OBSERVING REQUEST
University of Arizona Observatories

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

Brown dwarf Atmosphere Monitoring III: A photometric survey of the coolest brown dwarfs

P.I.: Abhijith Rajan⋆ (ASU; *abhijithrajan@asu.edu*; 480-727-2169)

CoI(s): J. Patience (ASU), P. A. Wilson (Exeter), K. Ward-Duong (ASU), R. De Rosa (Berkeley), J. Bulger (ASU), C. Morley (UCSC), D. McCarthy (UA), C. Kulesa (UA)

Abstract of Scientific Justification

Using the PISCES camera on the 6.5m MMT, we propose to extend our Brown dwarf Atmosphere Monitoring (BAM) program to photometrically monitor an unbiased sample of the coolest northern T- dwarfs spanning a range of near-infrared colors. The proposed observations are an extension of a 2014B proposal to explore atmospheric properties of ultracool T-dwarfs, which are a link between the coolest stars and giant planets in the solar system and around other stars. Recent work on synthetic atmosphere models has indicated that sulfide and chloride clouds condense in the mid to late T-dwarf spectral range and may impact the observable properties of the atmospheres including color and variability. To obtain empirical measurements for comparison with model atmospheres, we propose a 4-night project to photometrically monitor 10 – 12 of the coolest northern T-dwarfs in the J-band. The brown dwarfs cover a wide range of near-IR colors associated with different cloud models. Variability observations represent the prime mechanism to test predictions of partial or evolving cloud coverage. The observations will determine the presence or absence of variability, and test for the predicted correlation with color. Photometric monitoring is an essential tool with which it is possible to search for evidence and evolution of surface brightness inhomogeneities caused by cloud features, storms, or activity. The proposed program will provide a comprehensive dataset serving as a benchmark comparison to directly imaged planets, intensely irradiated Hot Jupiters, and synthetic atmospheric models incorporating different physical processes.

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	MMT	f/9	PISCES	*		4	bright	Mar–May	Jan–Jun	yes	no

Scheduling constraints and unusable dates *(up to 4 lines)*:

no text past this line

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	SDSSpJ162414.37+002915.6	16:24:14.367	+00:29:15.82	T6, J = 15.2 mag
2	2MASSIJ1047538+212423	10:47:53.85	+21:24:23.5	T6.5, J = 15.46 mag
3	SDSSpJ134646.45-003150.4	13:46:46.345	-00:31:50.13	T6.5, J = 15.49 mag
4	SDSSJ150411.63+102718.4	15:04:11.64	+10:27:18.4	T7, J = 17.03 mag
5	2MASSIJ1553022+153236	15:53:02.281	+15:32:36.91	T7, J = 15.82 mag
6	SDSSJ162838.77+230821.1	16:28:38.78	+23:08:21.1	T7, J = 16.25 mag
7	ULASJ085910.69+101017.1	08:59:10.69	+10:10:17.1	T7, J = 17.88 mag
8	SDSSJ162838.77+230821.1	16:28:38.78	+23:08:21.1	T7, J = 16.25 mag
9	ULASJ090116.23-030635.0	09:01:16.23	-03:06:35.0	T7.5, J = 17.9 mag
10	2MASSIJ1217110-031113	12:17:11.103	-03:11:13.17	T7.5, J = 15.86 mag
11	ULASJ141623.94+134836.3	14:16:23.94	+13:48:36.3	T7.5, J = 17.35 mag
12	ULASJ095047.28+011734.3	09:50:47.28	+01:17:34.3	T8, J = 18.02 mag
13	Ross458C	13:00:41.936	+12:21:14.72	T8, J = 16.69 mag
14	WISEJ111838.70+312537.9	11:18:38.70	+31:25:37.9	T8.5, J = 17.79 mag
15	ULASJ133553.45+113005.2	13:35:53.45	+11:30:05.2	T8.5, J = 17.9 mag
16	Wolf940B	21:46:38.83	-00:10:38.7	T8.5, J = 18.18 mag
17	WISEPJ121756.91+162640.2	12:17:56.91	+16:26:40.2	T9, J = 17.74 mag
18	WISEPJ174124.26+255319.5	17:41:24.26	+25:53:19.5	T9, J = 16.18 mag

