Hunting for Planets around Hot Stars: The ARMADA Survey at CHARA and VLTI

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Zoom in on orbit to see our real CHARA astrometry. Note the scale!

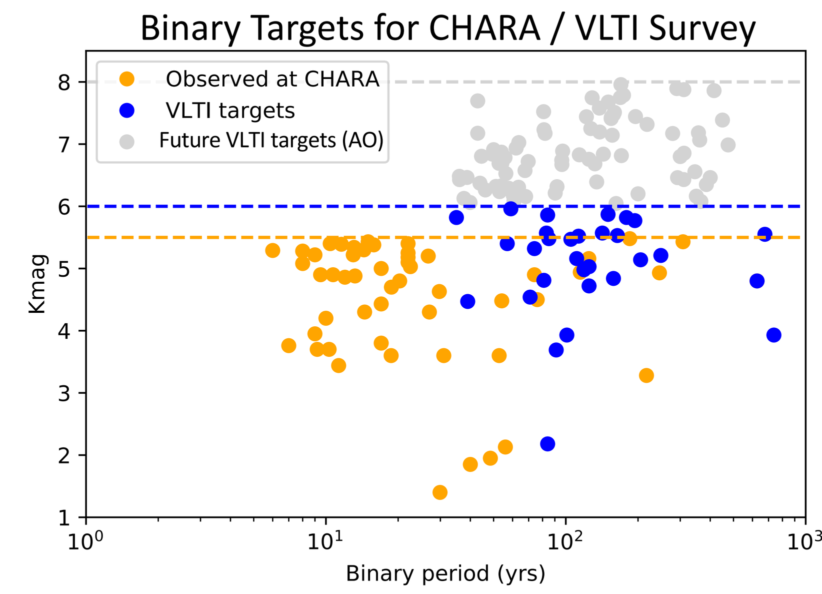
Our Survey --> ARrangement for Micro-Arcsecond Differential Astrometry (ARMADA)

MIRC-X at CHARA Array

- 6-telescope combiner in H-band
- Baselines up to 330 meters
- 40 binary targets

GRAVITY at VLTI

- 4-telescope combiner in K-band
- Baselines up to 140 meters
- 30 targets over 2 years

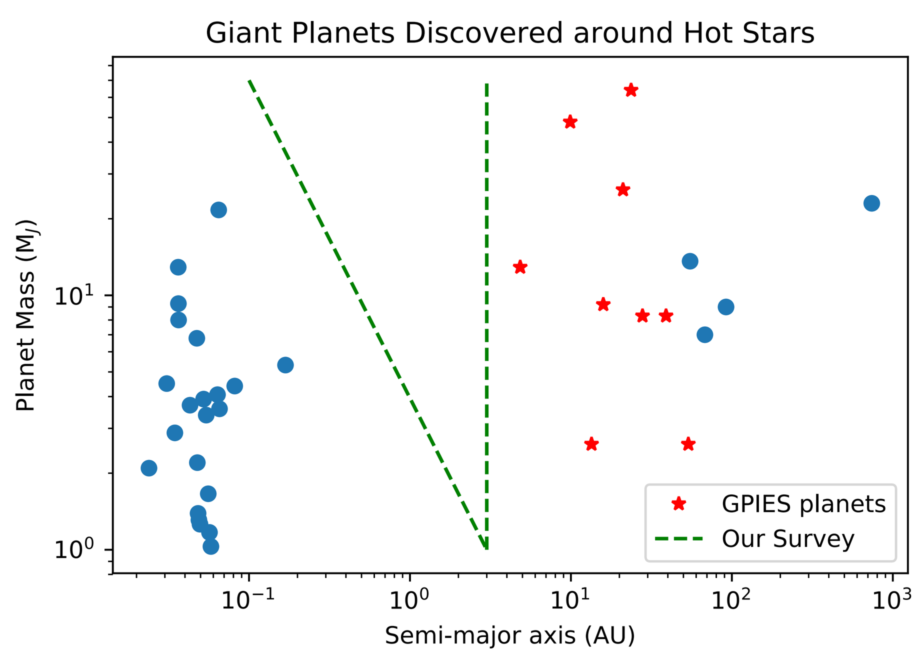


Main Goals of ARMADA Survey

- Populate au "gap" for A/B-type stars
- Test whether au giant planets show top-heavy distribution with stellar mass [e.g. 1,2]
- Measure degree of planet suppression caused by close binary companions of A/B stars
- Discover new compact triple systems for hot binaries

Background: Planets around Hot Stars

- Transit/RV methods struggle to detect planets around stars more massive than the Sun
- This is a regime where giant planets may be extremely common [1,2,3]



For A/B-type stars with T_{eff} > 7000K, there is a "gap" for giant planets on au orbits. This is a regime that is difficult to probe with RV or transit methods.

