JWST unveils the brown dwarf population of the most extreme star clusters of the Milky Way: Westerlund 1 and 2

Víctor Almendros-Abad

with the EWOCS team: M. Guarcello, K. Muzic, M. Andersen, A. Bayo, M. Gennaro, A. Ginsburg, E. Moraux, M. Robberto, T. Rom, E. Sabbi, A. Scholz, P. Zeidler et al.

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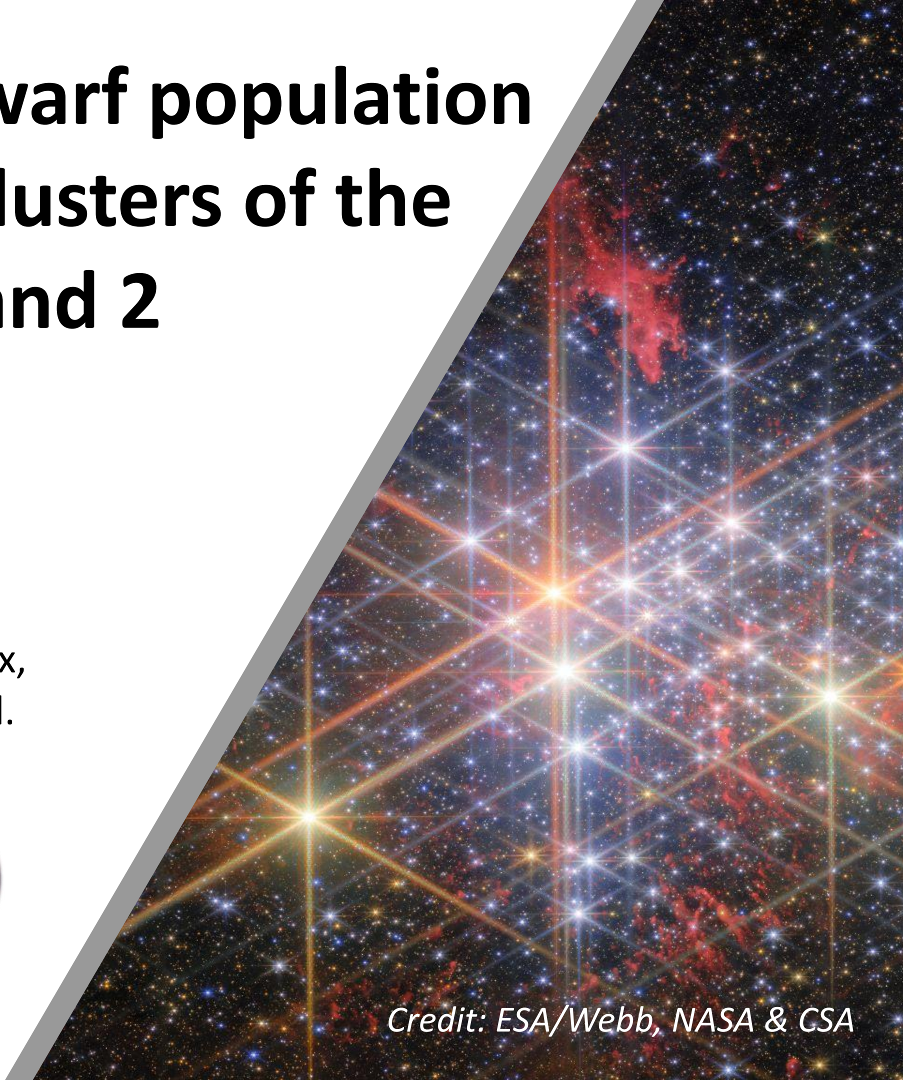
SPECULA PANORMITANA HINC ITUR AD ASTRA MDCCXC

E.W.O.C.S.

BDs 30versary: *02/09/2025*



Credit: ESA/Webb, NASA & CSA

Brown dwarfs

Formation

(1) As a star *(Padoan & Nordlund 2004, Hennebelle & Chabrier 2009)*

(2) As a planet *(Stamatellos et al. 2007, Goodwin et al. 2004)*

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→ High gas and stellar densities as well as presence of OB stars may stimulate BD formation!
(*Bonnell et al. 2008, Jones & Bate 2018, Whitworth & Zinnecker 2004*)

Formation

Brown dwarfs

Does the formation efficiency of BDs change with the environment?

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(2) As a planet *(Stamatellos et al. 2007, ... 2004)*

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Is the IMF universal?

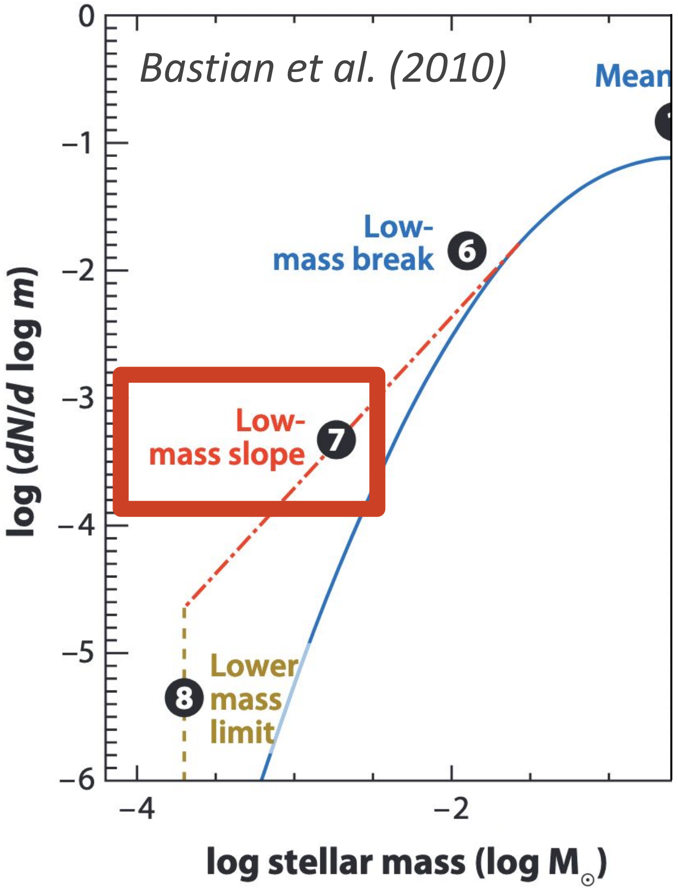
→ High gas and stellar densities as well as presence of OB stars may stimulate BD formation!

