Precise dynamical masses of new directly imaged companions by combining relative astrometry, radial velocities, and Hipparcos-Gaia eDR3 accelerations

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What is the occurrence rate of long period planets, brown dwarfs and low mass stellar companions?

How do these objects form?

What does the mass-luminosity-age relation of brown dwarfs and low mass stellar companions look like?

Test atmospheric models of giant gaseous planets and brown dwarfs

NASA Exoplanet Exploration Program Science Gap List

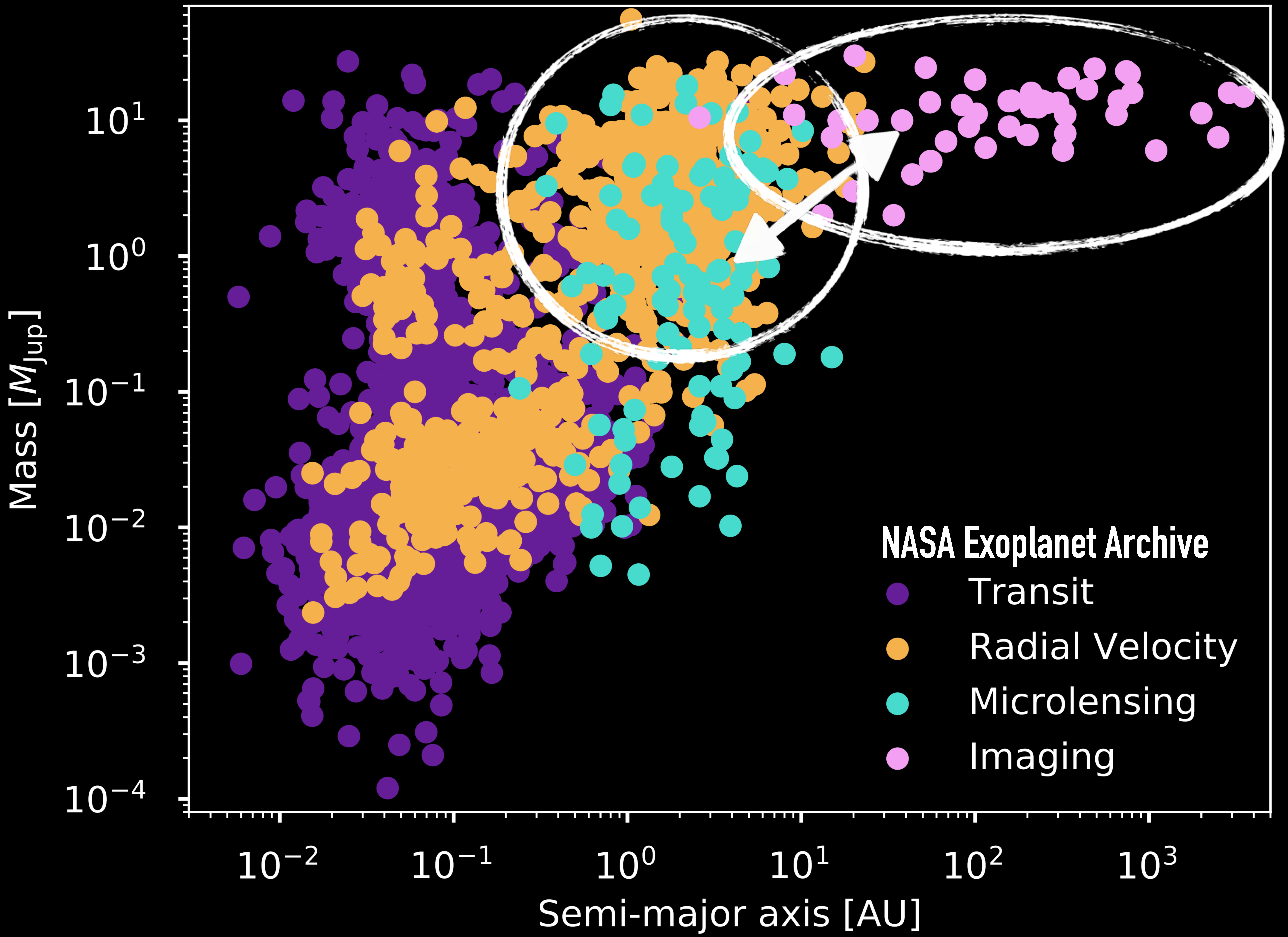
SCI-10: Precursor observations of direct imaging targets

“Precursor observations benefit future exoplanet missions by:

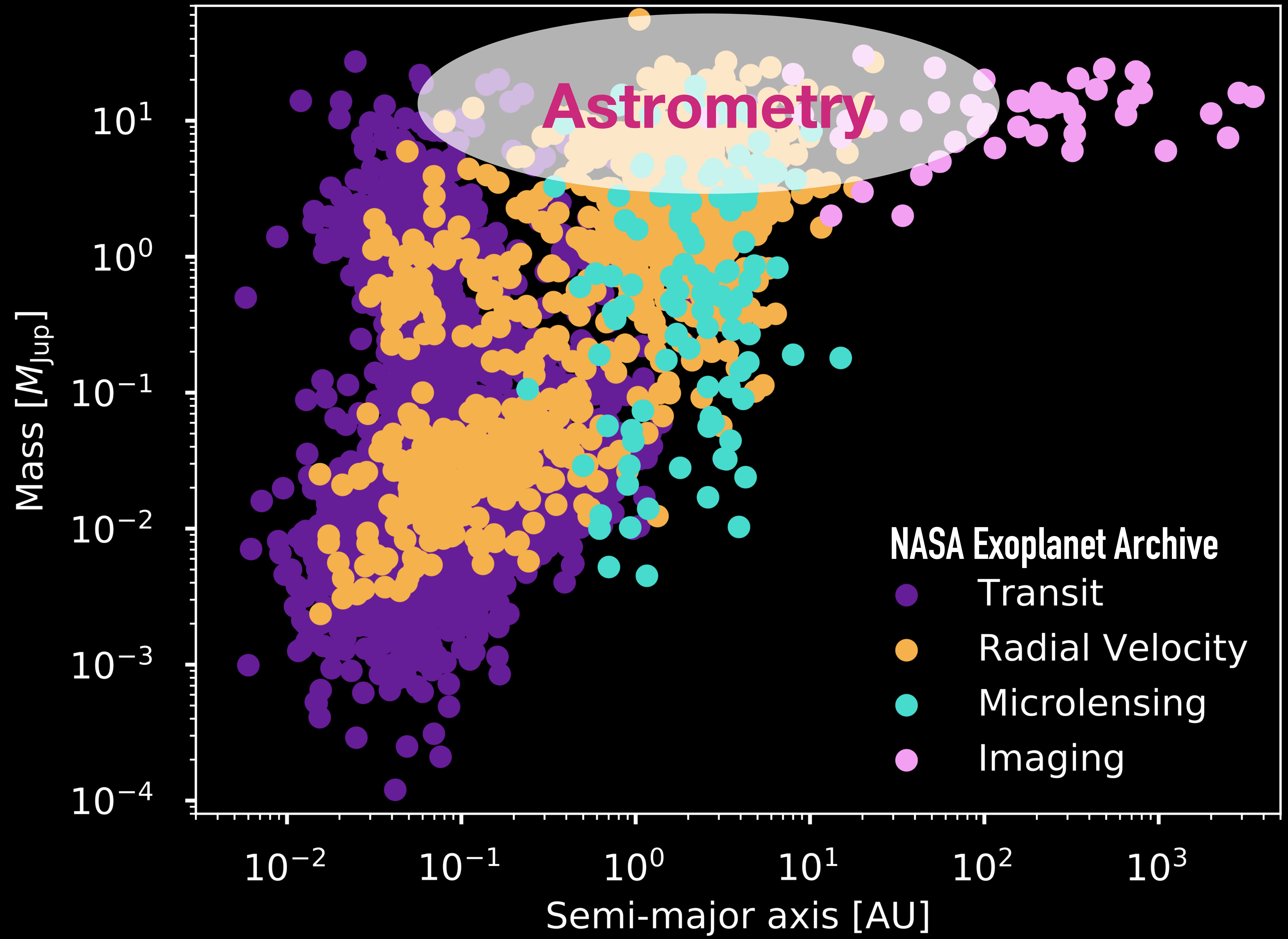
*1) **screening** for confusing background sources and close-in, low mass stellar and substellar companions that might compromise exoplanet imaging sensitivity;*

*2) **detecting exoplanets** for future characterization, or setting observational and/or dynamical limits on their presence;*

*3) **measuring stellar physical properties**, chemical abundances and radiation environments to enable accurate planet characterization including interpretation of exoplanet spectra”*



NASA Exoplanet Archive
Transit
Radial Velocity
Microlensing
Imaging
Mass [$M_{\rm Jup}$]
Semi-major axis [AU]
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}


Astrometry
NASA Exoplanet Archive
Transit
Radial Velocity
Microlensing
Imaging
Mass [M_{Jup}]
Semi-major axis [AU]
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

Radial Velocities

Minimum mass

Orbital period

Direct Imaging

Spectral information

Astrometry

Dynamical masses

Comprehensive Characterization


CORALIE Survey
VLT/SPHERE
Hipparcos + Gaia
Comprehensive
Characterization

The CORALIE Survey

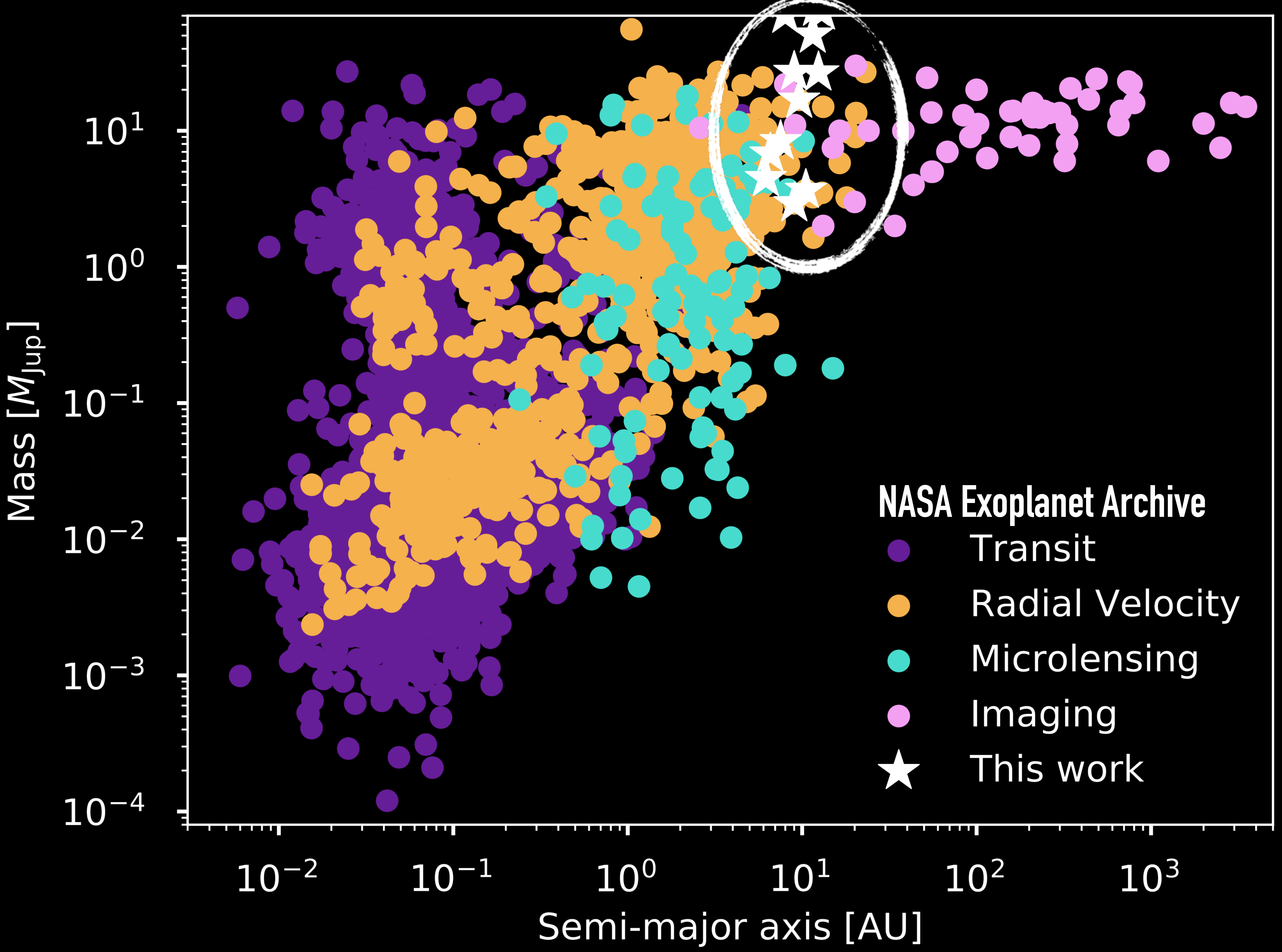
Contains 1647 main sequence G and K dwarfs

