SONYC * Substellar Objects in Nearby Young Clusters

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Motivation

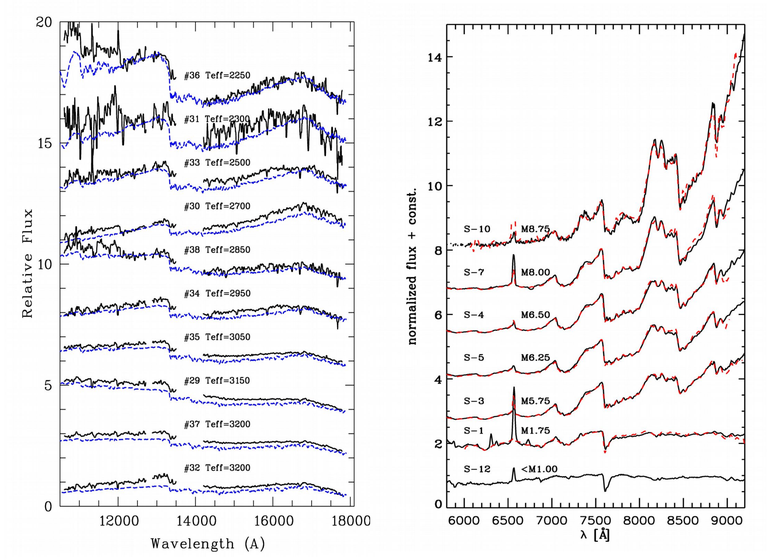
The origin of the lowest mass free-floating objects, i.e. brown dwarfs (BDs) and planetary mass object, is one of the major unsolved questions in star formation. Various competing origin theories exist, such as turbulent fragmentation, dynamical ejection from multiple systems or proto-planetary disks, and photo-erosion in the vicinity of OB stars. These theories are increasingly capable of providing predictions for the frequency and properties of substellar objects. A fundamental prerequisite to test the theories is to establish a census of young brown dwarfs, allowing us to probe the shape of the initial mass function and its minimum mass, multiplicity statistics, properties of accretion disks, spatial and kinematic distribution, as well as the dependence of these properties on star-forming environment.

SONYC is an ongoing survey to provide a census of the sub-stellar population in nearby star forming regions. We present here the survey with its major findings, and encourage the use of survey catalogs and spectra, available at **browndwarfs.org/sonyc.**

Method

(1) Identification of sub-stellar candidates through wide-field, deep optical and near-infrared imaging campaigns on 4- to 8-m-class telescopes (Subaru, VLT, CTIO-Blanco, NTT), archival photometry (2MASS, UKIDSS, *Spitzer*), and proper motions.

(2) Candidate verification through extensive follow-up low-resolution optical or NIR spectroscopy.



Examples of the confirmed low-mass stars and BDs in the NIR and optical.

Left: MOIRCS/Subaru spectra in NGC1333 (black), with the best-fit DUSTY atmosphere model (blue).

Right: VIMOS/VLT spectra in Lupus 3 (black), with the best-fit young very-low mass templates (red).

