

A novel water-band technique to identify brown dwarfs and planetary mass objects in the Solar neighbourhood

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Brown dwarfs - what are they?

- ❑ Failed stars with core temperatures insufficient to trigger hydrogen burning
- ❑ Mass range: $\sim 0.072 - 0.012 M_{\odot}$
- ❑ Evolution is a process of cooling \rightarrow decreasing luminosity with age
- ❑ Young dwarfs are brighter during early stages of evolution hence star forming regions are ideal sites to observe them

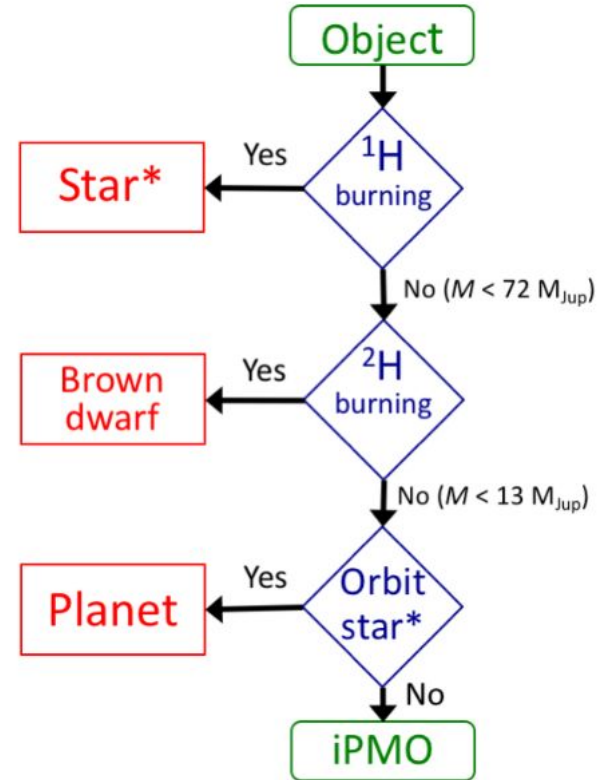


Image credits: Caballero 2018



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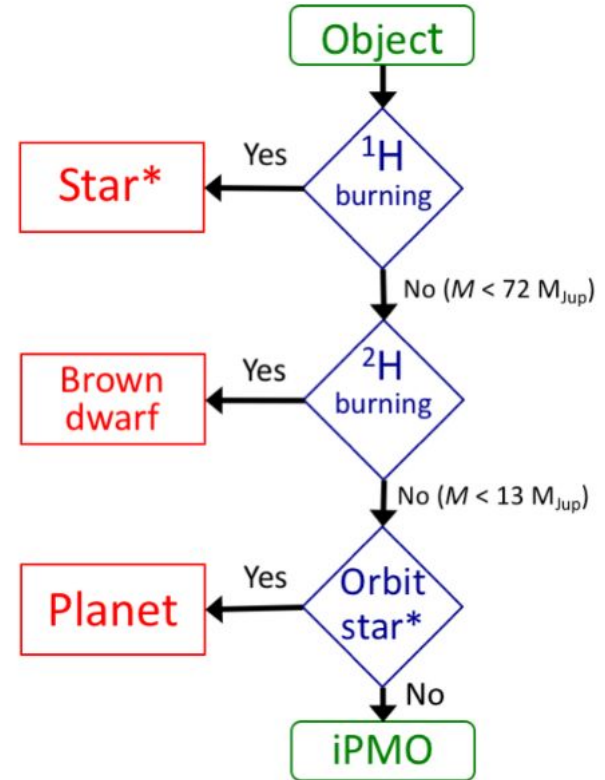


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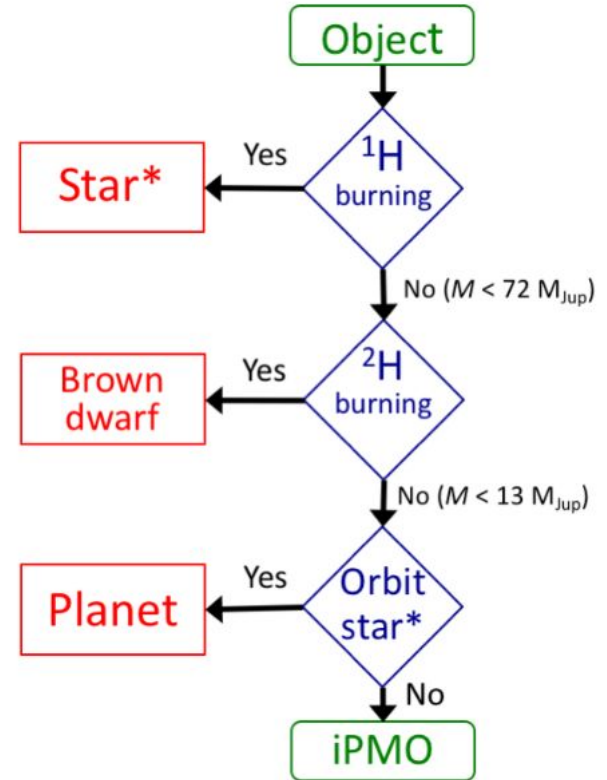


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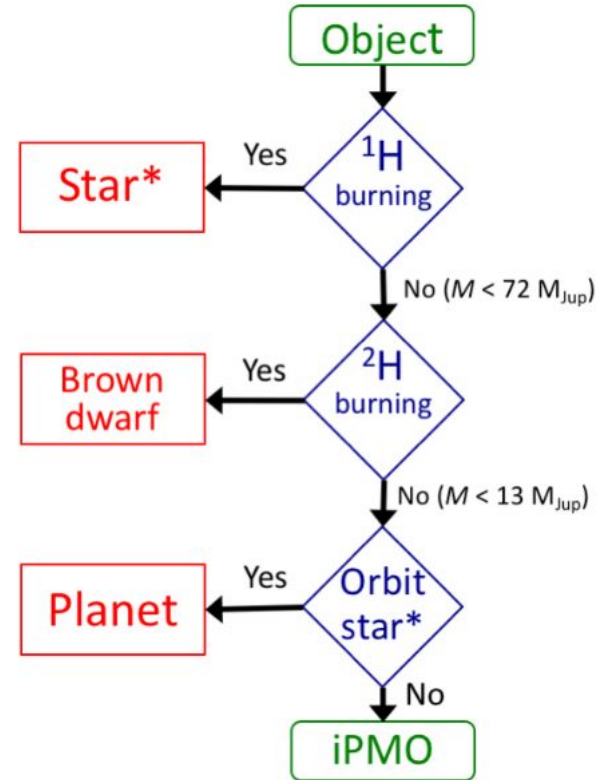