(*Bonnell et al. 2008, Jones & Bate 2018, Whitworth & Zinnecker 2004*)

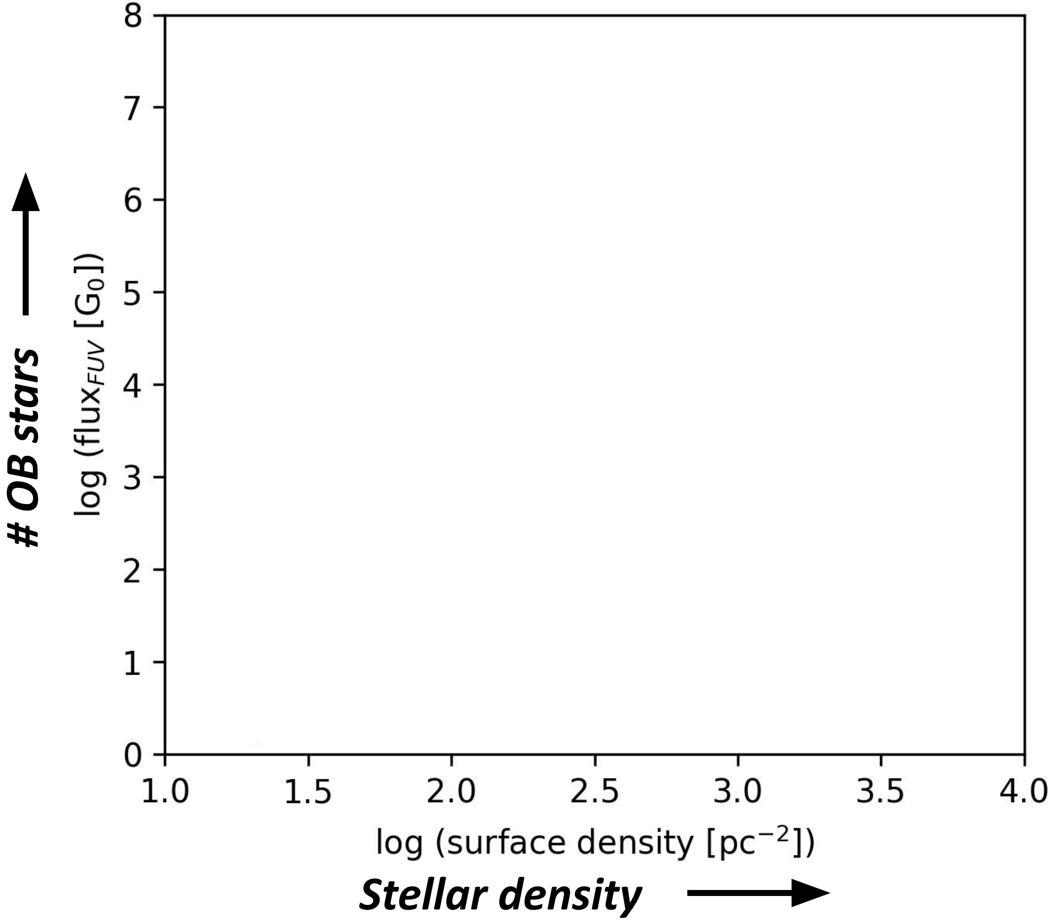
Initial mass function

- **Low-mass IMF parametrized by power-law of slope α:** $dN/dM \propto M^{-\alpha}$**,**

