Multiplicity at the Bottom of the Main Sequence

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NASA (Hubble) Sagan Fellow, UCSD
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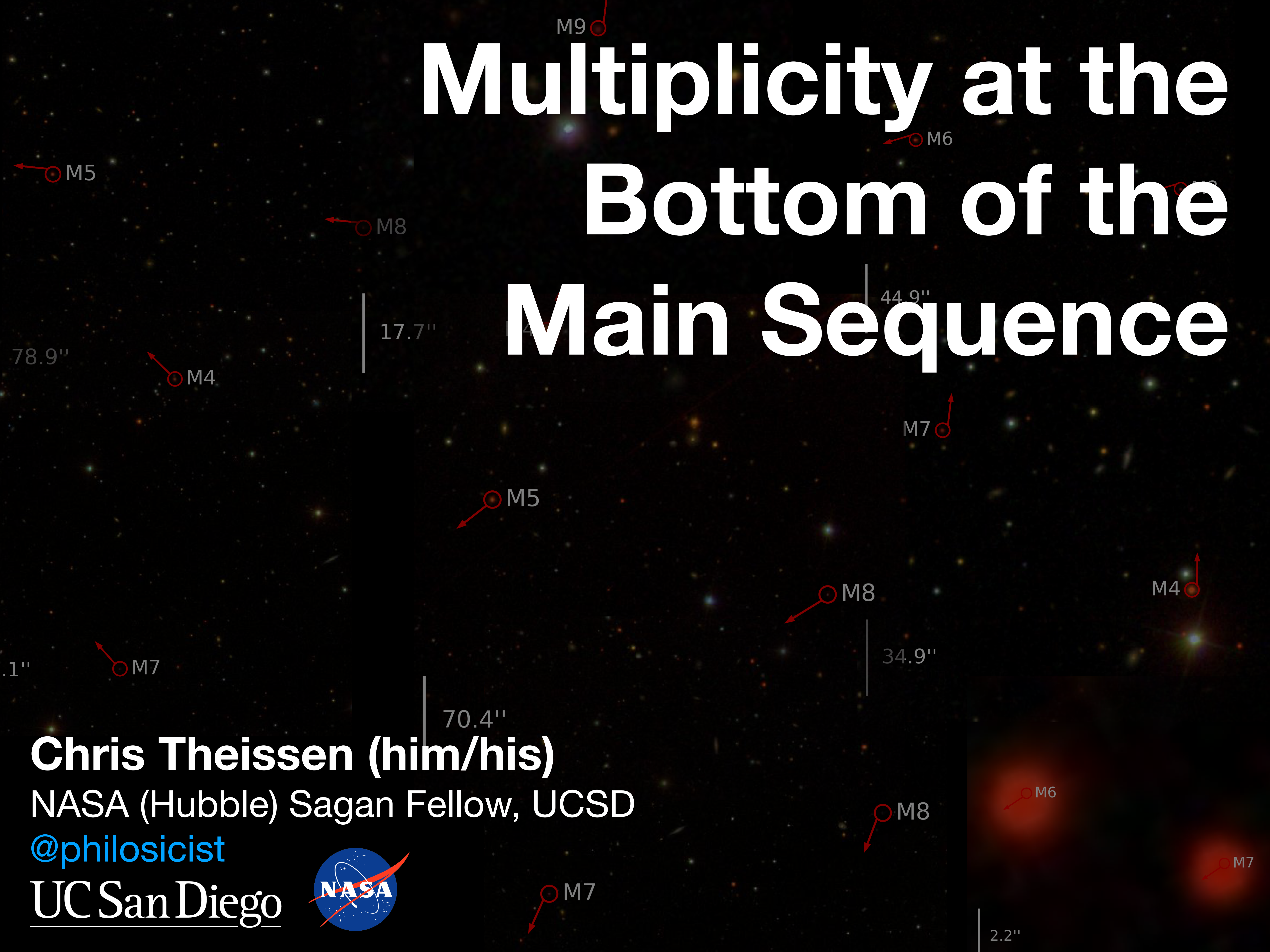
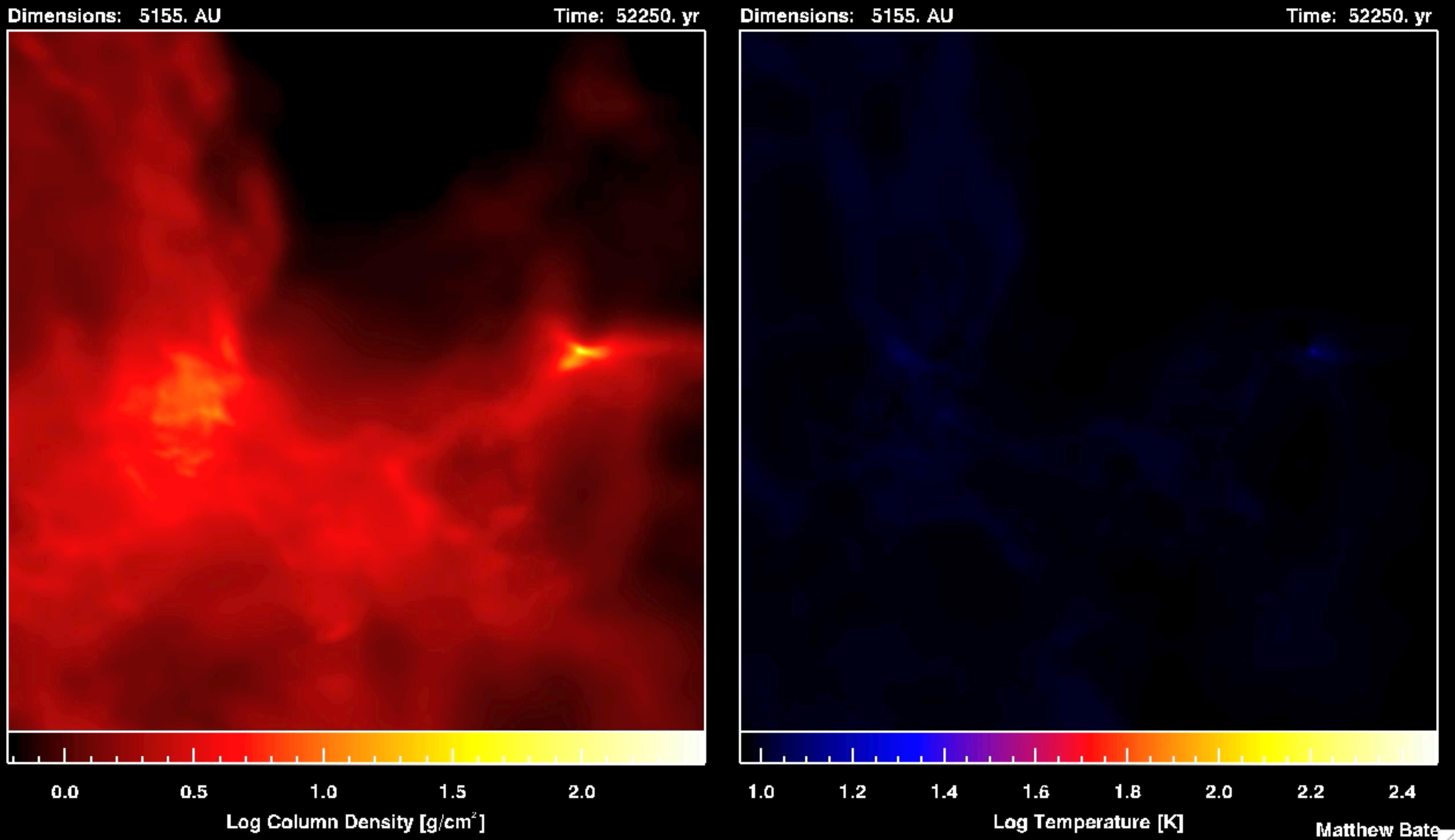
UC San Diego

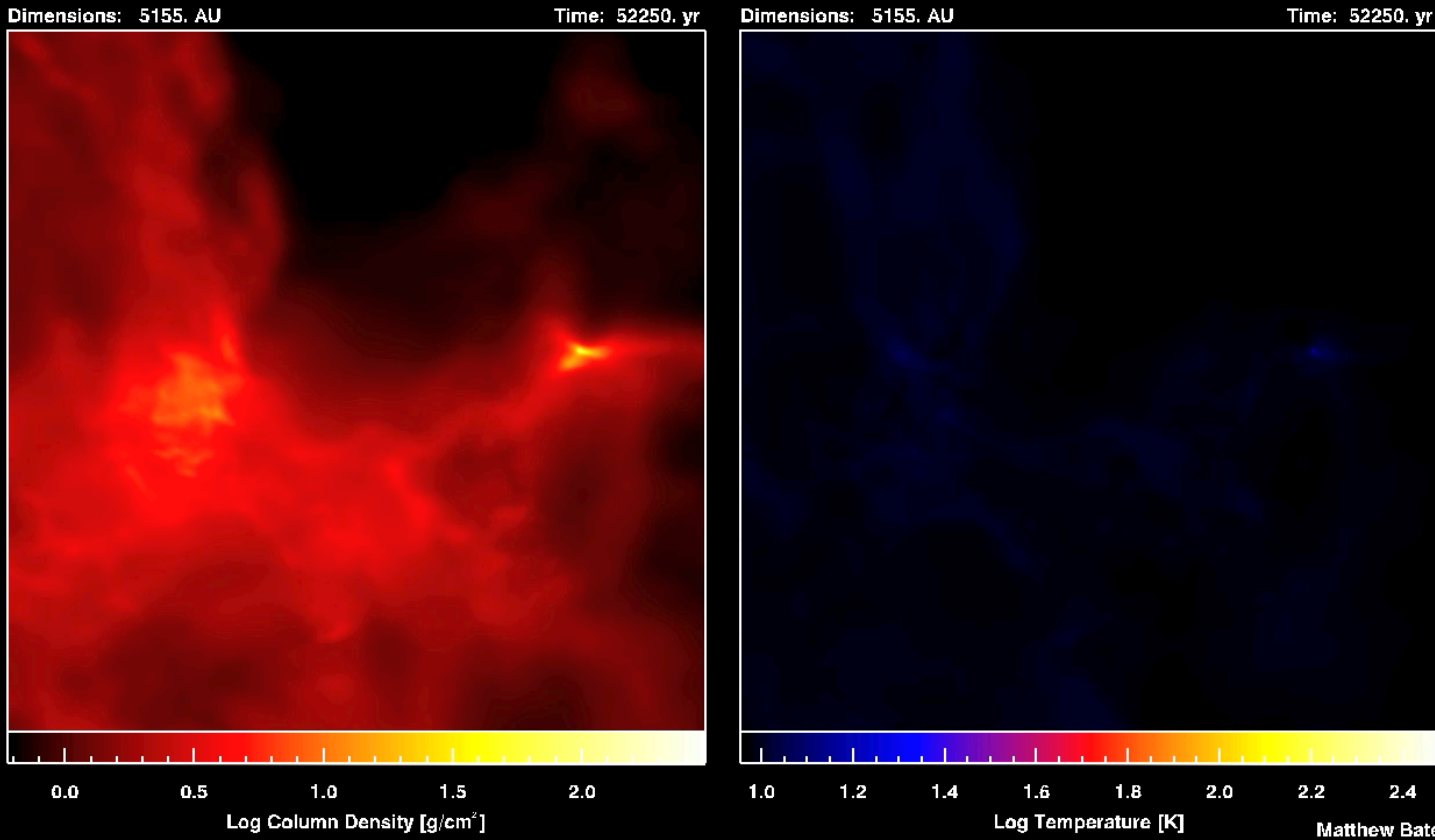


Binary (and higher order) formation in simulations



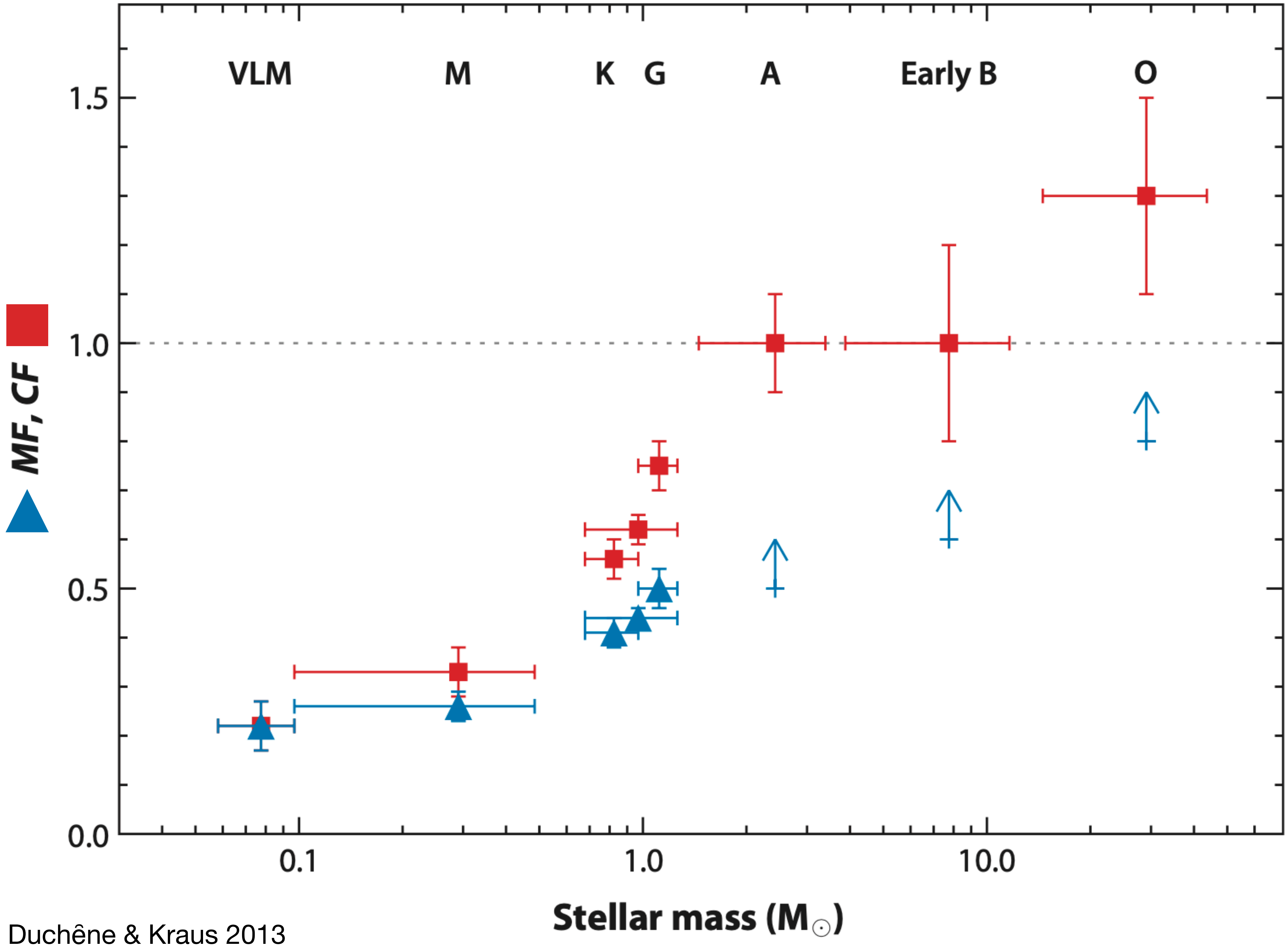
Bate 2009

Binary (and higher order) formation in simulations



Bate 2009

Multiplicity: Current state of the field



Duchêne & Kraus 2013

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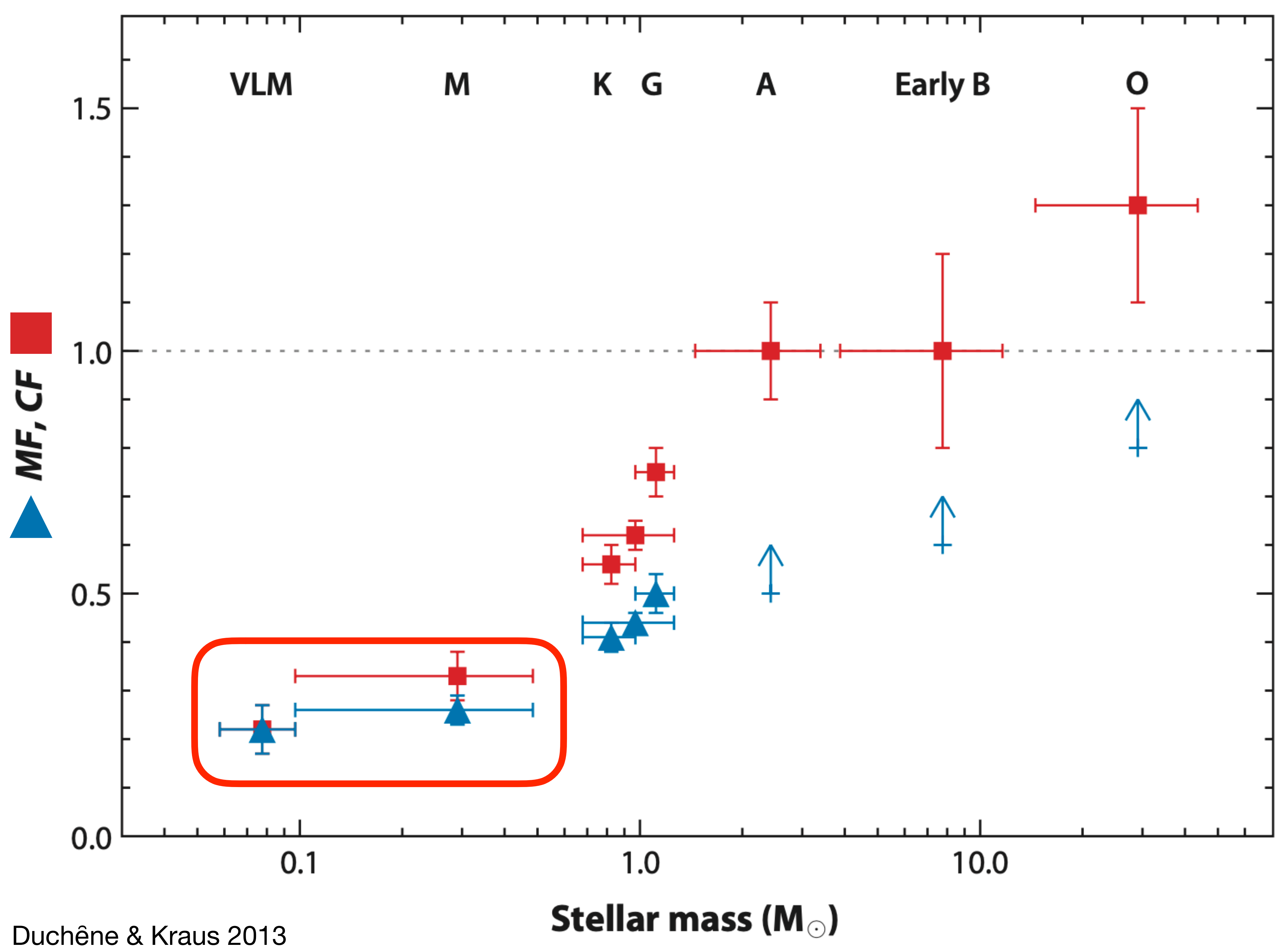
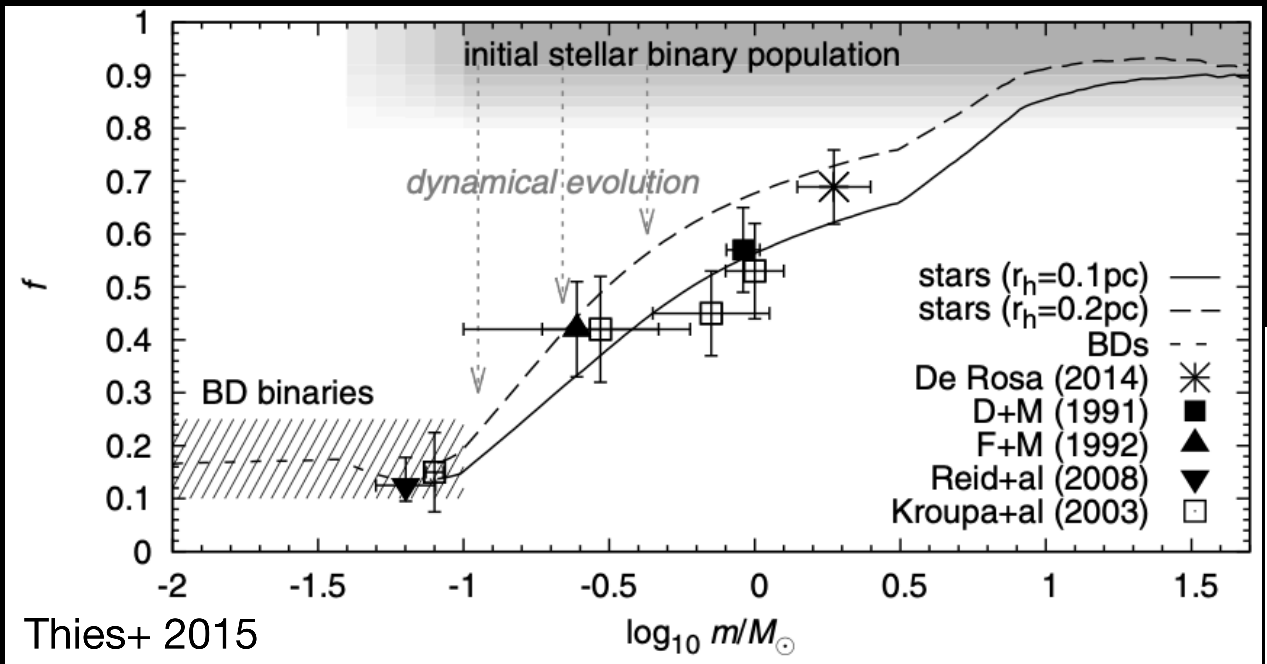
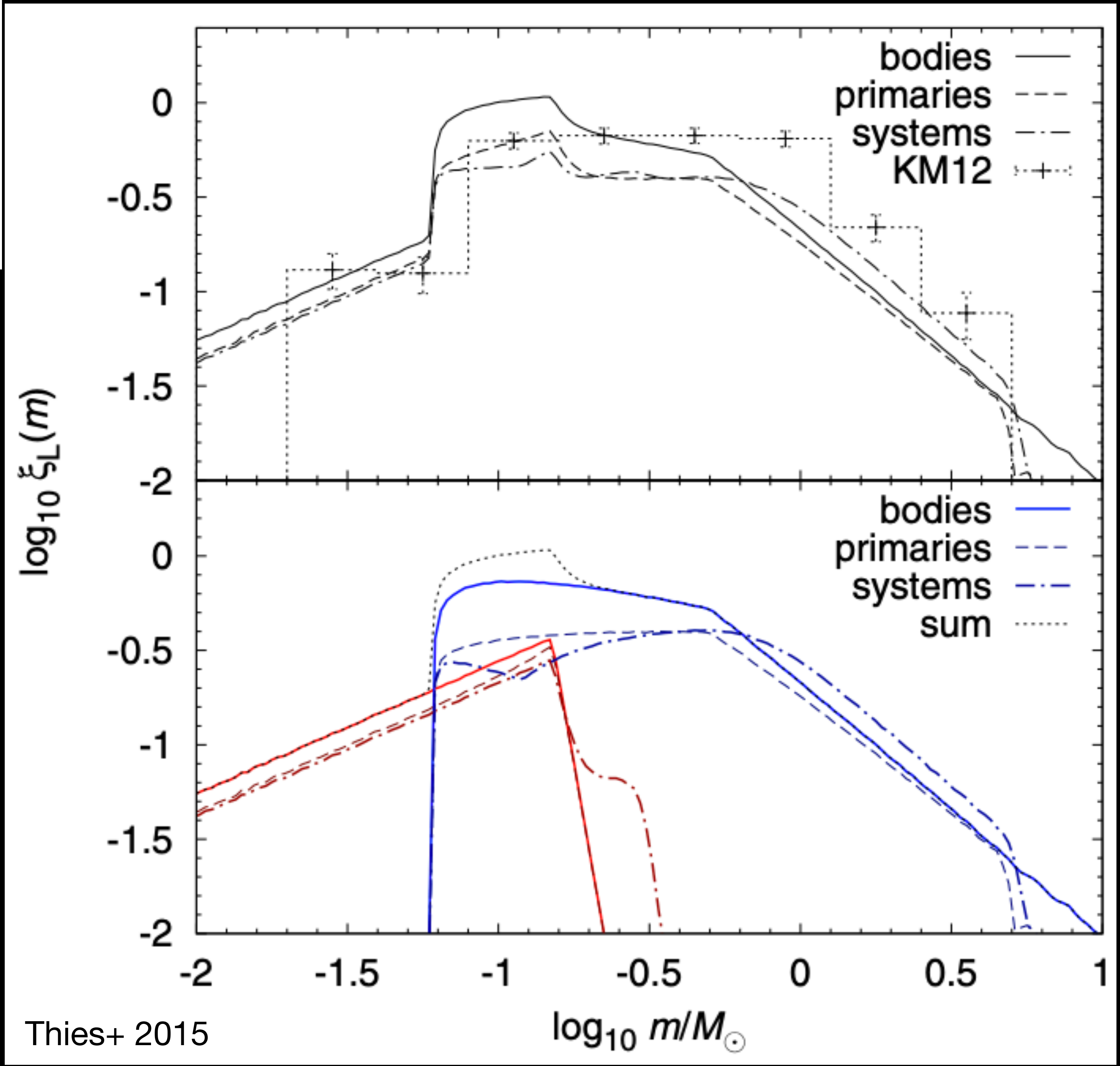


Duchêne & Kraus 2013

Why is multiplicity important? The Initial Mass Function



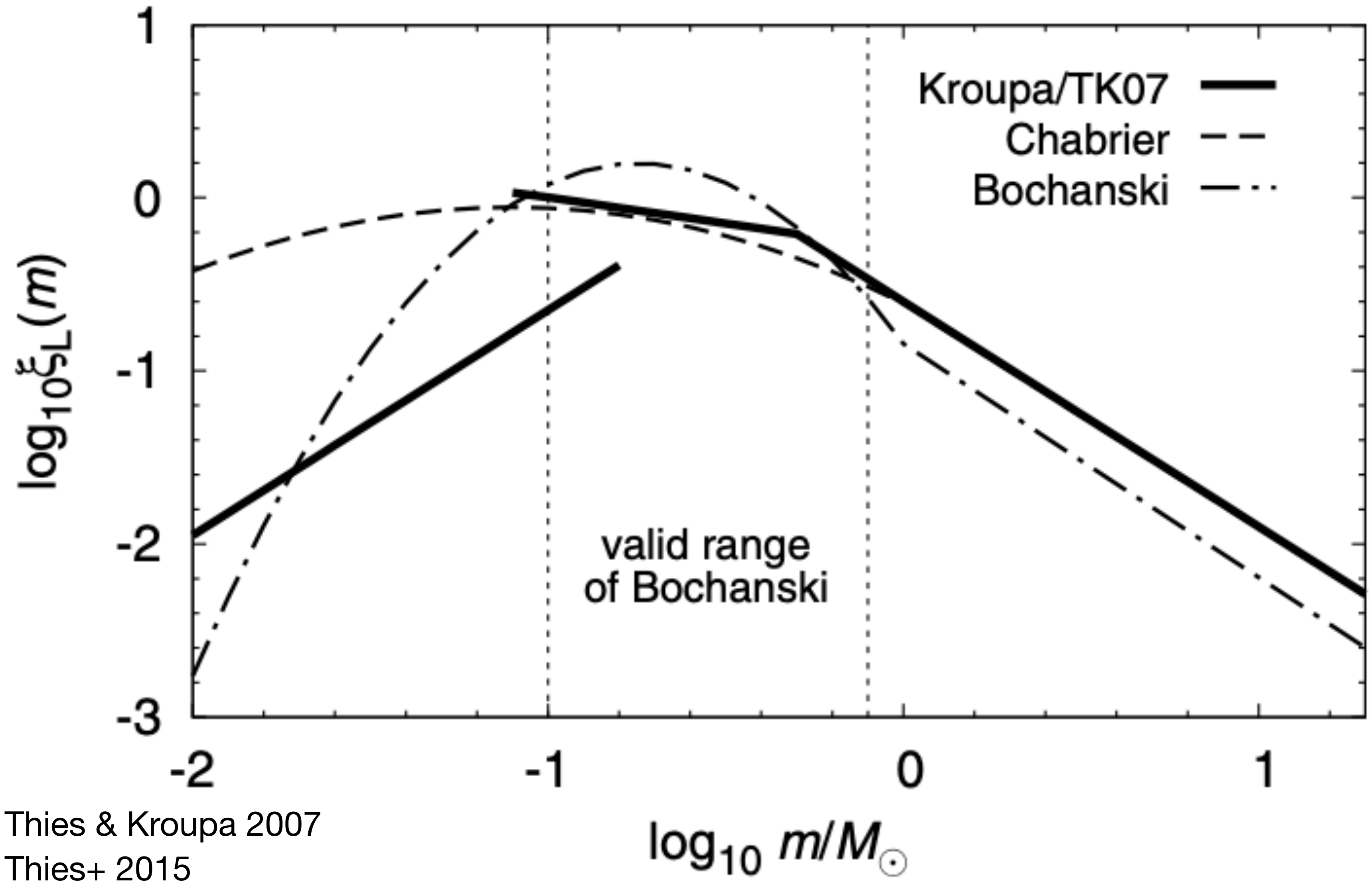
Multiplicity plays a critical role in the IMF



The overall shape of the IMF is dependent on the number of binary (and higher order) systems

Here, binarity is 20% for BDs, 80% for stars.

More on the IMF: Formation mechanisms

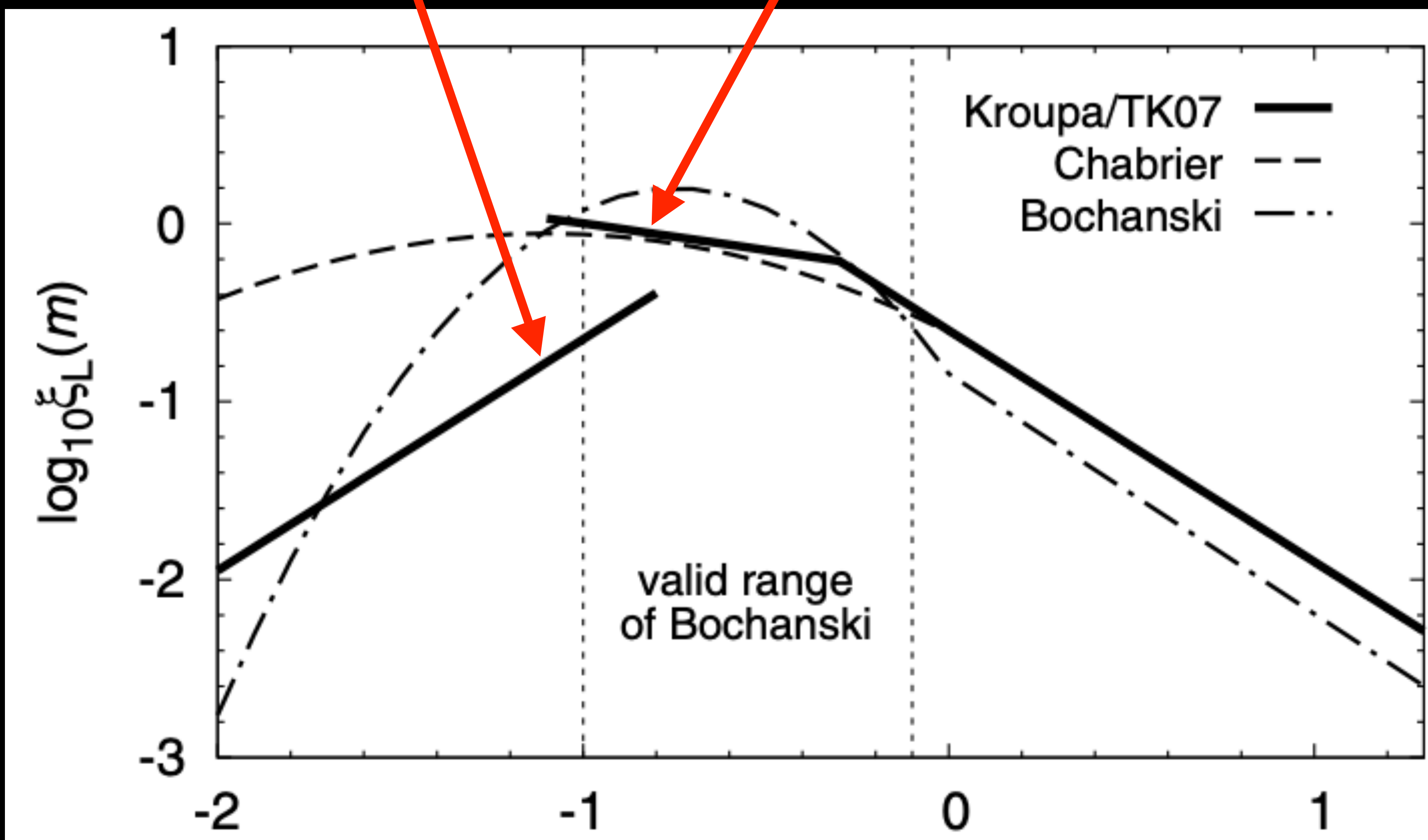


Thies & Kroupa 2007
Thies+ 2015

The overall shape of the IMF is highly dependent on the number of binary (and higher order) systems

More on the IMF: Formation mechanisms

Discontinuity has been interpreted as a different formation mechanism (stars versus BDs). Likely more than 1 formation pathway



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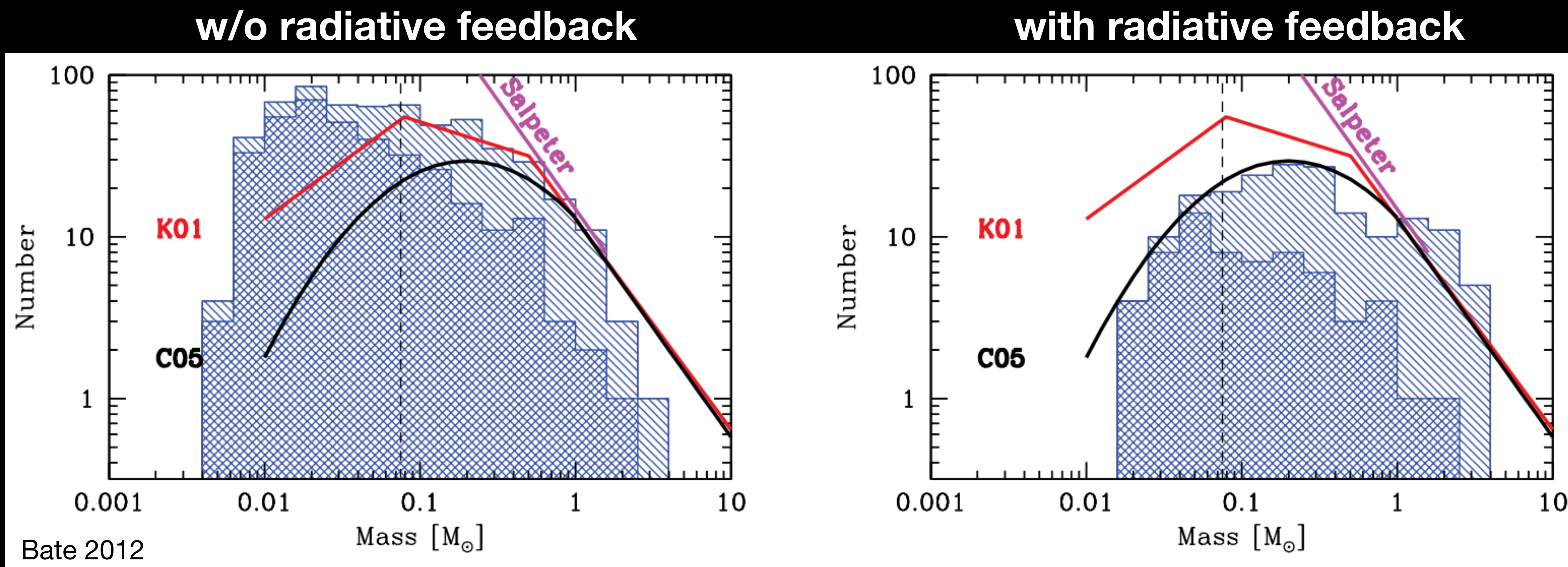
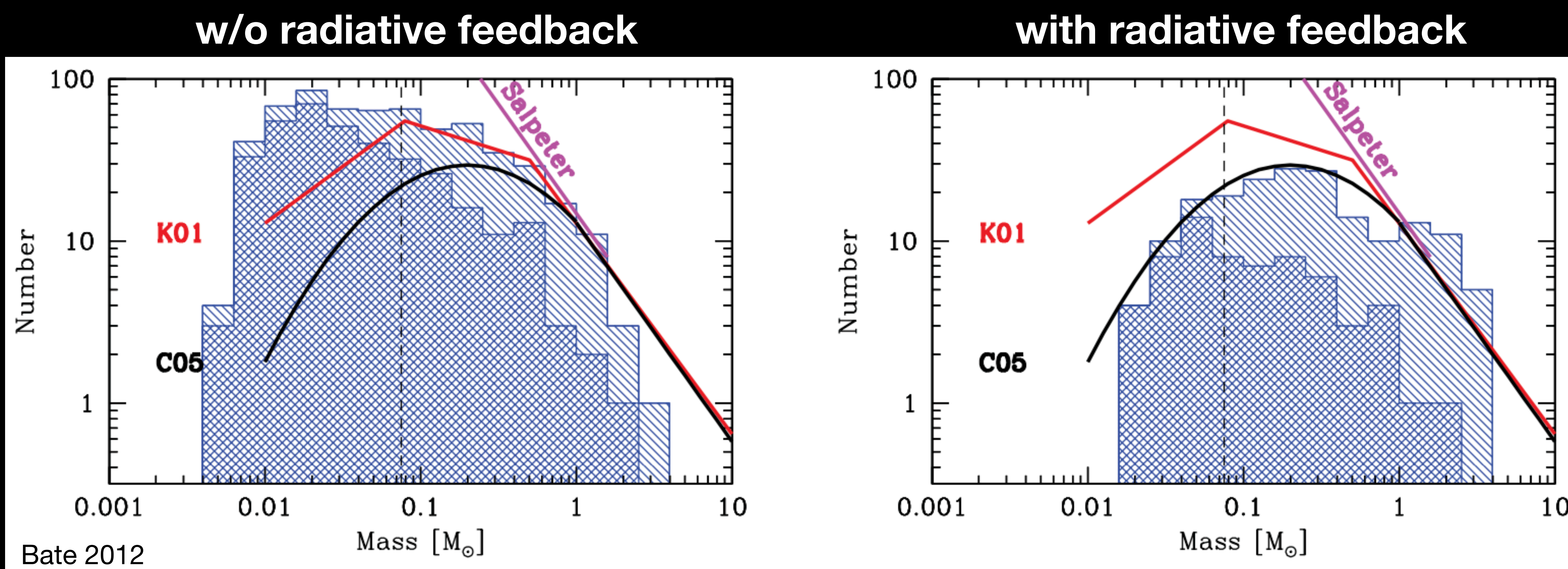
More on the IMF: Informing (most) modeling

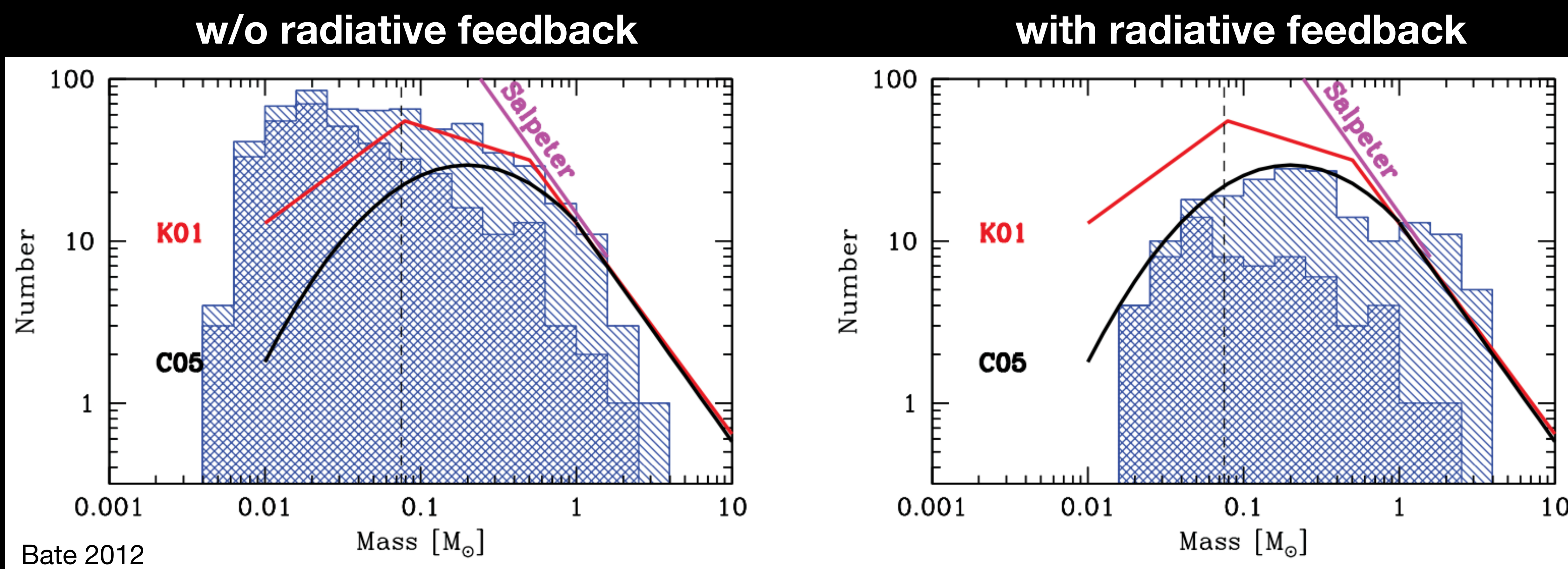


More on the IMF: Informing (most) modeling



comparison. In agreement with the smaller radiation hydrodynamical calculations of Bate (2009c), the introduction of the radiative feedback has clearly addressed the problem of the overproduction of brown dwarfs and low-mass stars that occurs when using a barotropic equation of state (Bate 2009a). In fact, comparing the histogram of objects with the parametrization of the observed IMF by Chabrier (2005), the agreement is almost too good to be true.

