OBSERVING REQUEST
University of Arizona Observatories

Year: 2015 **Term:** Jan–Jul **Proposal type:** short-term⋆

Testing the origins of brown dwarf companions with measurements of C/O ratios

P.I.: Abhijith Rajan⋆ (ASU; *arajan6@asu.edu*; 619-436-8541)

CoI(s): Jennifer Patience (ASU), Patrick Young (ASU), Robert De Rosa (UC Berkeley), Kimberly Ward-Duong⋆ (ASU), Don McCarthy (SO), Craig Kulesa (SO)

Abstract of Scientific Justification

With the AO-equipped ARIES spectrograph, we propose to measure the infrared spectra of a set of benchmark young brown dwarf companions with estimated masses approaching the planetary mass regime. From the $R \sim 3000$ ARIES spectra, the C/O ratio of each brown dwarf companion will be measured, providing a signature of the formation mechanism of these intriguing objects. Recent K-band spectroscopy of the HR 8799 c exoplanet revealed an elevated C/O ratio relative to the Sun, and this result was taken as evidence of formation from core accretion rather than gravitational instability. Formation models involving core accretion predict different values for the primary and secondary objects in the system, while gravitational instability models predict that the primary and secondary should have similar C/O ratios. The HR 8799 result relied on an assumption that the A-star primary C/O ratio was solar-like, since A-stars do not have enough lines to directly measure the abundance ratios. In contrast, the systems we propose to observe have later spectral type primaries, enabling a direct measurement of the C/O ratio from atomic lines in the optical spectrum and resulting in the strongest test of the relative abundances of the host star and companion. With previous Hectochelle observations, we will compare the proposed measurements with optical spectra of the bright primaries at high spectral resolution. There are no comparable C/O measurements of brown dwarf companions to those proposed in this study. Brown dwarfs have been postulated – but not proven – to form via an alternate mechanism analogous to star formation. The proposed data would provide the first direct evidence of the formation history of low mass brown dwarf companions and form an essential comparison for interpreting the results of the elemental abundances of exoplanets.

Summary of observing runs requested for this project

								Scheduling		Sharing	
Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Optimal	Acceptable	Poss.	Adv.
1	MMT	f/15	ARIES	*	*	1.0	bright	Feb–Mar	Jan–Apr	yes	yes
2	MMT	f/15	ARIES	*	*	1.0	bright	May–May	Apr–Jun	yes	yes

Scheduling constraints and unusable dates *(up to 4 lines)*: **Run 1** – If scheduled between Jan and mid-Feb, we request the last half of the night, if scheduled between mid-Feb and April we request the first half of the night. **Run 2** – If scheduled between April and mid-June, we request the last half of the night, if scheduled at the end of June we request the first half of the night.

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A ⋆ appended to the proposal type indicates a continuation proposal; a ⋆ 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	HIP 32702	06:49:21.36	+43:45:32.79	V = 7.32, ARIES K (0.5hr)
2	LP 261-75	09:51:04.60	+35:58:09.80	V = 15.33, ARIES K (1hr)
3	G 196-3	10:04:21.59	+50:23:14.96	V = 11.91, ARIES K (0.75hr)
4	GJ 3629	10:51:20.60	+36:07:25.55	V = 13.46, ARIES K (0.5hr)
5	GJ 417	11:12:32.35	+35:48:50.69	V = 6.41, ARIES K (0.75hr)
6	GSC 06214-00210	16:21:54.67	−20:43:09.15	V ∼12.5, ARIES K (1hr)
7	1RXS J160929.1-210524	16:09:30.31	−21:04:58.95	V ∼12.8, ARIES K(1.5hr)
8	HD 203030	21:18:58.22	−26:13:49.96	V = 8.43, ARIES K (1.5hr)
9	ARIES times are total on-source integration, excluding overheads.			

Approval for Instrument Use from PI: See attached e-mail from Don McCarthy.

