

# A new spectral class of brown dwarfs at the bottom of the initial mass function in IC 348

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#### IC 348



IC 348 is one of the best sites for brown dwarf surveys:

- Nearby ~300pc
- Densely populated ~500 members
- Only moderately obscured ~Av < 4 mag</li>

Past 30 years: uncovered over 70 probable brown dwarfs in this cluster

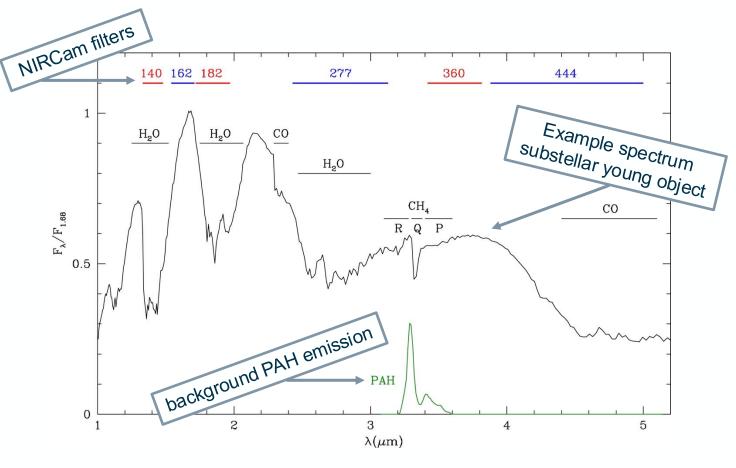
#### JWST:

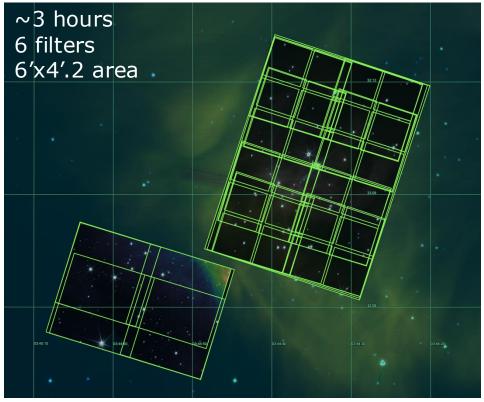
- Capable of detecting brown dwarf in regions like IC348 down to ~1Mjup
- IC 348 is compact on sky for small field of view of JWST (D~0.5°)



# Design of the first observing program with JWST/NIRCam@esa

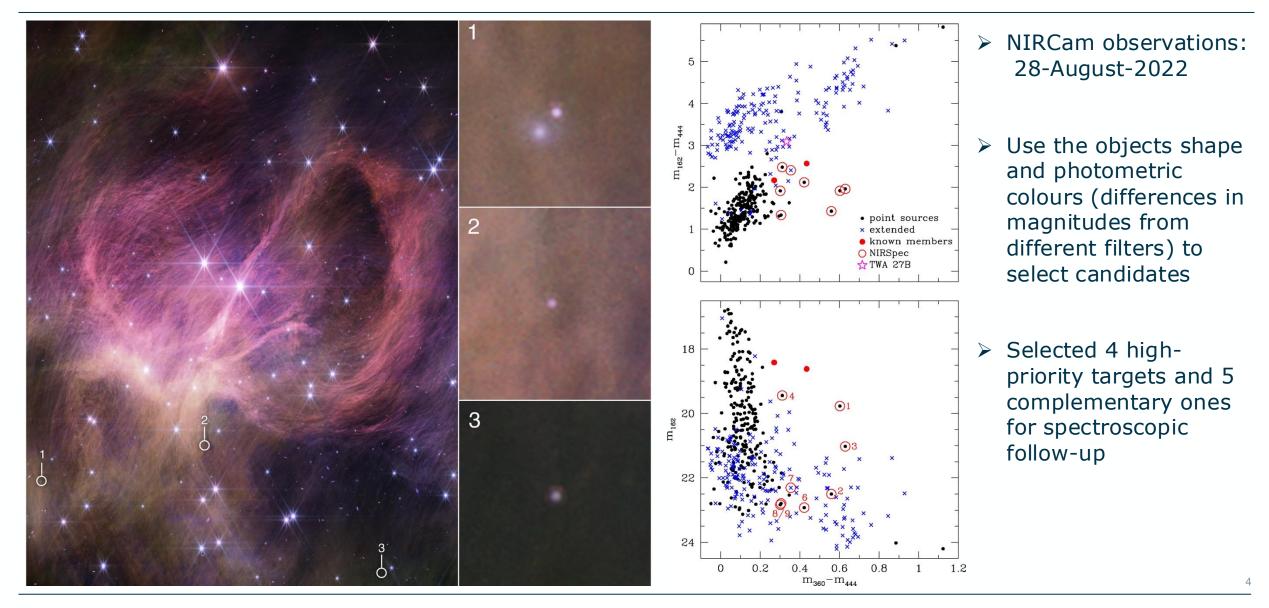
- > Based on known-spectra of brown-dwarfs, select best photometry filters to uncover new low-mass objects
- Design a mosaic pattern centred on the cluster IC 348 (distance~400 pc, age~3 Myr)





