OBSERVING REQUEST
University of Arizona Observatories

Year: 2015 **Term:** Jan–Jul **Proposal type:** engineering

Engineering of The MagAO System and Commissioning the new Clio2 and VisAO Coronagraphs

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CoI(s): Phil Hinz (SO), Jared Males (SO), Katie Morzinski (SO), Kate Follette* (SO), MagAO Team (SO), Clio2 Team (SO)

Abstract of Scientific Justification

UA's required instrumental commitment to Magellan is the facility AO system (MagAO) and its cameras (VisAO/Clio2). Around May/June (the 2015A MagAO run) we will have the third open science run with MagAO. We request a total of 4 critical engineering nights on Magellan (Clay) to install the MagAO adaptive secondary and its science cameras: Clio2 (1-5 microns) and VisAO (0.5-1 microns). MagAO has had three very successful runs (12 ApJ science papers: 20mas imaging and the discovery of 2 new exoplanet systems (Bailey et al. 2014; Biller et al. 2014) increasing the total imaged systems by $\sim$15%), and $\sim$ 6 more ApJ papers submitted/in prep). However, there is still an acute need to fix a few residual problems with the AO system and its IR camera Clio2.

Goals for this engineering time will be to install/remove the Adaptive Secondary Mirror (ASM) the Pyramid wavefront sensor (PWFS) and both the cameras– **2 nights (1 to go on, 1 off)**. Then we will prepare the system for "science time" by ensuring the comm2 active and adaptive (26-378 mode) optics look-up tables are (still) correct, and that the comm2 calibration for the AO system is still optimal in short ADI, SDI, APP and off-axis AO mode tests, as well as our continuing our on-going Vibration tests. We will confirm our AO correction on fainter stars, and calibrate our brand new Clio Vector APPs and our new VisAO coronagraphic masks **2 more nights**. This is complex run, but 4 nights is the minimum eng. start-up time needed for Arizona engineering. This is equal to the lowest number of nights ever requested for eng. work. After these eng. nights MagAO will be ready for the science nights allocated by the Magellan TACs, and with our new Coronagraphs better than ever before!

Summary of observing runs requested for this project

Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Scheduling: Optimal	Scheduling: Acceptable	Sharing: Poss.	Sharing: Adv.
1	MAG2	f/16	MagAO/Clio/VisAO	*	*	4	bright	May-Jun	May-Jun	yes	no

Scheduling constraints and unusable dates *(up to 4 lines)*: the first 3 of these nights must fall at the start of the May 2015 MagAO campaign. The last night is the last night of the campaign.

no text past this line

A $\star$ appended to the proposal type indicates a continuation proposal; a $\star$ appended to the name of a proposer indicates the proposer is a (graduate) student; a proposer whose name is underlined is certified on the proposed telescope/instrument combination; if a $*$ appears within the PI or AO box in the observations summary table, the instrument is a PI instrument and/or Adaptive Optics are requested – signatures are required on the next page.

Target list (attach list if longer than 26 objects)

#	Object	RA	Dec	mag / color / type / redshift / comment / etc.
1	bright and faint eng. binaries	09 to 24	20 to -60	Binaries used for testing AO system, H,J,K band Strehls
2	vAPP cal. Targ: HR8799bcde	23 07 28.71	+21 08 03.3	Clio2 vAPP cal. R=6, four L' bright planets
3	vAPP cal. Targ: HD95086	10 57 03	-68 40 02	Clio2 vAPP cal. R=7.4, 1-2 L' planets
4	Eta Car	10 45 03.591	-59 41 04.26	SDI Narrowband Emission line Calibrator, v=7 neb.
5	SCR 1845	18 45 05.30	-63 57 48.0	Astro Calibrator r=1arcsec T-dwarf comp. to V=15 Mstar
6	Westerlund 1	16 47 05.50	-45 51 6.0	Astro. Cal. Cluster of stars (Trap. too low in 2015A)
7	HD 165054, Baade's window	18 05 16.49	-28 41 10.79	Astro. Cal. Cluster of stars (Trap. too low in 2015A)

Approval for Instrument Use from PI: N/A

Graduate students *(provide the following information for **each** student named as PI or CoI on the cover page. Have the advisor's signature(s) appear on **all** submitted copies)*

Student's Name	Advisor's Name	Advisor's Signature	2nd-yr	Thesis
Kate Follette	Laird Close		no	yes
Ya-Lin Wu	Laird Close		no	yes

Scientific Justification

This is the third time an adaptive secondary will be used in the South for open science — these 4 nights are needed to make sure the MagAO systems (and its cameras) are ready for science.