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
Abhijith Rajan	Jennifer Patience	Jennifer Patience	no	no
Kimberly Ward-Duong	Jennifer Patience	Jennifer Patience	no	no

Scientific Justification

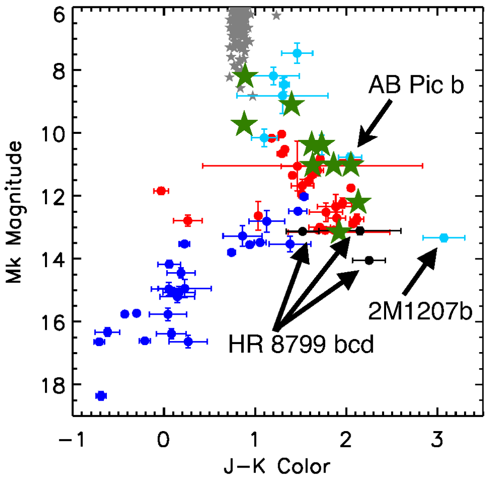
Background and Scientific Context: Giant planet formation models are grouped broadly into two categories - core accretion (e.g. Pollack et al. 1989) and gravitational instability (e.g. Boss 1995). In the core accretion scenario, the initial phase involves the accumulation of planetesimals into a core with sufficient mass (10 $M_{\oplus}$) to capture a gaseous envelope. After formation of the core and envelope, subsequent bombardment of additional planetesimals is expected to enhance the heavy element composition of the planet atmosphere relative to the host star which retains the composition of the nebular gas from which it formed. Enhancements by a factor of 3–30 of carbon in the atmospheres of Solar System giant planets compared to the Sun have been measured (Lodders 2004, Visscher & Fegley 2005, Gautier et al. 1995) and interpreted as an indication of formation by core accretion and planetesimal bombardment in the early stages of evolution (e.g. Atreya et al. 2003). By comparison, formation of giant planets or brown dwarfs by the direct gravitational collapse of the nebula in a manner analogous to formation of binary stars is expected to result in similar compositions for the companion and the host star. **Measurements of the compositions of the atmospheres of substellar companions represent an important pathway to the understanding of the formation and evolution history of low mass planetary and brown dwarf companions.** Critically, precise spectroscopic measurements of the host star are required to determine any differences in the relative abundances of various elements, which may provide an observational constraint on the substellar companion formation process.

Proposed Study of Substellar Companions: We have been pursuing a program to characterize the photometric and spectroscopic properties – including C/O ratio measurements – of a sample of young, substellar companions to nearby stars. This sample consists of eleven substellar companions to nearby Main Sequence stars, with ages in the ∼5–500 Myr range and masses estimated from evolutionary models that place them near the planet/brown dwarf boundary (Figure 1). The targets have been discovered and confirmed to be co-moving companions based on AO imaging (Wahhaj et al. 2011, Metchev et al. 2004, Reid et al. 2006, Bowler et al. 2012, Kirkpatrick et al. 2000, Ireland et al. 2011, Lafreniere et al. 2011, Metchev et al. 2006), except one wider system which did not require AO (Rebolo et al. 1998). The distribution of the sample of targets on an infrared color-magnitude diagram is shown in Figure 1, with comparison field L and T-dwarfs, the HR 8799 planets, and the 2M1207b and AB Pic b planetary mass companions showing the importance of this sample as planetary atmosphere analogues. Half of the targets are have positions in the color-magnitude between AB Pic b and 2M1207 b and will further explore the atmospheres of cooler, low mass objects that are challenging standard atmosphere models. Like the HR 8799 planets, the brown dwarf targets generally have redder colors. The targets span the young L-dwarf sequence and will provide benchmark spectra above and very close to the planet/brown dwarf boundary. For the young brown dwarfs, it is possible to obtain higher resolution spectra and photometry over a larger wavelength range that will enable important tests of theoretical models comparable to the HN Peg system (Leggett et al. 2008) and 2M1207 system (e.g. Barman et al. 2011, Skemer et al. 2011) and aid the interpretation of lower spectral resolution data from upcoming extreme AO planet search programs such as GPI (Macintosh et al. 2006) and SPHERE (Bezuit et al. 2006).