More on the IMF: Informing (most) modeling



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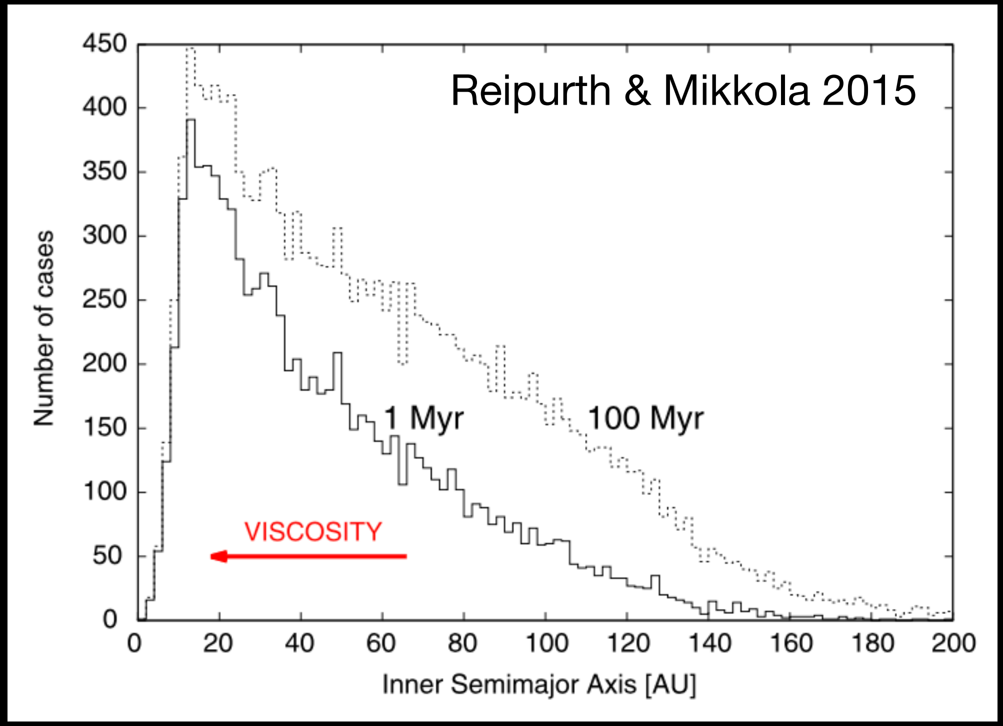
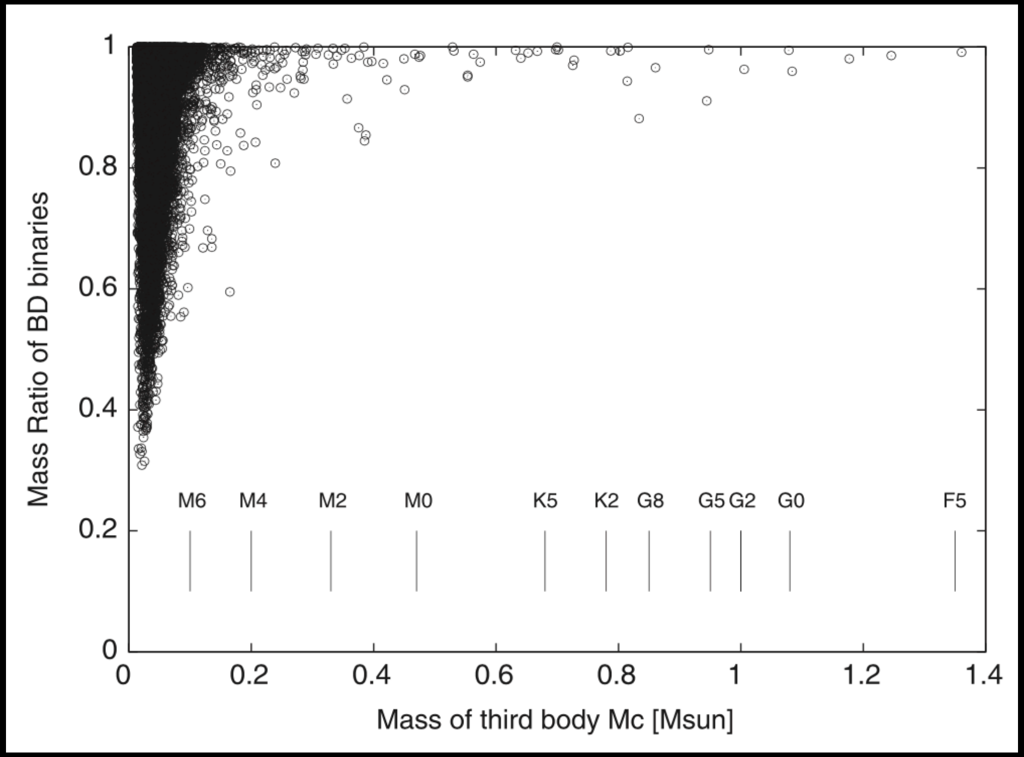
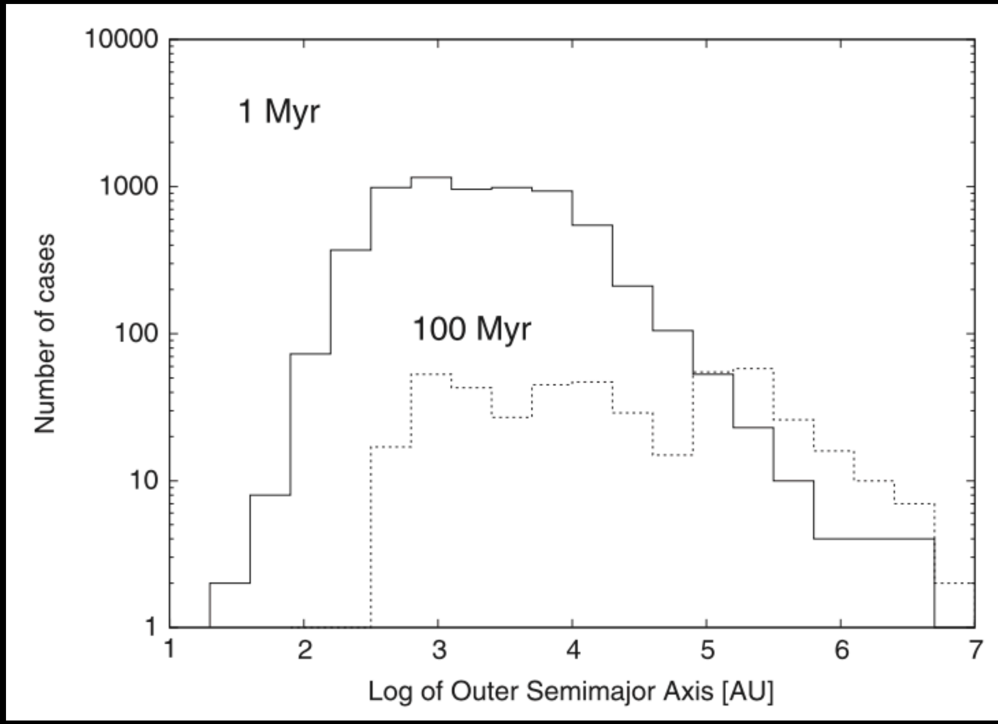
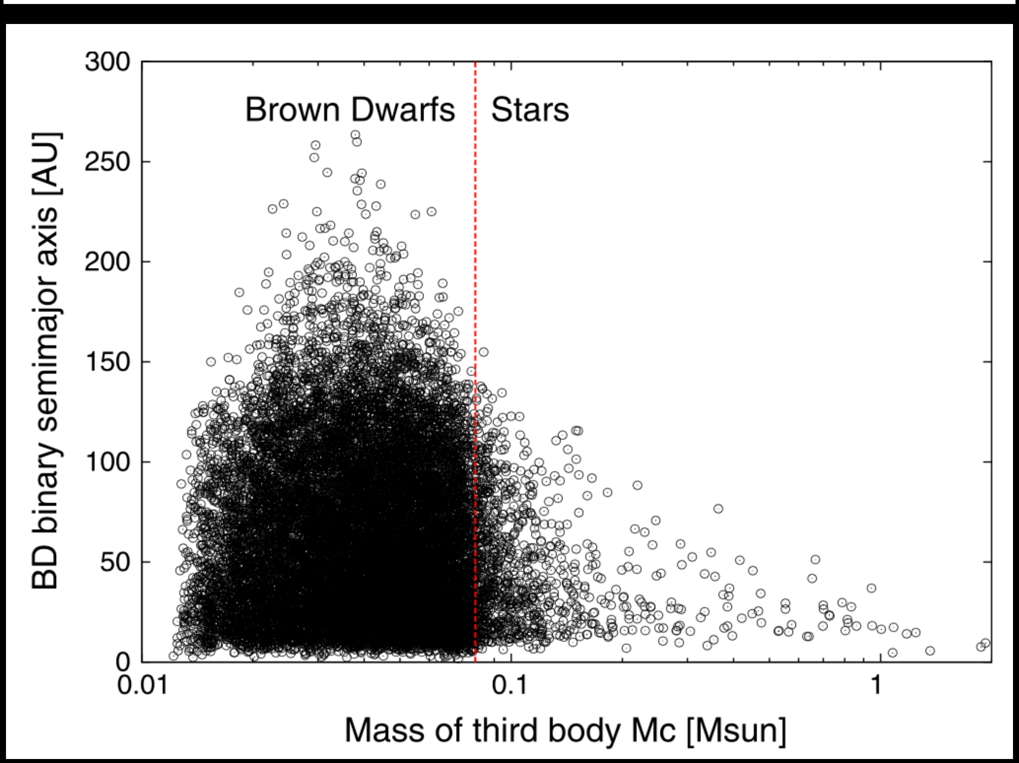
Why multiplicity? Testing formation scenarios

Multiplicity is an important function of formation scenarios for brown dwarfs









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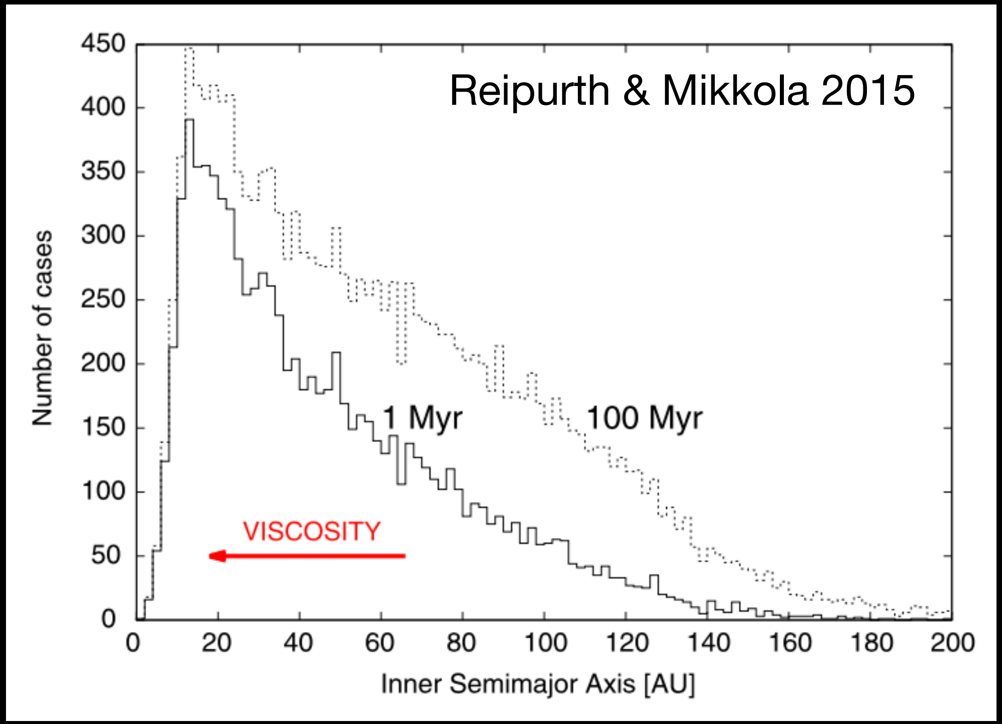
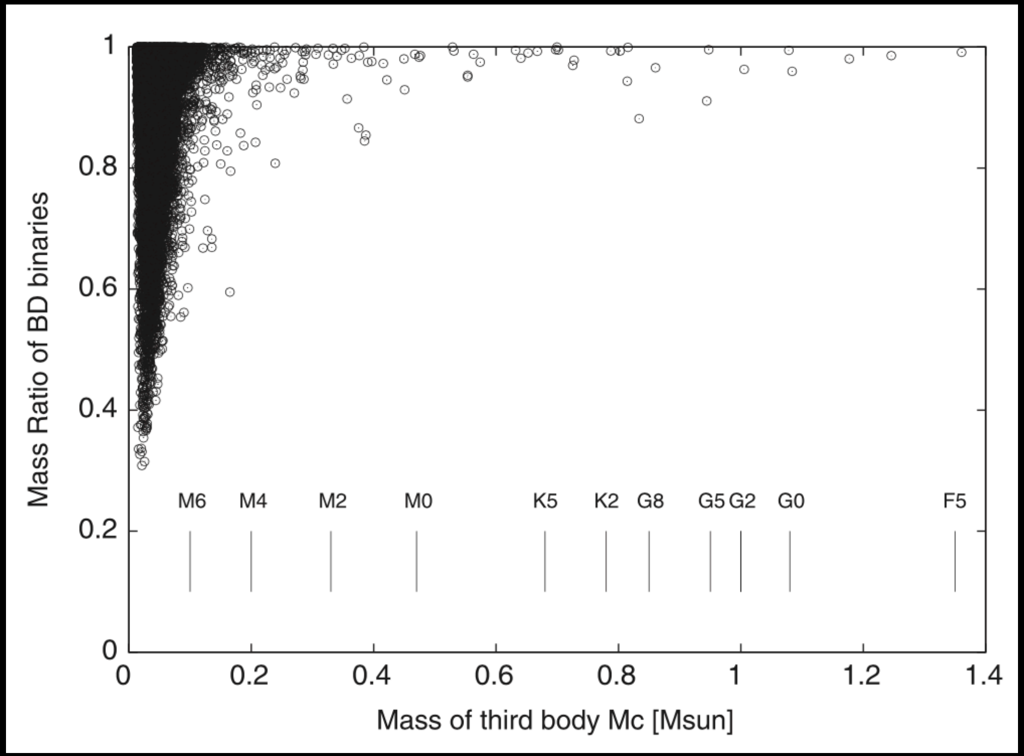
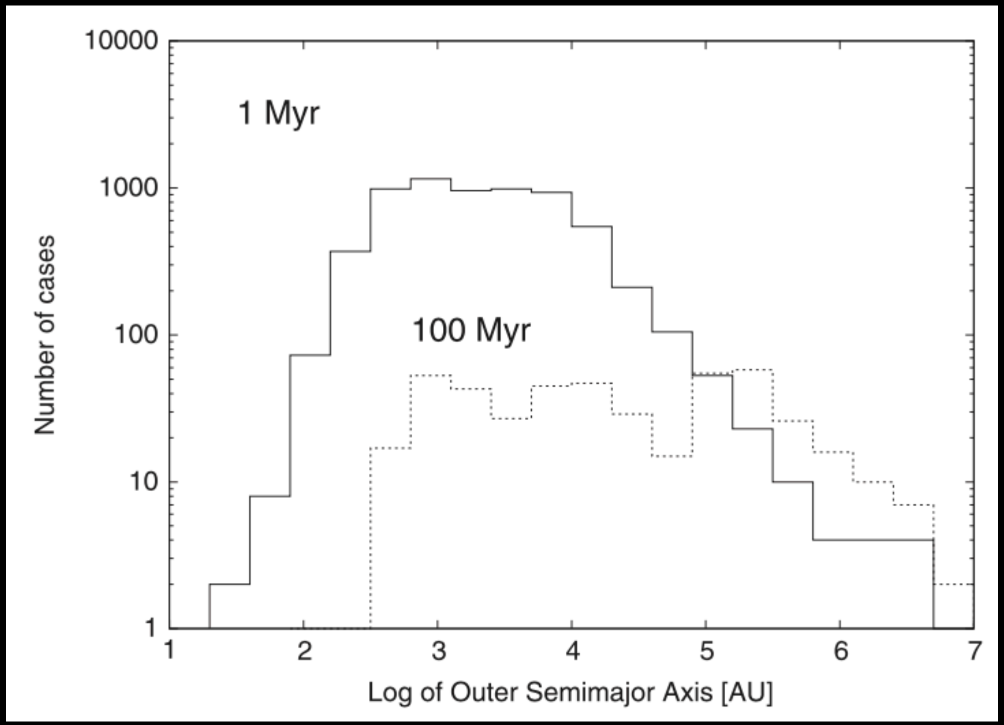
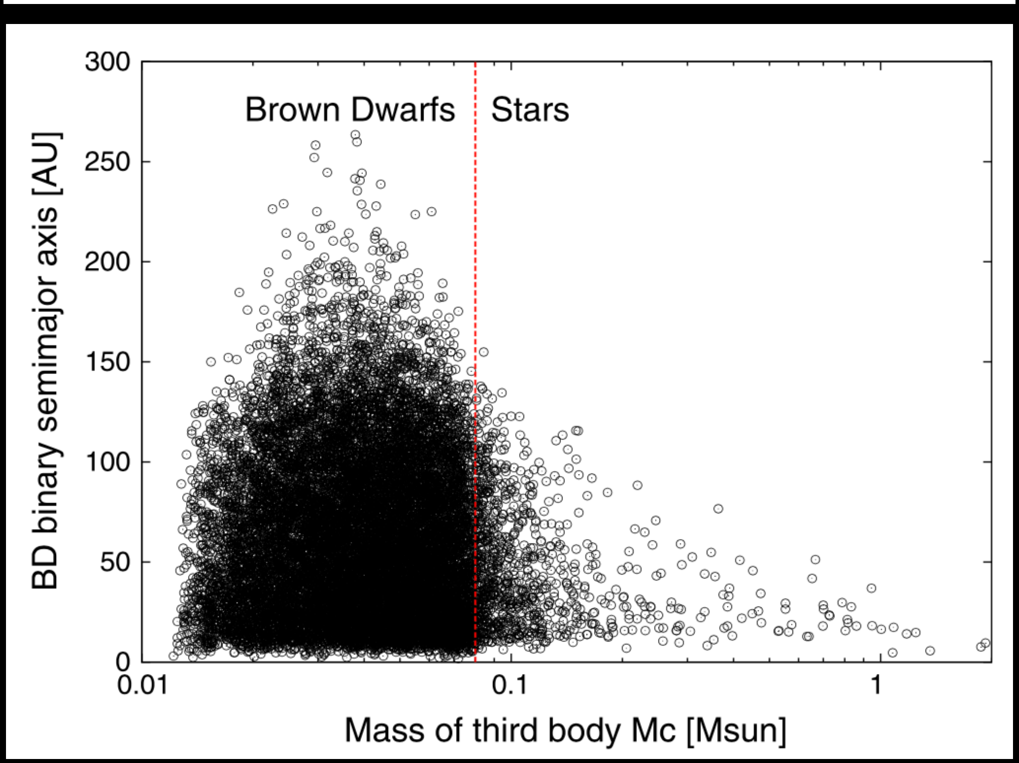
Populations initially pulled from an IMF 🤔









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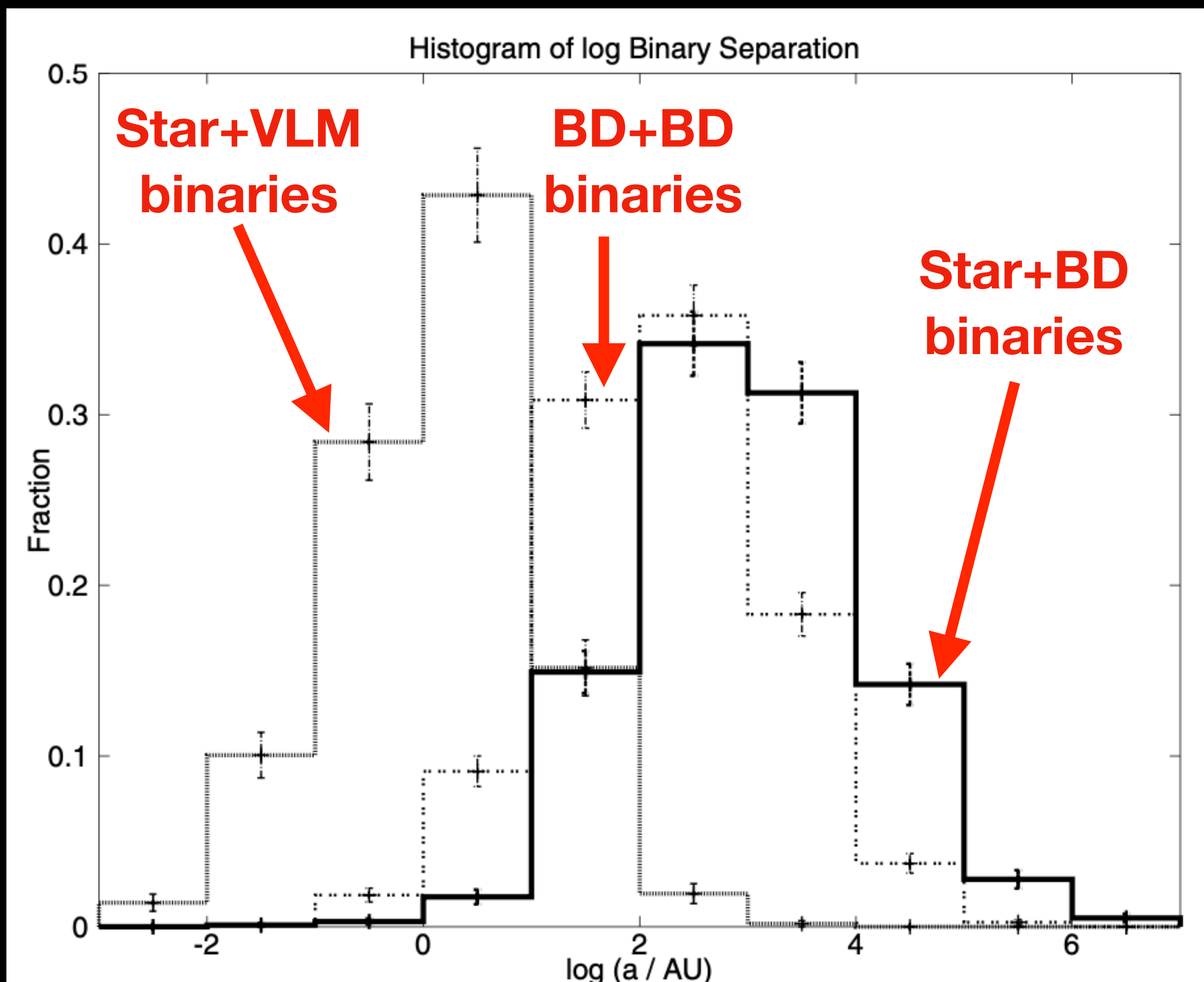
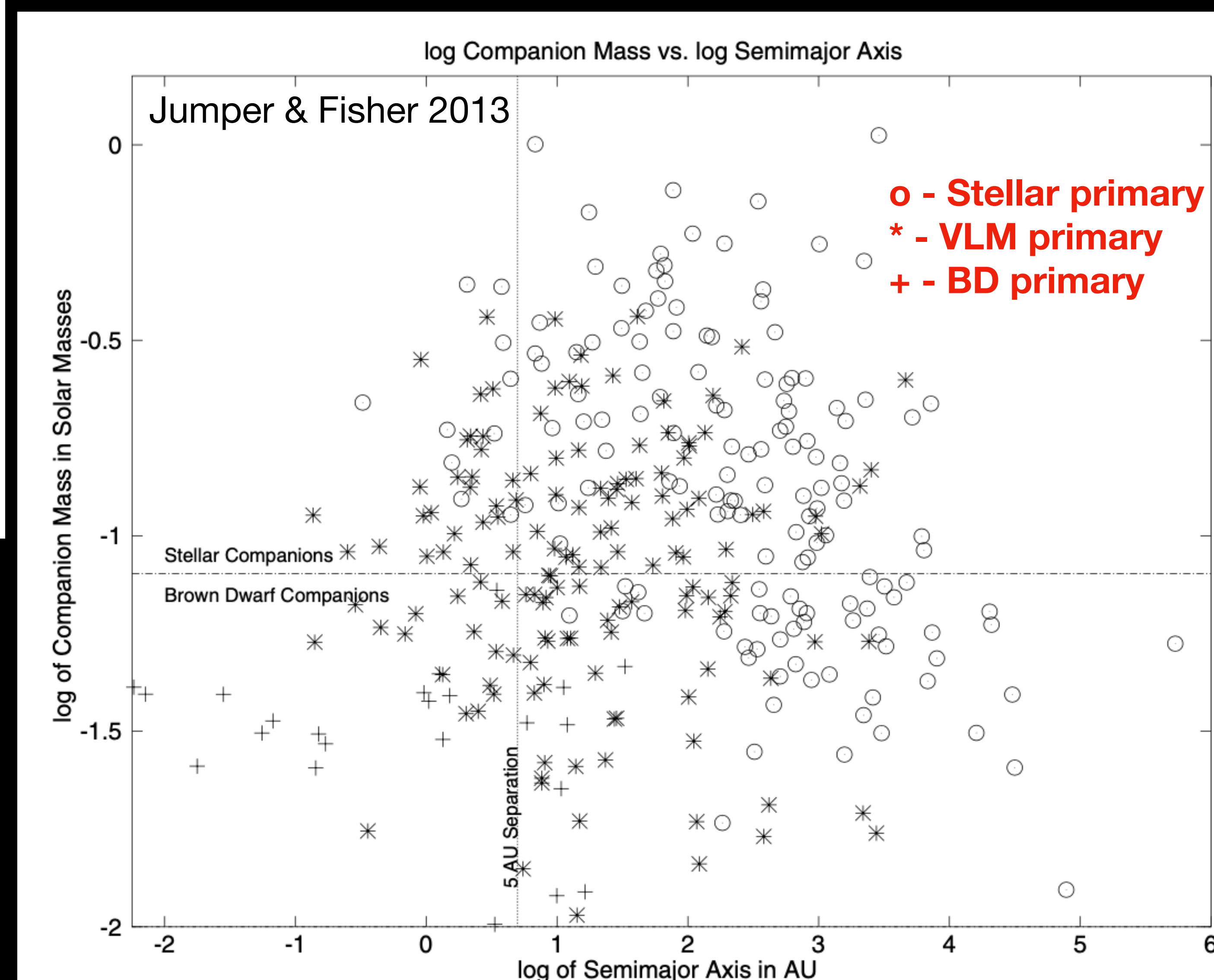


Turbulent Fragmentation



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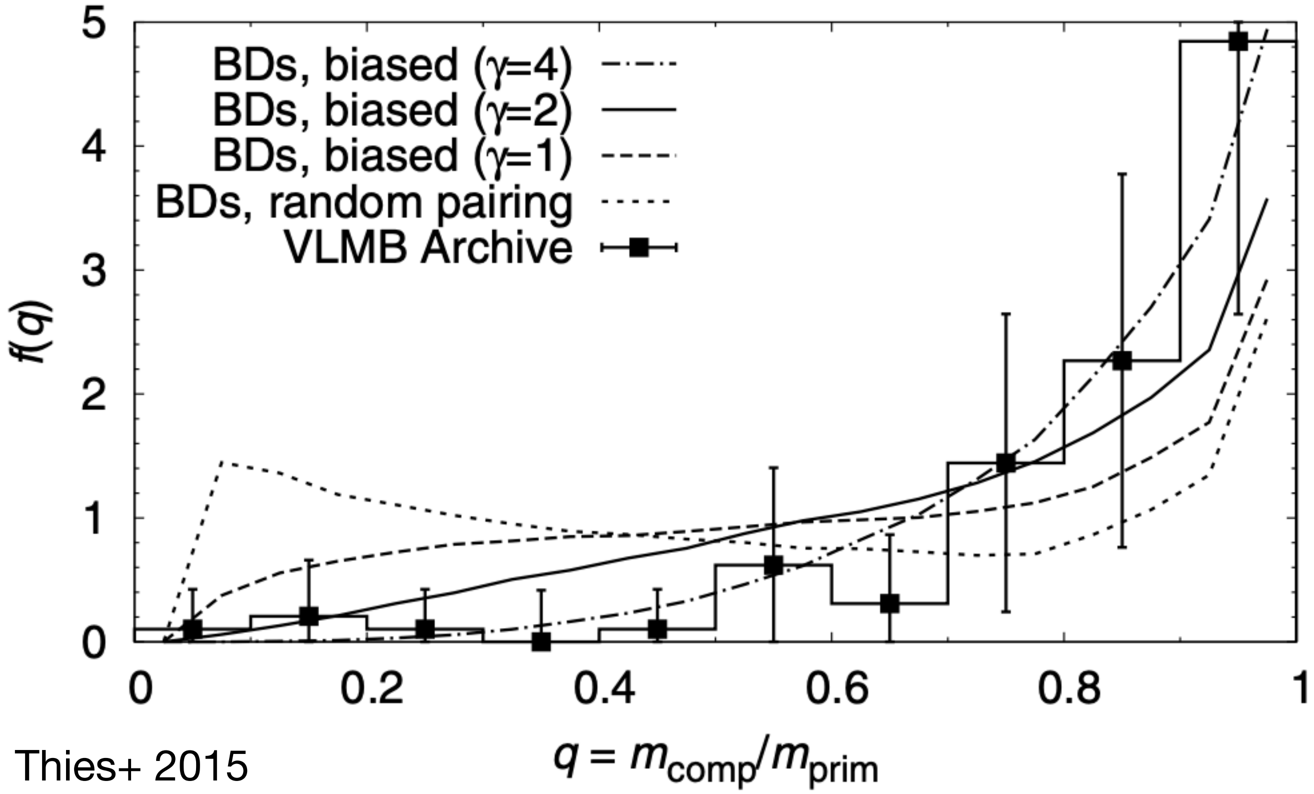

Thies+ 2015

The BD multiplicity fraction is only about 10%–20% (Bouy et al. 2003; Close et al. 2003; Martín et al. 2003; Kraus et al. 2006 and Law et al. 2008) and is assumed to be equal for both C05 and TK07 IMFs.

Thies+ (2015)

Reipurth & Mikkola 2015

Table 2
Single vs. Binary Ejected Brown Dwarfs at 1 Myr[a]

	All Binaries Fully Resolved[b]	25% Binaries Not Resolved[c]	50% Binaries Not Resolved[c]	75% Binaries Not Resolved[c]
BD Singles:	6.07%	7.22%	8.37%	9.53%
BD Binaries:	4.61%	3.46%	2.31%	1.15%
BD Total:	10.68%	10.68%	10.68%	10.68%
BD Binary fraction:[d]	0.43	0.32	0.22	0.11

[a] Percentages of simulations that produce ejected single or binary brown dwarfs.
[b] This assumes observations can resolve *all* binaries.
[c] This assumes observations fail to resolve some binaries, and count them as singles.
[d] The numbers refer to simulations at 1 Myr. The total number of (single + binary) brown dwarfs ejected at 10 Myr is 17.35% and at 100 Myr is 18.73%. The (fully resolved) binary fraction remains constant at 0.43 at 1, 10, and 100 Myr.

Duchêne & Kraus (2013)

40–1,000-AU range (Allen et al. 2007). Combining these various studies yields a total multiplicity fraction for field VLM objects of 20–25%, consistent with the frequency of $CF^{\rm field}_{M_\star \lesssim 0.1 M_\odot} = 22^{+6}_{-4}\%$ estimated by Allen (2007) from a Bayesian analysis of several input surveys. We adopt this latter

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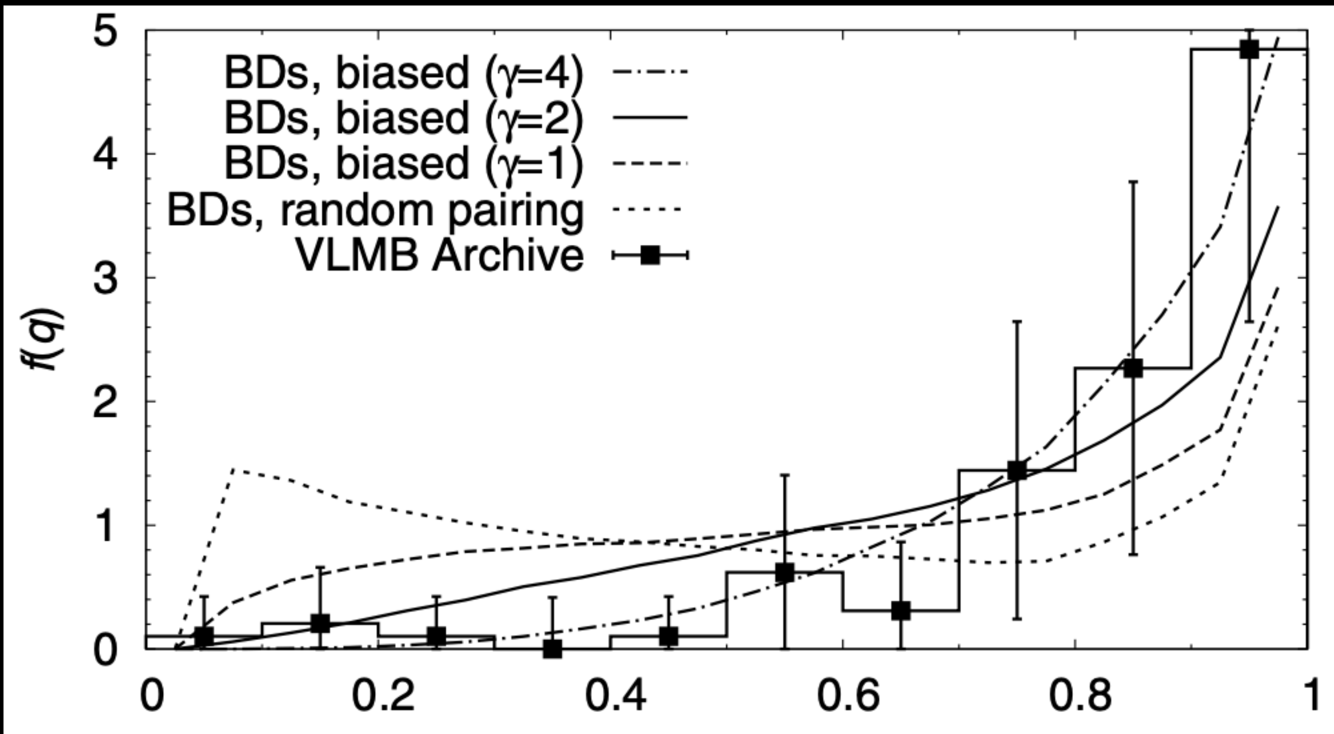

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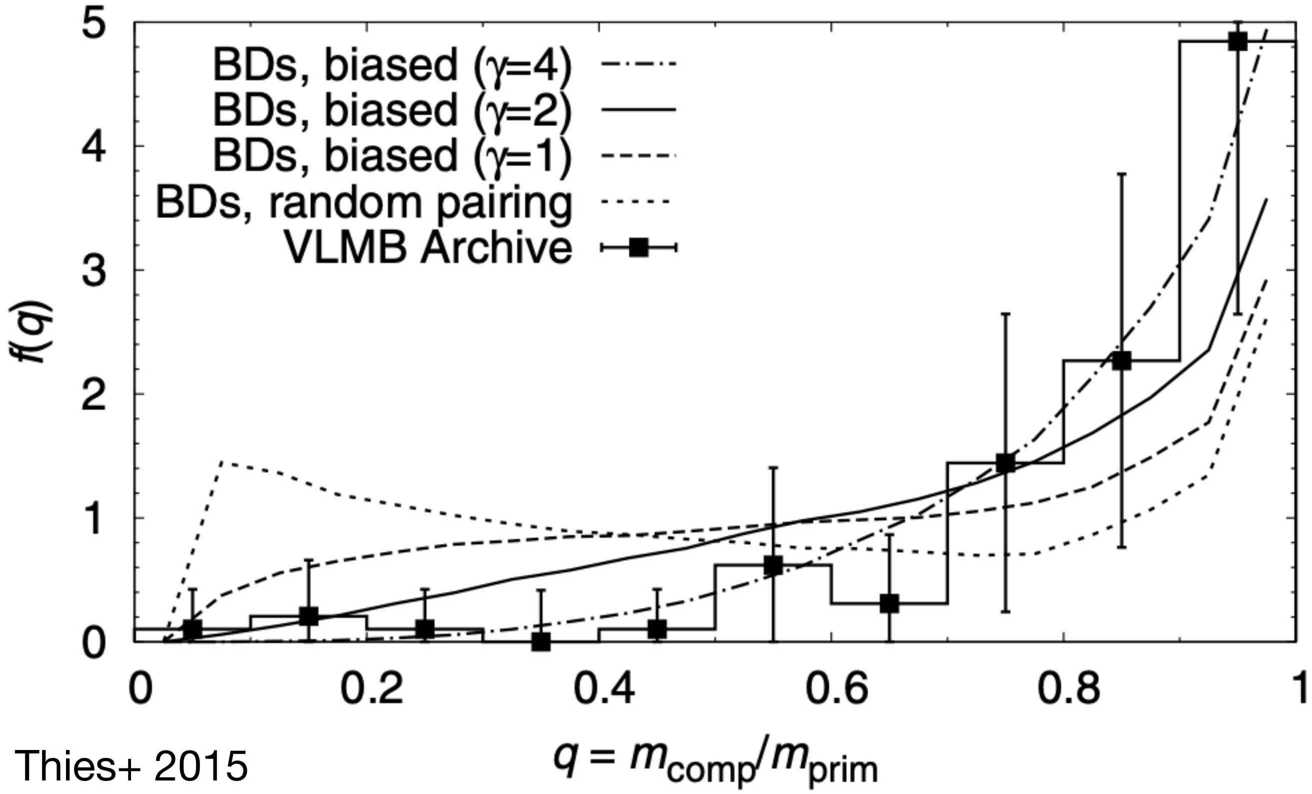

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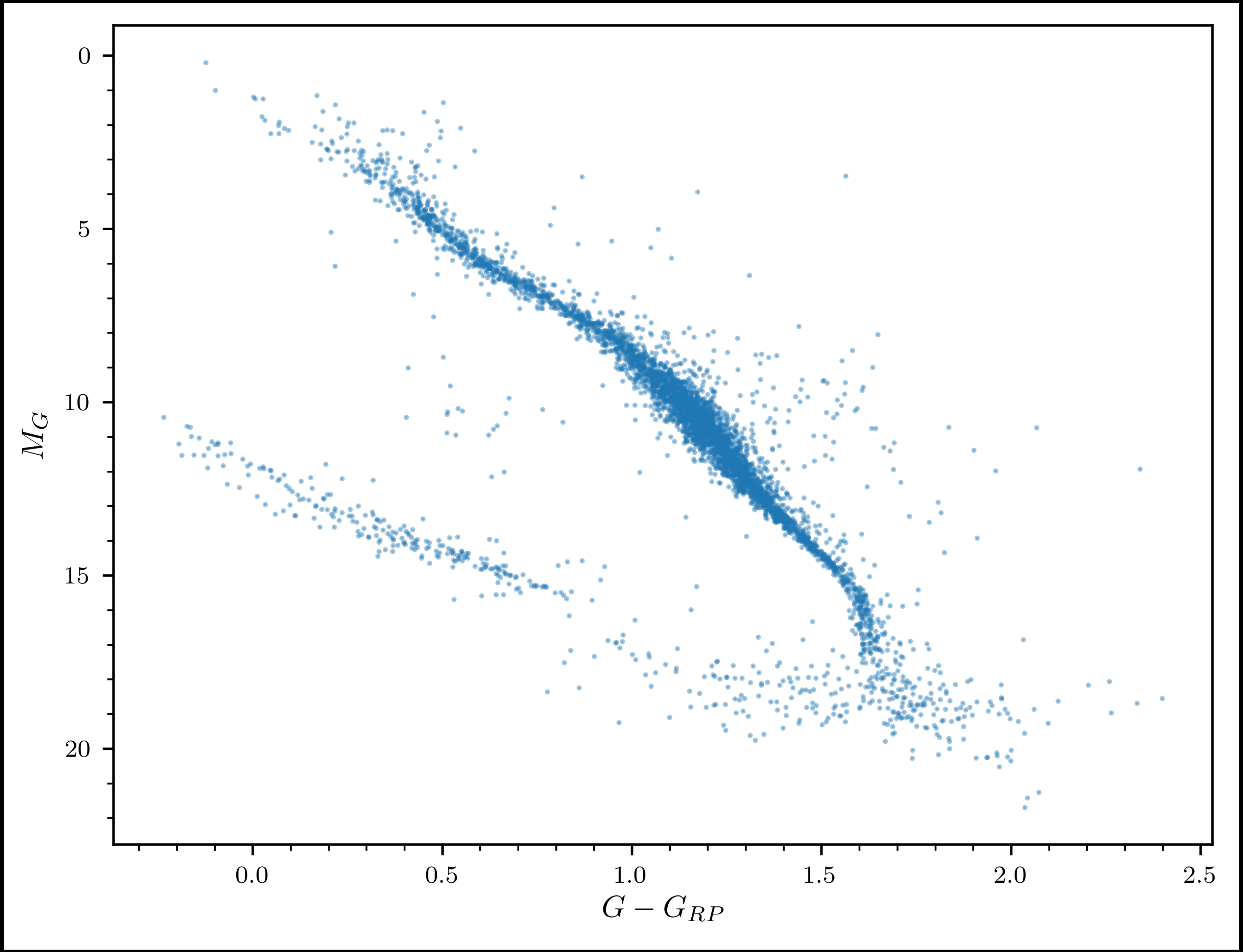
The *Gaia* 25 pc sample - Building a complete sample



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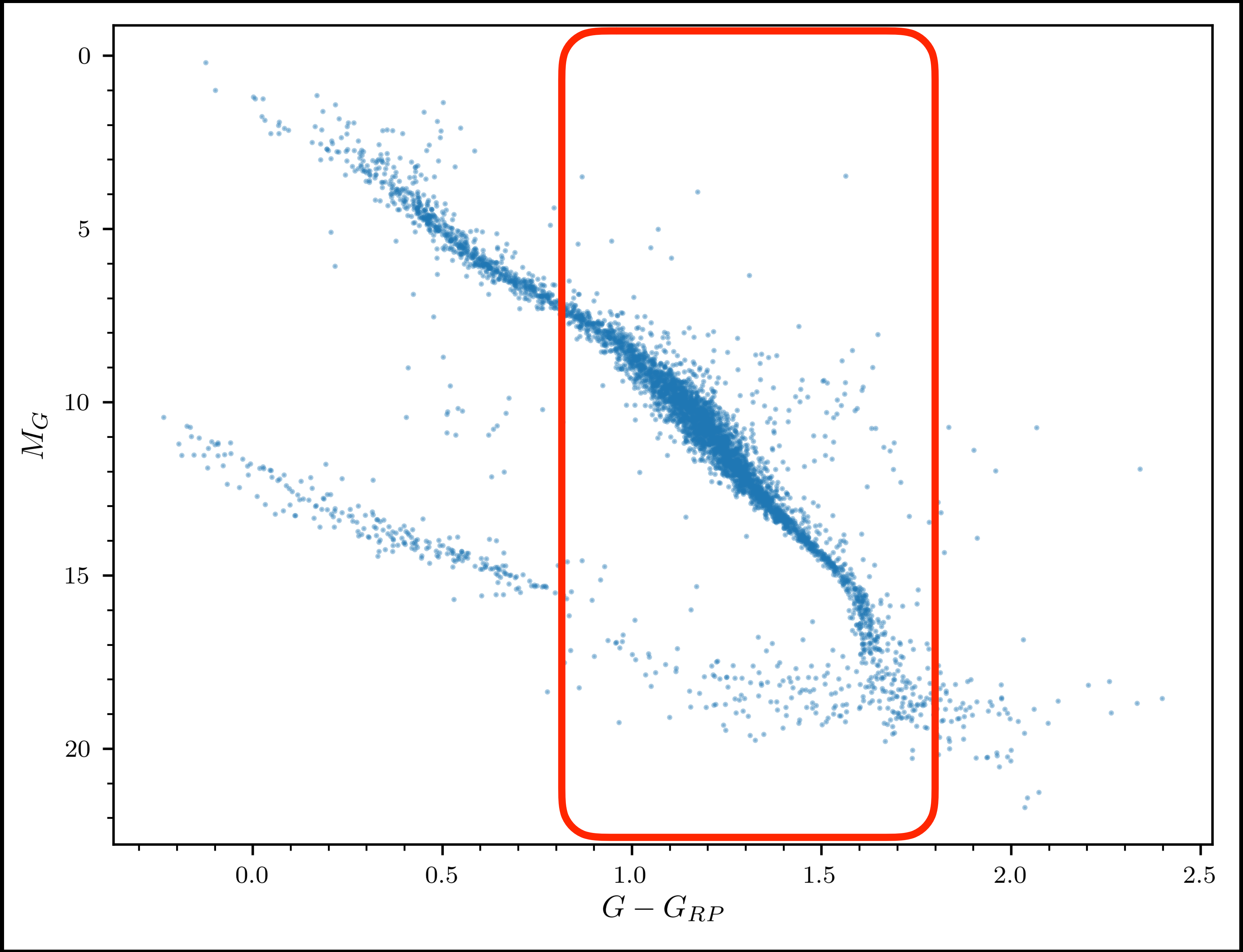

