Characterization of planets through resolved imaging and spectroscopy

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Planets; limits for this review

Exoplanet.eu

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Catalog

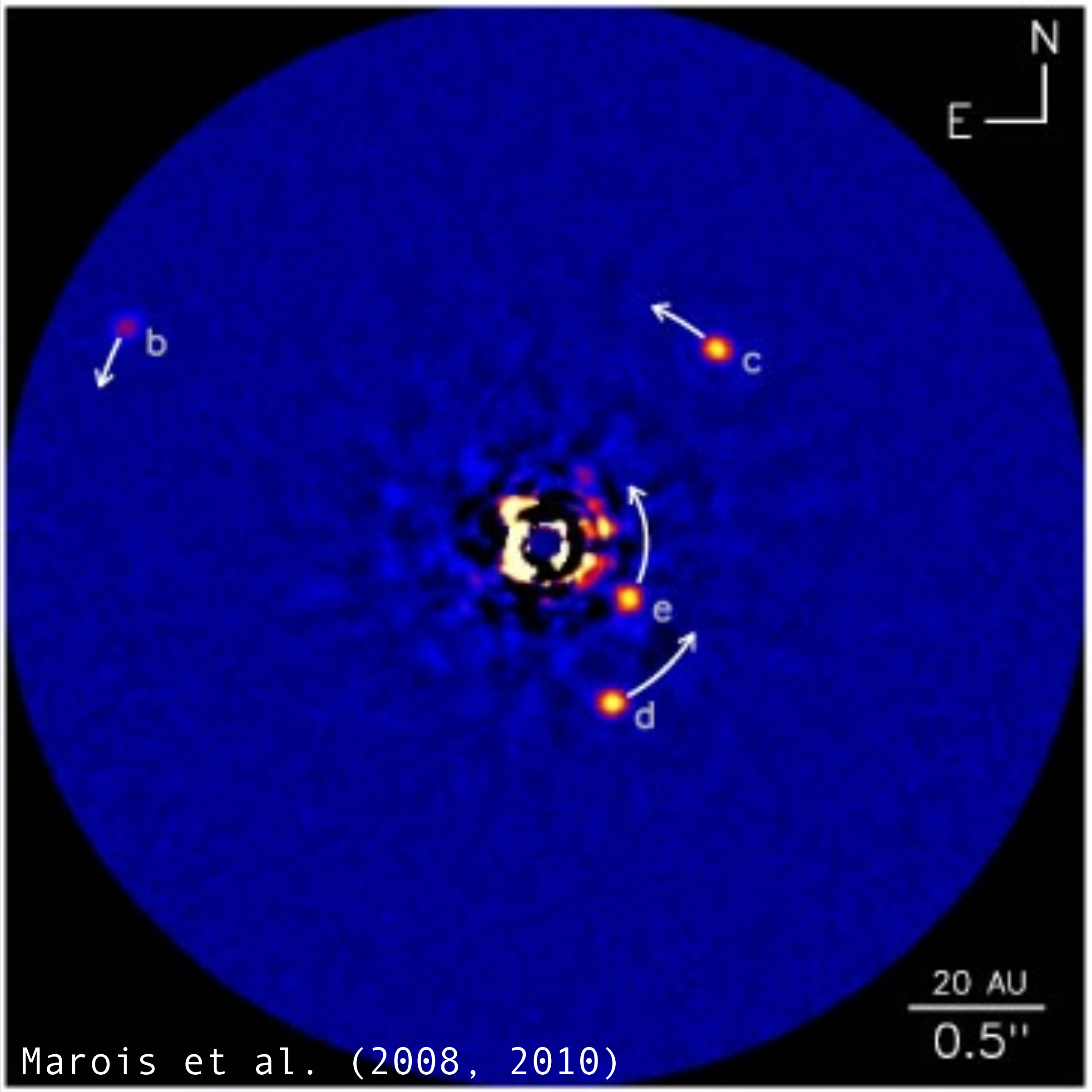
Detected by imaging | "imaging" IN detection | Filter

Showing 42 planetary systems / 46 planets / 2 multiple planet systems

Planet △	Mass (M_{Jup})	Radius (R_{Jup})	Period (day)	*a* (AU)	*e*	*i* (deg)	Ang. dist. (arcsec)	Status	Discovery	Update
1RXS1609 b	14.0	1.7	—	330.0	—	—	2.275862	R	2008	2011-12-14
2M 0103(AB) b	13.0	—	—	84.0	—	—	—	R	2013	2013-07-22
2M 0122-2439 b	13.0	—	—	52.0	—	—	—	R	2013	2013-07-12
2M 044144 b	7.5	—	—	15.0	—	—	0.107143	R	2010	2010-04-06
2M 0746+20 b	30.0	0.97	4640.0	2.897	0.487	138.2	0.237265	R	2010	2012-01-20
2M 2140+16 b	20.0	0.92	7340.0	3.53	0.26	46.2	0.1412	R	2010	2012-01-20
2M 2206-20 b	30.0	1.3	8686.0	4.48	—	44.3	0.167979	R	2010	2012-01-20
2M1207 b	4.0	—	—	46.0	—	—	0.877863	R	2004	2010-12-28
AB Pic b	13.5	—	—	275.0	—	—	5.813953	R	2005	2010-12-06

Most conservative count:
~7 planets

The HR 8799 system



Marois et al. (2008, 2010)

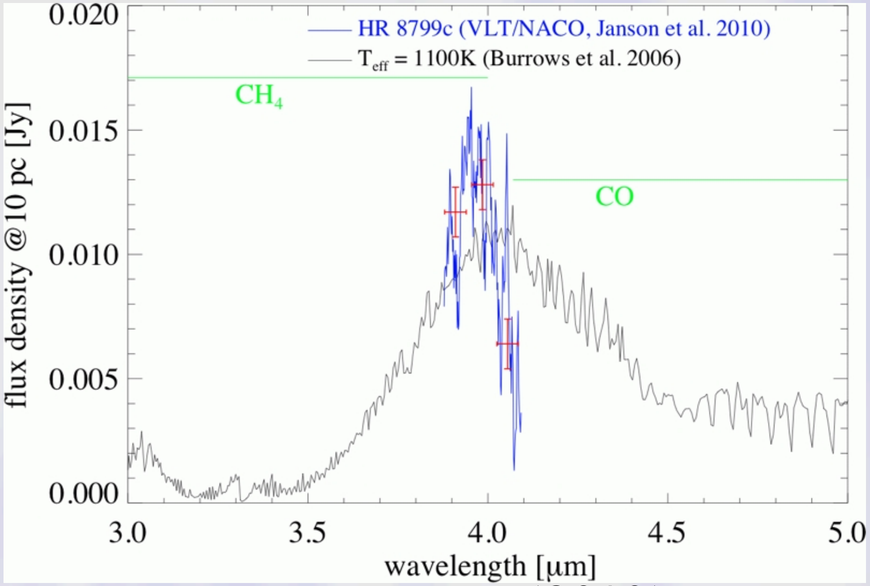
4 planets (so far) in one system

Masses of ~5-10 Mjup

Semi-major axes of ~14-68 AU

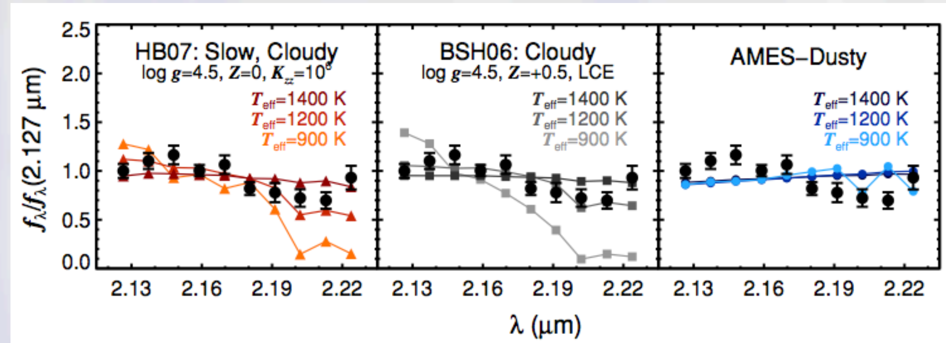
Masses are model dependent, but stability arguments point in the same direction