Radial velocity data from past ~20 years

50pc, solar type stars

Long term drifts hosting potential companions

Photo Credit: ESO



Mass [$M_{\rm Jup}$]
10^{1}
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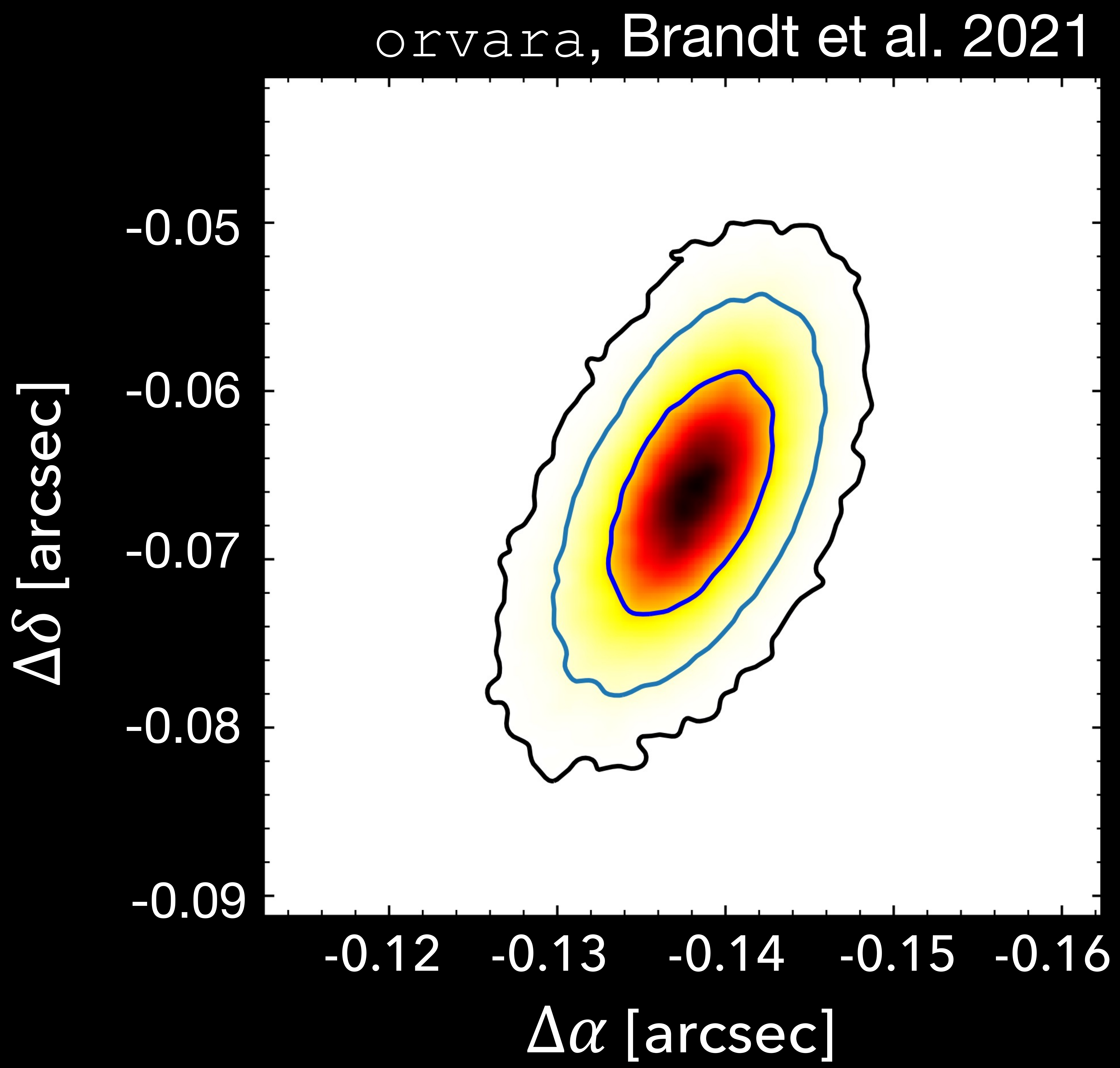
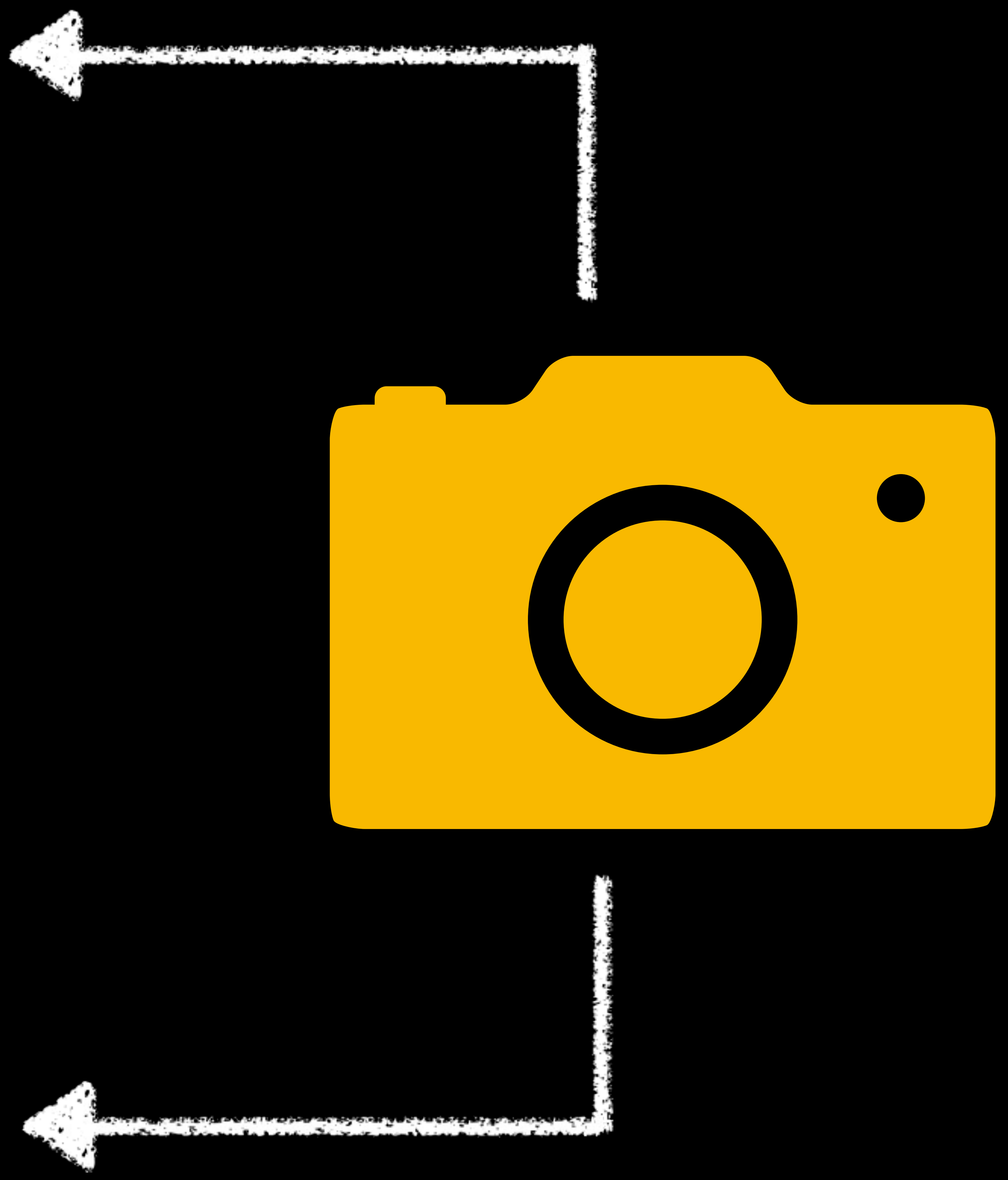
NASA Exoplanet Archive
Transit
Radial Velocity
Microlensing
Imaging
This work



Using pre-cursor information allows the relative astrometric position to be predicted improving the probability detection calculation.