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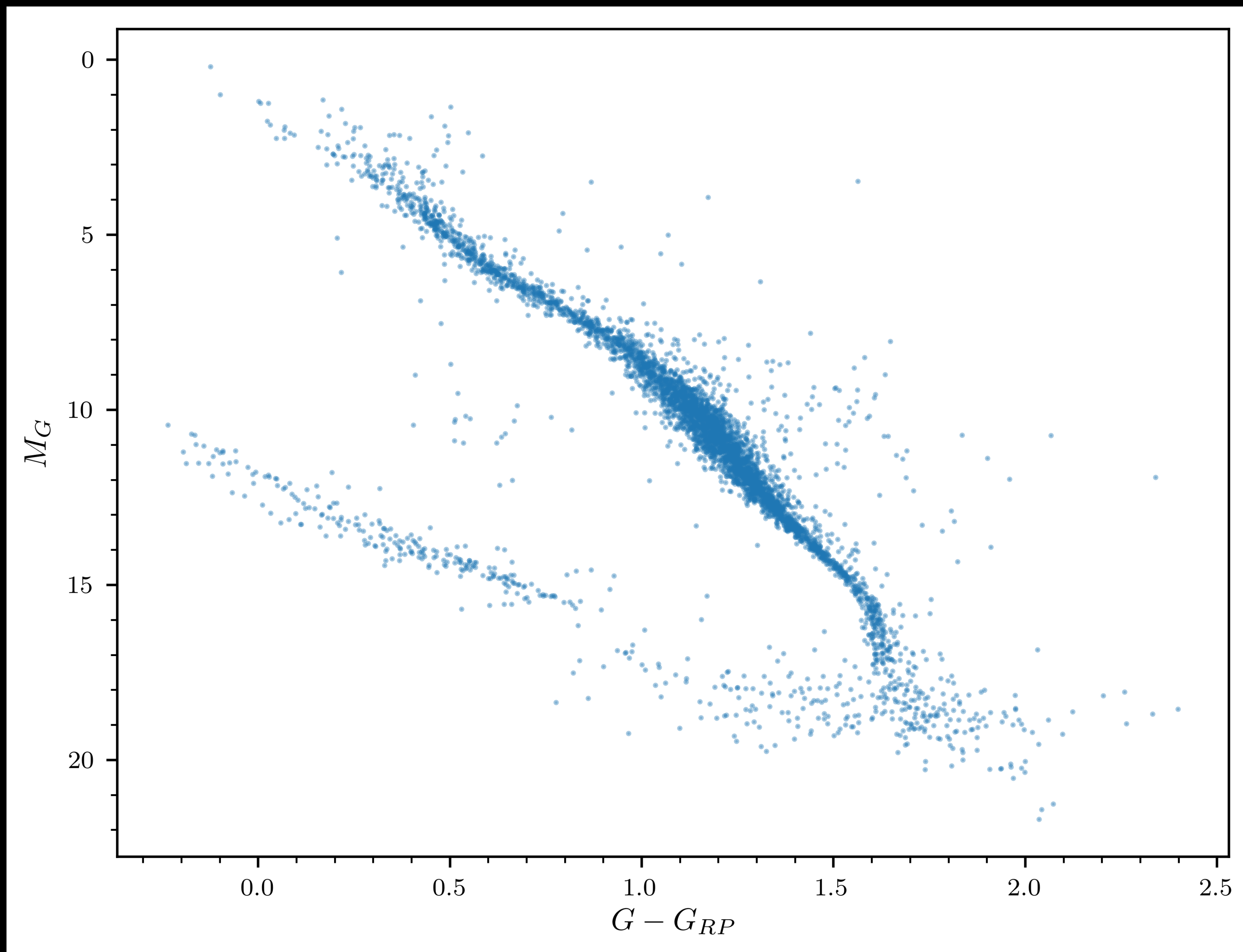

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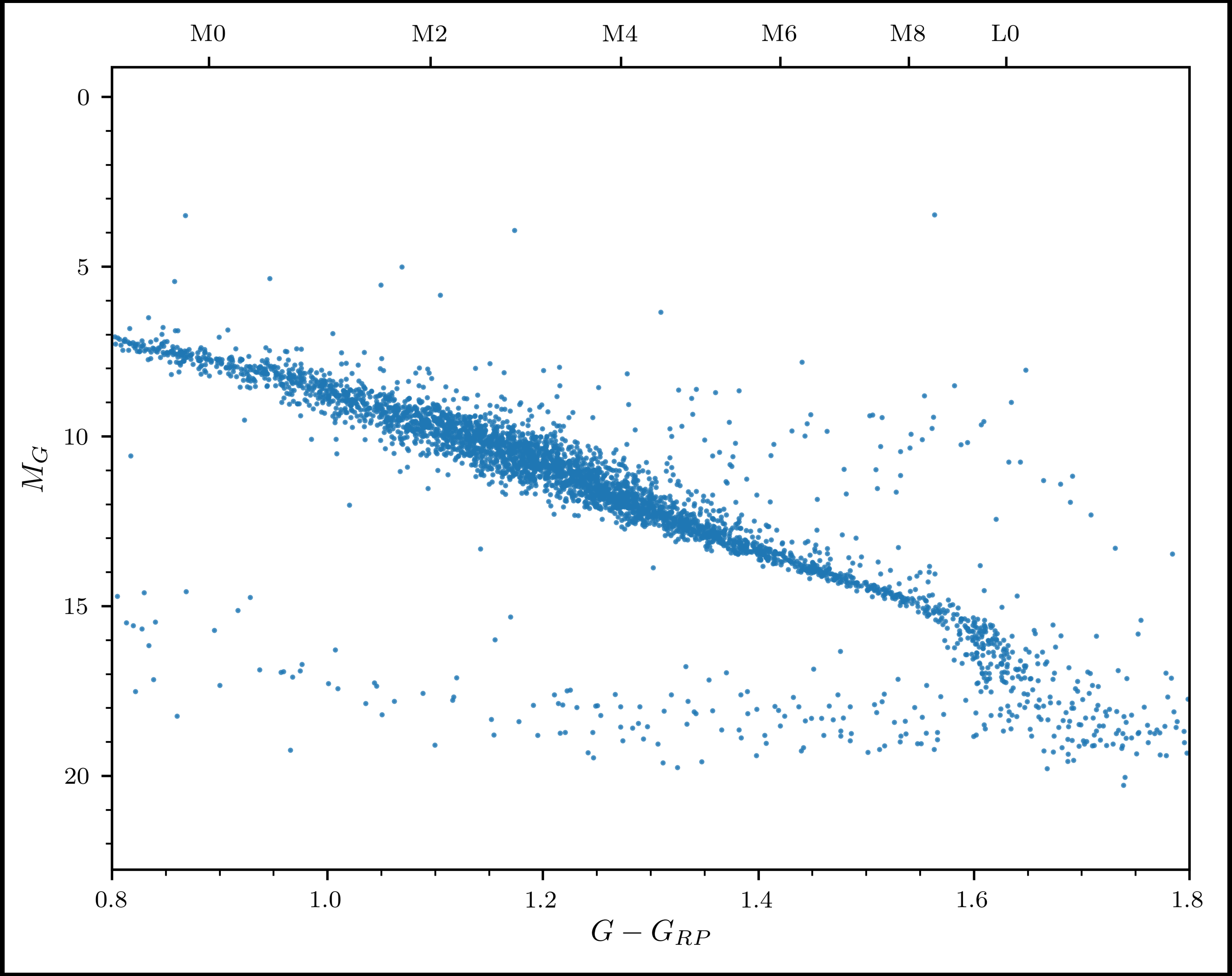

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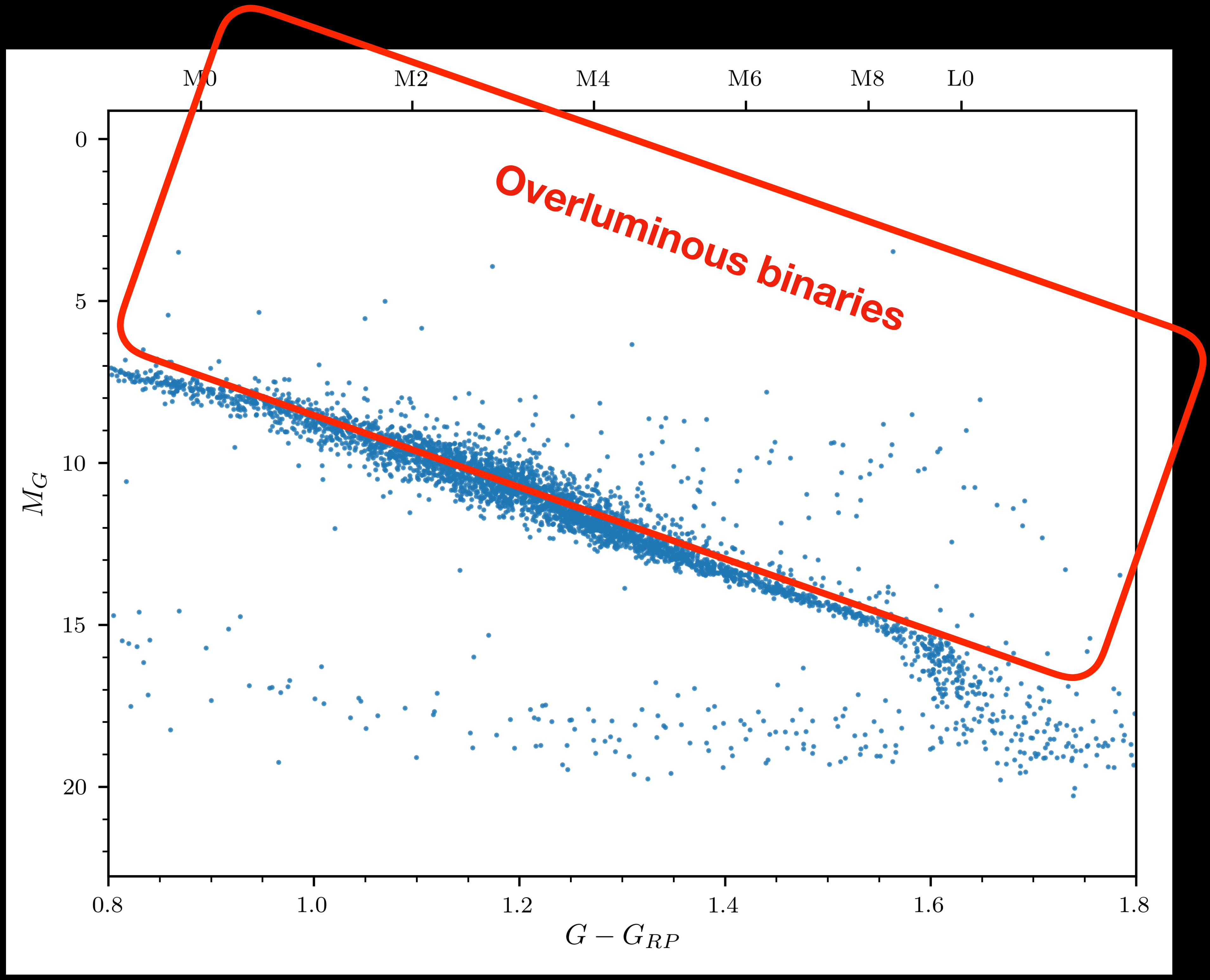
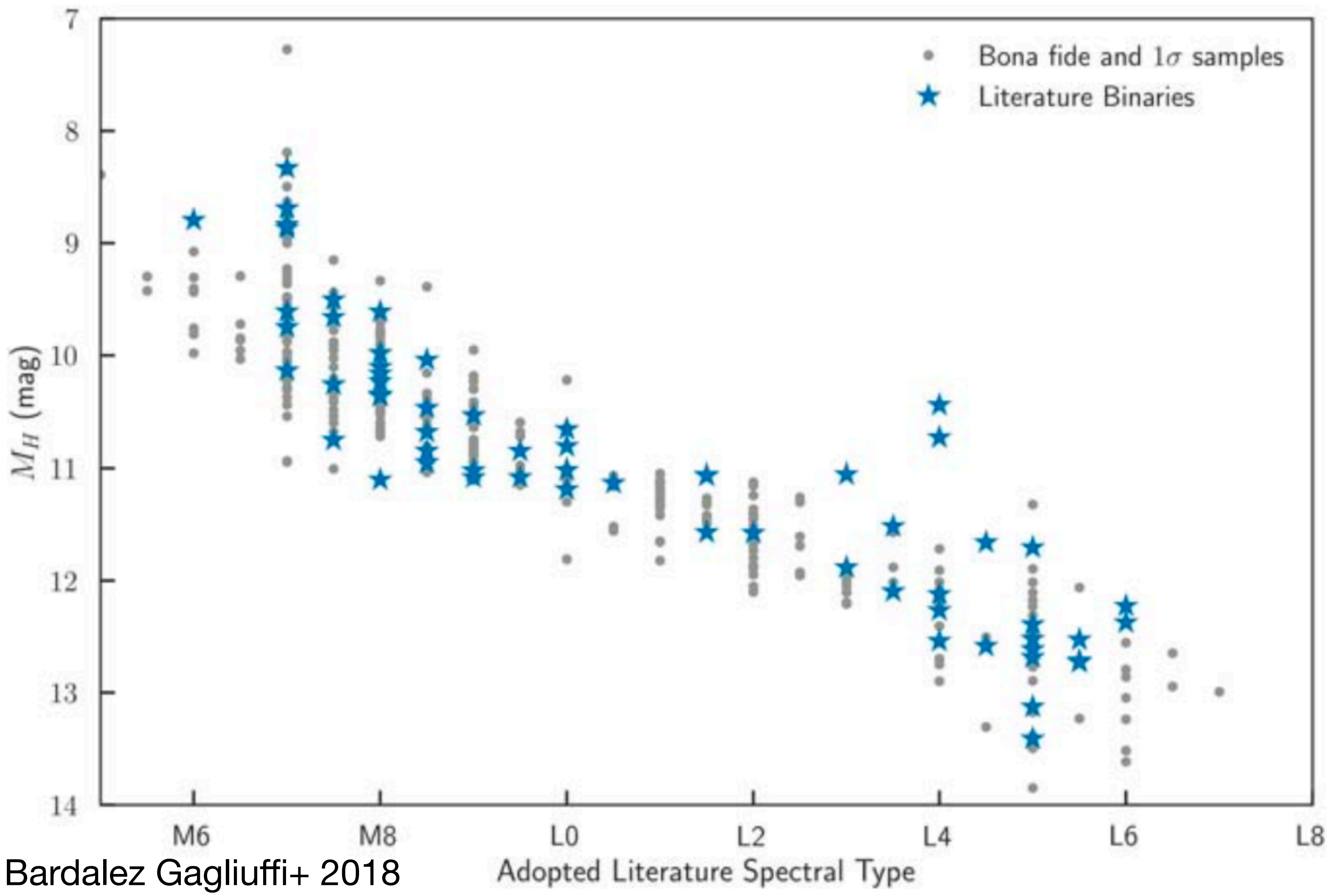


The VLM 25 pc sample



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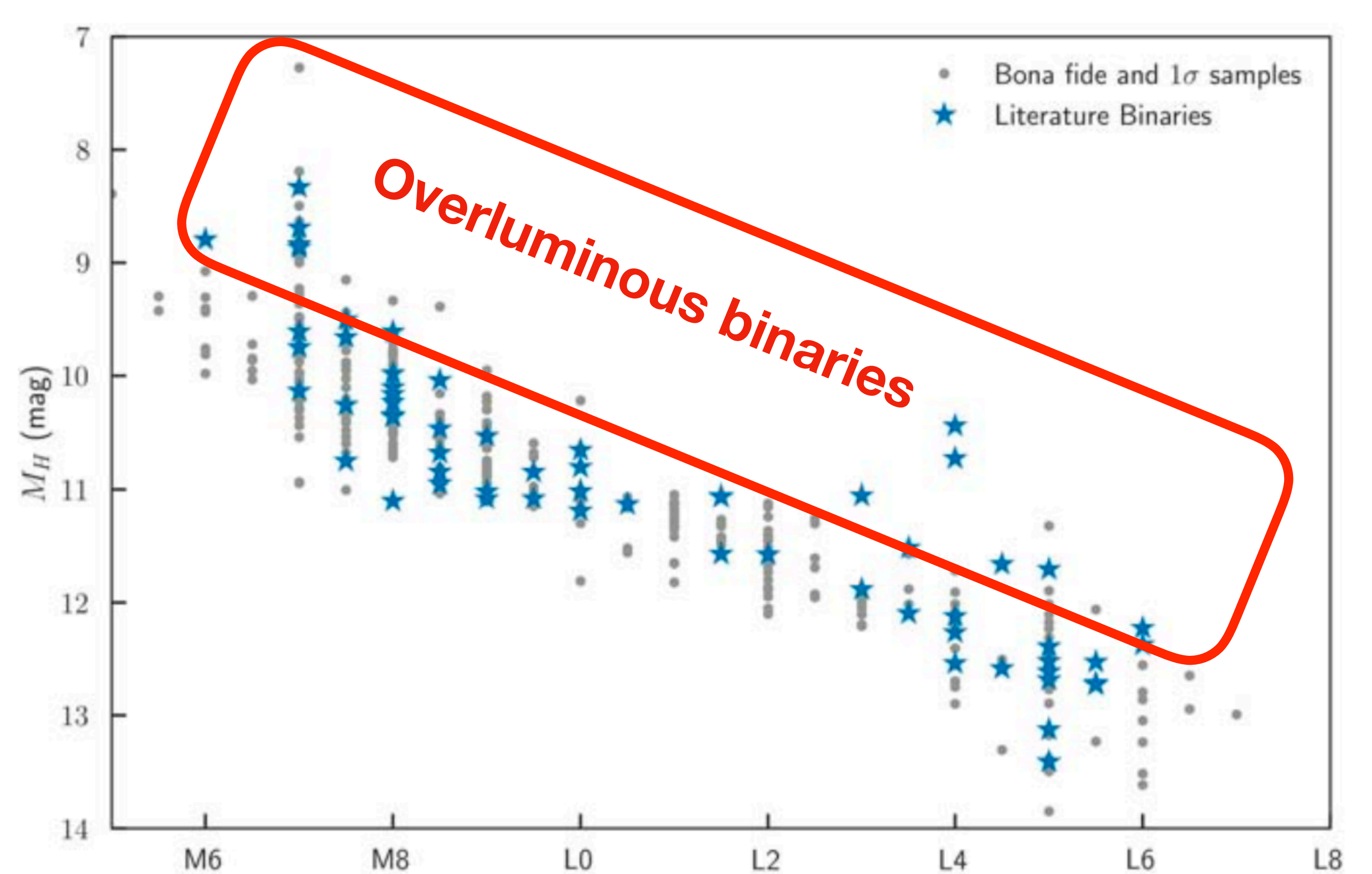

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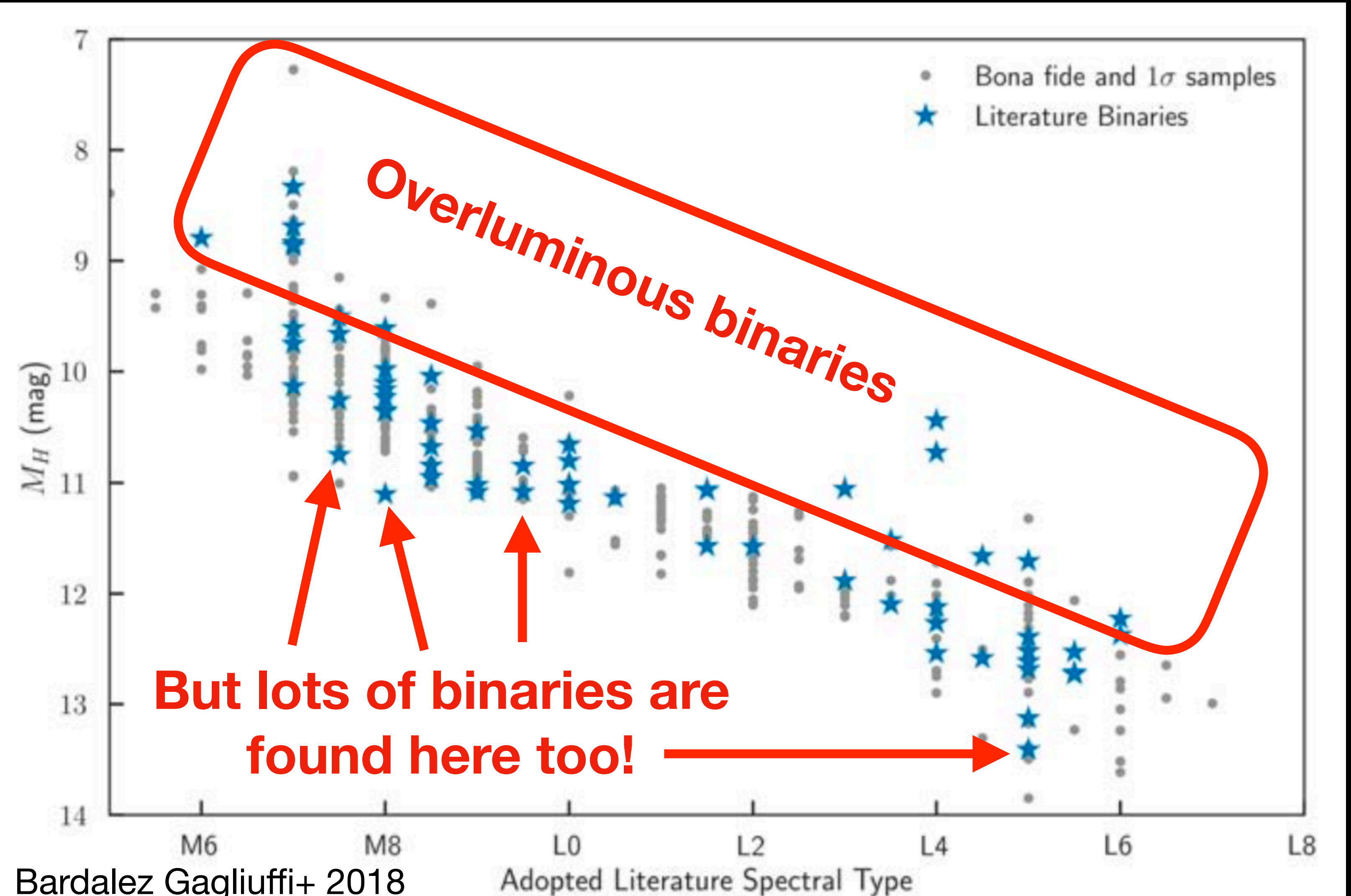

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Still finding new (nearby) binaries

WISE J1355-8258

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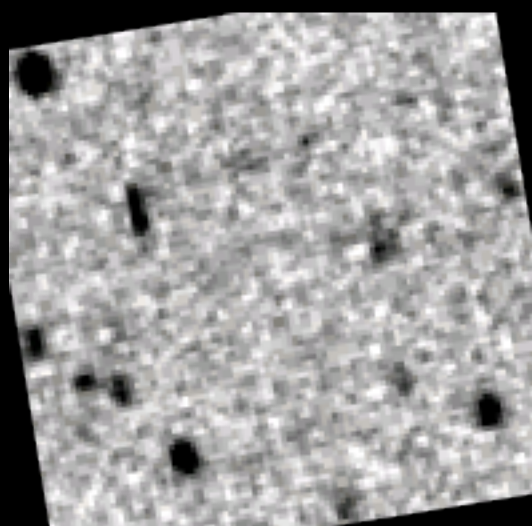
WISE J1355-8258

DSS IR



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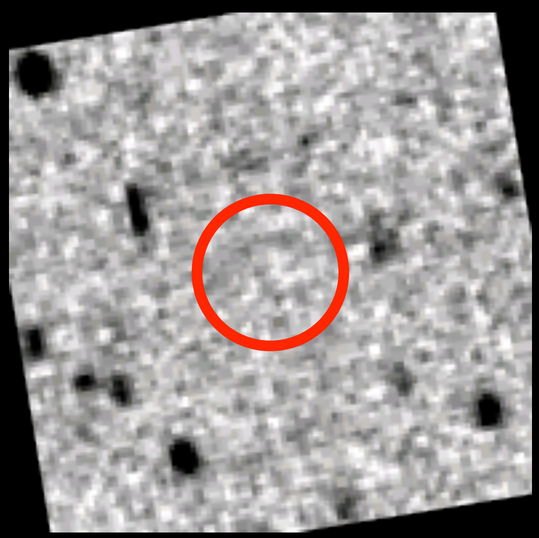

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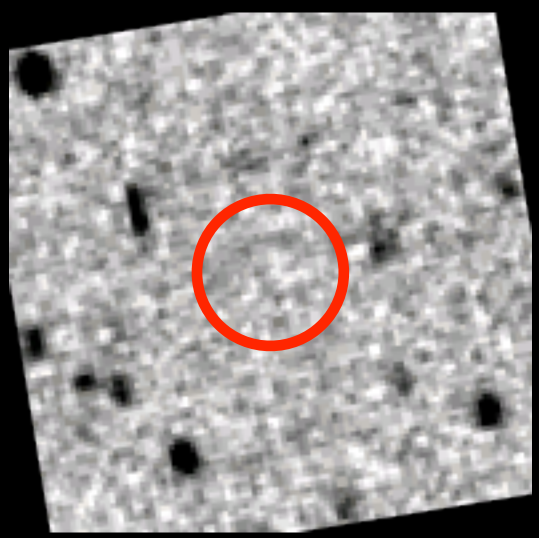
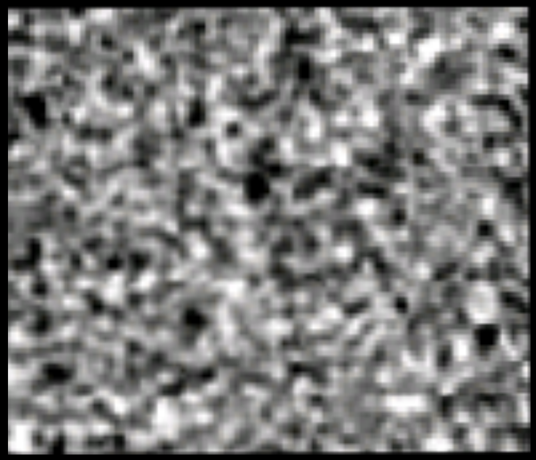


2MASS *K*$_s$



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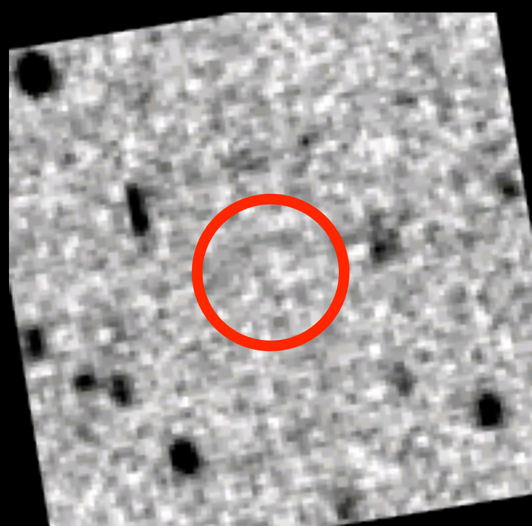
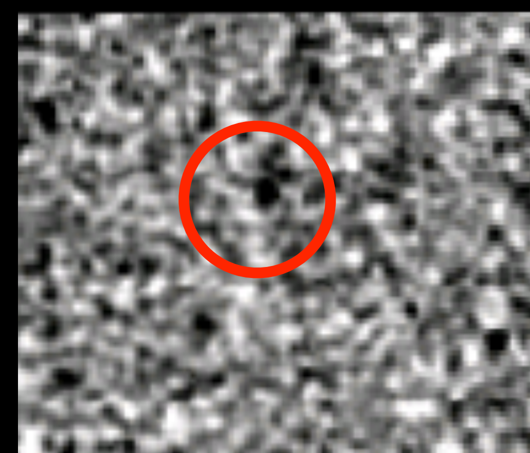


2MASS K_s



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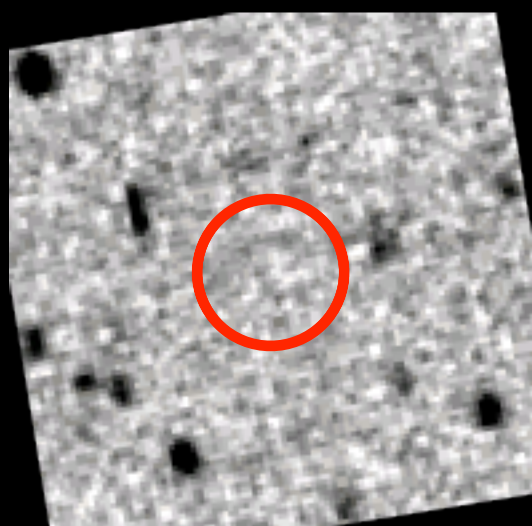

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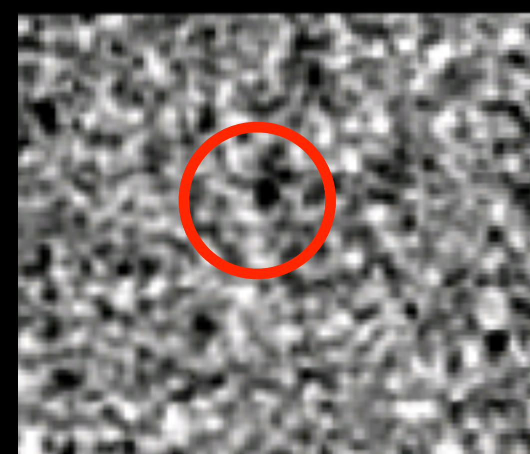

WISE W1

Still finding new (nearby) binaries

WISE J1355-8258

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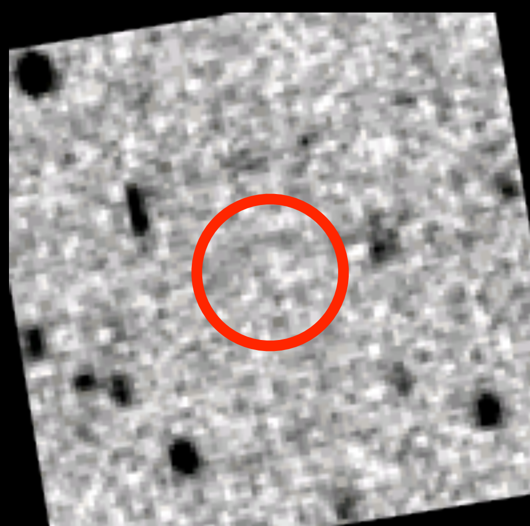

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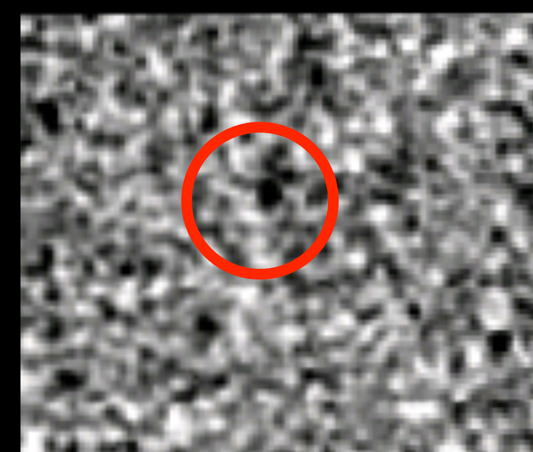

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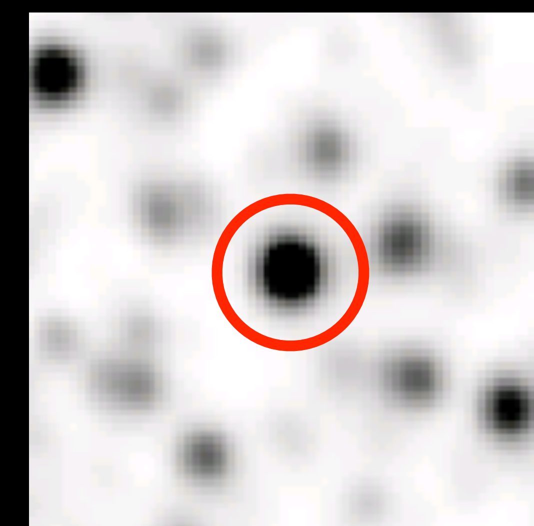

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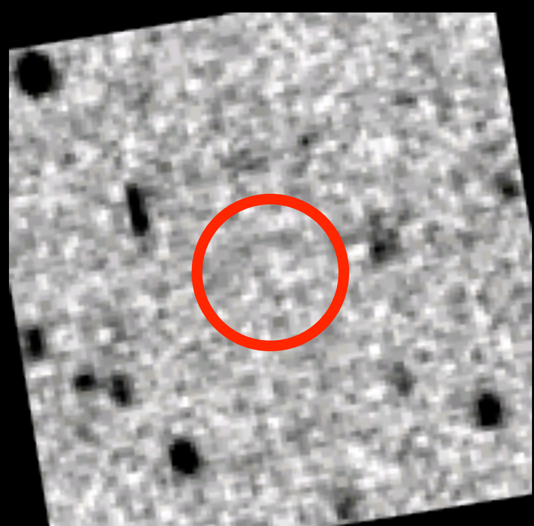

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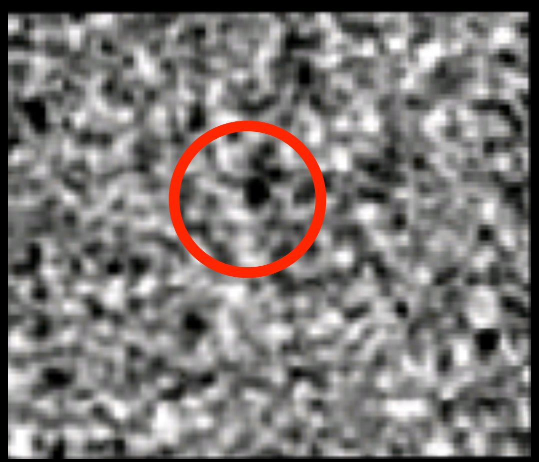

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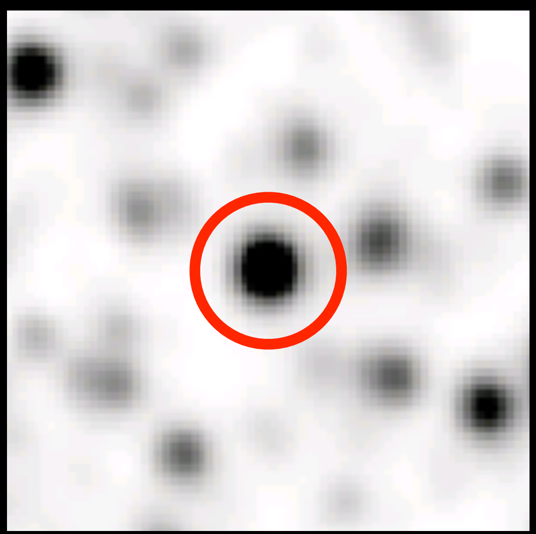

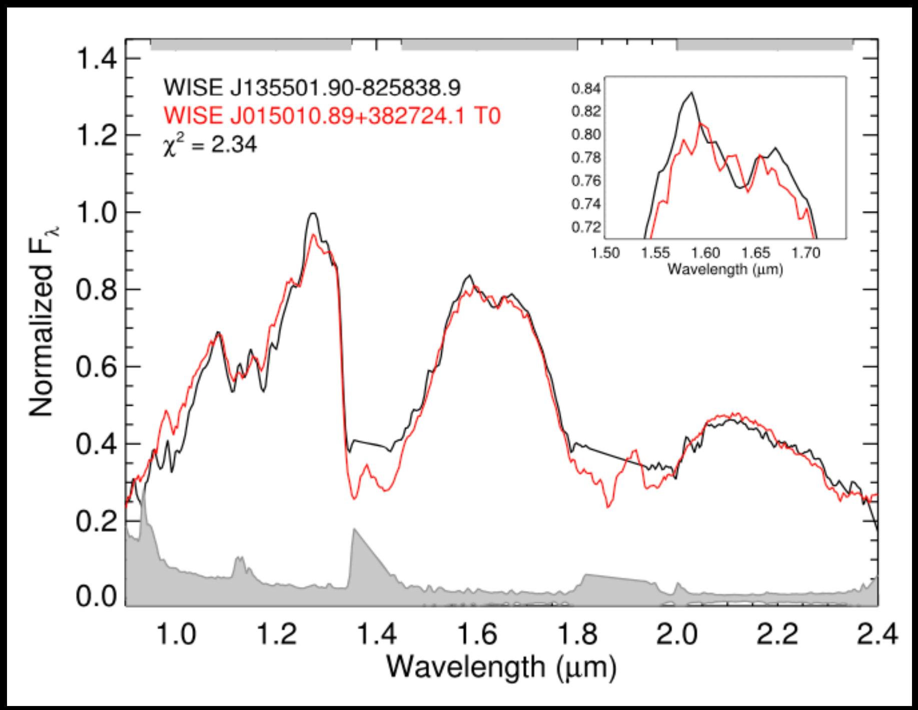

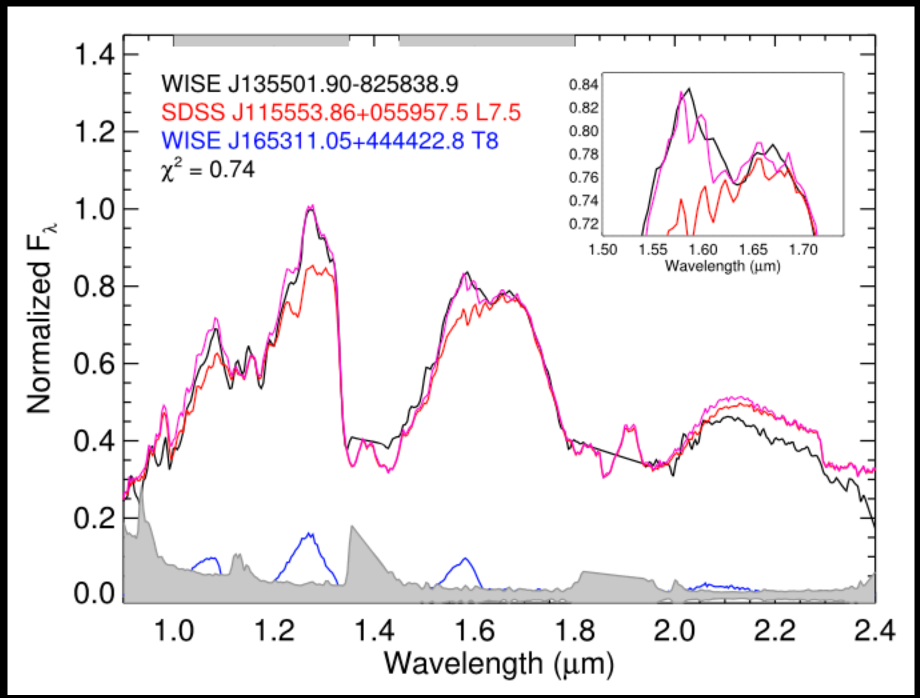

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Still finding new (nearby) binaries

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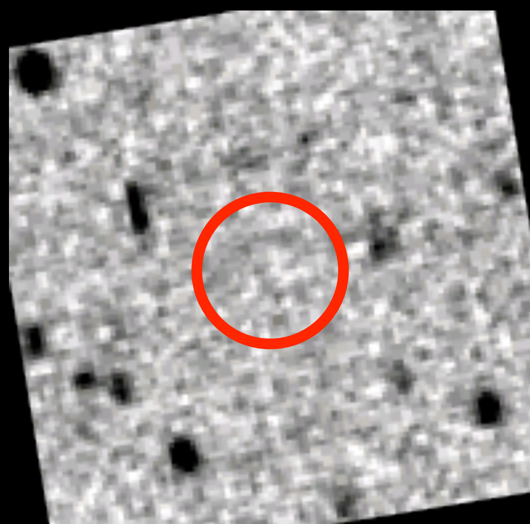

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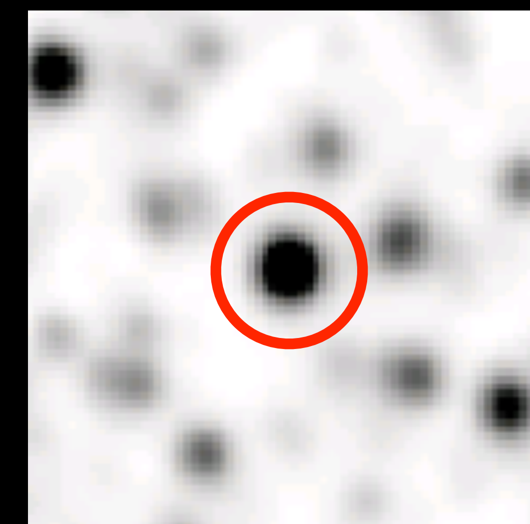

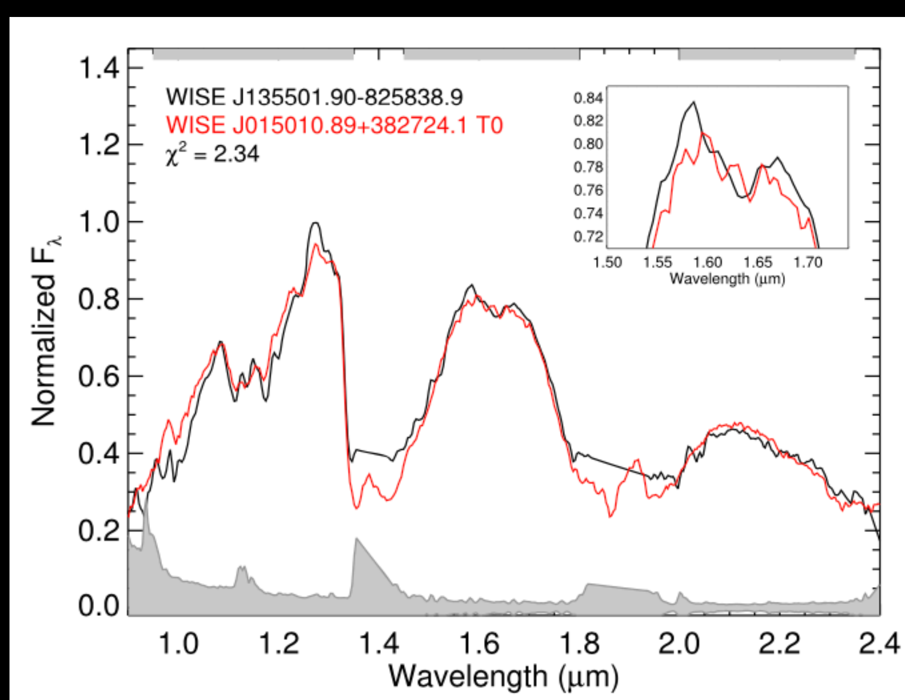

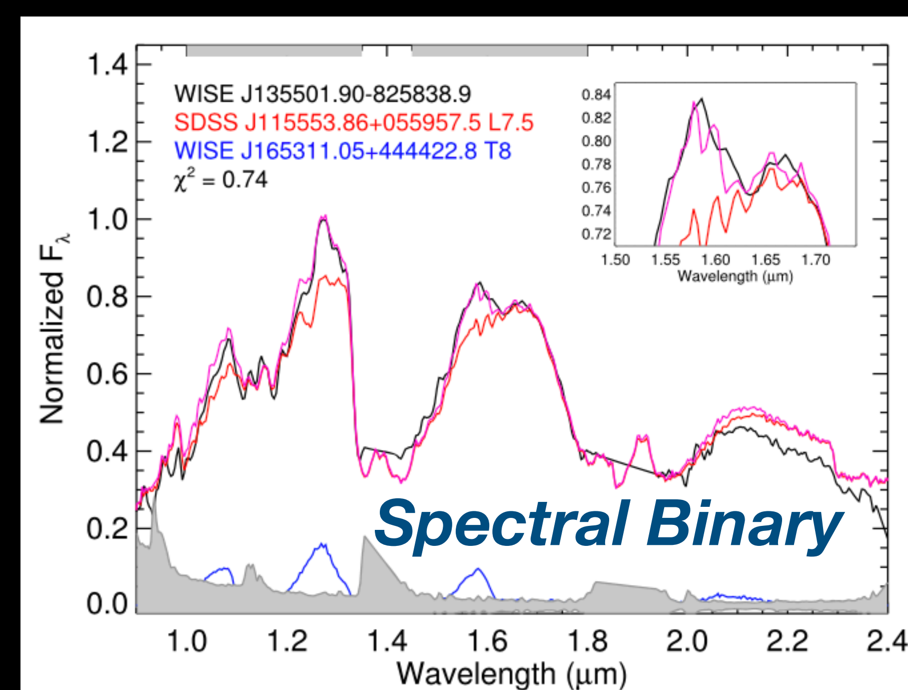

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Where does this fit in the IMF?

