Astrometric detection of giant planets in hot binary systems

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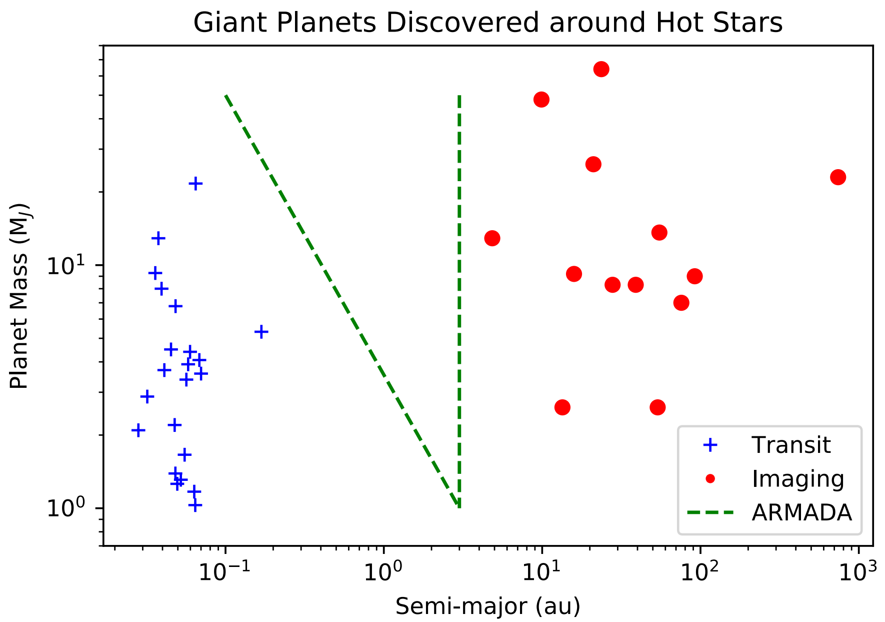
2021 Virtual CHARA Meeting

Planets around A-Type Stars

Difficulties:

- RV nearly impossible (weak/broad spectral lines)
- Most transit surveys focus on solar-type



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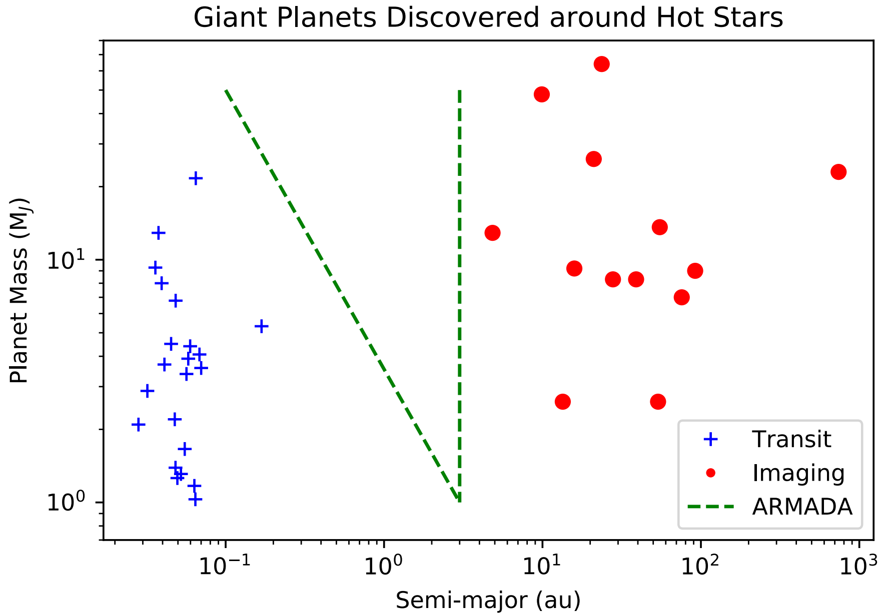
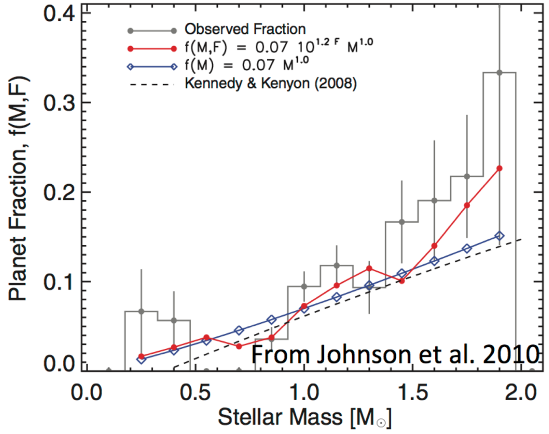
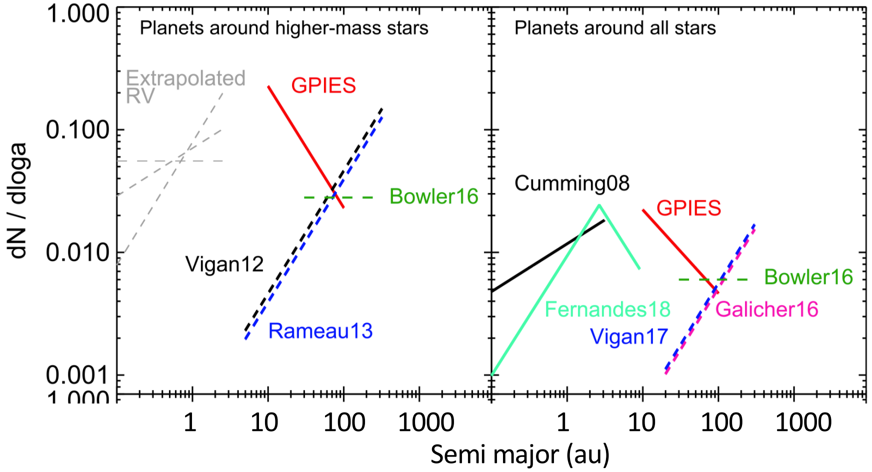


“Retired” A-Stars:

Johnson et al (2010), Bowler et al (2010)



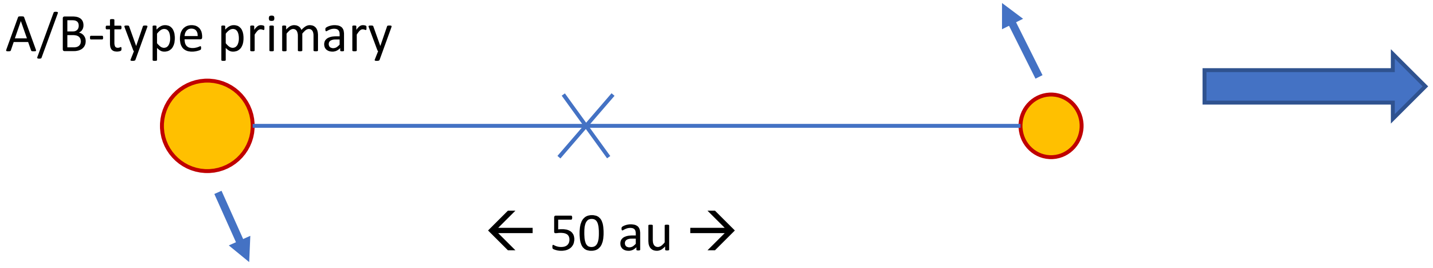
Planet occurrence rate as function of stellar mass?

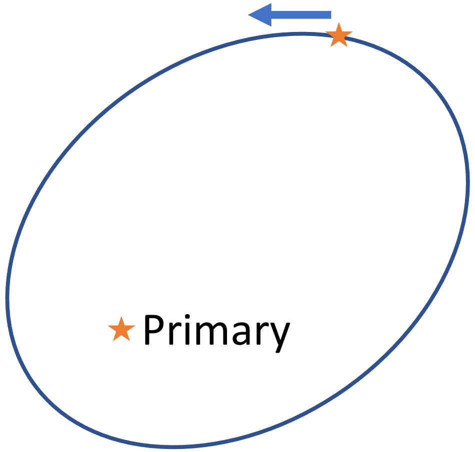


Vigan et al (2020); Nielsen et al (2019)

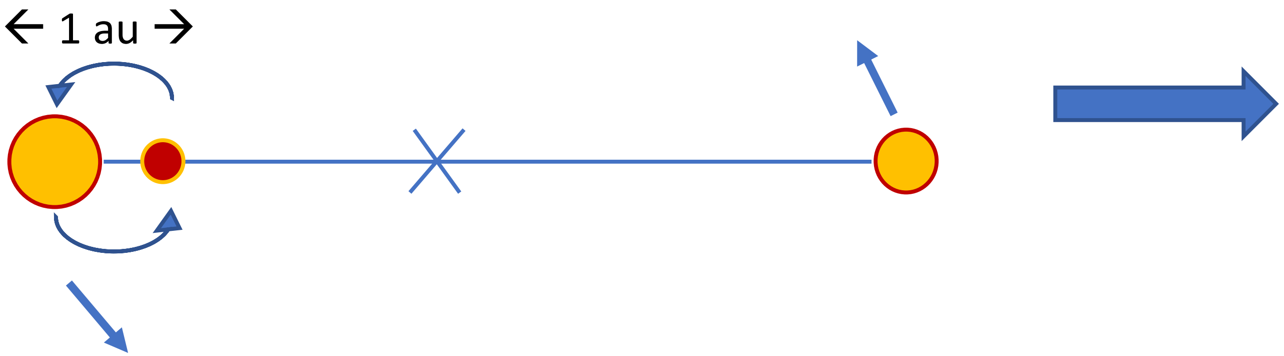
→ Top-heavy distribution for >5 au giant planets

