Beyond the Solar neighborhood.

The SHARP view of very massive young stellar clusters

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STAR FORMATION AROUND THE SUN

Nearby (e.g. < 1 kpc) star forming regions are perfect laboratories to study the physics of star and planet formation, and the early evolution of stars, and their protoplanetary discs and planets

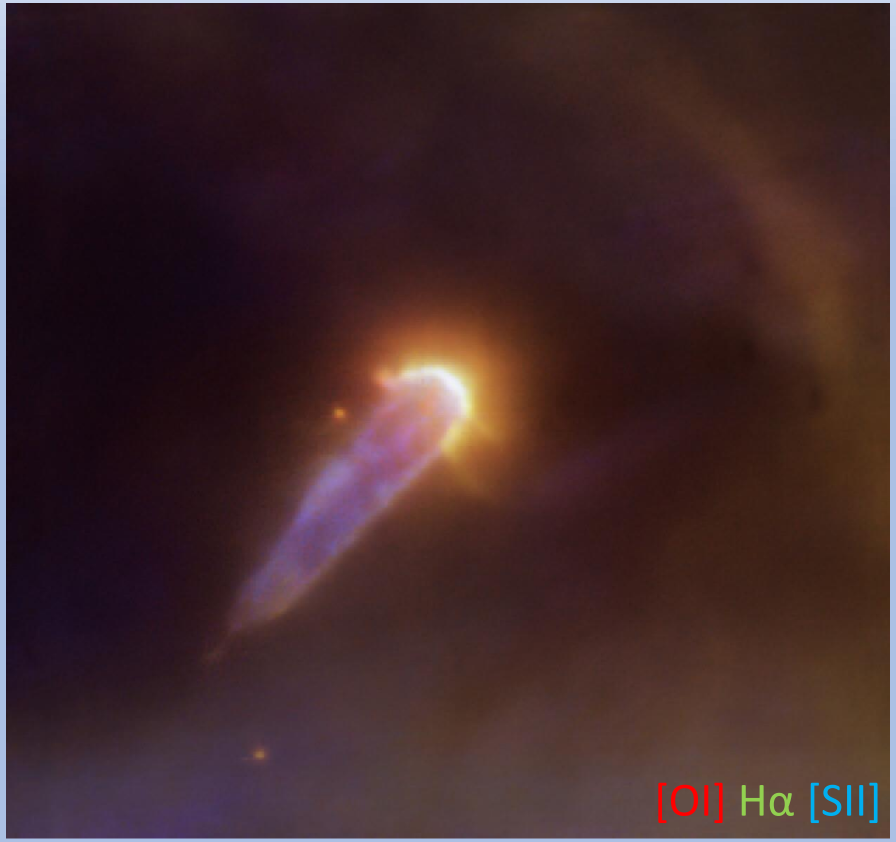
NGC2244

The Orion Nebula

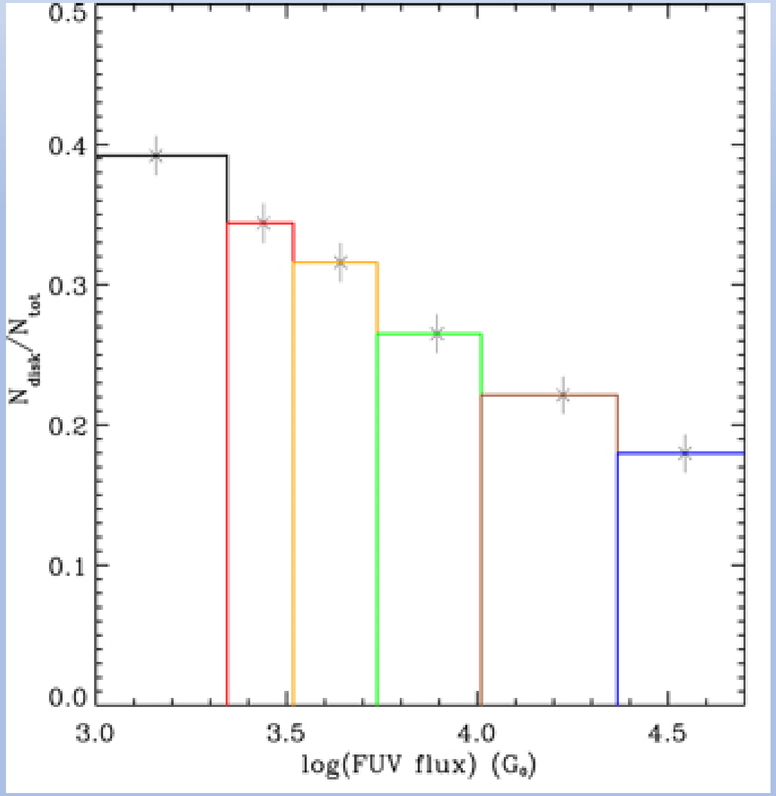
NGC2264

FEEDBACK FROM THE ENVIRONMENT

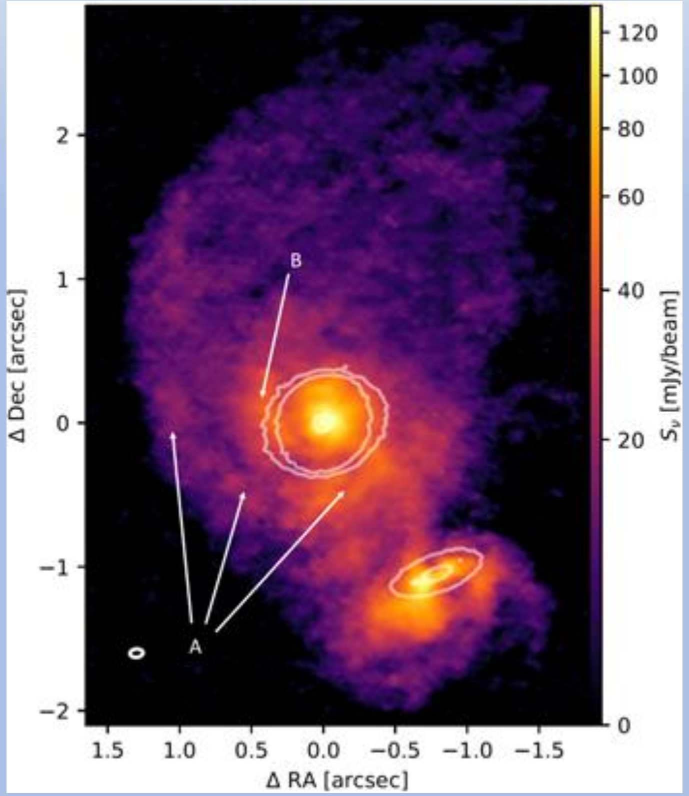
We also learn that the local environment is capable of affecting the evolution of protoplanetary discs and the early stellar evolution



An example of a protoplanetary disc evaporated by incident UV radiation. Single line MUSE images of proplyd 177–341W (Aru+2024)



Decline of the disc fraction as a function of the intensity of the local UV field, e.g. projected distance from massive stars (Guarcello+2023).



Discs in gravitationally interacting YSOs. Integrated CO emission map of the AS 205 system. (Kurtovic+2018)