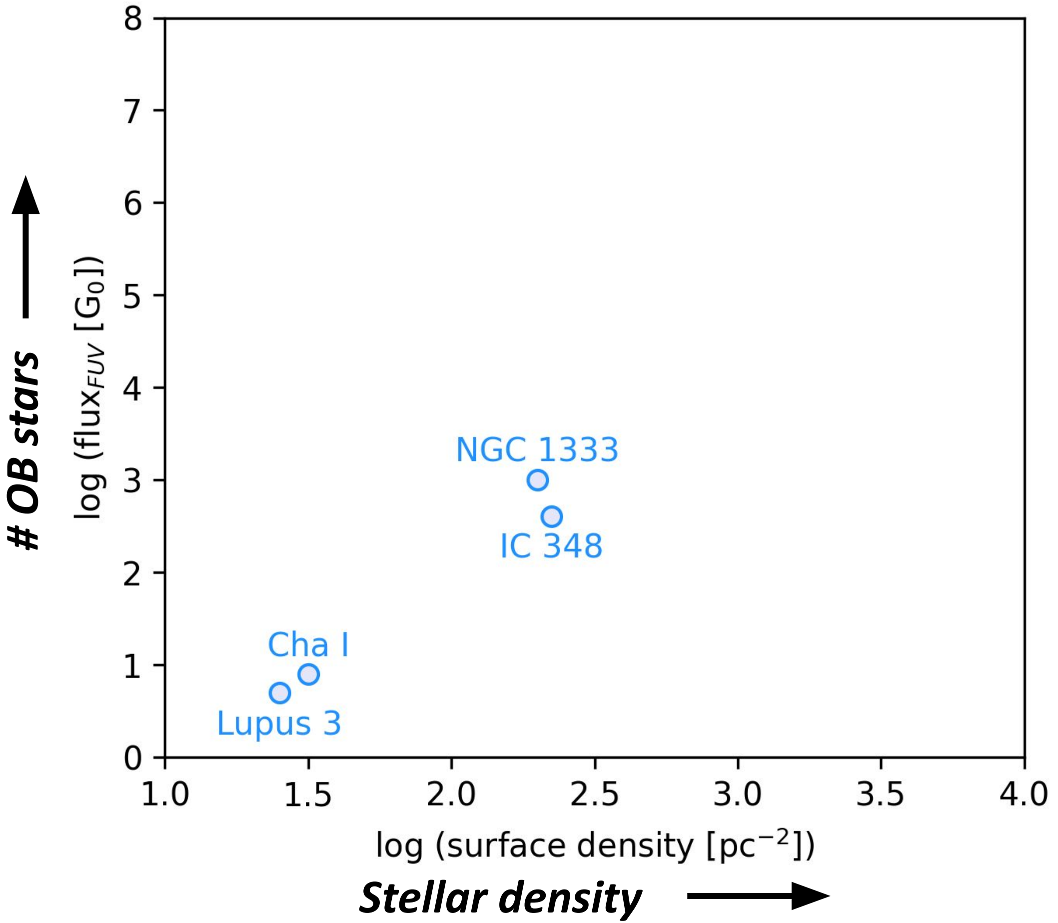
  ↑ α → more BDs



Effect of the environment on the IMF



Effect of the environment on the IMF - Nearby young clusters



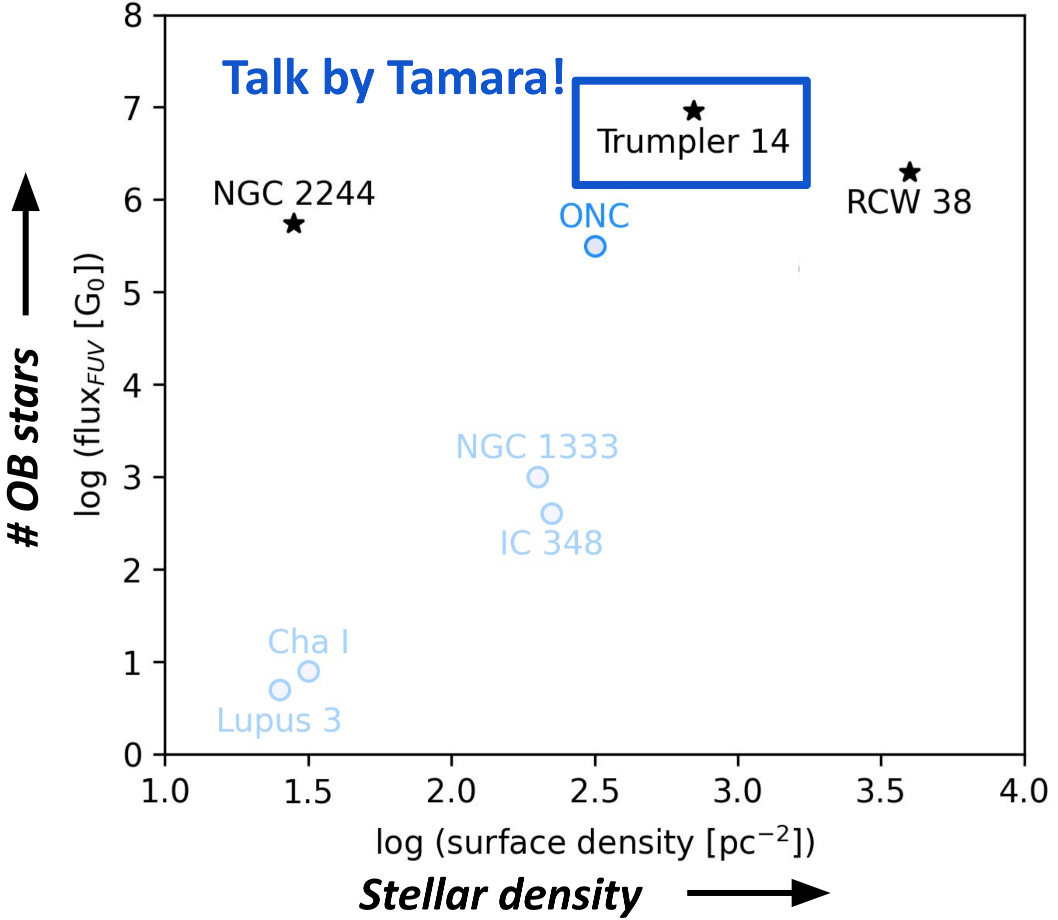
No significant IMF variations

(Muzic+15, Suarez+19, Bayo+11, …)

→ **High-mass BDs must form like stars** *(e.g. Luhman 2012)*

But these are "soft" and "uncommon" environments …

Effect of the environment on the IMF - Massive young clusters @<2 Kpc



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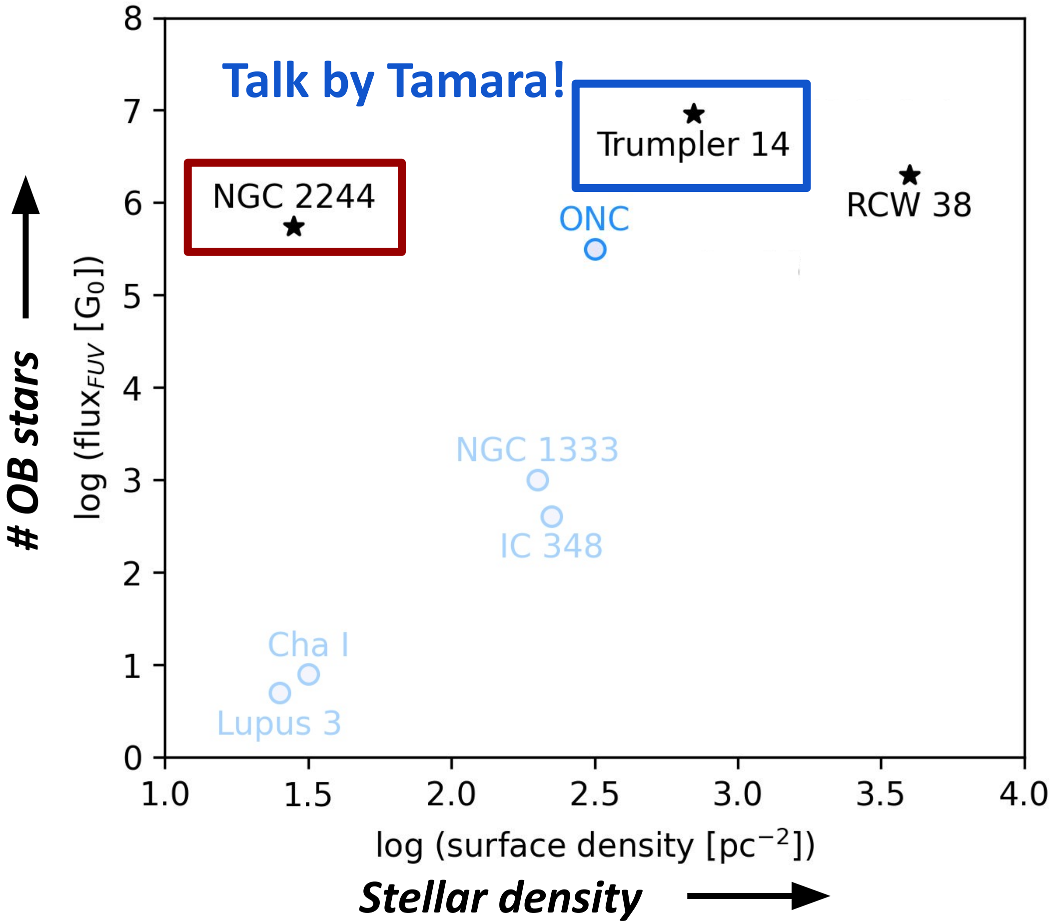
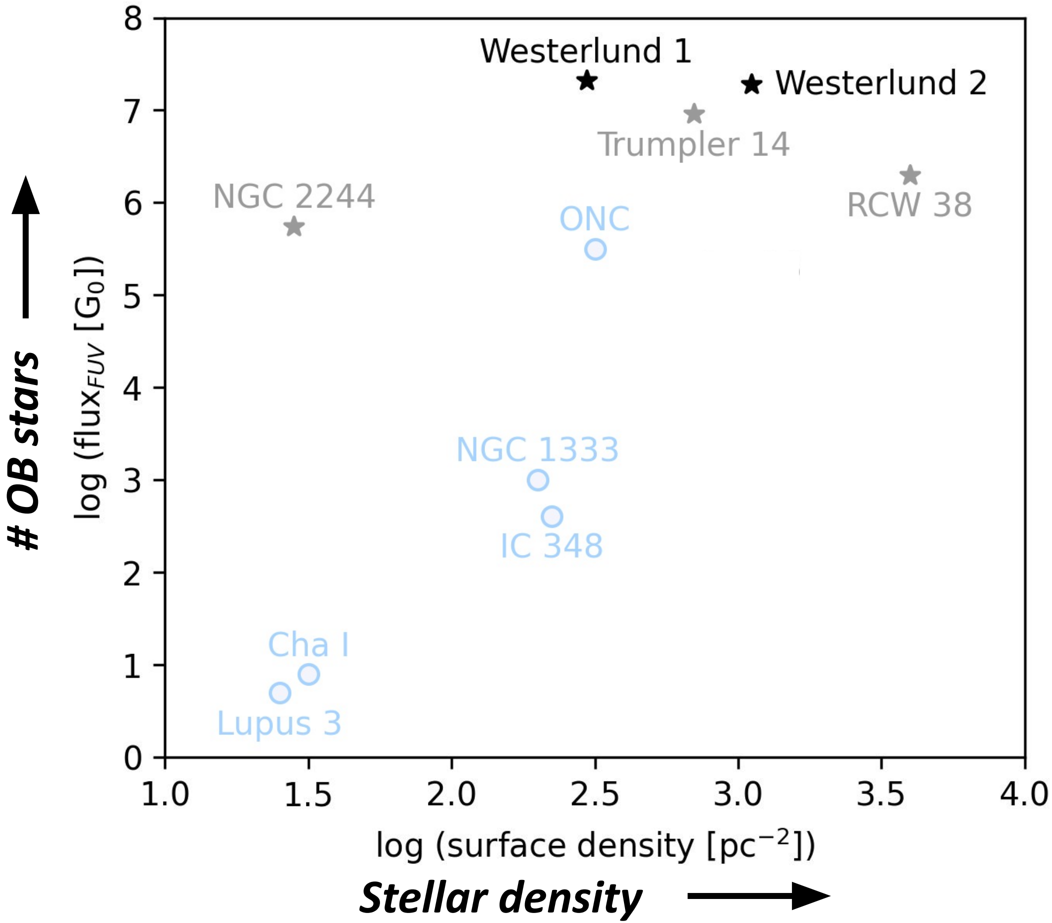


→ NGC 2244 hosts one of the richest BD known populations, α ~ 1 *(Muzic et al. 2019)* and **BDs are preferentially located closer to massive stars!**

(Almendros-Abad+2023)

Effect of the environment on the IMF - Supermassive star clusters



PI: M. Guarcello (INAF, Palermo)

This talk!