## 



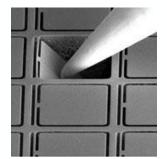


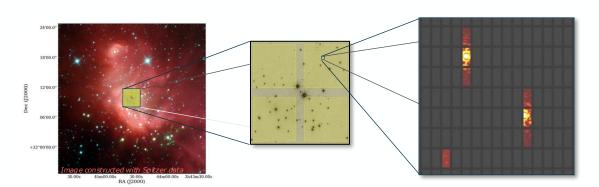
### Using JWST/NIRSpec to study brown dwarf candidates

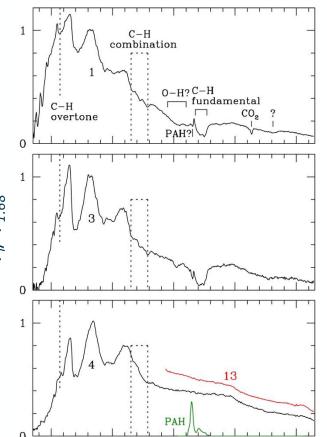










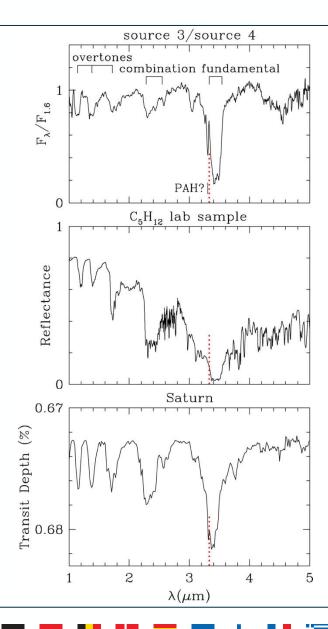


Wavelength (µm)

- NIRSpec observations:03-February-2023(4.5 hours)
- Discarded 5 sources:
- Reddened field dwarfs in the background
- 1 field star or galaxy
- Confirmed 3 new members:
- Comparision between estimated luminosity to evolutionary models result in temperatures of 1100-1800K and 3-8MJup
- Source 3 is a contender for the least massive free-floating brown dwarf directly imaged to date

#### Molecular discovery and open questions





Luhman, K., Alves de Oliveira, C. et al. 2024, AJ 167,19L <a href="https://doi.org/10.3847/1538-3881/ad00b7">https://doi.org/10.3847/1538-3881/ad00b7</a>

- ➤ 2 sources show a spectral signature of an unidentified hydrocarbon, absorption around ~3.4micron
- First time this molecule is detected in the atmosphere of an object outside our solar system
- ➤ Same infrared signature was detected by Cassini mission in the atmospheres of Saturn and its moon Titan, and modelled in terms of methane and other hydrocarbons, with a large component of the absorption still due to an unidentified aliphatic hydrocarbon
- ➤ One possibility is that these newly found objects inhabit a regime of physical properties that is previously unexplored (e.g., low temperature, low surface gravity, and thinning clouds)