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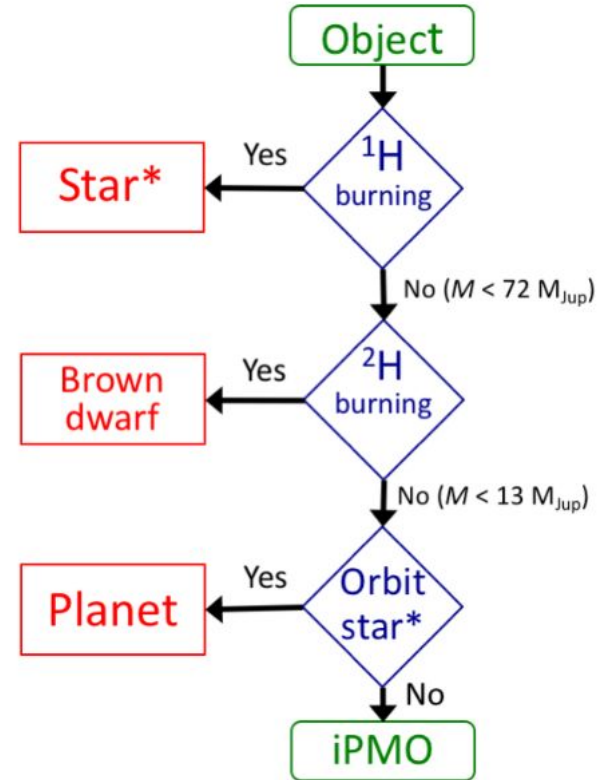


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Brown dwarfs - importance to study (IMF)

- IMF - Distribution of stellar mass at birth

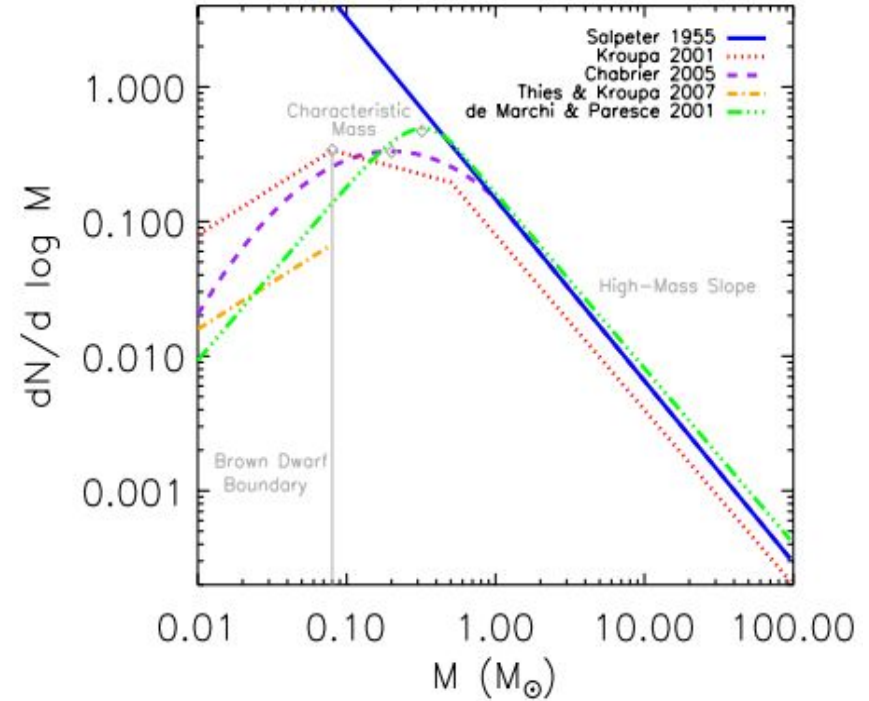


Image from Offner et al. 2014



Brown dwarfs - importance to study (IMF)

- IMF - Distribution of stellar mass at birth
- Important since it imposes constraint on the star formation process

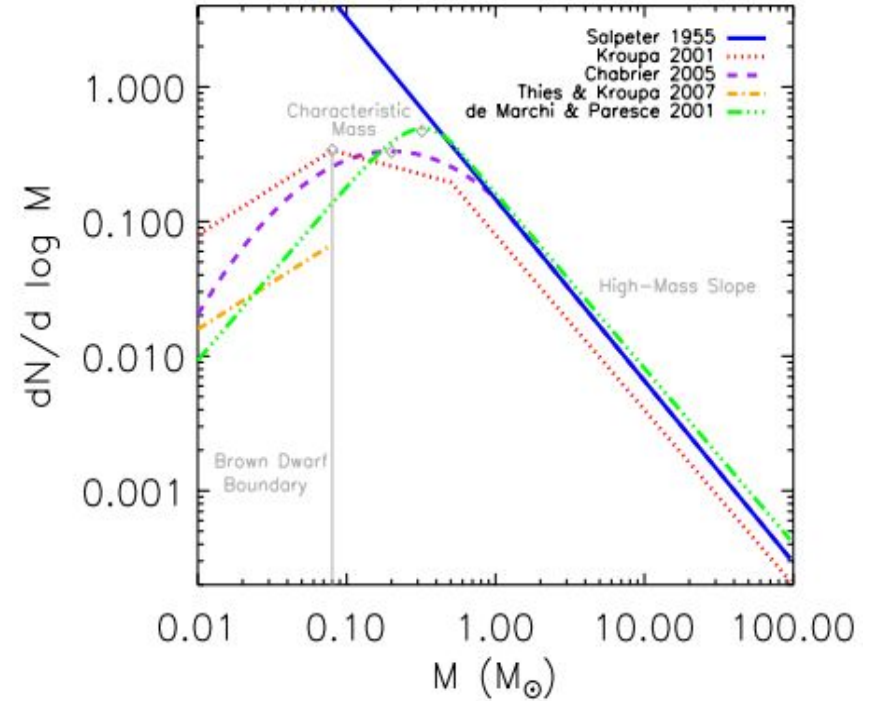


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$$dN/dM \propto M^{-\alpha} \text{ where } \alpha=2.35$$