Westerlund 1

Age: 5 Myr *(Clark+05, Ritchie+10, …)*
Distance: 4.2 kpc *(Negueruela+22)*
Av~10 mag *(Damineli+16, Andersen+17)*
Total mass: 52,000 Msun *(Brandner+08)*

Age: 1-2 Myr *(Vargas+13, Zeidler+15, …)*
Distance: 4.5 kpc *(Maiz-Apellaniz+21)*
Av~6.5 mag *(Vargas+13)*
Total mass: 37,000 Msun *(Zeidler+17)*

Westerlund 2

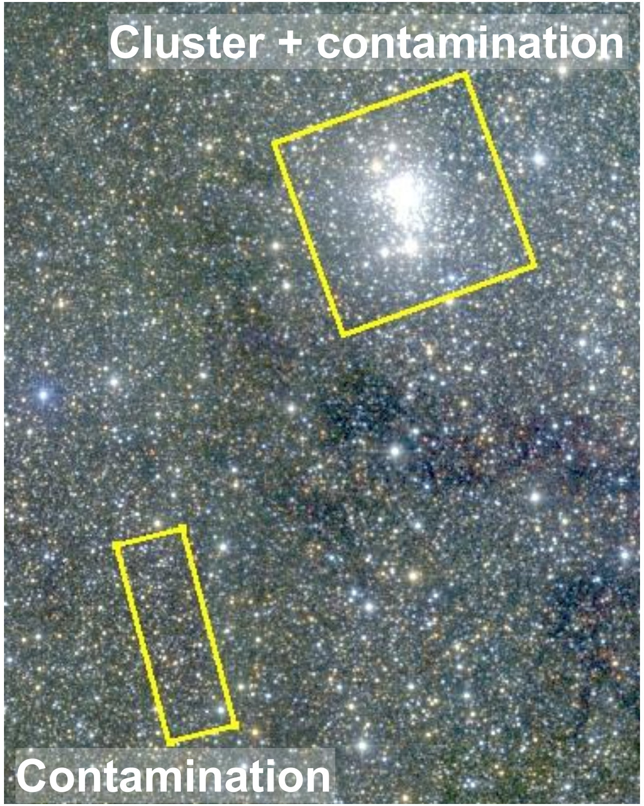
Initial Mass Function of Westerlund 1

Westerlund 1 with JWST (ID 1905, PI: M. Guarcello)

→ **NIRCam observations covering a ~6x6' FoV**

→ **NIRCam imaging of control field to study the Initial Mass function**

→ **Data reduction and initial results**
(Guarcello et al. 2025)




Credit: ESA/Webb,
NASA & CSA

Low-mass IMF of Westerlund 1

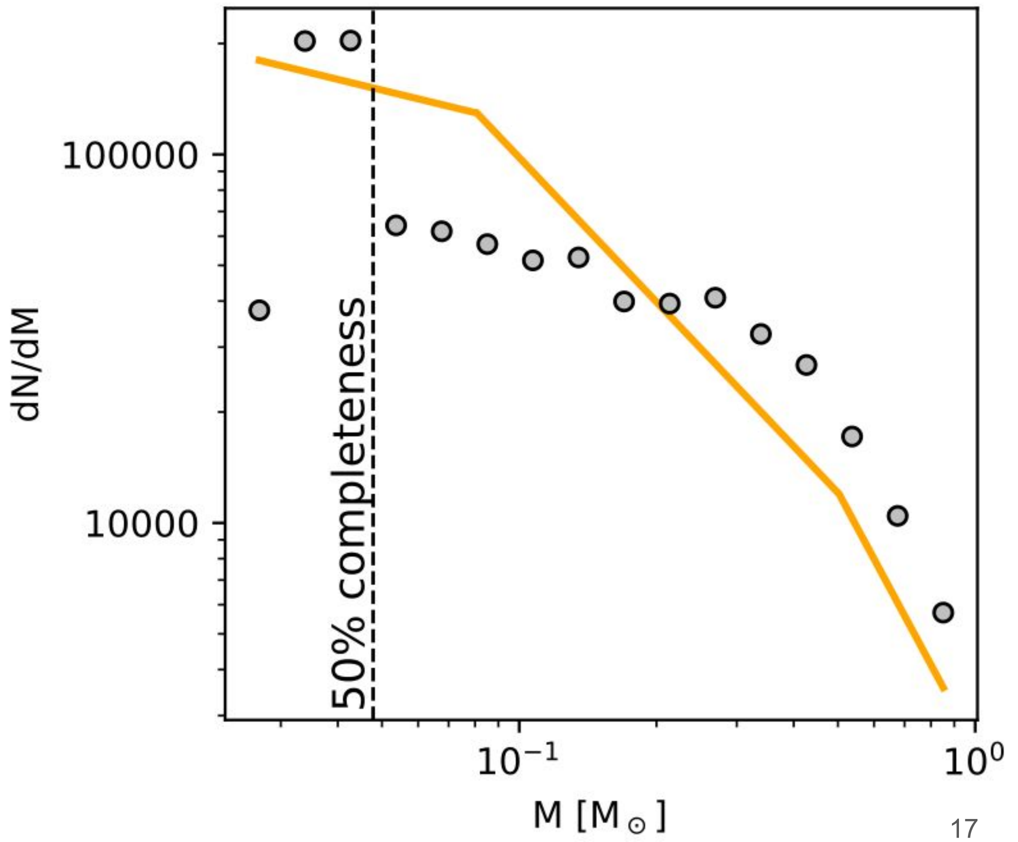
Almendros-Abad et al. in prep.