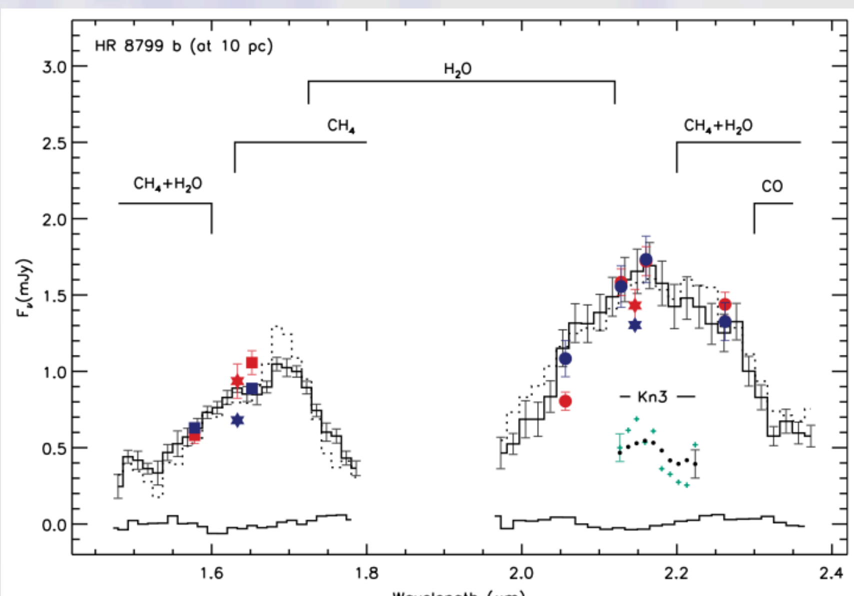
Spectroscopy in the HR 8799 system



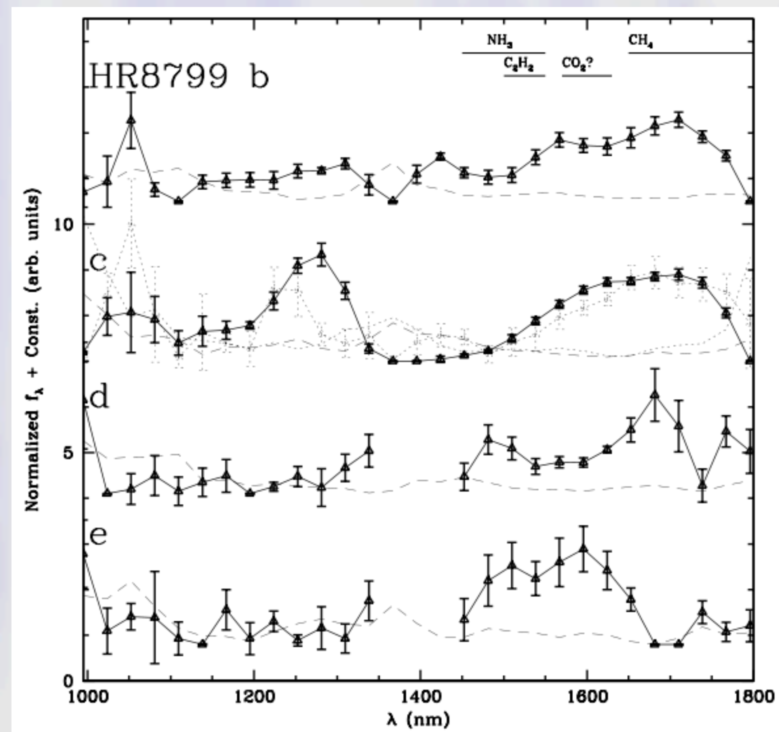
Janson et al. (2010)

Bowler et al. (2010)



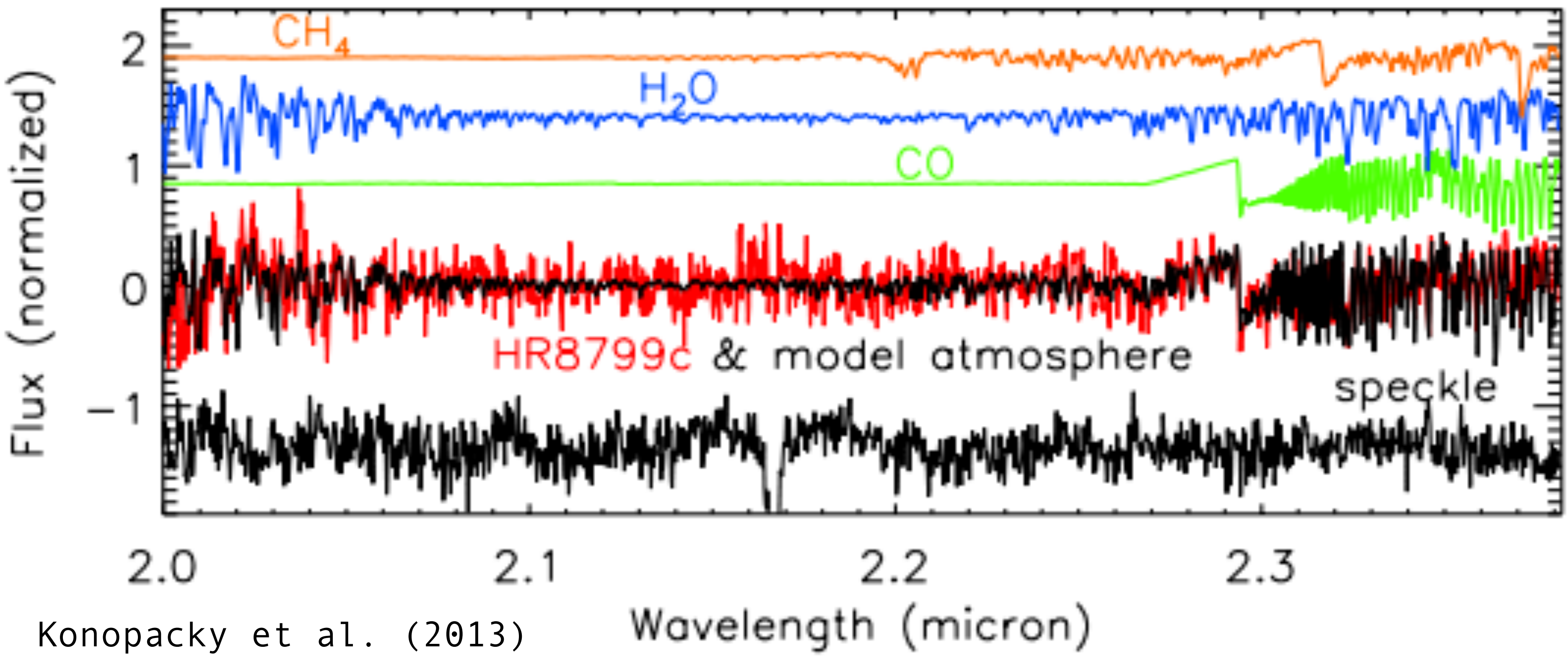


Barman et al. (2011)



Oppenheimer et al. (2013)

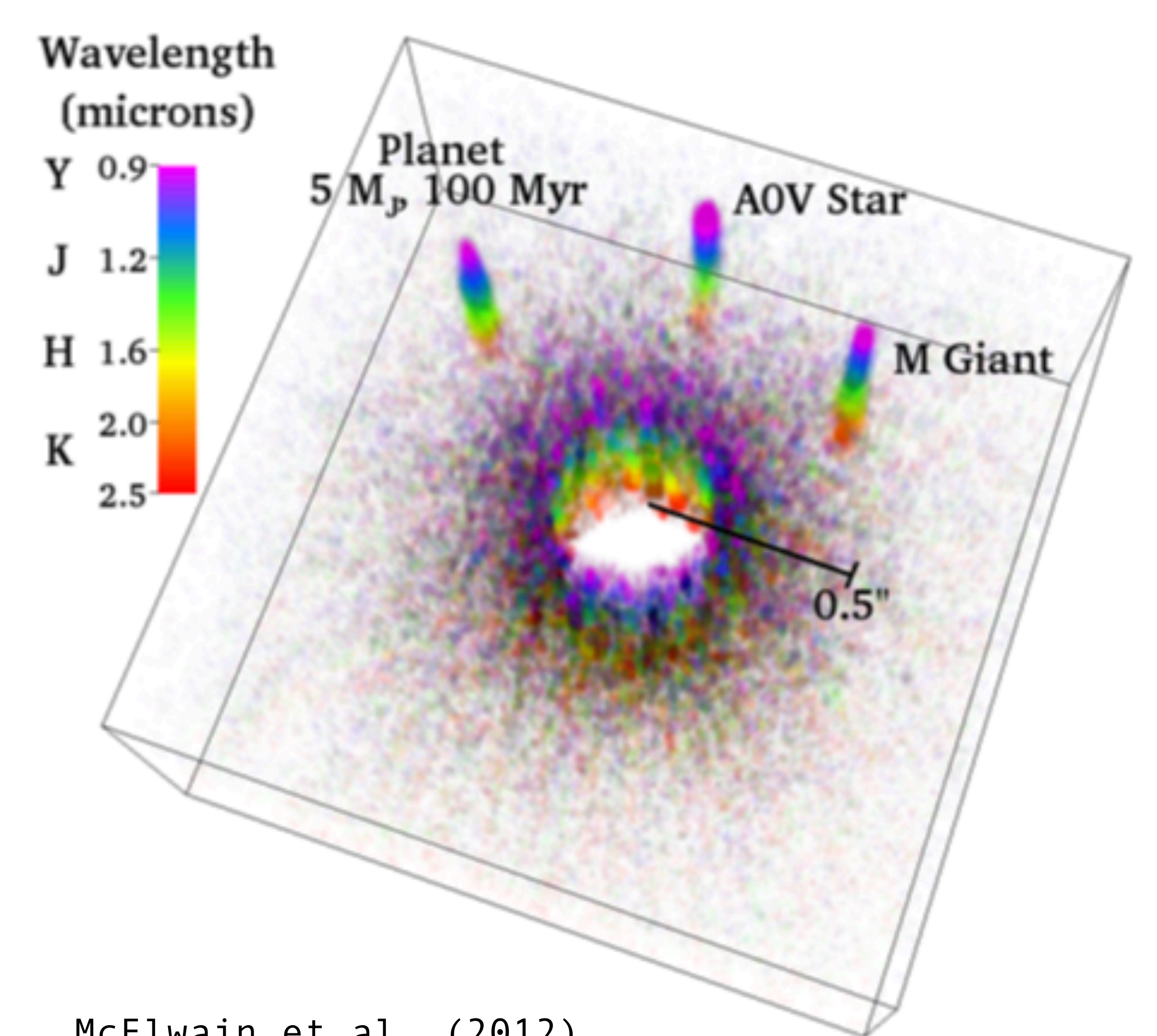
Spectroscopy in the HR 8799 system



Konopacky et al. (2013)