IRDIS

Infrared Dual Band
Imager and
Spectrograph



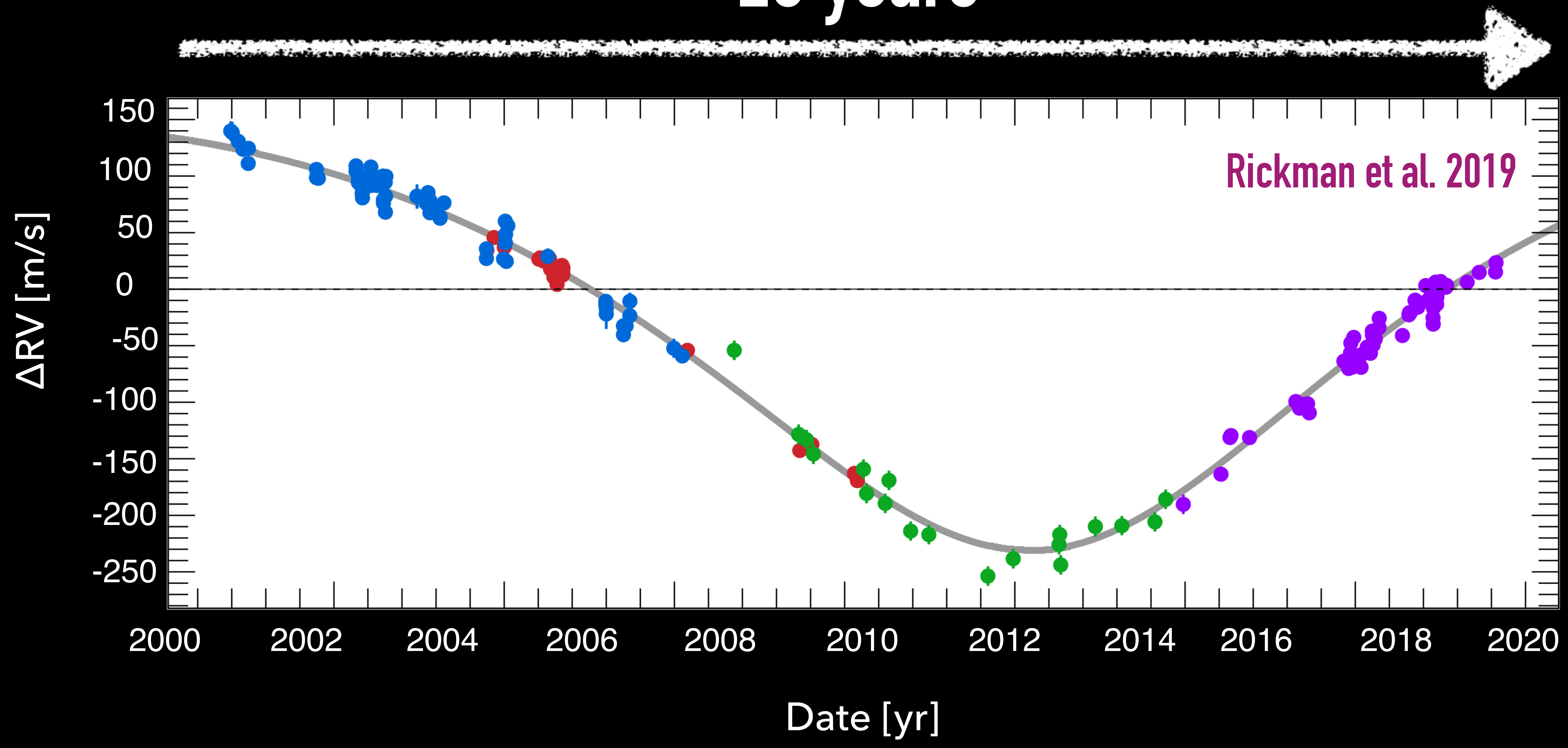
IFS

Integral Field
Spectrograph

HD 13724 B

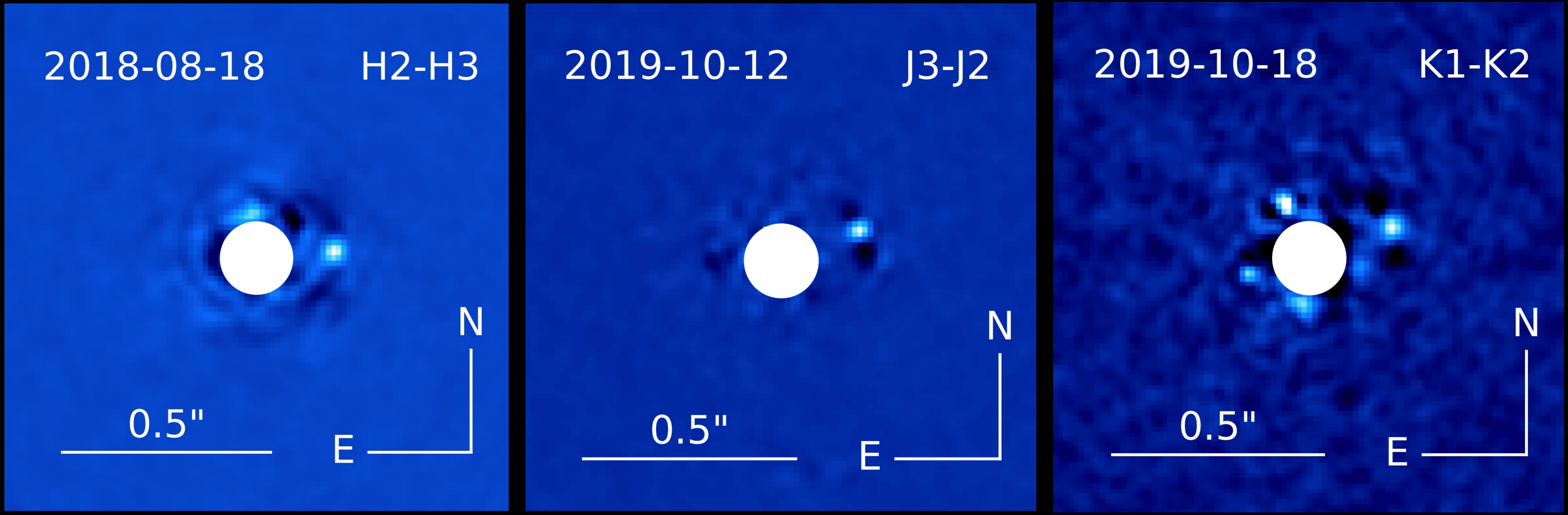
Min. mass: 27 M_{Jup}

20 years



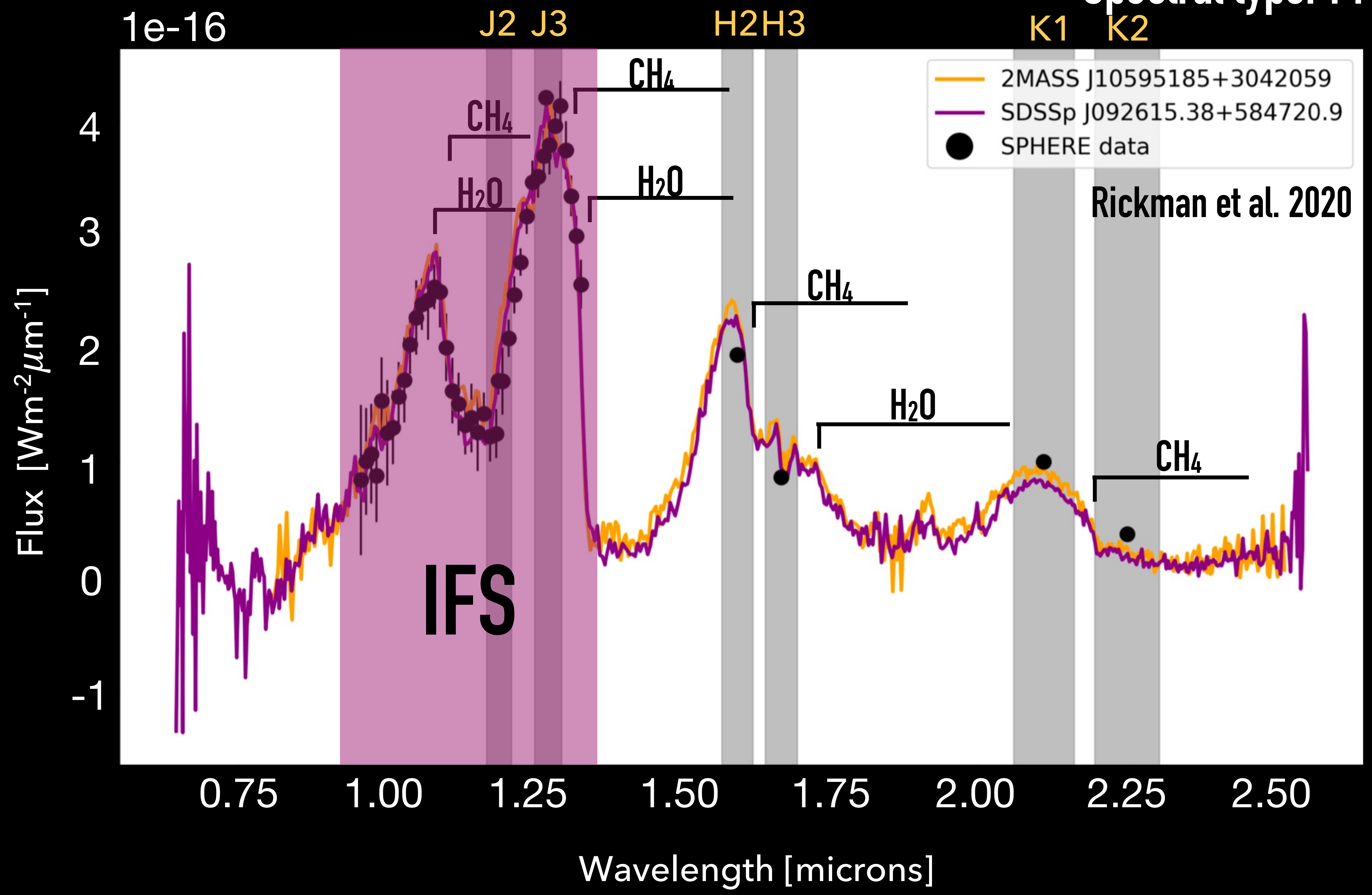
HD 13724 B

Rickman et al. 2020

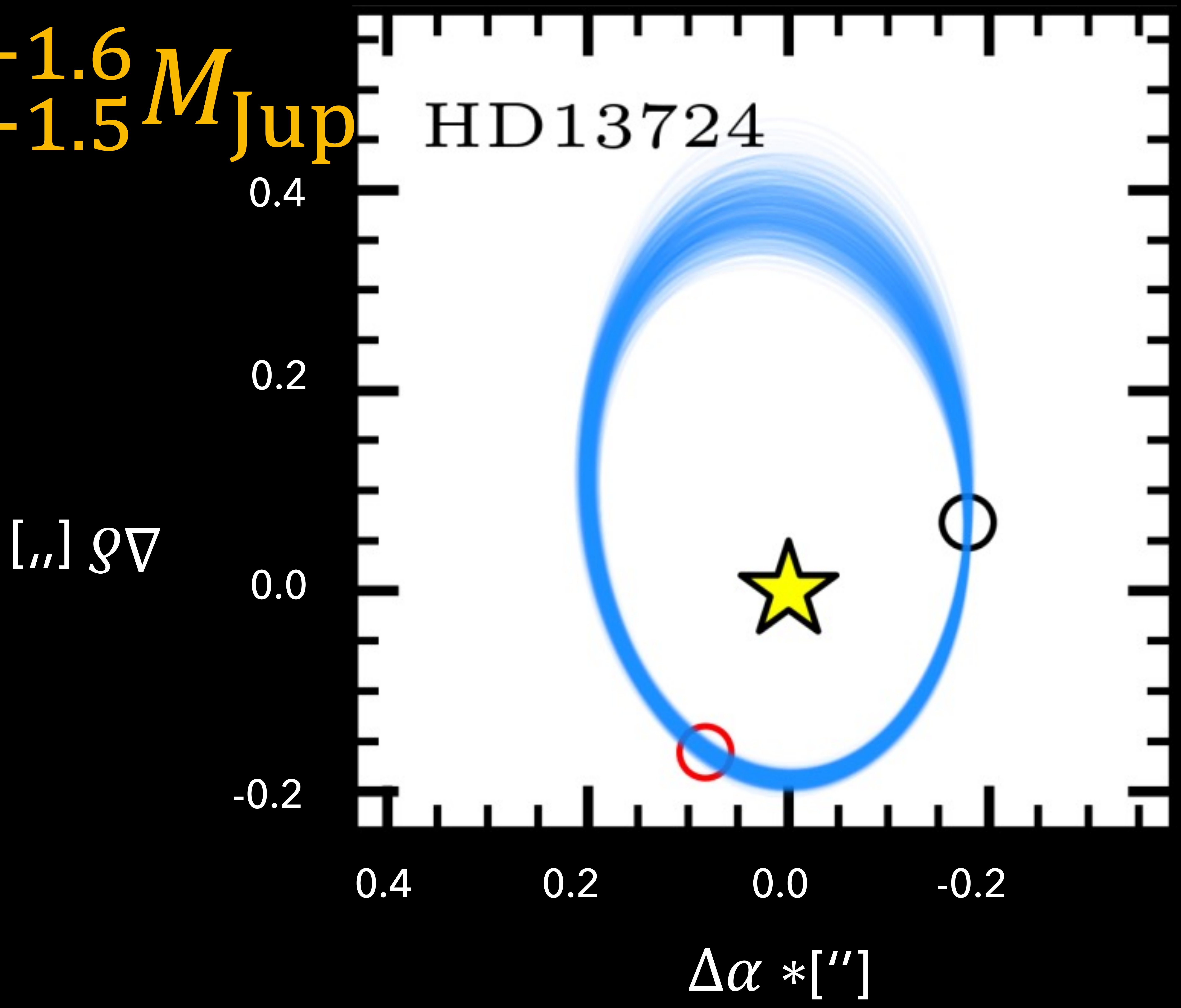


HD 13724 B

Temperature: 1000 K
Spectral type: T4

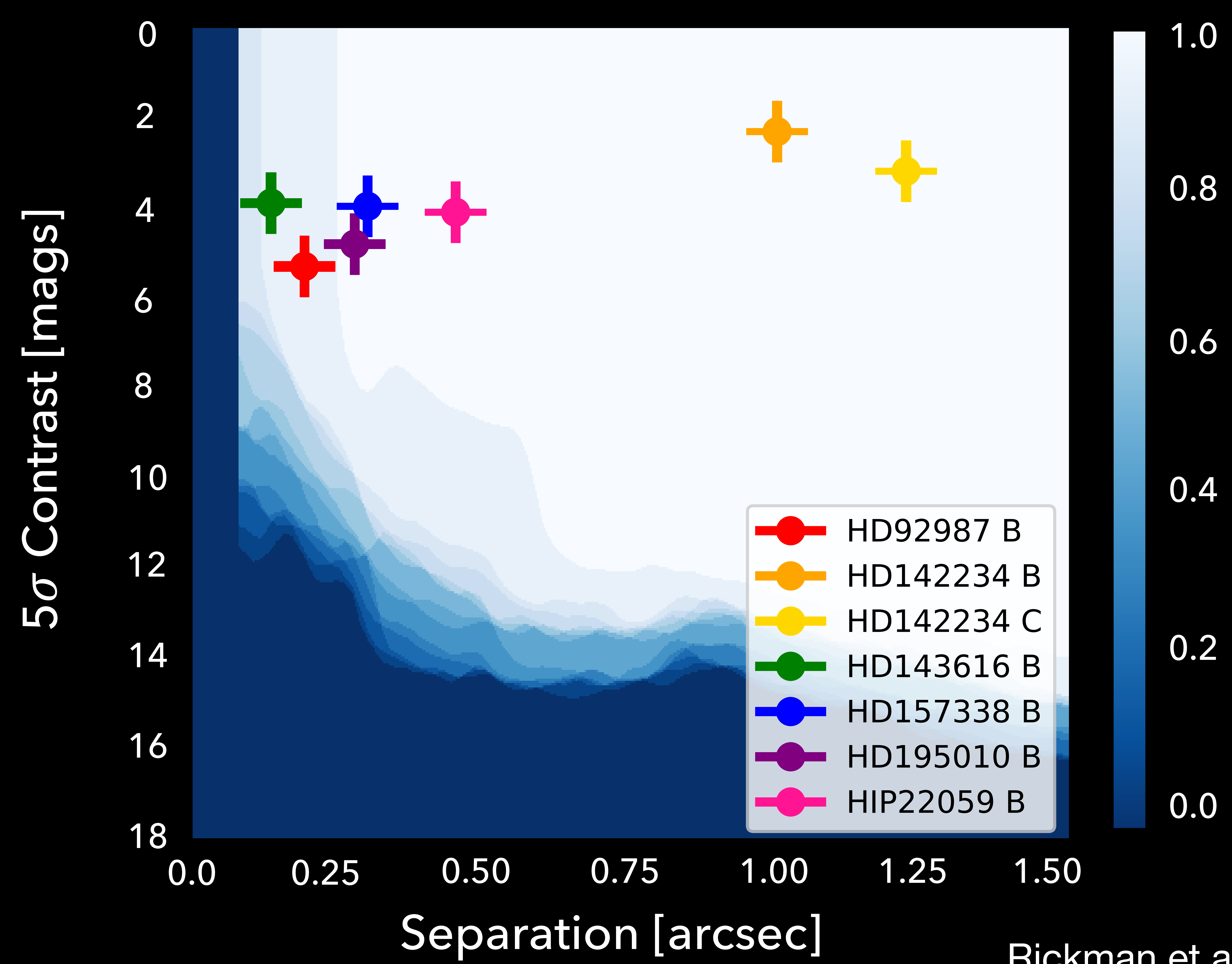


$36.2^{+1.6}_{-1.5} M_{\mathrm{Jup}}$