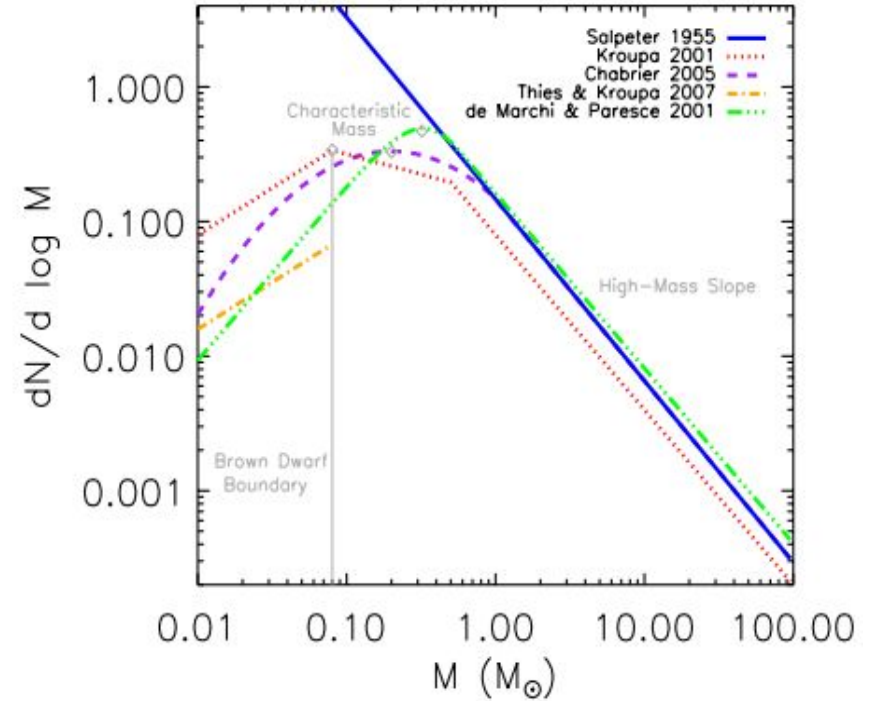


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- ❑ Various functional forms for the high-mass end support a universal IMF above $1 M_{\odot}$ but diverges and flattens towards low-mass end.

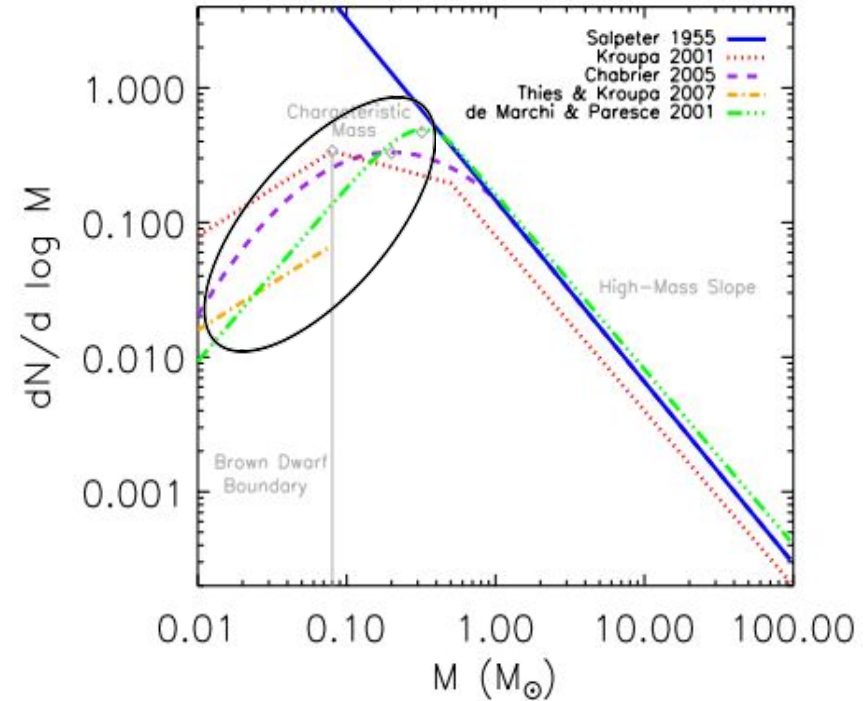


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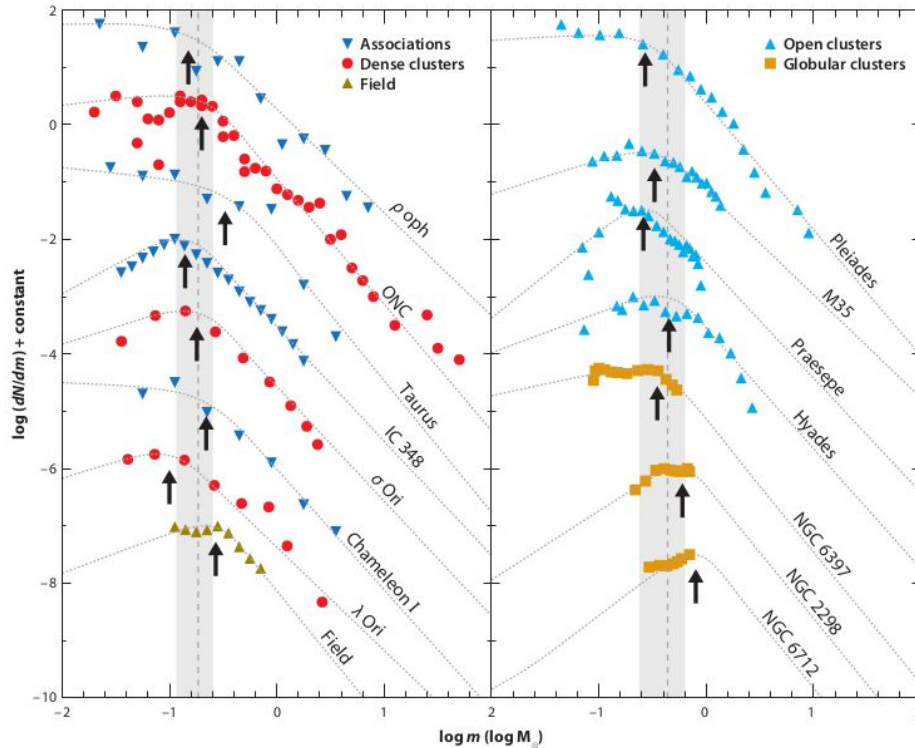