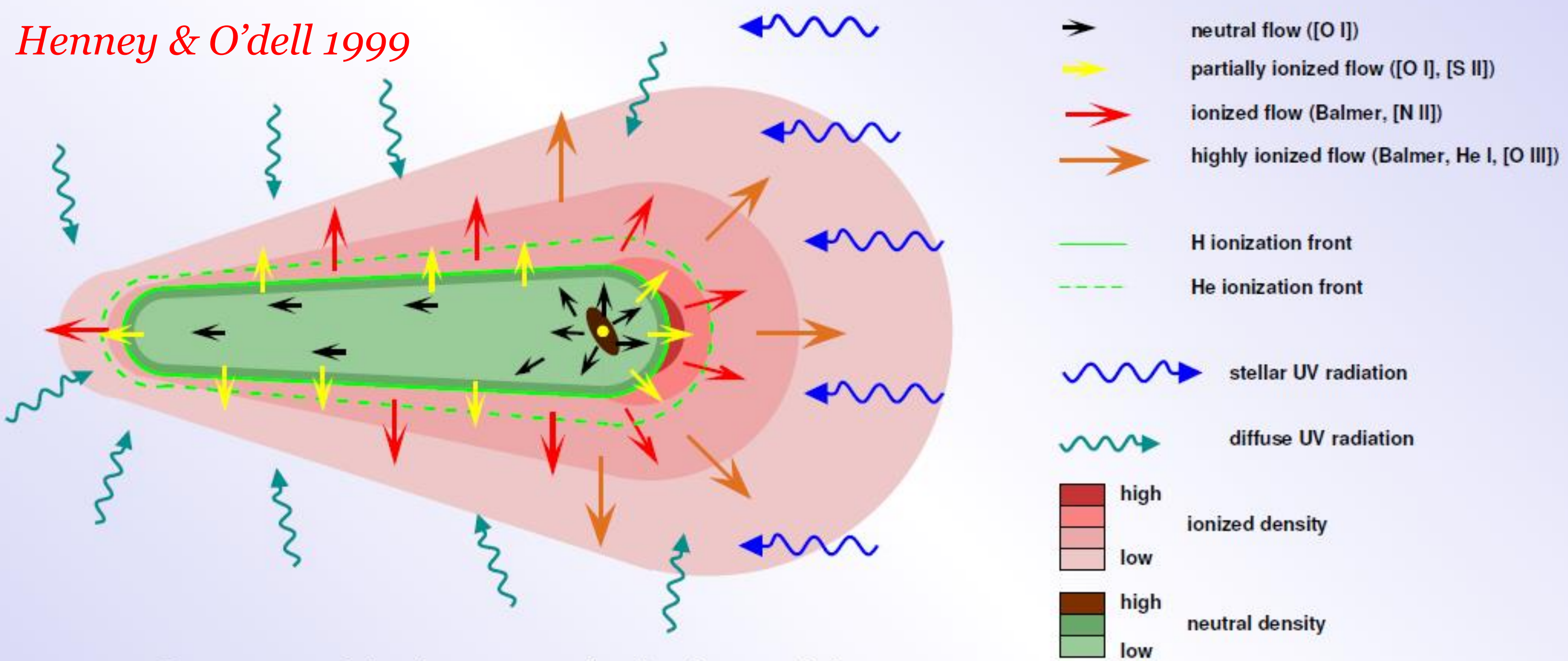
EXTERNAL PHOTOEVAPORATION

Incident UV radiation rises the temperature of discs up to few 1000 K.

This triggers a the formation of a photoevaporating wind of neutral gas.

Outflowing gas is then ionized by absorbing incident EUV radiation.

Henney & O'dell 1999



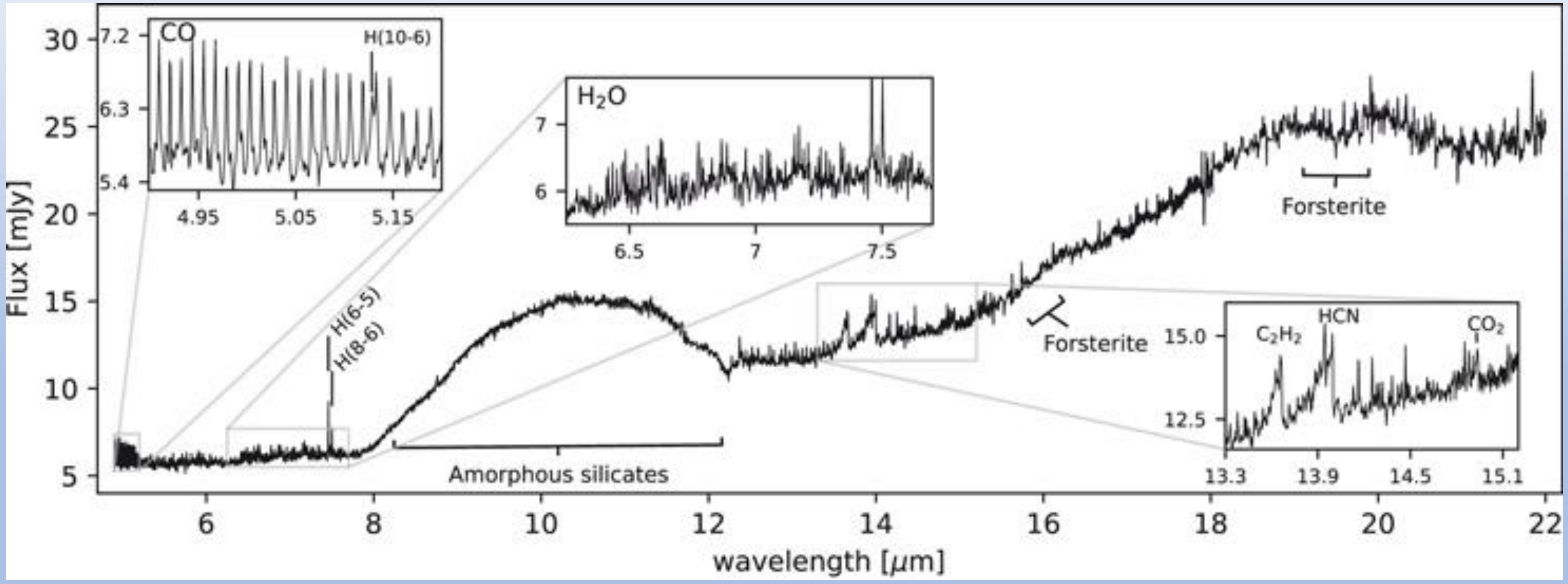
Components of the photoevaporating flow in a proplyd