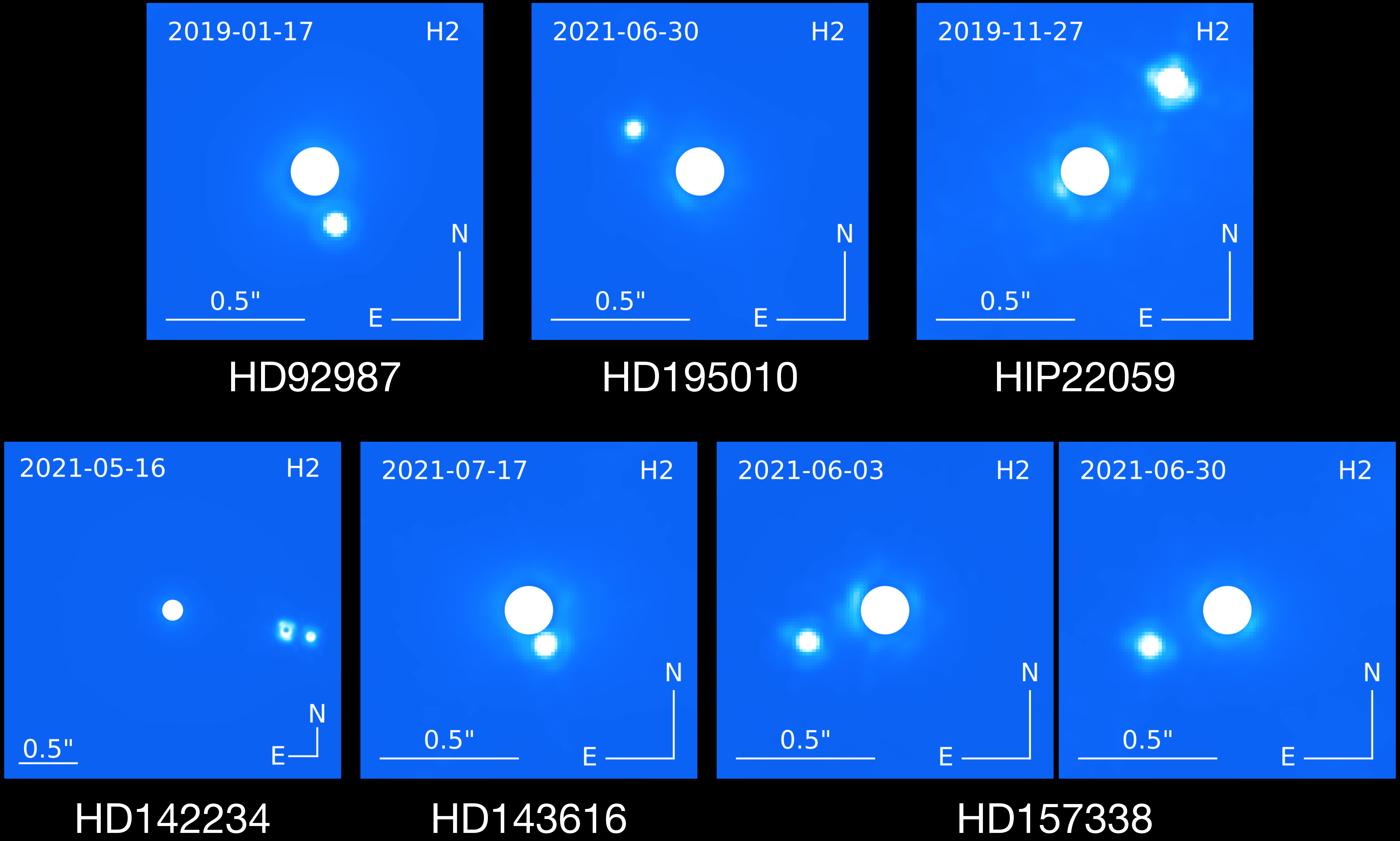


Brandt et al. 2021

Younger & lower-mass brown dwarfs are over-luminous compared to models, while older or higher-mass brown dwarfs are under-luminous



Rickman et al (2022a), in prep


2019-01-17
H2
0.5"
N
E
HD92987
2021-06-30
H2
0.5"
N
E
HD195010
2019-11-27
H2
0.5"
N
E
HIP22059
2021-05-16
H2
0.5"
N
E
HD142234
2021-07-17
H2
0.5"
N
E
HD143616
2021-06-03
H2
0.5"
N
E
2021-06-30
H2
0.5"
N
E
HD157338