It is also the third open AO science on the excellent LCO site. It is also the largest AO system developed by Arizona. In rather poor 75%-le 0.8" seeing the MagAO system and its VisAO science CCD can deliver 36% Strehls and 0.025" FWHM images at i' (0.76 um) on 8th magnitude stars. See Close et al. 2013 for more first light results. **On-sky this is (still) the World's highest resolution imager**. Please see http://visao.as.arizona.edu/ for the latest information about the MagAO project.

This proposal asks for 4 critical engineering nights to ready the MagAO system for open consortium wide science. Without these engineering nights we cannot offer the system for open science in 2015A.

The main goals for these 4 engineering nights are as follows:

1. Install ASM (adaptive secondary mirror), and reproduce the performance of MagAO in comm#2.

2. check the alignment of the ASM and Clio2 (under the direction of Clio2 PI Phil Hinz) to the M1 with collimation scope (and ASM alignment laser if needed).

3. Check the Calibration on-sky the SH (active optics) guider. Use the guider to do the final alignment of the ASM. Check that the Elevation look-up table is still correct.

4. Engineering tests of Closed loop AO on-axis bright stars with VisAO and Clio2 to check that performance is at least as good as in 2014A. Confirm that any remaining communication problems between the S-BCU and BCU-39 remain fixed since 2014B.

5. final calibration of the AO AOI software system to the TCS (check if the new (2014B) tilt offloading is causing any short periodic larger loop errors).Check if we can eliminate/reduce any of our vibrations with real-time powerspectra analysis tools (see fig 1).

6. Check and calibrate the closed-loop operation of the new Clio2 APP Vector coronographs (see fig 2 and fig 3). This is quite demanding in that we need to evaluate the contrasts (and focus) for the new APP Vector Coronagraphs (Purchased by J. Males's Lucas award) for the following filters: J, H, Ks, L', 3.3, 3.8, and M'. This will require 2 nights of telescope time.

7. Check and calibrate the closed-loop operation of the new VisAO Coronagraphic masks (note it is likely that steps 6 and 7 can be done together).

8. at the end of these first 3 nights (the last eng. night is for removing the system) we should be ready to start open Science: Close the loop on Bright and Faint stars (on and off axis) with Clio2 (and/or VisAO) as the science camera. Check that the Key science mode of on-axis bright guide star science still exceeds CDR top level science goals. Carry out TAC approved open science for the next ~ 25 (TBD) nights of the 2015A run.