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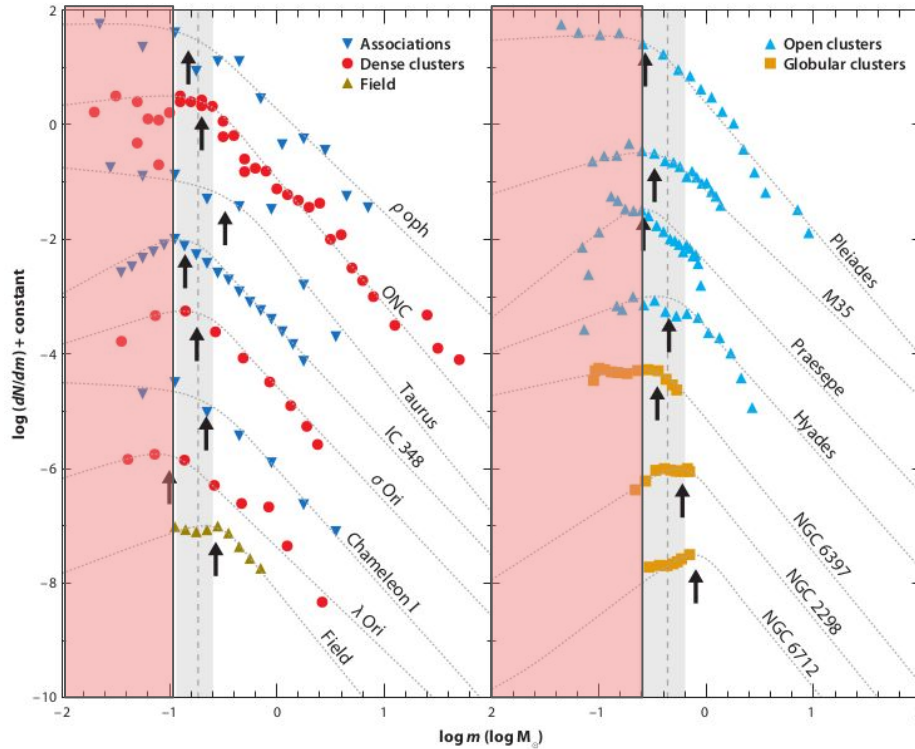
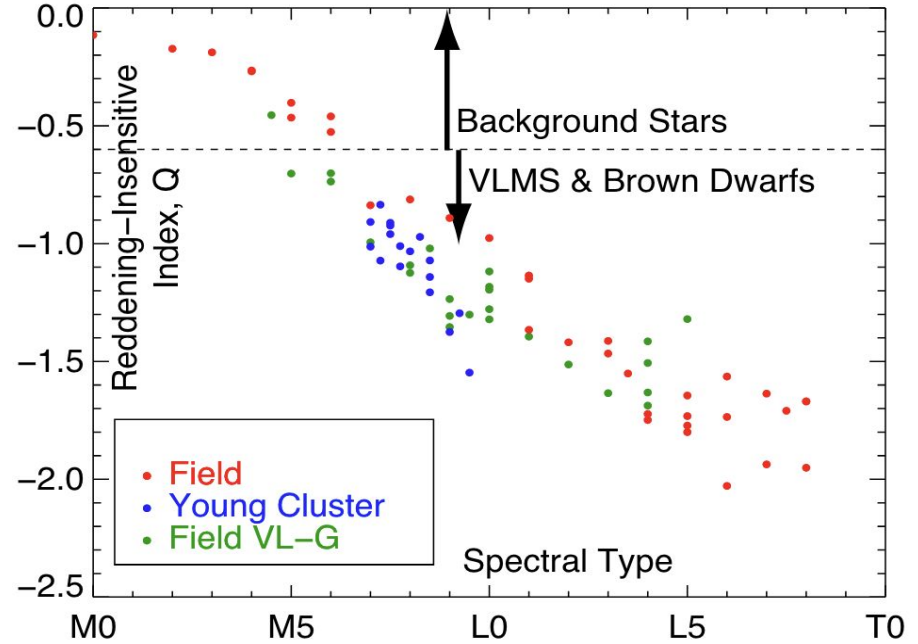
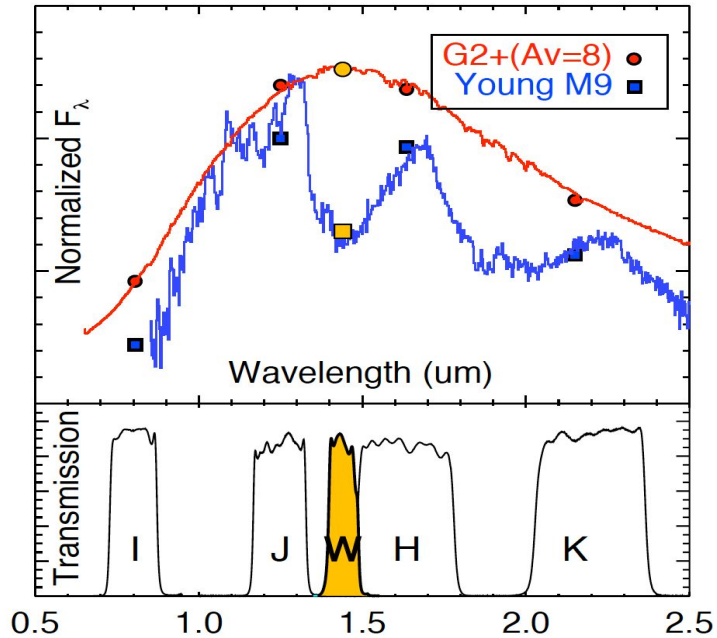


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Brown dwarfs - water band technique