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
A. Rajan	J. Patience	Jennifer Patience	no	yes
K. Ward-Duong	J. Patience	Jennifer Patience	no	no

Scientific Justification

Scientific Context

Brown dwarfs spanning the L, T, and Y sequence provide a link between the coolest stars and giant exoplanets. In particular, mid to late-T brown dwarfs encompass the temperature range (1100K – 450K) associated with currently imaged exoplanets (e.g. HR8799b$\sim$1100K; Barman et al. 2011, GJ 504b$\sim$500K; Kuzuhara et al. 2013). Brown dwarfs never achieve a stable nuclear burning phase and cool throughout their lifetimes. As they cool, complex molecules form condensate clouds, and, when the atmosphere is cool enough, the large condensate grains cannot remain suspended high in the atmosphere and sink below the observable photosphere.Observationally, the mid to late-T dwarf range is marked by a dramatic increase in the near-infrared color range for objects of a given spectral type (see Figures 1 & 2). Based on updated atmosphere models (Morley et al. 2012; 2014), this color spread is predicted to be an effect of the formation and eventual dissipation of sulfide and chloride clouds. Sulfide clouds start to form at temperatures of $\sim$900K (corresponding to spectral types later than T5) and reach a maximum optical depth at $\sim$600K ($\sim$T8). Varying the sedimentation efficiency (f_{sed}) of the clouds may explain the range of color seen in Figure 1. It has been suggested that any variability resulting due to the salt and sulfide clouds forming in late-T dwarfs might show the highest level of variability in the near-infrared (Morley et al. 2014).

The complexity of cloud formation in cool atmospheres is evident from images of our own Solar System gas giants which show banding and persistent storm systems. The dependence on mass, temperature and convection on the appearance of banding – such as that seen in the atmosphere of Jupiter and Saturn – is still unclear (Zhang & Showman 2014, Showman et al. 2009). To fully understand the cool atmospheres of brown dwarfs and giant exoplanets, we must have a physical model of the formation and dissipation of condensate clouds throughout the L,T,Y sequence. This lack of understanding is also shown by our current difficulty in explaining the very red near-IR colors and spectra of the directly-imaged planets around HR8799 (e.g. Marois et al. 2008, Barman et al. 2010) and low-mass companions to young stars such as 2M1207b (e.g. Patience et al. 2010, Skemer et al. 2011).

Previous Variability Studies

The Brown dwarf Atmosphere Monitoring (BAM) programs implemented by our team has thus far conducted two surveys. The BAM-I project used the SofI instrument on the 3.5 m New Technology Telescope to perform an extensive near infrared monitoring survey of an unbiased sample of 69 brown dwarfs spanning the L0 and T8 spectral range, with at least one example of each spectral type (Wilson, Rajan, Patience 2014). A total of 14 brown dwarfs were identified as variables, four of which have mid-T spectral types, with peak-to-trough amplitudes ranging from 1.7% to 10.8% over the observed duration. Approximately half of the variables show monotonic sinusoidal amplitude variations similar to 2M2139 (Radigan et al. 2012), and the remainder show aperiodic variations similar to SIMP0136 (Artigau et al. 2009). The BAM-I survey was designed to test the hypothesis that the L/T transition is a region of a higher degree of variability due to the presence of patchy clouds.

