OBSERVING REQUEST
University of Arizona Observatories

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

A Poor Weather Program to Characterize Cool Brown Dwarf Atmospheres

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CoI(s): Andy Skemer (SO)

Abstract of Scientific Justification

Using LBTI/LMIRCam and MagAO/Clio, we are engaged in several programs to study the 3-5μm atmospheric properties of directly-imaged exoplanets and low-mass brown dwarfs. Here we are proposing to characterize isolated brown dwarfs at similar wavelengths to create a comparison sample. Because brown dwarfs and gas-giants share similar compositions, temperatures, and radii, the large sample of brown dwarfs will be a baseline with which to compare directly imaged planets.

LBTI is a general purpose AO-imager and interferometer, and as a result, every program to date on LBTI has required good seeing. At the telescope, this often means that we have no suitable programs to execute in clear-skies and poor seeing, which is common at the LBT. By inserting a poor-weather program into the LBTI queue, we will increase the completion rate of other programs. And at the same time, we will do exciting science in what would otherwise be unusable conditions.

Note that we are asking for an actual allocation of LBT nights. PIs of other programs usually will not (and in the HOSTS and LEECH collaborations, cannot) give up their time in $\sim$1.3-2.0" seeing with no reimbursement. Our request is that the TAC allocate time to this program, which can be inserted into an LBTI queue. We welcome direction from the TAC as to which queue programs should be prioritized to benefit from this seeing-swap.

Summary of observing runs requested for this project

								Scheduling		Sharing	
Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Optimal	Acceptable	Poss.	Adv.
1	LBT	AO	LBTI/LMIRCam	*	*	2	bright	any	any	yes	yes

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	see attached	all		

Approval for Instrument Use from PI: Phil Hinz

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

Scientific Justification

Science Goals

Using LBTI/LMIRCam and MagAO/Clio, we've determined that exoplanets have 3-5 μm SEDs that are dramatically different from field brown dwarfs (Skemer et al. 2012,2013,in prep). The differences (related to clouds and turbulence induced chemistry) are thought to arise primarily as a result of the youth and low surface-gravity of directly imaged planets. Old and massive field brown dwarfs are a baseline with which to compare young, low-gravity exoplanets, and they are accessible in much larger numbers. Thanks to WISE, we have 3.3 and 4.5 μm photometry for hundreds of nearby brown dwarfs. The addition of 3.8 μm photometry would allow us to fully probe the 3-5 μm SEDs of brown dwarfs and compare them to exoplanets (see Figure 1). Currently, 3.8 μm photometry exists for 47 out of 178 brown dwarfs with known distances (heavily weighted towards the earlier spectral types), and much of the photometry is quite a bit lower precision than WISE's photometry at the surrounding wavelengths.

By obtaining 3.8 μm photometry on a large number of brown dwarfs, including lower-temperature brown dwarfs than have previously been studied, we will:

1. construct a $\sim$200 brown-dwarf sample with photometric SED coverage from 1-5 μm and tempertatures spanning the M-L-T spectral type sequence
2. study the diversity of brown dwarfs in 3-5 μm SEDs, which will help us constrain the ranges of cloud patchiness and non-equilibrium chemistry in old brown dwarfs, and
3. compare the properties of field-brown dwarfs to young gas-giant planets and young isolated brown dwarfs in a wavelength range that our group is investigating with LBTI/LMIRCam and MagAO/Clio.

Why this Hasn't Been Done Before and Why the LBT can do it Better

3.8 μm capable infrared cameras are not common, and those that exist have small fields of view due to the small (angular) pixels scales that are necessary to observe the bright 3-5 μm sky without saturating. With small fields of view and a high sky background, it is unusual to find a photometric calibrator in the same field as a science targets. The variable sky and the necessity to move back and forth between science field and calibration field make these observations difficult and time-consuming.