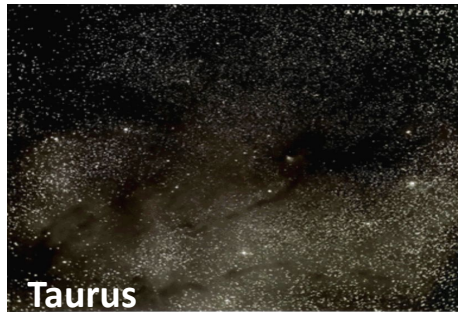
$$Q = (J-W) + e (H-W)$$

Images from Allers et al. (2013)
and Allers & Liu (2020)



W-band survey of nearby star forming regions with CFHT

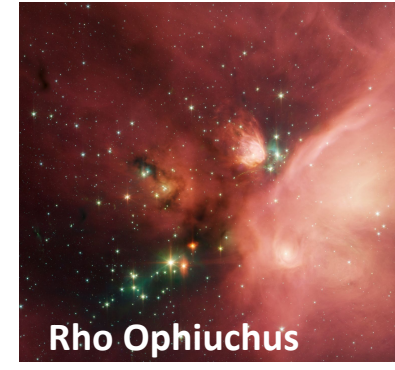
Largest and deepest survey of star forming regions in the solar neighborhood within 500pc in search of young planetary mass objects with sensitivity down to $\sim 3 M_{\text{Jup}}$



- Allers & Liu 2020
- Jose. J et al. 2021
- Dubber. S et al. 2021
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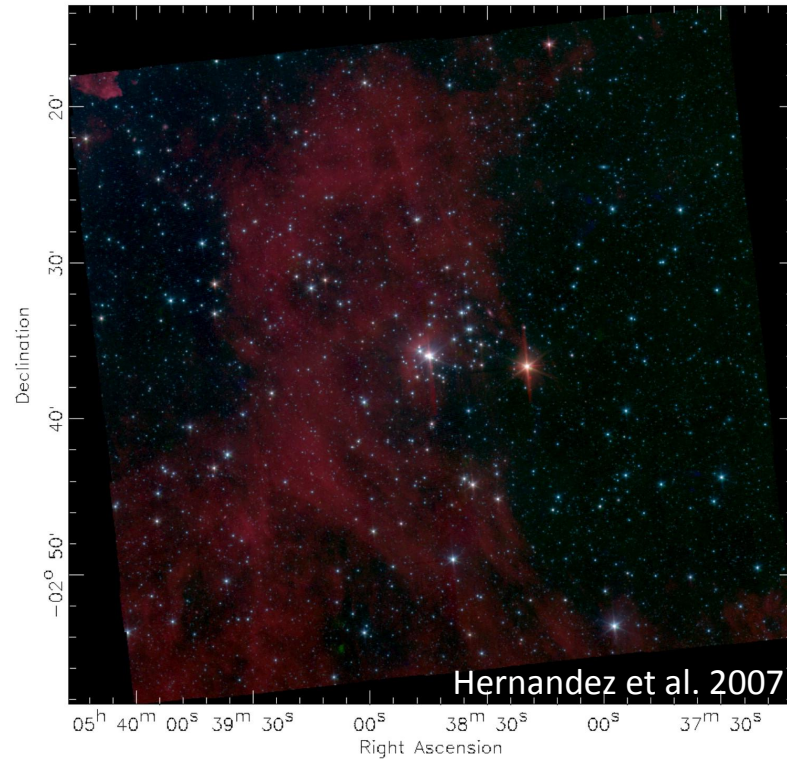
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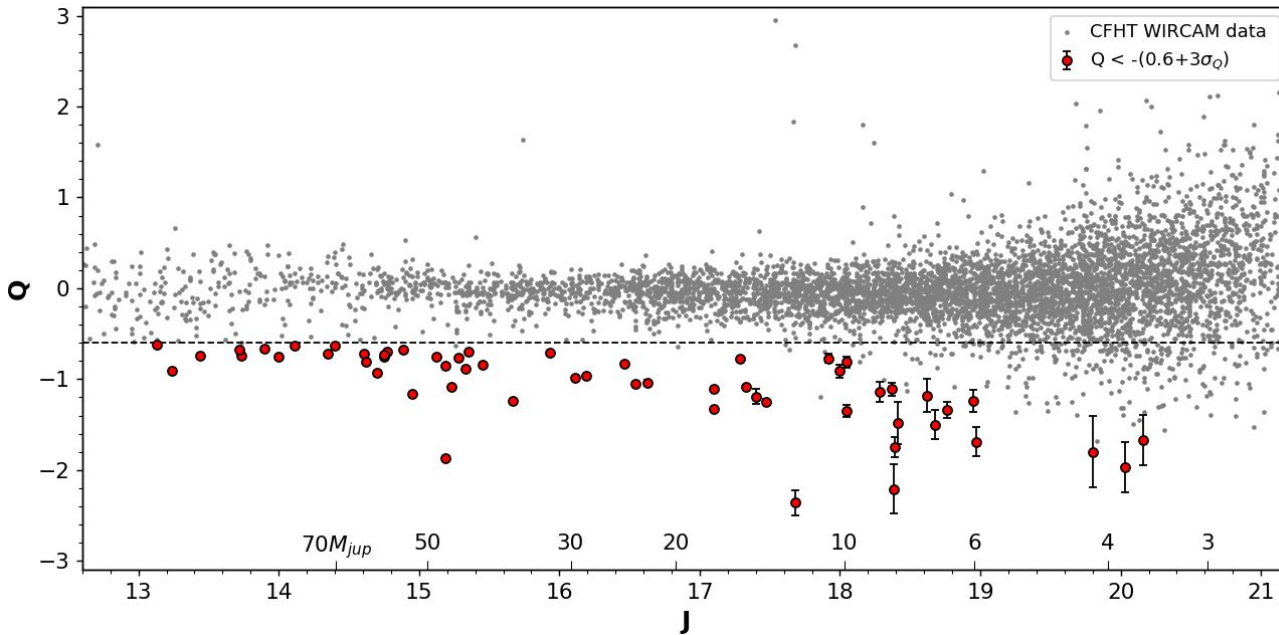
Identifying the low-mass objects in σ Orionis cluster with W-band

- Located in the Ori OB1b association
- Age : **~ 3 Myr**
- Distance : **~ 400 pc**
- Extinction : $E(B-V) \sim 0.05$ mag; **$A_V < 0.2$ mag**
- Ideal target to study low-mass stars and planetary objects