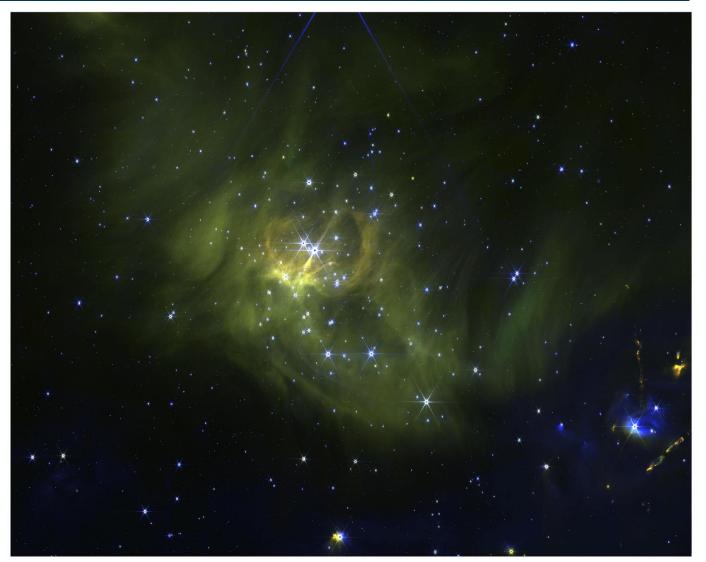
## Second, deeper and wider, JWST survey of IC348



16' x 20' field

4 filters to distinguish brown dwarfs (F162M./ F182M / F360M / F444W)

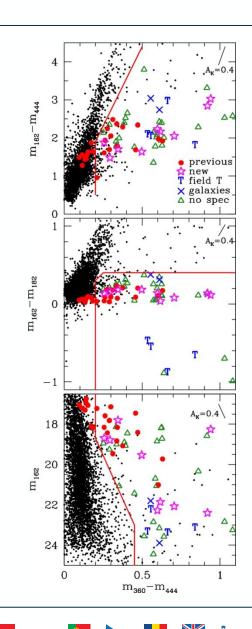
NIRCam observations: Aug & Sep 2024 (41.4h)

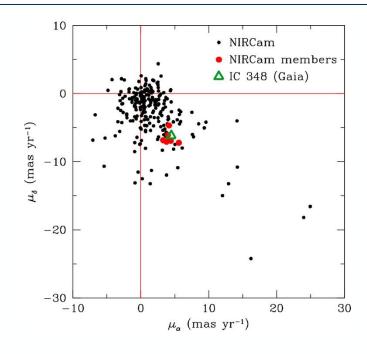


#### Selection of brown dwarf candidates



- Use the objects shape and photometric colours (differences in magnitudes from different filters) to select candidates
- Selected 39 new candidates (and 43 previously members)
- Proper motions: compared positions between 2 epochs of NIRCam observations (Aug 2022 vs Aug 2024)
  - Previously known members of IC348 and Gaia are tightly positioned with same velocity
  - None of the new members is in the overlapping observed field
  - 3 members from first survey are confirmed w/ proper motions

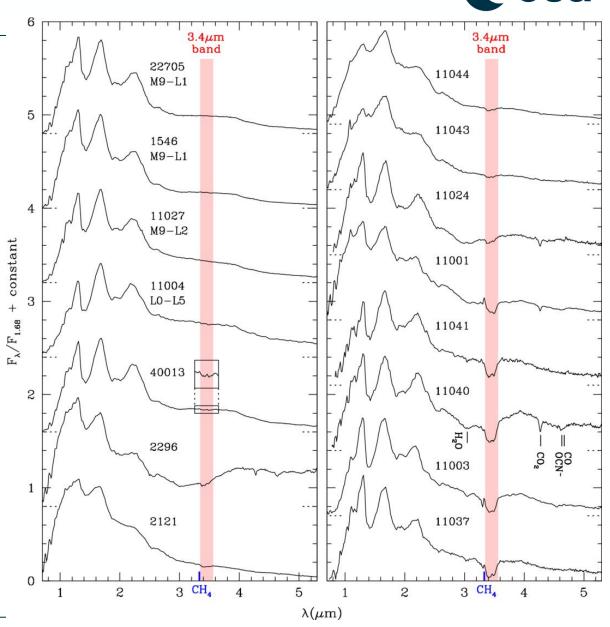




#### Spectroscopic follow-up

esa

- NIRSpec observations:February-2025(10.3 hours)
- Observed 15 brown dwarf candidates (+8 fillers)
- Confirmed 9 new brown dwarf members:
  - ➤ H2O absorption bands, triangular H-band, weak CO bands, and 2 candidates with large excess emission
- Non-members:
  - ➤ 4 field T-dwarfs, 4 reddened background stars, 3 active galaxies
- > New spectra for 3 previously known members