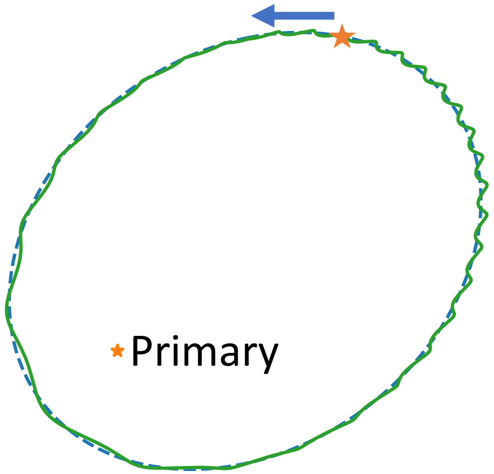
ARMADA Binary:





ARMADA Binary + S-Type Planet:



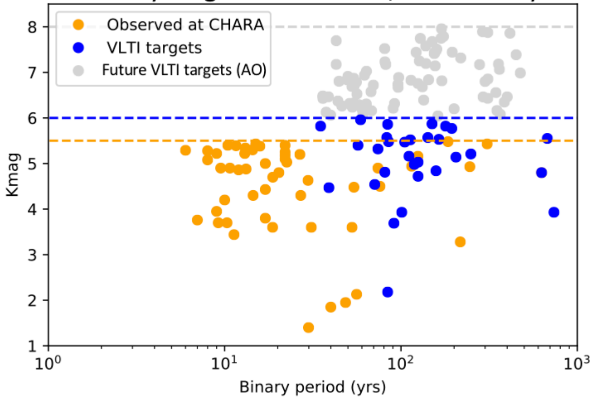


Gardner et al (2018) → ***Can detect most planets > 2 M_J on orbits > 0.7 AU***

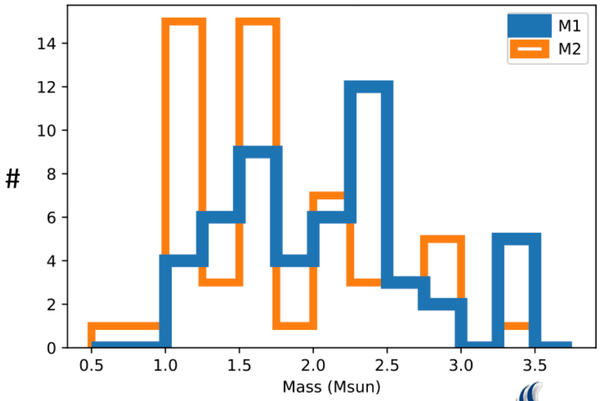
ARrangement for Micro-Arcsecond Differential Astrometry (ARMADA)

- Monitor ~70 “hot” binaries
  - Hmag < 6.0, sep < 0.2”
- North: CHARA/MIRC-X
- South: VLTI/GRAVITY

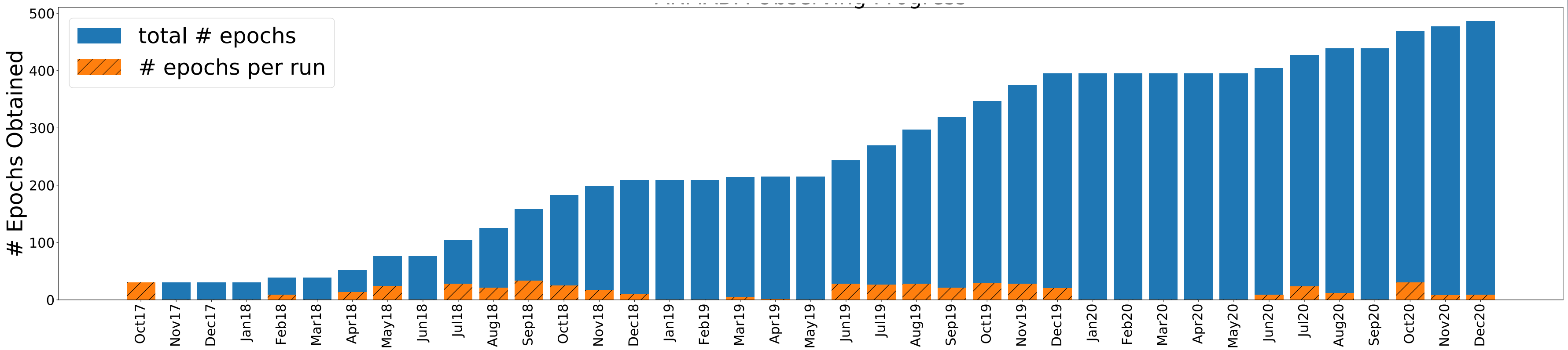
Binary Targets for CHARA / VLTI Survey



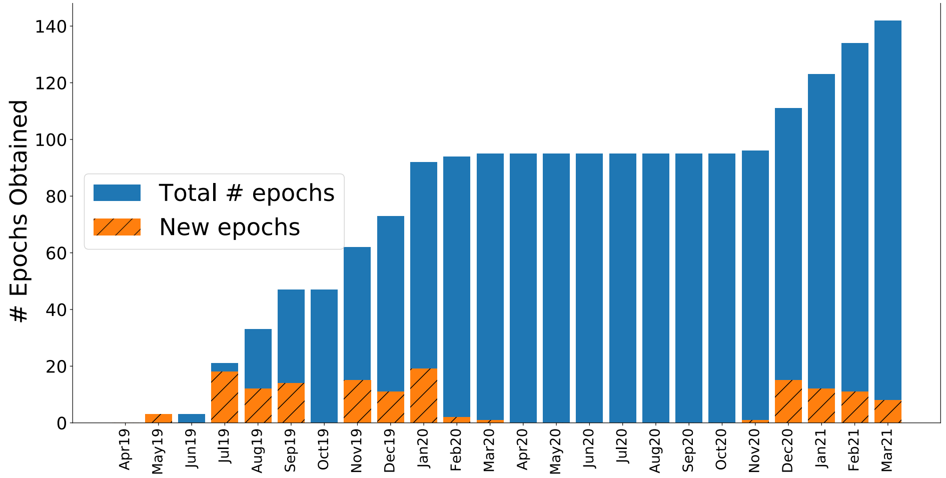
ARMADA Sample: Mass



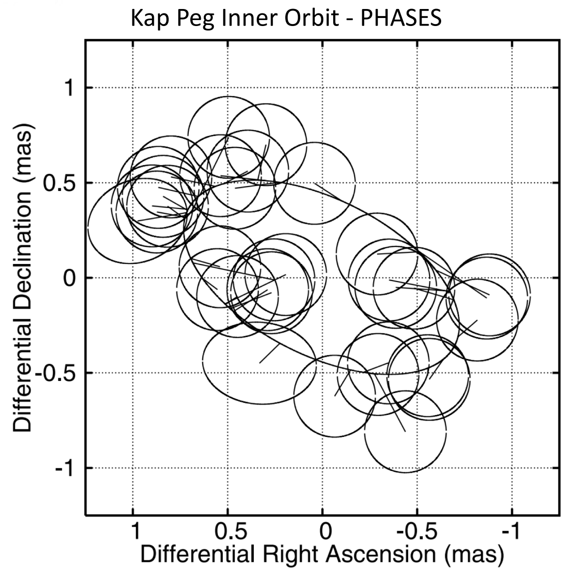
CHARA / MIRCX



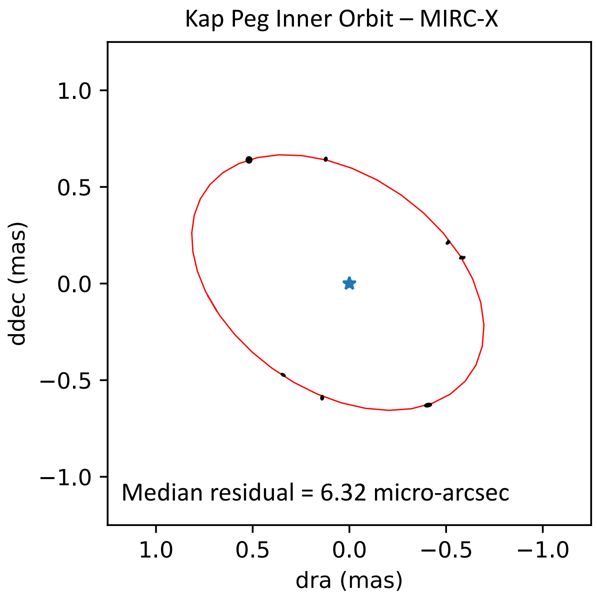
VLTI / GRAVITY



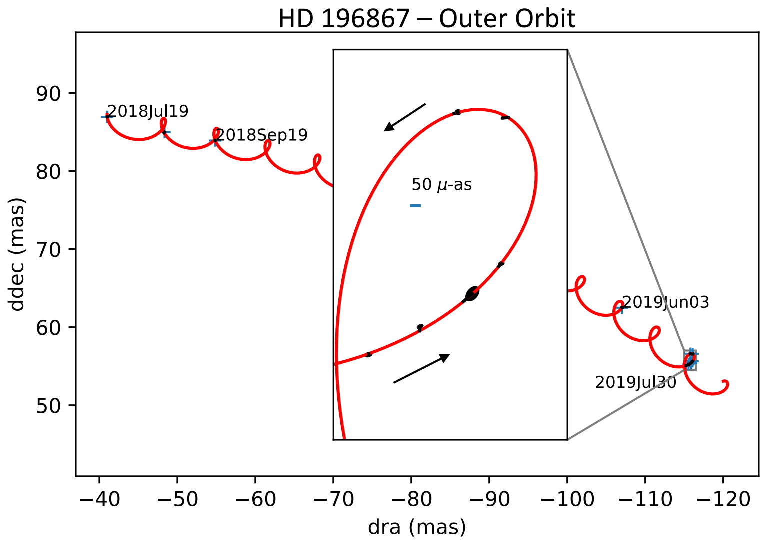
First Discoveries: Compact Triples



Muterspaugh et al (2006)