Unambiguous detection of carbon monoxide and water in HR 8799 c

Exoplanet spectroscopy



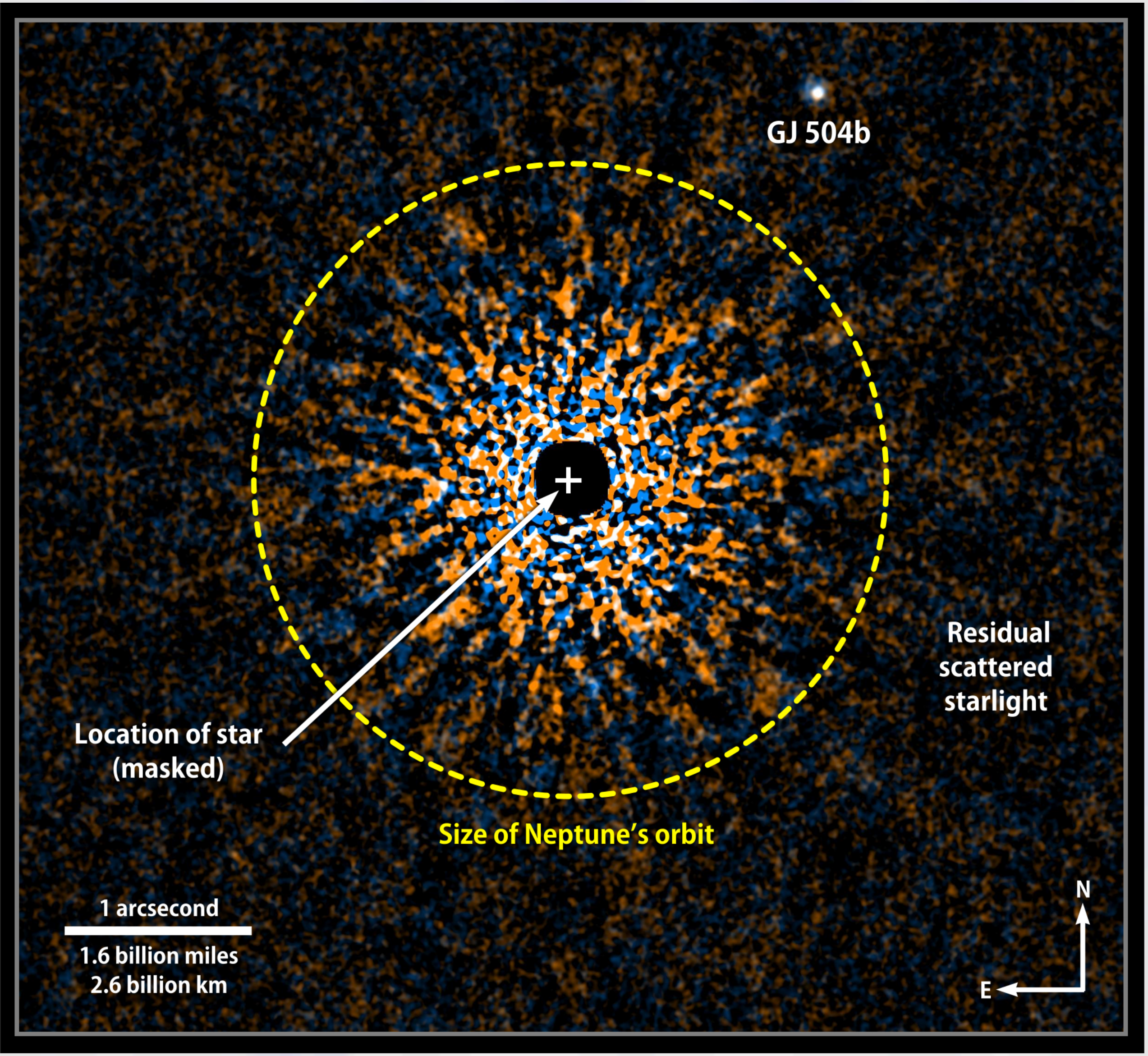
McElwain et al. (2012)

IFUs on essentially all ExAO systems (existing or upcoming)

SPHERE, GPI, CHARIS, P1640 etc.

Allows for high-fidelity characterization of everything in the field

Planet GJ 504 b



Kuzuhara et al. (2013)

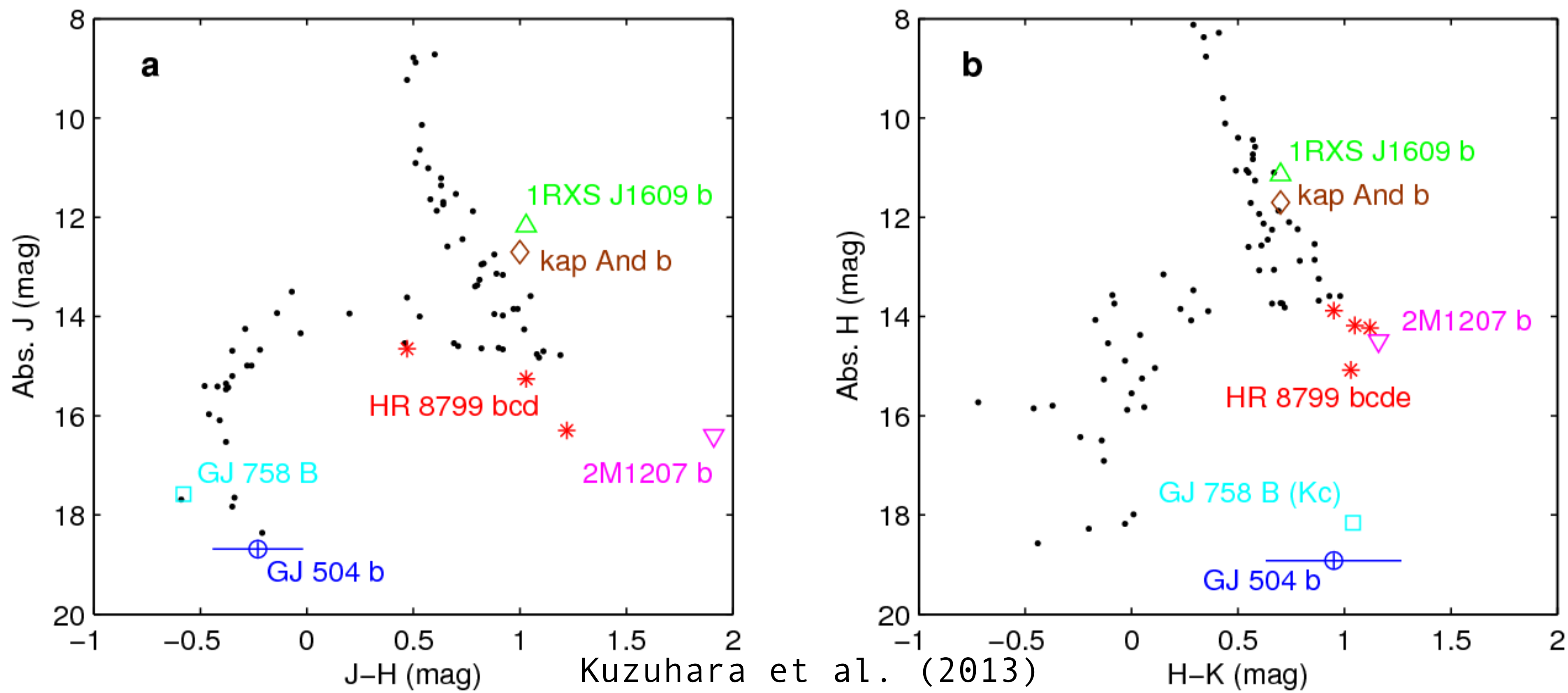
Sun-like (G0V-type) primary at 15 pc distance