In the BAM-II project, we conducted a pilot study monitoring an initial sample of four ultracool T6.5 to Y0 brown dwarfs for infrared photometric variability using the SWIRC camera on the 6.5m MMT (Rajan et al. 2014). T/Y transition objects with temperatures ranging from 450 – 900 K are expected to have salt and sulfide clouds form and breakup. One of the targets in the survey shows large amplitude peak-to-trough variations as high as 17% in our data (red star in Figure 1), making it the highest amplitude variable brown dwarf detected outside the L/T transition region. With an effective temperature of 600 K, it is the coldest variable brown dwarf detected to-date.

Whether the late-T variables are exceptional objects or typical is unknown, due to the limited number of T-dwarfs monitored for variability. Building upon these initial results, we propose BAM-III, to conduct a comprehensive survey of the mid to late-T range to discover new variables and search for correlations between variability and location on the color-color diagram, a predicted link to cloud properties.

Proposed BAM-III Observations

This is the second half of the BAM-III survey using the MMT/PISCES camera. We plan to cover ∼10 – 15 targets in the first epoch (Nov 1 – 3) and propose to complete the survey in the upcoming semester (2015A) by monitoring an additional ∼15 targets. With the full sample of targets, shown in Figure 2 and 3, we will determine the frequency and properties of variables among these ultracool brown dwarfs.The J-band probes the deepest into the atmosphere and patchy clouds will result in the largest amplitude at this wavelength. **Morley et al. 2014 predict that brown dwarfs with spectral types >T5 will display the greatest variability in the near-infrared wavelength range**. The expected rotation periods are in the 3-8 hr range based on v sin i measurement (Zapatero-Osorio et al. 2006), and we will observe each object over approximately half to a full rotational period in the J-band filter with PISCES on the 6.5m MMT telescope. Our sample has been selected to include the brightest northern T5 – T9 brown dwarfs with declination > -10 degrees. Additionally, we have chosen the targets to span the full J-H color range in Figure 1, corresponding to atmospheres ranging from cloudy (red solid line) to cloud-free (blue line) models. These objects are also of great intrinsic interest due to their low effective temperatures (450K – 1100K), overlapping with many recently detected cool exoplanets. By monitoring the coolest atmospheres and comparing the lightcurves with variables of earlier spectral types, we will be able to search for changes in the variability (in terms of amplitude, repeatability and multi-filter comparisons) due to the presence of cool magnetic spots, hot spots due to breaks in the cloud deck, and storms in these cool atmospheres. **The BAM-III sample will allow us to test model predictions that sulfide clouds form in patchy layers by searching for correlations between variability and location on the color-color diagram, where color is expected to be a function of cloud properties**.

Expected Periods and Level of Variations

Although, the BAM-I and II surveys photometrically monitored 74 L and T brown dwarfs, the number of late-T dwarfs observed in the two surveys is limited and covered only a small range of the near-infrared colors. Our previous observations suggest that in the near-IR we require individual measurements with a signal-to-noise S/N∼50-100 spread over several hours. With this sensitivity and cadence, we should be able to identify sources with non-periodic and periodic changes in brightness. We will investigate the scenario that the variations are due to holes opening in the cloud deck allowing flux to escape from deeper in the atmosphere (e.g., Marley et al. 2010).

The study of spectroscopic rotational velocities (v sin i) by Zapatero-Osorio et al. (2006) also gives a further guide to the expected periods of photometric variability (assuming surface features are the cause). Studies of L dwarfs found rotational velocities in the range $10<v$ sin $i<60$ km/s and for T dwarfs $15\geq v$ sin $i<40$ km/s. These are significantly shorter than stellar rotational periods, but are consistent with the prediction that brown dwarfs will spin up as their radii decrease due to gravitational contraction. Using model predictions for the radii of brown dwarfs (R∼0.08–0.10 $R_{\odot}$), this gives upper limits on the rotational periods of the observed sample of ∼2–12 hours for the L dwarfs and ∼2.5–8 hours for the T dwarfs. We propose to obtain ∼4 hour J-band photometric monitoring sequences on ∼30 late-T dwarfs to generate a statistically significant combine with our existing ∼4 hour data set on a red T8.5 brown dwarf to cover a wide range of colors for these cool objects. Variations in cloud properties have been modeled to explain the color range and the clouds may form in patchy layers which would be manifest in brightness modulations over a rotation cycle.