Light grey box = size of single HST pixel (50x50 milli-arcseconds)

Progress of Survey

- In Sep 2017 we began a survey of 40 binary stars at the CHARA Array for the purpose of detecting au giant planets around A/B-type stars
  - Expected completion in 2021
- Large program at VLTI will monitor 30 A/B-type binaries

Long-Baseline Interferometry: *Differential Astrometry* with Binary Stars

- MIRC-X at CHARA and GRAVITY at VLTI can achieve *~10 micro-arcsecond precision* for close binary stars (<0.2 arcseconds)
- **Thus, we are able to detect the "wobble" from giant planets around individual stars of A/B-type binary systems**

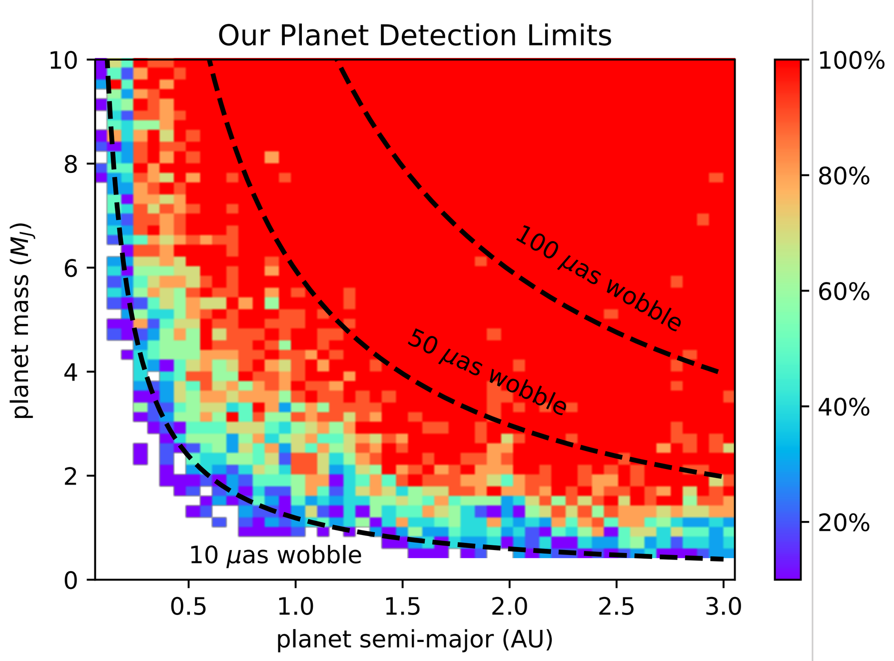
How to detect companions in this "gap"?

