

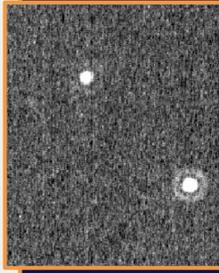
A New Stellar Companion from Binary Differential Imaging with MagAO/CLIO and MagAO-X

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Binary Differential Imaging (BDI):

- Simultaneously image science target and PSF reference star in same filter
- Combine binary imaging with Karhounen-Loeve Image Processing¹ (KLIP) and angular differential imaging (ADI)
- Image at L' to take advantage of large isoplanatic patch (~30") -> PSFs should be nearly identical²



HD Name	Alt Name	Separation ^{a,*} (arcsec)	Distance ^a (pc)	Age (Myr)	SpT	Group Membership ^{**}
HD 36705	AB Dor	8.8609 ± 50	14.93 ± 0.02	100 ^b	K0V + M5.6 ^c	AB Dor
HD 37551	WX Col	4.00175 ± 1	80.45 ± 0.07	15 ± 4 ^d	G7V + K1V ^c	AB Dor ^e
HD 47787	HIP 31821	2.15685 ± 2	47.83 ± 0.04	16.5 ± 6.5 ^f	K1IV + K1IV ^c	Field ^j
HD 76534	OU Vel	2.06874 ± 2	869 ± 14	0.27 ^h	B2Vn ⁱ	Field ^j
HD 82984	HIP 46914	2.0041 ± 30	274 ± 7	53.4 ± 15.1 ^f	B4IV ^f	Field ^j
HD 104231	HIP 58528	4.45718 ± 5	102.7 ± 0.5	21 ^k	F5V ⁱ	LCC ^m
HD 118072	HIP 66273	2.27647 ± 7	79.5 ± 0.4	40-50 ^p	G3V ^c	90% ARG ^j
HD 118991	Q Cen	5.56444 ± 6	88.3 ± 0.3	130-140 ^p	B8.5 + A2.5 ^q	Sco-Cen ^j
HD 137727	HIP 75769	2.20358 ± 3	111.7 ± 0.3	8.2 ± 0.6 ^f	G9III + G6IV ^c	Field ^j
HD 147553	HIP 80324	6.23216 ± 7	138.2 ± 1.3	11 ± 2 ^{k,r}	B9.5V + A1V ^s	UCL ^j
HD 151771	HIP 82453	6.8957 ± 3	270 ± 2	200-300 ^t	B8III + B9.5 ^s	Field ^j
HD 164249	HIP 88399	6.49406 ± 2	49.30 ± 0.06	25 ± 3 ^r	F6V + M2V ^c	Beta Pic ^{w,x}
HD 201247	HIP 104526	4.17040 ± 3	33.20 ± 0.04	200-300 ^y	G5V + G7V ^c	Field ^j
HD 222259	DS Tuc	5.36461 ± 3	44.12 ± 0.07	45 ± 2 ^r	G6V + K3V ^c	Tuc-Hor ^s
-	HIP 67506	9.38117 ± 9	89.5 ± 30 ^z	210 ± 5 ^t	G5 ^z	Field ^j
-	TWA 13	5.06925 ± 3	59.9 ± 0.1	10-20 ^r	M1Ve + M1Ve ^c	TW Hydra ^d
-	2MASS J01535076-1459503	2.8543 ± 10	33.85 ± 0.09	25 ± 3 ^r	M3 ^c	Beta Pic ^w

*Uncertainties in units of 10⁻⁵ arcsec

The MagAO/CLIO survey:

- 17 visual binary systems²:
- Nearby (<~200 pc)
 - Young (<~200 Myr)
 - Separation 2-10"
 - L' mag within ~2 mag
- Imaged 2015 - 2017
With MagAO + CLIO³
camera on Magellan Clay telescope in L'

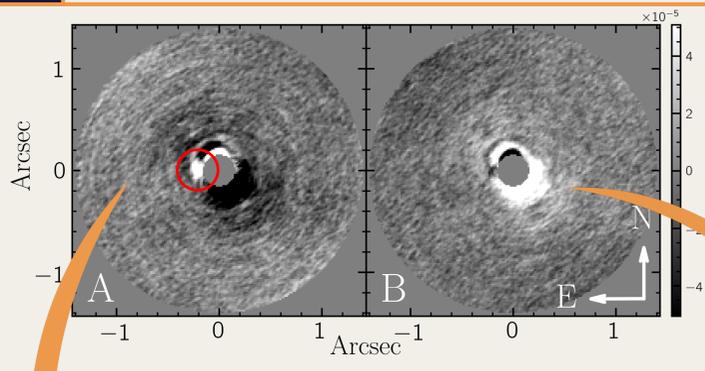
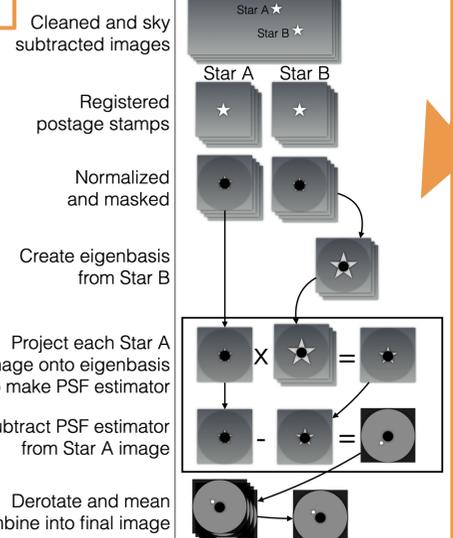
Key Result:

One candidate companion!