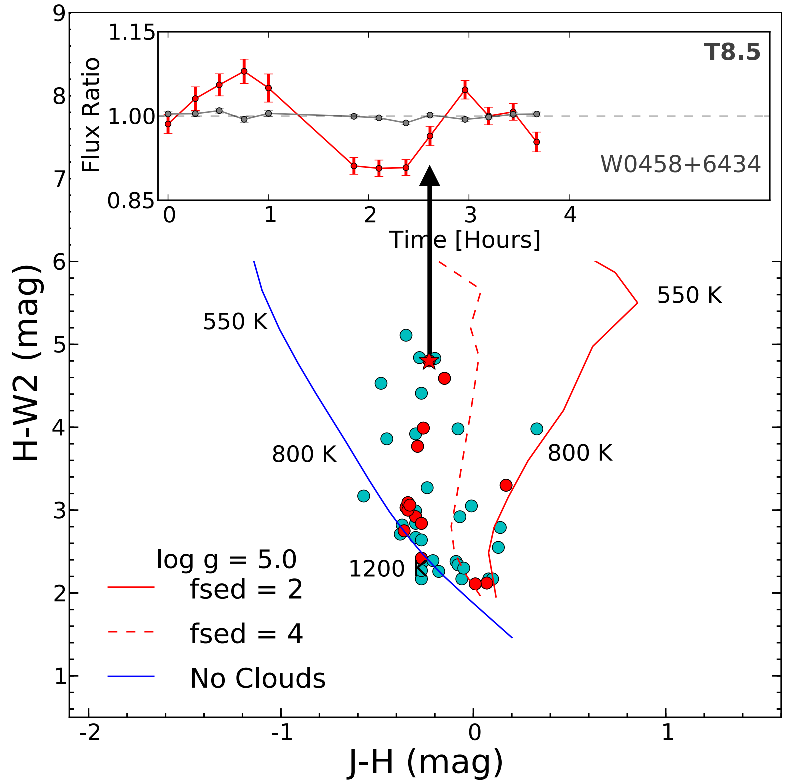

Figure 1 (left): Near-infrared versus *WISE* color-color diagram of the sample targets. The red circles are targets that will be observed in the 2014B semester. Also included are lines indicating sequences for atmospheric models incorporating a range of cloud properties including sedimentation efficiency (Morley et al. 2012). The blue line represents the case of cloud-free atmosphere, and the red lines plot the effects of clouds of increasing opacity. The f_{sed} range determines the cloud opacity and vertical extent, with f_{sed}=2 being the most opaque. The targets have been chosen to maximize the range of cloud models. The inset light curve is from the newly discovered variable brown dwarf - WISE0458+6434 (T8.5).