By pointing the two telescopes to different, but nearby fields of view ("wall-eyed" pointing), we can simultaneous image a science target and calibrator that are separated by up to 2 arcminutes (compared to LMIRCam's 10 arcsecond field-of-view). The simultaneous calibration, which is unique capability of the LBT, will allow more precise photometry measurements at wavelengths $>$3 μm than has previously been possible from the ground.

The Strategic Importance of a Poor Seeing Queue

LBTI's science portfolio includes high-contrast imaging, nulling interferometry, and general AO science. All of these programs require good seeing ($\lesssim$1") in order to achieve good AO correction. The program described here requires a large aperture (because brown dwarfs are faint) a 3-5μm camera, and a wide FOV (in this case, provided by wall-eyed pointing), but it does not require good seeing because we are just doing photometry on isolated objects. Programs that can make use of poor seeing, but otherwise usable conditions have an important role in improving the scientific efficiency of the LBT (see Figure 2).

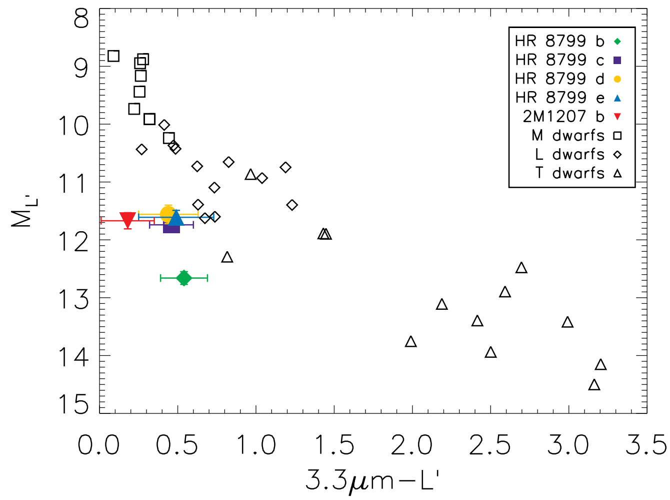

Figure 1: An example color magnitude diagram of field brown dwarfs and directly-imaged planets imaged from LBTI/LMIRCam and MagAO/Clio. The planets are systematically bluer than the brown dwarfs due to a combination of non-equilibrium chemistry and patchy clouds. Our proposed brown dwarf survey will increase the number of brown dwarfs on this diagram by a factor of 4 allowing us to understand the full range of brown dwarf properties in the context of the directly-imaged exoplanets.

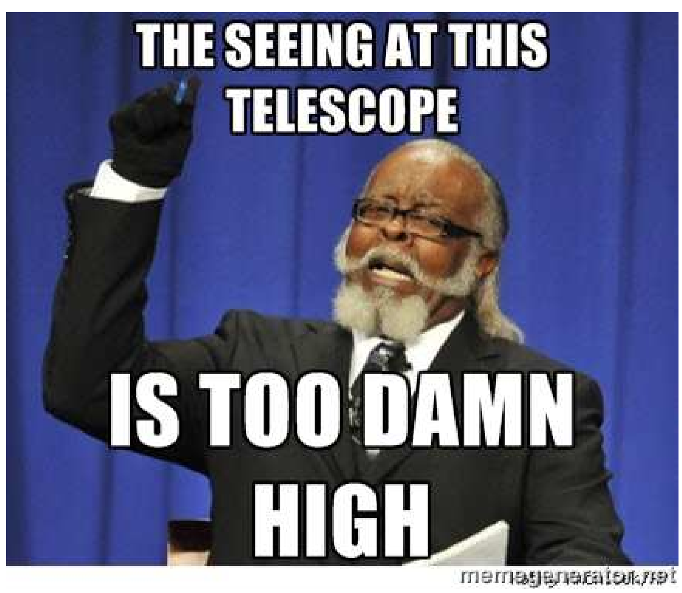

Figure 2: The crux of our problem.