- ***Recent paper: Gardner et al (2021)***
  - 3 triple systems
- **Visual orbit elements**: e.g. period, inclination, eccentricity, mass, mutual inclination



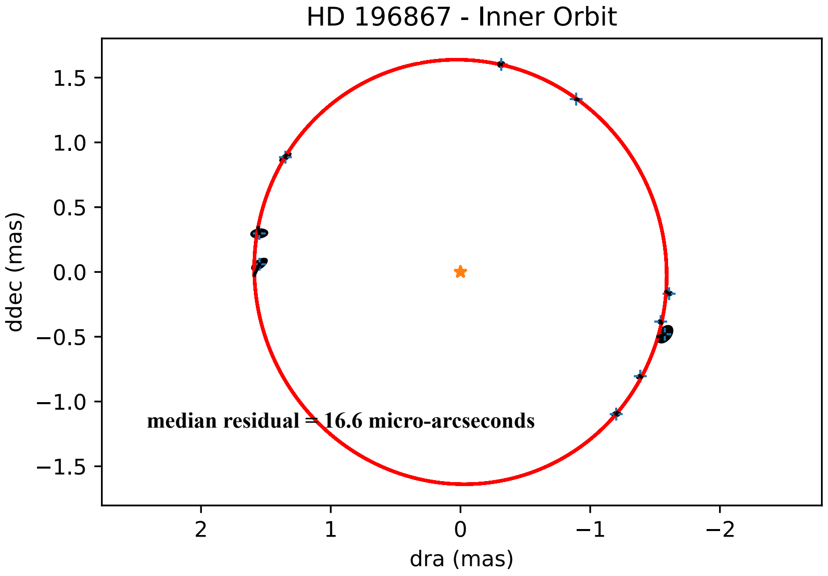
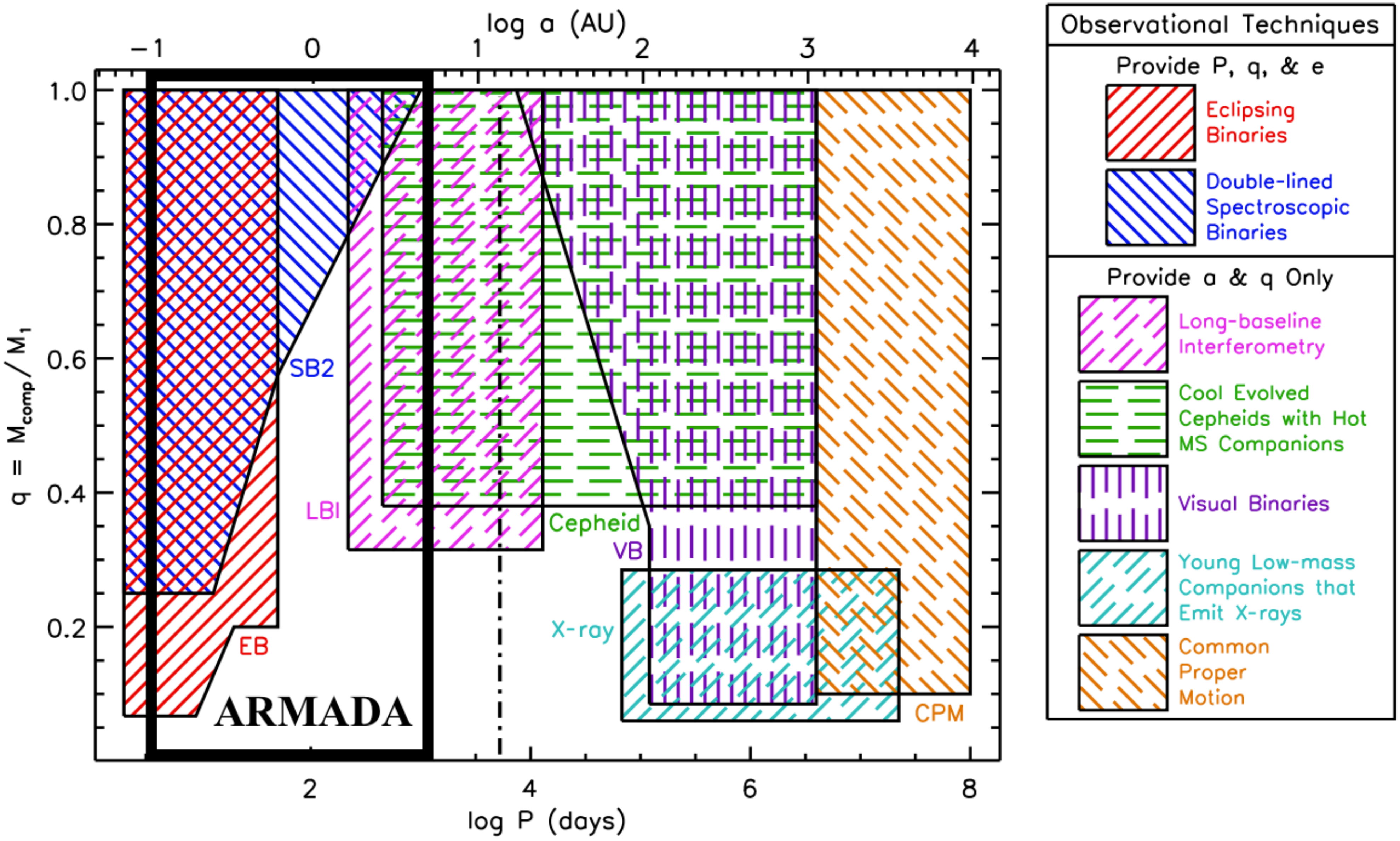
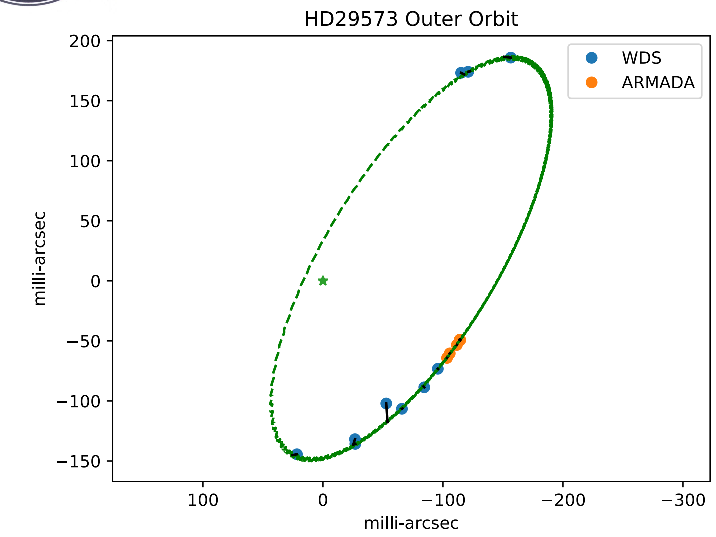
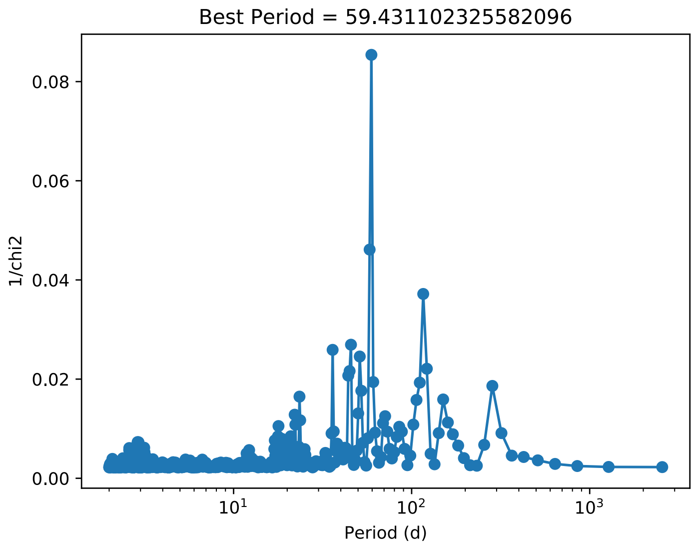