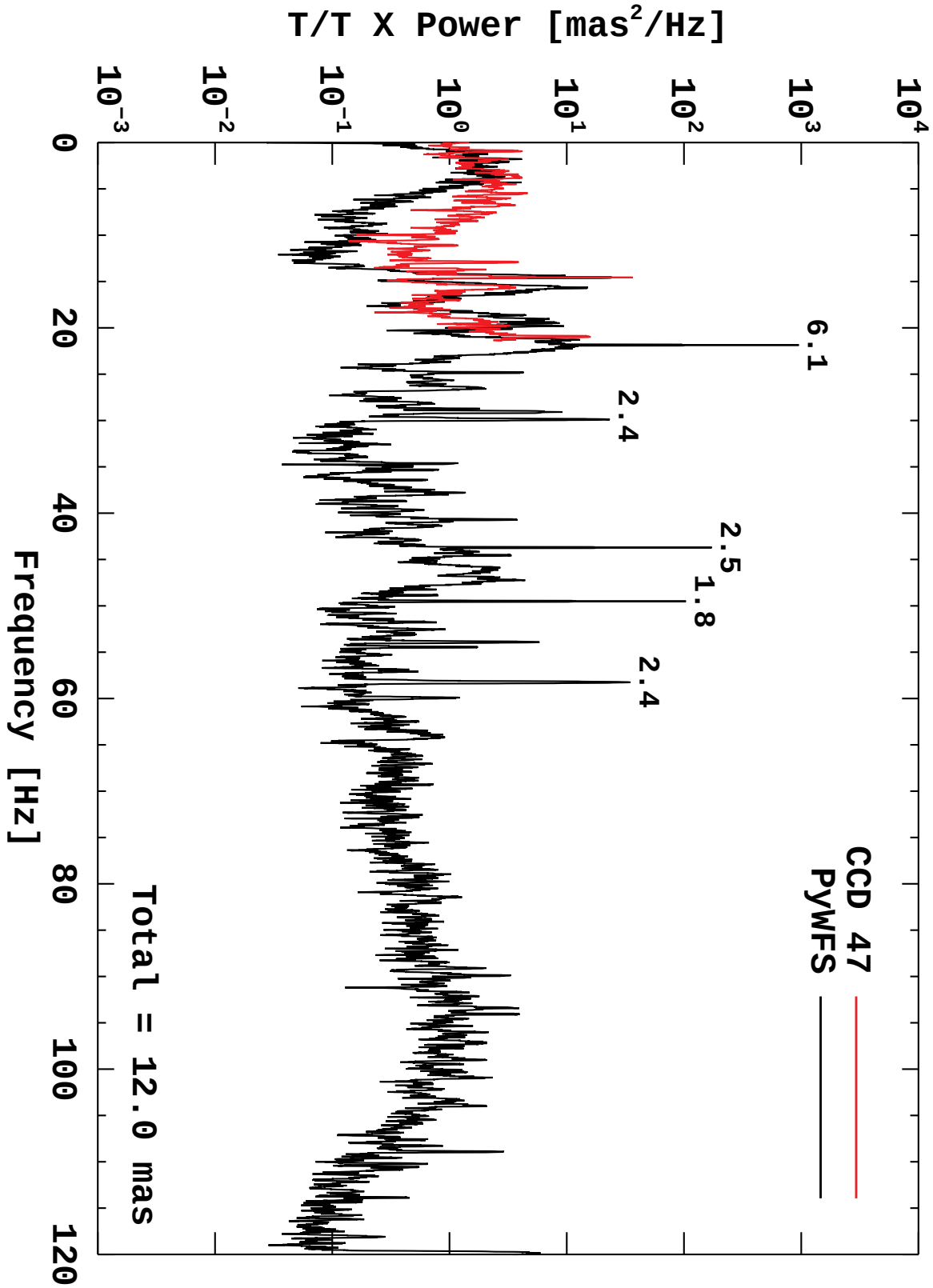

Figure 1: The current best vibrational environment for MagAO. We will continue make improvements in identifying and removing the sources of these vibrations in 2015A as proposed here. We are making progress with our new real-time powerspectrum tools to be used in 2015A. Our goal is $< 5mas$ of vibration. Numbers are the mas of jitter from each resonance.