Planet mass is ~3-8 Mjup

Projected separation is 43.5 AU

Age is ~200 Myr

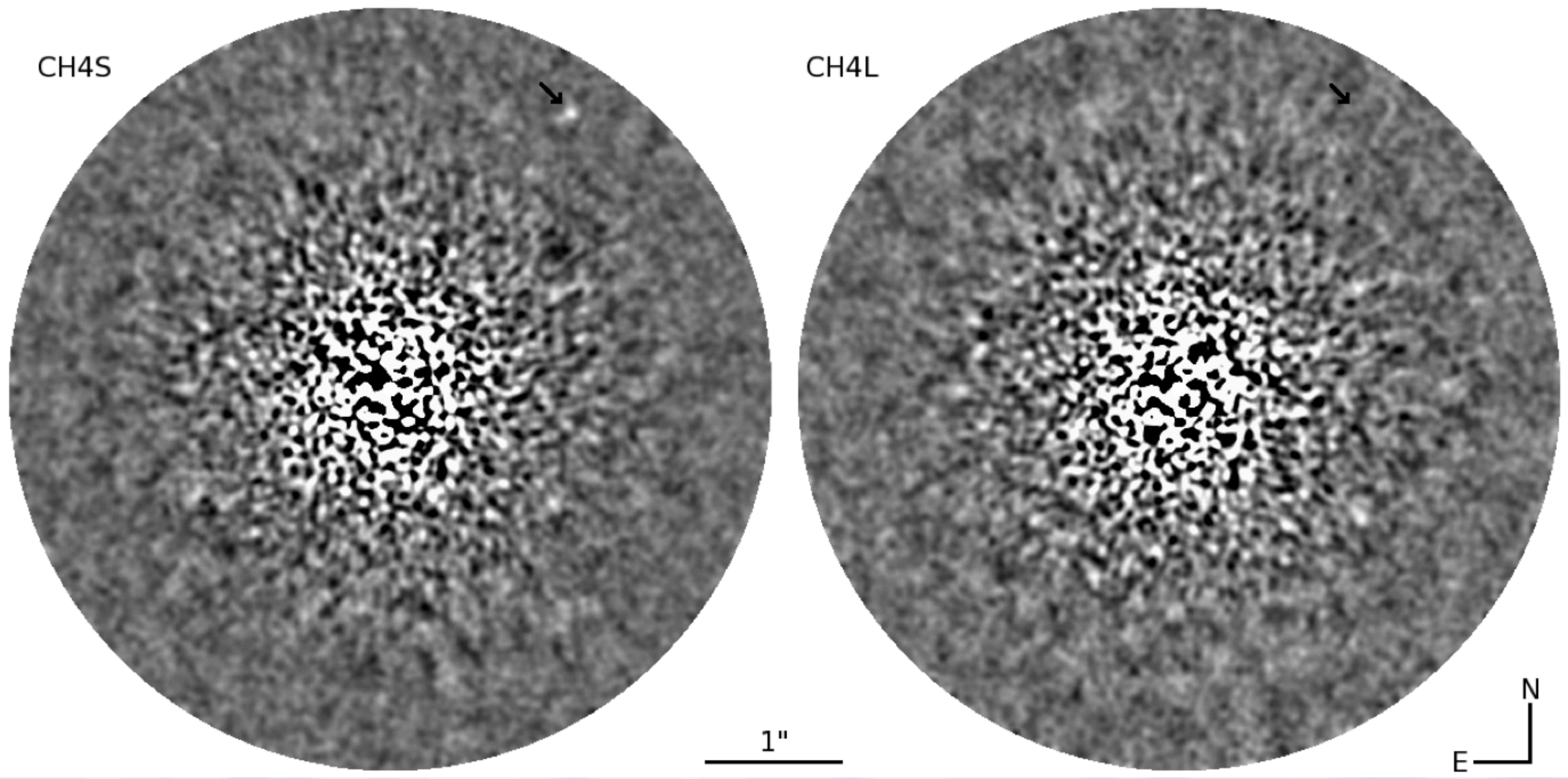
Broad-band photometry



Kuzuhara et al. (2013)

Color-magnitude diagrams provide indications about cloudiness and temperature

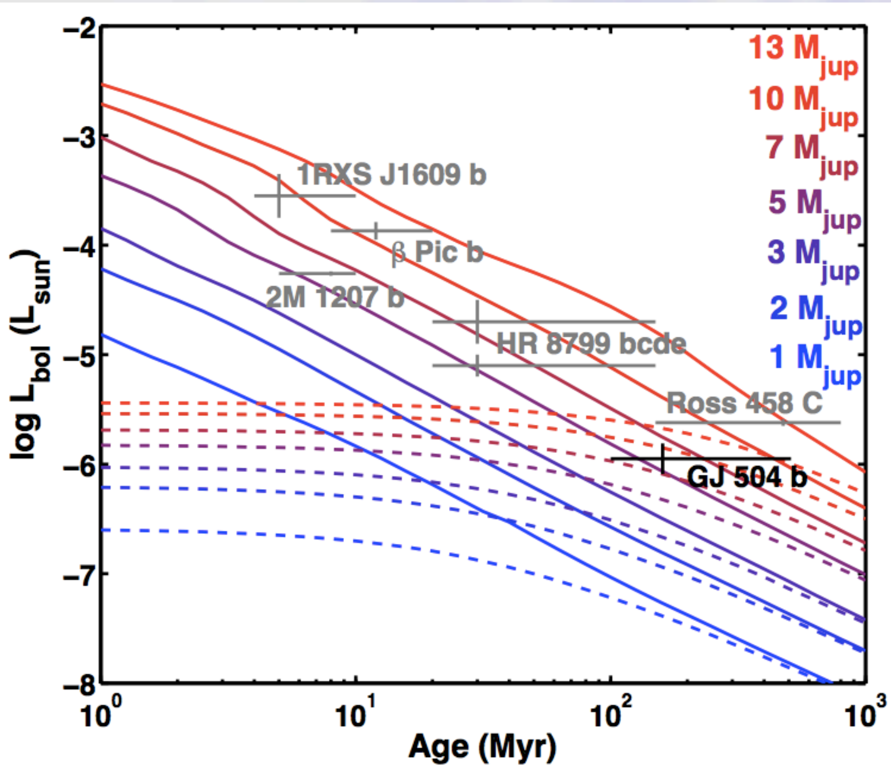
Spectral features with simultaneous imaging



Janson et al. (2013)

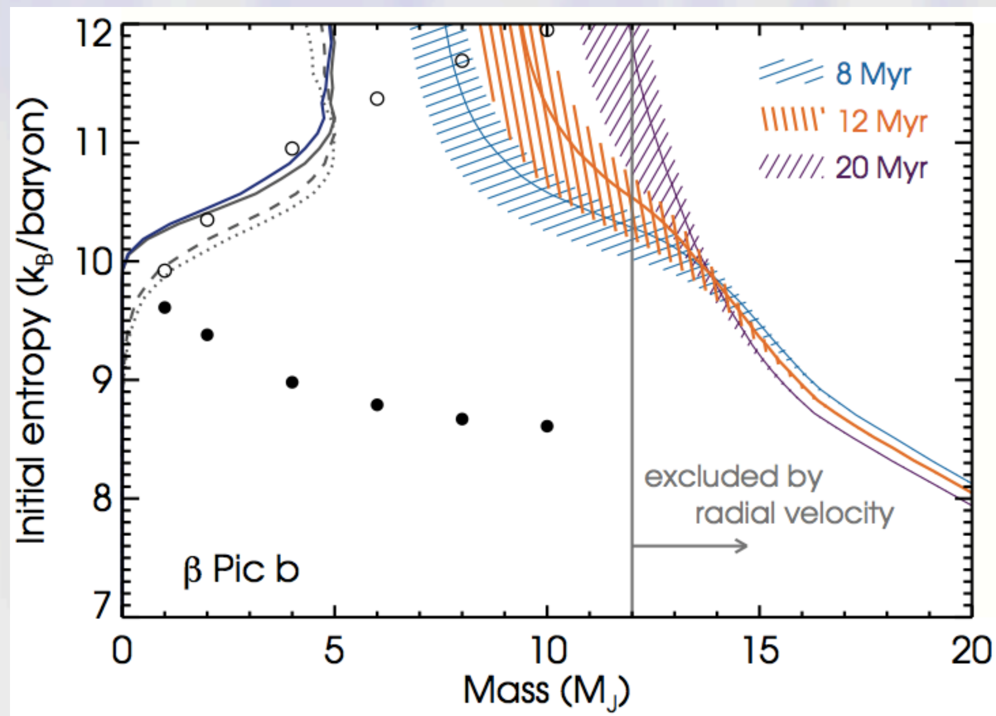
Methane in the atmosphere of GJ 504

Differentiating hot- vs cold-start



Janson et al. (2013)