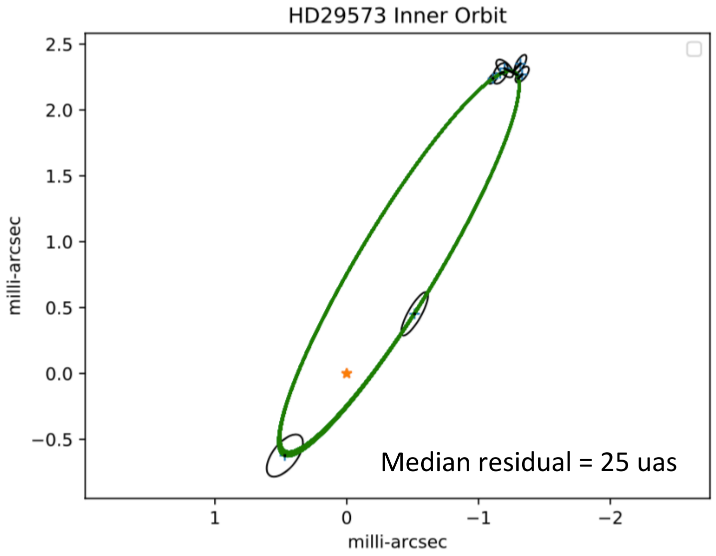
Figure from Moe & Di Stefano (2017)

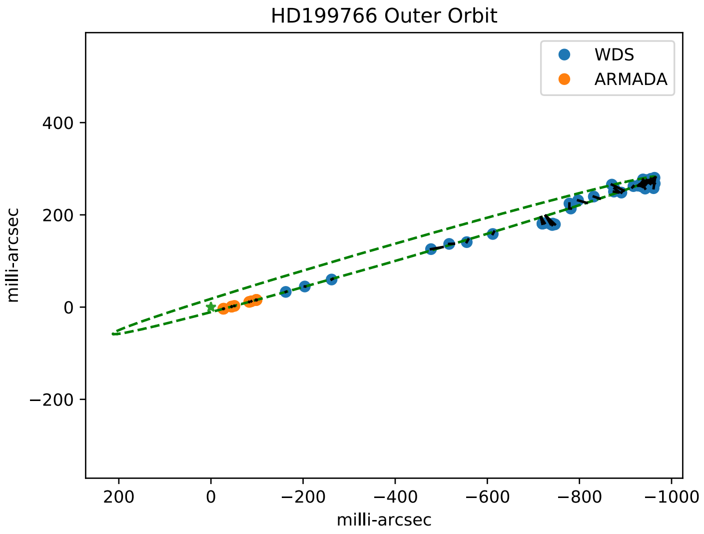


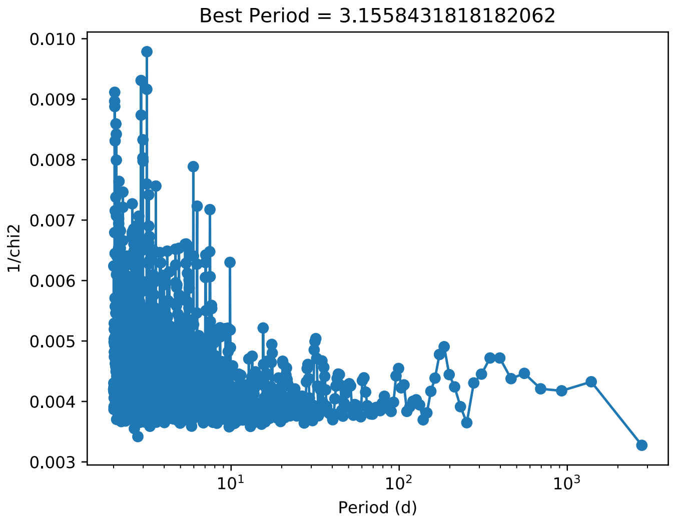
Triple Candidate Detections – CHARA/MIRCX