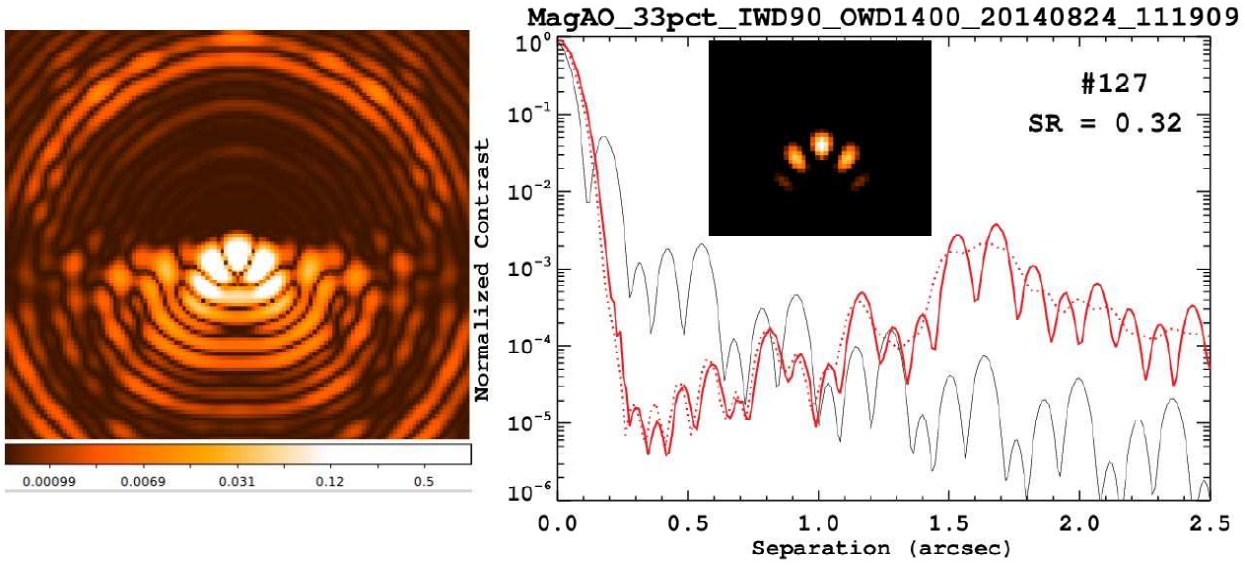

Figure 2: Design of the new Vector APP coronagraph (vAPP) that will be commissioned in 2015A. Note the amazing $\sim 10^{-5}$ contrast (red line) of the innermost 4 rings of the diffraction pattern (gray line).

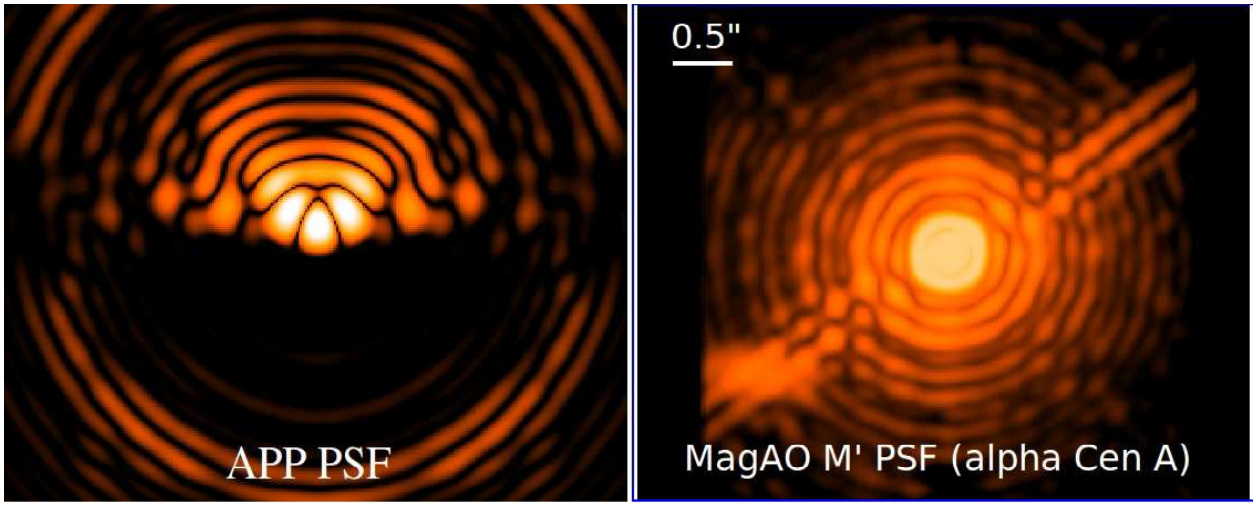

Figure 3: The expected performance of the vAPP vs. our current ∼98% Strehl M' images with MagAO/Clio of alpha Cen A. Clearly diffraction from the star is our major noise source – which the vAPP will eliminate in 2015A.

Experimental Design & Technical Description *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science.* ***(up to one page)***

For more detail of the individual mounting and unmounting and other eng. steps we refer TAC members to our commissioning plan (MAOP-039) and users manual– which is quite detailed and cannot be reproduced here.