Observational Predictions and Recent Measurements of C/O Ratios: The proposed MMT/ARIES observations are designed to measure the C/O ratio within the atmospheres of the proposed sample of substellar companions, an observational diagnostic of the formation history of these low-mass objects. The companion observations will be combined with our previously-proposed MMT/Hectochelle observations of the primary in each system, providing the first direct comparison of C/O ratios between a directly imaged substellar companion and its Main Sequence host. Specific predictions relating carbon and oxygen abundances to formation models include: (1) different C/O abundance ratios for primary and secondary for formation by core accretion and (2) similar C/O ratios for both components for formation by gravitational collapse (Öberg et al. 2011). Whether the secondary C/O ratio is higher or lower than the primary in the core accretion scenario depends on the formation location and subsequent accretion of planetesimals (Öberg et al. 2011). The impact of formation location is indicated in Figure 2 (Öberg et al. 2011), which shows the gas-phase C/O ratio as a function of radius expected in disks around different types of stars. The primaries of the stellar-substellar pairs span a range of spectral types from F5 to M4.5, which is ideal for this program. The locations of the primaries on a color-magnitude diagram is given in Figure 3.

Among the $>$1800 exoplanets known (e.g. *www.exoplanet.eu*), only exoplanets transiting bright stars and directly imaged exoplanets are amenable to the investigation of their atmospheres. Measurements of the HD189733b transiting exoplanet have suggested C and O abundances ranging from substantially depleted (Madhusudhan & Seager 2009) to significantly enriched (Swain et al. 2009), and the observations have been interpreted in the context of models describing the formation sequence and planetesimal composition (e.g. Mousis et al. 2011). Optical and near-IR measurements of secondary eclipses have been used to constrain the C/O ratio of several additional irradiated planets (e.g. Teske et al. 2013, Line et al. 2013). The atmospheres of directly-imaged planetary mass objects represent a complementary case study, and the first results on the C/O ratio of the imaged HR 8799c planet have recently reported a super-Solar value (Konopacky et al. 2013). Assuming a Solar composition for the HR 8799 A-star host, the K-band spectrum of HR 8799c is most consistent with a giant planet formed through core accretion (Konopacky et al. 2013). No comparable measurements for brown dwarfs exist, but are needed to explore their formation and to provide the essential broader context for the HR 8799 results. For this program, we propose to measure the C/O ratio of both the primary and substellar companions for a sample of eight systems with companion masses near the brown dwarf/planet-mass transition. If these systems genuinely formed in a different manner from the HR 8799 planets and are the result of direct gravitational collapse from nebular material, then the C/O ratios of the brown dwarfs should match those of the primaries – a direct observational test of the formation mechanism.

Summary of Proposed Observations: By combining near-infrared spectroscopy obtained using ARIES of a sample of eight substellar companions, and previous optical echelle spectroscopy obtained with Hectochelle of their primaries, we propose to characterize the atmospheres and relative C/O abundances of a sample of young, low-mass brown dwarfs spanning the full range of the L spectral type sequence. The proposed near-IR spectra will be used to construct an empirical grid of substellar atmospheres, building upon our previous work (Patience et al. 2010, 2012). The observations will also lead to the first comparison of the C/O ratio of an imaged substellar companion with that of the host star, providing essential context for the recent, ground-breaking C/O measurement of the directly-imaged planet HR 8799c. An example spectrum for one of the objects in our sample is shown in Figure 4. While we have obtained previous spectra for the primaries with Hectochelle, we were unable to get the necessary data in previous semesters with the ARIES spectroscopic mode, and the initial companion observations are scheduled for the current semester. Our proposed observations would therefore cover the remaining companions inaccessible during previously-scheduled runs.



