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Large Adaptive optics Survey for Substellar Objects (LASSO) at wide separations around young, nearby, low-mass stars

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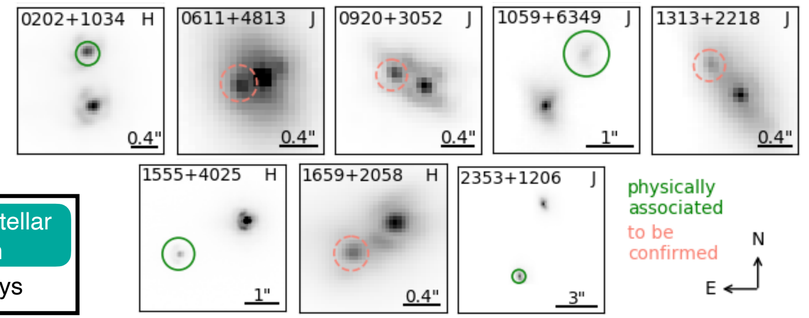


Motivation

Observe the diversity of substellar companions and system architectures → Analyze population trends to place stronger constraints on models → Understand planetary and stellar formation and evolution

- Main challenge is rarity of these wide-orbit substellar companions, with current occurrence rate estimates of 1-4%[1] ➔ need large surveys

Target selection

Cool Dwarf Catalog[2]
↓ x GALEX UV cuts to select for youth[3]
x GALEX: UV cuts
↓ x *Gaia* DR2 with parallaxes to select targets < 100 pc
x *Gaia* DR2: distance cut
↓ i'-band < 15 (or V-band < 17), Dec > -30°
~3000 LASSO targets

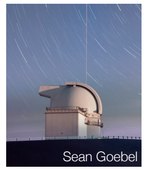
Observations

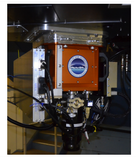
Robo-AO

- Obtained high-resolution images of 427 young, nearby, low-mass stars with Robo-AO in the visible and near-IR

Instrument

- Robotic AO laser guide star instrument[4]
- 2.1-m telescope on Kitt Peak, AZ (2015-2018)
- UH 2.2-m on Maunakea, HI (2019-today)
- Simultaneous visible and infrared imaging

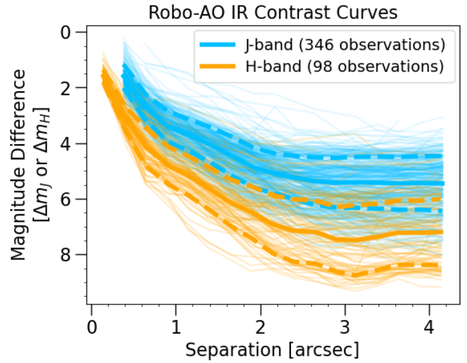


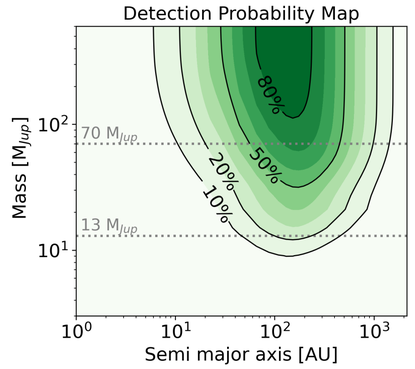


IR Camera

- SAPHIRA (Selex Avalanche Photodiode for High-speed Infrared Array) detector[5]
- Amplifies signal through avalanche gain while keeping the readnoise fixed

Sensitivity

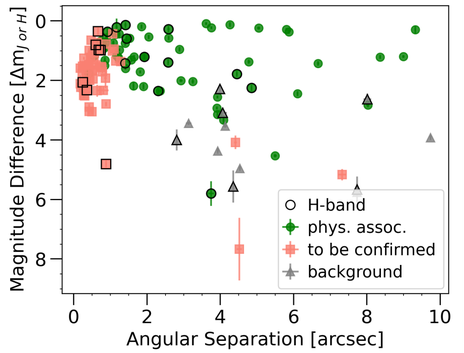


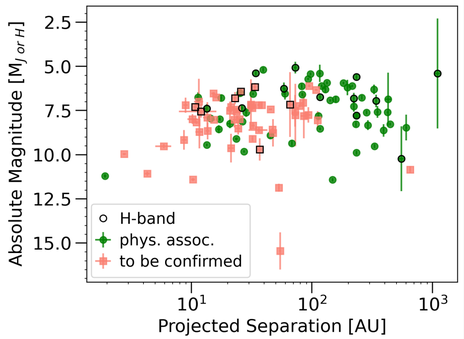


- Used `ExoDMC` python package[6]