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)***

When the seeing is poor, we will choose a brown dwarf in the appropriate RA range from our attached target list. We will point one telescope at the brown dwarf and another telescope at a nearby bright calibrator ("wall-eyed" pointing). The co-pointing limit of the LBT is ∼120", with the possibility of further improvement. In this range, almost all of our targets have a suitable calibrator, which can be chosen from 2MASS or WISE.

Observations will be taken in seeing-limited mode, or AO-mode with a very low-order correction (∼10-mode, low-gain) that can improve the seeing without risk of opening the loop in bad seeing. If AO is on, the loop parameters and wavefront sensor counts will be match between the two telescopes.

For each target, we will integrate until we have achieved a S/N of ∼30, which will be well-matched with the WISE photometry, and at the limit of our ability to absolutely calibrate using randomly chosen background stars. Based on WISE photometry, we will spend ∼30 minutes per target including 10-20 minutes to acquire the stars and coarsely close the AO loops. Thus we will be able to characterize ∼40 brown dwarfs in two nights of photometric, poor-seeing conditions.

Once per night, we will observe the same star with both apertures to calibrate the relative transmission between the two sides.

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 program will use poor-seeing conditions that are unusable by other programs. Here we are requesting two nights to contribute to a queue-like system, which will (1) ensure the completion of high priority LBTI programs, and (2) use two nights of poor-seeing for a brown dwarf photometry program.

At a rate of 20 brown dwarfs per photometric/poor-seeing night, we expect to characterize 120 brown dwarfs in 6 nights. Assuming 40% weather-loss (closed-dome or cloudy conditions), the full survey will take $\sim$10 nights over $\sim$5 semesters.

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 \command). (**up to one page**)*

NAME	RA	Dec	SpType	WISE2
LSR~J0011+5908	0.19217333	59.14446	M6.5	8.633
PC~0025+0447	0.46165933	5.0616	M9.5	14.135
2MASSW~J0030300$-$145033	0.50837	-14.84261	L7	13.263
ULAS~J003402.77$-$005206.7	0.56744067	-0.86872	null	14.5
CFBDS~J005910.90$-$011401	0.98640533	-1.23358	null	13.681
2MASSW~J0103320+193536	1.0588993	19.59338	L6	12.696
CTI~012657.5+280202	1.4608833	28.09824	M8.5	12.195
2MASS~J01490895+2956131	1.8191547	29.937	M9.5	11.312
SDSS~J020742.48+000056.2	2.1285693	0.01568	null	15.073
BRI~B0246$-$1703	2.81139	-16.85602	M8	10.984
TVLM~831-154910	2.836576	-1.85821	null	11.451
TVLM~831-161058	2.8536873	0.79344	M8	12.166
TVLM~831-165166	2.8618453	-1.03498	null	12.848
TVLM~832-10443	2.8739687	0.93954	M8	11.387
Teegarden's~star	2.8835693	16.88147	M6	7.057
PSO~J043.5395+02.3995	2.9026727	2.39965	null	12.737
TVLM~832-42500	3.043034	-1.27369	M6.5	12.275
LP~412-31	3.349904	18.90648	M8	10.148
SDSS~J032553.17+042540.1	3.4314507	4.42797	null	13.833
2MASSW~J0326137+295015	3.4371313	29.83757	L3.5	12.756
LSPM~J0330+5413	3.513584	54.23198	null	8.826
LHS~1604	3.8500127	-0.87924	M8	9.758
LHS~191	4.4388667	3.60997	M6.5	10.24
LHS~197	4.7718047	48.74775	M6	10.311
LSR~J0510+2713	5.172256	27.23423	M8	9.128
LHS~1742a	5.1774893	19.40218	esdM5.5	13.511
LSR~J0515+5911	5.2585953	59.18847	M7.5	9.808
2MASS~J05160945$-$044549	5.269294	-4.76387	null	13.665
2MASS~J05325346+8246465	5.548184	82.77959	sdL7	13.25
2MASSI~J0536199$-$192039	5.60555	-19.34436	L1:	12.789
LHS~207	5.63685	79.52186	M6	10.882
HD~46588B	6.774322	79.58459	null	13.078
SDSS~J074201.41+205520.5	7.7003613	20.92219	null	13.778
LP~423-31	7.873306	16.20436	M7	9.448
LHS~248	8.4970827	26.77634	M6.5	6.819
LHS~2021	8.5090447	9.78761	M6.5	10.331
SDSS~J083048.80+012831.1	8.5135513	1.47532	null	14.037
LHS~2026	8.541798	-1.57724	M6	10.698
2MASS~J08354256$-$081923	8.595158	-8.32326	L5	10.035
SDSSp~J083717.22$-$000018	8.621448	-0.00502	T0	14.688
LHS~2034	8.6749307	18.40255	M6	9.626
2MASSI~J0847287$-$153237	8.791314	-15.54367	L2	11.453
2MASSI~J0859254$-$194926	8.9904107	-19.82413	L6::	12.383
LP~368-128	9.006554	21.83484	M6	8.026
ULAS~J090116.23$-$030635.0	9.0211727	-3.10973	null	14.604
DENIS-P~J0909.9$-$0658	9.1659707	-6.97184	L0	11.957
TVLM~262-111511	9.70626	42.75991	M8	12.483