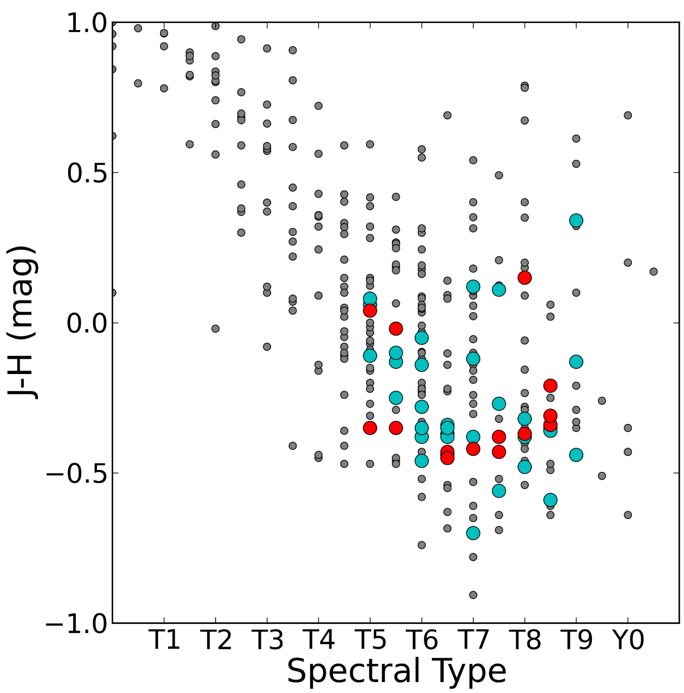

Figure 2 (above): Brown dwarf color-spectral type diagram with the complete sample (blue circles) plotted over the full T-Y spectrum (gray points). The red circles are targets that will be observed in the 2014B semester.

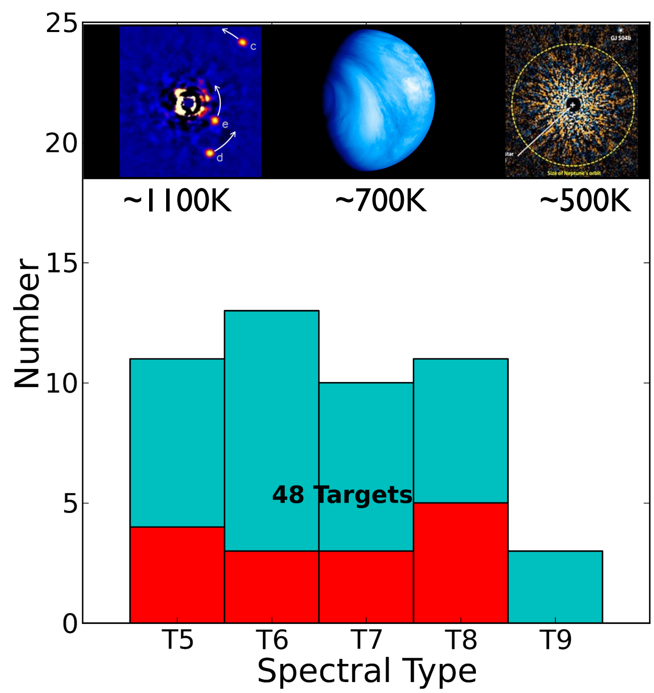

Figure 3 (above): Histogram showing the spectral distribution of the proposed targets, red region indicate targets that will be observed in the 2014B semester. Plotted above are similar temperature planets, including HR8799bcde, Venus, and GJ504b (left to right).

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)***

The proposed PISCES/MMT photometric monitoring campaign will observe 15-20 mid to late-T brown dwarfs this semester, searching for signs of variability in the coolest brown dwarf atmospheres. The PISCES field of view will ensure sufficient comparison stars, essential for high precision photometry that will be used as references to study the intrinsic variability of the target. The survey will be conducted in the J-band, which is the wavelength that probes deepest in the atmosphere of the brown dwarf and is thus most sensitive to holes in a cloud layer. This is also the wavelength range in which the largest amplitude of variability has been measured previously (Artigau et al. 2009, Radigan et al. 2012), and where the mid to late T-dwarfs are expected to show the greatest photometric variability (Morley et al. 2014). We will obtain several high signal-to-noise measurements of each target over a period of $\sim$4 – 5 hours (cadence dependent on brightness). Observing these targets over four nights (2 targets per night) will allow sufficient cadence to cover a substantial portion of the expected rotational periods of $\sim$3-8 hours for T-dwarfs (Zapatero-Osorio et al. 2006).

A histogram of our full target sample is presented in Figure 3. We will observe each target over a period of $\sim$4 hours. A time scale of a few hours is well-matched to a search for rotation-modulated variability, since expected rotation periods are 2 – 8 hours for T-dwarfs, considering the range of measured vsini values (15 – 40 km/s for T-dwarfs Zapatero Osorio et al. 2006). Periodogram analysis of some variables have shown clear peaks associated with periods in the range of 2 – 8 hours (e.g. Clarke et al. 2008; Radigan et al. 2012), which is consistent with an atmospheric feature rotating into and out of view. The sample has thus been designed to ensure that all the targets have declinations greater than -10 degrees and that they cover the full right ascension range and we can choose targets for observation at any time in the year.