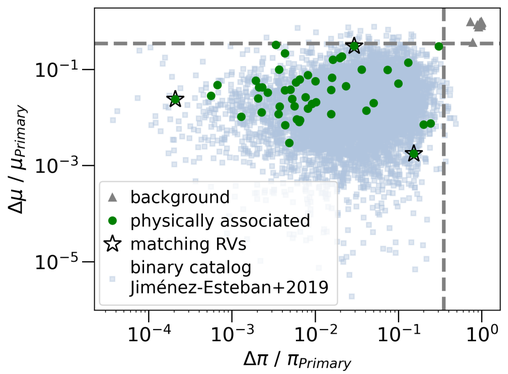
Companion detections

- 122 companion detections
  - 12 ruled out as background
- 110 companions around 104 stars (raw multiplicity fraction: 24.4 ± 2.1%)
  - One 43 ± 9 M_{Jup} companion[7]
  - One 81 ± 5 M_{Jup} companion[7]
  - Five substellar candidates (currently being followed up)
  - Six triple systems (3 confirmed, 3 currently being followed up)



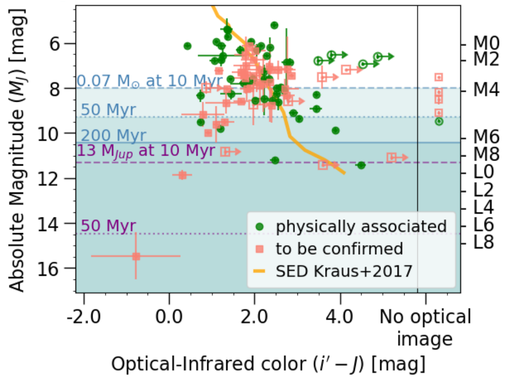


Physical association



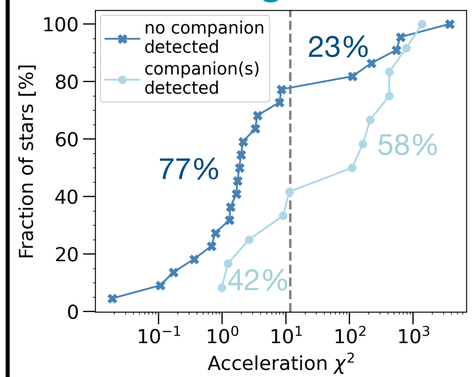
- We determined physical association from *Gaia* DR2 parallaxes and proper motions:
  - 58 are likely physically associated
  - 12 ruled out as background objects
  - 52 remain to be confirmed

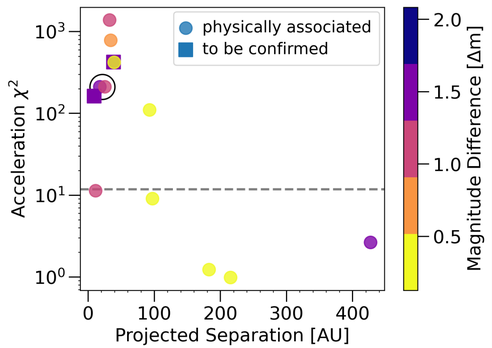
Optical-IR colors



- Optical-IR colors allow us to estimate if a companion is consistent with a low-mass companion or background object
- For companions not detected in the optical, we placed limits on their colors (arrows)
- Mass estimates from isochrone models[8,9]

Accelerating Stars





- From Hipparcos-Gaia Catalog of Accelerations (HGCA; Brandt 2018)
- Significant acceleration: $\chi^2 > 11.8$ (grey dashed line)
- A higher fraction of stars with detected companion(s) have significant accelerations compared to stars with no detected companion
- Clear correlation between acceleration significance and companion projected separation

References: [1] Bowler & Nielsen (2018), [2] Muirhead et al. (2018), [3] Rodriguez et al. (2013), [4] Baranec et al. (2014), [5] Finger et al. (2014), [6] Bonavita et al. (2020), [7] Bowler et al. (2015), [8] Chabrier et al. (2000), [9] Baraffe et al. (2015)