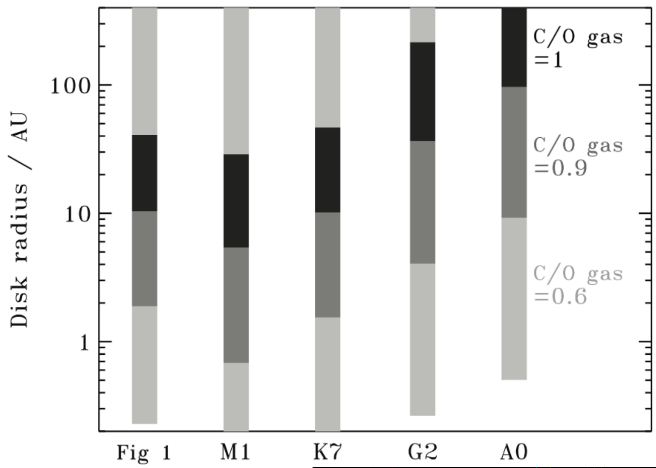
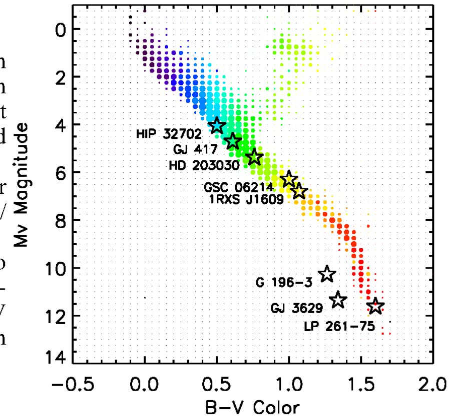
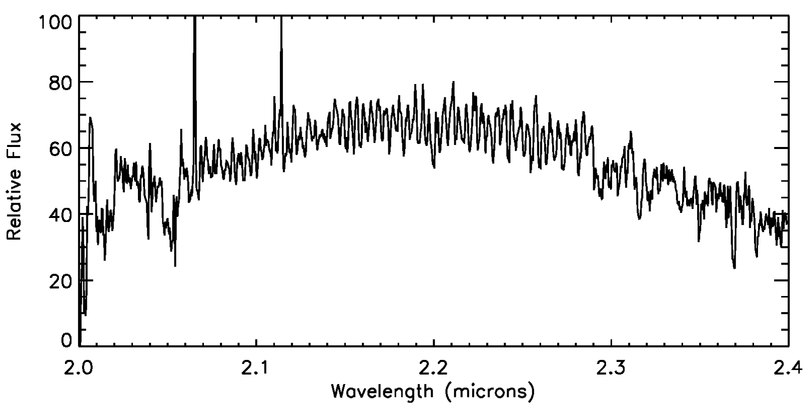


Figure 1 (top left): The positions of the intermediate age (~5-500 Myrs) brown dwarf companions to the proposed targets (green stars), along with comparison young (~2-50 Myrs) low mass brown dwarfs (cyan circles), the three outermost planets of the HR 8799 system (black circles), field M (small grey stars), L (red circles), and T-dwarfs (blue circles).
Figure 2 (top right): Predicted gas-phase C/O ratio as a function of radius for different spectral types. The C/O ratios are calculated assuming that the stellar C/O ratio is solar, i.e., 0.54, and a static disk (Öberg et al. 2011).
Figure 3 (right): The primaries span a range of spectral types from F5 through to M4.5 (black open stars). Plotted for reference are the *Hipparcos* stars with high-quality parallax measurements within 100 parsecs. For the fainter targets, the B-V color is quite uncertain as they are approaching the faint-limit for the B-band in the *Tycho2* catalog.





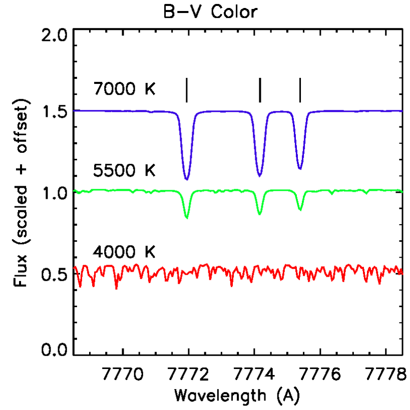


Figure 4 (left): Our preliminary reduction of an MMT/ARIES *K*-band spectra of the substellar companion G196-3B obtained in December 2012. Unfortunately, due to poor weather conditions, the signal-to-noise ratio is not ideal, making a C/O ratio estimate significantly more challenging.
Figure 5 (right): Three of the oxygen lines which will be used to determine the abundances of atomic oxygen within the atmospheres of the Solar-type primaries within the proposed sample. Three theoretical spectra are shown for 7000K (blue), 5500K (green), and 4000K (red). The strength of the atomic lines decreases with temperature, and are not easily discerned from the molecular absorption within low-mass M-type stars (red spectra). For these low-mass stars, the C/O ratio will be estimated by fitting the overall shape of the spectra to determine the amount of CO, TiO and VO molecular absorption within the atmosphere.