For the targets brighter than J=17 mag, we will be able to reach a signal-to-noise of $>$100 in 1 minute observations allowing us to probe to similar levels as the smallest variations reported. The targets with J= 17 – 19 mag, will require longer integrations of up to 2 minutes to achieve a signal-to-noise $>$50. Multiple observations will be combined to increase the sensitivity to small variations at the expense of the high frequency coverage where no large amplitude variations are found. Although more challenging, we will still be sensitive to variations in these very cool objects.

For each image, we will use the field of background stars to produce a lightcurve for each target brown dwarf - each of the targets has between 15 and 60 candidate comparison stars in the PISCES field-of-view. Using these comparison stars we will identify the ultracool dwarfs where there is evidence for periodic and non-periodic brightness modulations.

The targets represent the coolest brown dwarfs currently known that are observable with the MMT. Although some targets are as close as $\sim$3 pc, they are too faint to allow photometric monitoring at the required cadence with a smaller telescope. The 6.5m MMT diameter is required to probe the atmospheres of these intrinsically faint substellar objects.

In summary, we intend to determine the level, frequency and type of variability seen in late-T brown dwarfs and compare this program to results from our monitoring of brighter, earlier-type brown dwarfs with the ESO NTT (BAM-I) and pilot sample of late T/Y dwarfs from the MMT (BAM-II). Together with new atmospheric models these data will be used to infer the presence or absence of condensate clouds, and the effective temperatures over which they form.

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 is the second epoch for this project and three nights were approved in the 2014B semester, data for which has not yet been collected. Two similar projects to monitor cool brown dwarfs at the T/Y boundary were awarded 2 nights in 2012 and 2 nights in 2013. As indicated in the proposal text and previous use summary, one run was 75% useful and the other run was lost to bad weather and the results of the first run have been submitted as a paper.

2 – non-UAO Telescope Time

A related program targeting brighter targets with the NTT telescope were performed as part of an ESO large program, and further 16 nights of telescope time has been awarded to follow-up the variable brown dwarfs detected as part of the NTT monitoring survey. The ESO program is a multi-wavelength study of known variables and is distinct from the proposed J-band search for new variables in the late-T sequence which was not covered in the previous ESO program.

3 – Collaborations

Patience and her group are involved in several large survey programs – the **BAM** (Brown dwarf Atmosphere Monitoring) Project, the **VAST** (Volume-limited A-STar) snapshot survey, and the **IDPS** (International Deep Planet Search) current AO system survey, the **TBOSS** (Taurus Boundary of Stellar/Substellar) collaboration. 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 and De Rosa are Co-Is 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 observations with both instruments.

The BAM publications thus far are student-led: Rajan et al. 2014 [**TY pilot study**], received referee report; Wilson, Rajan, Patience 2014 [**LT large scale survey**], 2014, A&A, 566, 111. VAST publications thus far are primarily student/postdoc-led: De Rosa et al. 2011 [**X-ray A-stars**], De Rosa et al. 2012 [**A-star orbits**], De Rosa et al. 2014, [**A-star binary statistics**], De Rosa et al. 2014 [**A-star brown dwarf detection**], Patience et al. 2014, in prep [**A-star debris disk binaries**], Schneider et al. 2014, in prep [**A-star binary age estimates**]. TBOSS has been student led: Bulger et al. (2014) [**Herschel survey of Taurus**], A&A, accepted. The IDPS A-star subset has been published by a postdoc working with Patience: Vigan et al. 2012 [**IDPS A-star initial results**].

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**)*

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

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

• **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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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