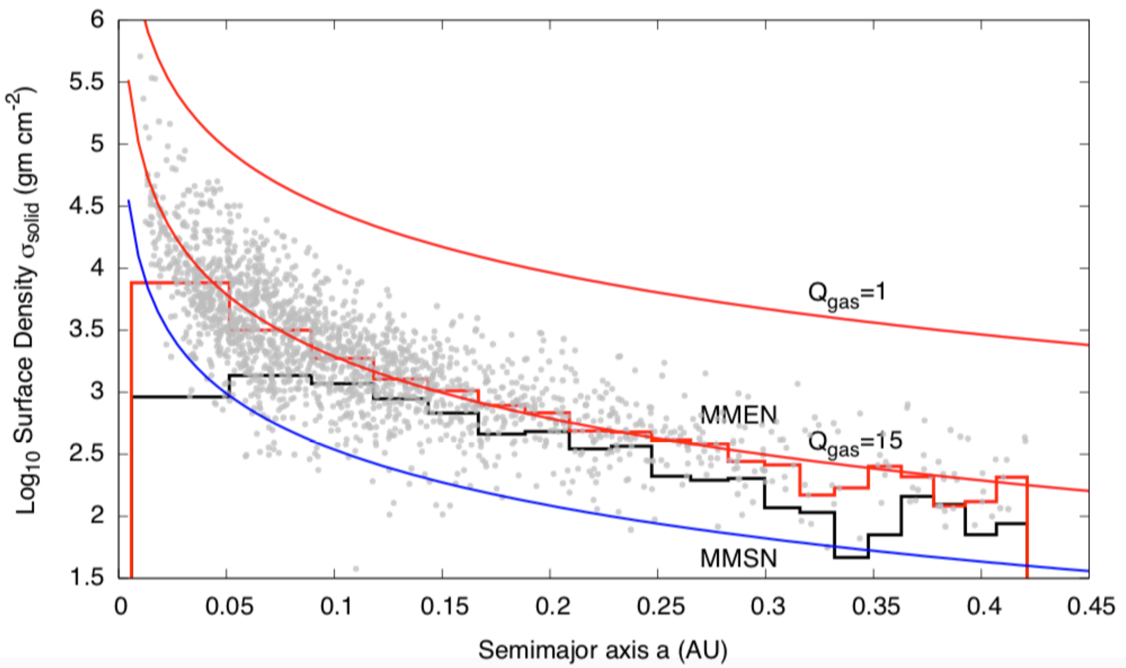
HL Tau





1: Water
2: NH_3
$NH_3.H_2O$
H_2S CL
3: CO & N_2 CL
(amorphous H_2O)
◆ CO_2
T_{mid} from MFH
$T_{brightness}$ of band 7
T [K]
R [AU]

Minimum Mass Extrasolar Nebula



Minimum Mass Extrasolar Nebula

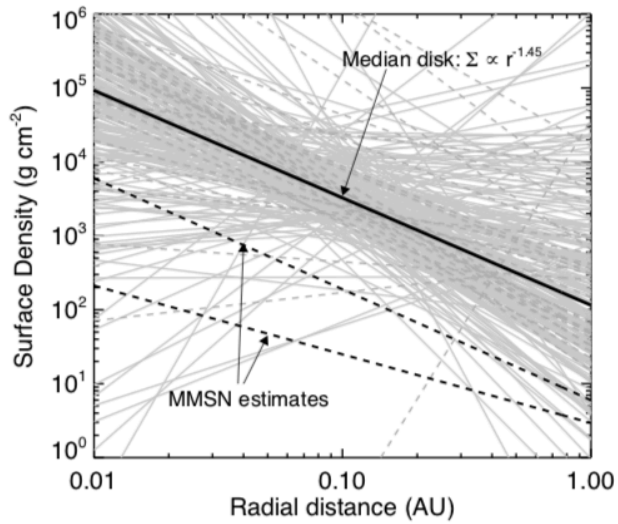


Figure 1. Diversity of minimum mass extrasolar nebulae. Each grey curve is the minimum-mass disk inferred from a system of Kepler planet candidates (solid grey) or radial velocity planets (dashed grey). The thick black curve is the median fit: $\Sigma \propto r^{-1.45}$. The black dashed curves represents two estimates of the minimum-mass solar nebula (MMSN) built using just the terrestrial planets.

