Results from 17 Binary Star Systems from the MagAO Binary Differential Imaging Survey & The Status of MagAO-X & GMagAO-X Extreme Adaptive Optics Instruments

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Background

- Starlight PSF subtraction in direct imaging companion searches can be improved by imaging science and reference stars simultaneously in the same filter band – "Binary Differential Imaging (BDI)"[1,2]
- Imaging at long wavelengths (L') exploits the region where substellar SED is maximum and the large isoplanatic patch at L' (>10") so science and reference PSF should be very similar.
- Rodigas et al. 2015 found ~0.5 mag deeper contrast inside 1" with BDI + KLIP[3] compared to ADI.

The Survey

- We observed 17 binaries from 2014-2017 using MagAO/Clio[4,5] on Magellan Clay Telescope in L' (3.77μm) and 3.9μm filters.
- Systems are young (<300 Myr), nearby (<200 pc), with separations >2" (so PSFs can be isolated) and <10" (so stars are within isoplanatic patch at L'), and contrast <2 mag (so PSF features have similar SNR).

HD Name	Alt Name	Separation[a] (arcsec)	Distance[a] (pc)	Age (Myr)	SpT	Group Membership[a]
HD 36705	AB Dor	8.8609 ± 0.0005	14.93 ± 0.02	100[b]	K0V + M5.6[c]	AB Dor
HD 37551	WX Col	$4.00175 \pm 1\times10^{-5}$	80.45 ± 0.07	18.3 + 11.6[d]	G7V + K1V[c]	AB Dor[e]
HD 47787	HIP 31821	$2.15685 \pm 2\times10^{-5}$	47.83 ± 0.04	16.5 ± 6.5[f]	K1IV + K1IV[c]	Field[j]
HD 76534	OU Vel	$2.06874 \pm 2\times10^{-5}$	869 ± 14	0.27[b]	B2Vn[i]	Field[j]
HD 82984	HIP 46914	$2.0041 \pm 3\times10^{-4}$	274 ± 7	53.4 ± 15.1[f]	B4IV[f]	Field[j]
HD 104231	HIP 58528	$4.45718 \pm 5\times10^{-5}$	102.7 ± 0.5	21[b]	F5V[i]	LCC[m]
HD 118072	HIP 66273	$2.27647 \pm 7\times10^{-5}$	79.5 ± 0.4	40-50[n]	G3V[c]	90% ARG[j]
HD 118991	Q Cen	$5.56444 \pm 6\times10^{-5}$	88.3 ± 0.3	130-140[n]	B8.5 + A2.5[o]	Sco-Cen[j]
HD 137727	HIP 75769	$2.20358 \pm 3\times10^{-5}$	111.7 ± 0.3	8.2 ± 0.6[f]	G9III + G6IV[c]	Field[j]
HD 147553	HIP 80324	$6.23216 \pm 7\times10^{-5}$	138.2 ± 1.3	11 ± 2[b,e]	B9.5V + A1V[a]	UCL[j]
HD 151771	HIP 82453	$6.8957 \pm 3\times10^{-5}$	270 ± 2	200-300[p]	B8III + B9.5[a]	Field[j]
HD 164249	HIP 88399	$6.49406 \pm 2\times10^{-5}$	49.30 ± 0.06	25 ± 3[a]	F6V + M2V[c]	Beta Pic[w,x]
HD 201247	HIP 104526	$4.17040 \pm 3\times10^{-5}$	33.20 ± 0.04	200-300[p]	G5V + G7V[a]	Field[j]
HD 222259	DS Tuc	$5.36461 \pm 3\times10^{-5}$	44.12 ± 0.07	45 ± 2[a]	G6V + K3V[c]	Tuc-Hor[q]
–	HIP 67506	$9.38117 \pm 9\times10^{-5}$	102 ± 30[k]	210 ± 5[k]	G5[g]	Field[j]
–	TWA 13	$5.06925 \pm 3\times10^{-5}$	59.9 ± 0.1	10-20[r]	M1Ve + M1Ve[c]	TW Hydra[q]
–	2MASS J01535076-1459503	$2.8543 \pm 1\times10^{-4}$	33.85 ± 0.09	25 ± 3[s]	M3[s]	Beta Pic[w]

Summary of binaries in survey

BDI + KLIP

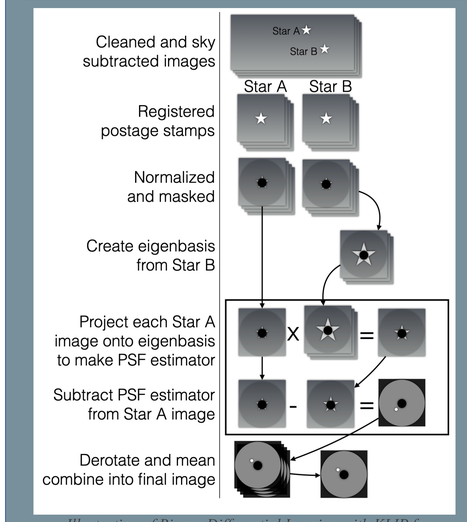
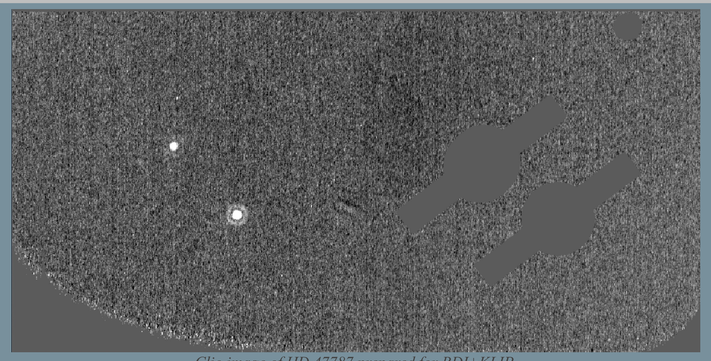