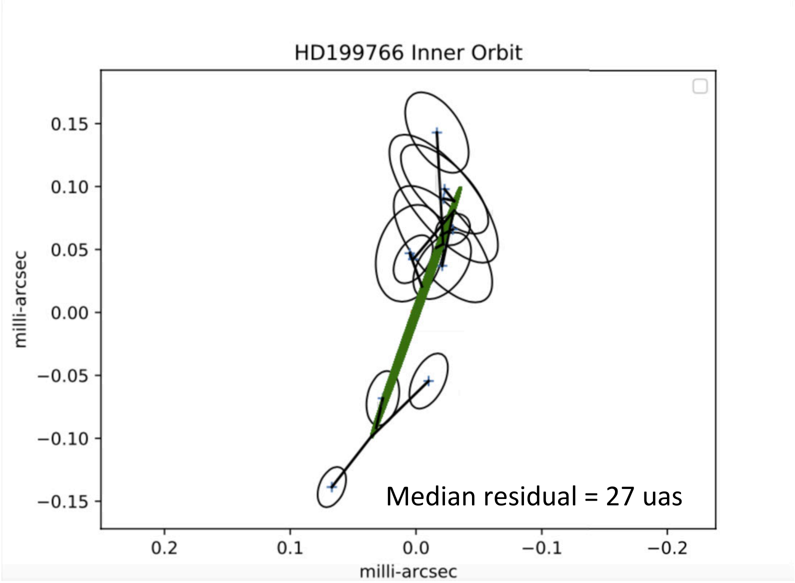




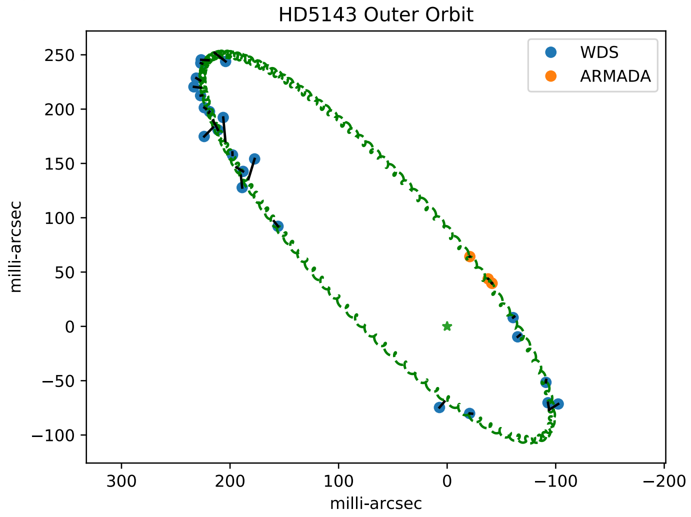


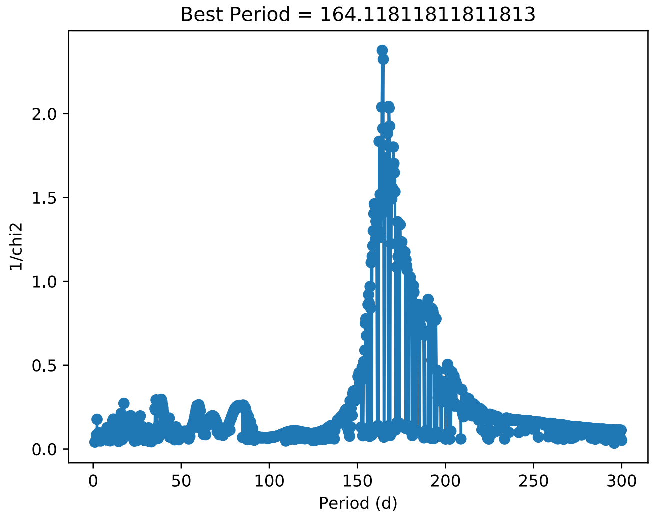


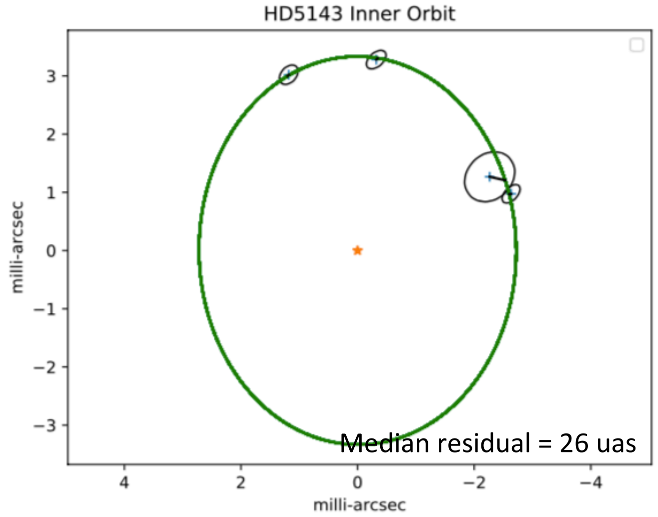


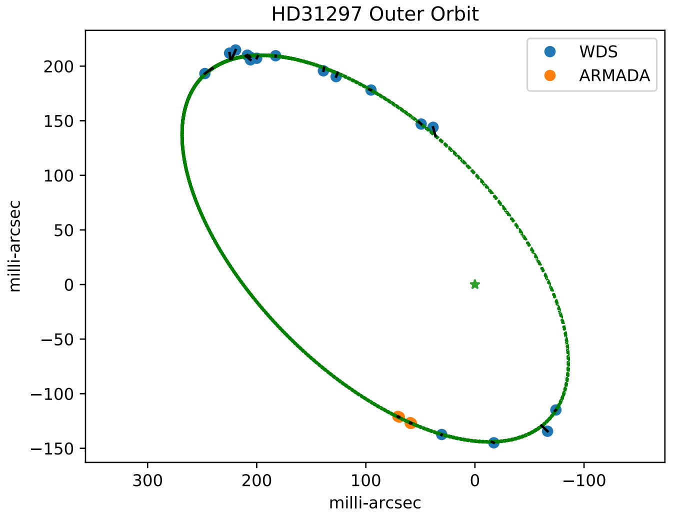


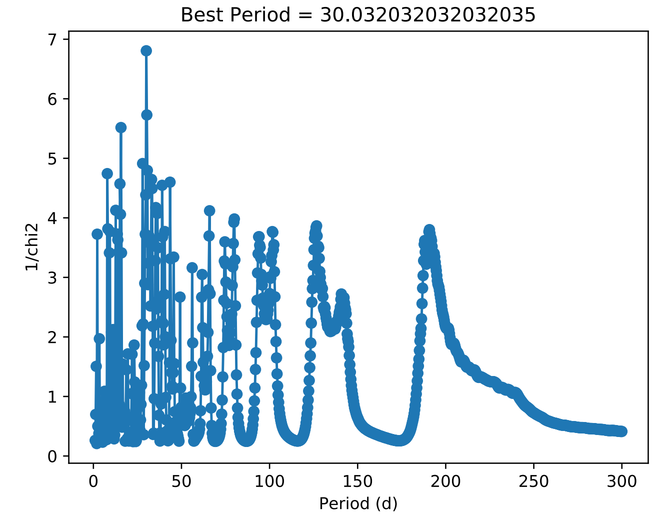
Triple Candidate Detections – VLTI/GRAVITY