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Table 2
Properties of the WISE J1355–8258 System

Property	System	Case 1		Case 2		Case 3		Reference
		A	B	A	B	A	B	
NIR Spectral Type	L9pec	L6.0 ± 1.0	T3.0 ± 1.8	L7.0 ± 0.6	T7.5 ± 0.4	L7.0 ± 0.6	T7.5 ± 0.4	1
Assumed Age (Gyr)	⋯	2–5		2–5		0.13–0.2		1
Magnitudes								
Δ 2MASS J[a]	⋯	1.0 ± 0.8		2.4 ± 0.4		2.4 ± 0.4		1
Δ 2MASS H[a]	⋯	1.4 ± 0.9		3.5 ± 0.3		3.5 ± 0.3		1
Δ 2MASS K_s[a]	⋯	1.9 ± 1.0		4.1 ± 0.4		4.1 ± 0.4		1
2MASS J	16.14 ± 0.13	16.5 ± 0.3	17.5 ± 0.6	⋯	⋯	16.3 ± 0.1	18.6 ± 0.4	1, 2
2MASS H	15.31 ± 0.13	15.6 ± 0.3	17.0 ± 0.8	⋯	⋯	15.4 ± 0.1	18.9 ± 0.3	1, 2
2MASS K_S	14.72 ± 0.14	14.9 ± 0.2	16.8 ± 0.8	⋯	⋯	14.7 ± 0.1	18.9 ± 0.4	2
FourStar J	16.47 ± 0.05	⋯	⋯	⋯	⋯	⋯	⋯	1
FourStar H	15.45 ± 0.04	⋯	⋯	⋯	⋯	⋯	⋯	1
FourStar K_S	15.01 ± 0.05	⋯	⋯	⋯	⋯	⋯	⋯	1
WISE $W1$	14.12 ± 0.03	⋯	⋯	⋯	⋯	⋯	⋯	2
WISE $W2$	13.55 ± 0.03	⋯	⋯	⋯	⋯	⋯	⋯	2
WISE $W3$	12.5 ± 0.3	⋯	⋯	⋯	⋯	⋯	⋯	2
WISE $W4$	⩽9.7	⋯	⋯	⋯	⋯	⋯	⋯	2
M_J[b]	15.0 ± 0.4, 15.1 ± 0.4	14.2 ± 0.4	14.8 ± 0.4	⋯	⋯	15.1 ± 0.4	17.5 ± 0.6	1
M_H[b]	14.1 ± 0.4, 13.8 ± 0.4	13.0 ± 0.4	14.1 ± 0.4	⋯	⋯	14.2 ± 0.4	17.7 ± 0.6	1
M_{K_S}[b]	13.5 ± 0.4, 13.2 ± 0.4	12.3 ± 0.4	14.0 ± 0.4	⋯	⋯	13.6 ± 0.4	17.7 ± 0.7	1
Kinematics								
RV (km s^{-1})	22 ± 5	⋯	⋯	⋯	⋯	⋯	⋯	1
$\mu_\alpha \cos\delta$ (mas yr^{-1})	−241 ± 8	⋯	⋯	⋯	⋯	⋯	⋯	2
μ_δ (mas yr^{-1})	−142 ± 14	⋯	⋯	⋯	⋯	⋯	⋯	2
d[c] (pc)	⋯	33 ± 9	33 ± 19	27 ± 3	27 ± 4	17 ± 2		1
U[d] (km s^{-1})	⋯	−25 ± 9		−18 ± 4		−7 ± 4		1
V[d] (km s^{-1})	⋯	−38 ± 8		−34 ± 4		−27 ± 4		1
W[d] (km s^{-1})	⋯	−19 ± 7		−17 ± 3		−13 ± 2		1
Masses								
Mass (M_{Jup})	⋯	72^{+4}_{-5}	61^{+6}_{-8}	70^{+2}_{-4}	42^{+5}_{-6}	11 ± 1	9 ± 1	1
Mass ratio	⋯	0.84 ± 0.06		0.60 ± 0.08		0.82 ± 0.02		1

Where does this fit in the IMF?

Bardalez Gagliuffi+ 2018

Table 2
Properties of the WISE J1355–8258 System

Property	System	Case 1		Case 2		Case 3		Reference
		A	B	A	B	A	B	
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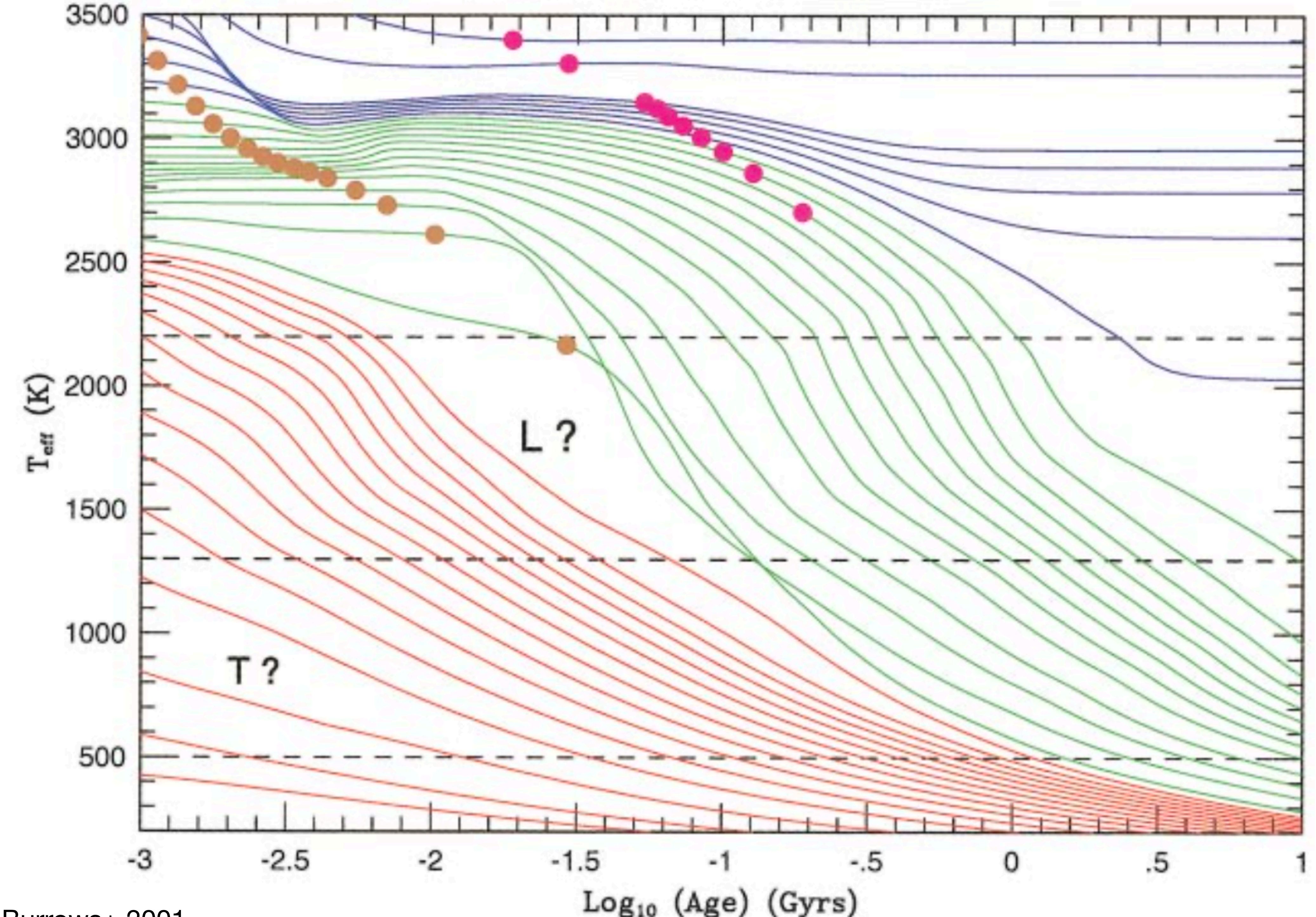
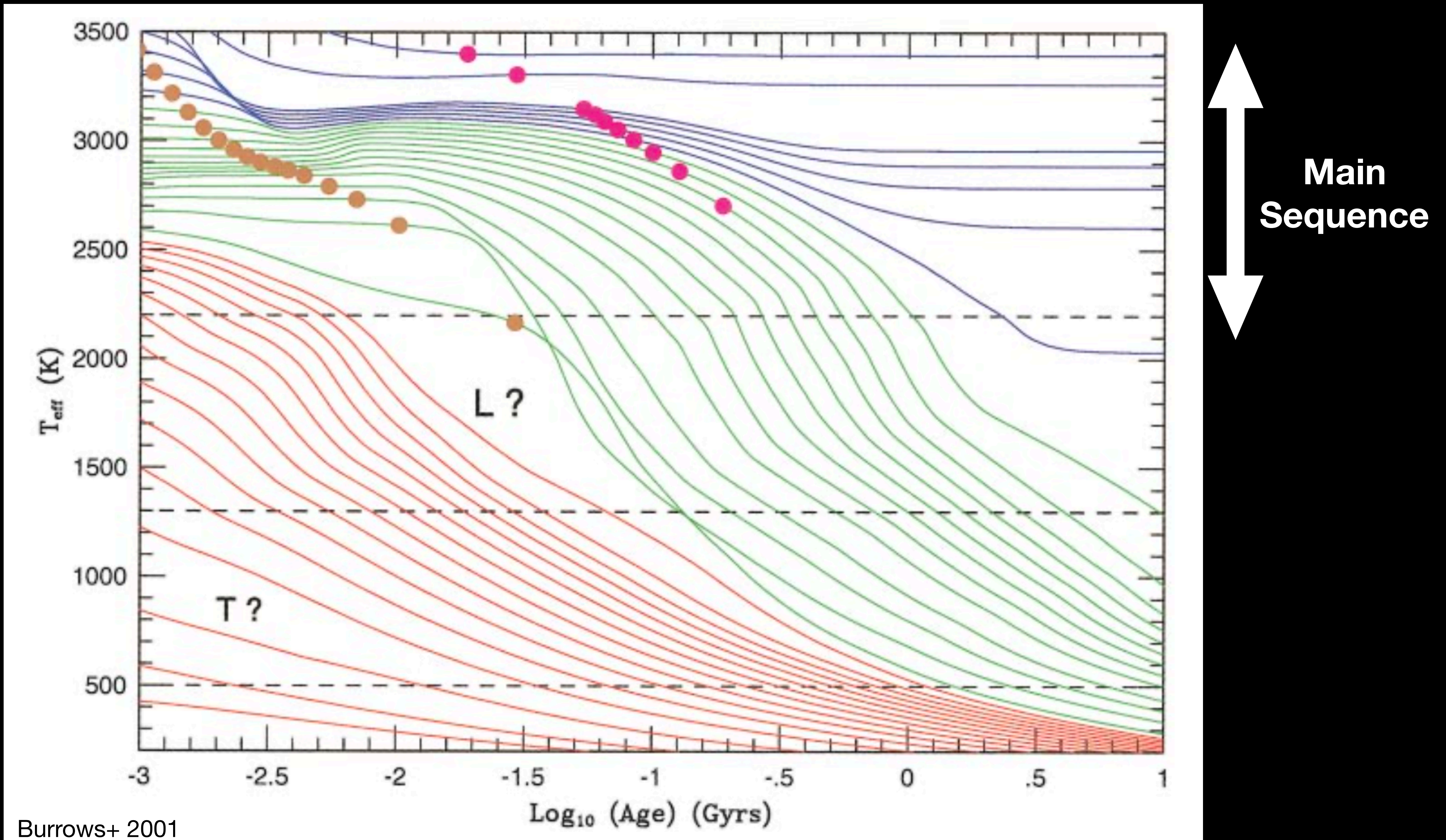
Mass-age-temperature degeneracy



Burrows+ 2001

Mass-age-temperature degeneracy



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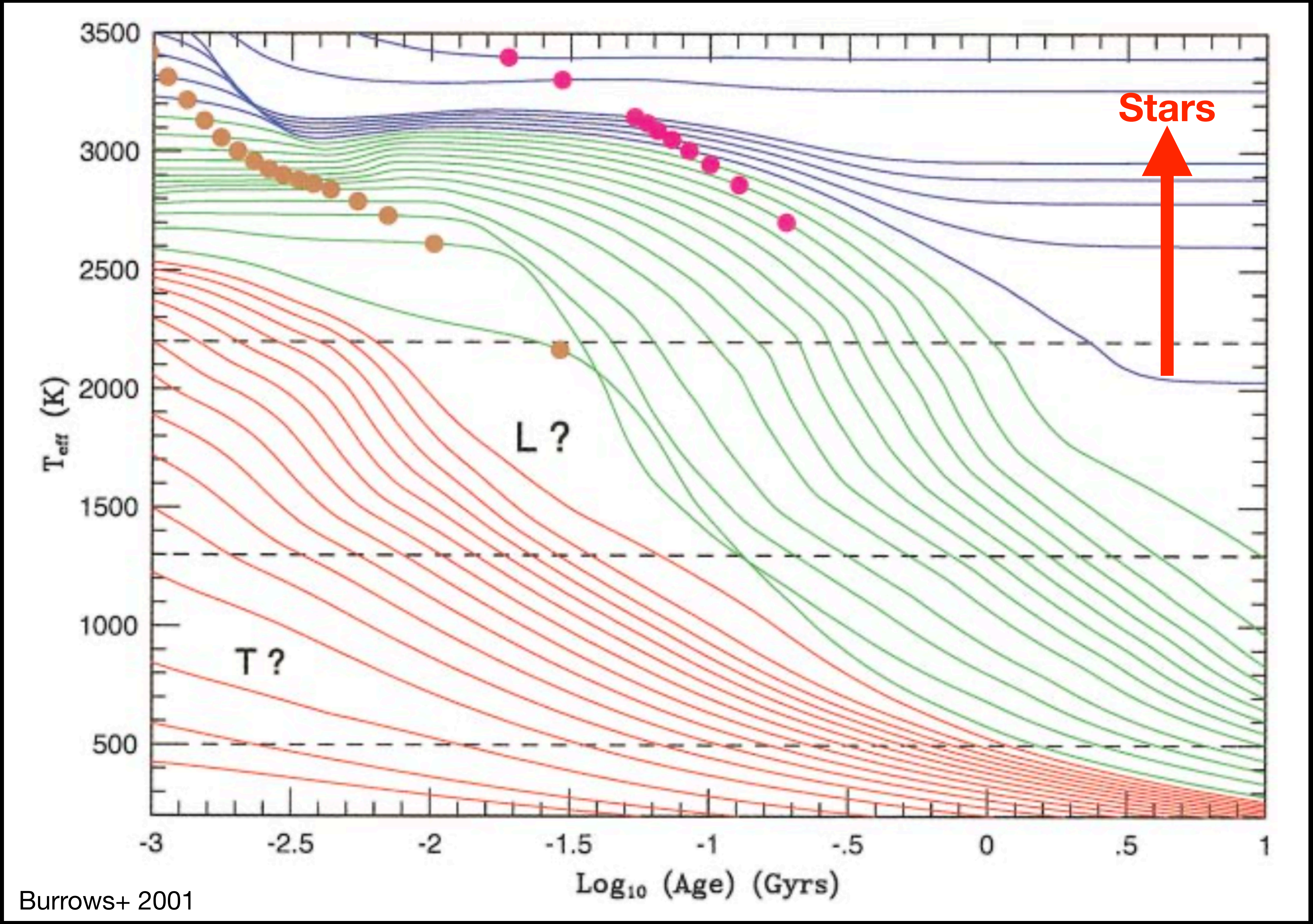
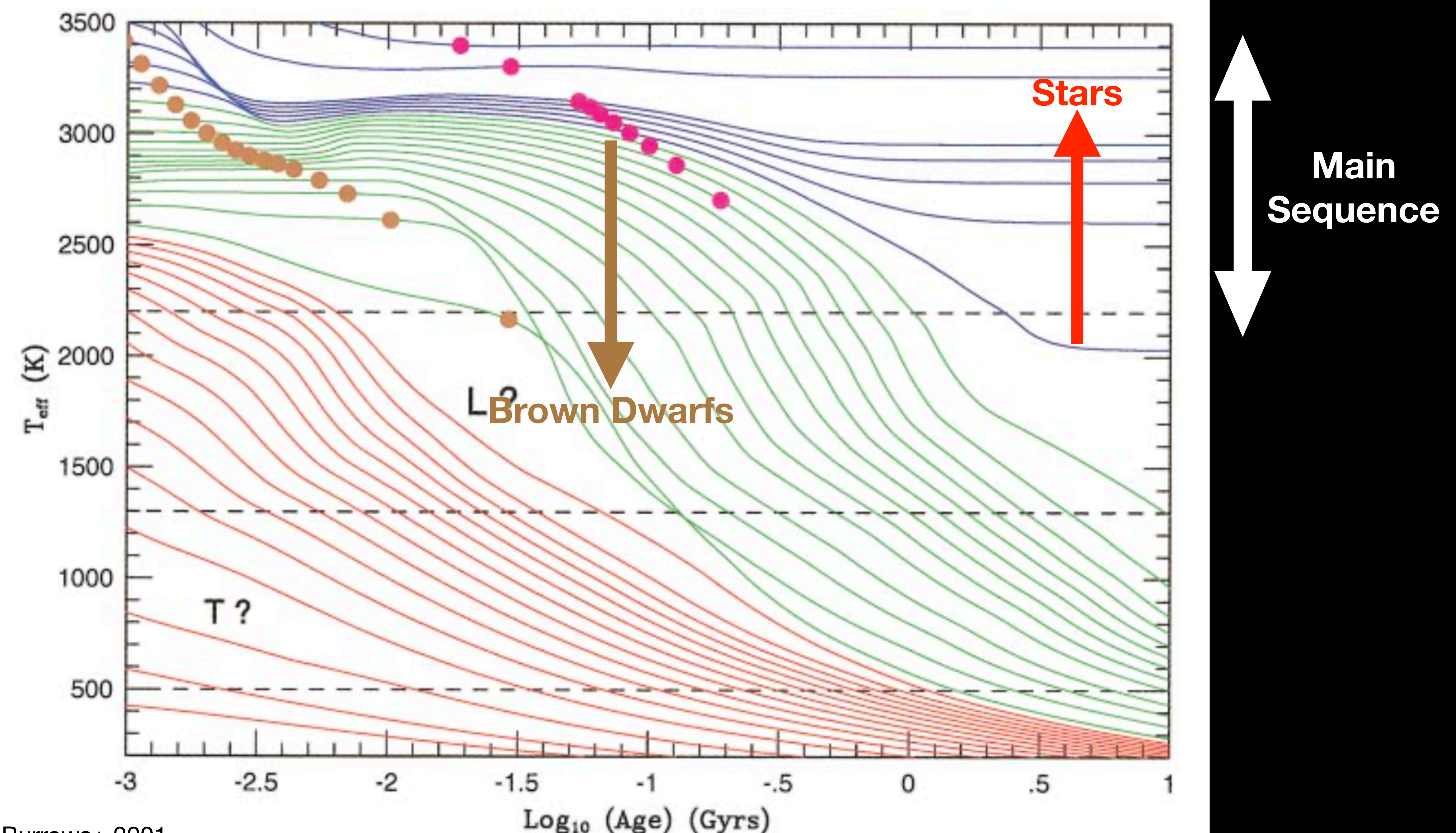


Main Sequence

Mass-age-temperature degeneracy



Burrows+ 2001

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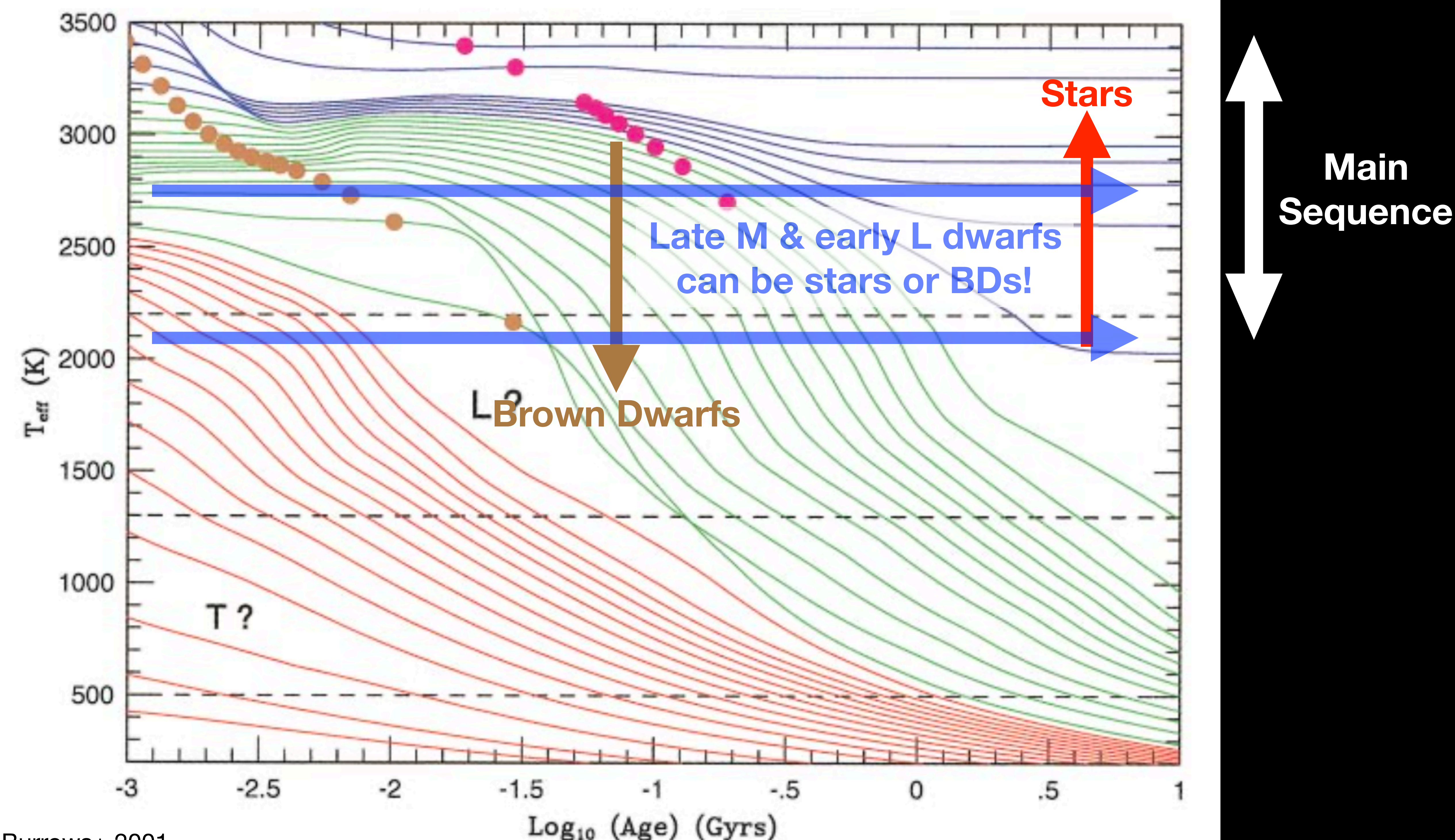

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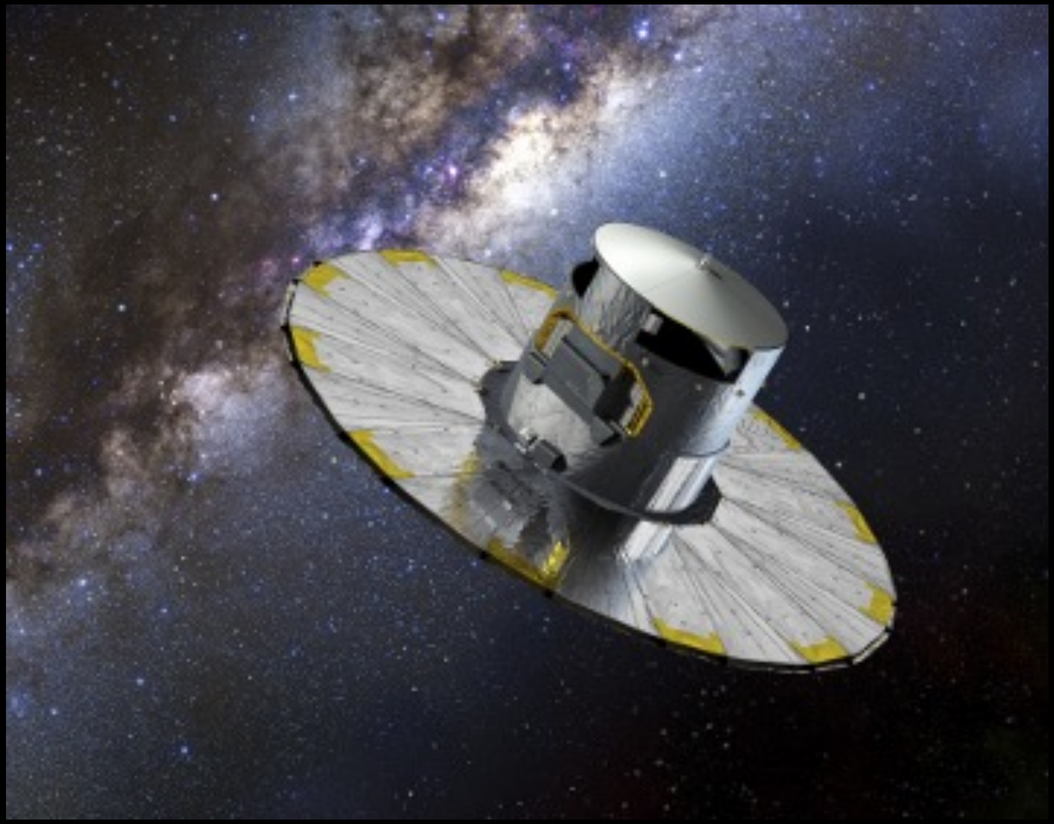
Gaia can save us!



ESA/Gaia

Jackie Faherty @jfaherty · 23h

This is me waiting for the Gaia data release of over a billion parallaxes (distances to stars).... @ESAGaia **#GaiaDR2** #gaiaday

Adrian Price-Whelan @adrianprw · Mar 18

during a great Sunday phone chat with @davidwhogg, we noted that after >5 years of "preparing" for @ESAGaia DR2, we're not even emotionally prepared for the fact that we're still not prepared for DR2 -- omg April is going to be fun

David W. Hogg @davidwhogg · Jan 25

This table is breaking my brain #GaiaSprint #GaiaDR2 cosmos.esa.int/web/gaia/dr2

	# sources in Gaia DR2	# sources in Gaia DR1
Total number of sources	**> 1,500,000,000**	**1,142,679,769**
Number of 5-parameter sources	> 1,300,000,000	2,057,050
Number of 2-parameter sources	> 200,000,000	1,140,622,719
Sources with mean G magnitude	> 1,500,000,000	1,142,679,769
Sources with three-band photometry (G, G_{BP}, G_{RP})	> 1,100,000,000	-
Sources with radial velocities	> 6,000,000	-
Lightcurves for variable sources	> 500,000	3,194
Known asteroids with epoch data	> 13,000	-
Additional astrophysical parameters:	> 150,000,000	-

David W. Hogg @davidwhogg · Mar 23

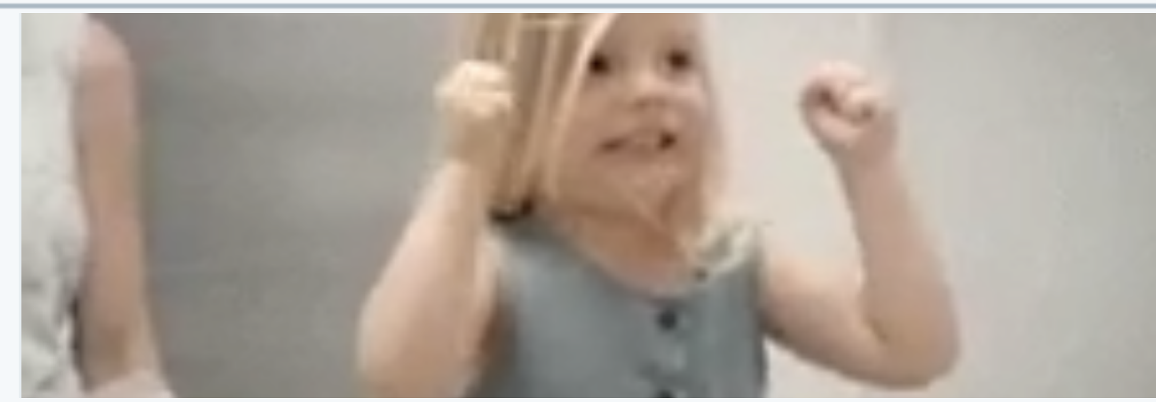
I am so zen about @ESAGaia #GaiaMission **#GaiaDR2** on April 25. We have a lifetime to figure it out!

Jackie Faherty @jfaherty · Apr 4

It is exactly three weeks until everything we know about the Milky Way will change and all we understand about stars will be updated. Are you ready for Gaia???? **#GaiaDR2** @ESAGaia #gaiaday

Gaia can save us! All of us!

David W. Hogg @davidwhogg · 12h
I'm going to want way more booze to CELEBRATE this week! #GaiaDR2



Jackie Faherty @jfaherty · Apr 18
Is the time of the Gaia DR2 data drop public yet????? Inquiring minds want to know! #waitingforGaia @ESAGaia

Jackie Faherty @jfaherty · 34m
People of twitter, there are two days left until all of stellar astrophysics, galactic kinematics and all things in between gets turned on its head by @ESAGaia #WaitingForGaia #yearofthemilkyway Get excited!!!!!!

David W. Hogg @davidwhogg · Mar 23
I am so zen about @ESAGaia #GaiaMission #GaiaDR2 on April 2
lifetime to figure it out!

Jackie Faherty @jfahe
It is exactly three week
change and all we unde
Gaia???? #GaiaDR2 @ESAGaia #gaiaday

Gaia can save us? Nope

I/345/gaia2
Post annotation

Gaia DR2 (Gaia Collaboration, 2018)
Gaia data release 2 (Gaia DR2). (**Download** all Gaia Sources as VOTable **cdsclient** here)

(original column names in green) *(1692919135 rows)*

start AladinLite plot the output query using TAP/SQL

No object found around (ICRS) position 13:55:01.9-82:58:39
search similar catalogs around position

Gaia can save us? Nope

I/345/gaia2 Gaia DR2 (Gaia Collaboration, 2018)

Post annotation

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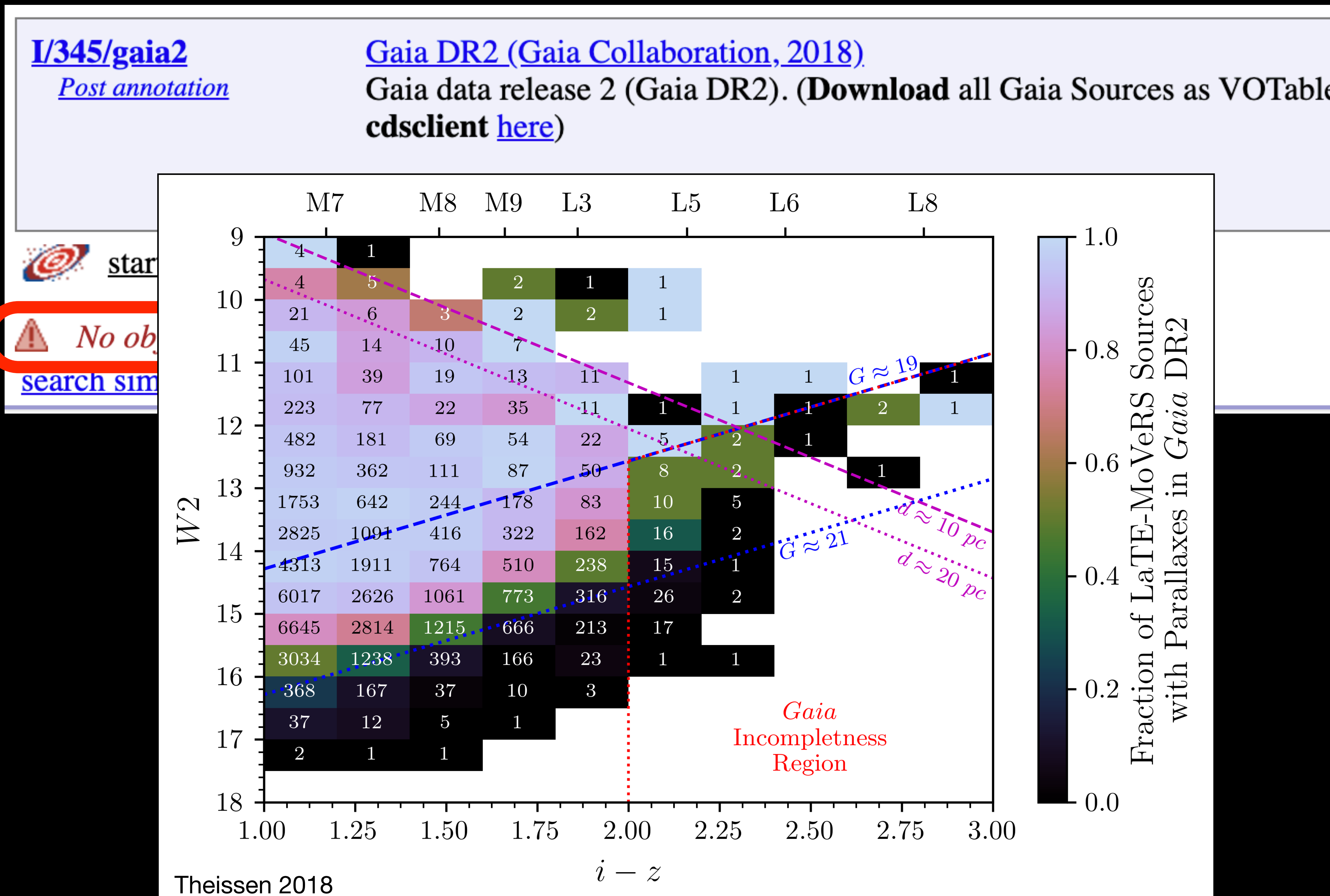
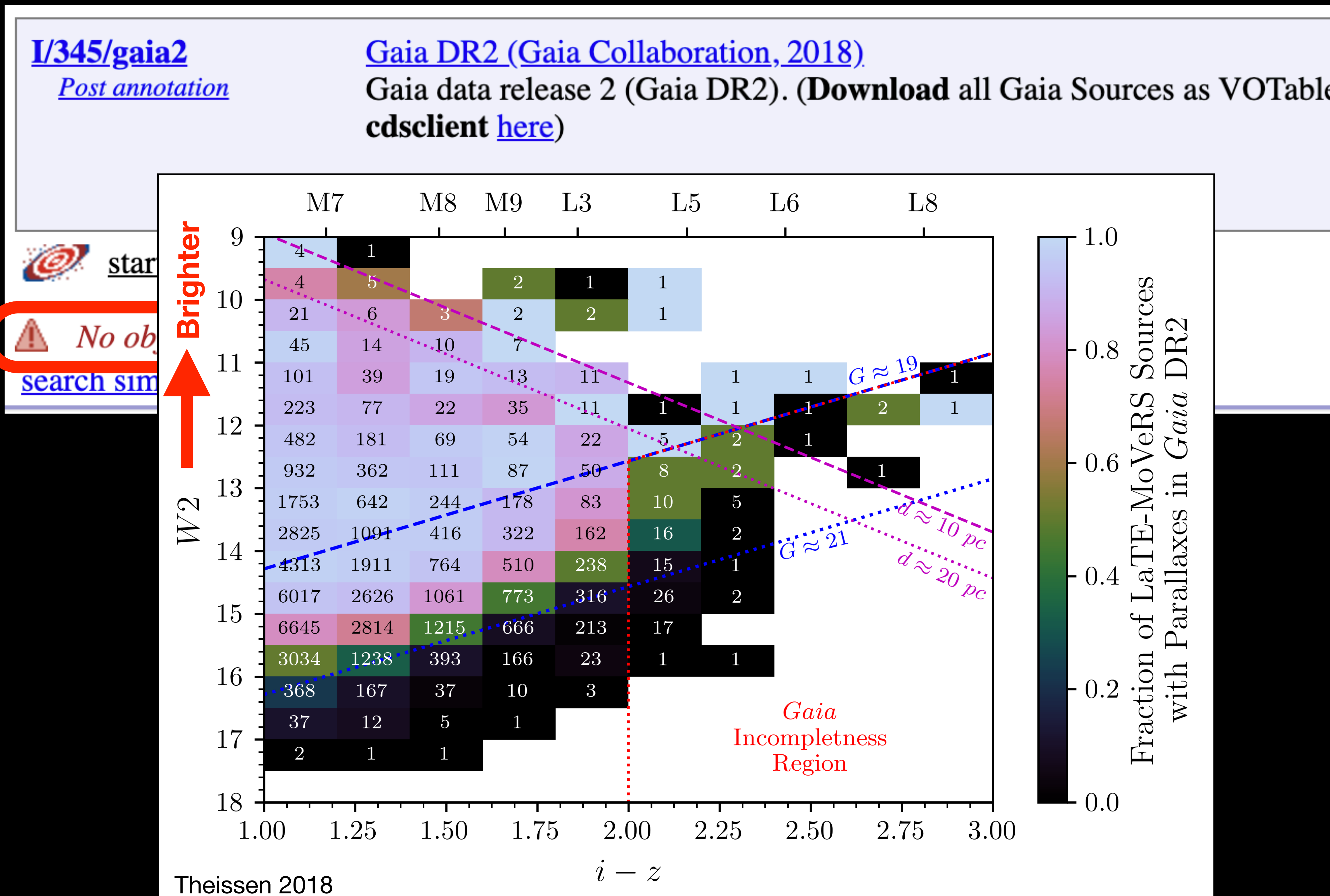
Gaia can save us! (nope)

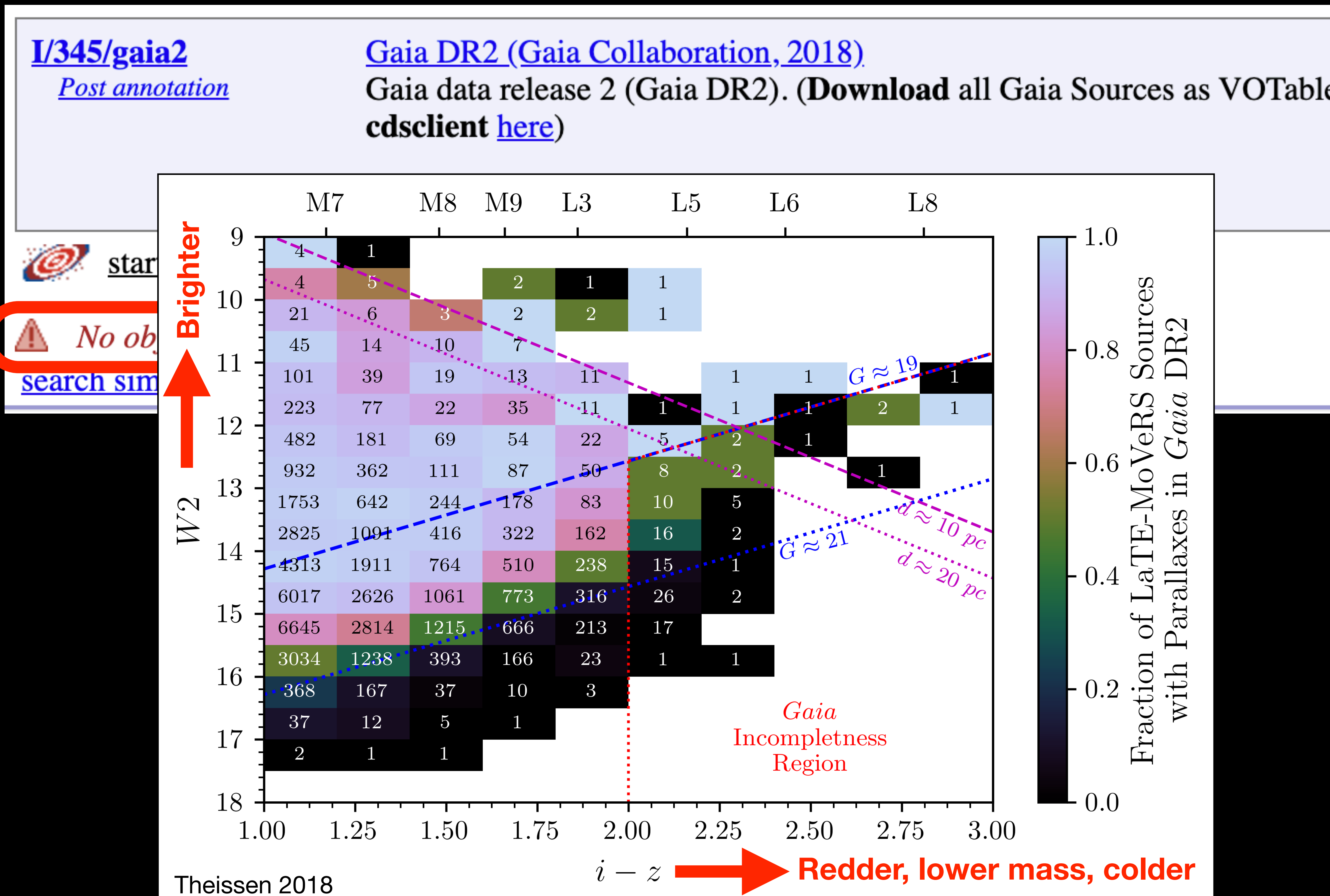


Gaia can save us! (nope)