Power-law IMF: $dN/dM \propto M^{-\alpha}$

↑ **α ➞ more BDs**

Nearby SFRs → α = [0.4-1]

Initial Mass Function



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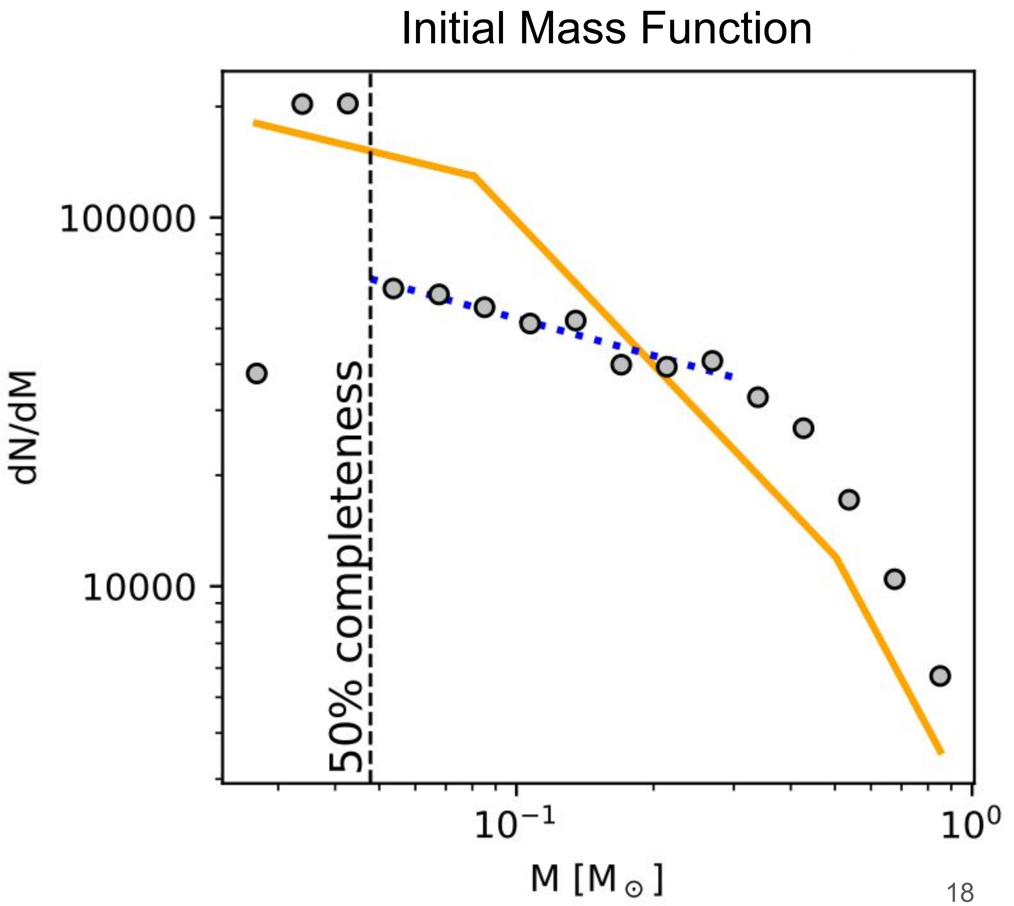
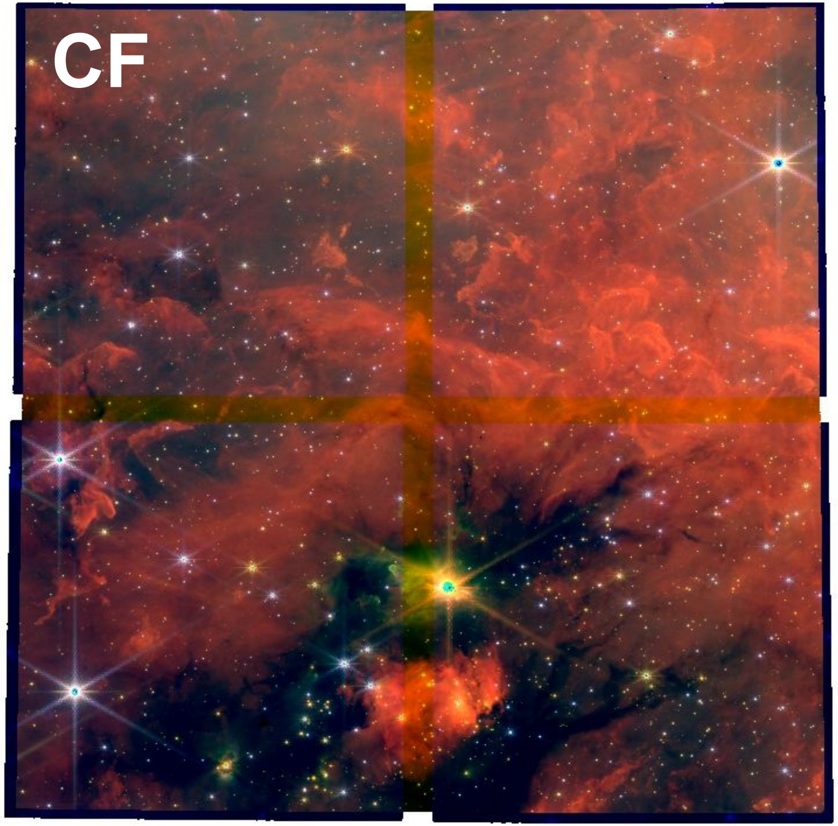
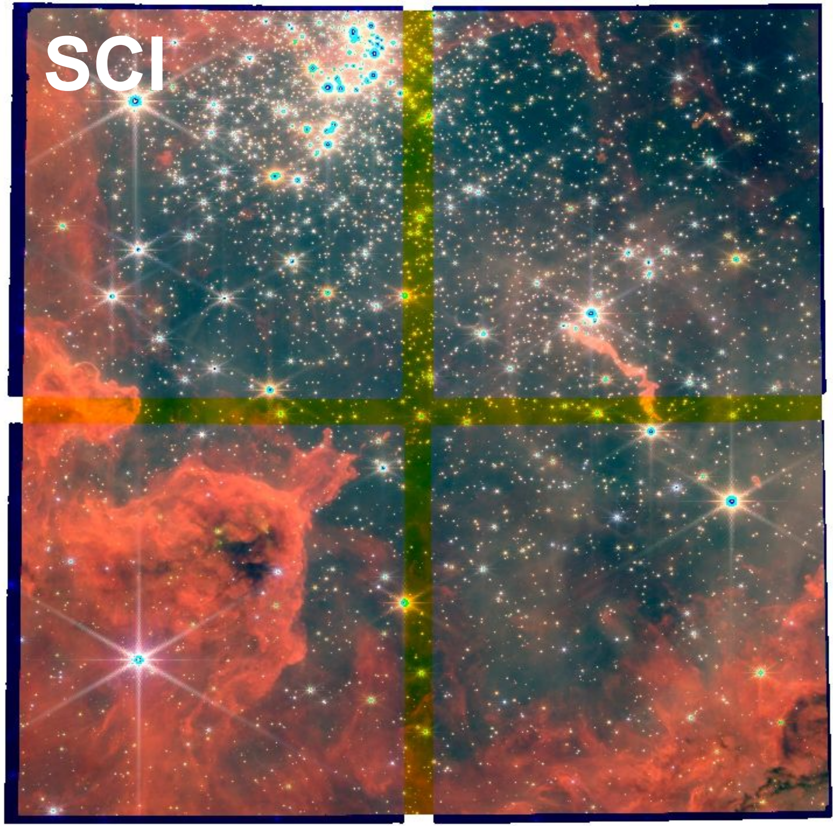
- **Wd1 → α = 0.34±0.05**



Initial Mass Function of Westerlund 2

Westerlund 2 with JWST (ID 3523, PI: M. Guarcello)