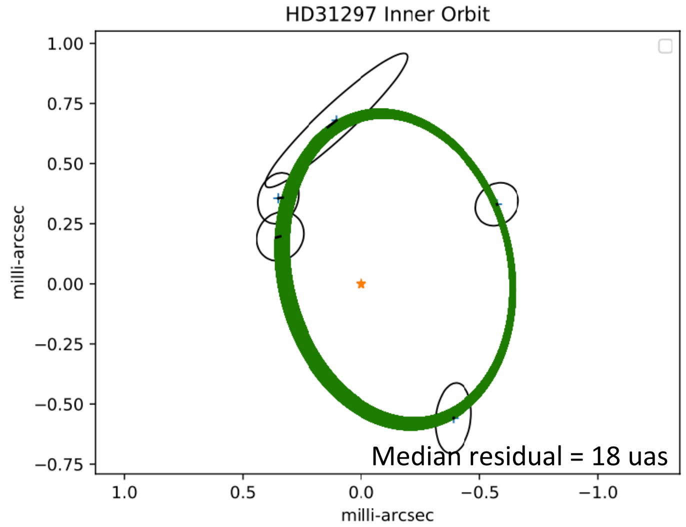




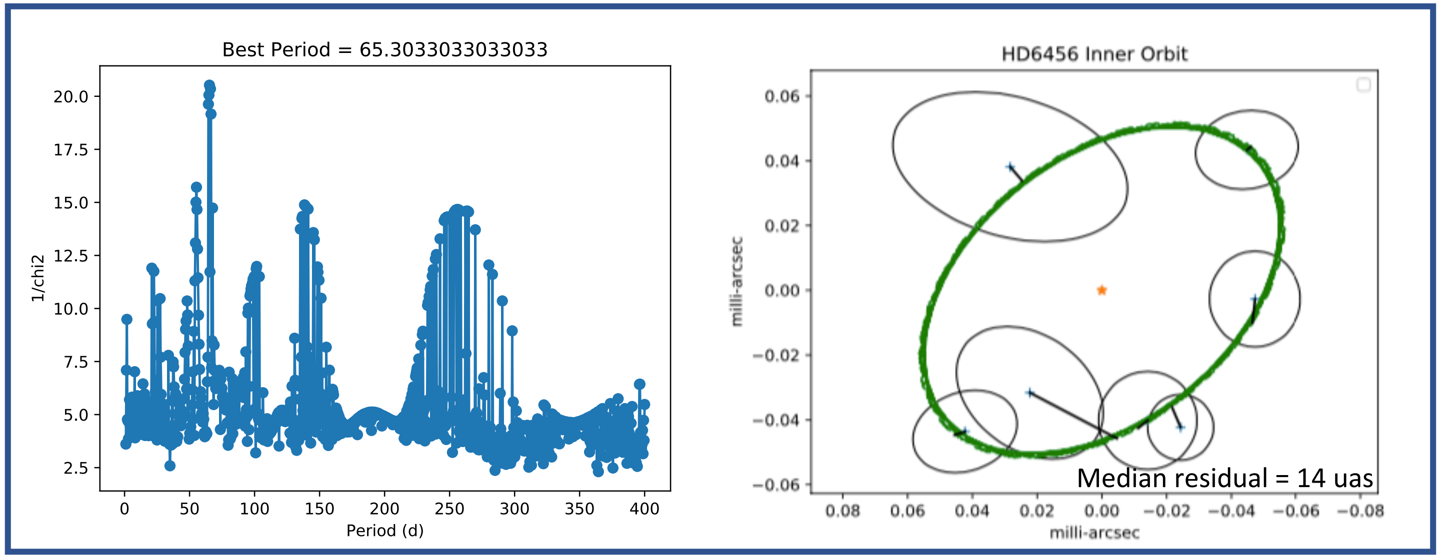


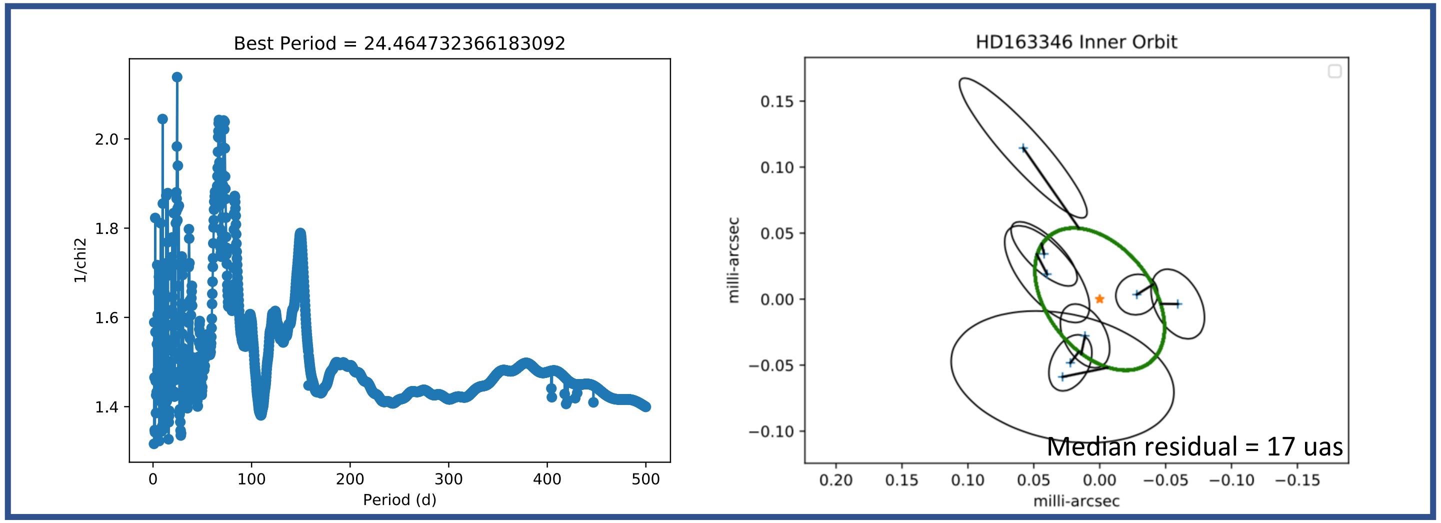


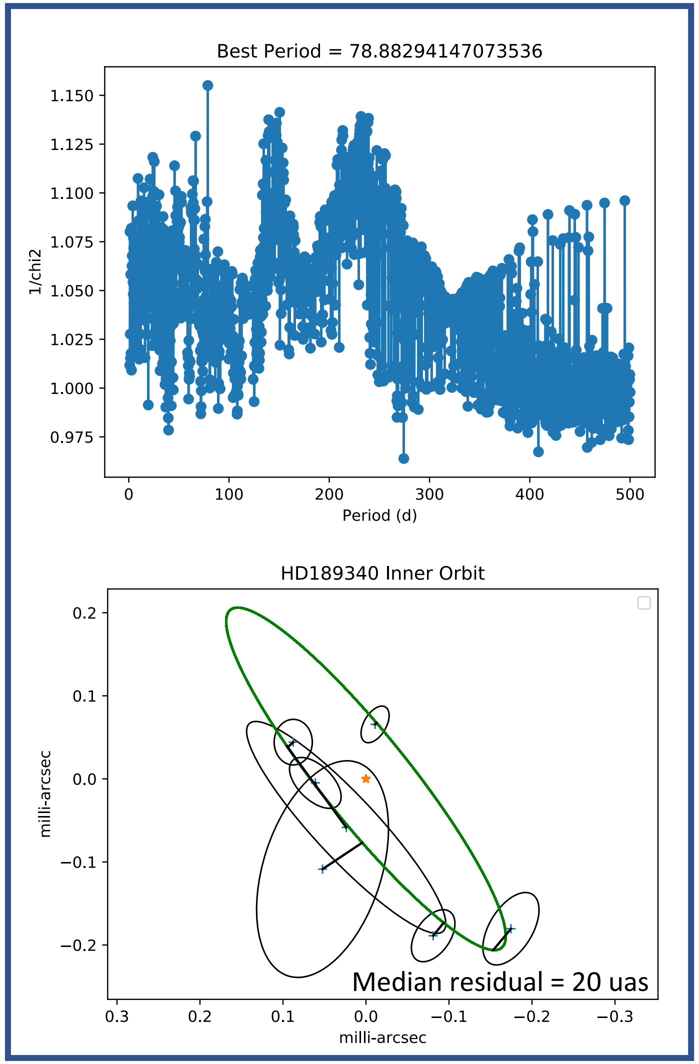




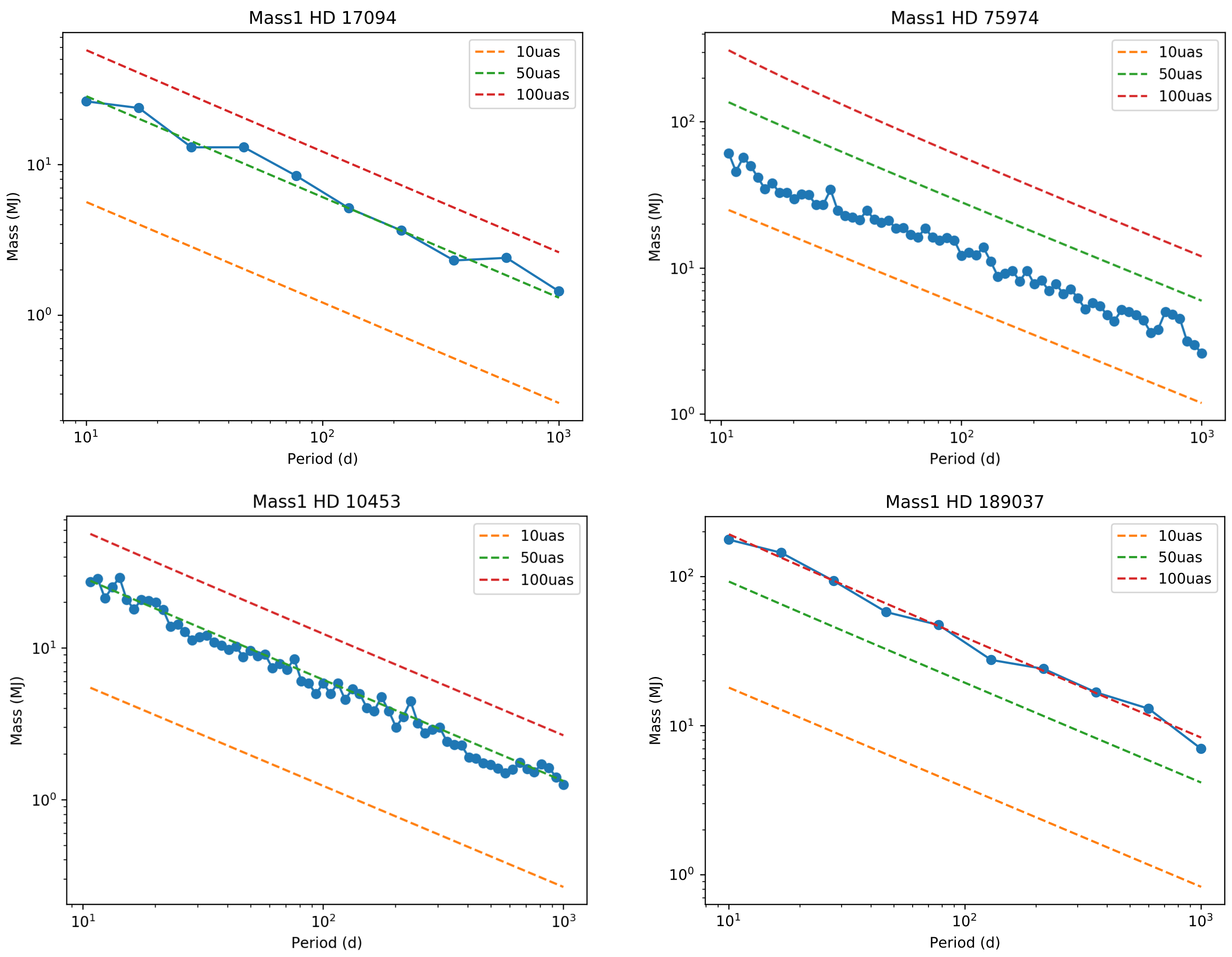
Brown Dwarf Candidates – Need more data!







Mass Limits for Non-Detections



- Inject 1000 randomly oriented planets at each inner period
- Adjust ”wobble” until we can recover 99% injected planets

- Currently detecting 99% of ~50uas wobbles with this scheme
  - Can exclude stellar mass companions, BDs, and (in some cases) giant planets with data we already have

Summary

- Goal: Improve exoplanet census with long-baseline interferometry by targeting A/B-type binary systems
- We hope to recover exoplanets >1 M_{Jup} on ~AU orbits
    - First discoveries are compact triples, brown dwarf candidates
    - Can already exclude stellar companions, and approaching planetary mass objects

Future Work

- Keep gathering epochs!
    - Another ~year at CHARA & VLTI
- Paper submitted on first compact triple objects, more detections to publish soon
- RV follow-up on candidate detections

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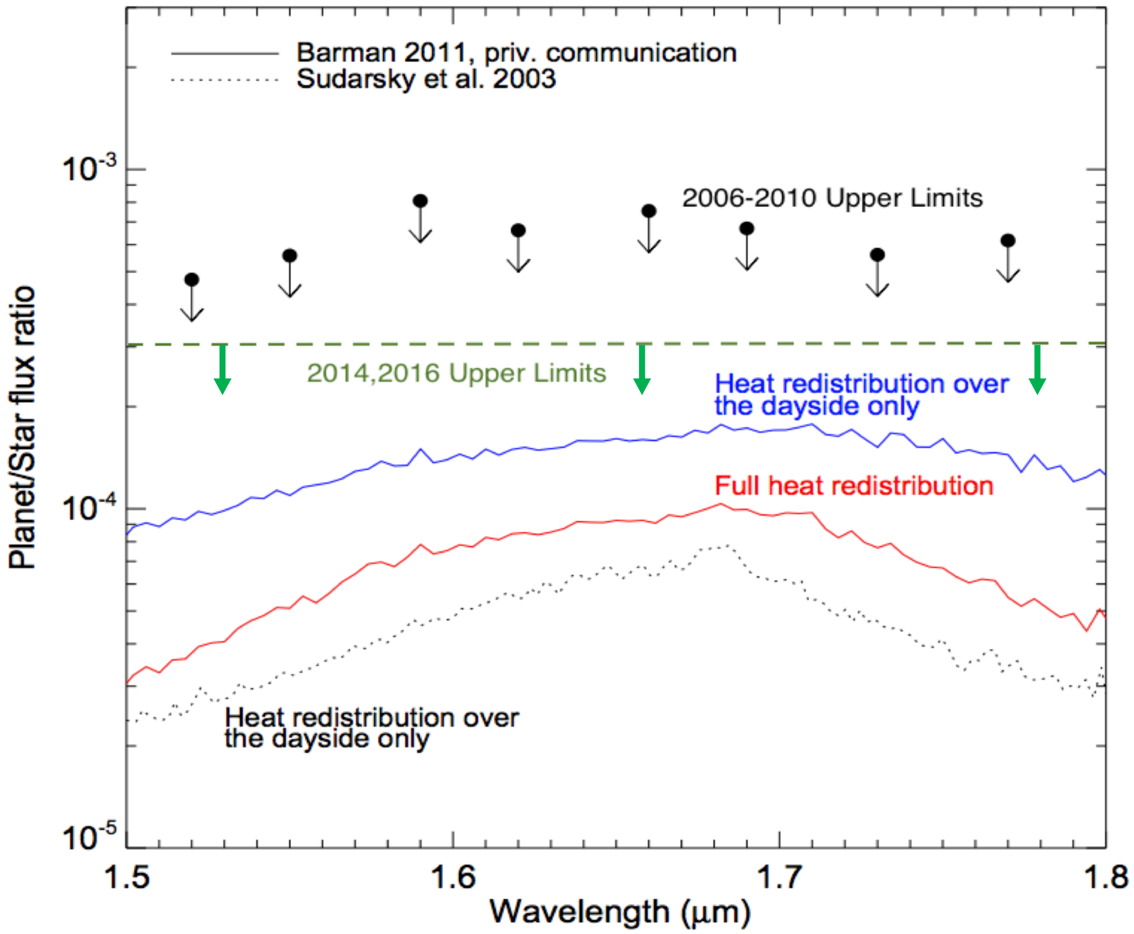
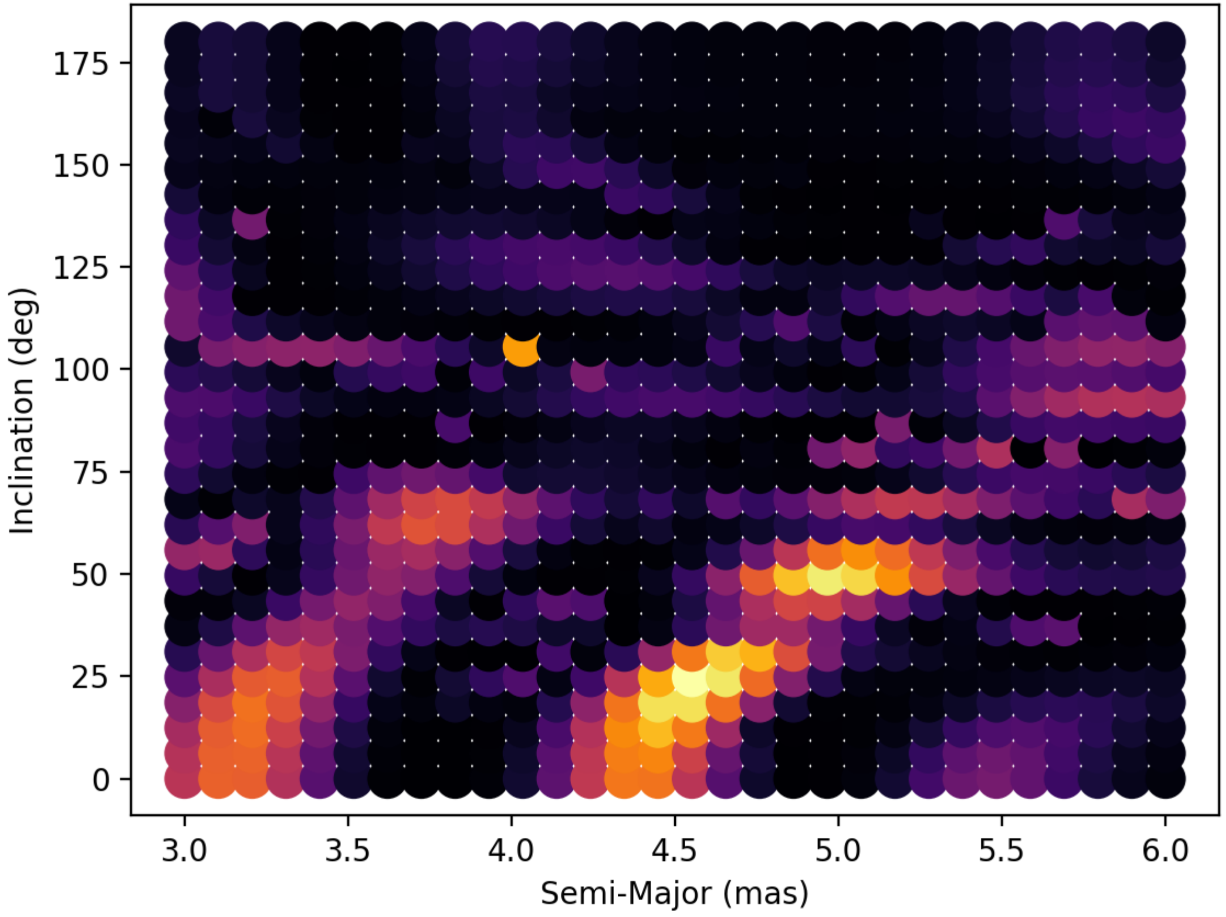
Another MIRCX project: Detecting flux from hot Jupiter