Theissen 2018

Gaia can save us! (nope)



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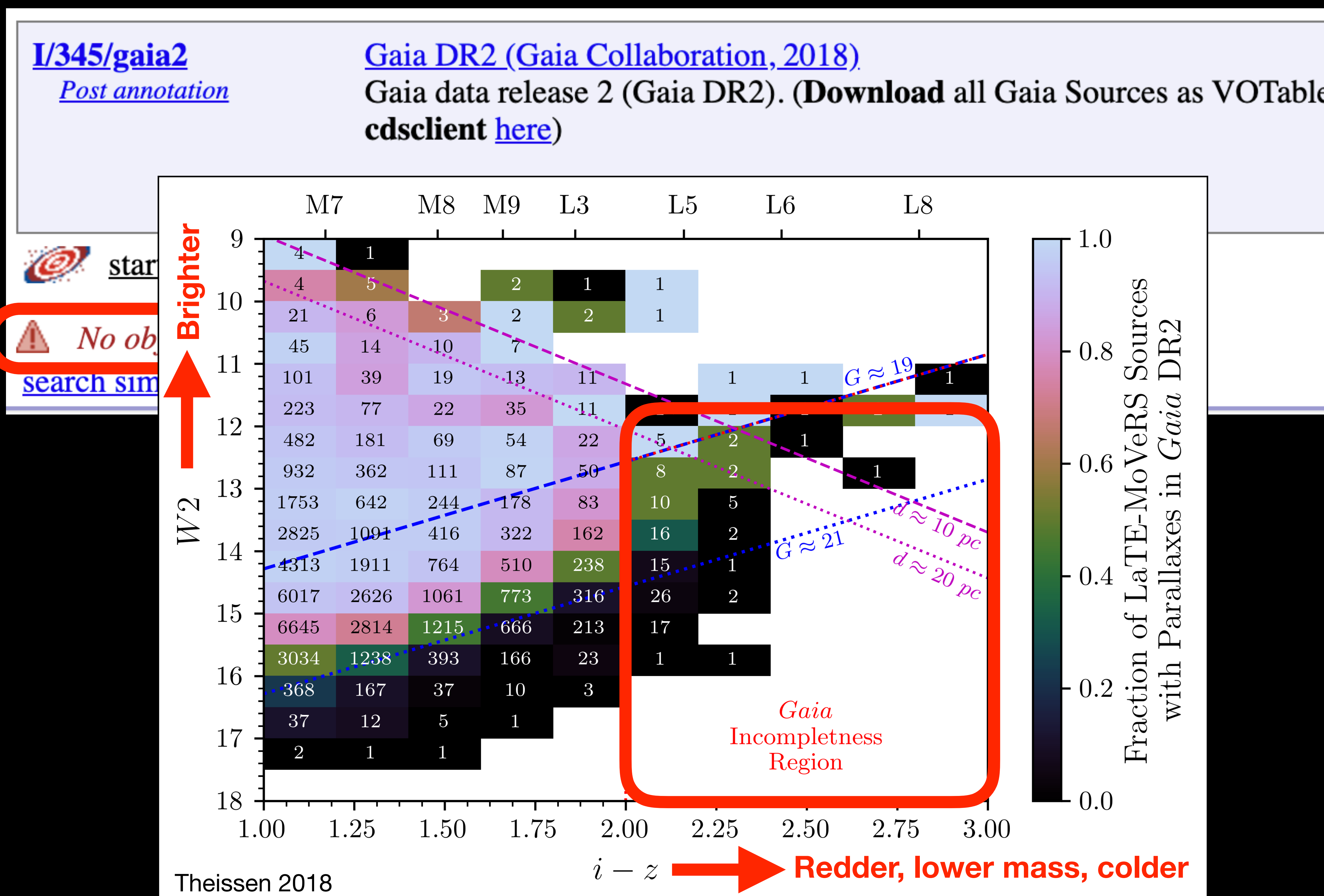

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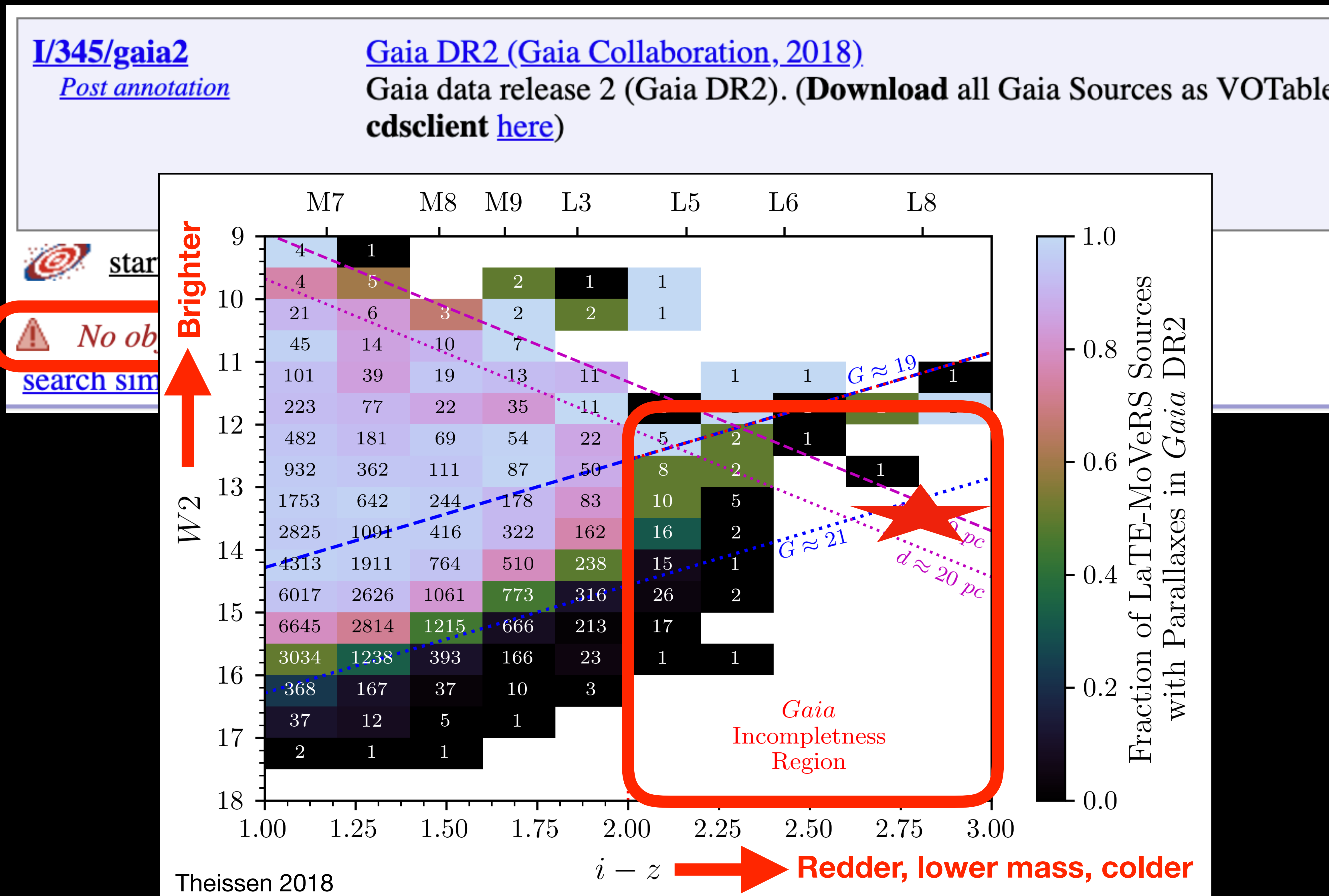
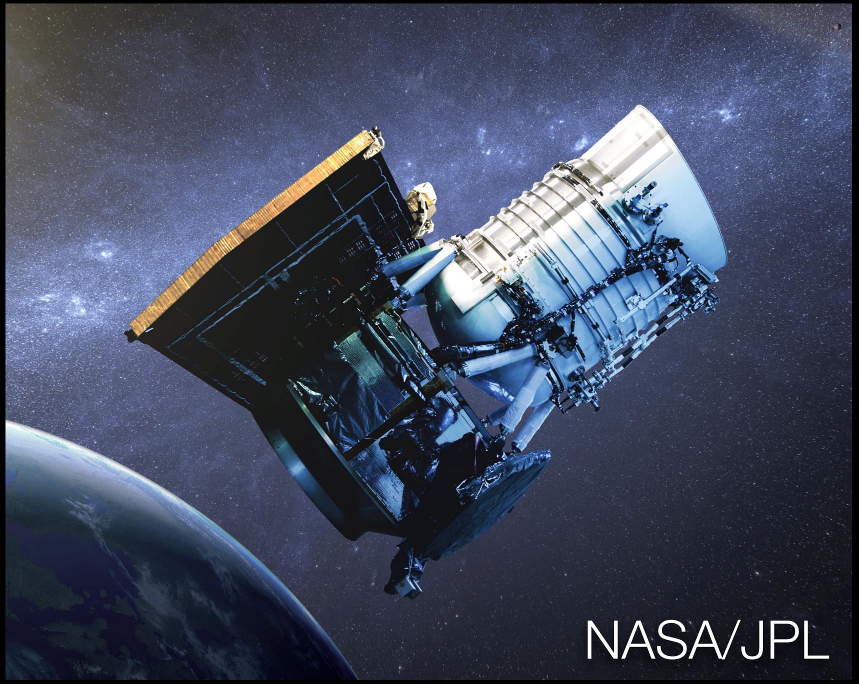
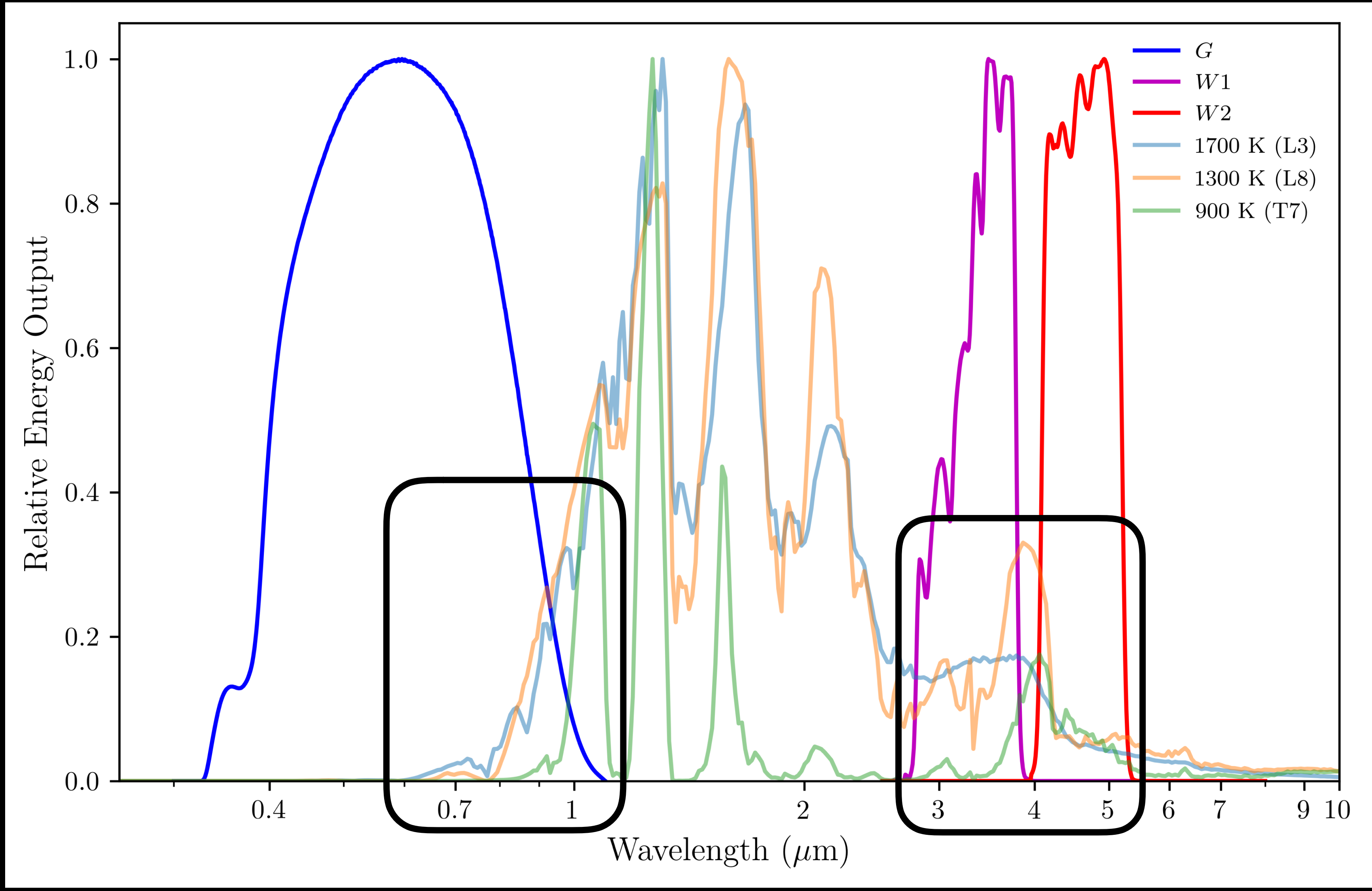


The *Wide-field Infrared Survey Explorer (WISE)*

All-sky survey in 4 mid-infrared (MIR) bands (3.4, 4.6, 12, and 22 microns)

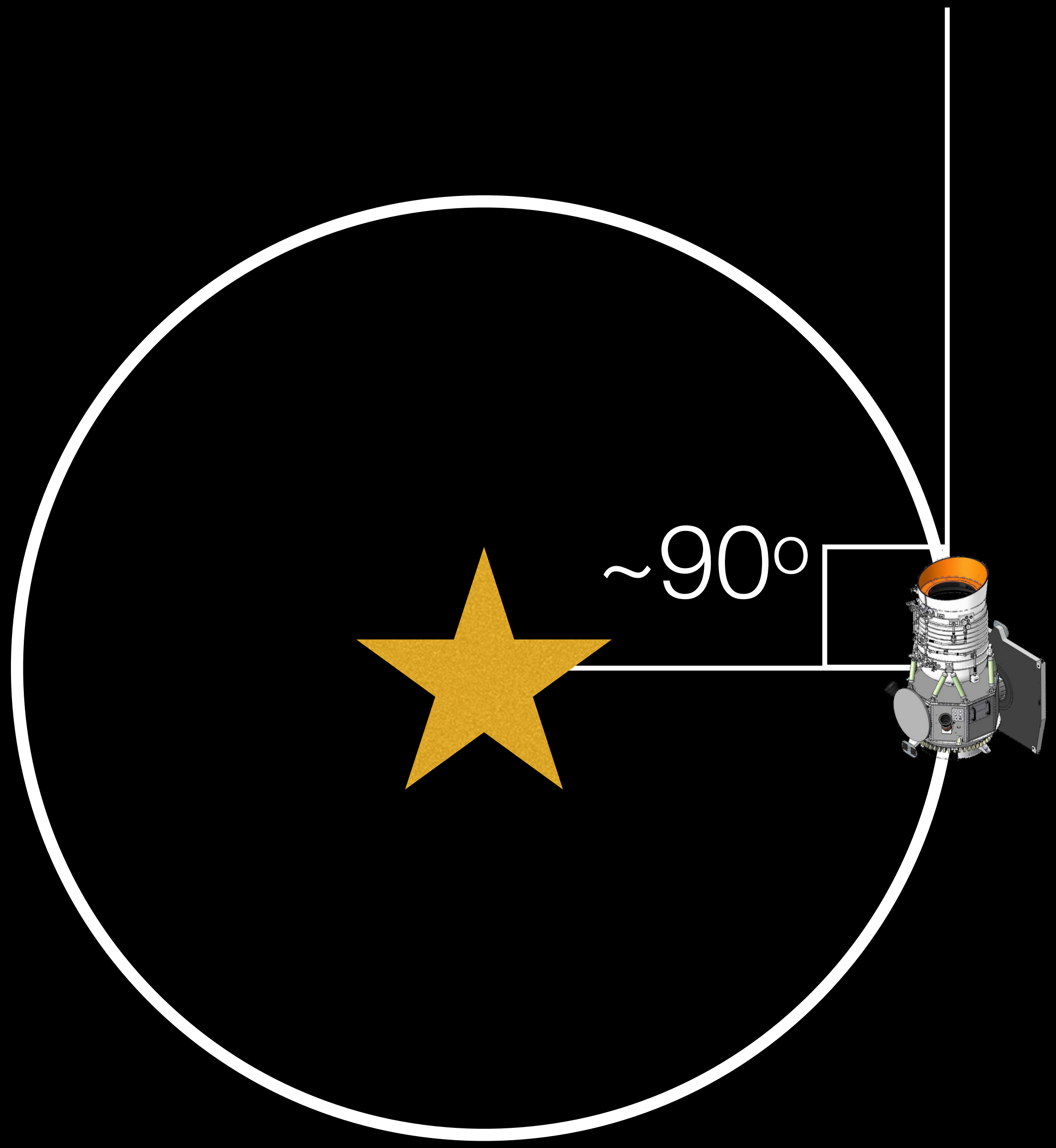




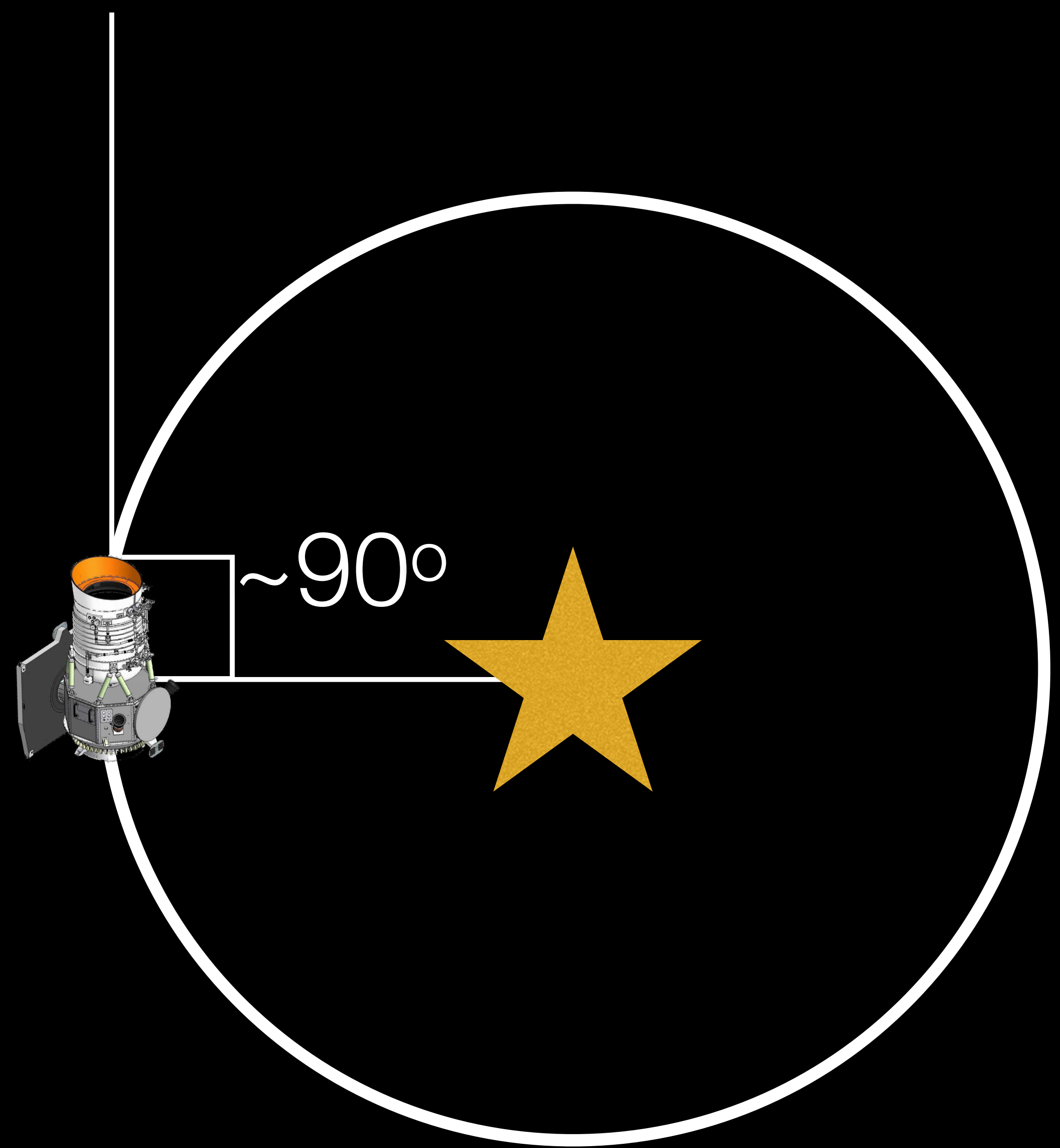
Ultracool objects produce very little flux at optical (Gaia) wavelengths.

Flux increases at MIR wavelengths for the coolest objects.

WISE survey strategy



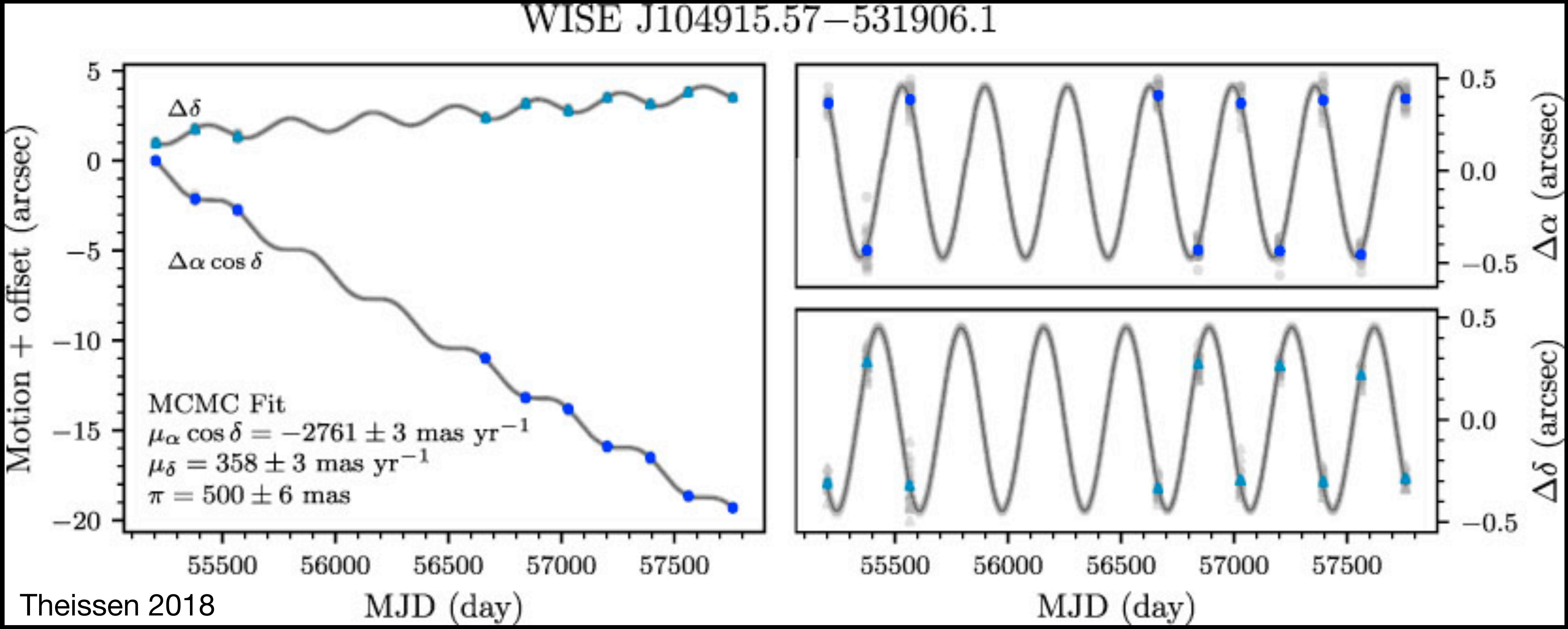
WISE survey strategy



WISE survey strategy (still ongoing)

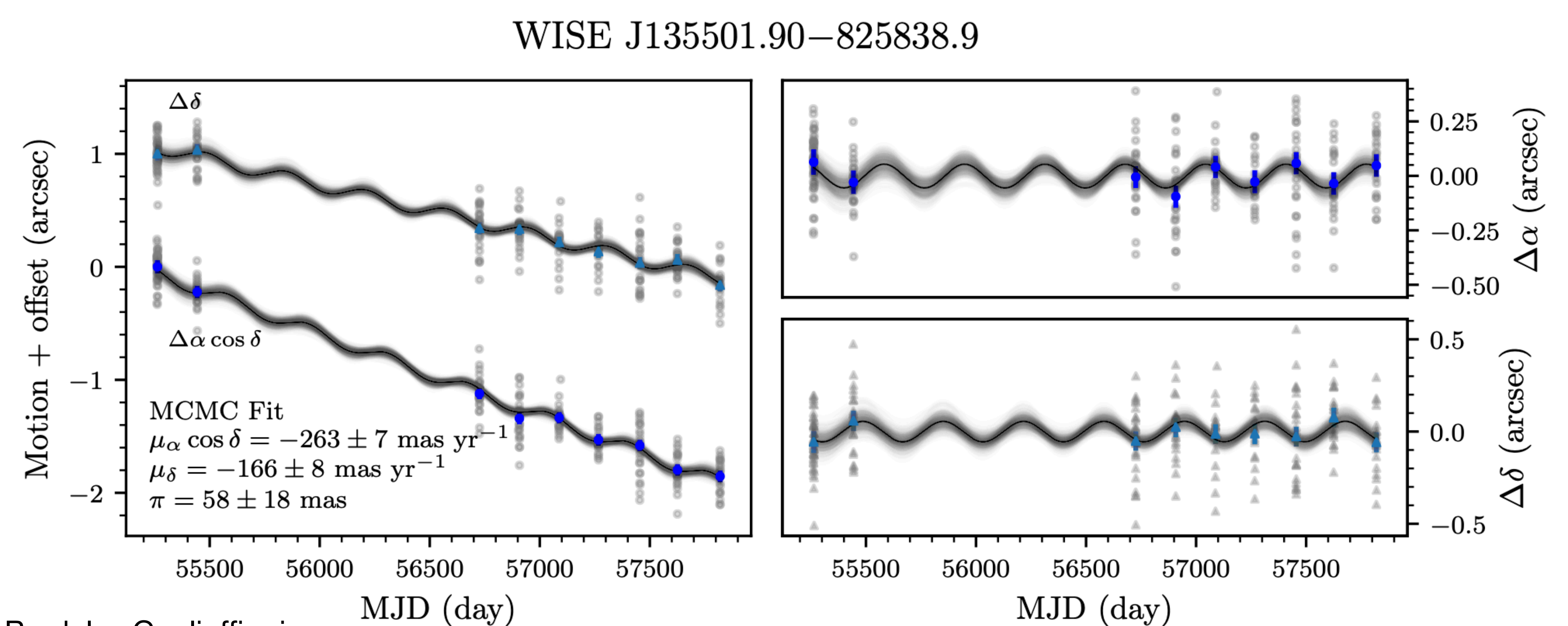
Roughly every 6 months for ~8 years

Luhman 16AB: 3rd closest system (L7.5+T0.5)



Theissen 2018

WISE J1355-8258: Constraining the distance



Bardalez Gagliuffi+, in prep

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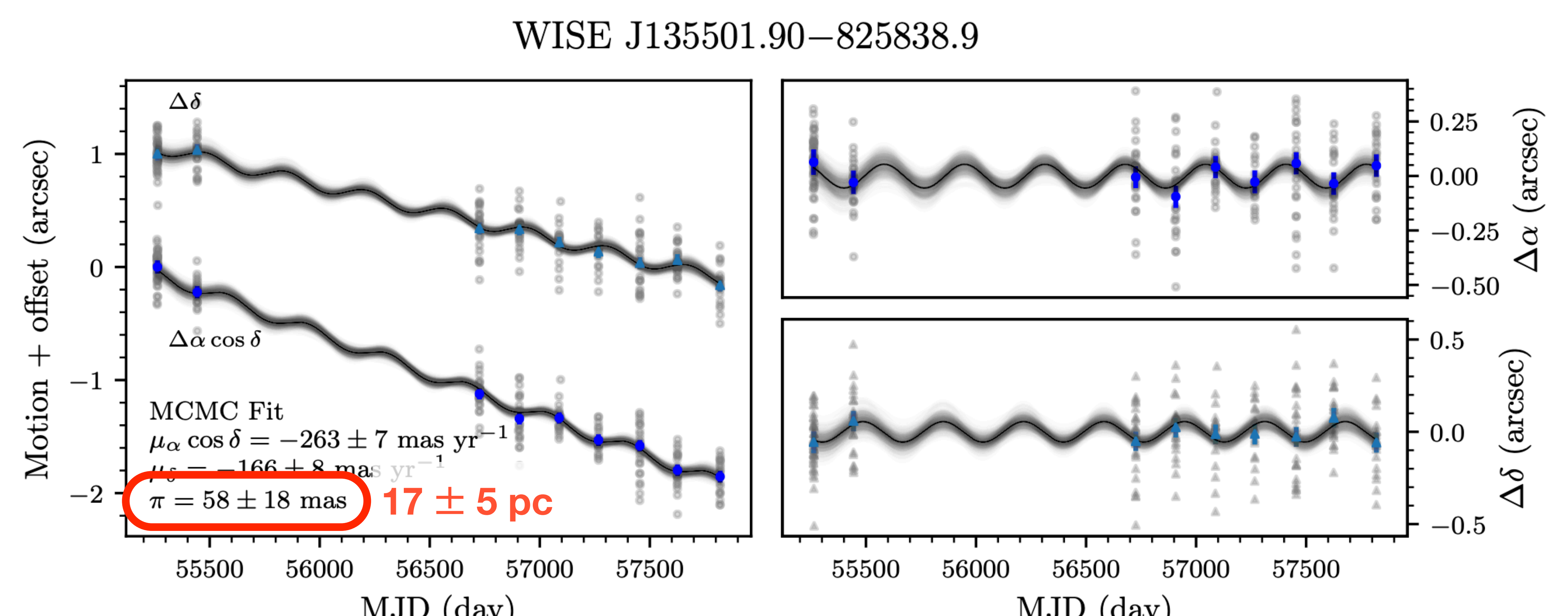

Bardalez Gagliuffi+, in prep

Young or old? Distance is the key

Bardalez Gagliuffi+ 2018

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Young or old? BD or giant planet? Distance is the key

Bardalez Gagliuffi+ 2018

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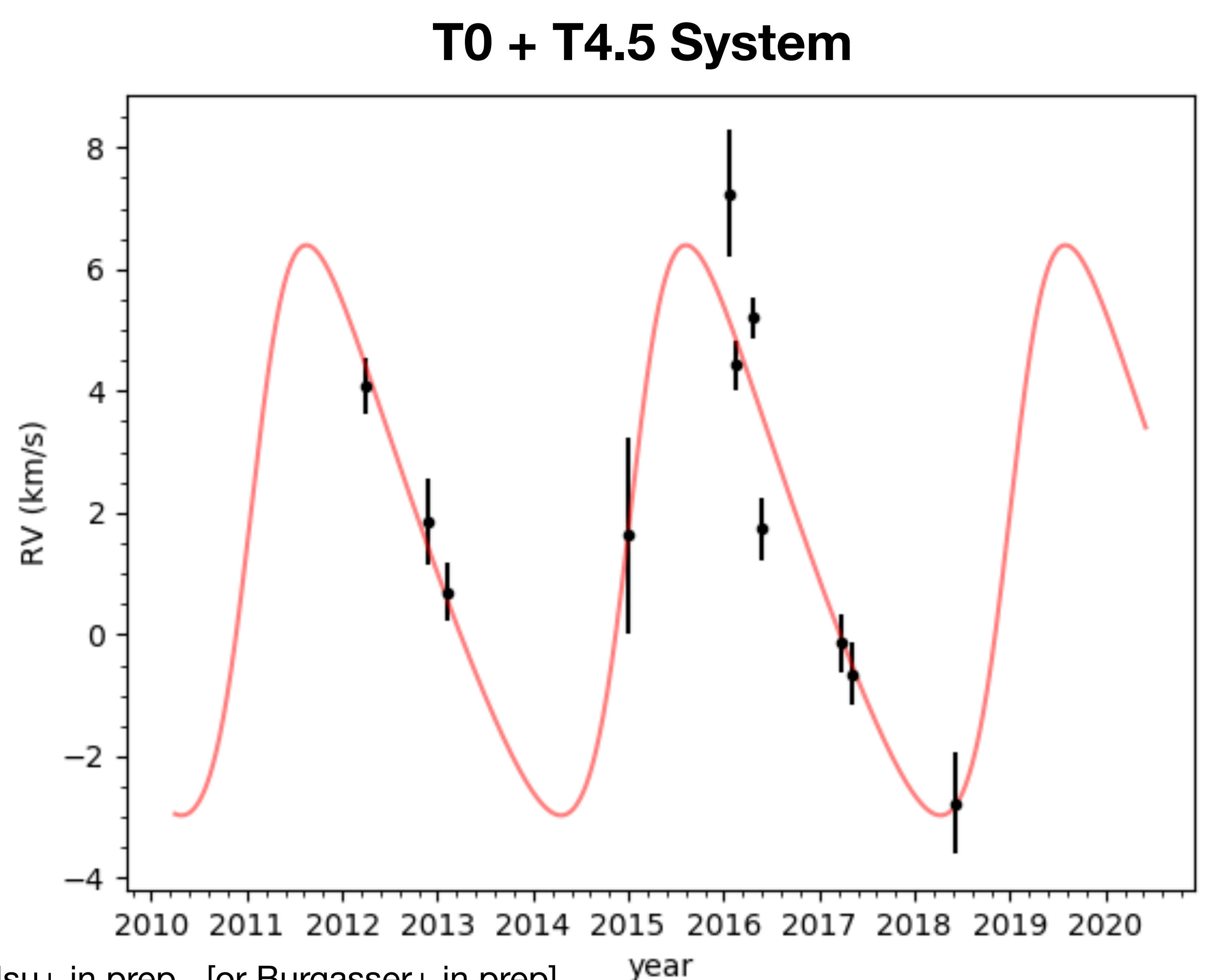
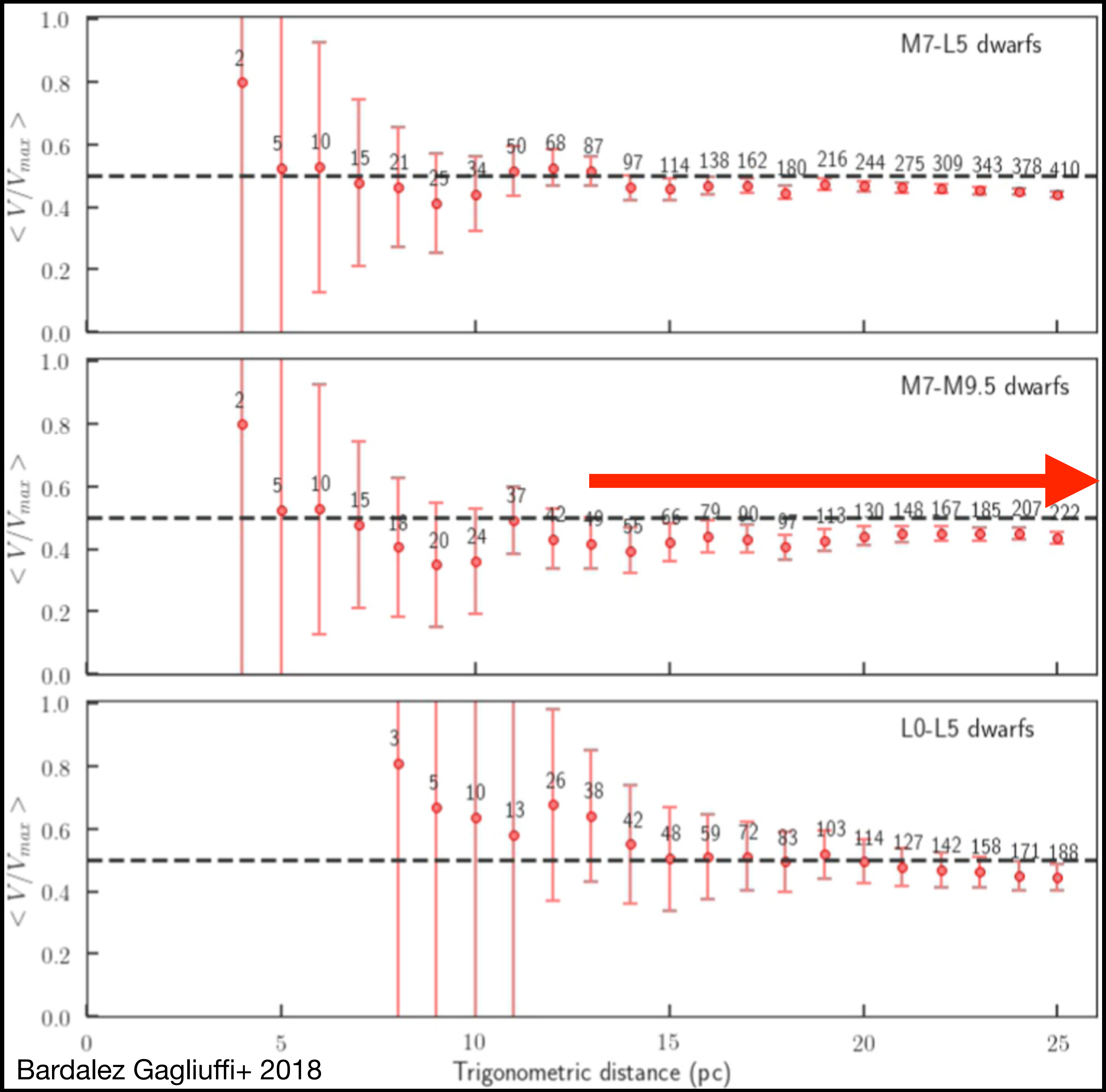
Assumed Age (Gyr)	···	2–5		2–5		0.13–0.2		1
Magnitudes								
Δ 2MASS J[a]	···	1.0 ± 0.8		2.4 ± 0.4		2.4 ± 0.4		1
Δ 2MASS H[a]	···	1.4 ± 0.9		3.5 ± 0.3		3.5 ± 0.3		1
Δ 2MASS K_s[a]	···	1.9 ± 1.0		4.1 ± 0.4		4.1 ± 0.4		1
2MASS J	16.14 ± 0.13	16.5 ± 0.3	17.5 ± 0.6	···	···	16.3 ± 0.1	18.6 ± 0.4	1, 2
2MASS H	15.31 ± 0.13	15.6 ± 0.3	17.0 ± 0.8	···	···	15.4 ± 0.1	18.9 ± 0.3	1, 2
2MASS K_S	14.72 ± 0.14	14.9 ± 0.2	16.8 ± 0.8	···	···	14.7 ± 0.1	18.9 ± 0.4	2
FourStar J	16.47 ± 0.05	···	···	···	···	···	···	1
FourStar H	15.45 ± 0.04	···	···	···	···	···	···	1
FourStar K_S	15.01 ± 0.05	···	···	···	···	···	···	1
WISE $W1$	14.12 ± 0.03	···	···	···	···	···	···	2
WISE $W2$	13.55 ± 0.03	···	···	···	···	···	···	2
WISE $W3$	12.5 ± 0.3	···	···	···	···	···	···	2
WISE $W4$	⩽9.7	···	···	···	···	···	···	2
M_J[b]	15.0 ± 0.4, 15.1 ± 0.4	14.2 ± 0.4	14.8 ± 0.4	···	···	15.1 ± 0.4	17.5 ± 0.6	1
M_H[b]	14.1 ± 0.4, 13.8 ± 0.4	13.0 ± 0.4	14.1 ± 0.4	···	···	14.2 ± 0.4	17.7 ± 0.6	1
M_{K_S}[b]	13.5 ± 0.4, 13.2 ± 0.4	12.3 ± 0.4	14.0 ± 0.4	···	···	13.6 ± 0.4	17.7 ± 0.7	1
Kinematics								
RV (km s^{-1})	22 ± 5	···	···	···	···	···	···	1
$\mu_\alpha \cos\delta$ (mas yr^{-1})	−241 ± 8	···	···	···	···	···	···	2
μ_δ (mas yr^{-1})	−142 ± 14	···	···	···	···	···	···	2
d[c] (pc)	···	33 ± 9	33 ± 19	27 ± 3	27 ± 4	17 ± 2		1
U[d] (km s^{-1})	···	−25 ± 9		−18 ± 4		−7 ± 4		1
V[d] (km s^{-1})	···	−38 ± 8		−34 ± 4		−27 ± 4		1
W[d] (km s^{-1})	···	−19 ± 7		−17 ± 3		−13 ± 2		1
Masses								
Mass ($M_{\rm Jup}$)	···	72^{+4}_{-5}	61^{+6}_{-8}	70^{+2}_{-4}	42^{+5}_{-6}	11 ± 1	9 ± 1	1
Mass ratio	···	0.84 ± 0.06		0.60 ± 0.08		0.82 ± 0.02		1

Many unresolvable binaries lie within 25 pc



Hsu+ in prep [or Burgasser+ in prep]

What are the completeness limits at the bottom?