→ Astrometry method

→ Need ~10 *micro-arcsecond* precision for Jupiter-mass companions

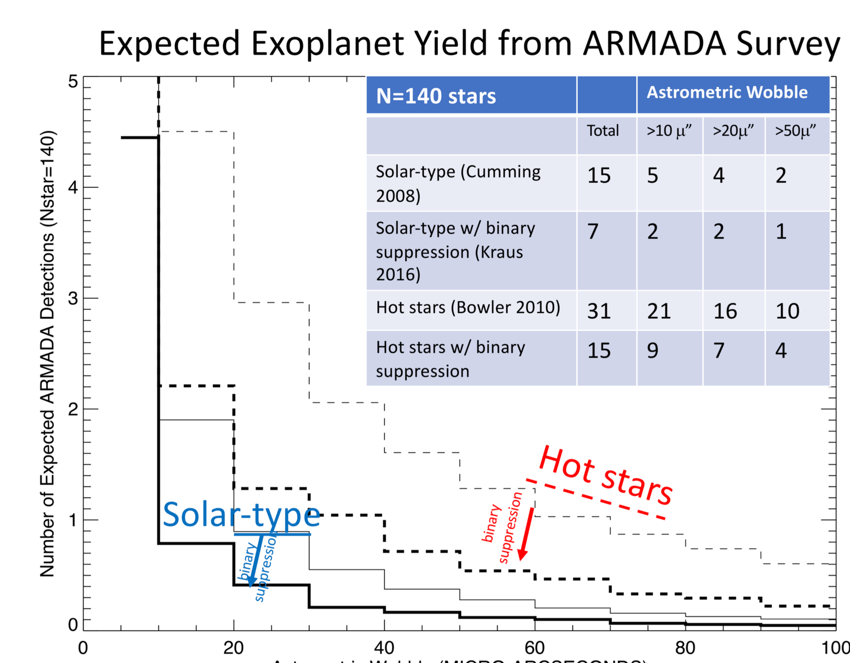
→ *This precision is possible with long-baseline interferometry, if we target binary stars*

Our Planet Detection Limits



← We add planets of varying mass/semi-major axis to our δ Del astrometry data (Gardner et al, 2018). The color bar records the percentage of injected planets successfully recovered at each point on the grid.

Constraining Exoplanet Demographic Models for Hot Stars

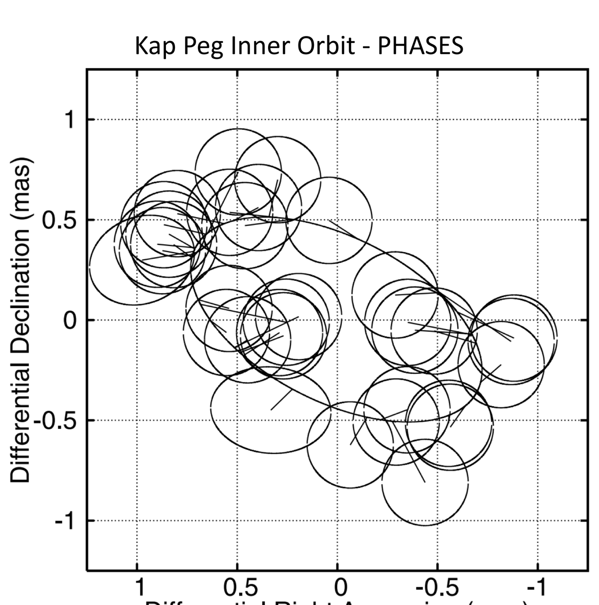


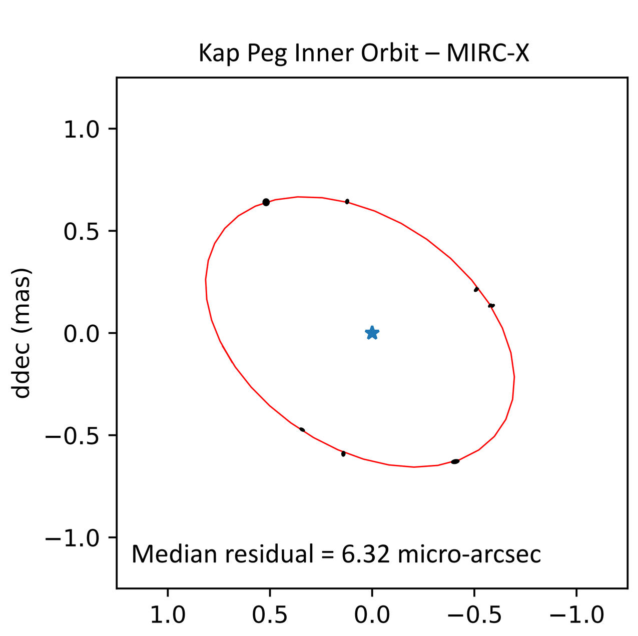
N=140 stars		Astrometric Wobble		
	Total	>10 μ"	>20μ"	>50μ"
Solar-type (Cumming 2008)	15	5	4	2
Solar-type w/ binary suppression (Kraus 2016)	7	2	2	1
Hot stars (Bowler 2010)	31	21	16	10
Hot stars w/ binary suppression	15	9	7	4

← We use Monte Carlo simulations for different demographic models to test how many exoplanets we expect to detect with ARMADA. Our number of detections will inform exoplanet demographic models for stars more massive than the Sun.

