Young Brown Dwarfs:
Testing star formation across environments

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R. Schoedel (IAA-CSIC), et al.
SONYC survey – brown dwarfs in nearby star forming regions

New program to look for brown dwarfs in massive young clusters – RCW 38
Bastian et al. (2010)
SONYC
Substellar Objects in Nearby Young Clusters

Two main goals:

(I) Establish the deep substellar IMF in various SFRs, using consistent methodology

(II) Provide clean samples of brown dwarfs - groundwork for characterization of their properties
SONYC Summary

2006 – 2015 (tbc)

15 nights at 8-m telescopes

5 regions
> 700 spectra
~ 100 confirmed brown dwarfs
& very low-mass stars

9 papers

browndwarfs.org/sonyc
Candidate selection

Cha-I

Muzic et al. (2011)
ρ-Oph

Geers et al. (2011)
ρ-Oph

Spectroscopy is mandatory!

Geers et al. (2011)
$$\frac{N(\star)}{N(\odot)} = 2 - 5$$

SONYC

brown dwarfs

low-mass stars

Mass in Jupiter masses
**IMF** \( \frac{dN}{dM} \propto M^{-\alpha} \)

\( \alpha \sim 0.6 - 1.0 \)

| \( \sigma \text{ Ori} \) | 0.6 ± 0.2 | 0.006 – 0.35 | Peña Ramírez+2012 |
| **Upper Sco** | 0.45 ± 0.11 | 0.009 – 0.2 | Lodieu+2013 |
| **Collinder 69** | 0.2 – 0.4 | 0.01 – 0.65 | Bayo+2011 |
| **IC 348** | 0.7 ± 0.4 | 0.012 – 0.075 | Alves de Oliveira+2013 |
| **ρ Oph** | 0.7 – 0.8 | 0.03 – 1.0 | Scholz+2013 |

Muzic et al. (2015)
Dense cluster – more BDs?

Initial $\langle \rho \rangle \sim 10^2 \text{ M}_\odot \text{ pc}^{-3}$ IC348

$10^3 \text{ M}_\odot \text{ pc}^{-3}$ NGC1333  Parker & Alves de Oliveira (2017)
Dense cluster – more BDs?

Most BD formation theories predict some dependence on environment

Density:
- any theory that requires ejection
- gas infalling on star clusters
- turbulent fragmentation framework

Presence of O stars:
- photoionization of intermediate-mass cores

(Bate 2012; Padoan & Nordlund 2002; Bonnell et al. 2008; Vorobyov et al.; Whitworth & Zinnecker 2004)

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Most of the nearby SFRs are fairly similar

**Ultimate test:** much denser environment, many OB stars
Testing the environmental differences

Massive clusters are far away!

10 MJup @1 Myr, 1 kpc, Av=0-10 → H=18.9-20.8

New program to observe selected clusters with VLT and Gemini-S

RCW 38  RCW 36  NGC 2244
**RCW 38**

**Young:** ~1 Myr

**Dense:** densest young cluster within 4 kpc (MYStIX survey)

Density wrt other SFRs:
- > 2 times that of ONC
- ~10 NGC1333
- > 25 Cha I

**Rich in massive stars:** 60 OB candidates (Wolk et al. 2006, Winston et al. 2011)

AO imaging with NACO/VLT
RCW 38

Muzic et al. (2017, submitted)

\[
\frac{N(\star)}{N(\bigcirc)} = 2.0 \pm 0.6
\]

No evidence for significant environmental differences
The (complicated) case of the ONC

Low-mass content is mass segregated (Andersen et al. 2011)

Older (4-5 Myr) population in front (Alves & Bouy 2012; Bouy et al. 2014)

Not all the surveys use spectroscopy
Conclusions

- Census of substellar objects in young clusters mostly complete down to the D-burning limit, in selected regions even down to ~5 MJup

- For every brown dwarf, there are 2 - 5 stars

- First results in massive young cluster RCW 38: no evidence for environmental differences

- Future:
  - *Gaia*: distances
  - *JWST*: 1-2 MJup objects in NGC 1333 (spectroscopy) and RCW 38 (imaging)