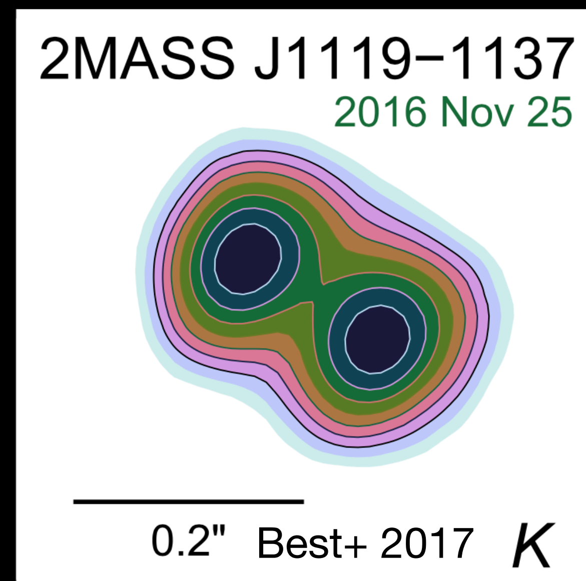
Incomplete at ~13 pc

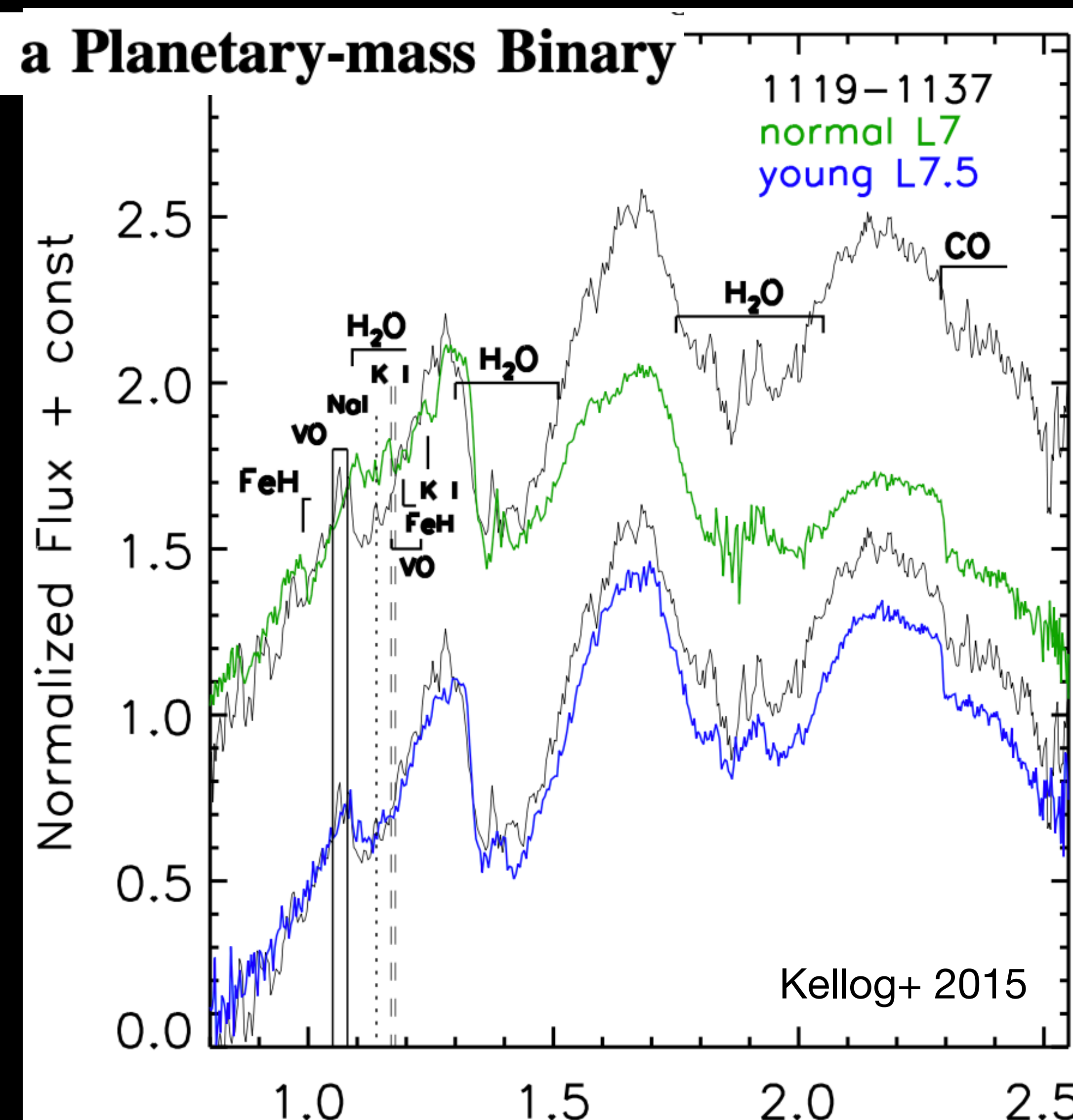
Complete to 25 pc (maybe)

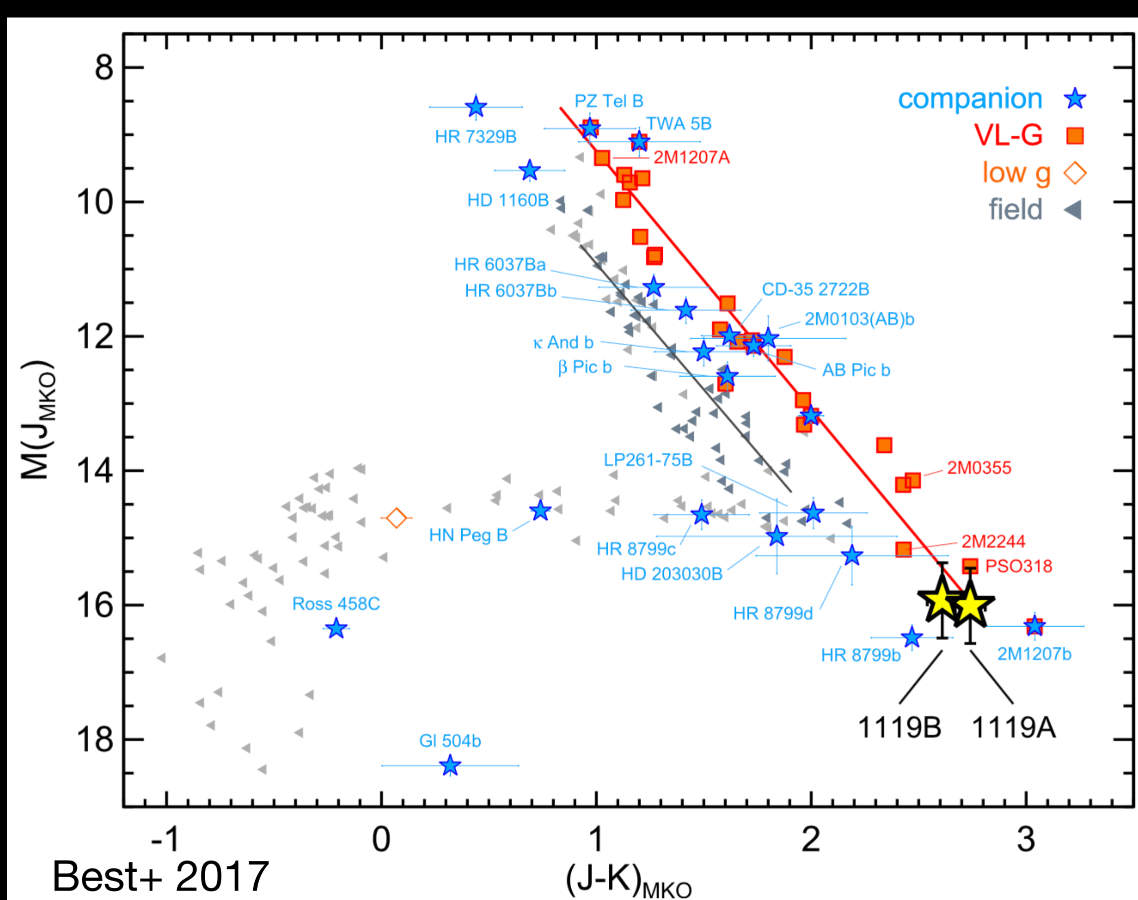
Brown dwarf? Giant planet? Planetary-mass object?

The Young L Dwarf 2MASS J11193254−1137466 Is a Planetary-mass Binary

The lowest mass binary detected: 2MASS J11193254–1137466







	Model-derived (Lyon/DUSTY) Assuming TWA Membership		
Age (Myr)	10 ± 3 Myr		7
Mass (M_{Jup})	$3.7^{+1.2}_{-0.9}$	$3.7^{+1.2}_{-0.9}$	3
T_{eff} (K)	1013^{+122}_{-109}	1006^{+122}_{-109}	3
	Model-derived (Lyon/DUSTY) Assuming Young Field (VL-G)		
Age (Myr)	10–100 Myr		8
Mass (M_{Jup})	$9.2^{+2.3}_{-1.9}$	$9.0^{+2.4}_{-1.9}$	3
T_{eff} (K)	1065^{+133}_{-118}	1059^{+133}_{-118}	3

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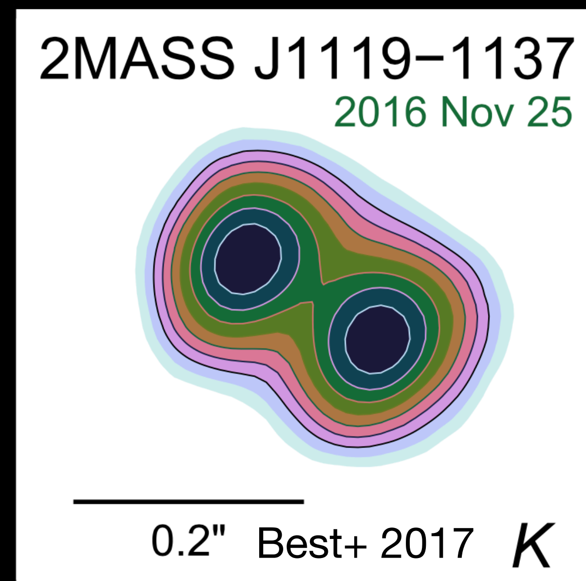

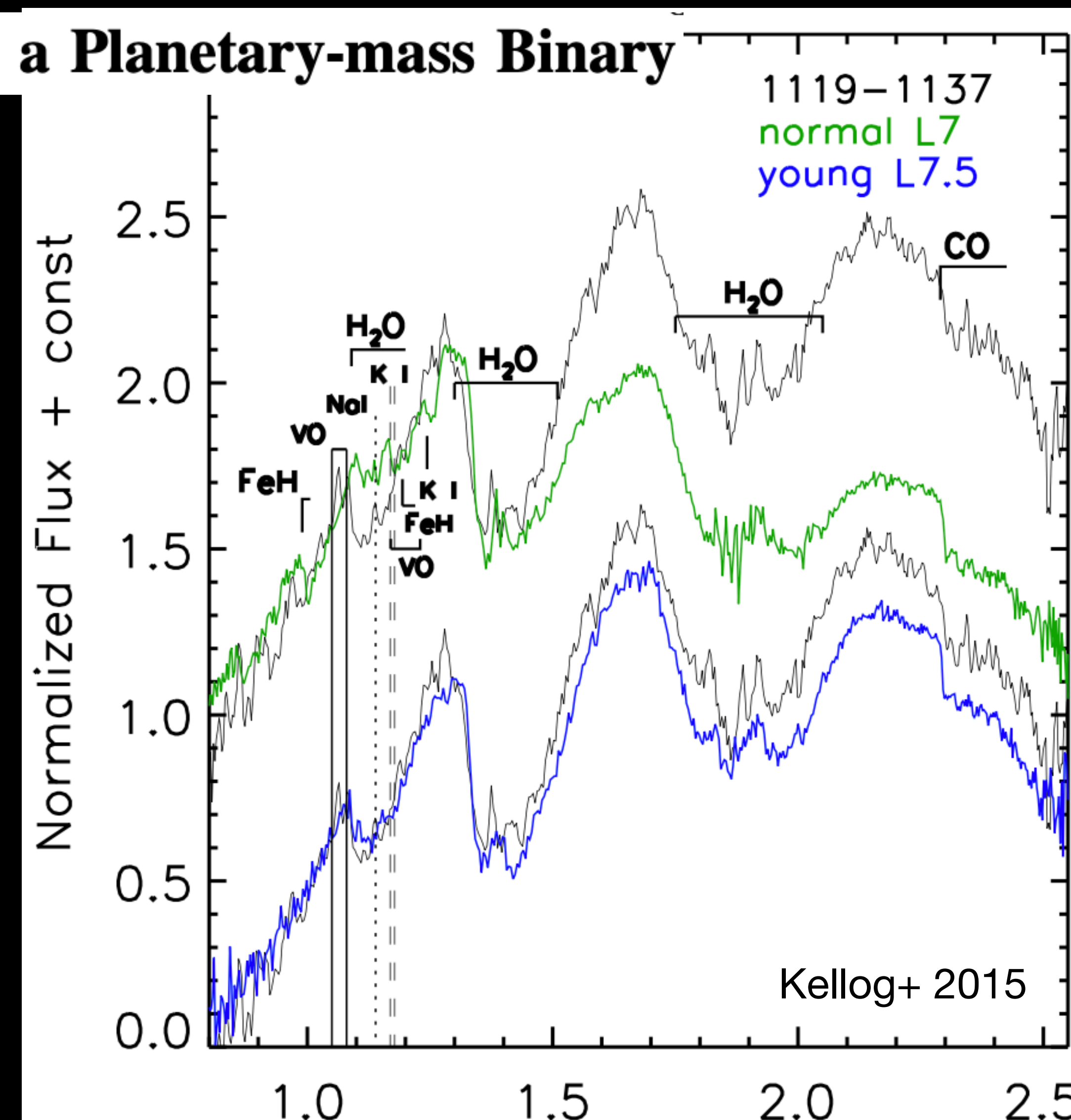

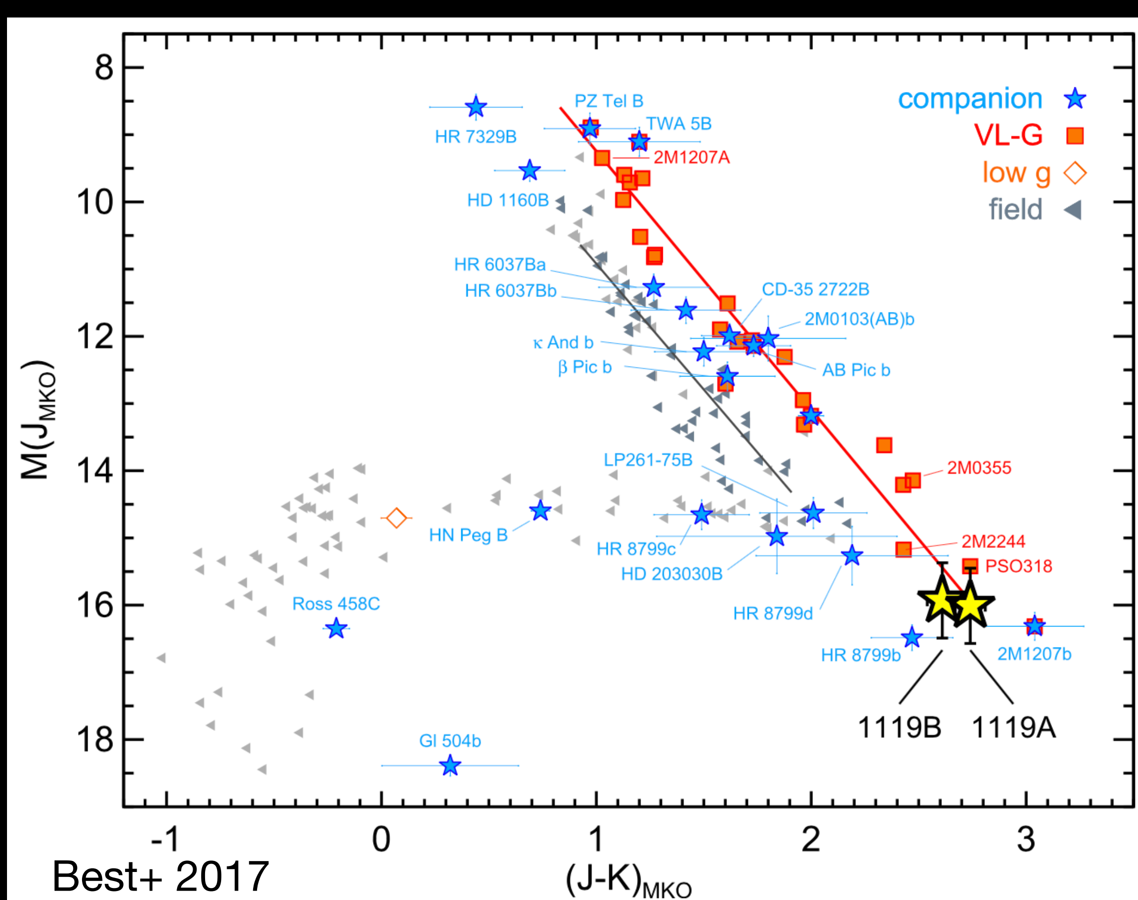

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Extreme mass ratios are hard to detect

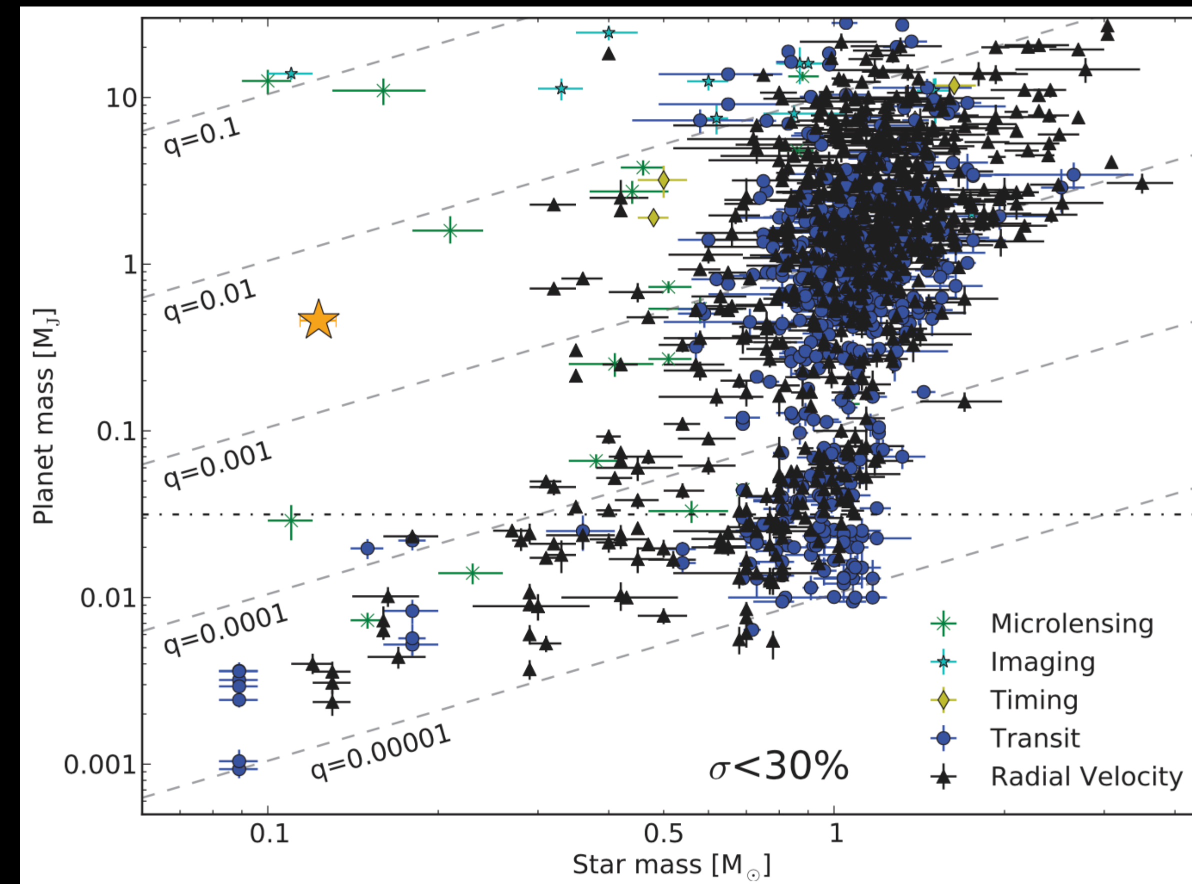
RESEARCH

REPORT

EXOPLANETS

A giant exoplanet orbiting a very-low-mass star challenges planet formation models

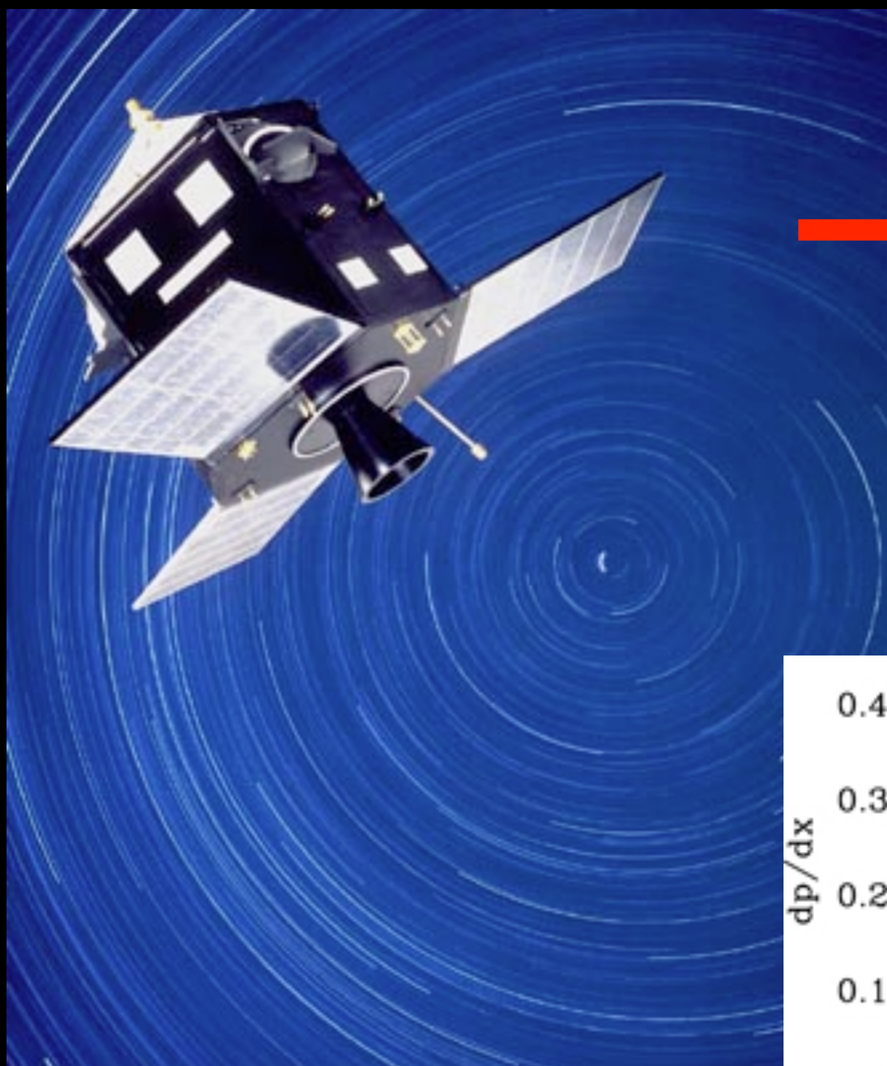
J. C. Morales[1,2]*, A. J. Mustill[3], I. Ribas[1,2], M. B. Davies[3], A. Reiners[4], F. F. Bauer[5],



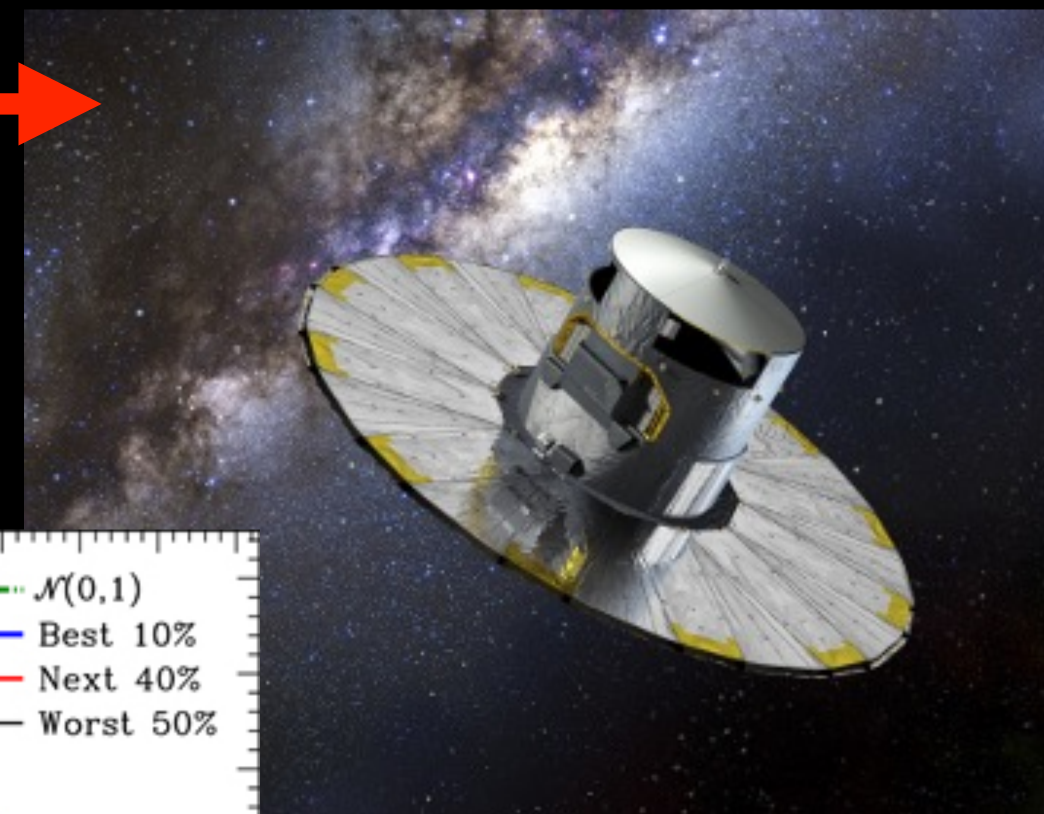
Surveys have shown that super-Earth and Neptune-mass exoplanets are more frequent than gas giants around low-mass stars, as predicted by the core accretion theory of planet formation. We report the discovery of a giant planet around the very-low-mass star GJ 3512, as determined by optical and near-infrared radial-velocity observations. The planet has a minimum mass of 0.46 Jupiter masses, very high for such a small host star, and an eccentric 204-day orbit. Dynamical models show that the high eccentricity is most likely due to planet-planet interactions. We use simulations to demonstrate that the GJ 3512 planetary system challenges generally accepted formation theories, and that it puts constraints on the planet accretion and migration rates. Disk instabilities may be more efficient in forming planets than previously thought.

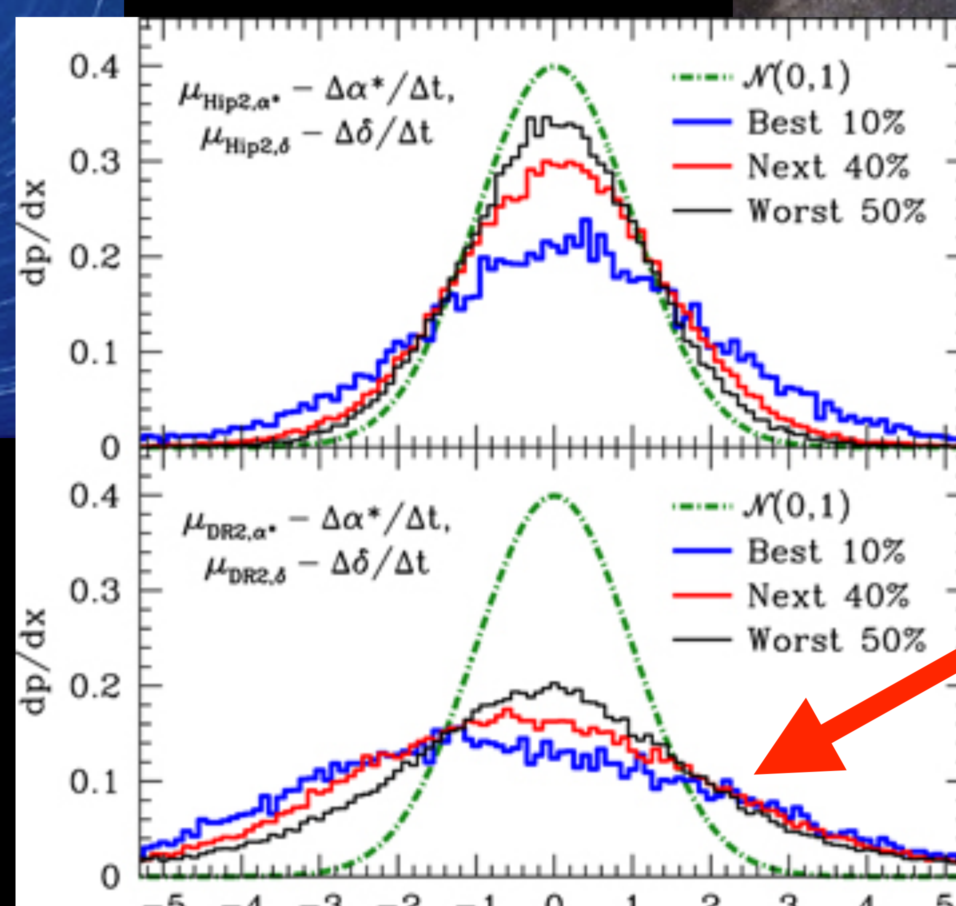
Binary systems are important diagnostics for anchoring the degenerate secondary component to the higher-mass primary for things like age & temp.

Finding new binaries: *Hipparcos*-*Gaia* accelerators



~24 year baseline





Brandt 2018

Gaia **uncertainties underestimated (but we won't get into that)**

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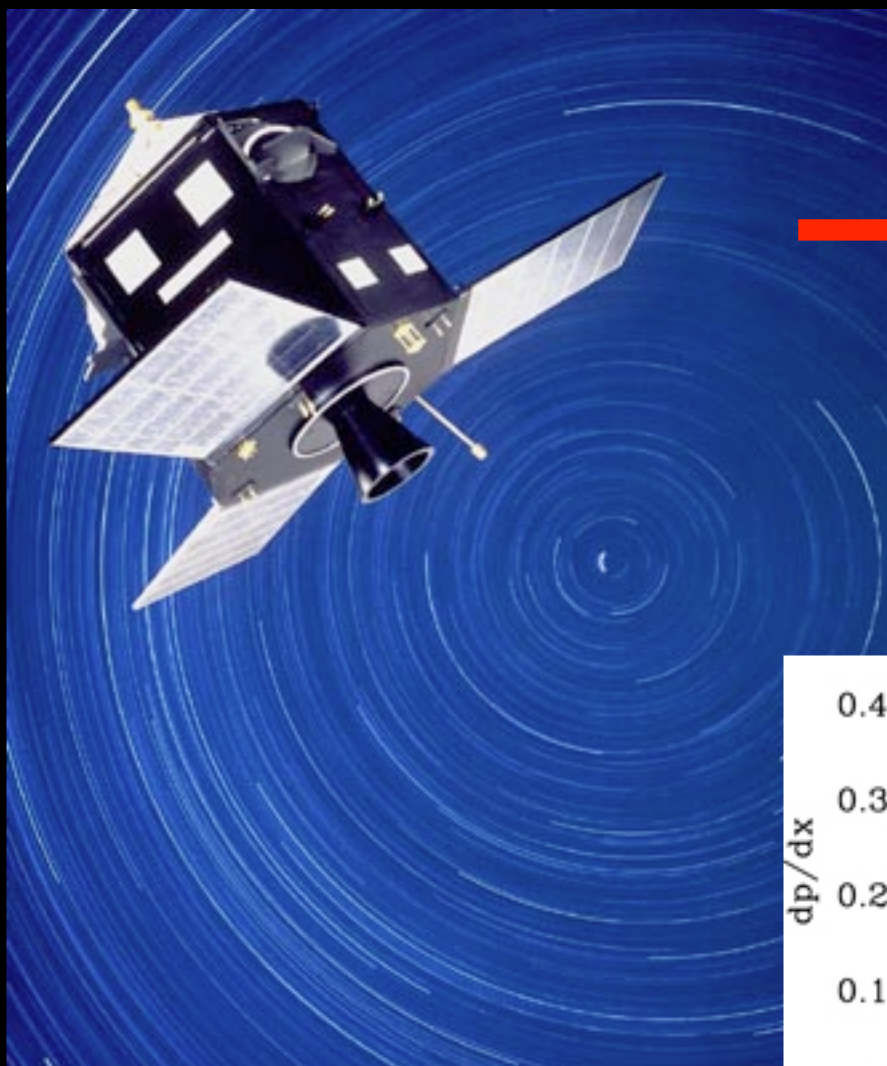

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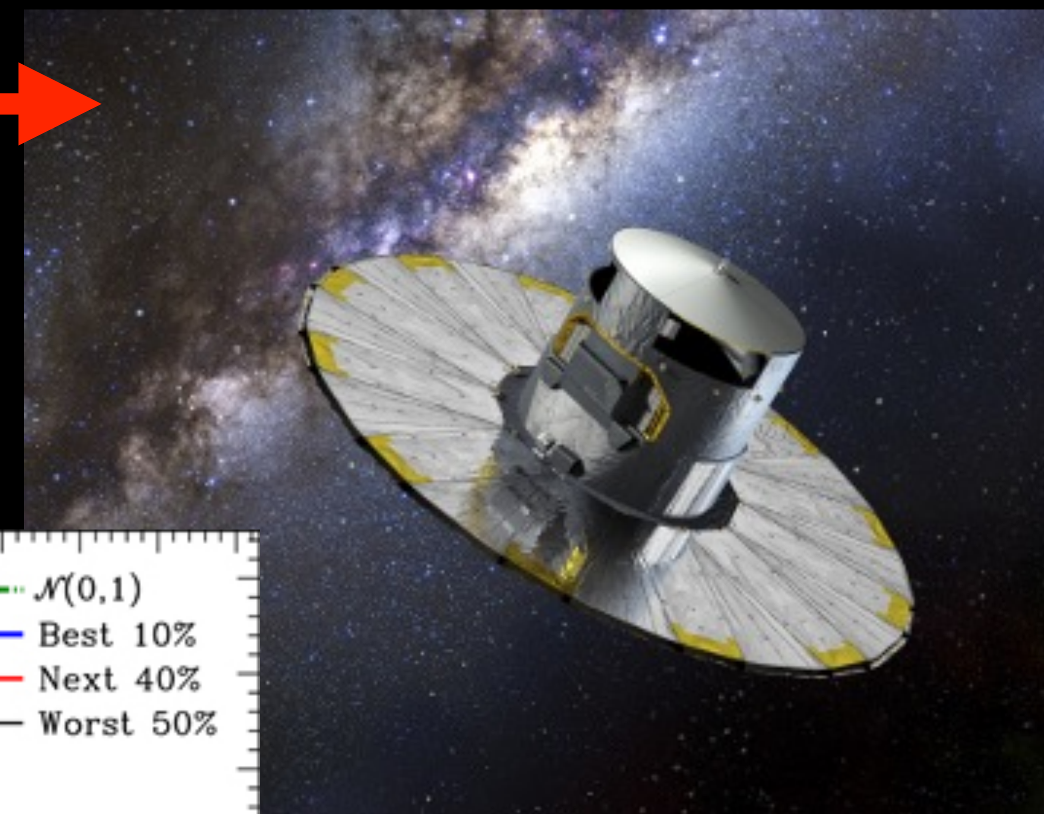

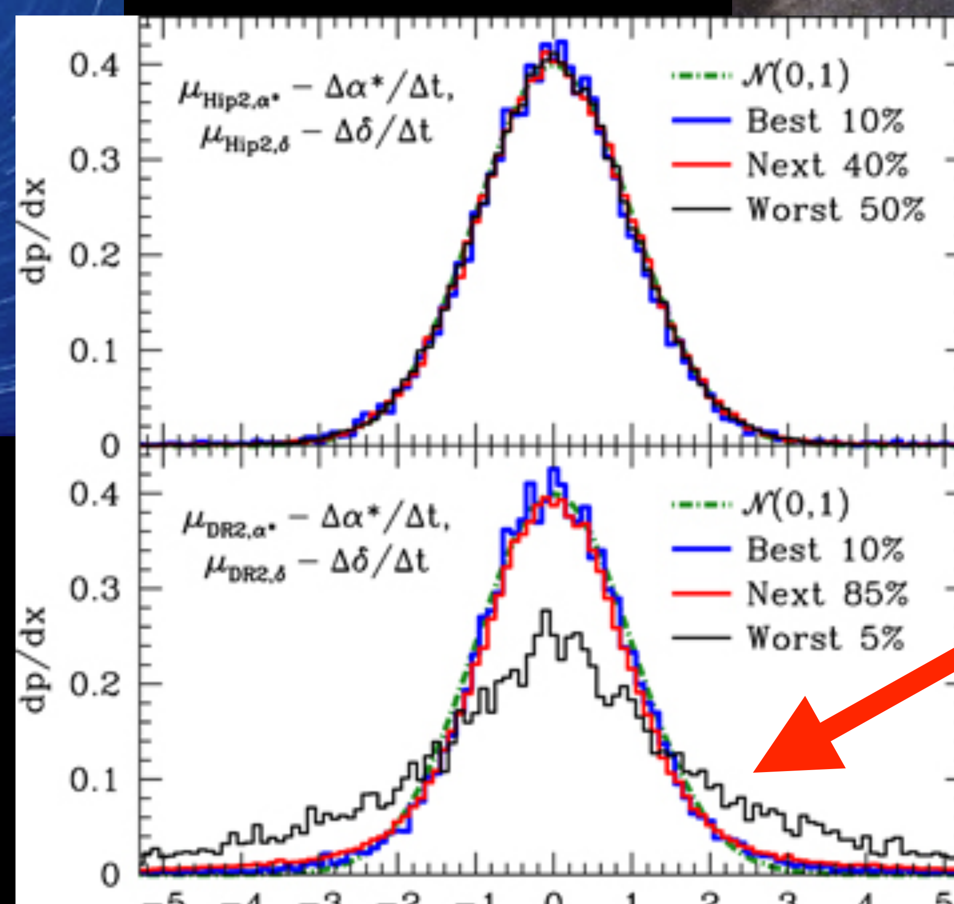

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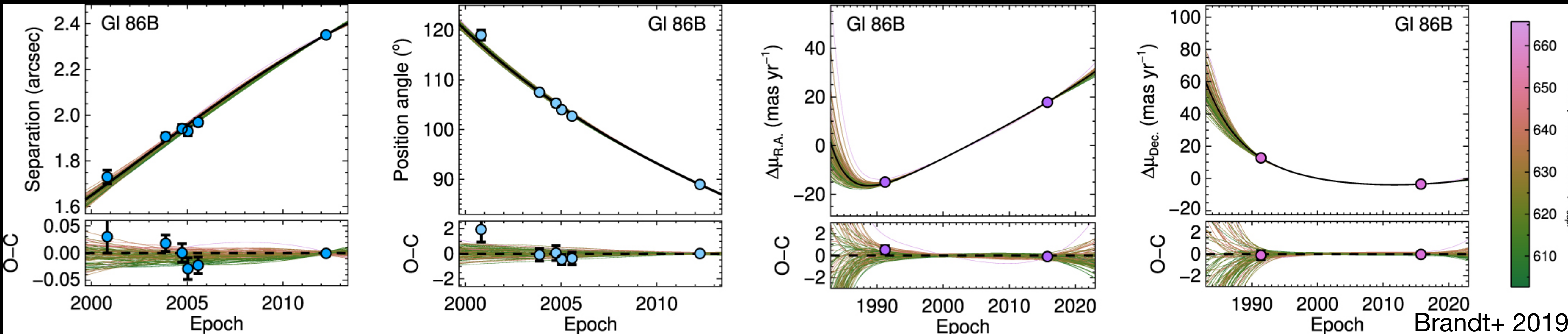
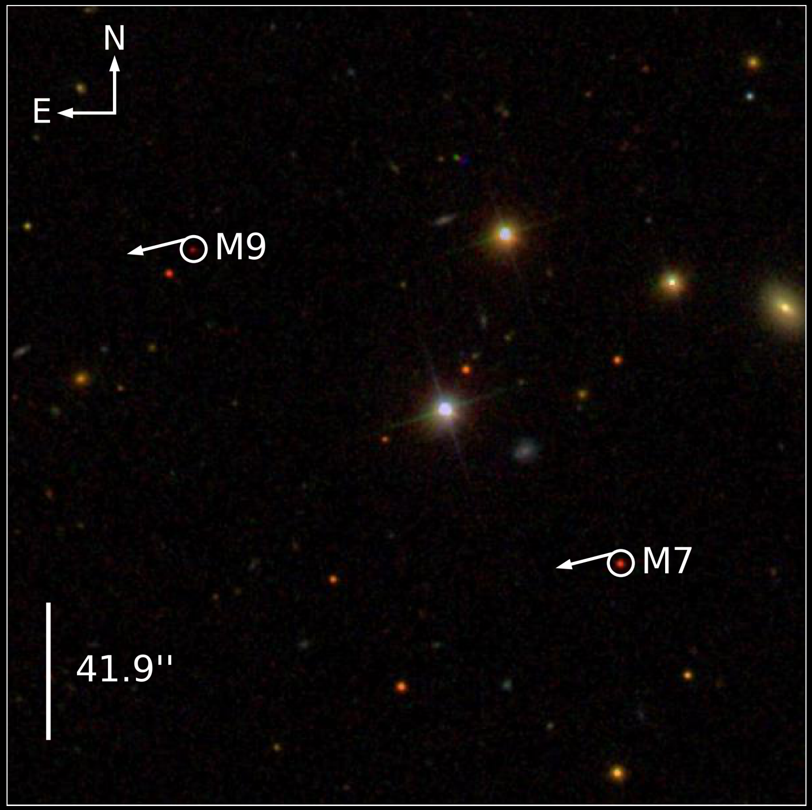
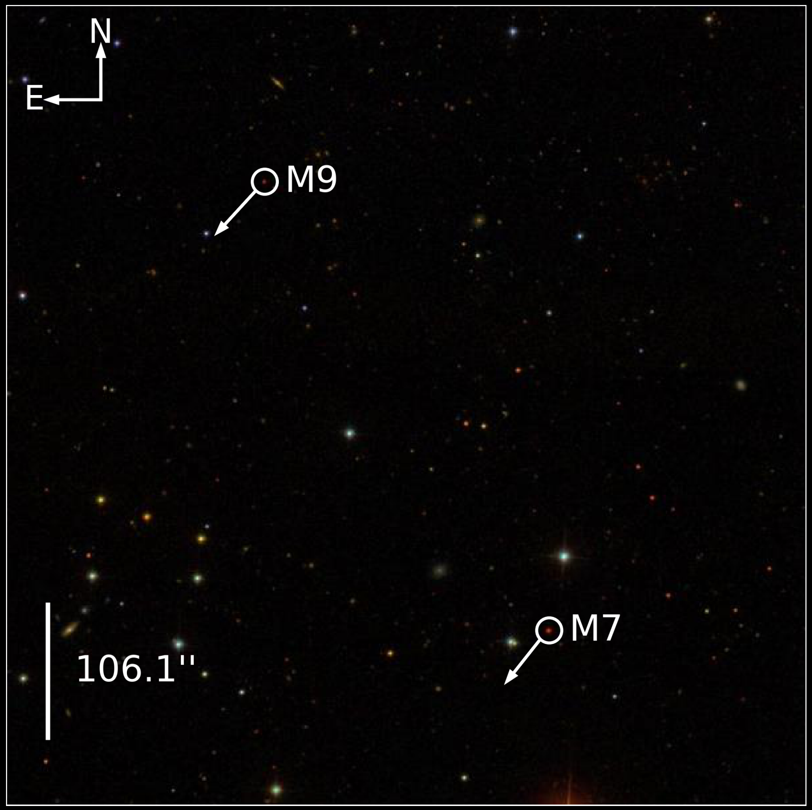
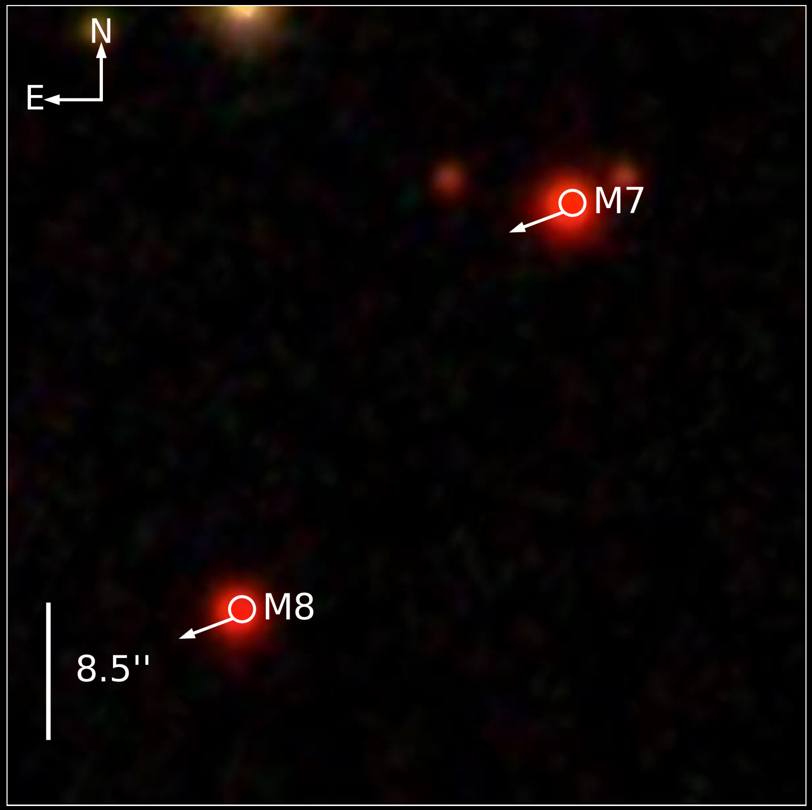