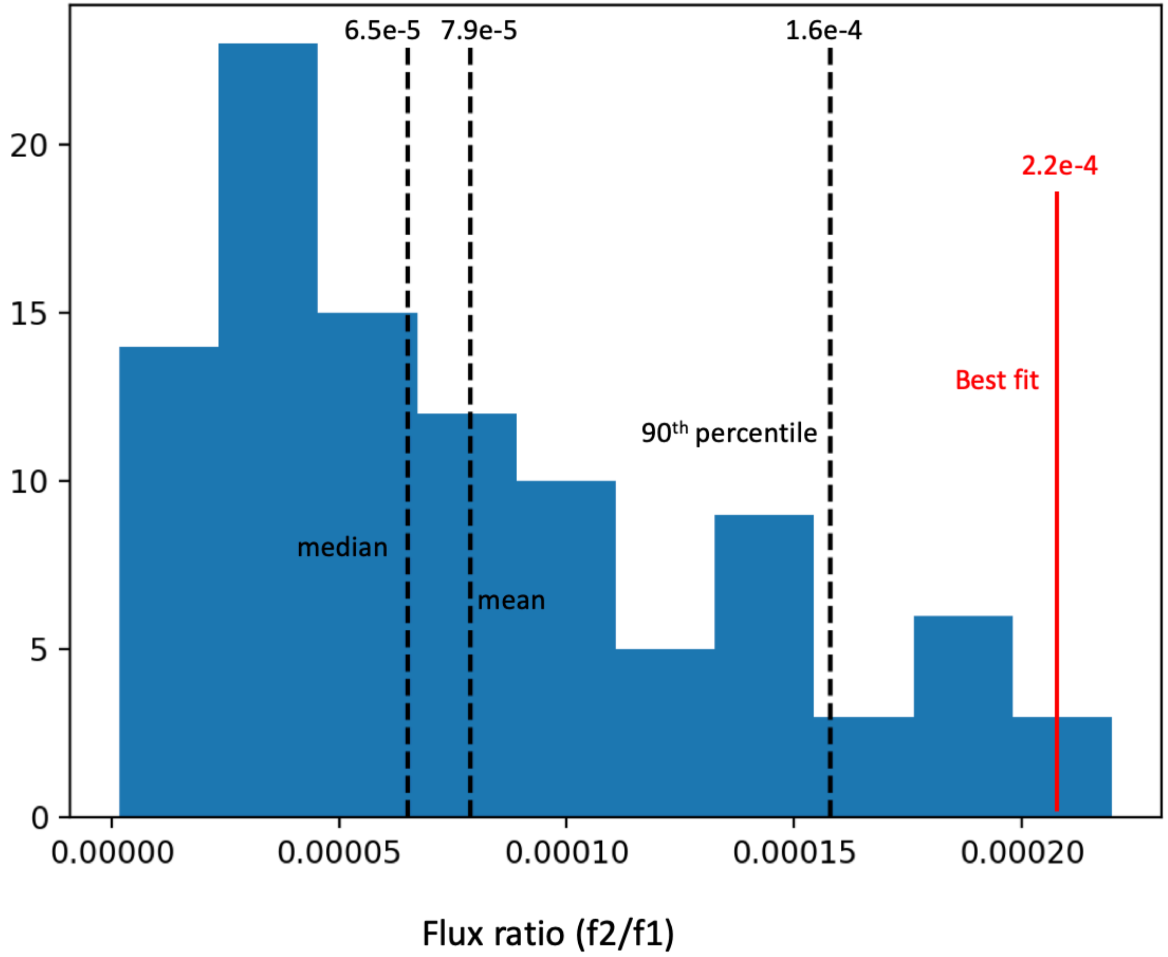
- Model Star-Planet as a high contrast binary (1:10,000)
- Precision closure phases

Zhao et al (2011)