Please contact Laird Close for a copy of MAOP-039.

Summary of Time Requested and Awarded *The TAC needs to understand the scope of this project — (1) tell us how many UAO nights you've already had for this project, how many you request this time, and (a good guess of) how many you need to complete the project; (2) if a substantial amount of observing for this project comes from non-UAO telescopes, tell us about that observing, and how the UAO part fits in; (3) if you are collaborating with people who have telescopes, especially if you are part of a large collaboration, tell us who is leading the project, and how UAO time and your participation fit in. (**up to one page**)*

This 2015A run will be a normal "AO science" campaign run (open to the entire Magellan community) after 5 months past the May/June 2015A run there will likely be a 2015B MagAO run (around December 2015? TBD).

Previous Use of Steward Facilities *List **all** allocations of telescope time for the present project and allocations for other projects on facilities available through UAO during the past 2 years, together with the current status of the data (cite publications where appropriate). Mark those allocations related to the present proposal (i.e, precede text with* `\related` *command). (**up to one page**)*

The MagAO PI led two of the first refereed MagAO papers already published (Close et al. 2013 ApJ; Wu, Close et al. ApJ; and Follette, Close et al. 2013), and has led the commissioning of MagAO (**see below for a partial list of some of these papers –all publications just from the 2 commissioning runs**).

We have made excellent use of our 2 past MagAO commissioning runs. The first-ever ground-based optical imaging of an exoplanet (β Pic b), in our Y_S filter, is published:

⋆ Males, Close et al., 2014 ApJ 786 32 "Magellan Adaptive Optics first-light observations of the exoplanet $beta$ Pic b. I. Direct imaging in the far-red optical with MagAO+VisAO and in the near-IR with NICI" arXiv:1403.0560

For more examples of published refereed results with VisAO and SDI results see:

⋆ Kopon, D., Close L.M. et al. Design, implementation, and on-sky performance of an advanced apochromatic triplet atmospheric dispersion corrector for the Magellan adaptive optics system and VisAO camera. PASP, 125, 966, 2013

⋆ Follette, K. B., Close, L.M. et al. The First Circumstellar Disk Imaged in Silhouette at Visible Wavelengths with Adaptive Optics : MagAO Imaging of Orion 218-534. ApJ, 775, L13, 2013

⋆ Close, L. M., Males, J., et al. Diffraction-limited Visible Light Images of Orion Trapezium Cluster With the Magellan Adaptive Secondary AO System (MagAO). ApJ, 774, 94, 2013

⋆ Wu, Y. L., Close, L.M. et al. High Resolution H alpha Images of the Binary Low-mass Proplyd LV 1 with the Magellan AO System. ApJ, 775, 45, 2013

⋆ Close, L.M. Follette, K. et al. "Discovery of Halpha emmision from the Close Companion in the HD142527 Transitional Disk". ApJ Lett 781 L30 2014

⋆ Rodigas et al. 2014 "Polarized Light Imaging of the HD 142527 Transition Disk with the Gemini Planet Imager: Dust around the Close-in Companion". ApJ Lett 791 L37

⋆ Nielsen, E. et al. 2014 " The Gemini NICI Planet-Finding Campaign: The Orbit of the Young Exoplanet beta Pictoris b", ApJ 2014 in press eprint arXiv:1403.7195

For published refereed examples of Clio2 high contrast imaging see:

⋆ Morzinski et al., in prep. "Magellan AO First-Light Observations of Beta Pictoris b. II. High-contrast imaging at 25um with MagAO/Clio"

⋆ Bailey et al. "HD 106906 b: A Planetary-mass Companion Outside a Massive Debris Disk" 2014 ApJ Lett 780 L4

⋆ Skemer, et al. (2014) ApJ 792, 17 "Directly Imaged L-T Transition Exoplanets in the Mid-Infrared" arXiv:1311.2085

⋆ Biller, et al. (2014) ApJ Lett 792, L22 "An Enigmatic Point-like Feature within the HD 169142 Transitional Disk" arXiv:1408.0794