2MASS~J09490860$-$154548!	9.819056	-15.76348	null	13.96
TVLM~262-70502	9.86325	42.56407	null	12.668
2MASSI~J1010148$-$040649	10.17078	-4.11387	L6	12.517
TVLM~263-71765	10.183401	42.75099	M8	11.841
SSSPM~J1013$-$1356	10.218707	-13.93901	sdM9.5	13.545
TVLM~213-2005	10.357619	50.91787	null	11.841
HD~89744B	10.370803	41.24075	L0	12.949
SDSS~J103026.78+021306.4	10.507441	2.21847	null	14.435
SDSS~J104335.08+121314.1	10.726412	12.22082	null	12.853
SDSS~J104409.43+042937.6	10.735951	4.49381	null	13.093
2MASSI~J1047538+212423	10.798293	21.40652	T7	12.972
LHS~2314	10.817607	5.03964	M6	11.171
LHS~2471	11.897965	6.99892	M6.5	9.823
SDSS~J115553.86+055957.5	11.931636	5.99936	null	12.848
SDSS~J115700.50+061105.2	11.950138	6.18475	null	14.54
2MASSW~J1200329+204851	12.009145	20.81426	M7	11.402
BRI~B1222$-$1222	12.414507	-12.64312	M9	10.792
2MASS~J12373919+6526148	12.627555	65.43745	T7	12.946
SSSPM~J1256$-$1408	12.937238	-14.14434	null	12.869
SDSS~J125637.13$-$022452.4	12.943657	-2.4145	sdL3.5	15.106
Ross~458C	13.011592	12.35408	null	13.736
2MASS~J13204159+0957506	13.344887	9.96406	M7.5	12.185
2MASS~J13204427+0409045	13.345632	4.15128	L3::	12.882
SDSSp~J132629.82$-$003831	13.441617	-0.64208	L8:	12.754
2MASSW~J1328550+211449	13.481955	21.24683	L5	13.368
ULAS~J133553.45+113005.2	13.598185	11.50141	null	13.865
SDSSp~J134646.45$-$003150	13.77954	-0.53059	T7	13.567
ULAS~J141623.94+134836.3	14.273317	13.81009	null	12.791
SDSS~J141624.08+134826.7	14.273391	13.80801	L6	11.023
SDSS~J141659.78+500626.4	14.283298	50.10718	null	14.411
BD~+01~2920B	14.389127	1.27726	null	14.849
LSR~J1425+7102	14.418086	71.03604	sdM8	13.663
LHS~2919	14.467832	13.93715	M7.5	9.599
LHS~2930	14.510522	59.7236	M6.5	9.343
SDSS~J143517.20$-$004612.9	14.588111	-0.77028	L0	14.883
SDSS~J143535.72$-$004347.0	14.593258	-0.72975	L3	14.557
SDSSp~J144600.60+002452.0	14.766838	0.41443	L6	12.898
TVLM~513-42404	15.039251	25.43189	null	13.06
TVLM~513-42404B	15.039255	25.43442	null	13.586
SDSS~J150411.63+102718.3	15.069954	10.45459	null	14.062
ULAS~J150457.65+053800.8	15.082682	5.63356	null	14.232
SDSS~J151114.66+060742.9	15.187406	6.12866	null	13.229
TVLM~513-8328	15.239039	23.68476	null	12.354
SDSS~J152103.24+013142.7	15.350909	1.52852	null	13.915
2MASSW~J1526140+204341	15.437236	20.72818	L7	12.826
DENIS-P~J153941.9$-$052042	15.661639	-5.34523	L4:	11.744
2MASS~J16150413+1340079	16.251149	13.66887	null	14.194
GJ~618.1B	16.340596	-4.27543	L2.5	12.661