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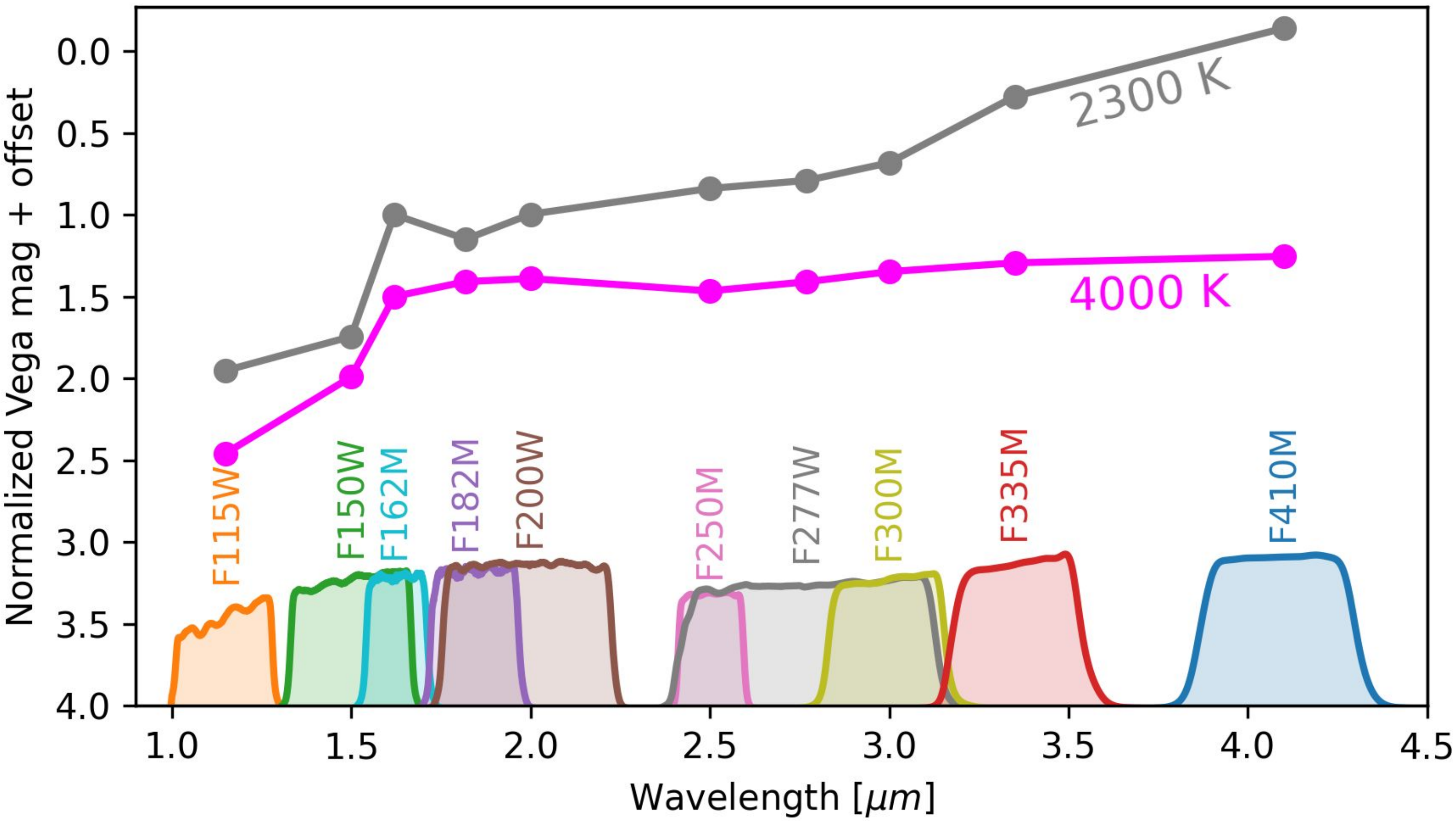


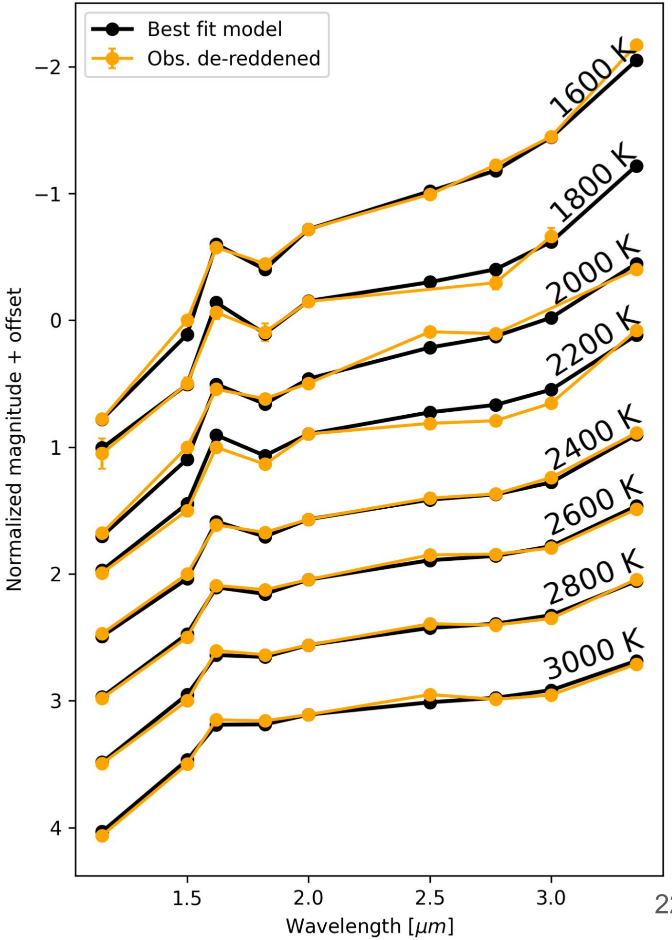
Substellar candidates of Wd2

Almendros-Abad et al. submitted

→ SED fitting with BT-Settl models

- If Teff ≲ 3000 K ⇒ BD candidate
- Visual inspection of best fits

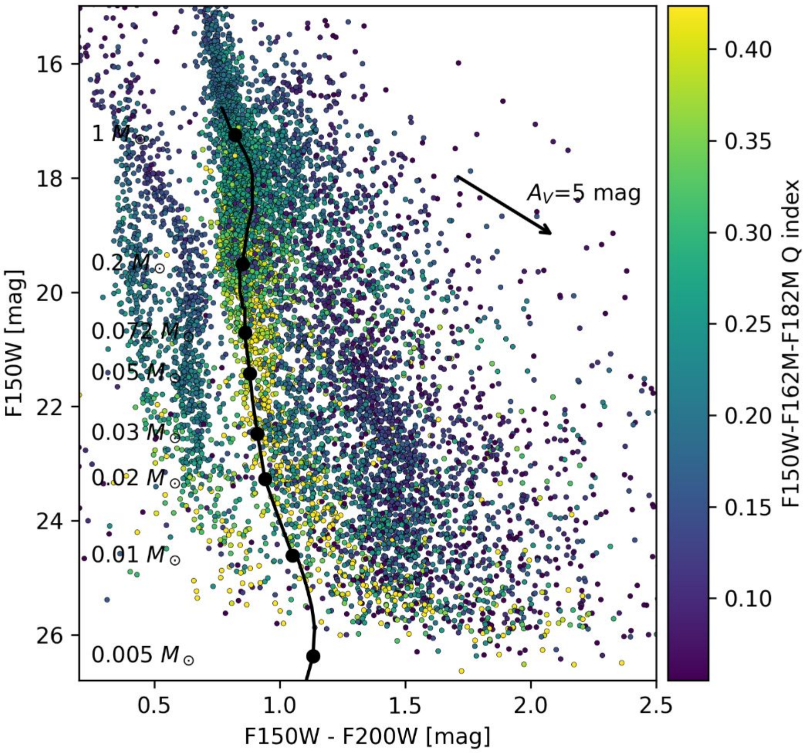
→ Identification of 207 BD candidates



Substellar candidates of Wd2

Almendros-Abad et al. submitted

$$Q = m_1 - m_2 + e \times (m_3 - m_2)$$



→ **Reddening-free Q indices using 3 filters containing: F150W, F162M, F182M, F200W**