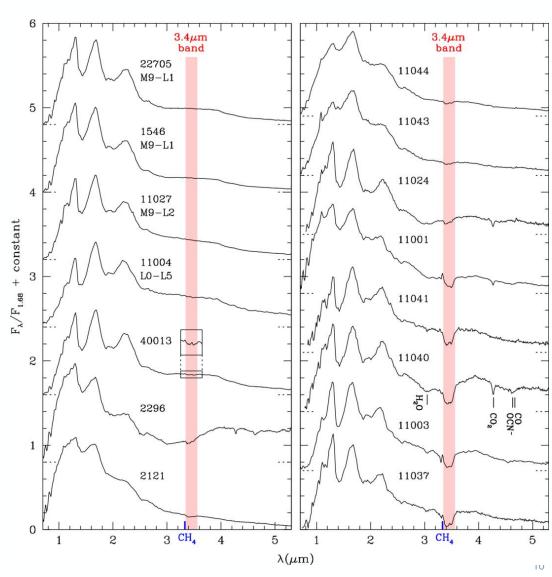


#### 3.4µm absorption feature



#### Current results:

- 11 members with significant detections
- Strength of the feature is correlated with apparent magnitude
- Spectral sequence:
  - Typical L dwarf spectra, no 3.4 micron absorption
  - 3.4µm absorption appears, Titanium Oxide and Vanadium Monoxide (TiO, VO) re-emerge
  - 3.4µm absorption increases, TiO + VO strengthen,
    H2O bands weaken, near-IR slopes bluer
  - 3.4µm stronger, H2O turns again similar to L dwarfs, near-IR slopes reader
- Sources with intermediate 3.4µm strengths have bluest near-IR slopes



### Proposed new "H" spectral class



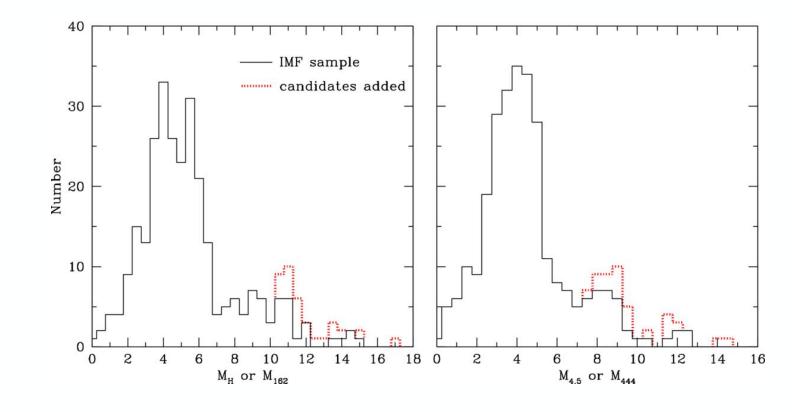
K.L. Luhman and C. Alves de Oliveira 2025 *ApJL* **986** L14 (**DOI** <u>10.3847/2041-8213/addc55</u>)

- Nature Astronomy Highlights: H is for hydrocarbon, Paul Woods (DOI 10.1038/s41550-025-02642-3)
- AAS Journal Author Series interviews: <a href="https://youtu.be/2lz3Kewi6GI?si=4hAKqdgAHyZ2CX6U">https://youtu.be/2lz3Kewi6GI?si=4hAKqdgAHyZ2CX6U</a>
- L/T/Y spectral classes are defined primarily by the significant weaking of Titanium Oxide in the red-optical (L), onset of methane (T), and ammonia (Y) at near-IR, respectively
- New population does not fall into any of these classes propose a new one based on the presence of the 3.4µm absorption feature
- Kirkpatrick et al. 1999 had proposed H, L, T, Y: propose H, which could stand for "hydrocarbon" (a nonmethane aliphatic variety)
- Depending on the trends among spectral features that emerge in a larger sample, it may be possible to define H subclasses through a combination of the 3.4 µm band and features from other species like TiO, VO, and H2O

