Astrometric Accelerations as Dynamical Beacons

Discovery and JWST Follow-Up of the 3 $M_{\rm Jup}$ Planet AF Lep b

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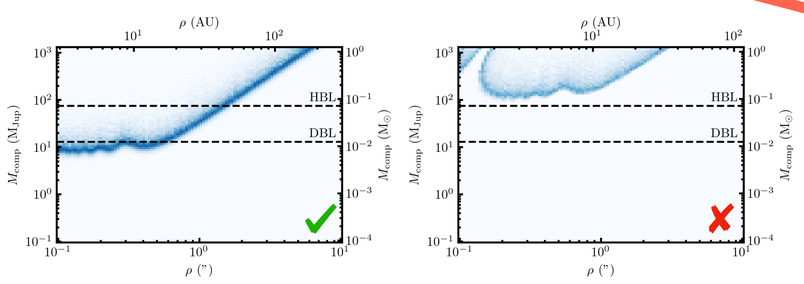
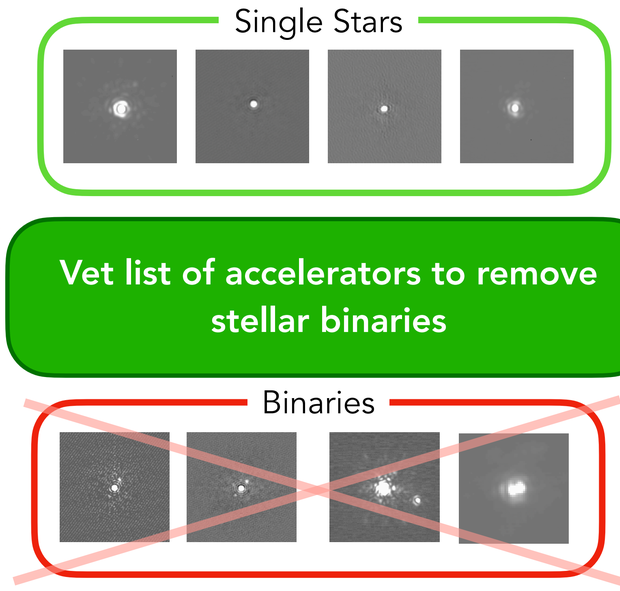
We are conducting a high-contrast imaging survey of Hipparcos-Gaia accelerating stars to search for new planets.

Identify the most promising young, accelerating stars

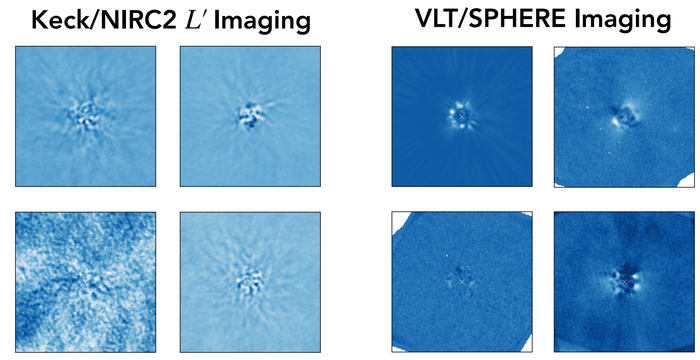


Predicted masses vs. separation for two potential targets generated from HGCA[1,2] proper motions

Vet list of accelerators to remove stellar binaries



Binary fraction of ~35%



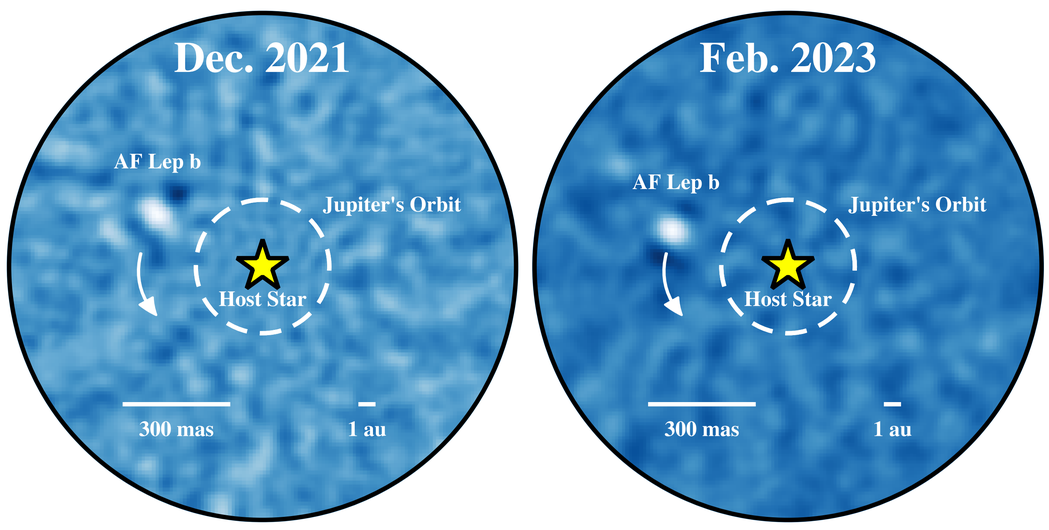
Deep adaptive optics imaging of single stars that emerge from binary vetting