References: Ackerman & Marley 2001, ApJ, 556, 872; Atreya et al. 2003, P&SS, 51, 105; Allard et al. 2001, ApJ, 556, 357; Allard et al. 2003, ASPC, 294, 483; Allard et al. 2010, ASPC, 448, 91; Barman et al. 2011, ApJ, 735, 39; Bonnefoy et al. 2010, A&A, 512, 52; Boss et al. 1997, Science, 276, 1836; Bowler et al. 2012, ApJ, 756, 69; Burrows et al. 2006, ApJ, 640, 1063; Chabrier et al. 2000, ApJ, 542, 464; Freedman et al. 2008, ApJS, 174, 504; Gautier et al. 1995, ESOC, 52, 257; Helling et al. 2008, MNRAS, 391, 1854; Ireland et al. 2011, ApJ, 726, 113; Kirkpatrick et al. 2000, AJ, 120, 447; Konopacky et al. 2013, Sci, 339, 1398; Lafreniere et al. 2011, ApJ, 730, 42; Line et al. 2013, in press; Lodders et al. 1994, Icar, 112, 368; Madhusudhan & Seager 2009, ApJ, 707, 24; Marley et al. 2002, ApJ, 568, 335; Marley et al. 2003, IAUS, 211, 333; Marois et al. 2008, Sci, 322, 1348; Marois et al. 2010, Nat, 468, 1080; Metchev et al. 2004, ApJ, 617, 1330; Metchev et al. 2006, ApJ, 651, 1166; Mousis et al. 2011, ApJ, 727, 77; Oberg et al. 2011, ApJ, 743, 16; Patience et al. 2010, A&A, 517, 76; Patience et al. 2012, A&A, 540, 85; Pavlenko & Jones 2002, A&A, 396, 967; Pollack et al. 1996, Icar, 124, 62; Rebolo et al. 1998, Sci, 282, 1309; Reid et al. 2006, PASP, 118, 671; Rice et al. 2010, ApJS, 186, 63; Saumon & Marley 2008, MNRAS, 391, 1845; Schmidt et al. 2009, PASP, 121, 1083; Sneden 1973, ApJ, 184, 839; Sousa et al. 2007, A&A, 469, 783; Skemer et al. 2011, ApJ, 732, 107; Skemer et al. 2012, ApJ, 753, 14; Swain et al. 2009, ApJ, 704, 1616; Szentgyorgyi et al. 2011, PASP, 123, 1188; Teske et al. 2013, in press; Visscher & Fegley 2005, ApJ, 623, 1221; Wahhaj et al. 2011, ApJ, 729, 139.; Witte et al. 2009, A&A, 506, 1367

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**)*

Observational Strategy: We propose to use the ARIES instrument in order to obtain AO-assisted K spectroscopy of a number of nearby, young, low-mass brown dwarf companions. Since each target is a substellar companion to a Main Sequence star, the primary will be used by the wavefront sensor to run the AO system, with the exception of LP261-75. The separation between primary and substellar secondary are well within the off-axis limit of the MMT AO system for four of the six proposed targets. For GJ417 B, separated by $90''$ from its primary, we will fix the shape of the secondary using GJ417 A. For LP261-75 ($V = 15.3$) the secondary will be fixed using a nearby bright star. The proposed observations will be combined with existing literature data. Given that the atmospheres of these objects can be characterized with the overall spectral shape, high spectral resolution is not essential, however a minimum resolution of $R \sim 3000$ is required in the K-band to estimate the C/O ratios. For the proposed observations, we will use the low-resolution grating with the $0\farcs4$ slit for the K-band spectra. Total on-source integration time estimated from previous observing experience with ARIES (e.g. Figure 4), and the limiting magnitude on the instrument website, are given in the sample table. **In total, we request two 1.0 night MMT/ARIES runs to complete this component of the study.**

To determine the C/O ratio of the companions from the ARIES K-band spectra, we will construct a grid of comparison theoretical spectra with different input C/O ratios from synthetic atmosphere models and then search for the best match to the data. To limit the range of allowable $T_{\rm eff}$ and $\log(g)$ which are the two main physical properties that influence the atmospheres of brown dwarfs and impact the measurement of the C/O ratio, we will use optical/thermal-IR photometric measurements available within the literature. For comparison with the Hectochelle optical spectra previously obtained for the primaries, we will measure C/O ratios from multiple carbon and oxygen spectral lines for early-type primaries, and estimate the C/O ratio with theoretical stellar atmospheres for the later-type primaries (representative examples of the atomic lines and spectral features used in the analysis are shown in Figure 5).