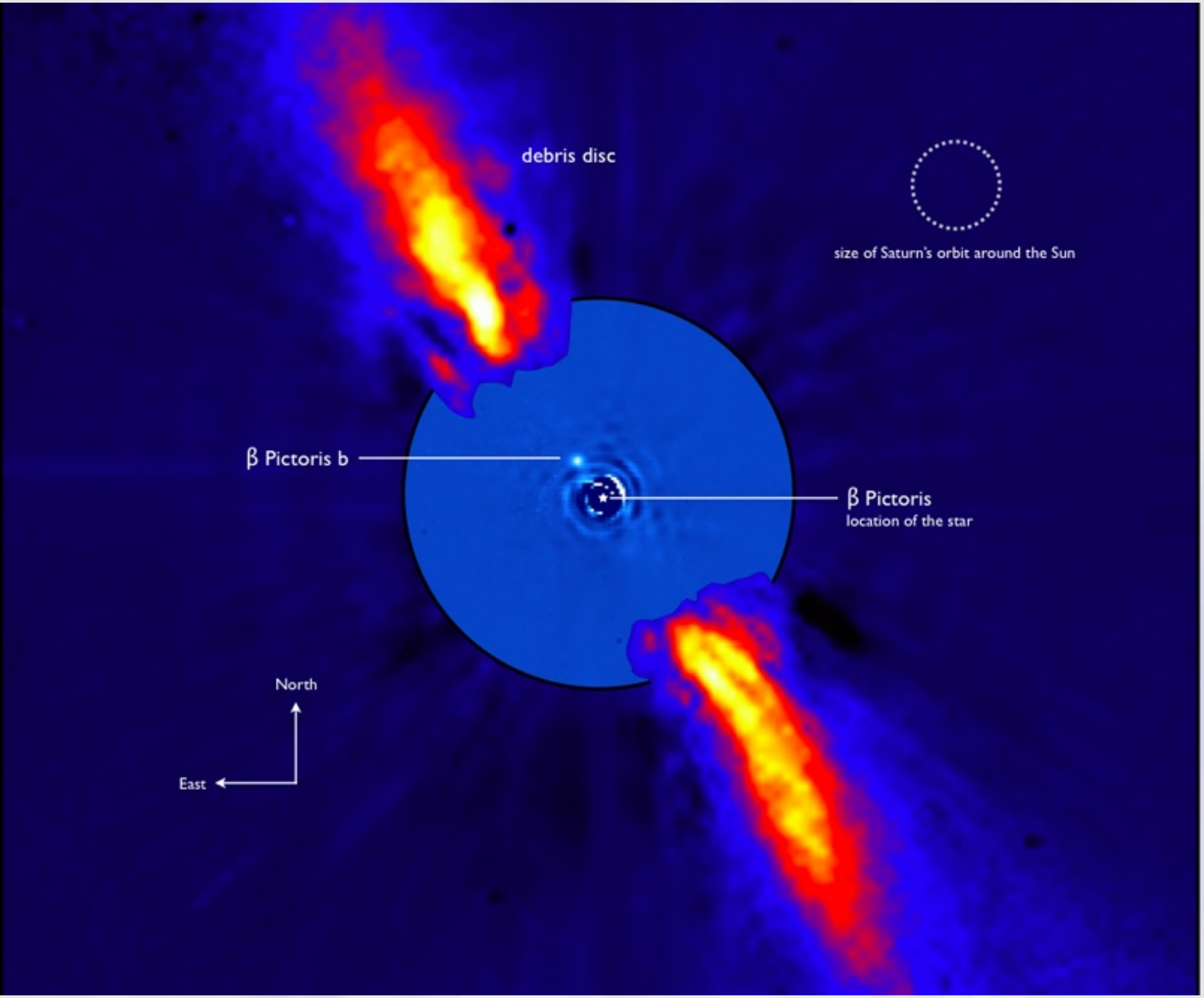
Uncertainties in the initial entropy during planet formation lead to discrepant mass-luminosity relationships (hot vs cold)



Marleau et al. (2013)

The entropy can be constrained with sufficient information

The planet beta Pic b



Lagrange et al. (2009) ESO composition

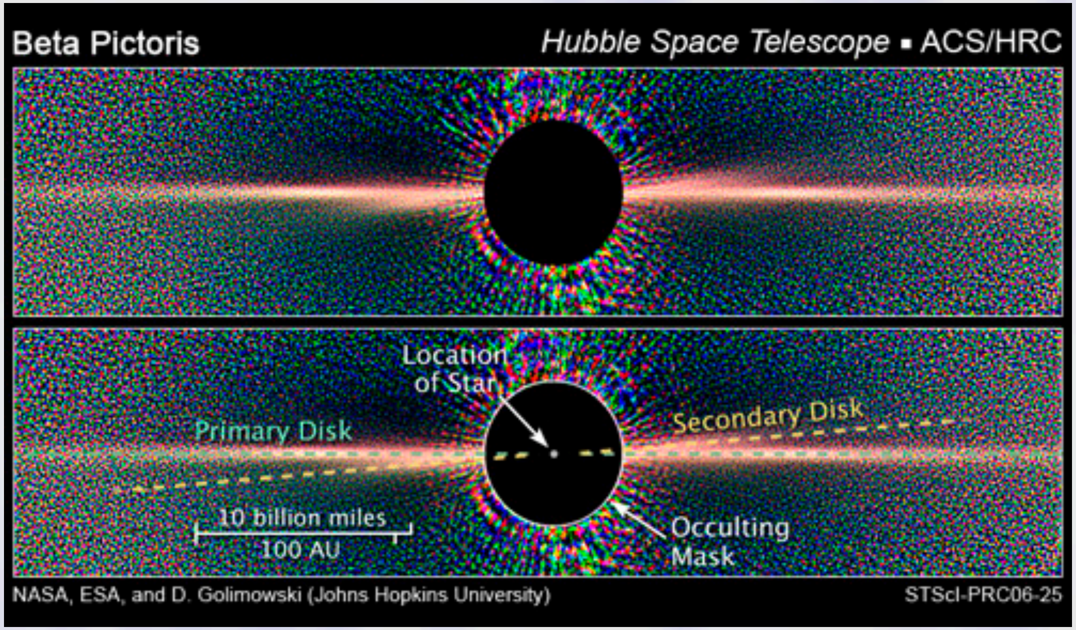
A-type star with prominent debris disk

Planet mass is ~10 Mjup

Planet semi-major axis is ~8-9 AU

Easy to explain with in-situ formation by core accretion (Bonnefoy et al. 2013)

Interaction with the beta Pic disk

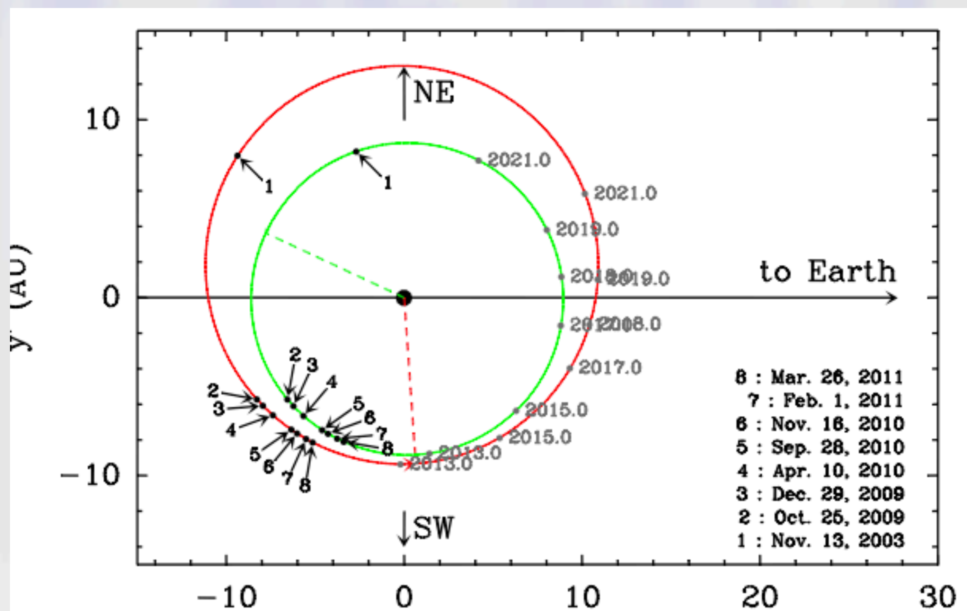


Disk warp seen before detection of beta Pic b

Led to inference of a planet, slightly misaligned with the disk plane

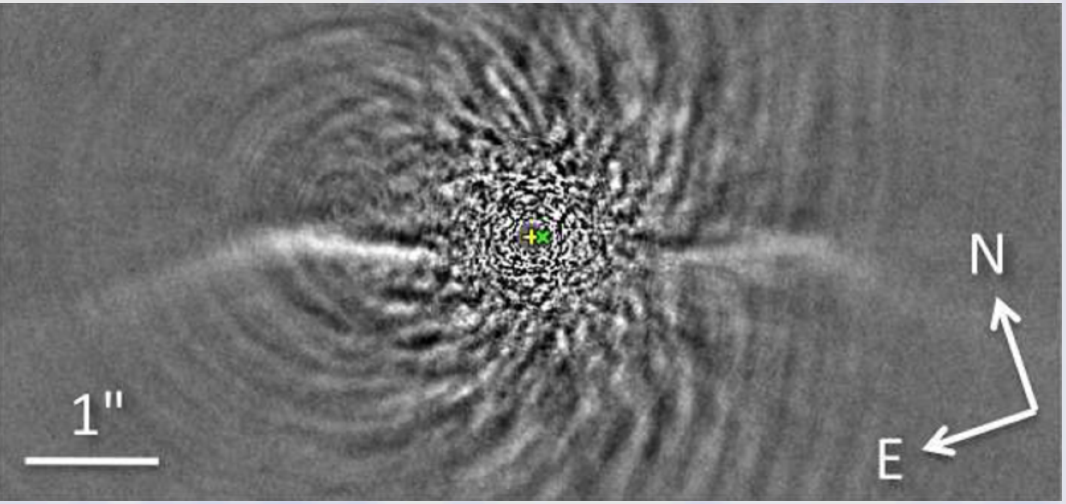
The orbit of the planet is now known to match the misalignment needed to cause the warp