Early Results – Compact Triple Systems

- *The giant orbit on this poster shows the discovery of a 30-day inner companion to B-type binary alpha Del. One clearly sees the additional "wobble" on top of the binary motion.*
- ARMADA will be extremely successful at identifying new *compact triple systems* with A/B-type primaries (Gardner et al., submitted)

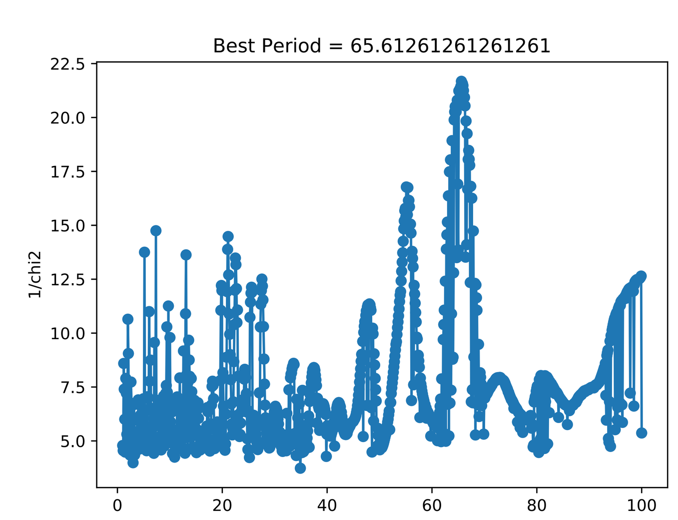


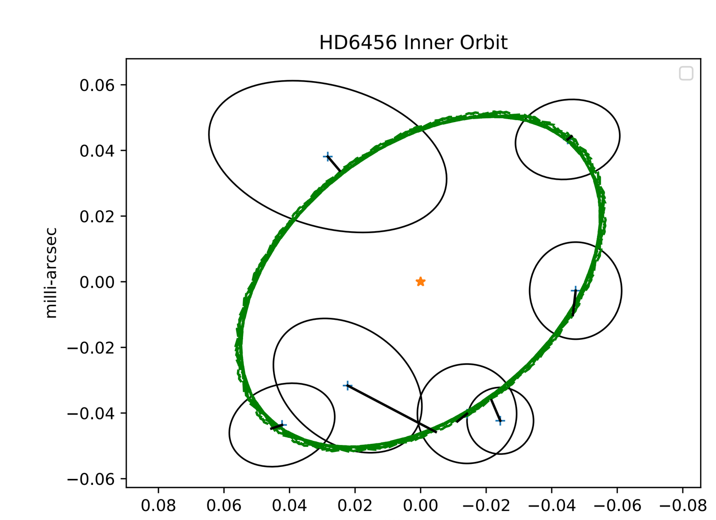


← As a test, we have been monitoring known triple system Kappa Peg with MIRC-X at CHARA. We compare our 8 MIRC-X epochs to that of a previous similar astrometric survey PHASES at the Palomar Testbed Interferometer (Muterspaugh et al, 2006). With MIRC-X/CHARA and GRAVITY/VLTI our astrometric precision is orders of magnitude better than previous interferometric instruments.

Early Results - Candidate Substellar Companions

- Though we need an estimated ~10 epochs per target to confidently detect substellar companions, we are beginning to reveal our first substellar candidates
- Below is a 30 $M_{Jupiter}$ candidate, with a 65-day period around an A-type binary





(Left) To search for additional companions to the wide binary, we perform a binary + planet fit on a grid of inner period values. Here we have a candidate detection at 65 days. (Right) Subtracting out the binary motion, we show the "wobble" motion caused by the substellar companion. The "wobble" semi-major axis here is about 60 micro-arcseconds.

References

[1] Bowler, B. P., Johnson, et al. 2010, ApJ, 709, 396

[2] Johnson J. A., et al, 2010, PASP, 122, 905

[3] Nielsen et al, 2019, AJ, 158, 1

[3] Gardner, T., et al, 2018, ApJ, 855, 1

[4] Muterspaugh, M.W., et al, 2006, ApJ, 636, 2

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