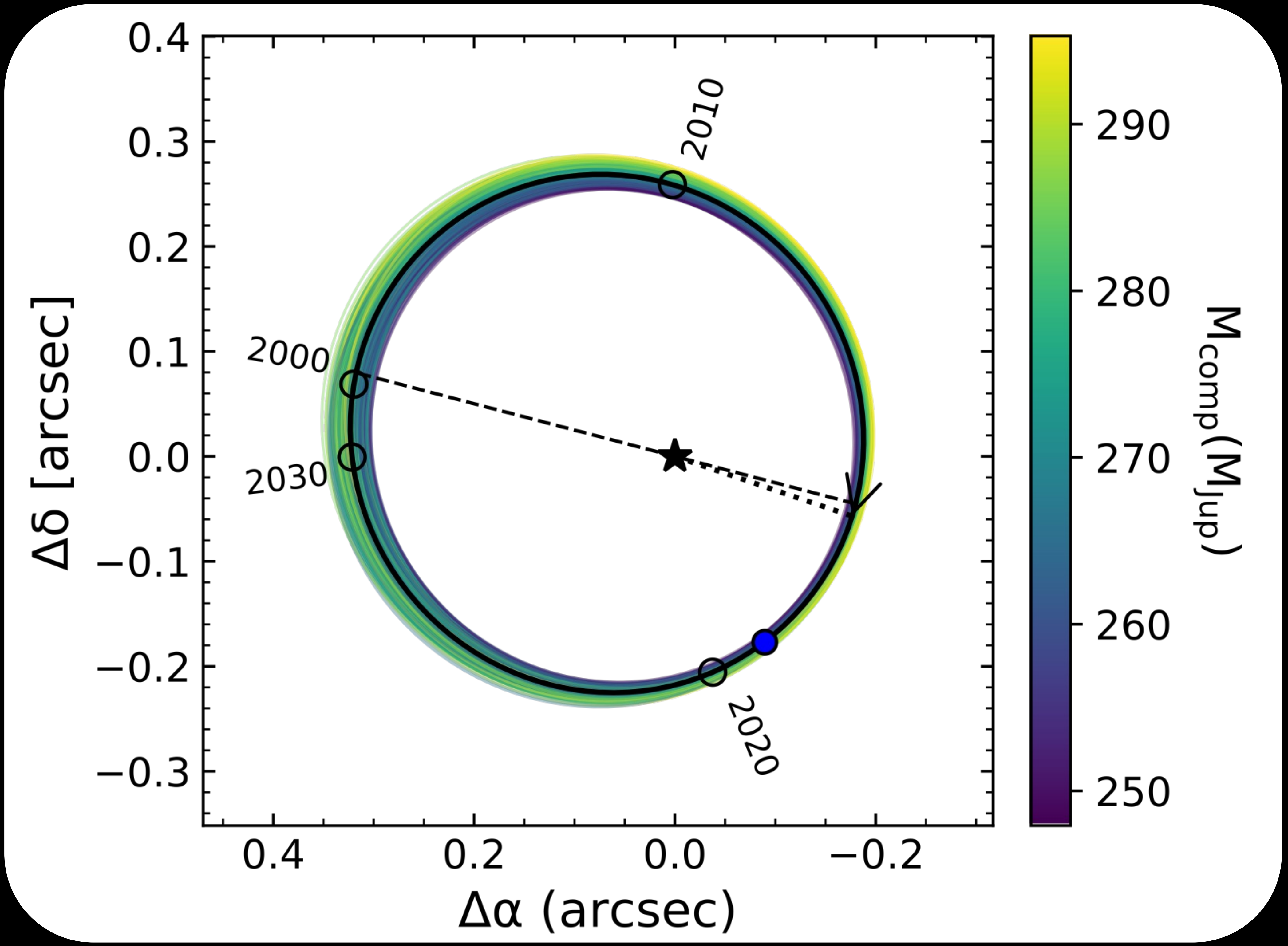
HD92987

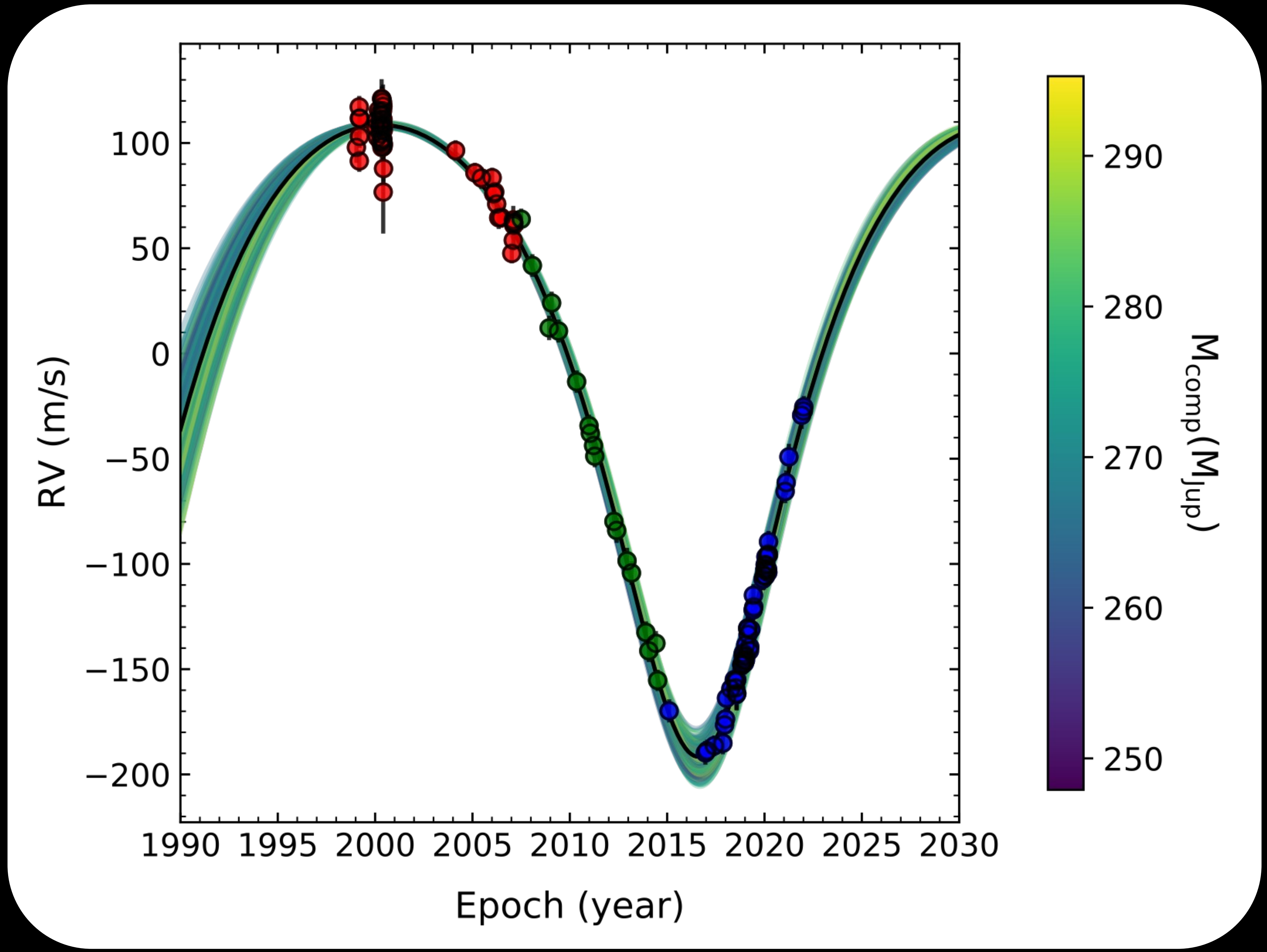
$\sim 17 M_{\mathrm{Jup}}$ Rickman et al (2019)

$\sim 256 M_{\mathrm{Jup}}$ Venner et al. (2021)