Illustration of Binary Differential Imaging with KLIP for constructing a PSF model

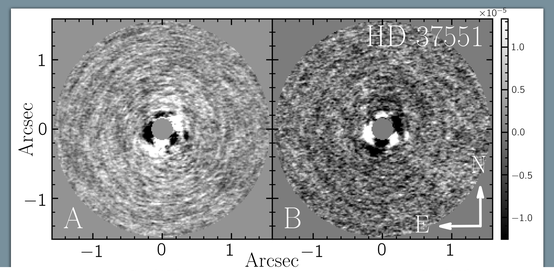
- Construct PCA eigenbasis using Star B images
- Project Star A image onto eigenbasis up to desired number of basis modes to perform LSQ fit and make PSF model
- Subtract model from Star A image
- Repeat for all Star A images, derotate, and mean combine
- Repeat for Star B using Star A to make eigenbasis

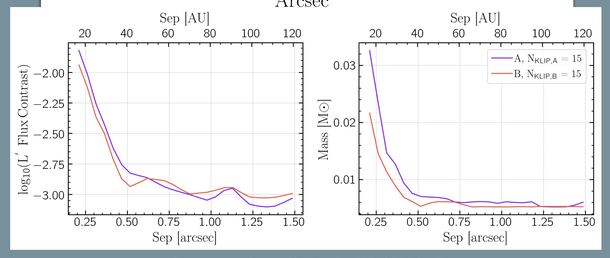


Clio image of HD 47787 prepared for BDI+KLIP

Results

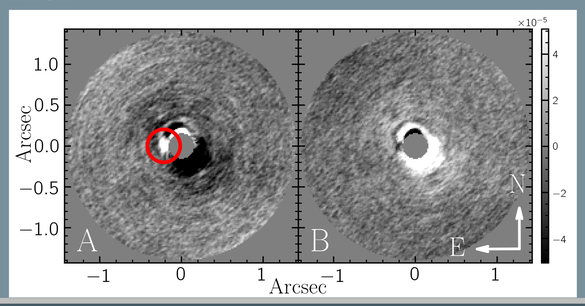
- Quantified performance using signal injection & recovery to determine contrast at which signal SNR crosses 5-sigma
- Converted to mass limits using L' abs mag and literature age to interpolate mass with BTSettl isochrones[6]





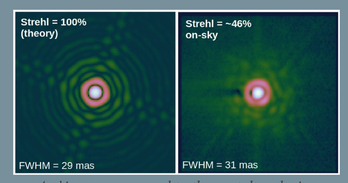
Contrast and mass limits for HD 37551 AB

- One candidate companion signal detected (red circle below). We proposed to observe with MagAO-X in 2022 to confirm companion status. Estimated ~60-90 Mjup candidate companion

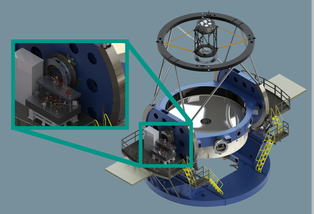


MagAO-X

- First light Dec 2019[7]
- Subsequent observations disrupted by COVID-19
- VIS-X spectrograph first light expected in 2022



A z' image compared to theory taken during commissioning



Render of MagAO-X on the Nasmyth platform of Magellan Clay telescope at Las Campanas Observatory in Chile

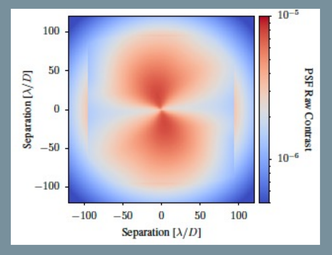
MagAO-X commissioning team, Dec 2019

GMagAO-X

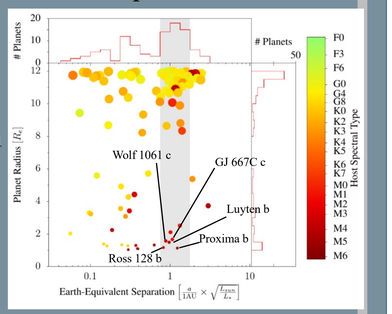
- Follow-on to MagAO-X for GMT
- Passed GMT conceptual design review Sep 2021
- PDR planned for mid-2022

Science Objectives[8]

- Reflected light imaging and biosignatures of nearby known exoplanets
- Accreting protoplanets in H-alpha
- Disk imaging



Post-coronagraph raw contrast using Males & Guyon 2018 model for I-8 mag star



102 nearby known exoplanets from RV which could be detected in a single night with GMagAO-X as a function of Earth-equivalent instellation,with potentially habitable terrestrial planets labeled.

Design[8]

- One 3000 actuator DM per 8.4m mirror -> same Strehl ratio as projected for MagAO-X

References

[1]Kaspar et al 2007, A&A, 472, 321; [2]Rodigas et al. 2015, ApJ, 811, 157; [3]Karhunen-Loève Image Processing, Soummer et al. 2021, ApJ, 755, L28; [4]Close et al. 2012, ApJ, 749, 180; [5]Morzinski et al. 2015, ApJ, 815, 108; [6]Baraffe et al. 2015, A&A, 577, A42; [7]Males et al. 2020, SPIE Proceedings, 11448, 114484L; [8]Males et al. 2019 Astro2020 White Papers no. 236

About the Author

Logan is a 3rd year graduate student at the University of Arizona Steward Observatory. She is returning to her first love – astronomy – after a career as an officer in the US Navy and another in education. She is the founder of the Student Veterans Research Network (see AAS education poster!). She likes exoplanets, hiking, and her 3 year old lab Lani.