Disk structure is an independent tool for characterizing planets



Chauvin et al. (2012)

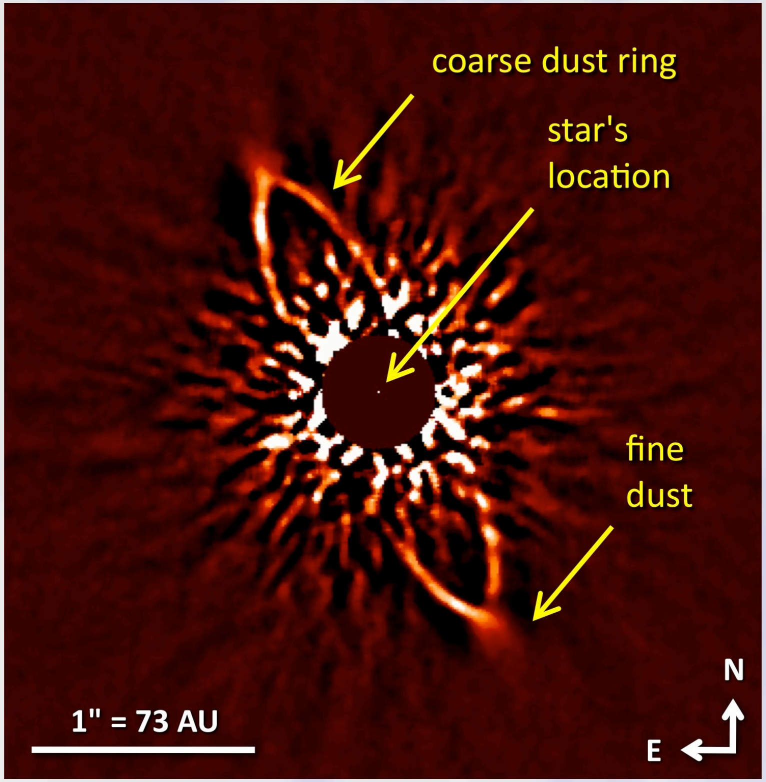
Sharp inner edges



The Moth; Buenzli et al. (2010)

Several debris disks have sharp, eccentric inner edges

Possibly caused by planets (certainly the case for e.g. beta Pic)

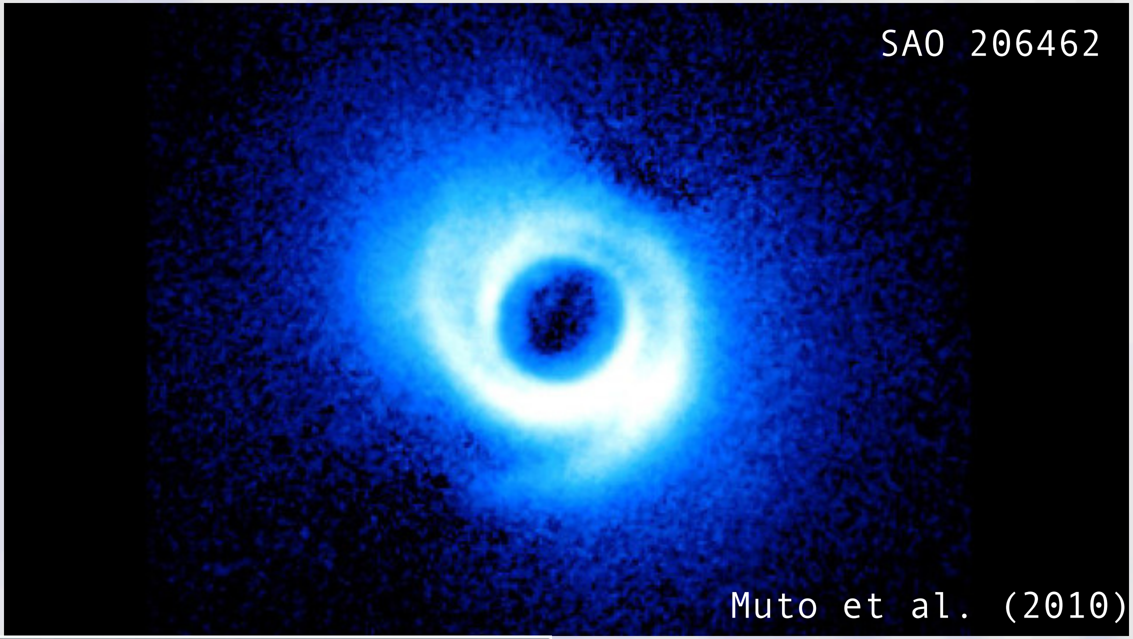


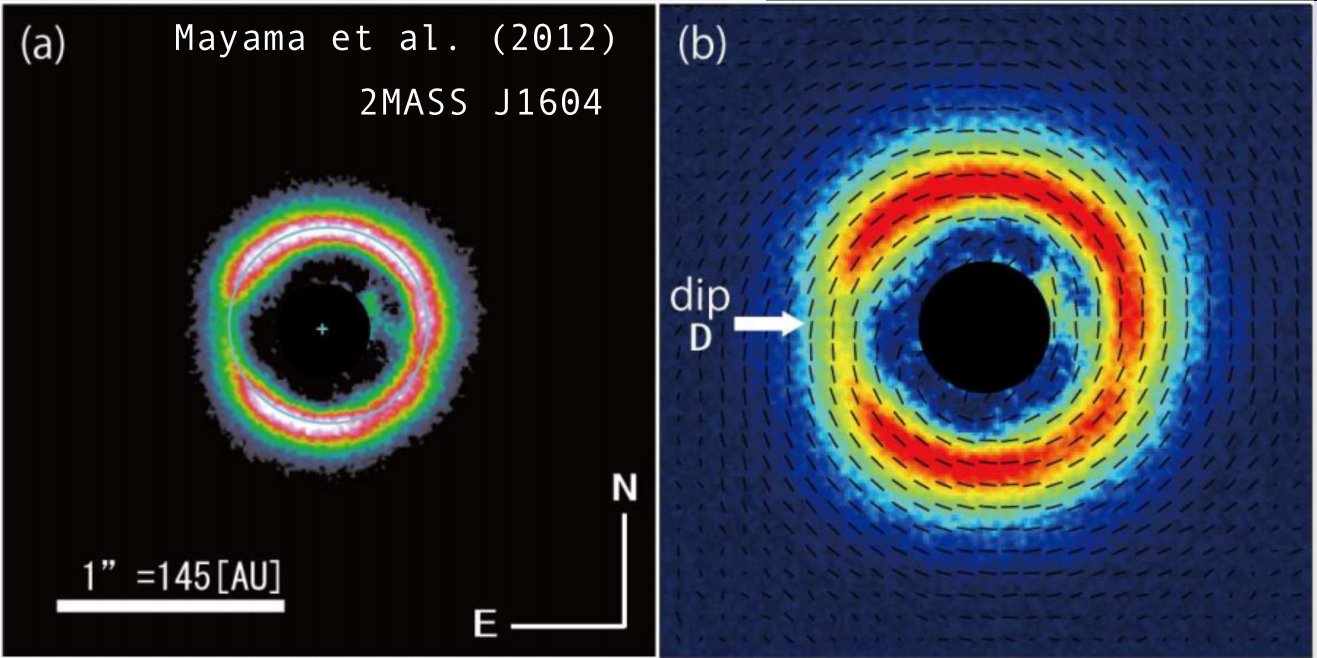
HR 4796A; Thalmann et al. (2011)

Apsidally locked, edge-planet separation depends on planet mass

Structures in primordial disks

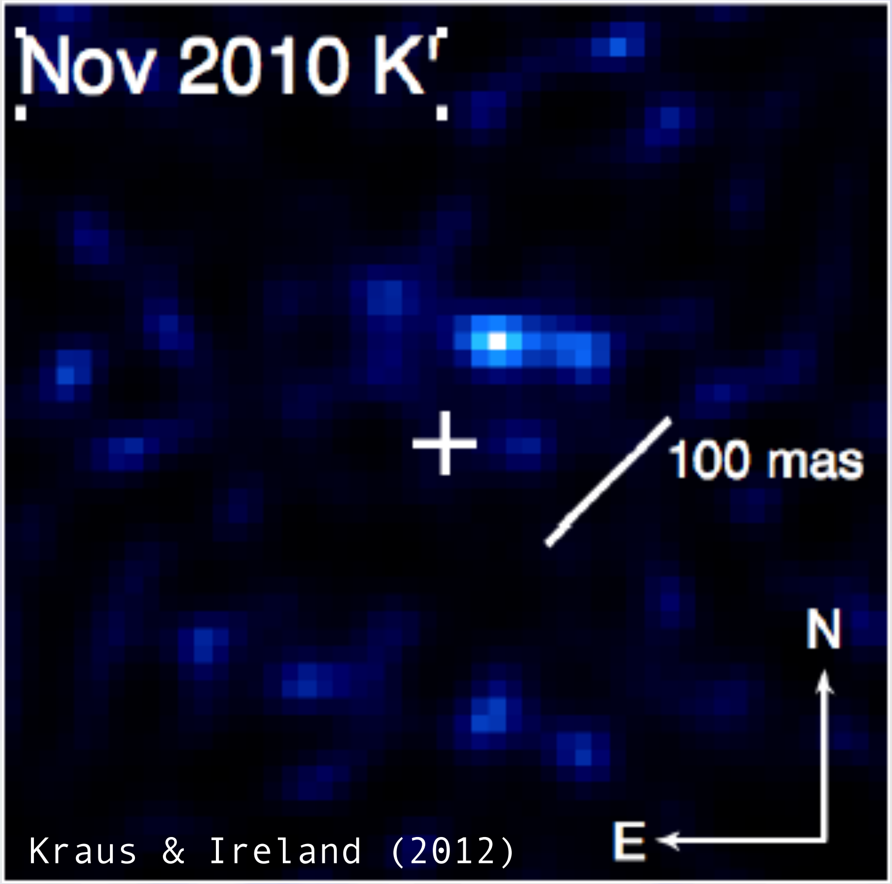
Spirals, gaps, warps etc. could be caused by planets (as well as other things)