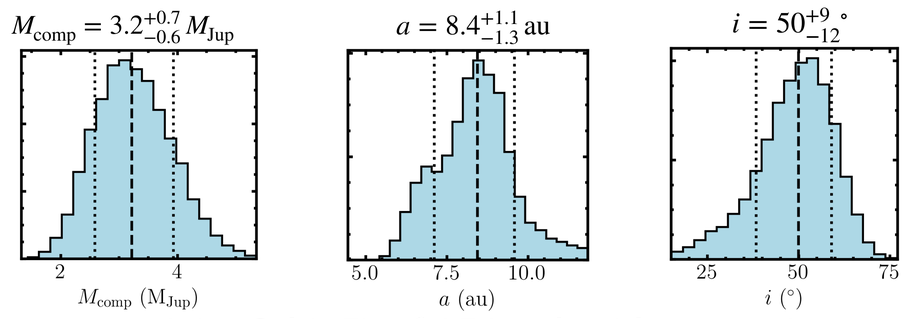
Our goal is to improve upon the yields of previous imaging campaigns. New planet and brown dwarf discoveries will constrain the formation and evolution of substellar companions through their dynamical masses.

AF Lep b: The Lowest-Mass Imaged Planet with a Dynamical Mass

Franson et al. (2023)

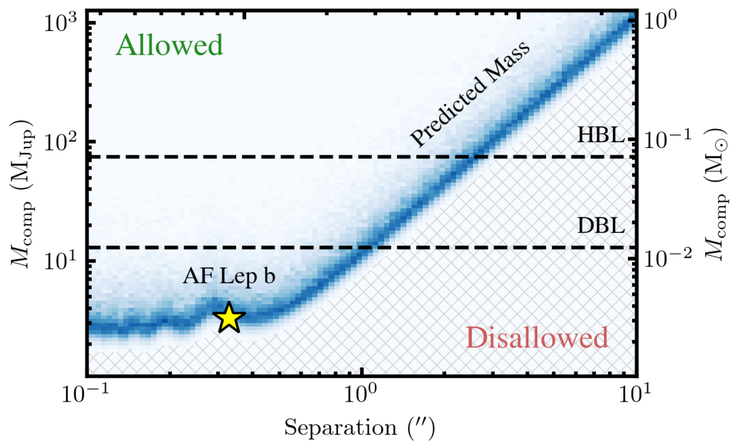
Keck/NIRC2 Imaging Over 13 Months Showing Orbital Motion

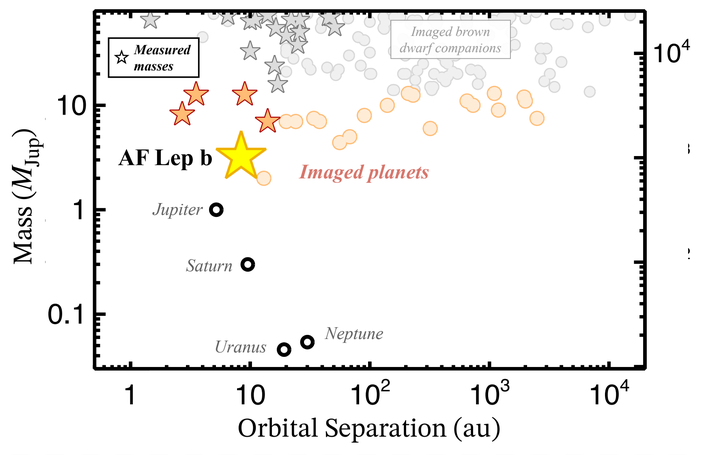




Joint Orbit Fit of AF Lep b with `orvara`[3]