# Properties of the substellar population: magnitude histograms



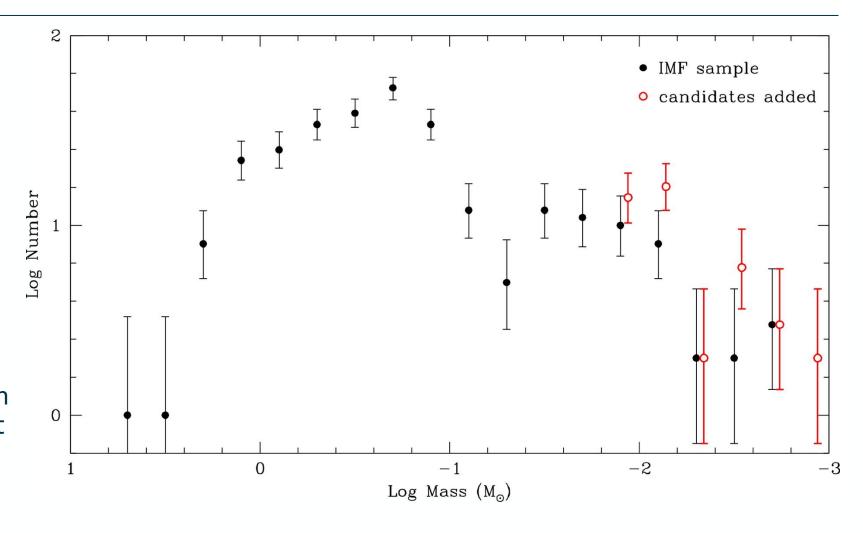
- Selected an extinction-limited sample: 281 members
- Focus on observational parameters, such as the histogram of absolute magnitudes which should be correlated to mass
- Features: bump in histogram where weak-to-moderate 3.4µm absorption feature shows, could be equivalent to J-band bump seen in the L/T transition



#### Properties of the substellar population: IMF



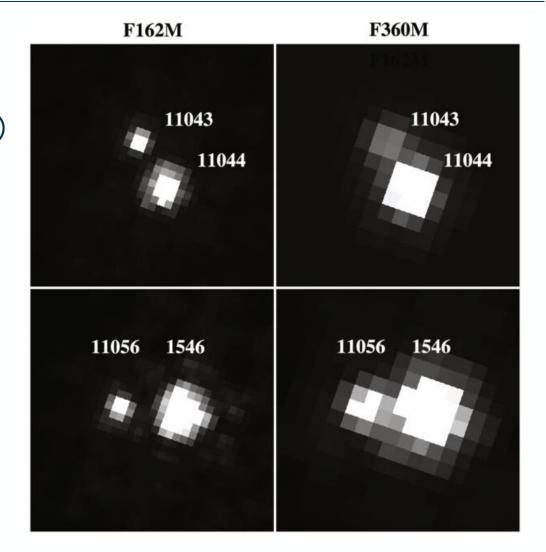
- Compared derived bolometric luminosities to evolutionary models from Chabrier et al. 2023 at 5 Myr
- Estimate for lowest mass member with spectroscopic confirmation is 2M<sub>Jup</sub> and ~900K temperature
- IMF: extending from 5Mo to 2M<sub>Jup</sub>; consistent with mass function declining slowly down to ~3M<sub>Jup</sub> and then somewhat faster



#### Properties of the substellar population: multiplicity



- Resolved 2 close pairs as likely binary systems
- Angular separations of 0.23" and 0.27" (72 and 85AU)
- Mass estimates: 6 / 12  $M_{Jup}$  and 8 / 18  $M_{jup}$
- Rare examples of young binary brown dwarfs with separation > 10 AU and and secondary masses < 10  $M_{\rm Jup}$



#### **Next steps**



- Currently working on higher resolution data from IC348-1
- Will continue to characterize the remaining candidates spectroscopically, using also what we learned from the selection (e.g., reducing the likely contamination from T dwarfs and galaxies)

#### Thank you for your attention!

Luhman K.L. and Alves de Oliveira C. 2025 *ApJL* **986** L14 Luhman K.L., Alves de Oliveira C., Baraffe I. *et al.* 2024 *AJ* **167** 19