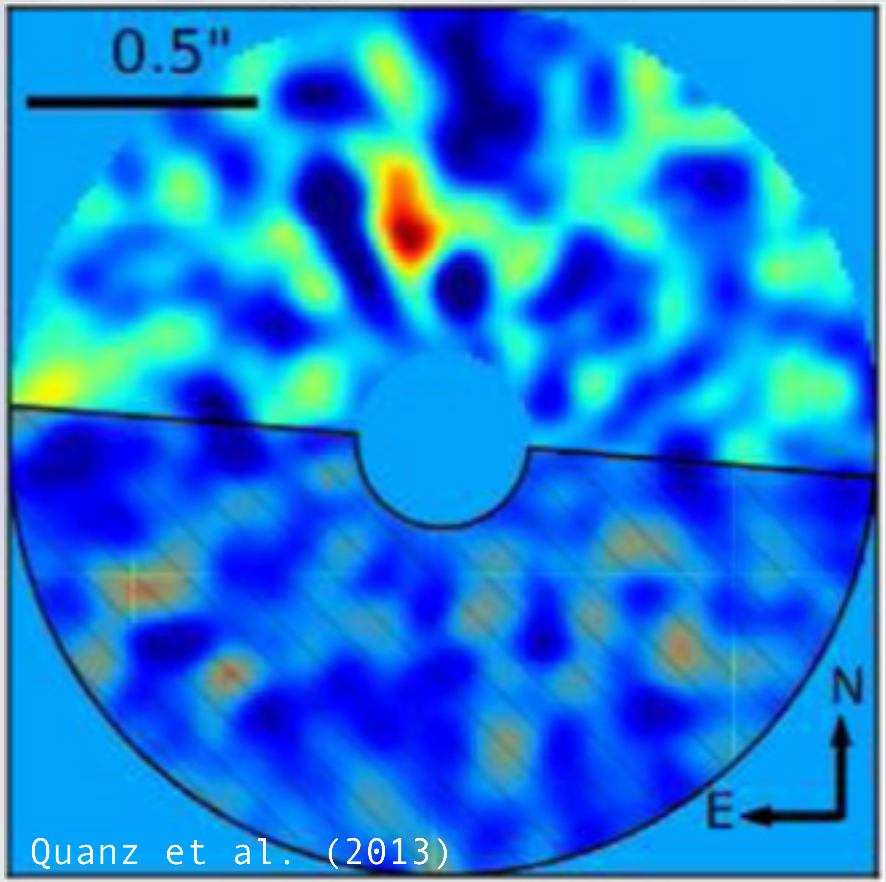


Potential to characterize planets as they form

Prospects for characterization of young systems



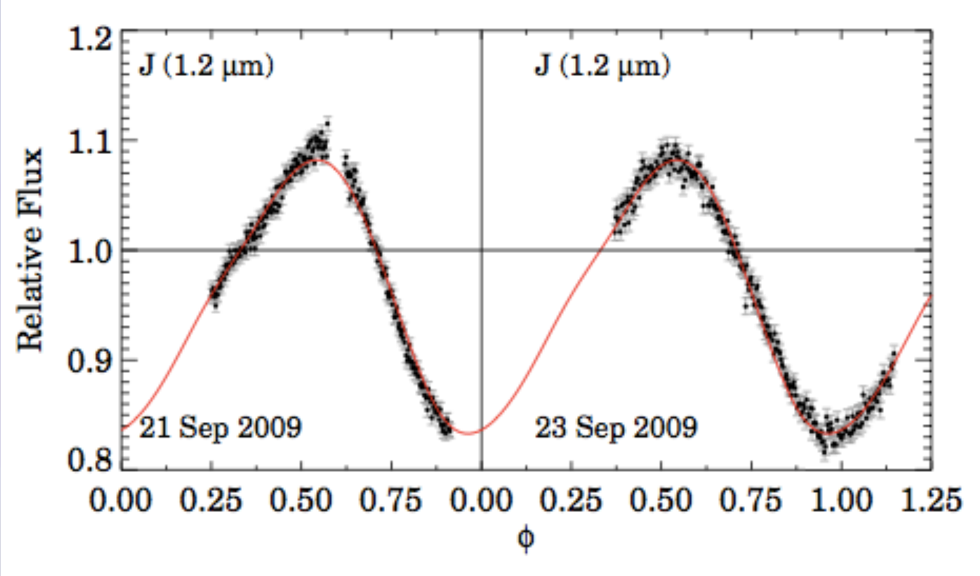
Apparently self-luminous small-scale structures in disks of LkCa15 and HD 100546



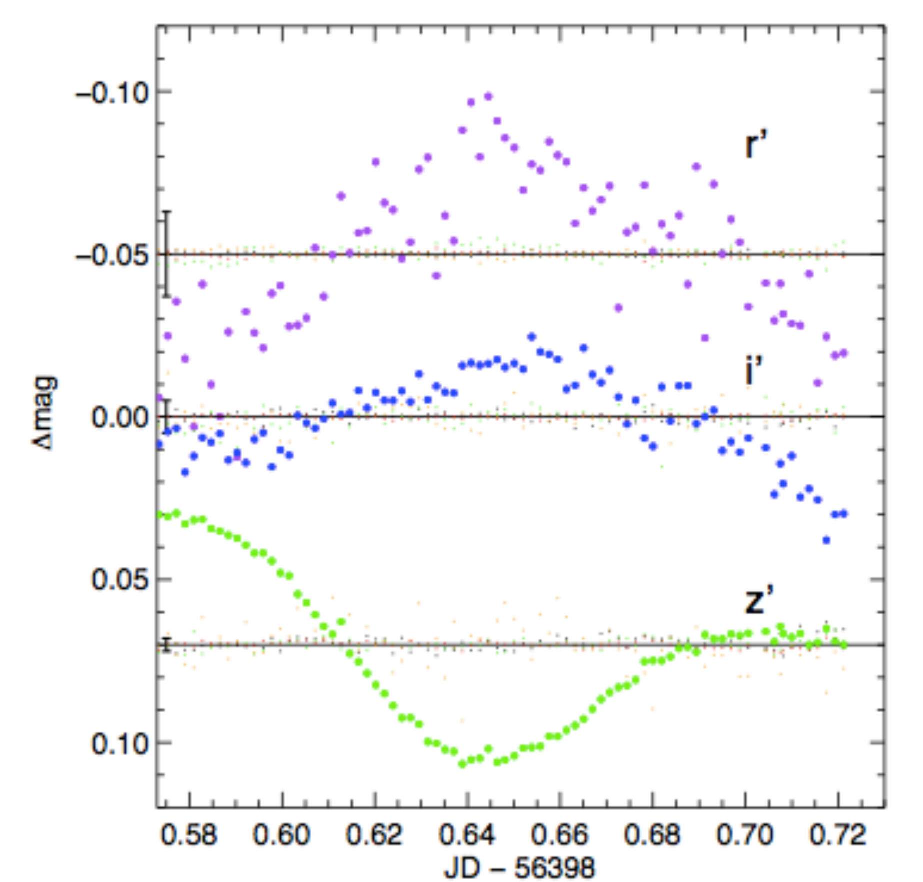
Not clear what they are yet, but exciting prospects for characterization.