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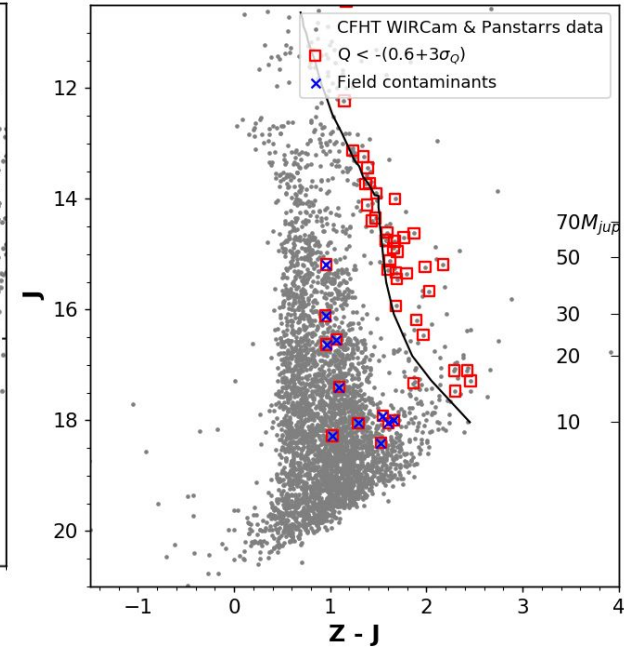
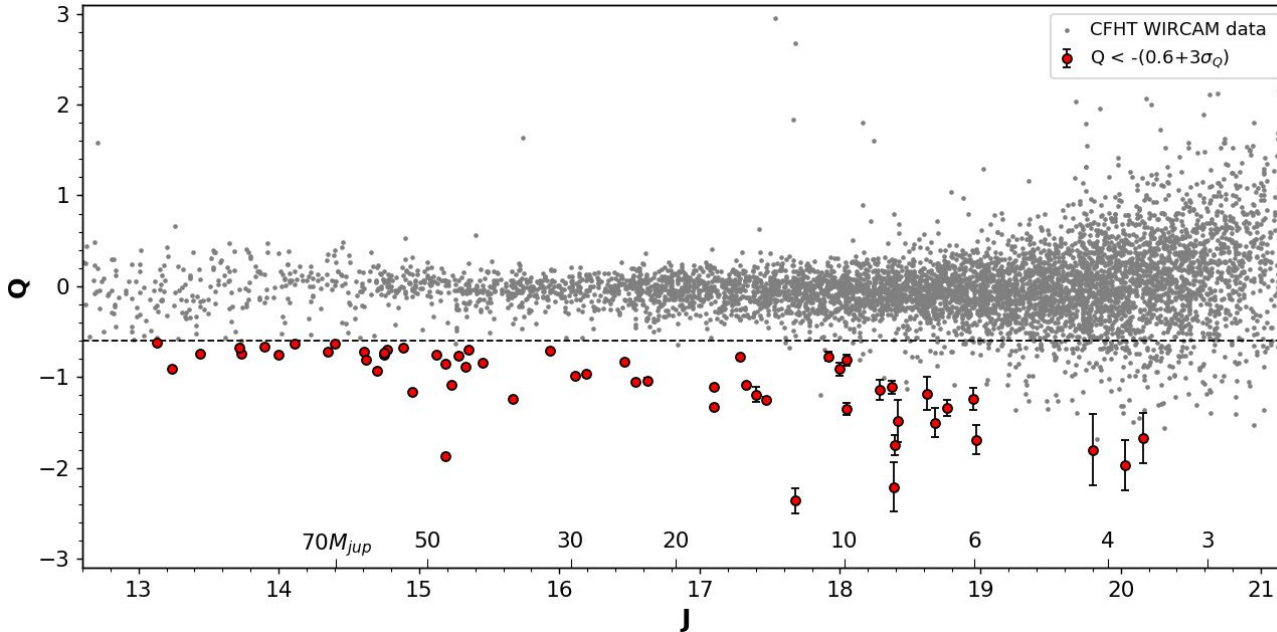
Low-mass candidate selection : $Q < -(0.6 + 3 Q_{err})$



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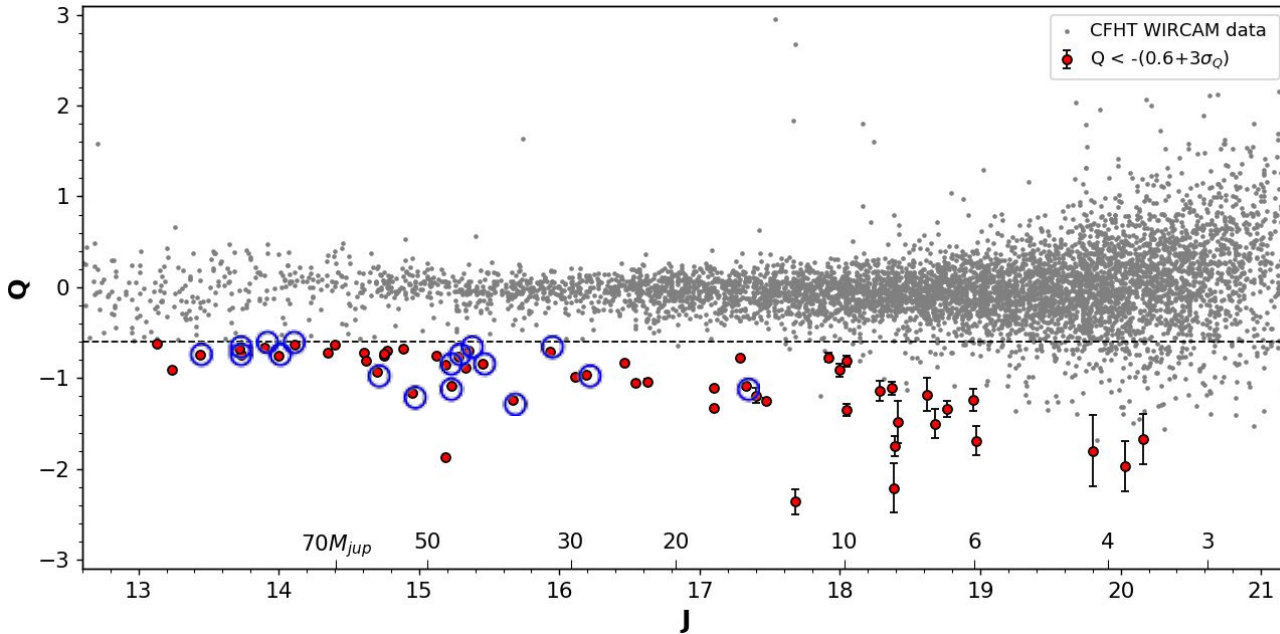
Low-mass candidate selection : $Q < -(0.6 + 3 Q_{err})$ \longrightarrow location in **optical, NIR**
CMD and Gaia eDR3 astrometry consistent with the cluster