Ups And b – September 2019





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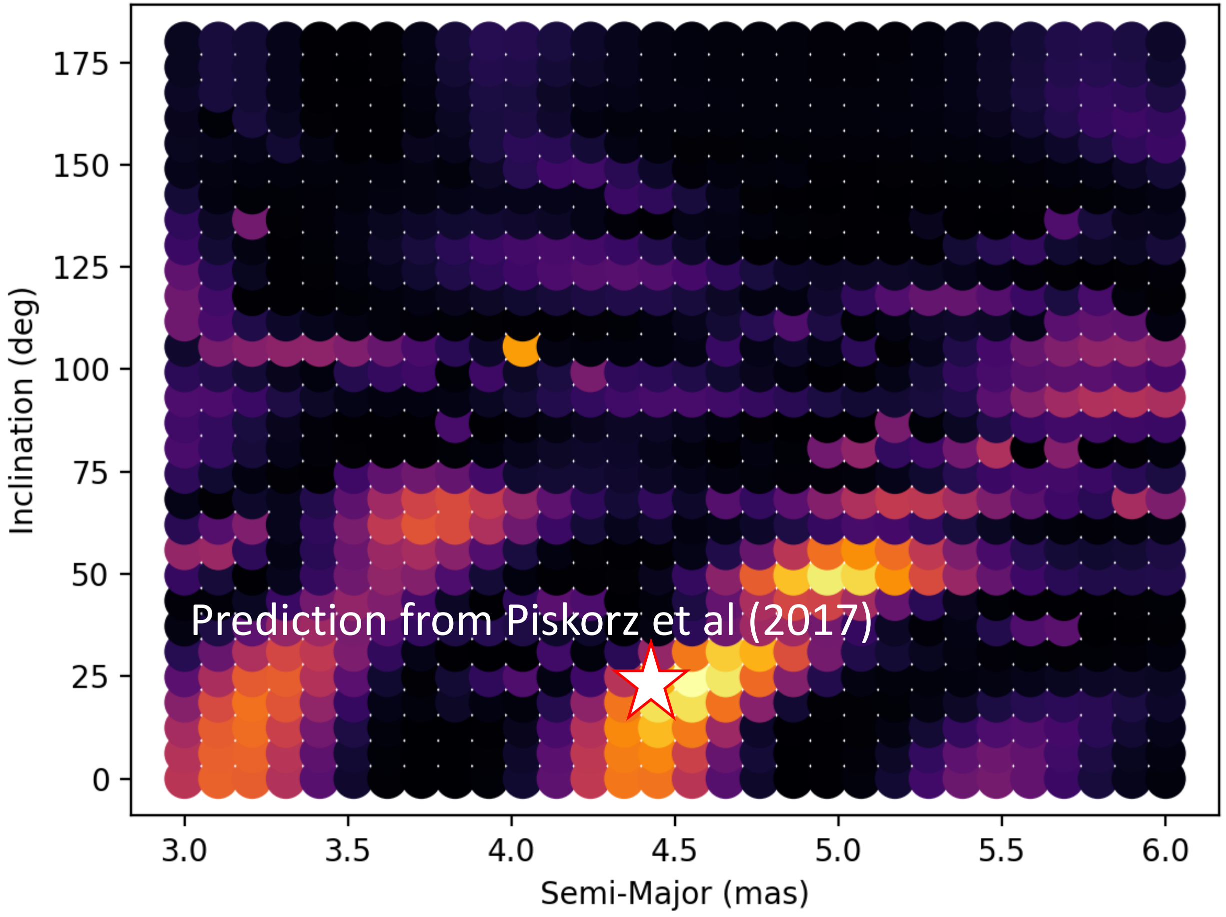
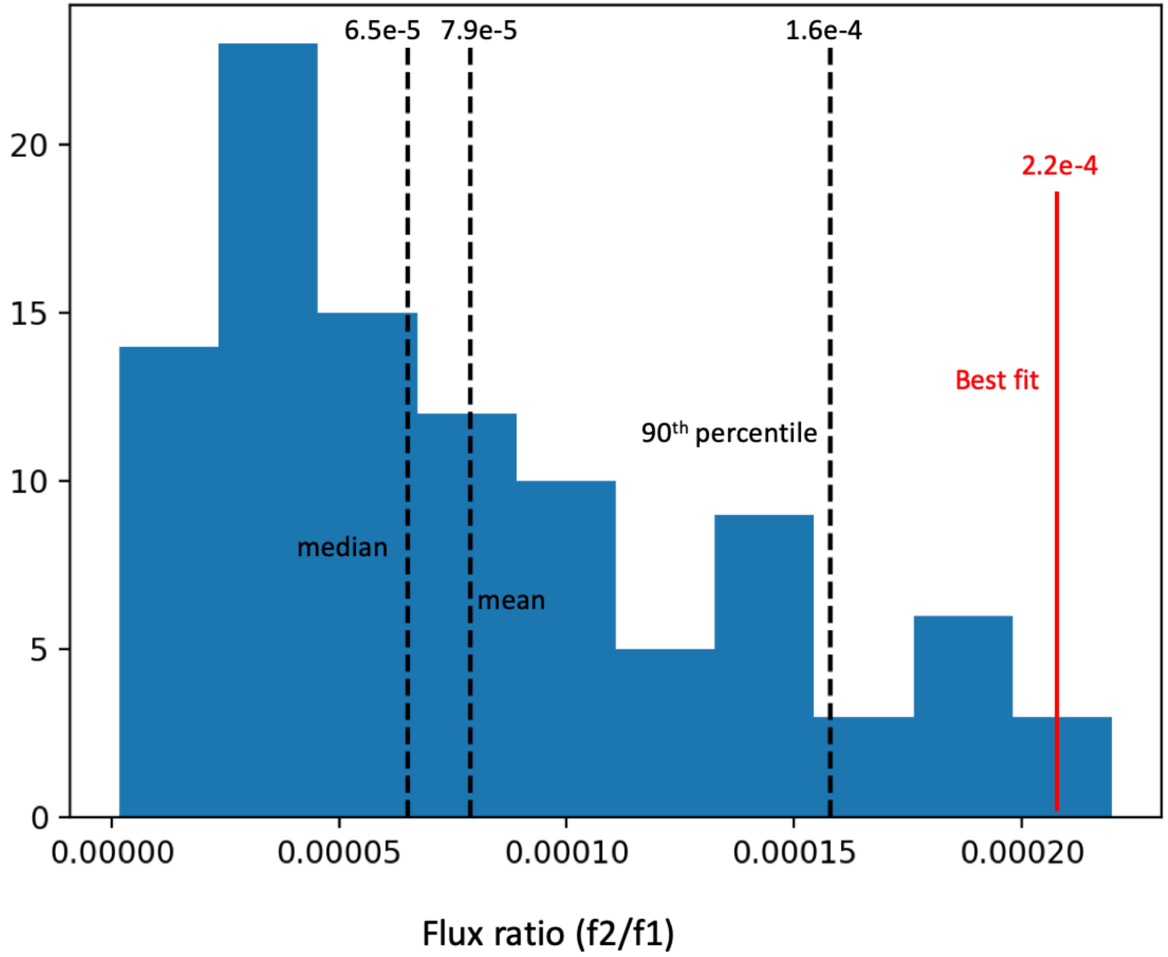


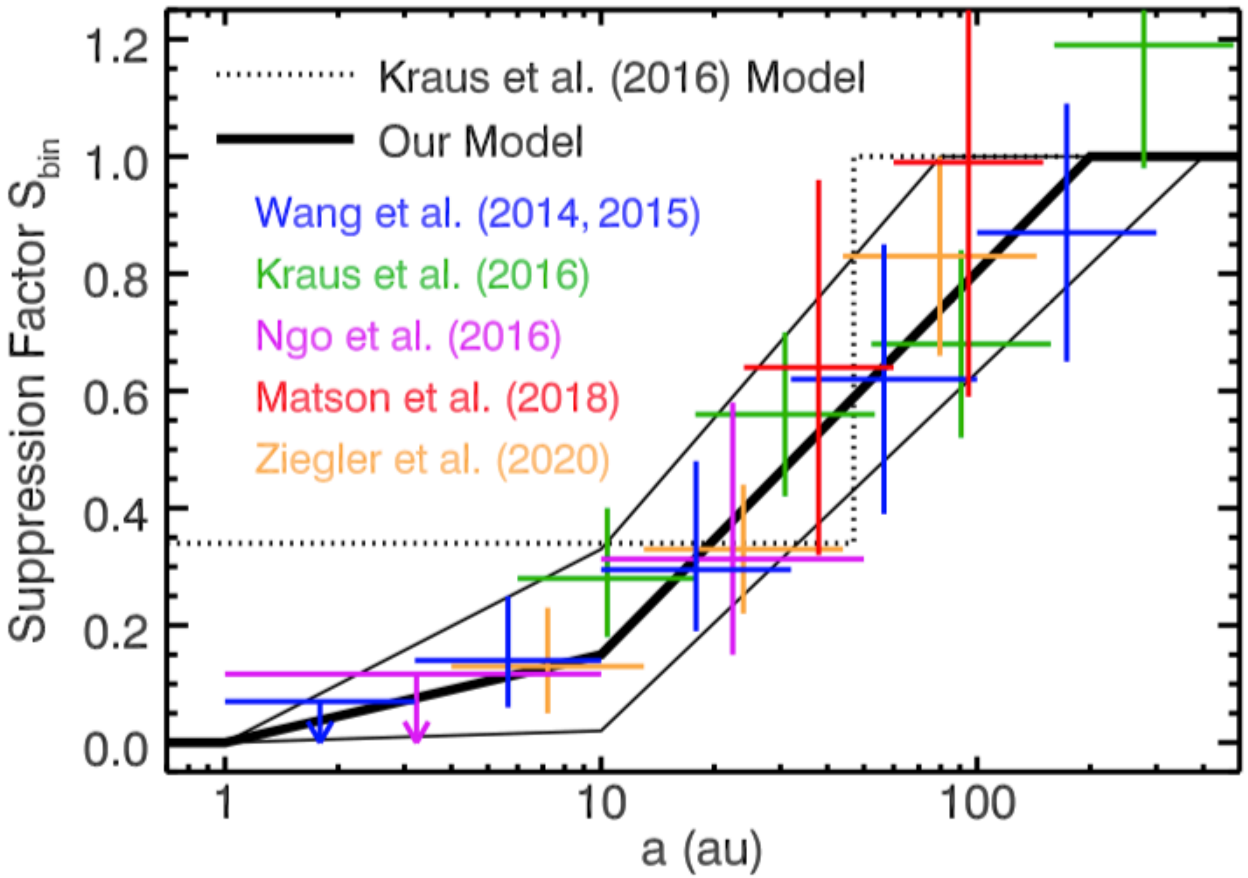


Planets in Binary Systems?

- Difficult to find S-type planets

- Varying degree of suppression shown once binary separation < 50-100 au
    - *Solar-type* stars, Kepler/TESS planets
    - Moe & Kratter (2020); Kraus et al (2016), Ziegler et al (2019)

Moe & Kratter (2020) → Solar-type and low mass stars:



Goal: Vary binary separation from 10-100 au, test if suppression occurs for hot stars

Goal: Test/Improve Exoplanet Demographic Models

Expected Exoplanet Yield from ARMADA Survey

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