2MASS~J16262034+3925190	16.438984	39.42197	sdL4	13.091
SDSS~J162838.77+230821.1	16.477491	23.13878	null	13.961
SDSS~J163022.92+081822.0	16.506377	8.30616	null	14.468
2MASSW~J1645221$-$131951	16.756142	-13.33102	L1.5	10.489
LHS~3241	16.77543	34.58207	M6.5	9.148
WISE~J164715.57+563208.3	16.787724	56.53492	null	13.086
vB~8	16.92647	-8.39448	M7	8.365
2MASSW~J1658037+702701	16.967724	70.45043	L1	11.384
DENIS-P~J170548.3$-$051645	17.096762	-5.27951	L0.5	11.4
2MASSI~J1711457+223204	17.196037	22.53456	L6.5	13.812
WISEP~J174124.27+255319.6	17.690173	25.89288	T9	12.334
2MASS~J17502484$-$001615	17.840234	-0.27087	null	10.903
SDSSp~J175032.96+175903.9	17.842483	17.98451	null	14.48
2MASS~J17545447+1649196	17.915131	16.82213	null	13.371
LP~44-162	17.954277	70.70033	M7.5	9.891
SDSS~J175805.46+463311.9	17.968182	46.55275	null	13.823
2MASSI~J1835379+325954	18.593861	32.9985	M8.5	8.539
LP~335-12	18.65919	29.87123	M6.5	9.514
LP~44-334	18.667329	72.68167	M6.5	9.554
2MASSW~J1841086+311727	18.685726	31.2911	L4p	13.261
vB~10	19.282673	5.1506	M8	8.249
GJ~1245B	19.898636	44.41529	M6	6.968
LSR~J2036+5059	20.606015	51.00144	sdM7.5	12.475
DENIS-P~J205754.1$-$025229	20.965026	-2.87507	L1.5	10.981
LP~397-10	21.268415	22.64619	M6	10.424
LSPM~J2124+4003	21.408983	40.06666	M6.5	8.986
Wolf~940B	21.777453	-0.17742	null	14.236
LSPM~J2158+6117	21.976272	61.285	M6	10.01
GRH~2208$-$20	22.180553	-19.8736	M7.5	12.585
TVLM~890-60235	22.384875	0.503	M7	12.639
LHS~523	22.481778	-13.42163	M6.5	9.436
LP~460-44	22.596961	18.67497	M7	10.951
G~216-7B	22.62571	39.37772	M9.5	11.426
SDSSp~J225529.09$-$003433	22.924742	-0.576	L0:	13.763
2MASS~J23062928$-$050228	23.108134	-5.04127	M7.5	9.799
2MASSI~J2356547$-$155310	23.948547	-15.88643	null	13.708