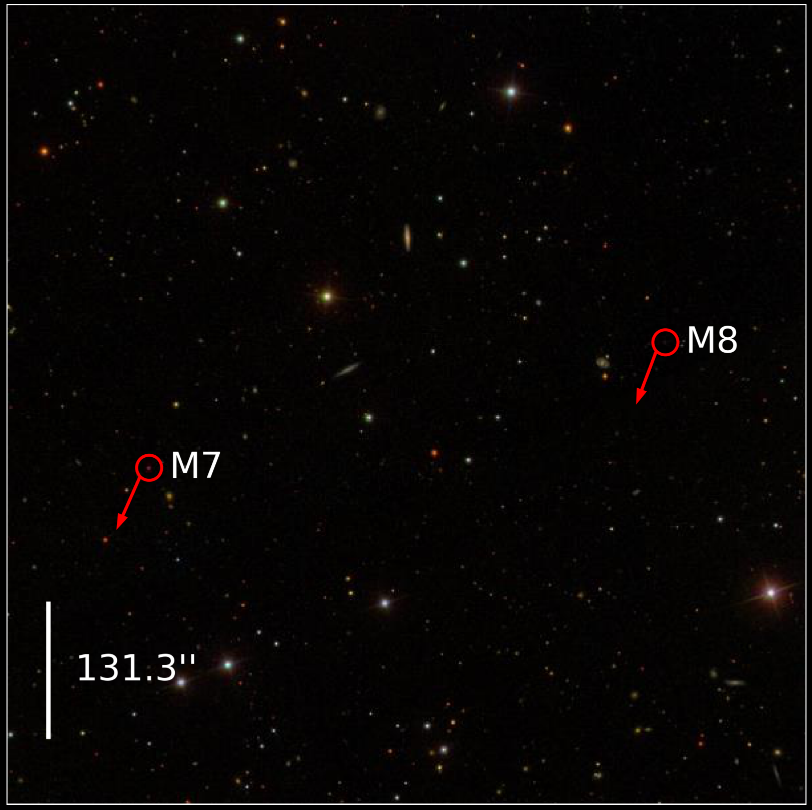
Property	Median $\pm 1\sigma$	95.4% c.i.	Prior
Fitted parameters			
Companion mass M_{comp} (M_{Jup})	625 ± 11	603, 648	$1/M$ (log-flat)
Host-star mass M_{host} ($M_\odot$)	$1.39^{+0.24}_{-0.23}$	0.92, 1.88	$1/M$ (log-flat)
Parallax (mas)	$92.72^{+0.05}_{-0.04}$	92.63, 92.81	$\exp[-0.5((\varpi - \varpi_{DR2})/\sigma[\varpi_{DR2}])^2]$
Semimajor axis a (au)	$21.7^{+0.5}_{-0.7}$	20.6, 23.3	$1/a$ (log-flat)
Inclination i (°)	$125.4^{+0.9}_{-0.8}$	123.7, 127.0	$\sin(i)$, $0° < i < 180°$
$\sqrt{e}\,\sin\omega$	$-0.54^{+0.04}_{-0.05}$	−0.63, −0.43	uniform
$\sqrt{e}\,\cos\omega$	$0.488^{+0.014}_{-0.016}$	0.458, 0.523	uniform
Mean longitude at $t_{ref} = 2455197.5$ JD, λ_{ref} (°)	109^{+6}_{-5}	98, 120	uniform
PA of the ascending node Ω (°)	$232.2^{+1.7}_{-1.6}$	228.9, 235.5	uniform
Semiamplitude of Gl 86 b (m s^{-1})	$378.9^{+1.0}_{-1.1}$	376.8, 381.1	$1/K_1$ (log-flat)
Orbital period of Gl 86 b P_{pl} (d)	15.76485 ± 0.00016	15.76453, 15.76518	$1/P_{pl}$ (log-flat)
Mean longitude of Gl 86 b at t_{ref} $\lambda_{ref,plx}$ (°)	252.3 ± 0.6	251.0, 253.6	uniform
$\sqrt{e_{pl}}\,\sin\omega_{pl}$	$-0.223^{+0.006}_{-0.007}$	−0.235, −0.209	uniform
$\sqrt{e_{pl}}\,\cos\omega_{pl}$	$-0.001^{+0.019}_{-0.017}$	−0.037, 0.035	uniform
RV zero-point (m s^{-1})	200 ± 40	120, 280	uniform
RV jitter σ (m s^{-1})	$0.00029^{+0.06732}_{-0.00029}$	0.00000, 3.75636	$1/\sigma$ (log-flat)
Computed properties			
Orbital period P (yr)	72^{+6}_{-8}	59, 910	…
Semimajor axis (mas)	2010^{+50}_{-70}	1910, 2170	…
Eccentricity e	$0.53^{+0.04}_{-0.03}$	0.45, 0.60	…
Argument of periastron ω (°)	$311.9^{+2.6}_{-3.4}$	306.4, 320.2	…
Time of periastron $T_0 = t_{ref} - P\frac{\lambda - \omega}{360°}$ (JD)	2469900^{+1800}_{-2300}	2466300, 2475400	…
Mass ratio $q = M_{comp}/M_{host}$	$0.43^{+0.06}_{-0.08}$	0.31, 0.61	…

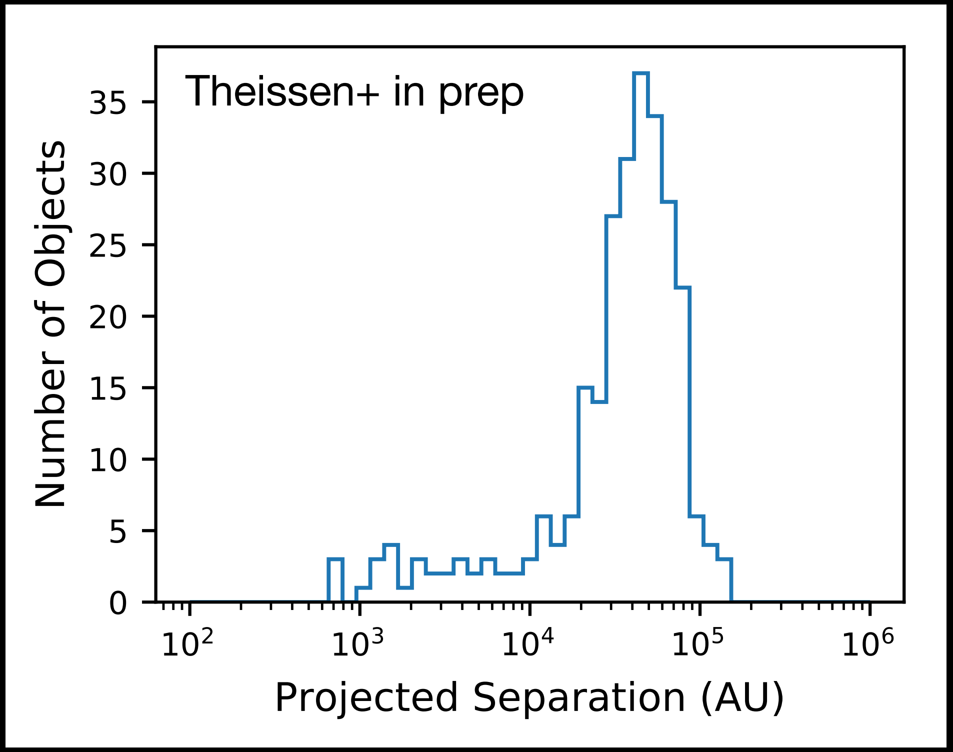
Wide (very low-mass) binaries in the field (>1000 au)

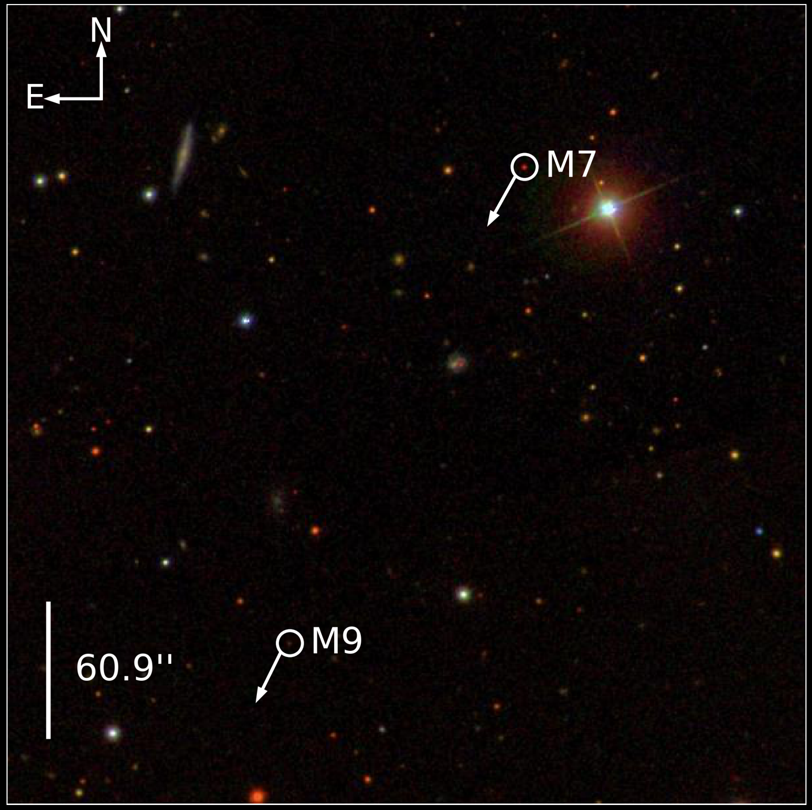




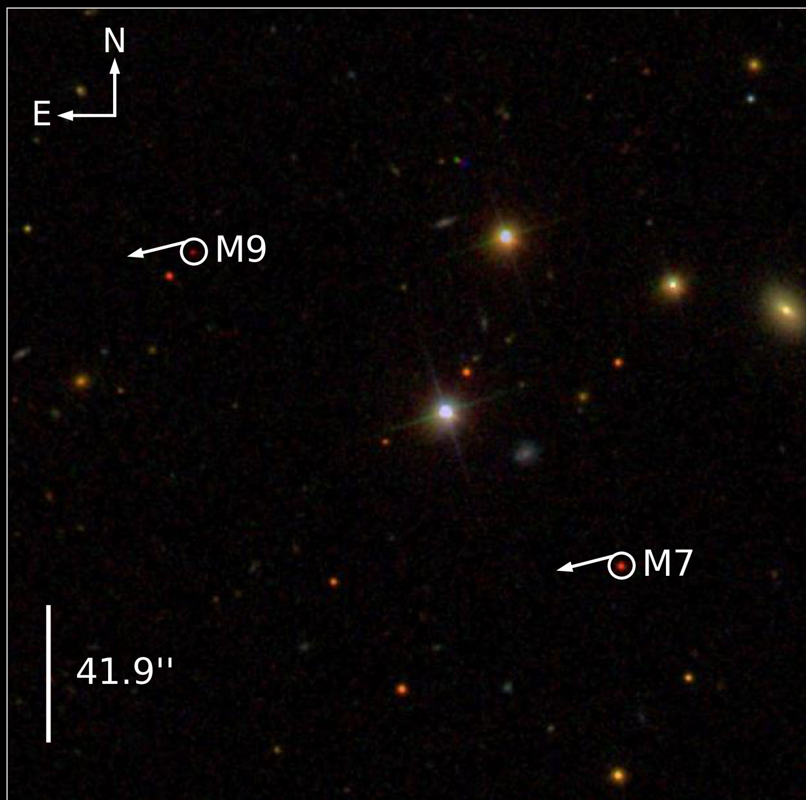


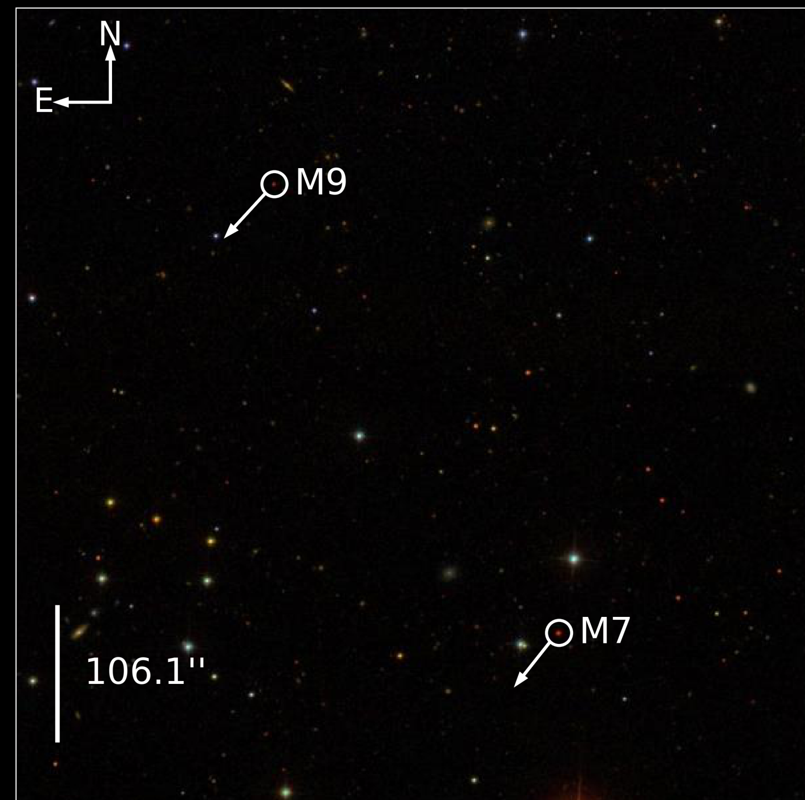


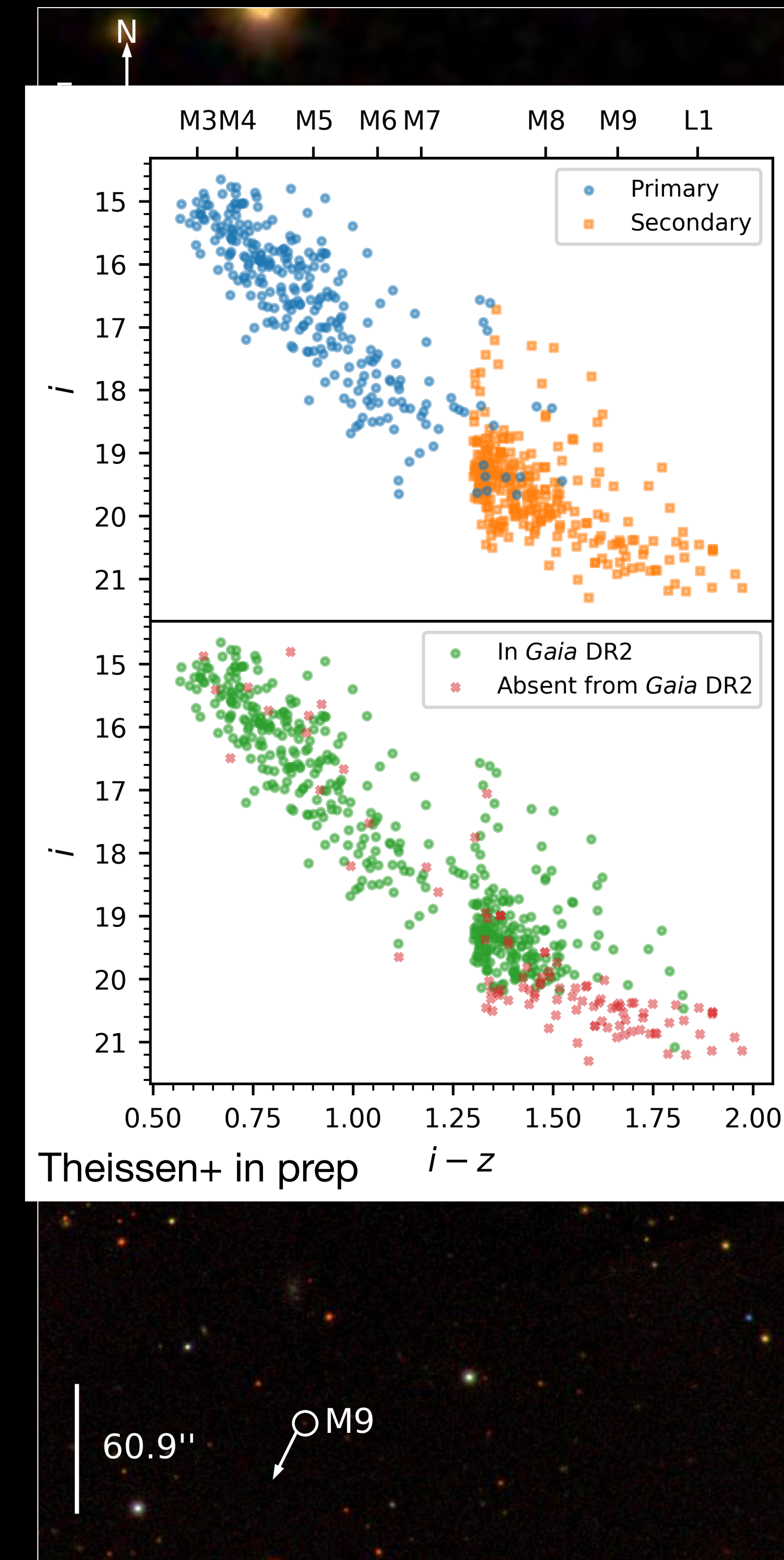


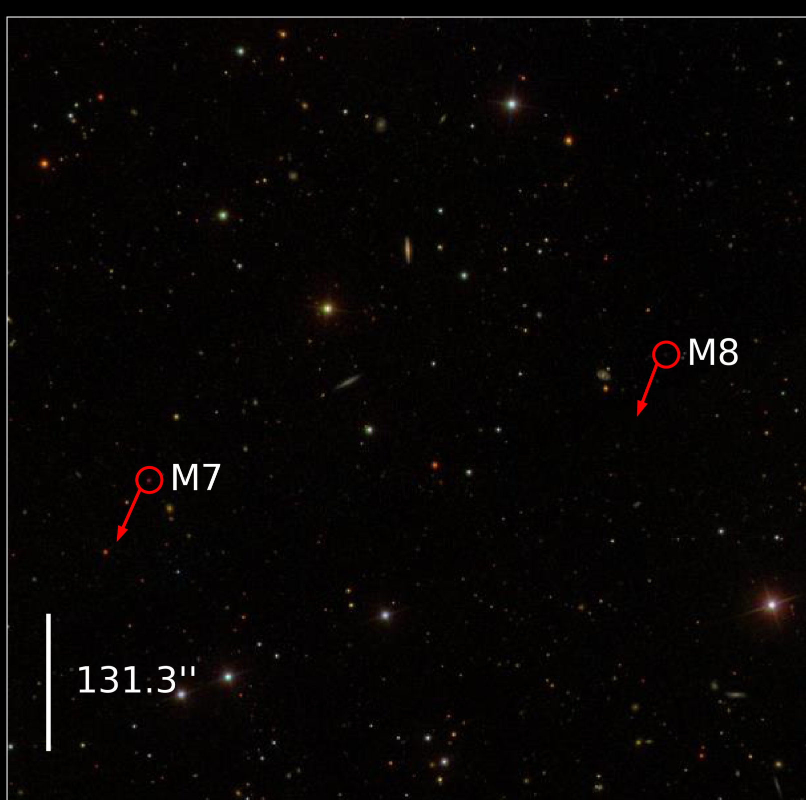


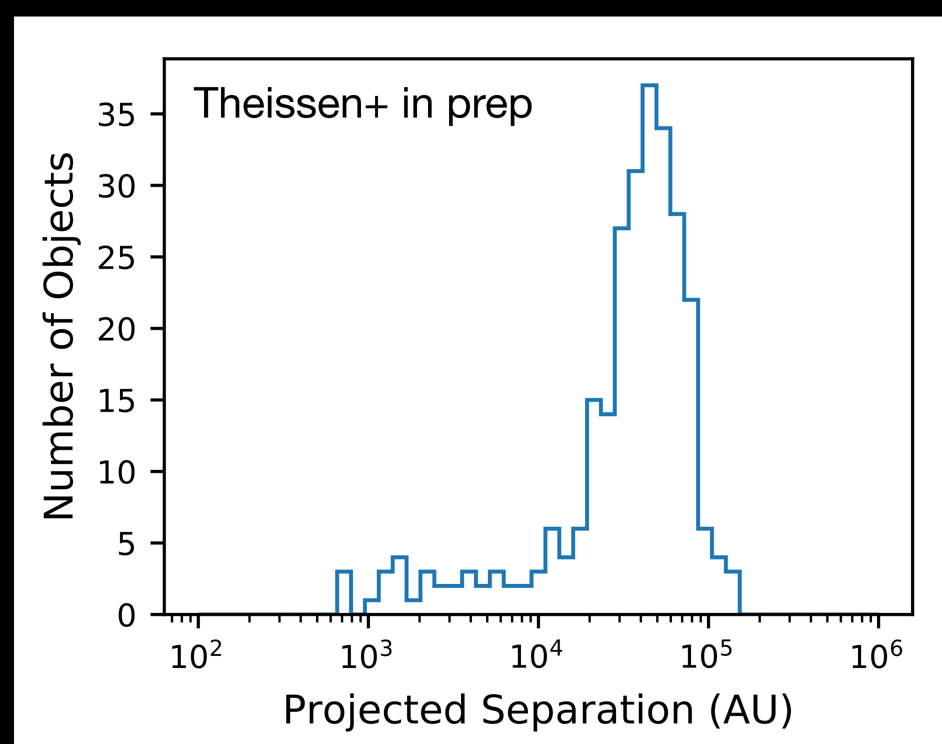
Wide (very low-mass) binaries in the field (>1000 au)



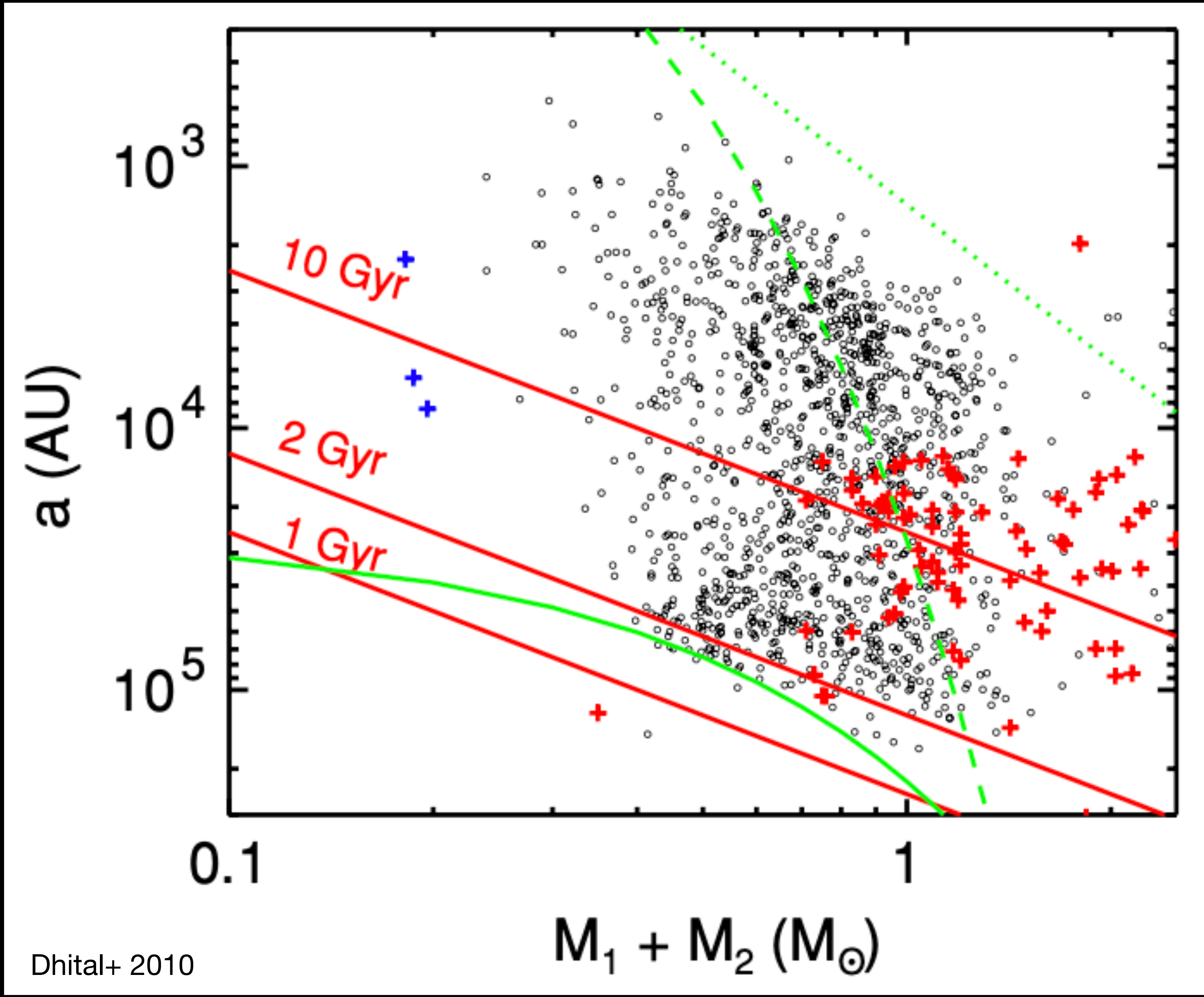








Why are wide binaries so wide? Binding energies



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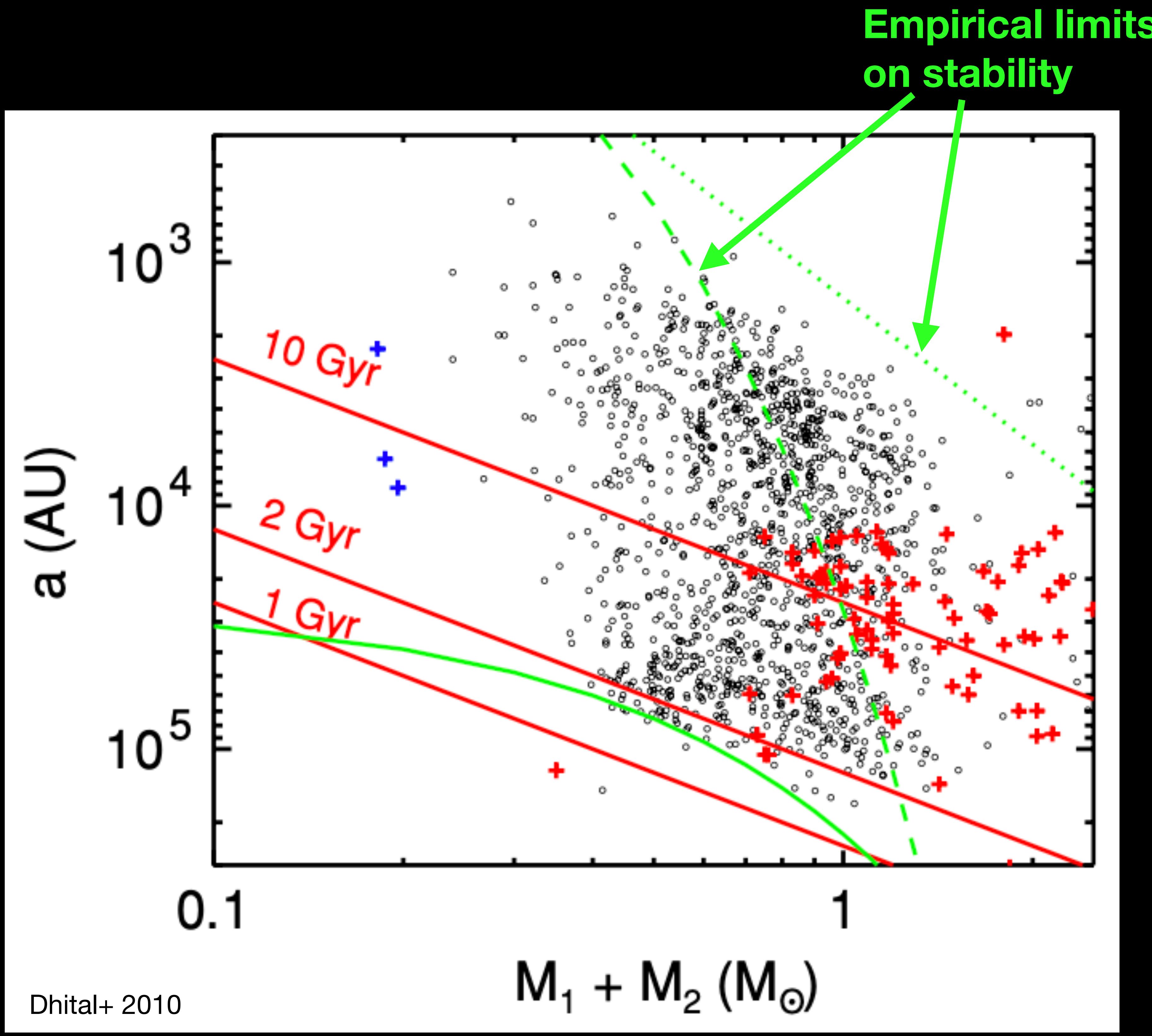

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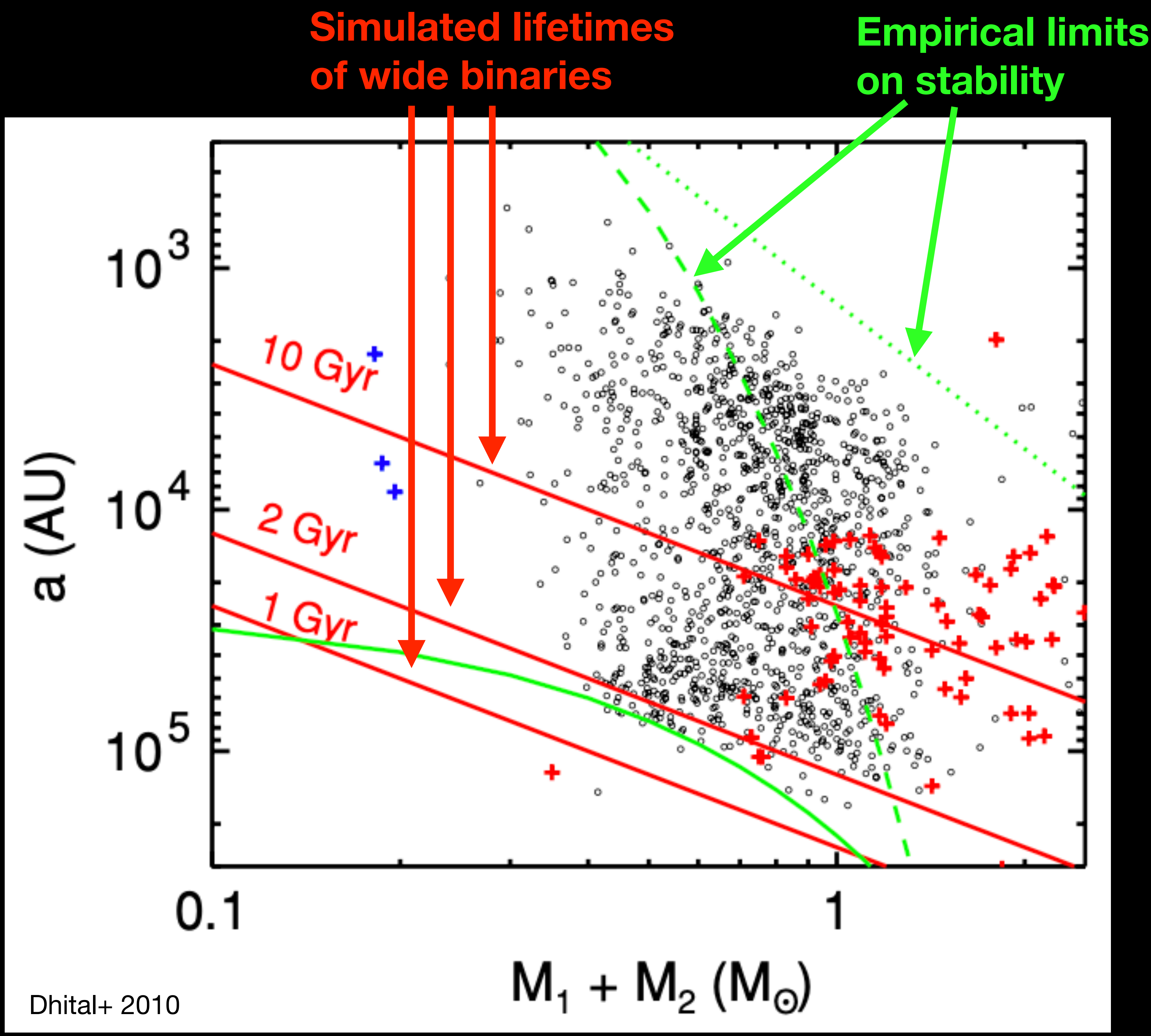
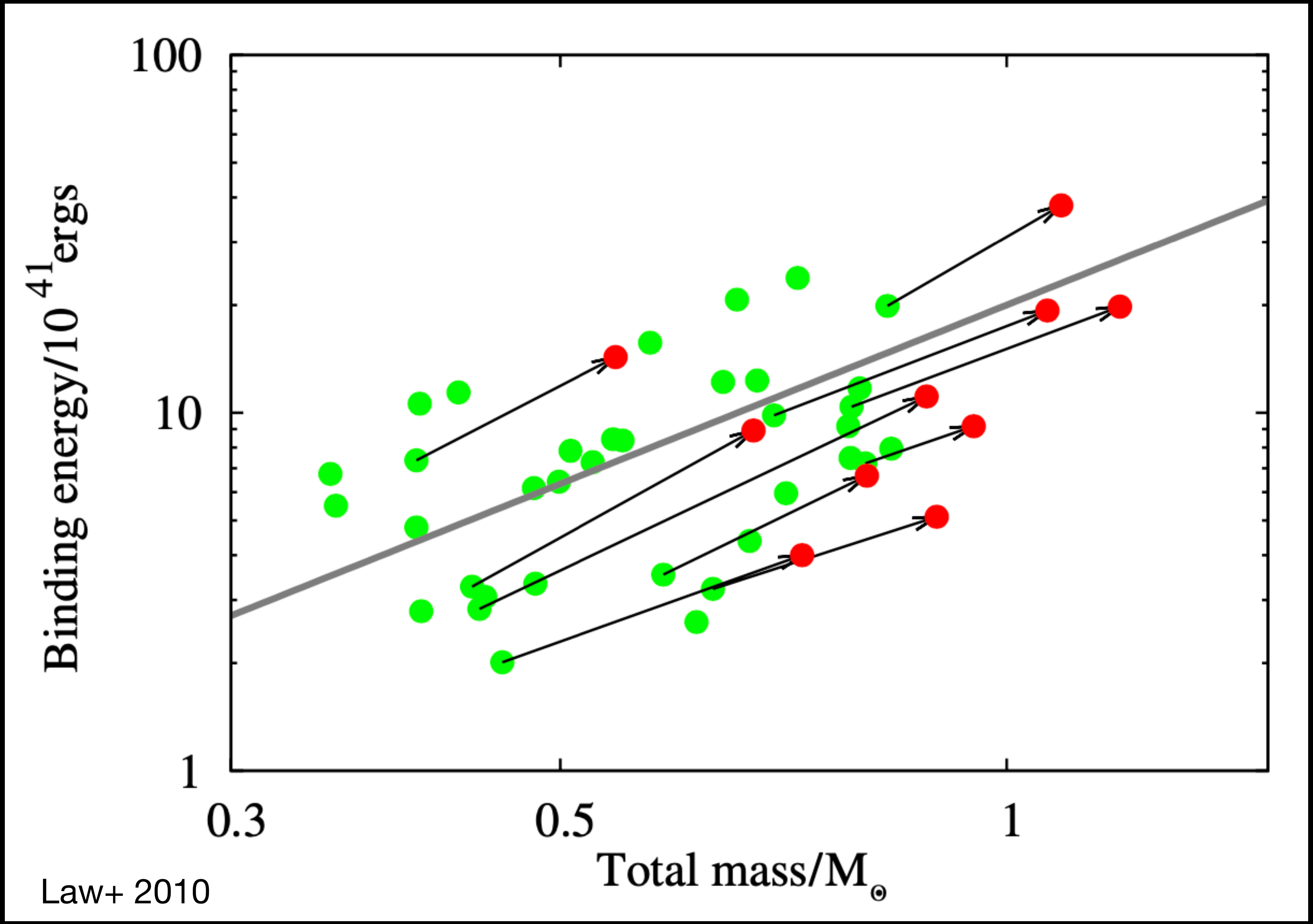


Why are wide binaries so wide?: binding energies

Hierarchical triple systems can resolve (some) binding energy issues



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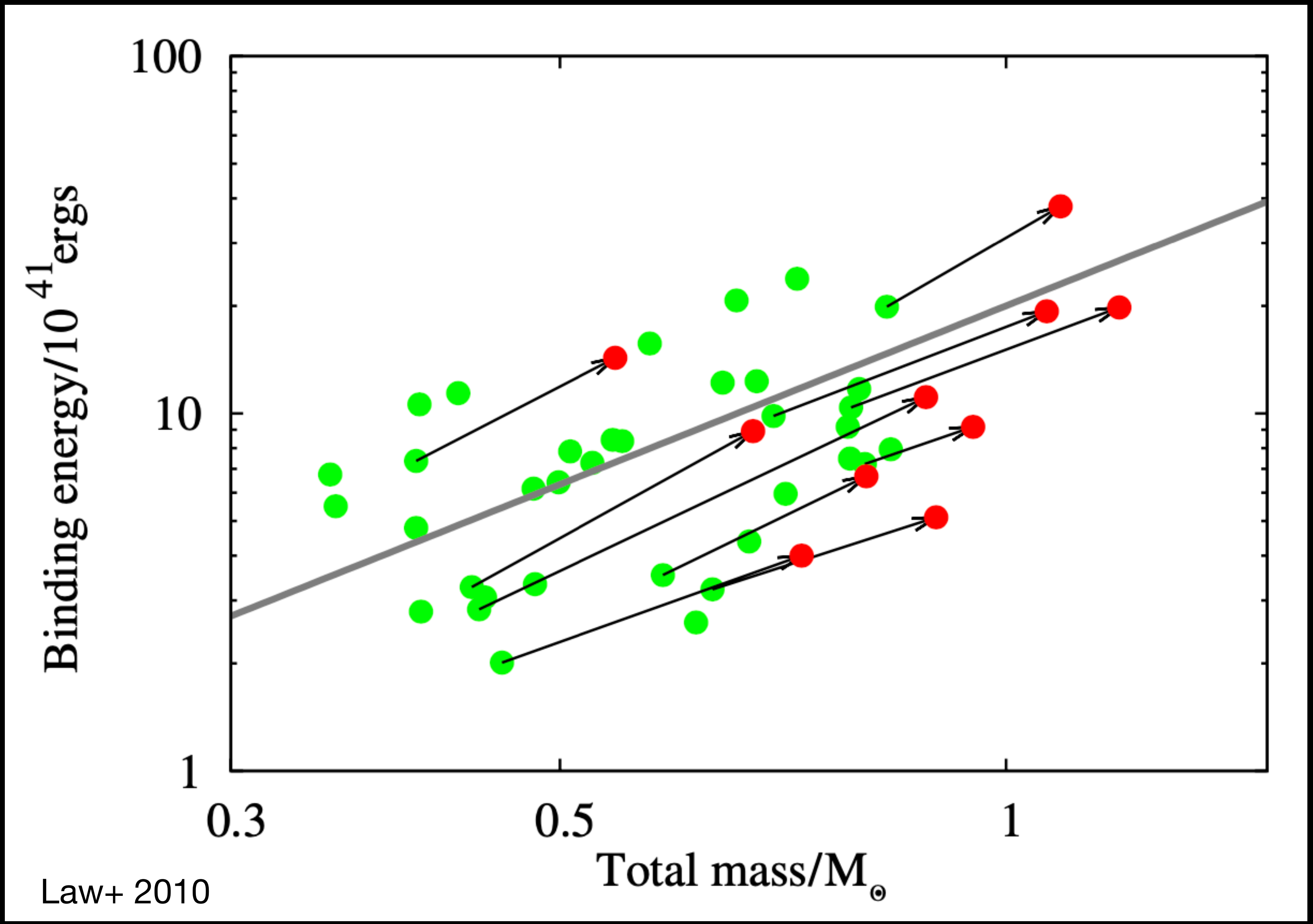

~50% of wide, early M dwarf (>M5) binaries were hierarchical triples!