Prospects for variability studies

Some brown dwarfs display clear (up to 30%) variability



2MASS J 2139; Radigan et al. (2012)

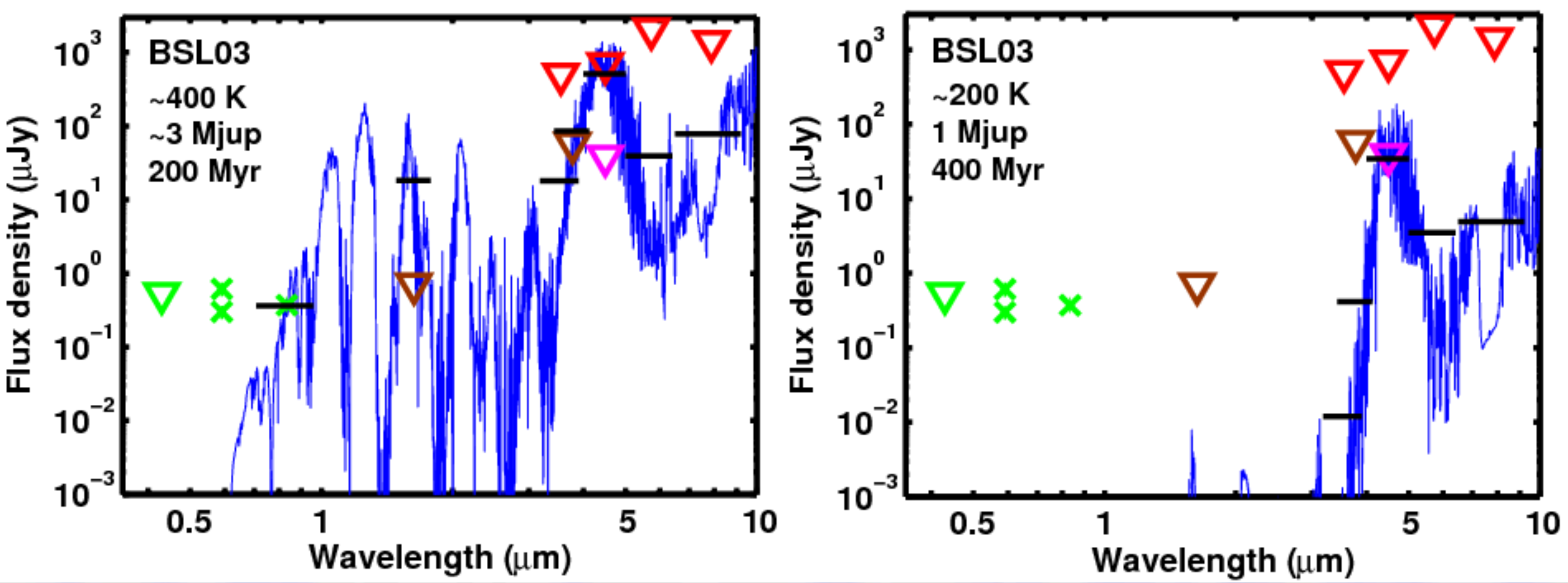


WISE J1049; Biller et al. (2013)

Planets share similar atmospheric properties

Short-term timescale => rotation period. Longer-term timescale => weather. Variations with wavelength => different layers

Anticipating the E-ELT

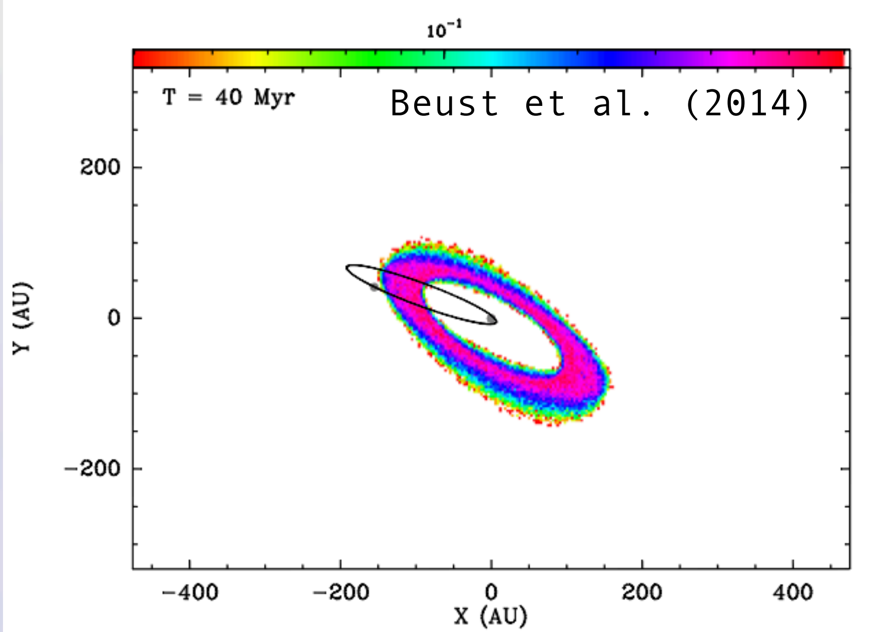


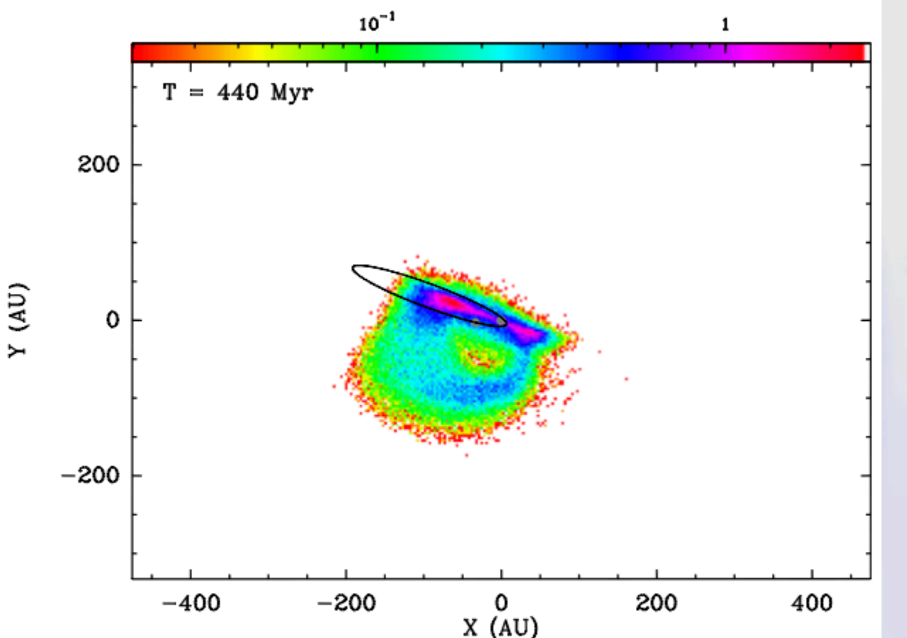
Time required to reach certain sensitivity in the background-limited regime scales as t ~ D^4

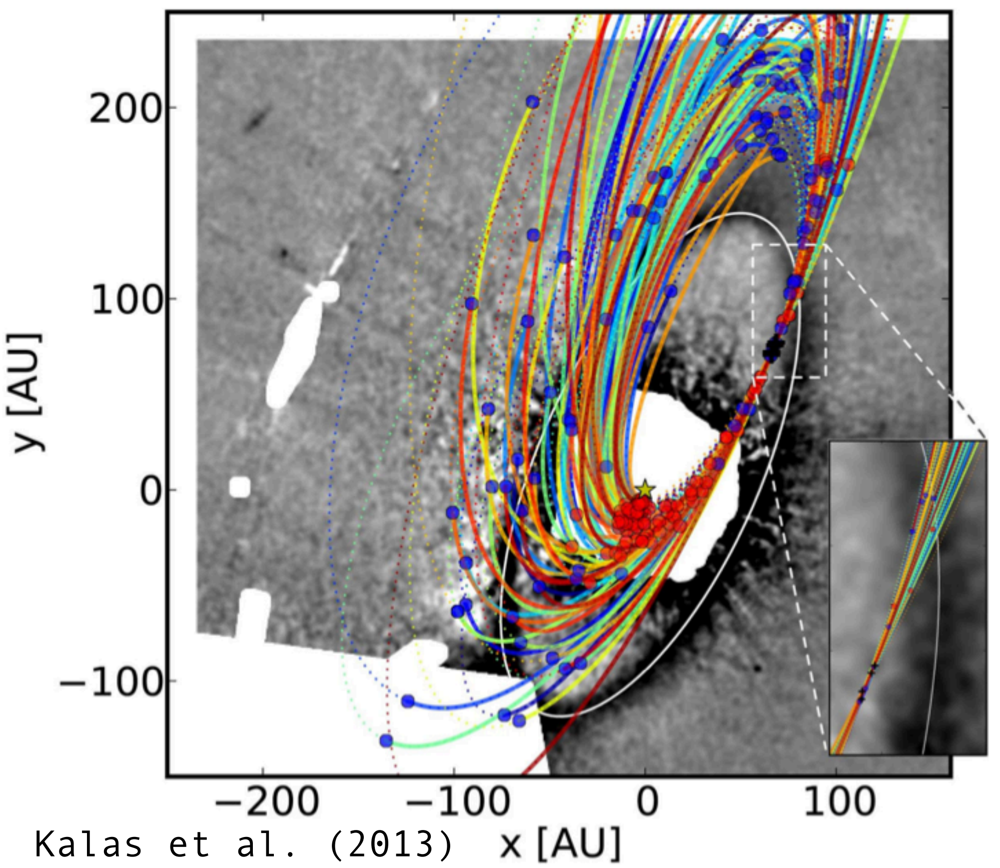
Thanks for your attention

Fomalhaut

Orbit versus disk morphology places constraints on the properties of Fomalhaut b







Kalas et al. (2013)