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**)*

1 – UAO Telescope Time

This proposal had two previous ARIES allocations: one run of 4 nights, one run of 2 nights. As indicated in the proposal text and previous use summary, both ARIES runs were lost to bad weather. During one of the A-star companion search runs, we obtained a test spectrum during an RA gap for the companion project. The test spectrum is shown in this proposal figure section. A third upcoming ARIES spectroscopy allocation is scheduled for October and November of this semester, and the requested ARIES targets represent remaining secondaries inaccessible in previously and currently scheduled runs. An allocation of Hectochelle time for this proposal in the previous semester (2014A) allowed us to obtain the necessary optical spectra on the primary stars for the C/O measurements, and thus provides the critical comparison dataset for our analysis with the proposed ARIES spectroscopy.

2 – non-UAO Telescope Time

A related program targeting Southern brown dwarf companions was allocated SINFONI time during the previous semester at ESO, and a spectrum of AB Pic b was obtained with spectral resolution comparable to the ARIES request.

3 – Collaborations

Patience and her group are involved in several large survey programs – the **VAST** (Volume-limited A-STar) snapshot survey, the **IDPS** (International Deep Planet Search) current AO system survey, and the **BAM** (Brown dwarf Atmosphere Monitoring) Project. Patience is the PI of the VAST survey which combined AO telescope access across a partnership of $\sim$10 collaborators to observe $\sim$250 A-stars. Patience is a co-I of the IDPS survey, which targets $\sim$250 young M-B stars, with primary responsibilities related to the B/A-star sample. Patience is a co-I of the BAM program that was extended to observe fainter brown dwarfs at the MMT. Publications and papers in progress from these surveys are listed below. Patience is a Co-I of the recently initiated **LEECH** LBT survey and the upcoming **GPIES** Gemini survey for imaged planets in the North and South, and her group has contributed to defining the target sets for both programs and some early LEECH observations.

VAST publications thus far are student/postdoc-led: De Rosa et al. 2011 [**X-ray A-stars**], De Rosa et al. 2012 [**A-star orbits**], De Rosa et al. 2013, *received referee report* [**A-star binary statistics**], Bulger et al. 2013, in prep [**A-star debris disk binaries**], Schneider et al. 2013, in prep [**A-star binary age estimates**]. The IDPS A-star subset has been published by a postdoc working with Patience: Vigan et al. 2012 [**IDPS A-star initial results**]. The BAM publications thus fare are student-led: Rajan et al. 2013 [**TY pilot study**], received referee report; Wilson et al. 2013 [**LT large scale survey**], draft sent to collaborators

This proposal is distinct from the companion search projects, since this program is a characterization project. This spectroscopy work is also different from the broadband SED proposal for Mag AO, since photometry does not have the spectral resolution required to measure the CO and H_2O lines and determine the C/O ratio.

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)***

Companion Characterization - Allocations and Papers:

⋆ **LBT: 2013A - Thermal-IR measurements of substellar companions:** - *PI: Patience (1 night)* - 50% useful

⋆ **MMT: 2013C-UAO-S11 - ARIES Substellar spectroscopic characterization** - *PI: Ward-Duong (2 nights)* - 0% useful, **2014A-UAO-S1 - ARIES Substellar spectroscopic characterization** - *PI: De Rosa (4 nights)* - 25% useful

⋆ **De Rosa et al. 2014**, *Debris Disks and Multiplicity within the 75pc Volume-limited A-Star (VAST) Survey*, 2014 *IAUS*, 299, 334 - Includes MMT data

⋆ **De Rosa et al. 2014**, *The VAST survey - IV. A wide brown dwarf companion to the A3V star ζ Delphini, MNRAS*, accepted - Characterization most similar to MMT proposal; includes MMT data