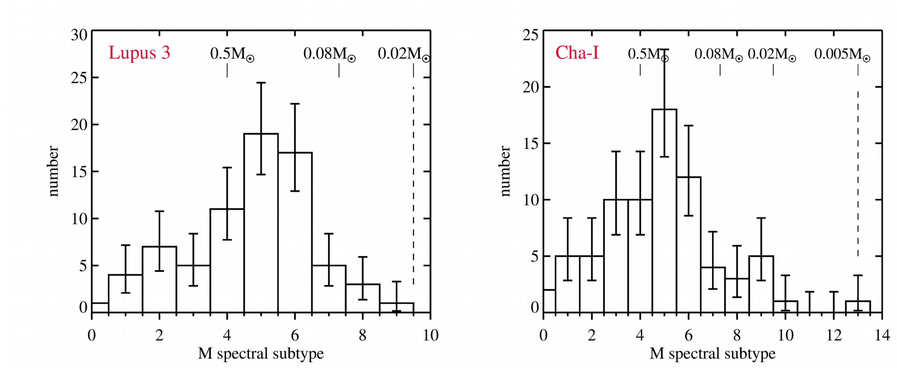
Overview of the SONYC survey

	Cha-I	ρ Oph	NGC 1333	Lupus 3	UpSco
Distance [pc]	160	125	300	200	145
Age [Myr]	~ 2	~ 1	~ 1	~1	5-10
Survey Area [deg^2]	0.25	0.25	0.25	1.4	57
Completeness [$M_\odot$] at A_V [mag]	0.005 ≤ 5	0.003-0.03 ≤15	0.004-0.008 ≤5	0.009-0.02 ≤5	0.02 ≤5
# of subst. candidates	142 (opt)	309 (opt) 83 (Spitzer)	196 (opt) 10 (Spitzer)	409 (opt-NIR)	96 (opt-NIR)
# of spectra	34	160	160	138	30
# of confirmed VLMOs(*)	9	19	35	9	24
Papers	Muzic et al. (2011) Muzic et al., subm.	Geers et al. (2011) Muzic et al. (2012)	Scholz et al. (2009) Scholz et al. (2012a) Scholz et al. (2012b)	Muzic et al. (2014) Muzic et al., subm.	Dawson et al. (2011) Dawson et al. (2013) Dawson et al. (2014)

(*) VLMO = Very Low Mass Object, includes brown dwarfs and low mas stars of M-type

Substellar Mass Function

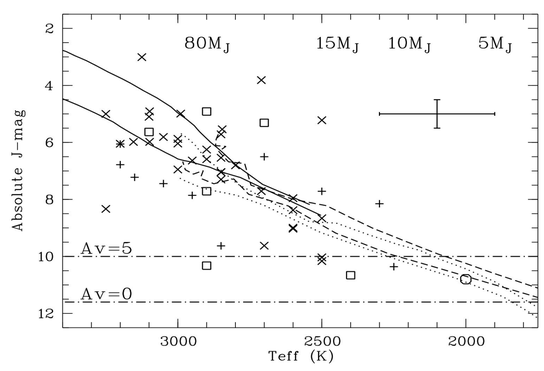
* Through SONYC and similar surveys by other groups, the substellar IMF is now well characterized down to 5-10 M_{Jup}



Distribution of spectral types for the VLM population of Lupus 3 and Cha-I. The dashed lines mark the completeness limit of the two surveys for Av=5. The rough mass limits according to BT-Settl and AMES-Dusty isochrones are shown on top of the plot.

* The ***ratio of the number of stars to BD***s is found to be between 2 and 5. In a consistent analysis of NGC 1333 and IC 348, two young clusters in Perseus, and considering various sources of uncertainties, we find that environments with higher object density may produce a larger fraction of very low mass objects (Scholz et al. 2013).

* ***Free-floating planetary mass objects,*** down to ~5 M_{Jup}, are observed to be rare, 20-50 times less numerous than stars. These findings (a) imply that the total contribution of planetary mass objects to the mass budget of the clusters can be neglected, and (b) disagree strongly with recent micro-lensing survey claims of free-floating planetary mass objects being twice as common as stars.



Absolute J-band magnitude vs. Teff for NGC1333. The dash-dotted lines mark the completeness limit of our survey at Av=0-5.

* Based on the optical spectra of low-mass stars and BDs in Lupus 3, we derive the ***spectral type – Teff*** relation:

$$\mathrm{Teff} = (4120 \pm 175) - (172 \pm 26) \times \mathrm{SpT}, \text{ for SpT=M1 - 9}$$

Access to the data | Questions/Comments?

Spectra, photometric catalogues, and links to SONYC publications are available at: **browndwarfs.org/sonyc**

For questions/comments please contact:
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