What we need to explain

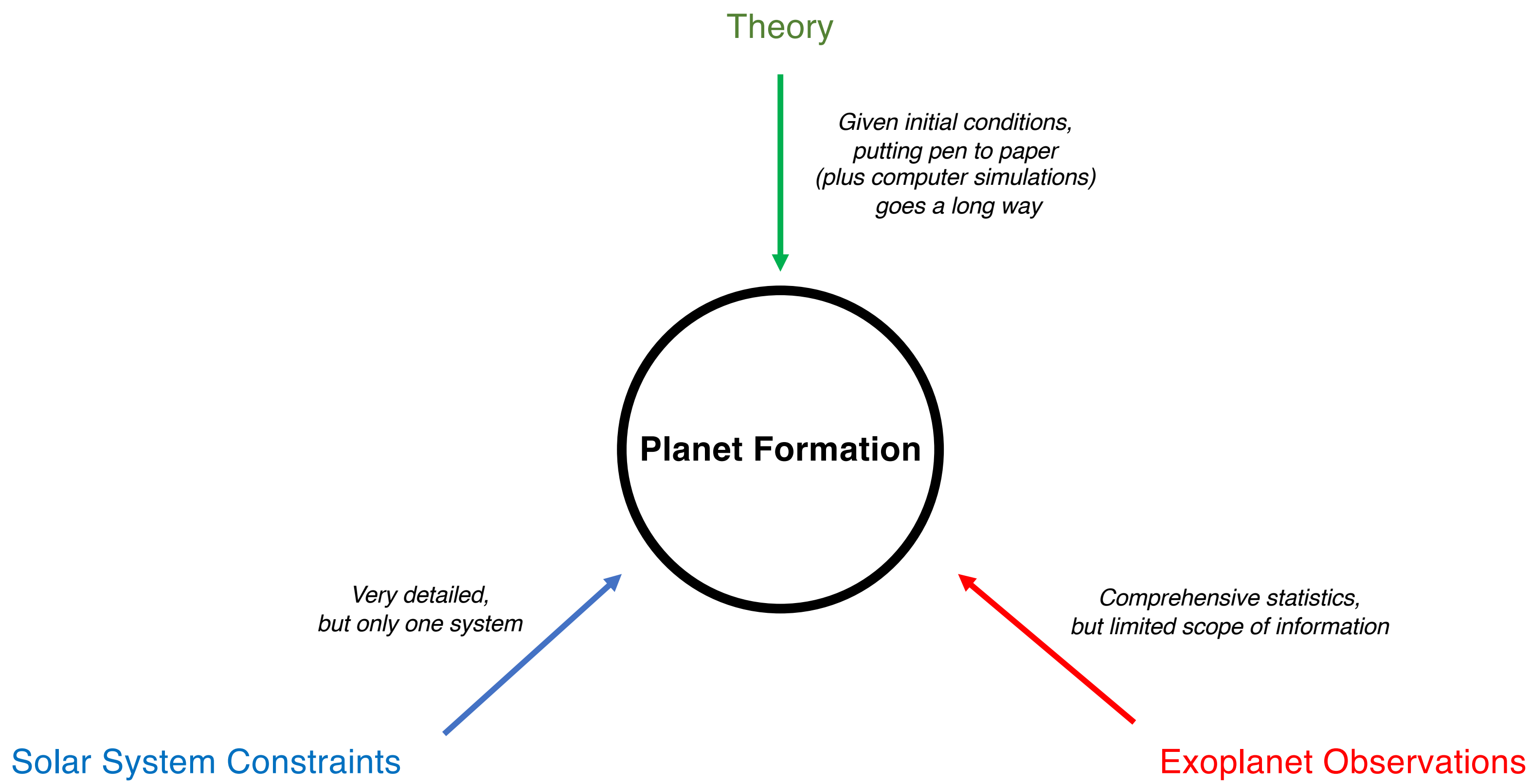
How do terrestrial and gas giant planets form?

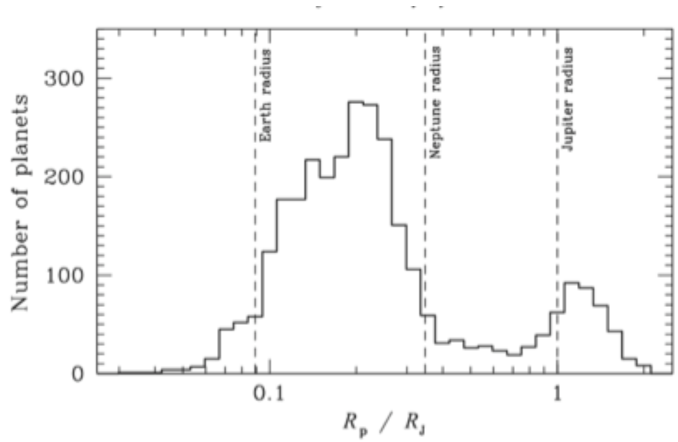
How can we understand their orbits:

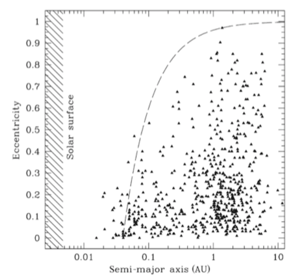
- in the Solar System?
- in extrasolar planetary systems?

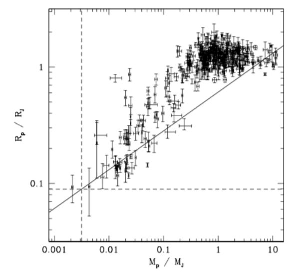
The hope is that this will inform questions such as:

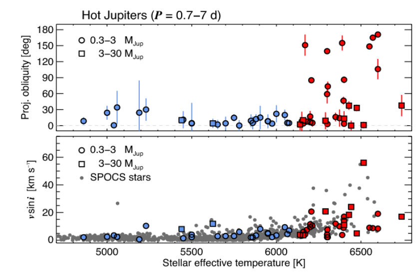
- how typical is the Solar System?
- how common are habitable planets?