→ **Identification of 294 BD candidates**

→ **Recover >97% of SED fitting candidates**

Low-mass IMF of Westerlund 2

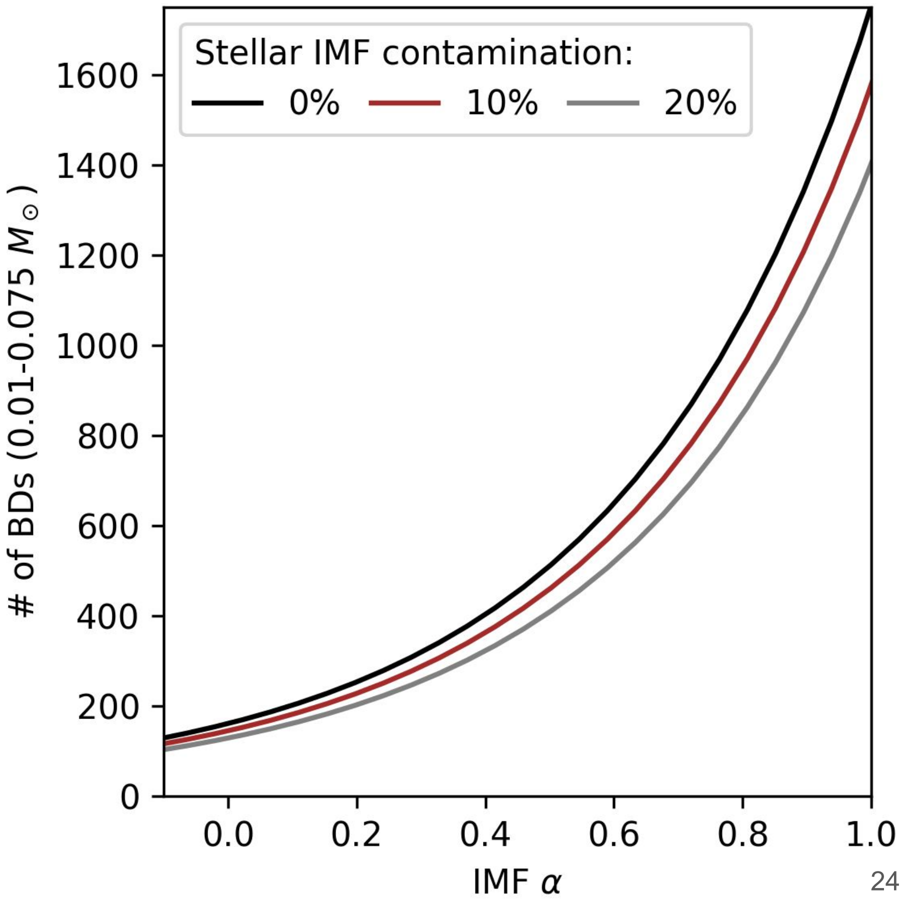
Almendros-Abad et al. submitted

Power-law IMF: $dN/dM \propto M^{-\alpha}$

↑ **α ➞ more BDs**

Nearby SFRs → α = [0.4-1]

- **Wd1 → α = 0.34±0.05**



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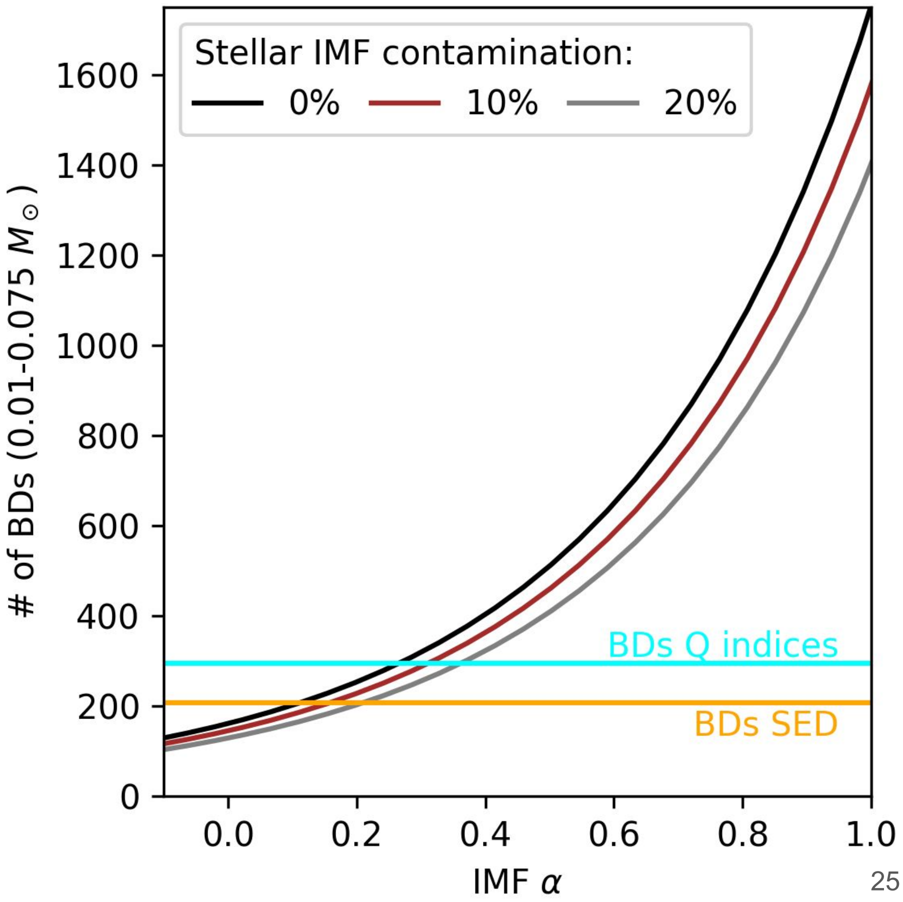
Power-law IMF: $dN/dM \propto M^{-\alpha}$