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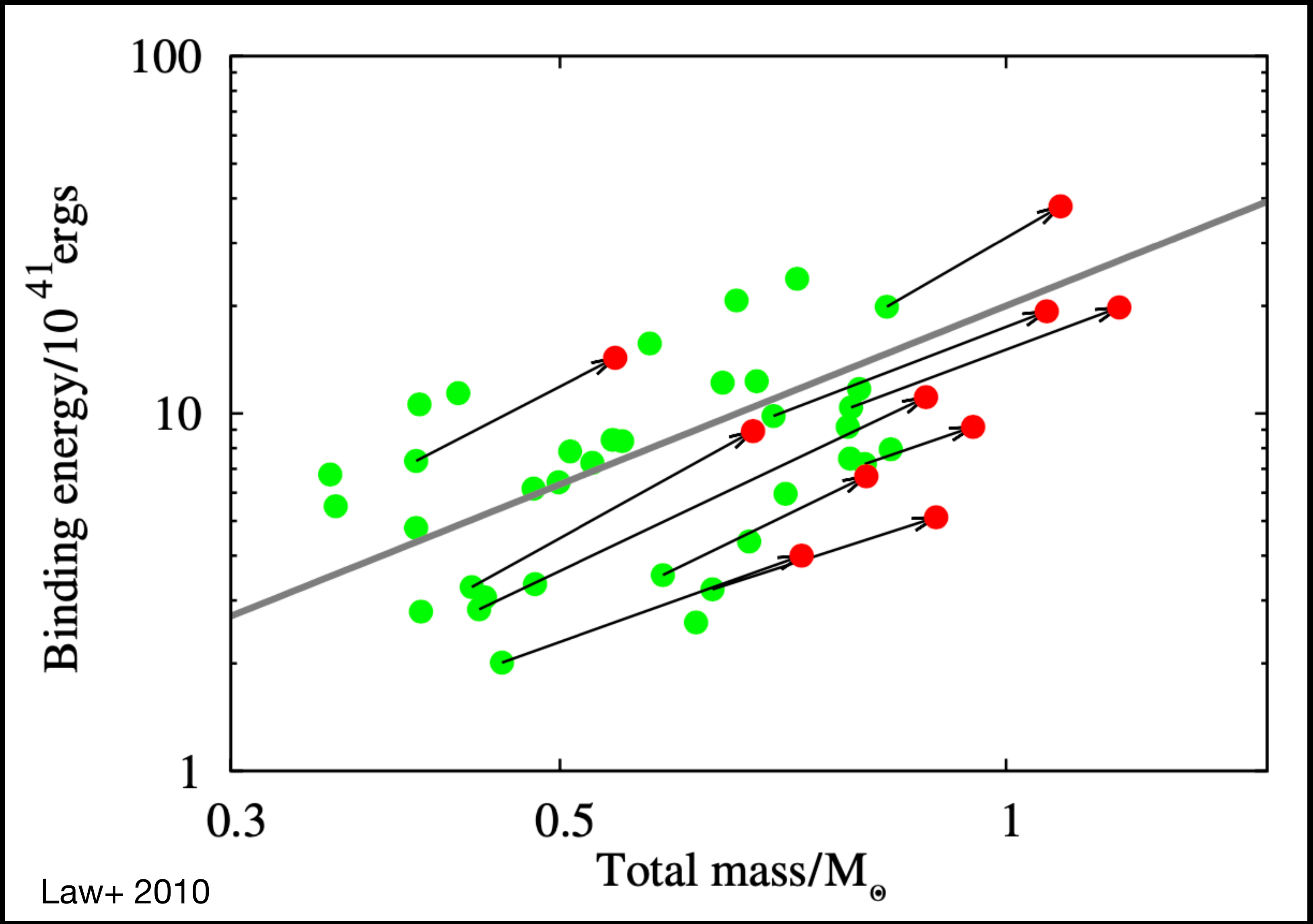
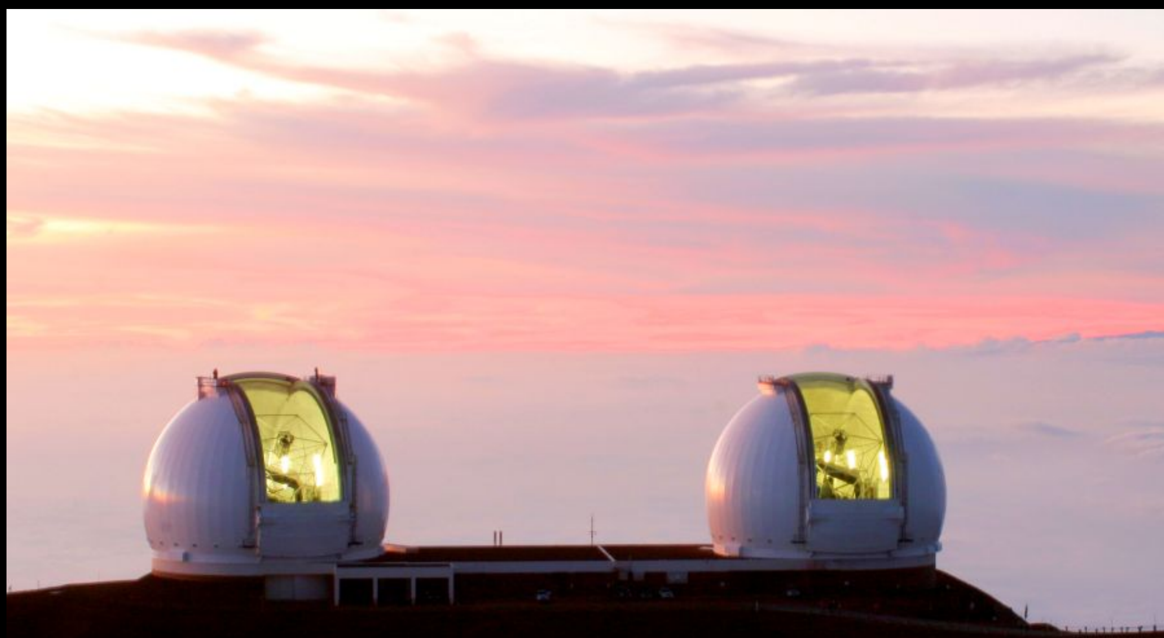


~50% of wide, early M dwarf (>M5) binaries were hierarchical triples!

Only 8-10 known very low-mass triples (M_{tot} < $0.3M_{sun}$)

Finding more triples: Facilities & Instruments

Keck 10-m



NIRES - Med-res NIR spectra
ESI - Med/High-res optical spectra
NIRSPEC - High-res spectra
*OSIRIS - NIR integral field spectra

NASA IRTF 3-m

SpeX - Low-res NIR spectra

Lick Shane 3-m

ShARCS -
AO NIR Imaging

*Proposed time

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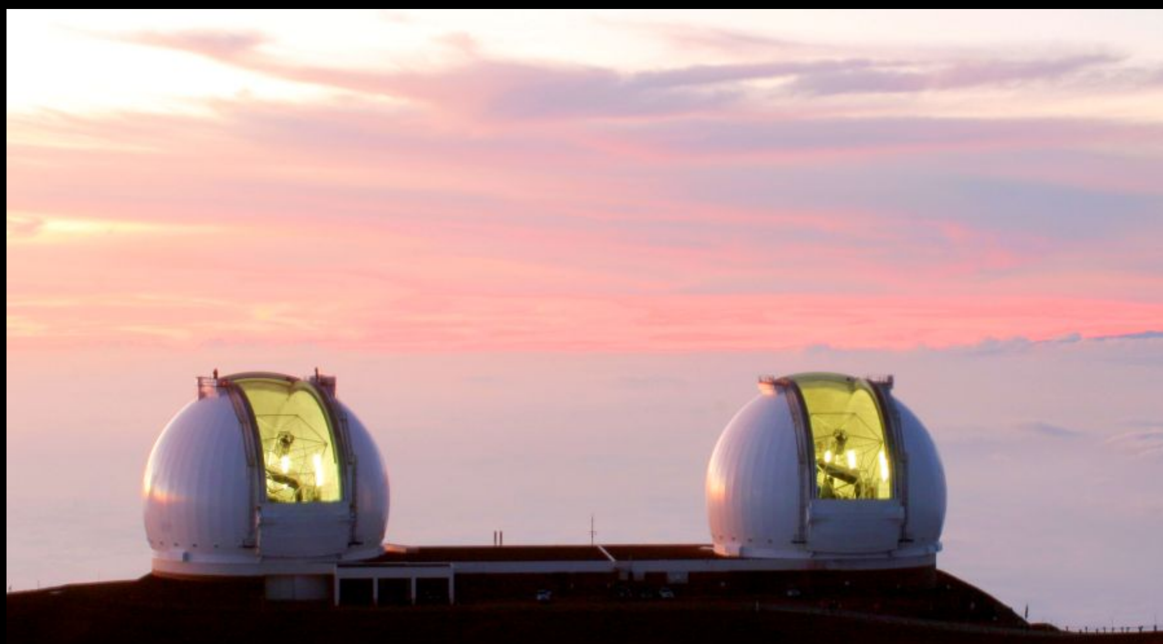

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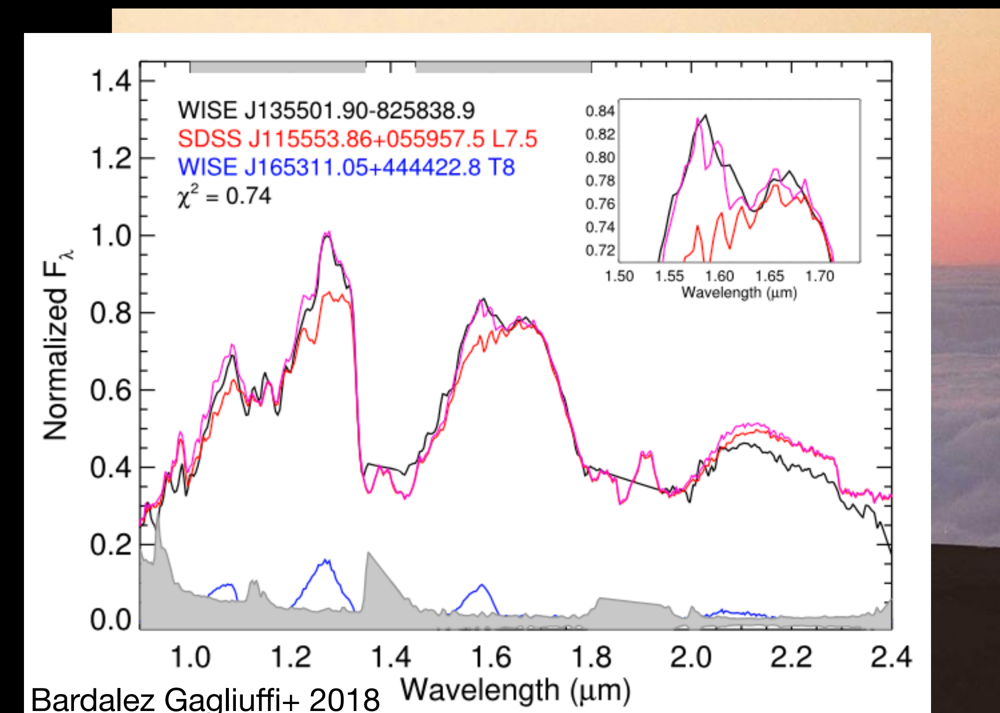

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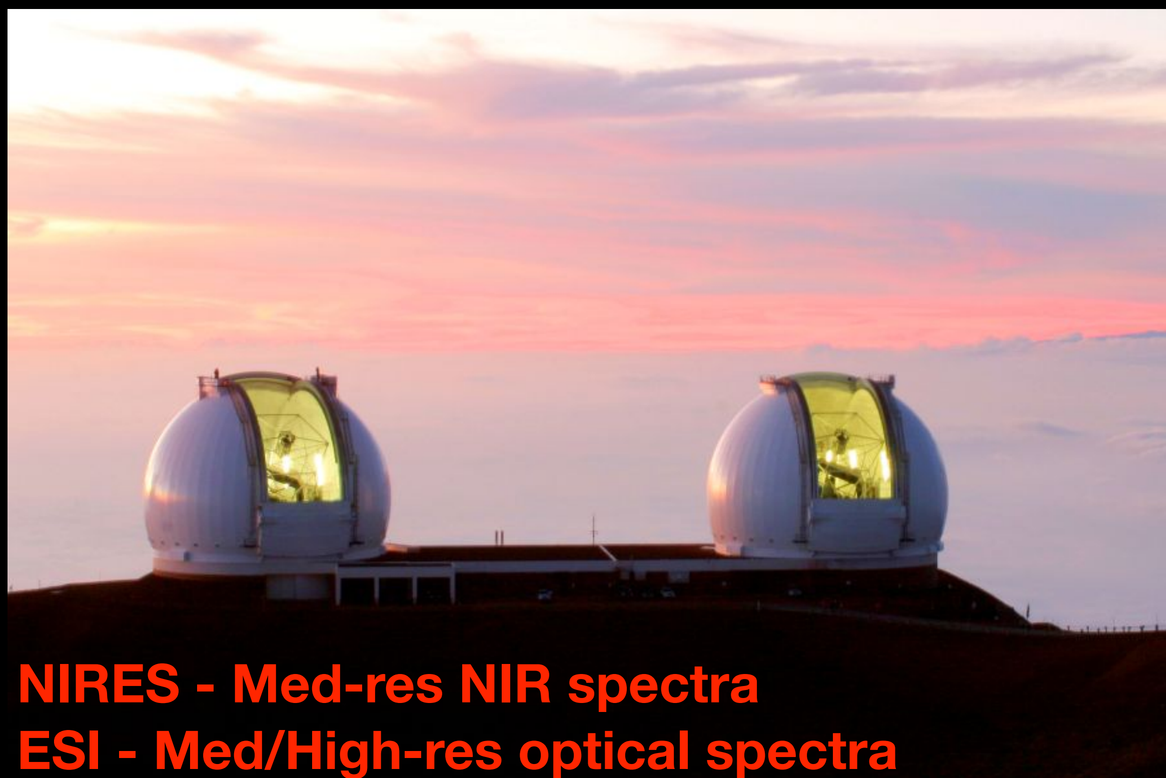

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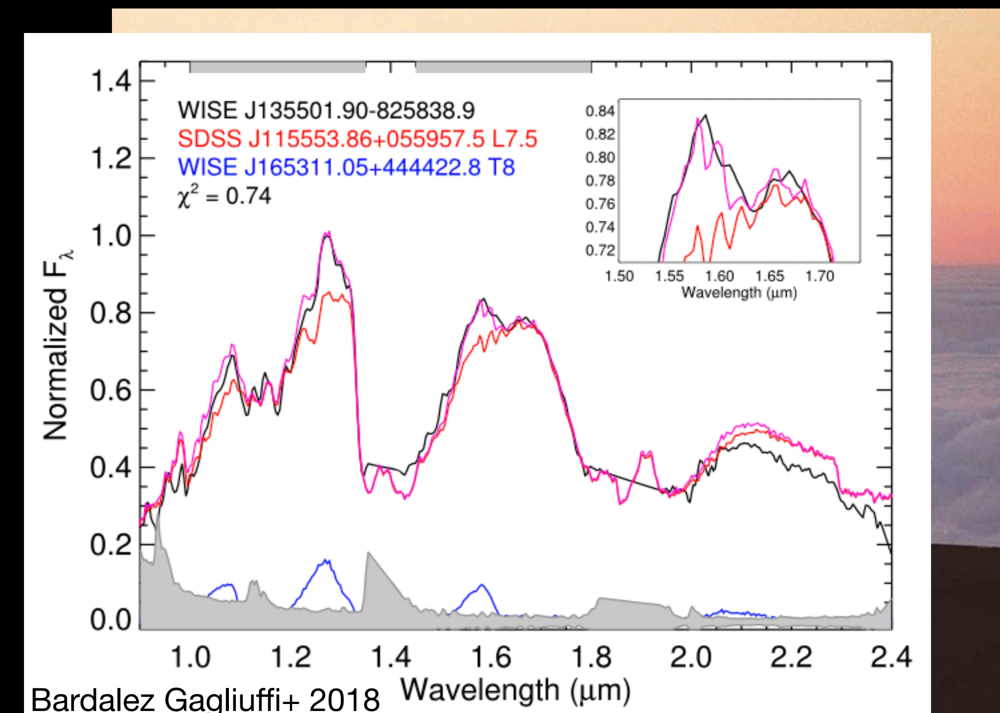

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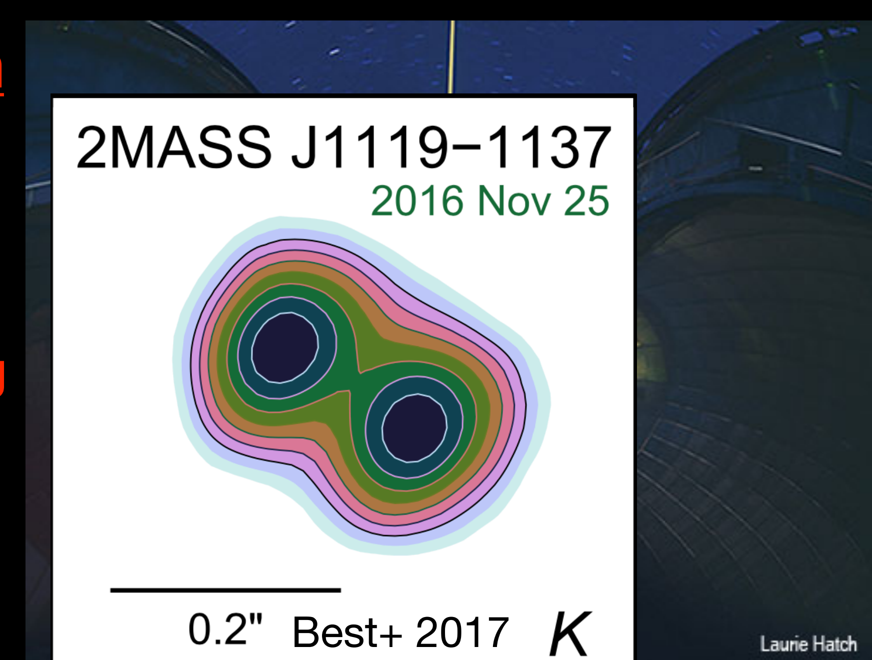

ShARCS -
AO NIR Imaging

***Proposed time**

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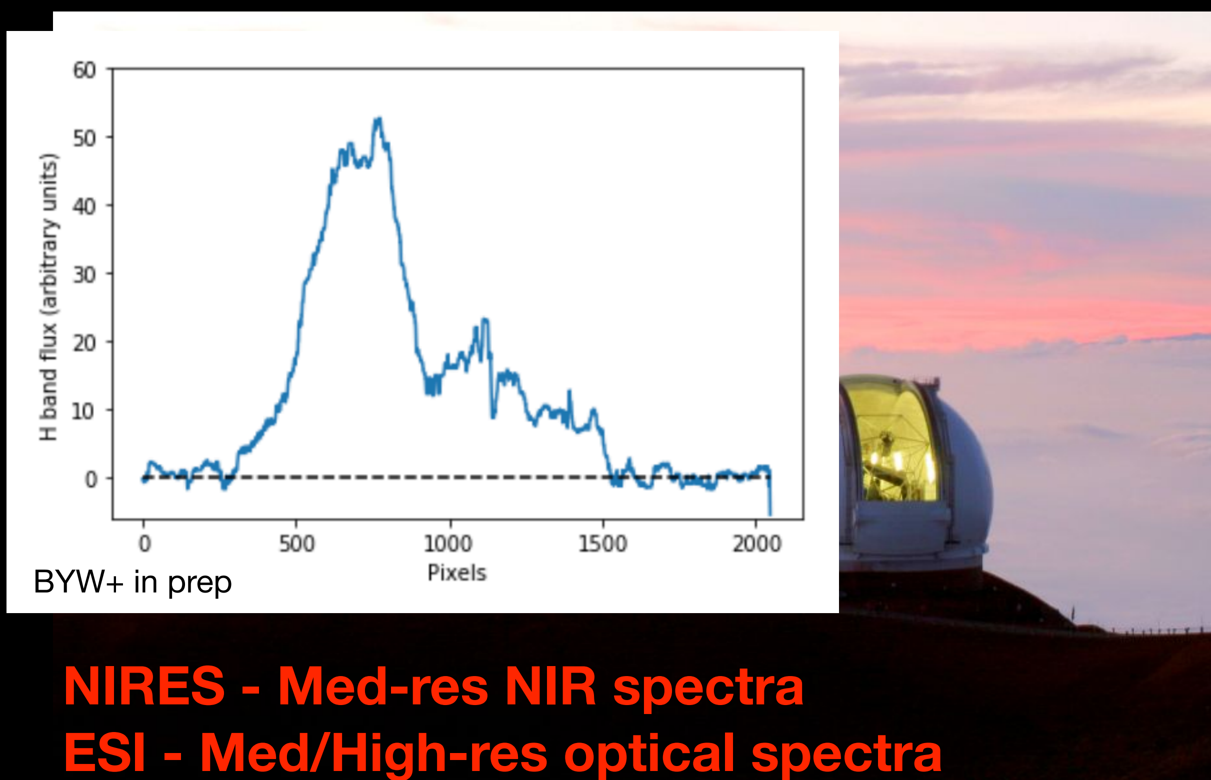

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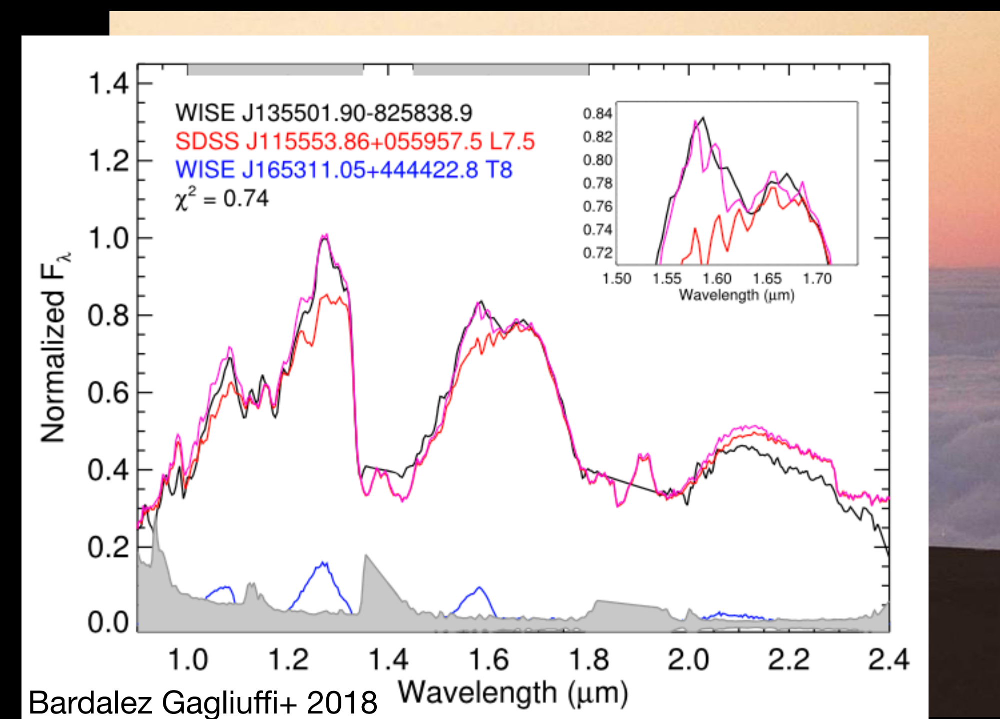

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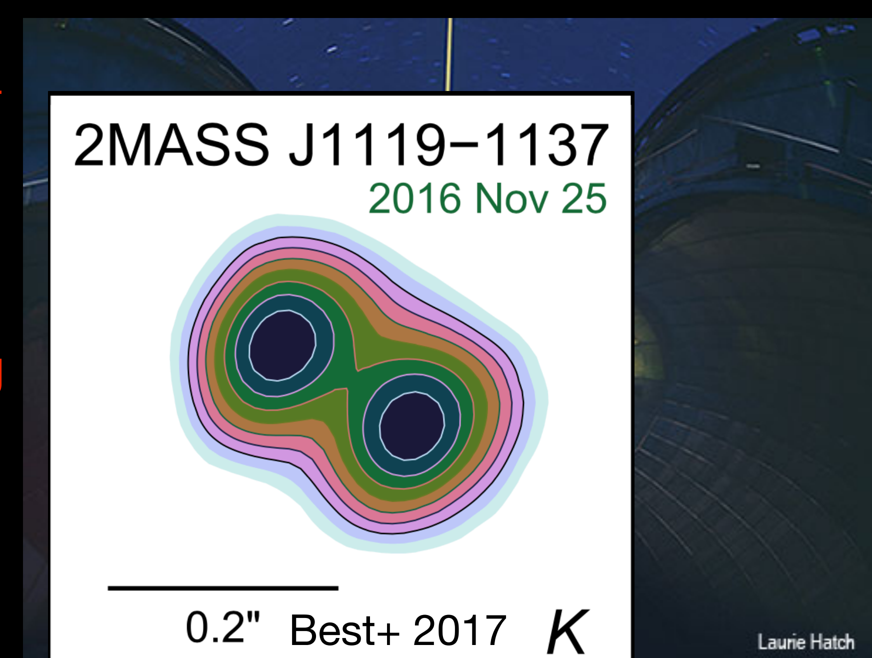

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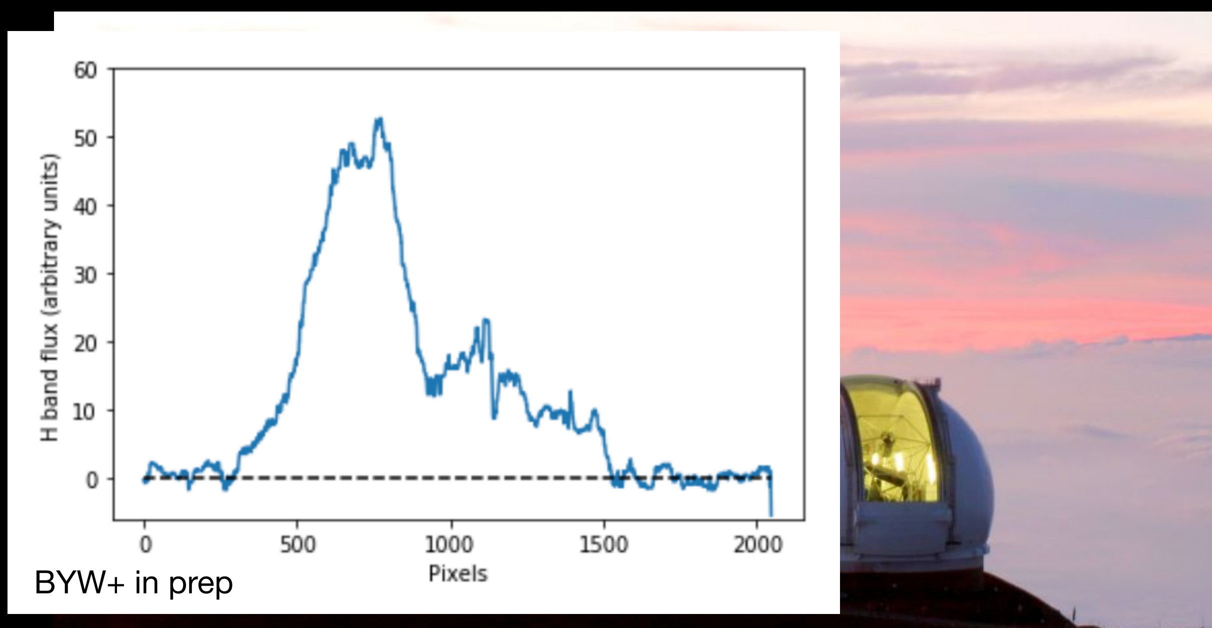

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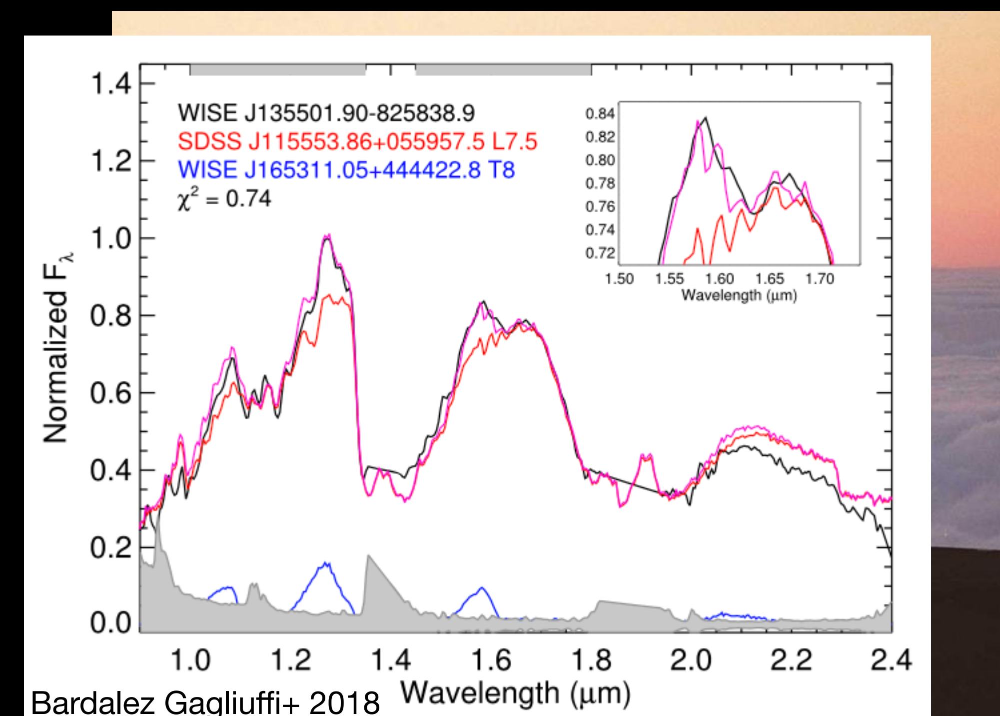
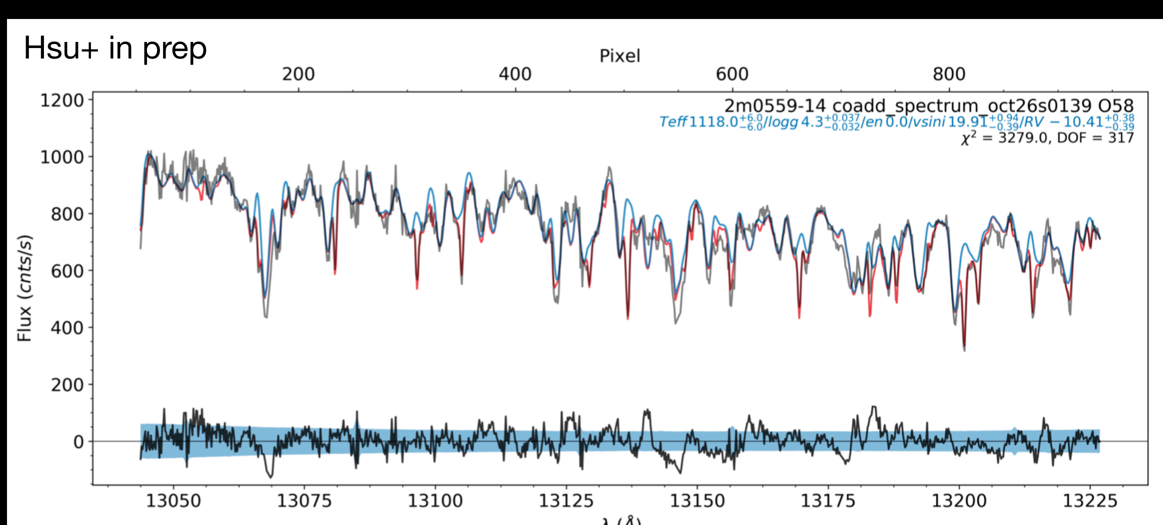
*OSIRIS - NIR integral field spectra

NASA IRTF 3-m

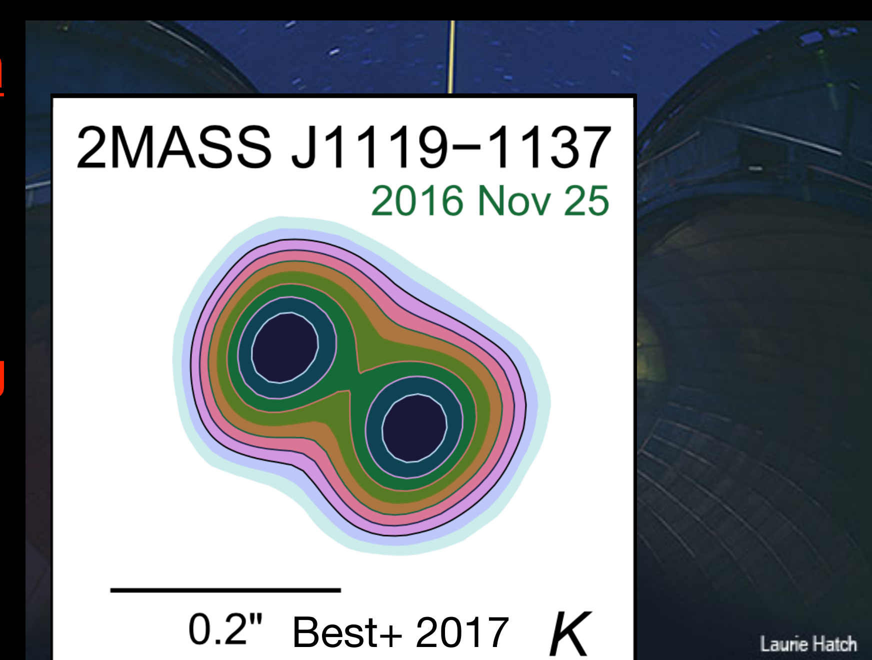


SpeX - Low-res NIR spectra



Lick Shane 3-m

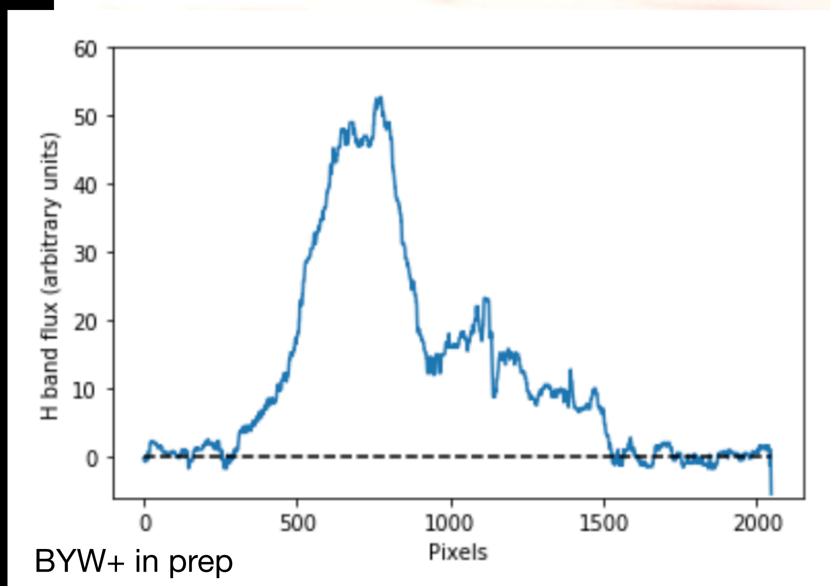
ShARCS -
AO NIR Imaging

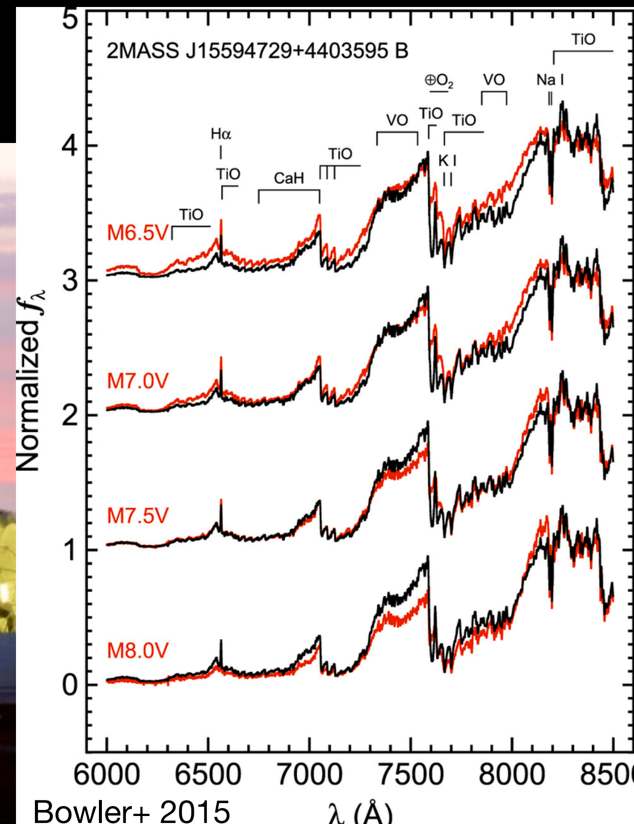


*Proposed time

Finding more triples: Facilities & Instruments

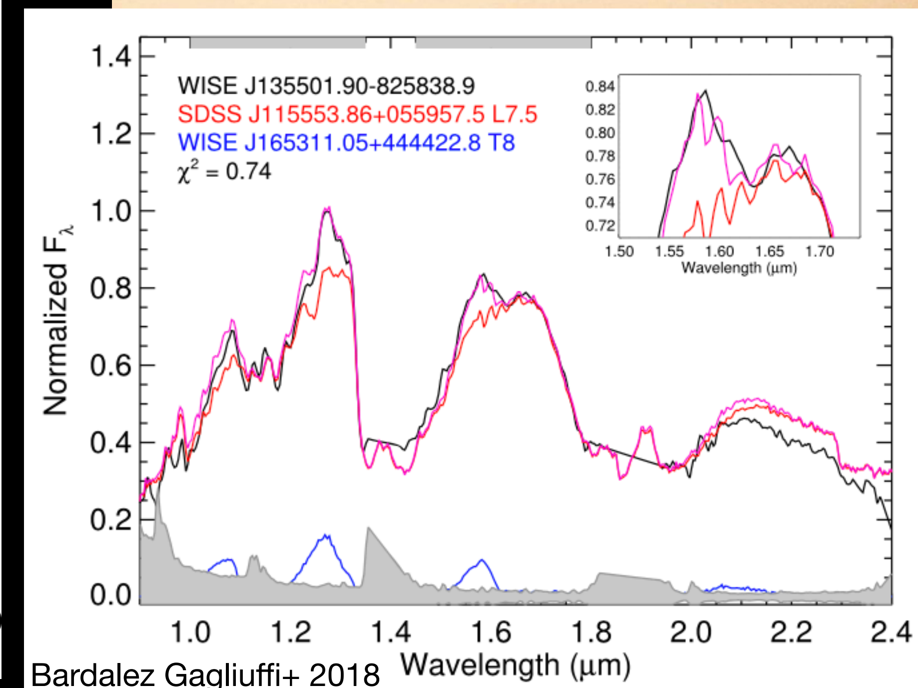
Keck 10-m



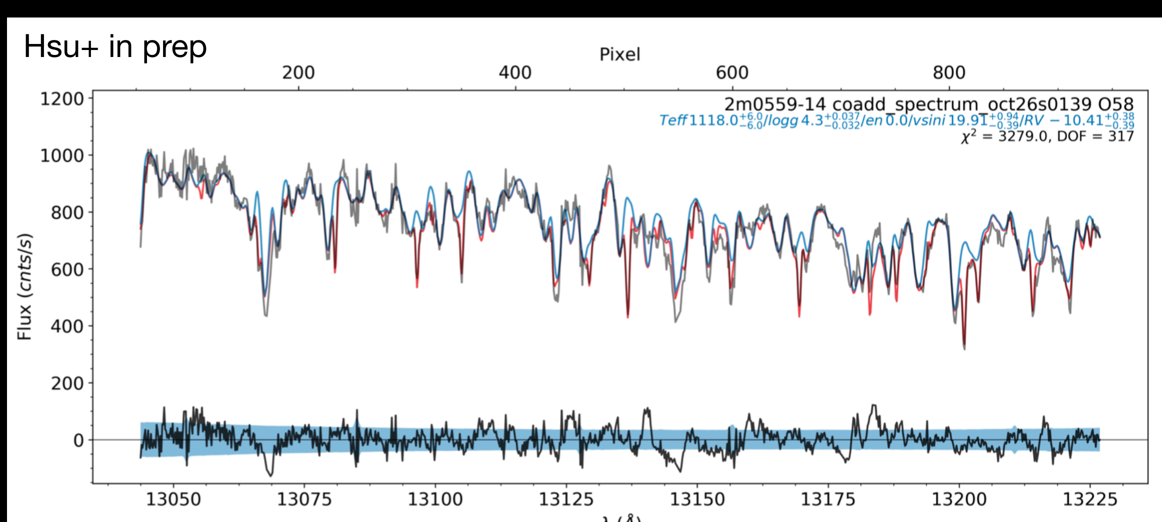


NIRES - Med-res NIR spectra
ESI - Med/High-res optical spectra
NIRSPEC - High-res spectra
***OSIRIS - NIR integral field spectra**

NASA IRTF 3-m

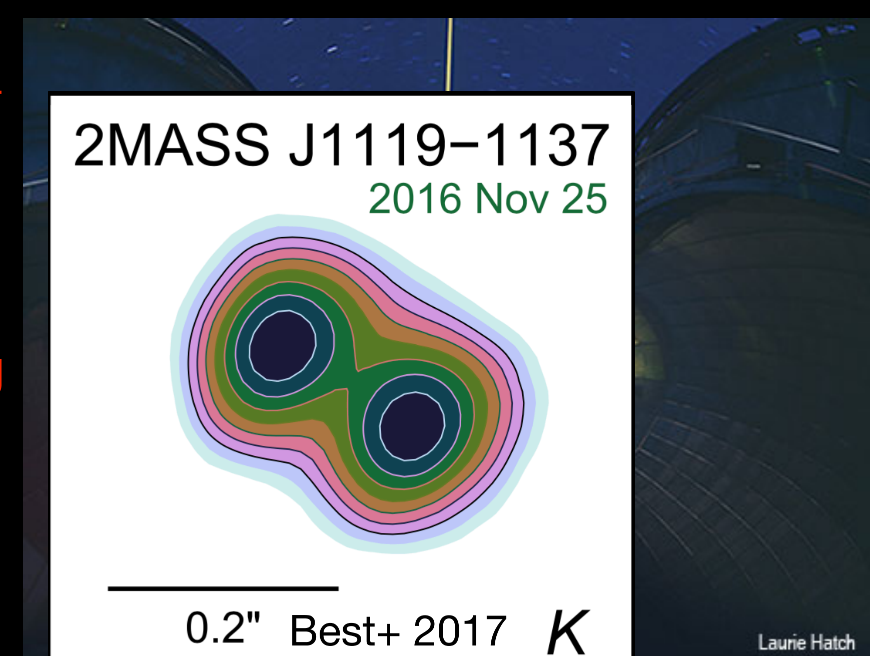


SpeX - Low-res NIR spectra



Lick Shane 3-m

ShARCS - AO NIR Imaging



***Proposed time**

New discoveries (almost) every day

Backyard Worlds discovery

White dwarf + T dwarf comoving system

Extremely useful project for searching the Zone of Avoidance

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Still looking for a good acronym

Many results forthcoming!

Thanks