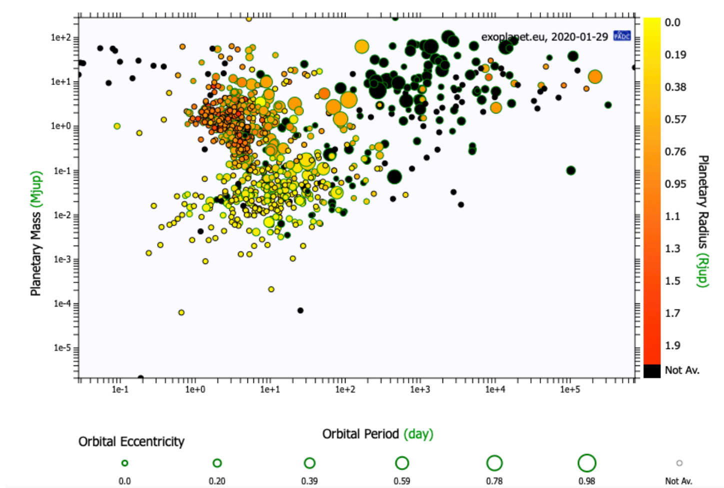

Theory
Given initial conditions,
putting pen to paper
(plus computer simulations)
goes a long way
Planet Formation
Very detailed,
but only one system
Comprehensive statistics,
but limited scope of information
Solar System Constraints
Exoplanet Observations

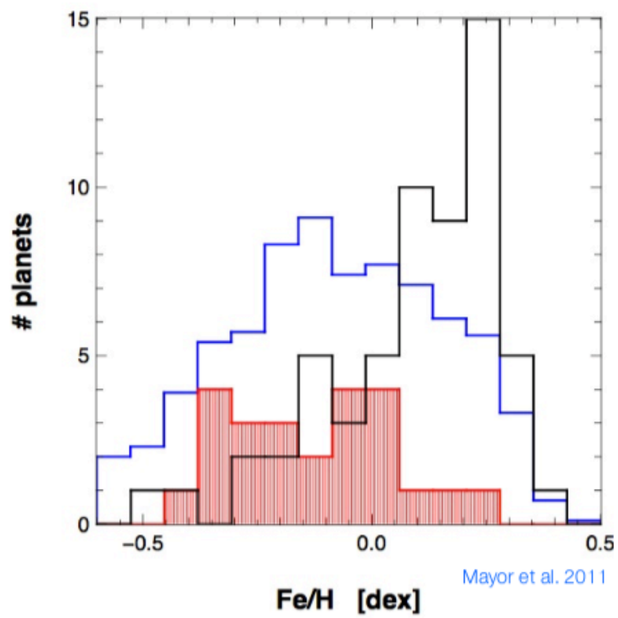

Number of planets
Earth radius
Neptune radius
Jupiter radius
R_p / R_J

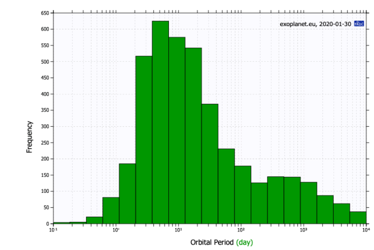

Eccentricity
Solar surface
Semi-major axis (AU)

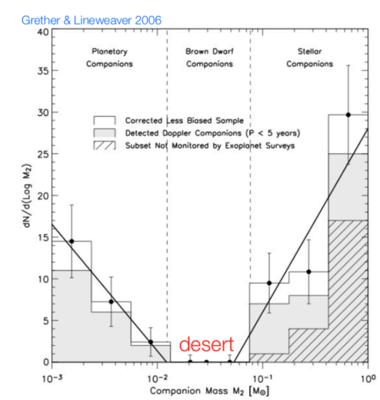

R_p / R_J
M_p / M_J


Hot Jupiters (P = 0.7–7 d)
Proj. obliquity [deg]
0.3–3 M_Jup
3–30 M_Jup
SPOCS stars
v sin i [km s⁻¹]
Stellar effective temperature [K]


exoplanet.eu, 2020-01-29
Planetary Mass (Mjup)
Planetary Radius (Rjup)
Not Av.
Orbital Eccentricity
Orbital Period (day)


planets
Fe/H [dex]
Mayor et al. 2011


exoplanet.eu, 2020-01-30
Frequency
Orbital Period (day)


Grether & Lineweaver 2006
Planetary Companions
Brown Dwarf Companions
Stellar Companions
Corrected Less Biased Sample
Detected Doppler Companions (P < 5 years)
Subset Not Monitored by Exoplanet Surveys
dN/d(Log M₂)
desert
Companion Mass M₂ [M☉]