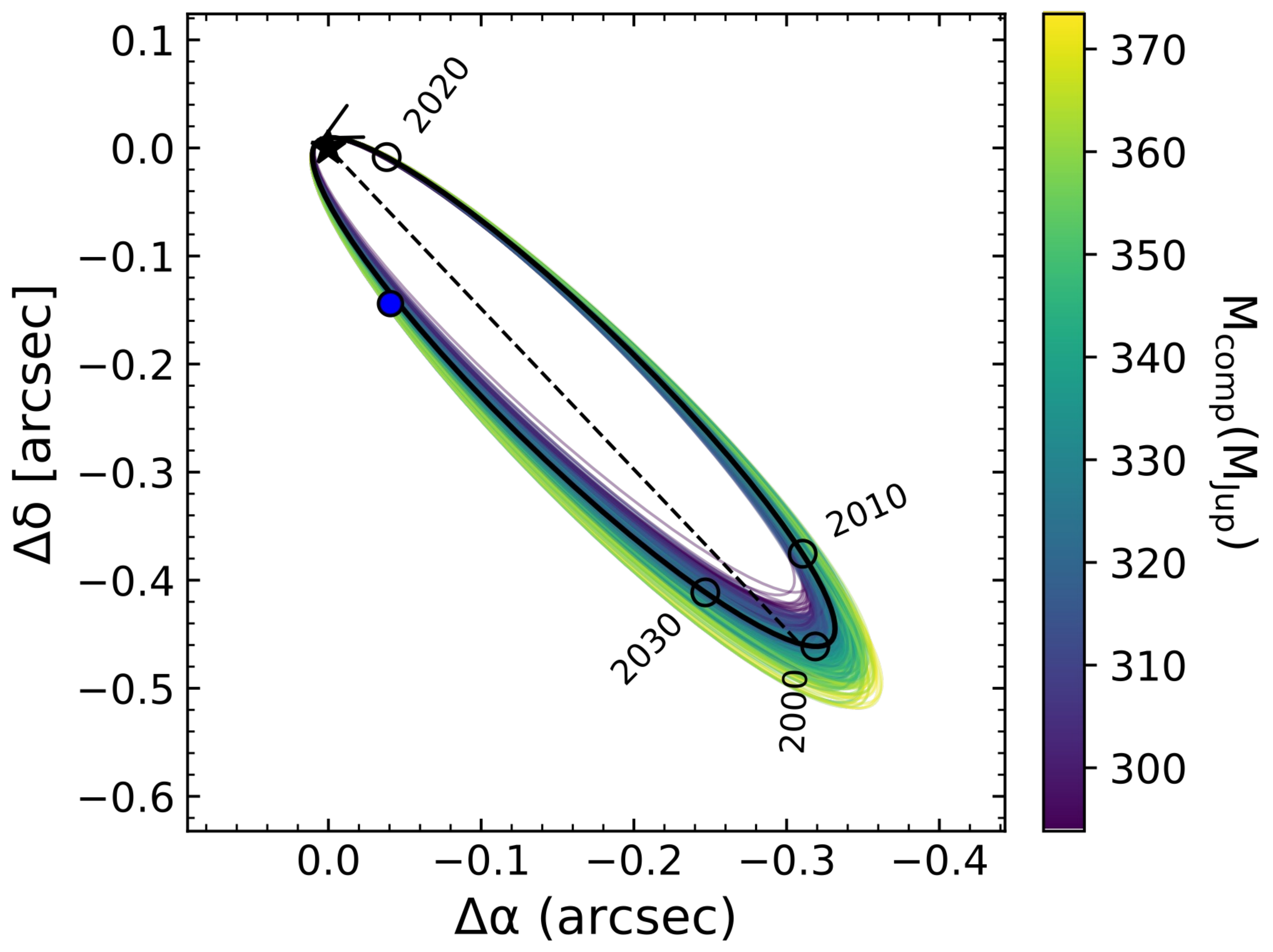
$271 \pm 10 M_{\mathrm{Jup}}$

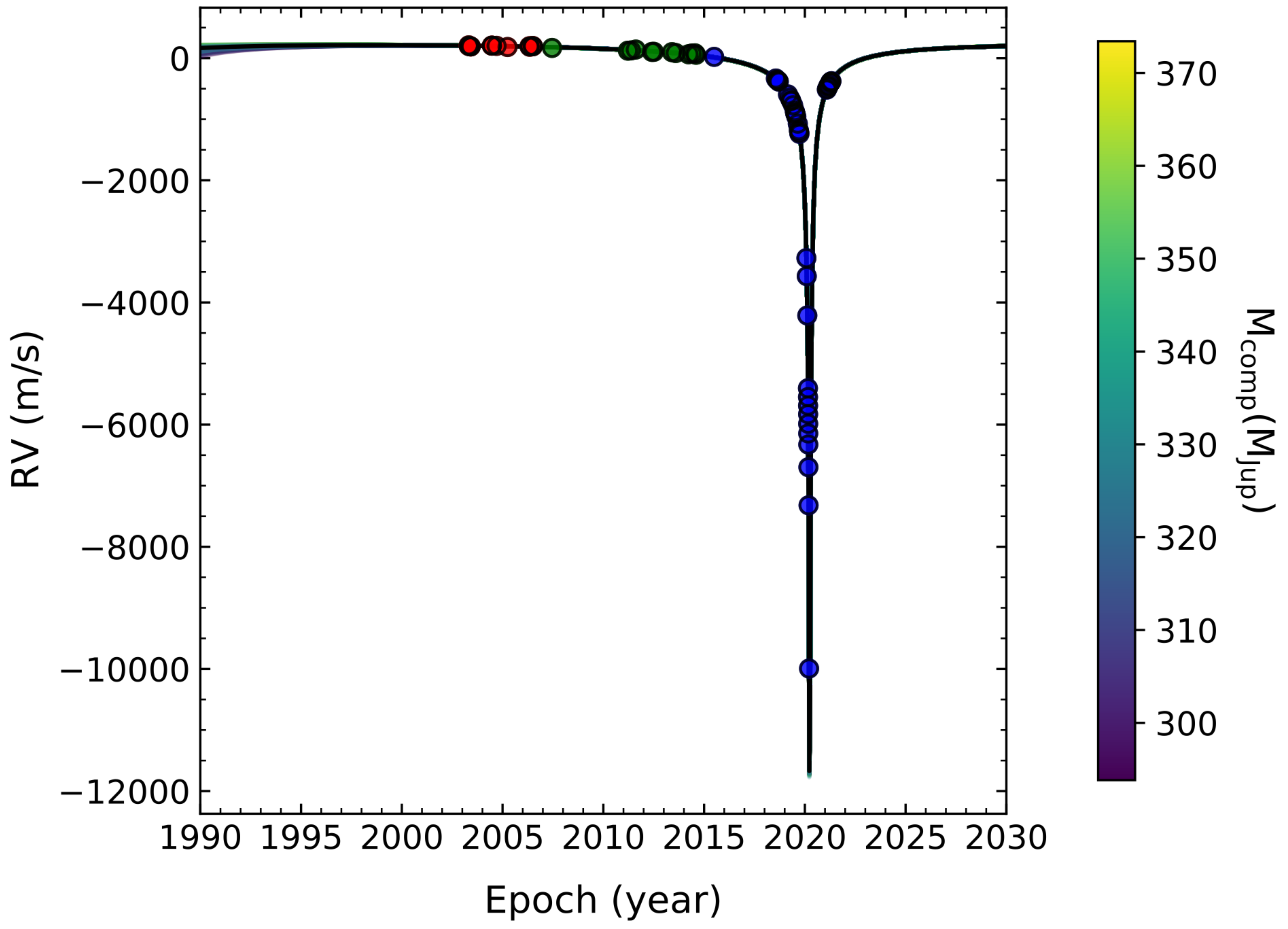
Rickman et al (2022a) in prep





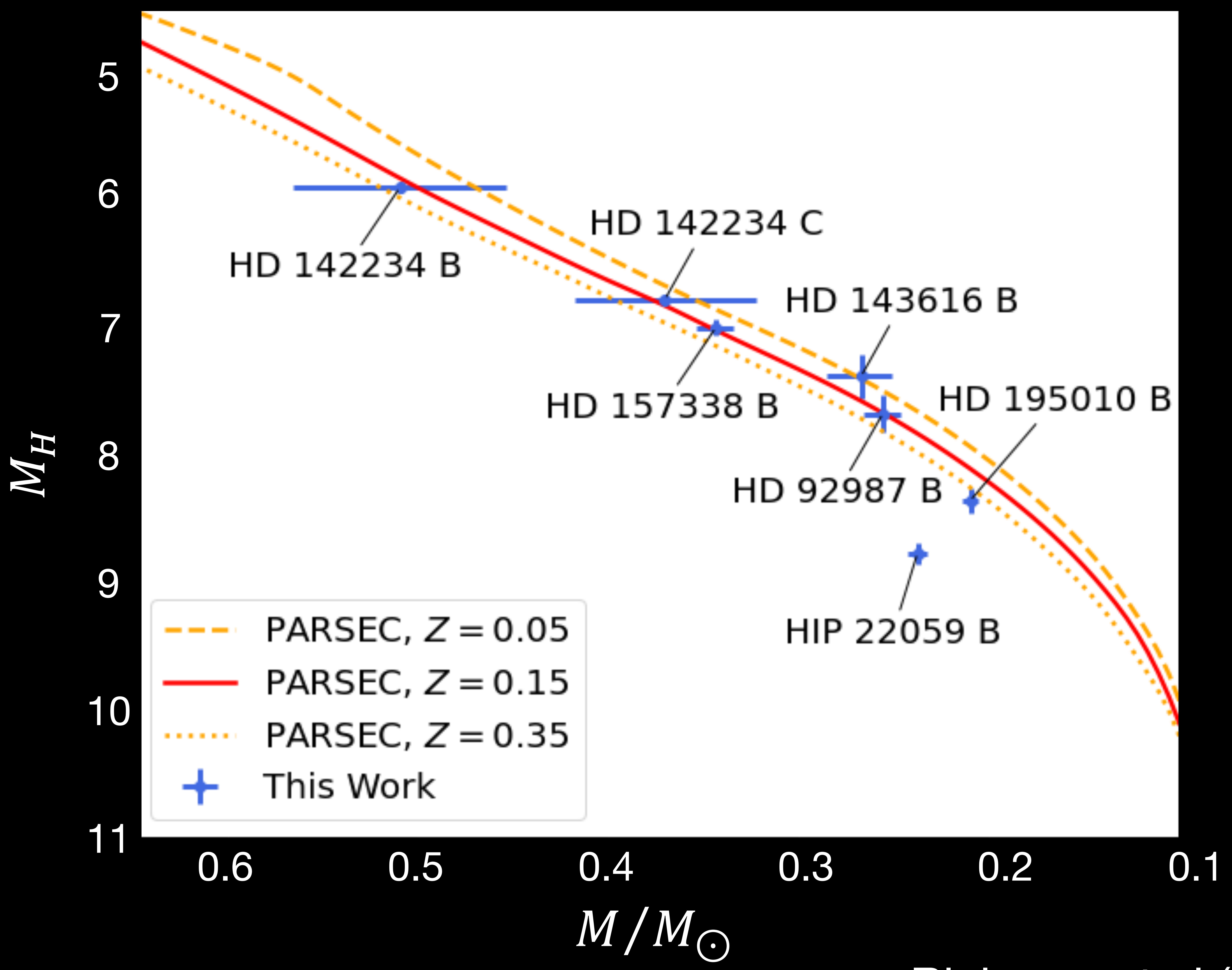
HD143616B





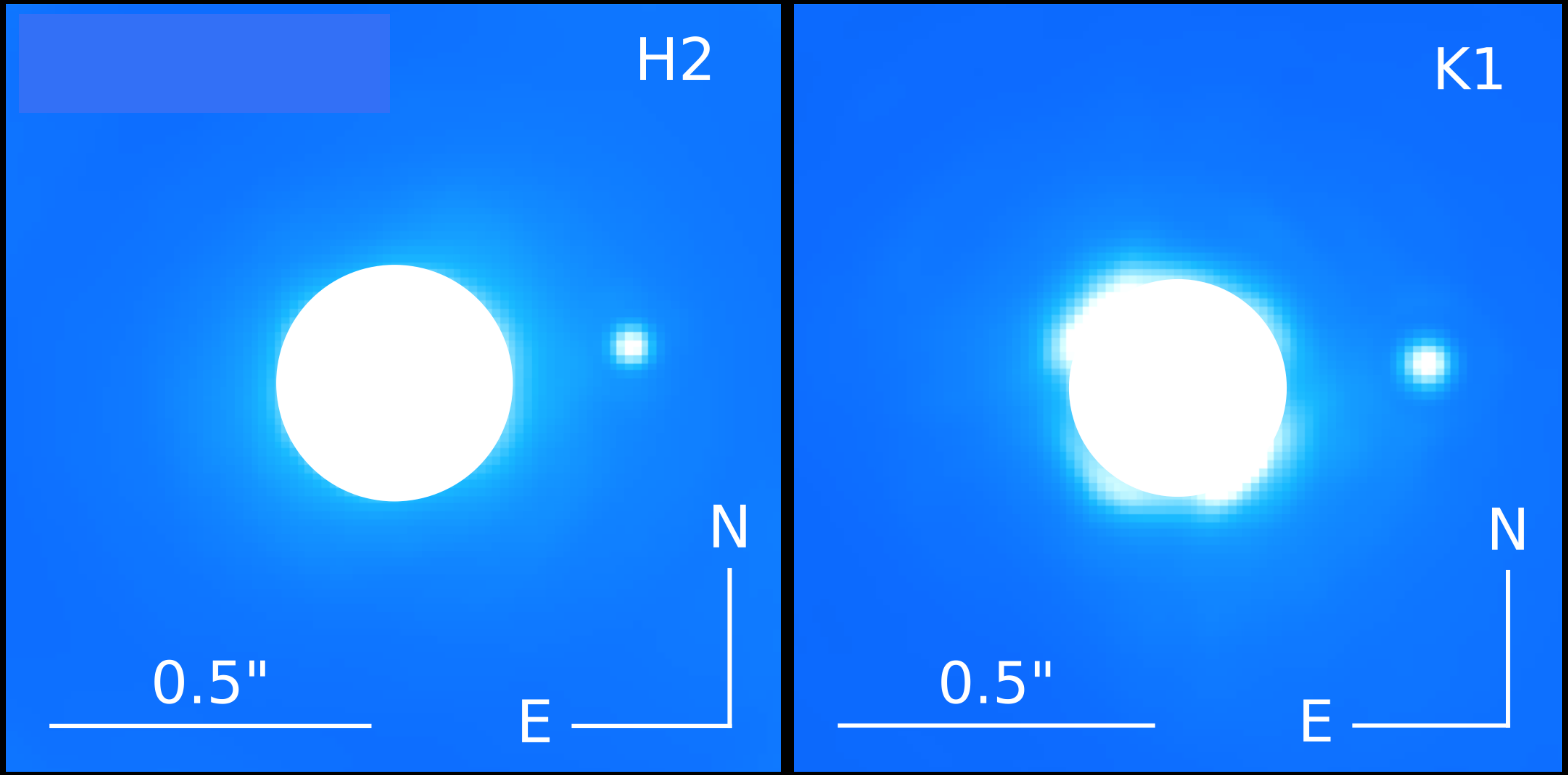
$330 \pm 13 M_{\mathrm{Jup}} \quad e = 0.97 \pm 0.01$