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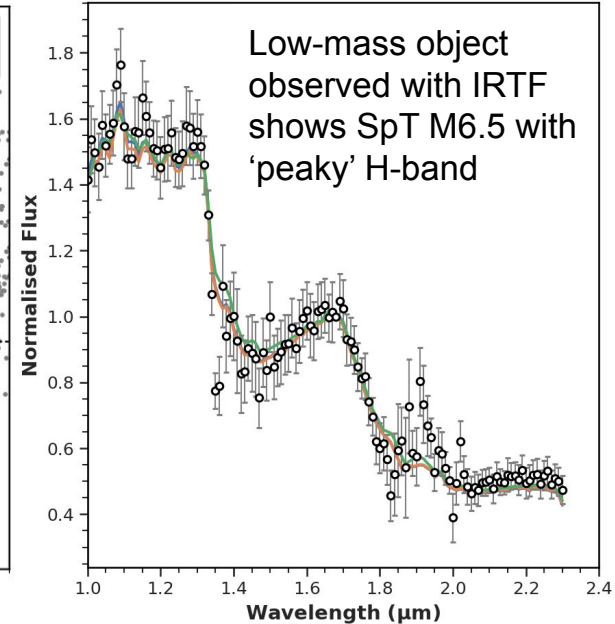
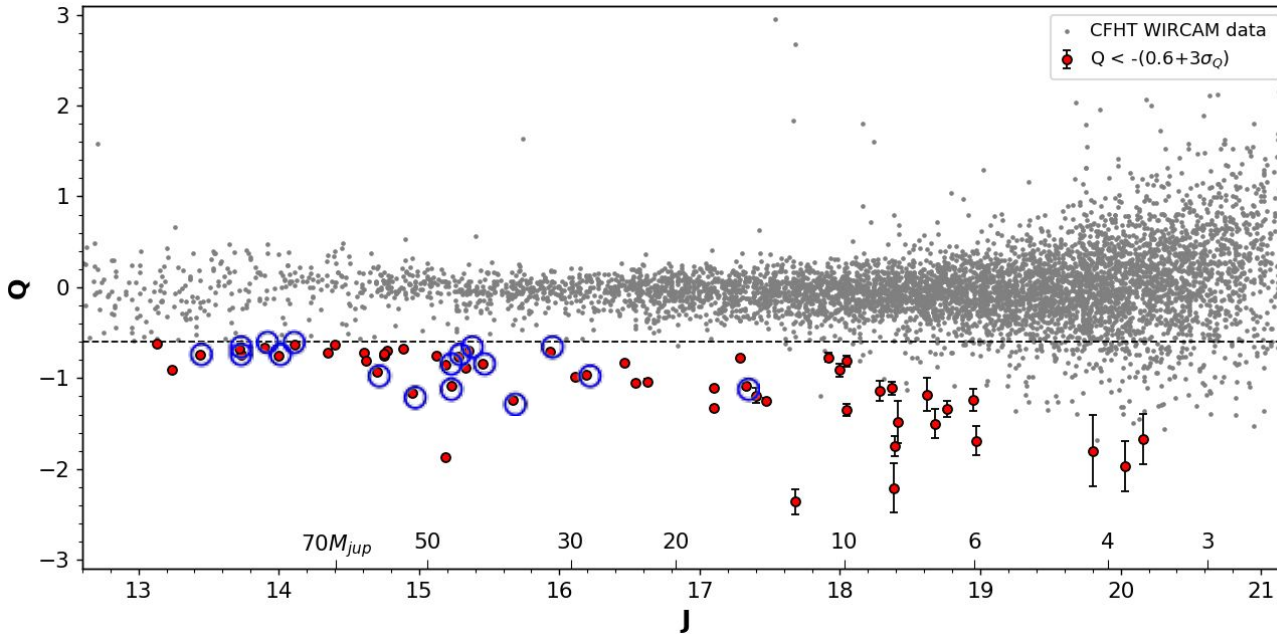
Spectroscopic follow-up with the **3.2m NASA IRTF - SpeX**