⋆ **De Rosa et al. 2014**, *The VAST survey - V. Confirmation observations of low-mass companions to nearby A-type stars, MNRAS* - Analysis of MMT data complete, paper in progress

⋆ **Maire et al. 2014**, *The LEECH Exoplanet Imaging Survey. Further constraints on the planet architecture HR 8799 system, A&A*, in prep

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Brown dwarf Atmosphere Monitoring - Allocations and Papers:

MMT: 2012A-UAO-S3 - SWIRC Brown dwarf variability monitoring - *PI: Patience (2 nights)* - 75% useful, **2013A-UAO-S99 - SWIRC Brown dwarf variability monitoring** - *PI: Rajan (2 nights)* - 0% useful

• **Rajan et al. 2014**, *Searching for Photometric Variability across the L, T & Y Dwarf Sequence*, 2014 IAUS, 299, 301 - Includes MMT data

• **Wilson, Rajan & Patience 2014**, *The Brown-dwarf Atmosphere Monitoring (BAM) Project I: Multi-epoch monitoring of extremely cool brown dwarfs*, A&A, 566, 111 - The paper established the code and observing practices for all current and future BAM projects, including the MMT proposal

• **Rajan et al. 2014**, *The Brown-dwarf Atmosphere Monitoring (BAM) Project II: Multi-epoch monitoring of extremely cool brown dwarfs*, MNRAS, submitted - Includes MMT data

• **Burgasser et al. 2014**, *Splinter Session on Cool Cloudy Atmospheres: Theory and Observations*, Cool Stars 18, submitted - Includes MMT data

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Companion Search - Allocations and Papers:

Magellan: 2013B - FourStar search for companions to GPI targets - *PI: Patience (2 nights)* - not useful

MMT: 2013A-UAO-S2 - ARIES A-star companion follow-up - *PI: De Rosa (4 half-nights)* - 50% useful, **2013B-UAO-S2 - ARIES A-star companion follow-up** - *PI: De Rosa (1 night)* - 75% useful, **2013C-UAO-S10 - ARIES A-star companion follow-up** - *PI: De Rosa (2 nights)* - 75% useful

• **Patience et al. 2014**, *The TBOSS (Taurus Boundary of Stellar/Substellar) Survey of Disk Properties*, 2014 IAUS, 299, 224 - Sample for follow-up projects, including LBT proposal

• **Bulger et al. 2014**, *The Taurus Boundary of Stellar/Substellar (TBOSS) Survey I: far-IR disk emission measured with Herschel*, A&A accepted - Sample for follow-up projects, including LBT proposal

• **Ward-Duong et al. 2014**, *A Direct Imaging Study to Search for and to Characterize Planetary Mass Companions*, 2014 IAUS, 299, 74 - Includes MMT data

• **Ward-Duong et al. 2014**, *The M-dwarfs in Multiples (MinMs) survey - I. Stellar multiplicity among low-mass stars within 15 pc*, MNRAS, submitted - Includes MMT data

• **Skemer et al. 2014** *LEECH: A 100 Night Exoplanet Imaging Survey at the LBT*, 2014 IAUS, 299, 70

From: Don McCarthy <dwmccarthy@gmail.com>
Subject: **Re: proposals**
Date: 28 September 2014 21:47:44 MST
To: Jennifer Patience <Jennifer.Patience@asu.edu>
Cc: Craig Kulesa <ckulesa@as.arizona.edu>

OK, Jenny!

FYI, the new detector in ARIES is still undergoing some tests and is not yet ready for prime time. So, we continue to swap the same detector between ARIES and PISCES. Thus, the two instruments cannot be scheduled close in time.

Don

On Sun, Sep 28, 2014 at 9:18 PM, Jennifer Patience <Jennifer.Patience@asu.edu> wrote:

> Hi, Don. My students and I are working on proposals for the upcoming deadline. Will PISCES be available at the MMT? If possible, we would like to submit an MMT/PISCES proposal for brown dwarf monitoring as part of one of my students (Abhi Rajan) thesis projects. We would also like to submit AO ARIES proposals for companion search and characterization observations continuing our ongoing projects (part of the thesis for Kim Ward-Duong). As always, we are happy to include you and Craig in all the results.
>
> -- Jenny