Predicted Mass from Astrometric Acceleration





- 3 $M_{\rm Jup}$ directly imaged planet around Sun-like star in β Pic moving group (24 ± 3 Myr)
- L' contrast of 9.94 ± 0.14 mag and separation of 340 mas
- Mild tension between dynamical mass and hot-start model predictions ($3 - 5\,M_{\rm Jup}$)
- Orbital inclination closely matches the host-star inclination (54^{+11}_{-9}°), implying spin-orbit alignment
- Two other independent discoveries by De Rosa et al. (2023) and Mesa et al. (2023)

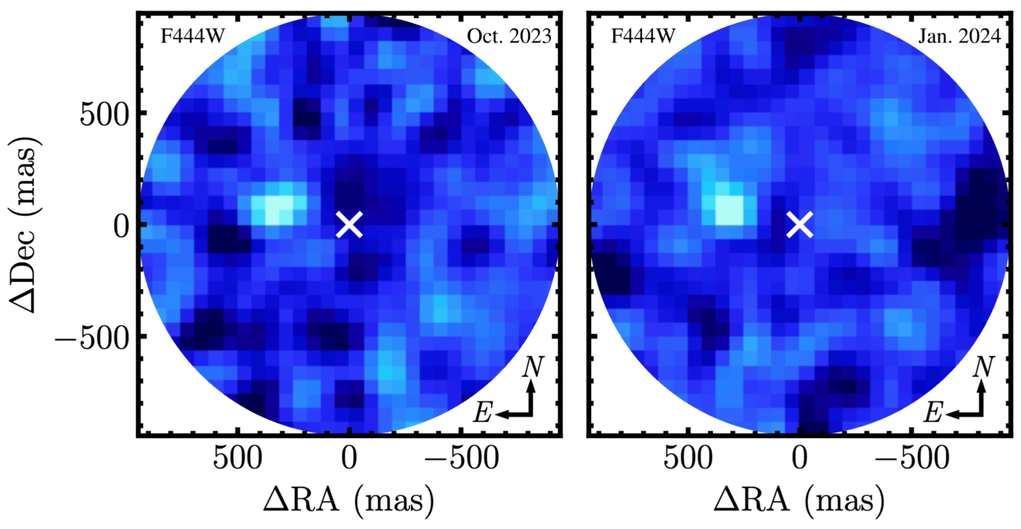
Discovery Paper

Imaging AF Lep b from 4–5 μm with JWST/NIRCam

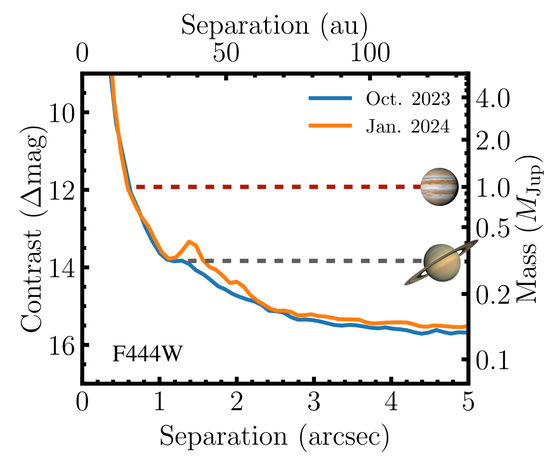
Franson et al. (submitted)

JWST Follow-Up Paper

- JWST Cycle 2 DDT Program (PID 4558; Co-PIs Franson, Balmer)
- AF Lep b recovered with JWST/NIRCam with a S/N of ~10σ at 320 mas ($1.8\,\lambda/D$) separation and F444W contrast of 10.11 ± 0.11 mag
- Affirms presence of disequilibrium chemistry and enhanced atmospheric metallicity
- Coronagraphic transmission of only 7% at AF Lep b separation
- Closest-separation planet imaged with JWST



JWST/NIRCam 4.4 Micron Imaging of AF Lep b



Deep Upper Limits on Additional Planets

References

[1] Brandt, T. D. 2018, ApJS, 239, 31
[2] Brandt, T. D. 2021, ApJS, 254, 14
[3] Brandt, T. D., et al. 2021, AJ, 856, 40
De Rosa et al. 2023, A&A, 672, A94
Franson et al. 2023, ApJL, 950, L19
Franson et al. 2024, ApJL, submitted
Mesa et al. 2023, A&A, 672, A93