↑ α ➞ more BDs

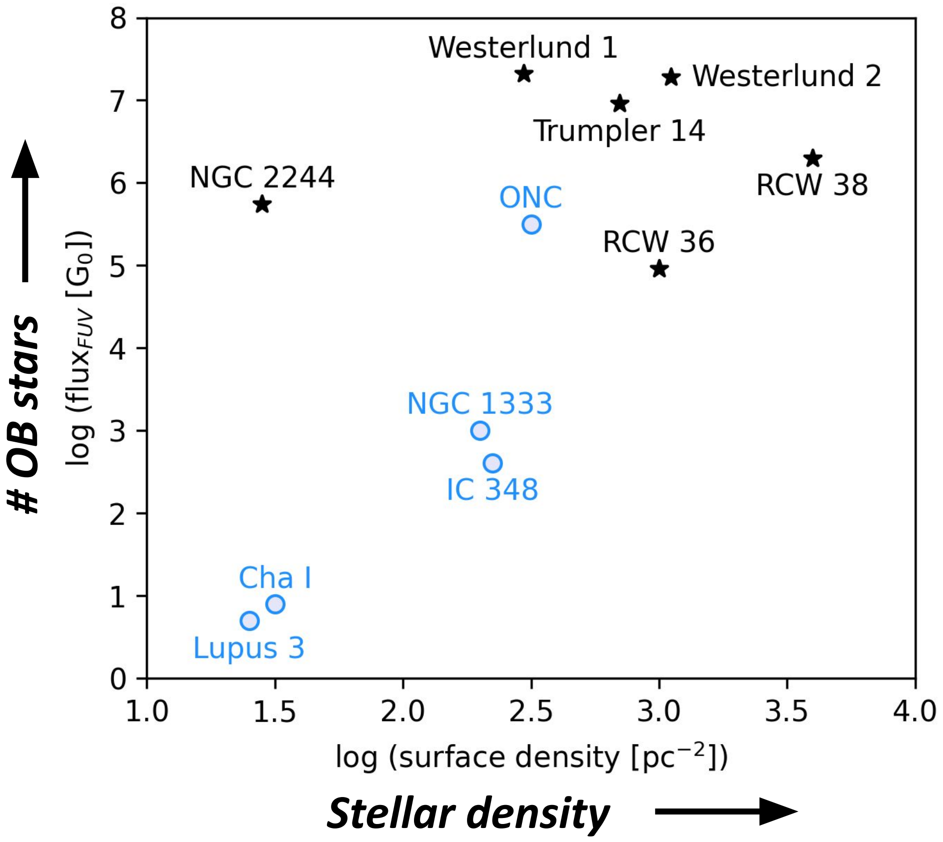
Nearby SFRs ⟶ α = [0.4-1]

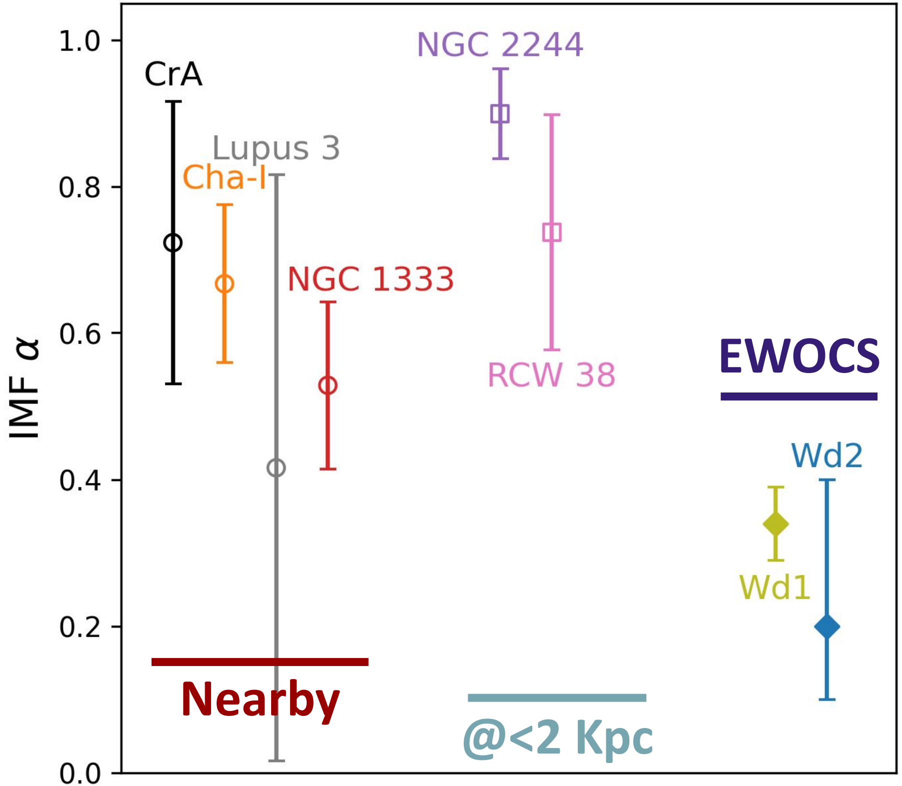
- **Wd1 ⟶ α = 0.34±0.05**
- **Wd2 ⟶ α = [0.1-0.4]**



Effect of the environment on the low-mass IMF

Adapted from Muzic et al. accepted





Conclusions

→ Deep JWST MIRI & NIRCam observations of Westerlund 1 and 2 (EWOCS project)

→ **Wd1 substellar IMF α=0.34±0.05**

→ **Wd2 substellar IMF α=[0.1-0.4]**

→ **Both Wd1 and Wd2 have similarly shallow IMFs!** Wait for Tamara's talk!

→ And stay tuned for more EWOCS results!

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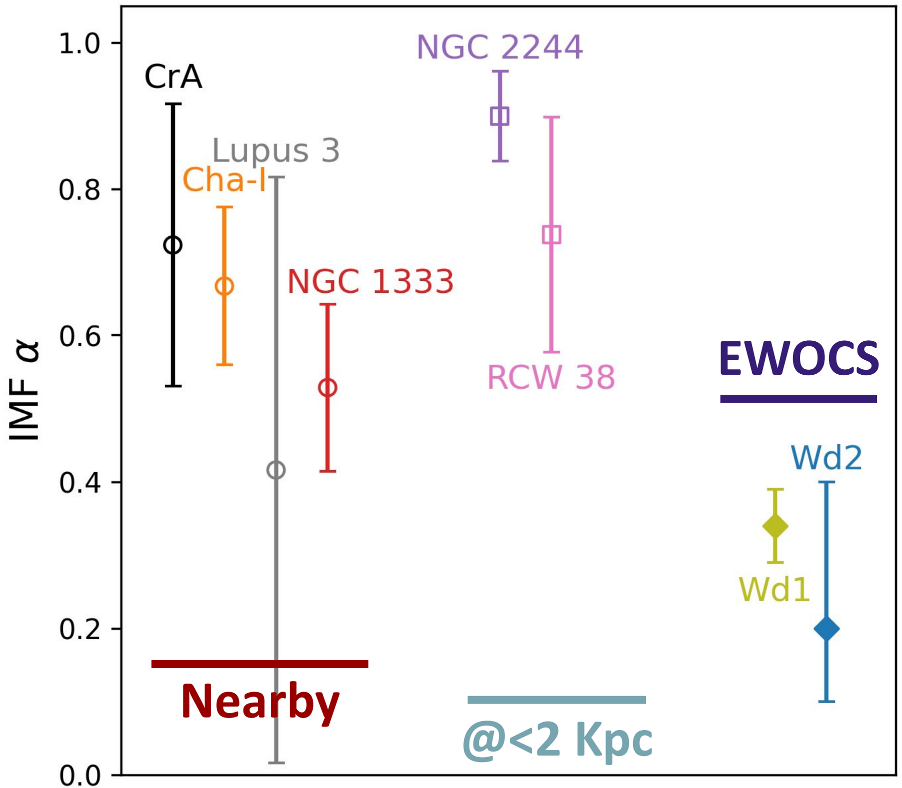

victor.almendrosabad@inaf.it