Rickman et al (2022a), in prep

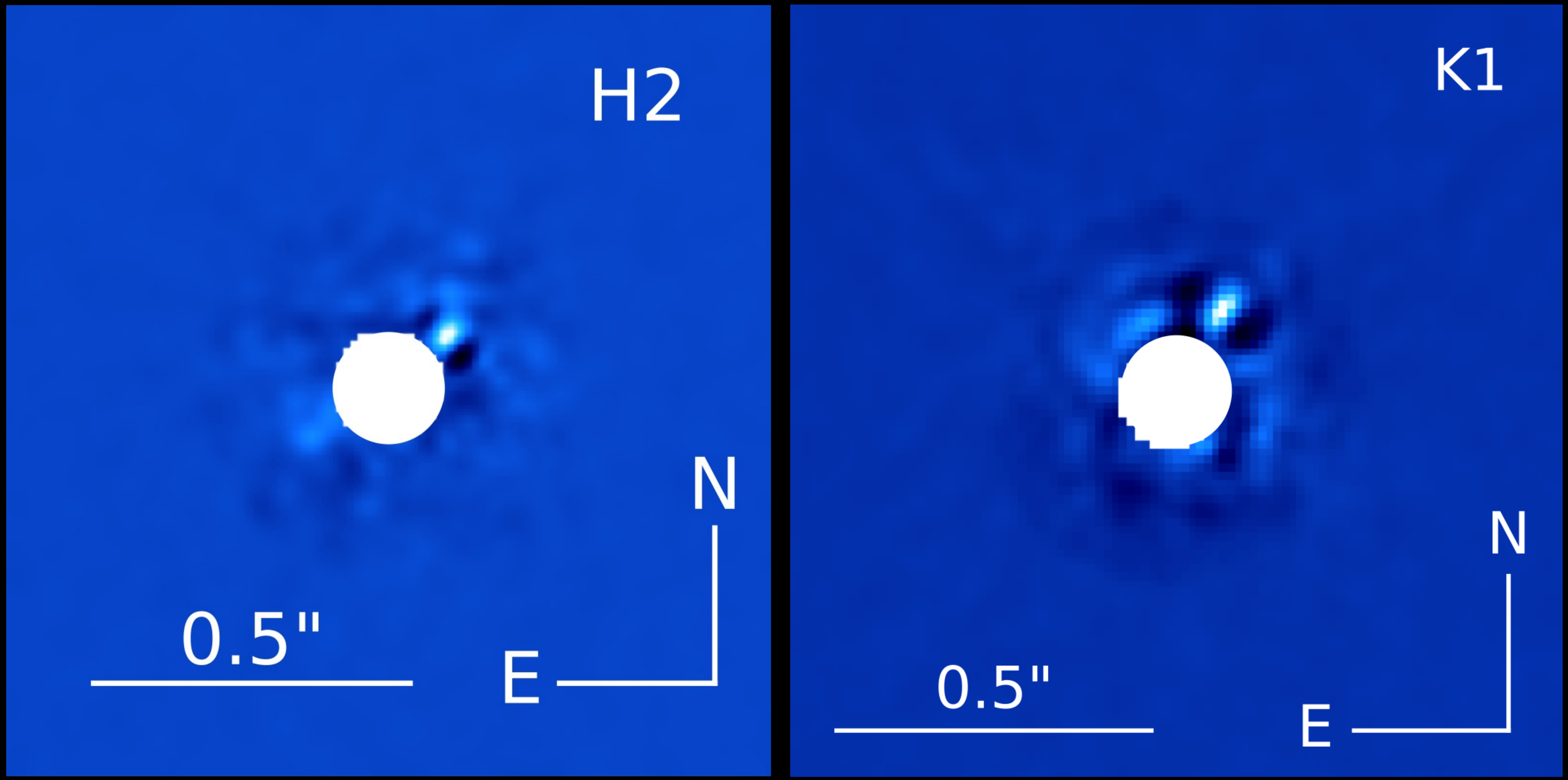


Rickman et al (2022a), in prep

HD206505B



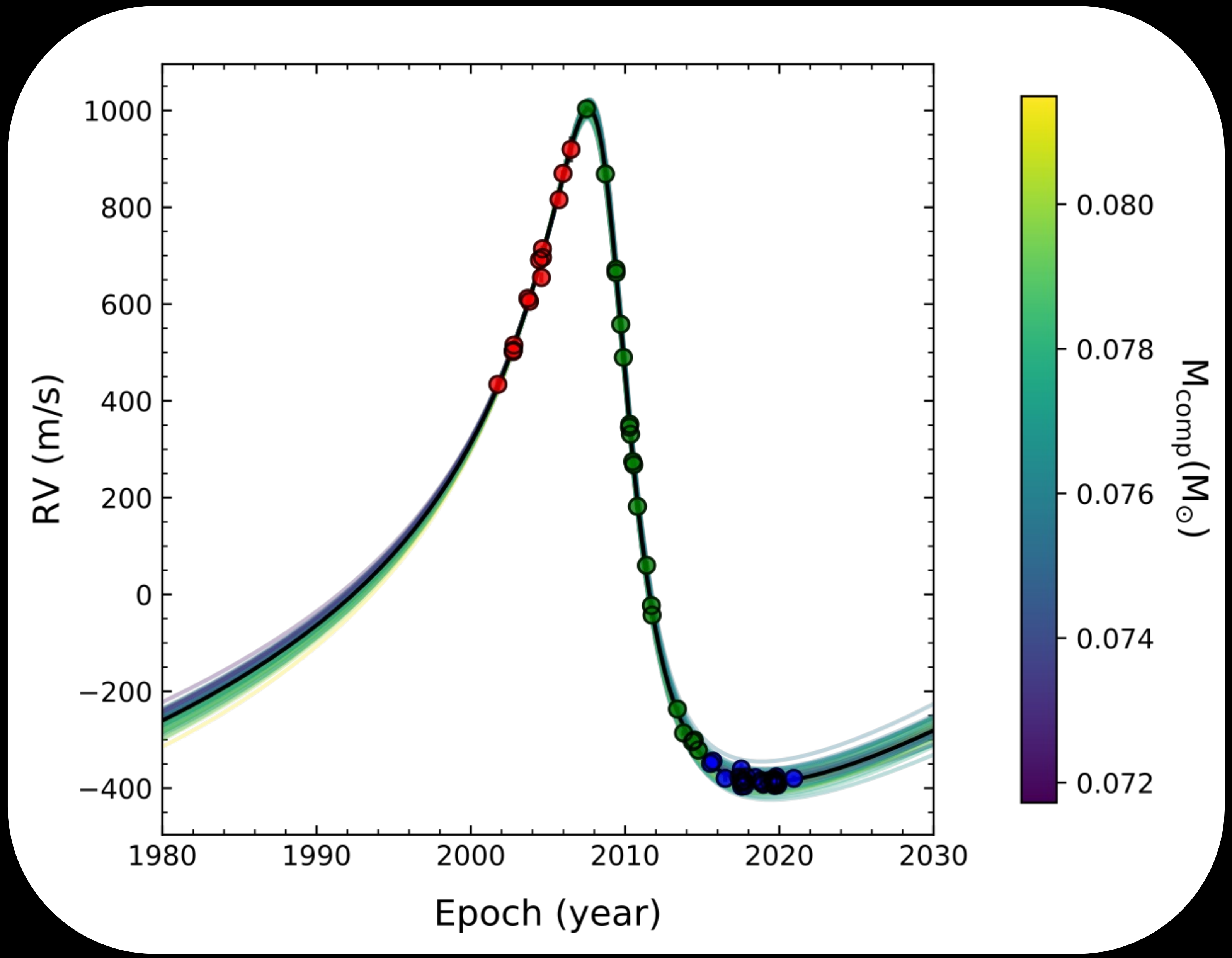
HD112863B

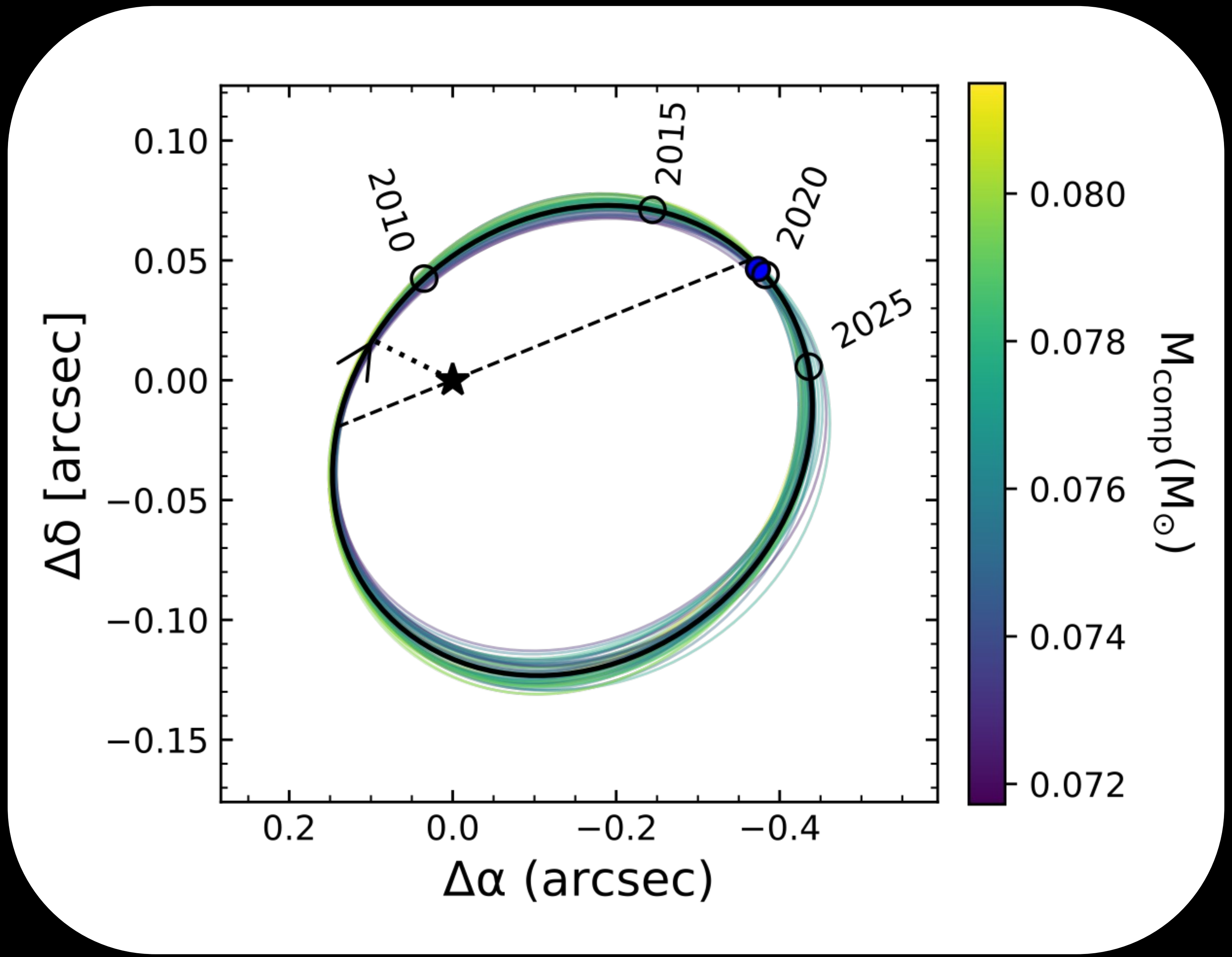


Rickman et al (2022b), in prep

HD206505B

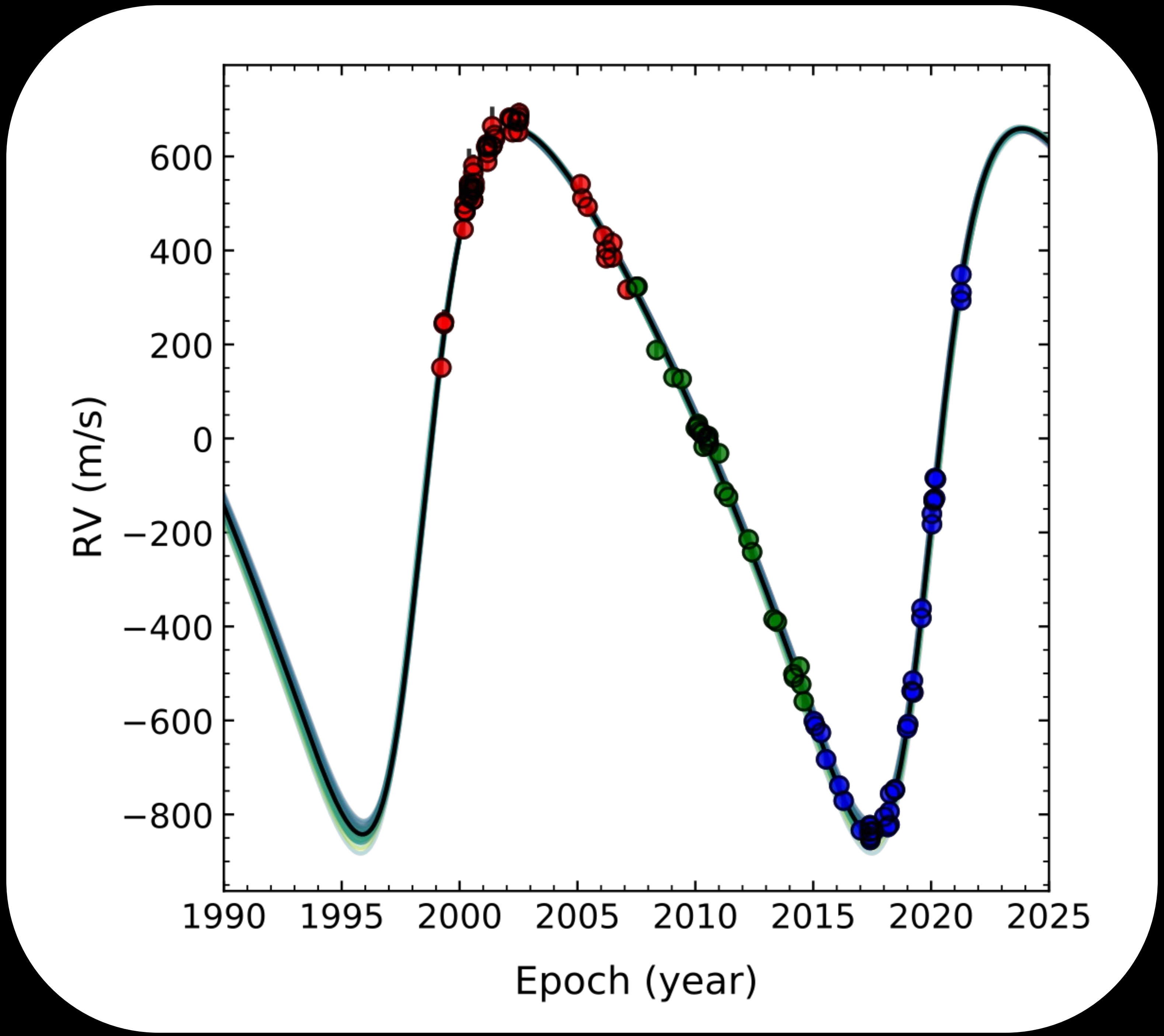
$76.5^{+2.1}_{-2.0} M_{\mathrm{Jup}}$

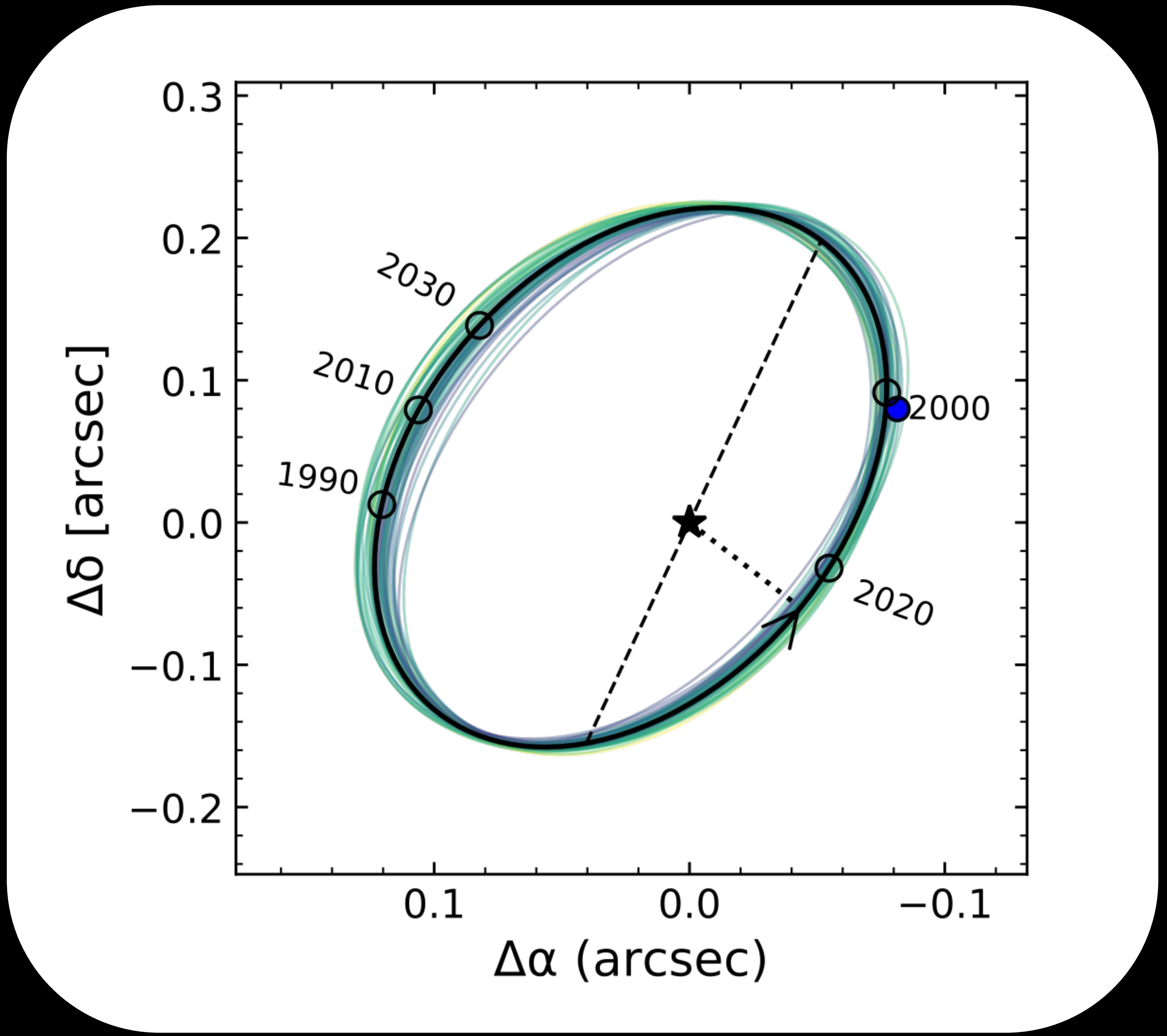




HD112863

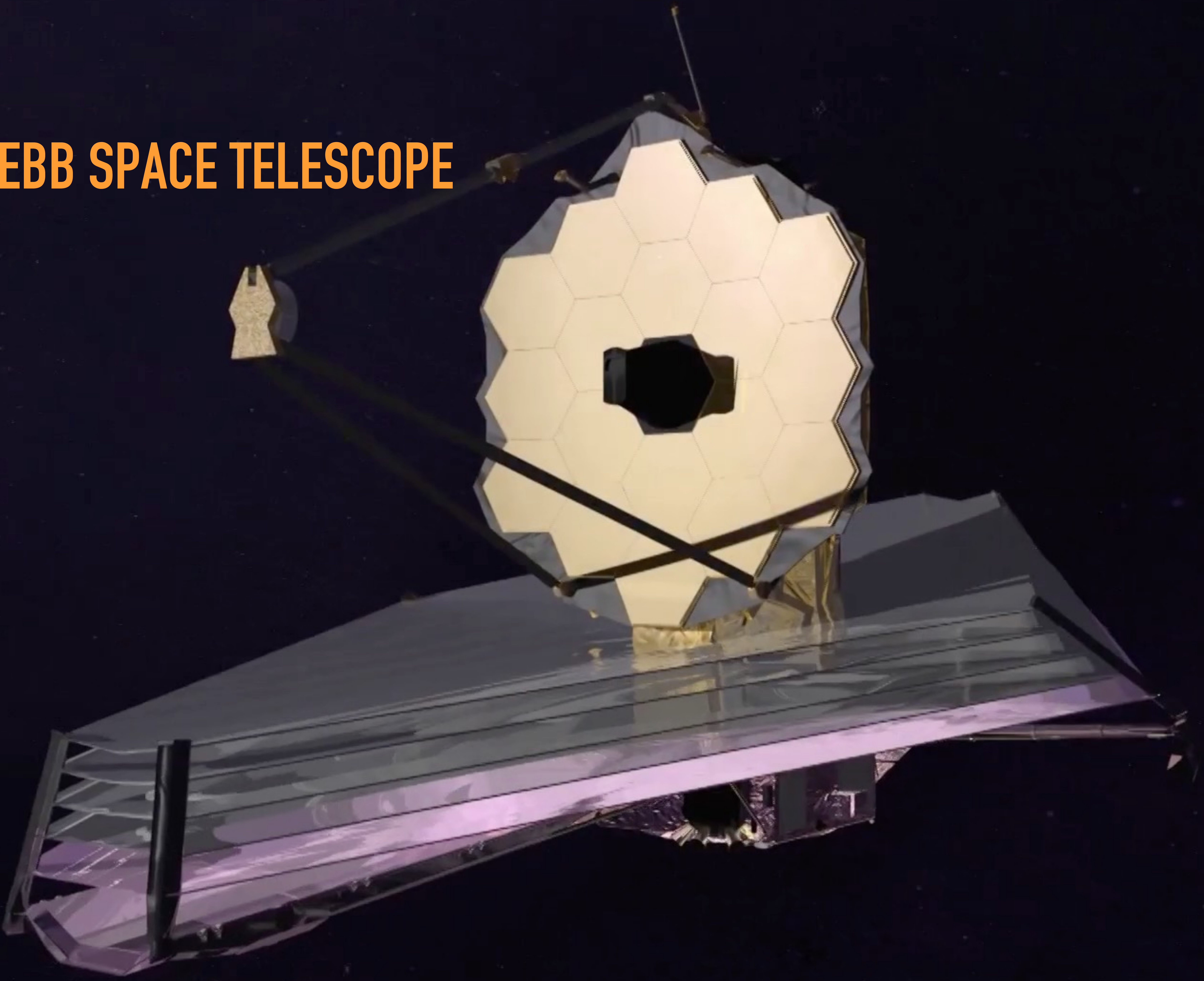
$73.5 \pm 1.5 M_{\mathrm{Jup}}$





Rickman et al (2022b), in prep

JAMES WEBB SPACE TELESCOPE



Conclusions

This work helps us understand the occurrence rates of planets/BDs/stars around nearby solar-type stars and populate the mass-luminosity relation for very low mass stars

Pre-cursor observations (vetting with quick imaging, RVs + astrometry) increases the detection efficiency of directly imaged companions for targeted searches with future upcoming instruments on JWST, ELT, and future direct imaging missions

Combining exoplanet detection techniques is vital in comprehensively characterizing exoplanets

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