- Rotated with the sky
- Significant acceleration btwn Hipparcos and Gaia⁵
- Poor Gaia astrometric solution

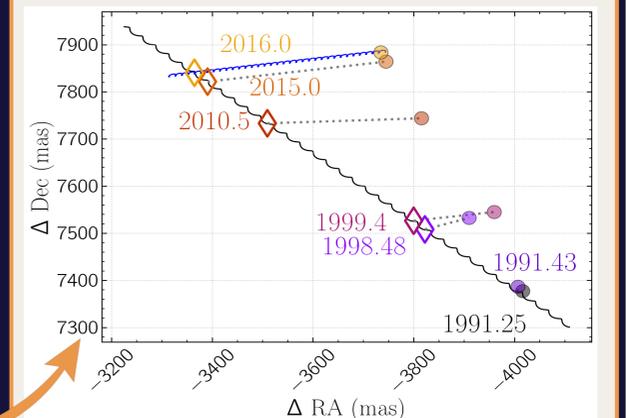
Processed with KLIP:

- Principle component analysis (PCA) applied to image data.
- Each star is used to form the basis set for the other⁴



Aside: HIP 67506 B is NOT bound

- HIP 67506 was identified as a wide binary in the Hipparcos and Tycho Doubles and Multiples Catalog with another star with separation 9"
- Dubbed HIP 67506 A and B
- We conducted a common proper motion analysis with WDS and Gaia astrometry
- HIP 67506 B is not gravitationally bound and is ~10x further distant than HIP 67506 A!



Relative astrometry of HIP 67506 B relative to HIP 67506 A. The motion of a background star at the position of HIP 67506 B is shown by the black track for the Gaia EDR3 proper motion and parallax given for HIP 67506 B, with the predicted position at WDS observation epochs marked by colored diamonds. The observed WDS positions are marked by filled circles. The astrometry is more consistent with a more-distant background star than a bound companion!

Followed up with MagAO-X⁶:

- April 18th, 2022
- z', i', r', g'
- Easily detected!

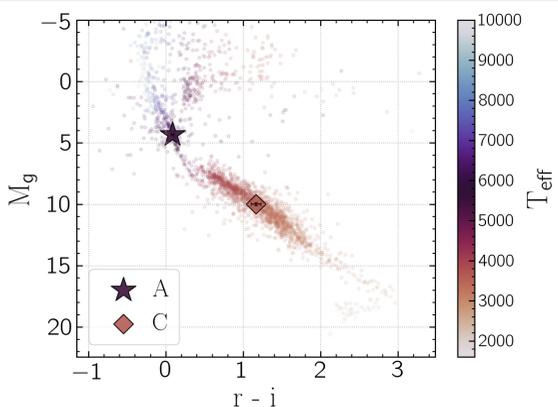
Confirmed!

Introducing the NEW HIP 67506 C!

MagAO-X

0.1"

z'
April 18th, 2022



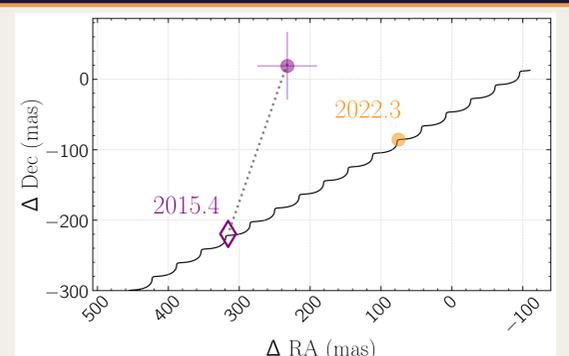
Color-Magnitude diagram of stars in the CARMENES⁷ sample of M, L, and T dwarfs and selected Hipparcos stars (earlier SpTs) in Sloan r-i color vs g' abs magnitude, colored by spectral type, with our MagAO-X photometry (converted to Sloan system) of HIP 67506 A (maroon) and B (orange). B is consistent with mid-M and A is consistent with late-K to early-M colors.

HIP 67506 C:

- Best fit models give SpT = M4V, T_{eff} = 3100K, log(g) = 5.0

HIP 67506 A:

- Best fit models give SpT = F8-G2, T_{eff} = 6000K, log(g) = 3.0



Common proper motion plot of HIP 67506 C relative to A. Motion of signal if it were an unmovng background object given by the black track, and 2015 observation location given by the diamond. Circles mark actual observed location. This shows C is likely a bound companion

About the Author:

Logan is a graduate student at the University of Arizona Steward Observatory studying how planetary systems form and evolve with Dr. Jared Males. She was a US Navy Nuclear Power Officer from 2003-2008, and a middle school science teacher from 2009-2015, and calls Austin TX home.

References:

1. Soummer, R. et al. 2012, ApJL, 755, L28; 2. Rodrigues, T. et al. 2015, ApJ, 811, 157; 3. Morzinski, K. et al. 2015, ApJ, 815, 108; 4. Pearce, L. et al. (Submitted to MNRAS); 5. Kervella, P. et al. 2022, A&A, 657, A7; 6. Males, J. et al. 2020, Proceedings of SPIE, id. 114484L; 7. Cifuentes et al. 2020, A&A, 642, A115; 8. Allard, F. et al. 2012, RSPTA, 370, 1968; 9. Pickles, A. et al. 1998, PASP, 110, 749