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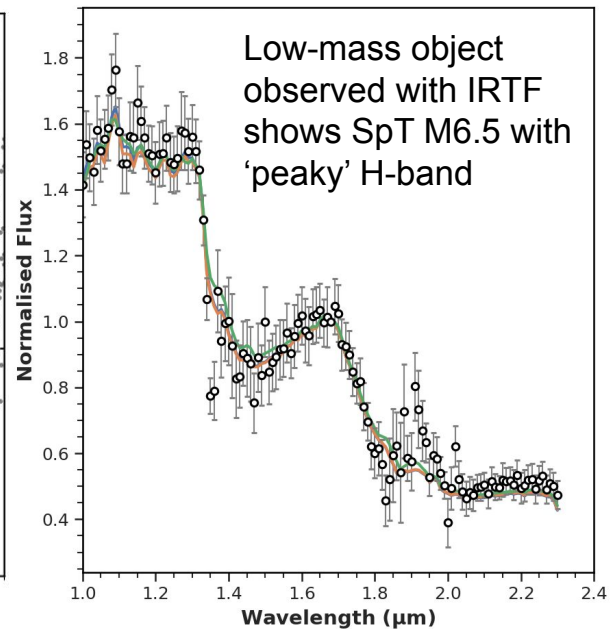
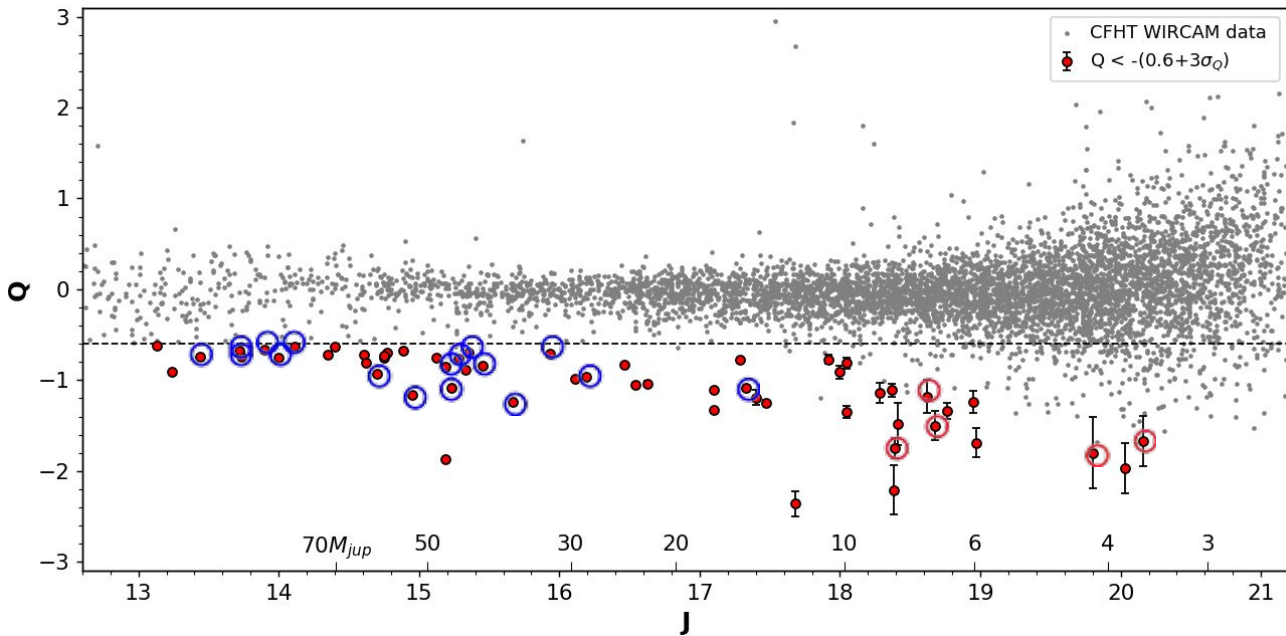
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5 newly proposed planetary mass candidates ($J > 18\text{mag}$).

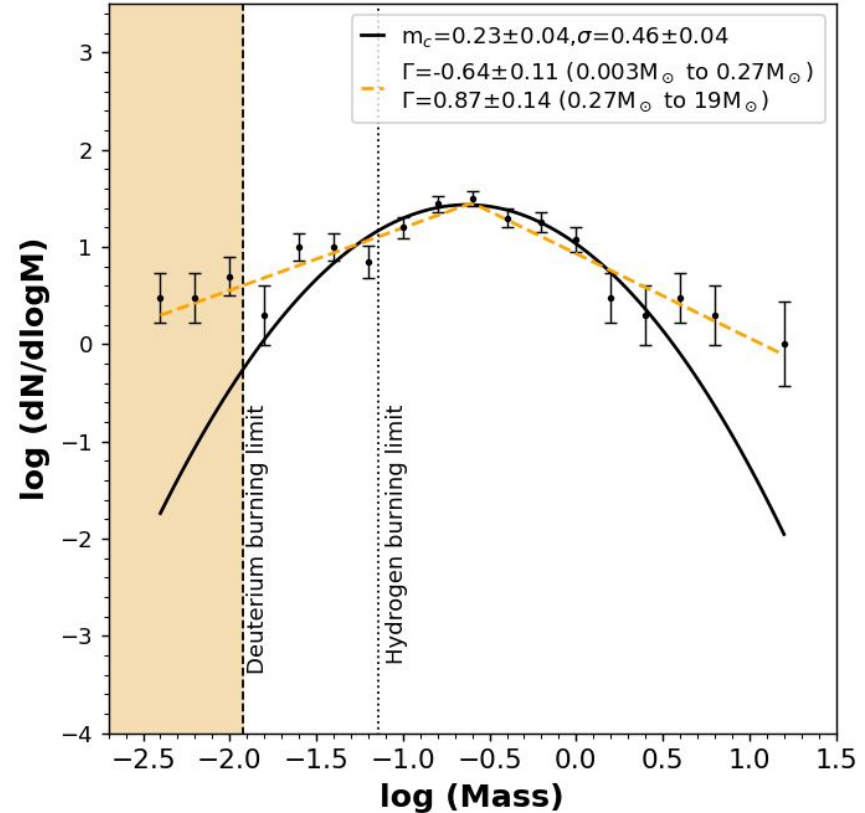


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Results

- IMF of σ Ori for wide mass range (19-0.003 M_{\odot})
- Power-law fit better describes the sub-stellar IMF than log-normal fit.
- Results agree with previous studies on other nearby young star forming regions (Suarez et al. 2019, Muzic et al. 2019).
- Comparison to diverse stellar clusters, shows that the shape of the IMF is largely insensitive to environmental properties.



Conclusions

- ★ *Brown dwarfs are analogues to exoplanets and are crucial in understanding the sub-stellar IMF and the environmental effects on the low-mass star formation.*
- ★ *W-band photometry is a novel technique which can be efficiently used to photometrically identify the low-mass sub-stellar objects.*
- ★ *For the nearby young σ Ori star forming region, the candidate low-mass objects identified with the W-band technique are *all confirmed to be young brown dwarfs.**
- ★ *The IMF probes down to the planetary mass regime and the segmented power-law fit to the IMF is consistent with other nearby regions.*
- ★ ***Future prospects*** - Companion search for these cool objects with high resolution imaging; test the environmental dependence on their formation with other galaxy regions; explore the disk properties around these low-mass objects.



A vibrant, multi-colored nebula in space, featuring swirling clouds of red, orange, and blue gas. Numerous bright stars are scattered throughout the scene, some appearing as sharp points of light and others as larger, glowing spheres. The overall atmosphere is ethereal and awe-inspiring.

THANK YOU!