The mass loss can be severe.

In the most extreme cases (e.g. nearby massive stars) discs can be dispersed in <1-2 Myrs

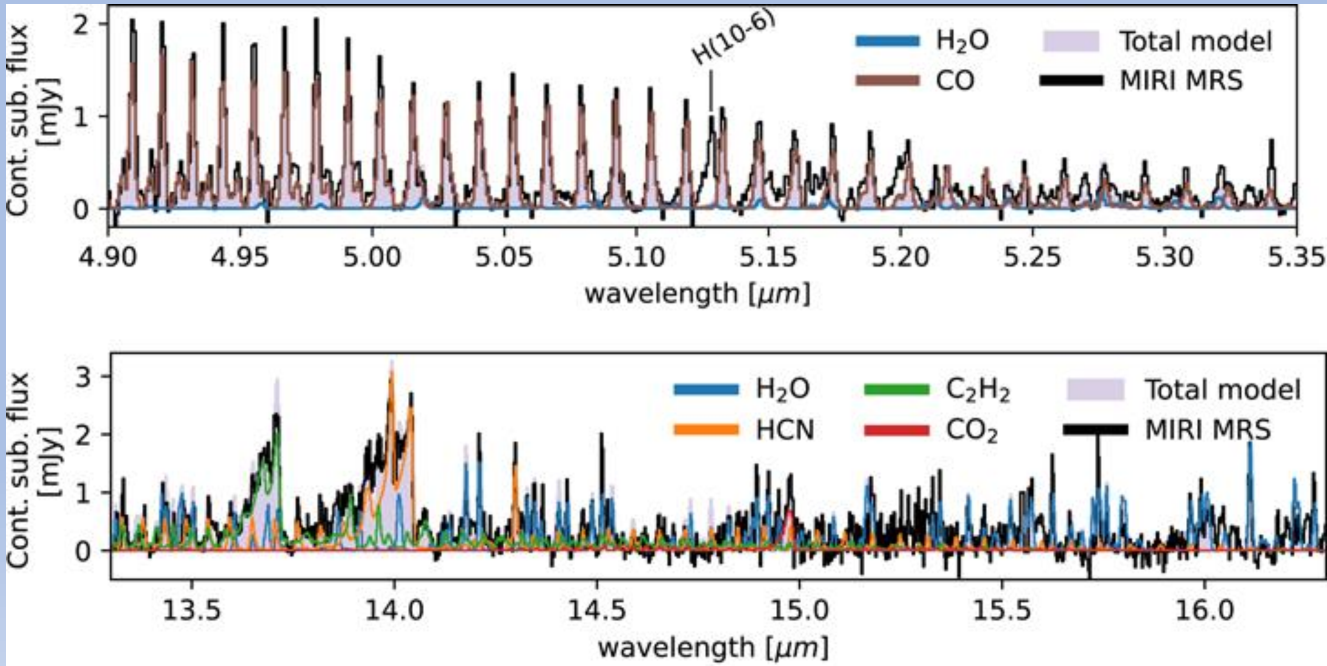
Not a complete list: McCullough 1995; Johnstone, Hollenbach, Bally 1998; Henney&Arthur 1998; Johnstone 1998; Storzer&Hollenbach 1998, 1999; Henney+ 1999; Richling+ 2000; García-Arredondo+ 2001; Facchini+2016; Eisner+ 2018; Haworth+2018; Winter+ 2019; Boyden+2020; Winter & Haworth 2022; Haworth+2023

SPECTROSCOPY OF DISCS AT HIGH UV FLUX



MIRI-MRS spectrum of high-FUV disc in NGC6357 from the XUE program (Ramirez-Tannus+2023)

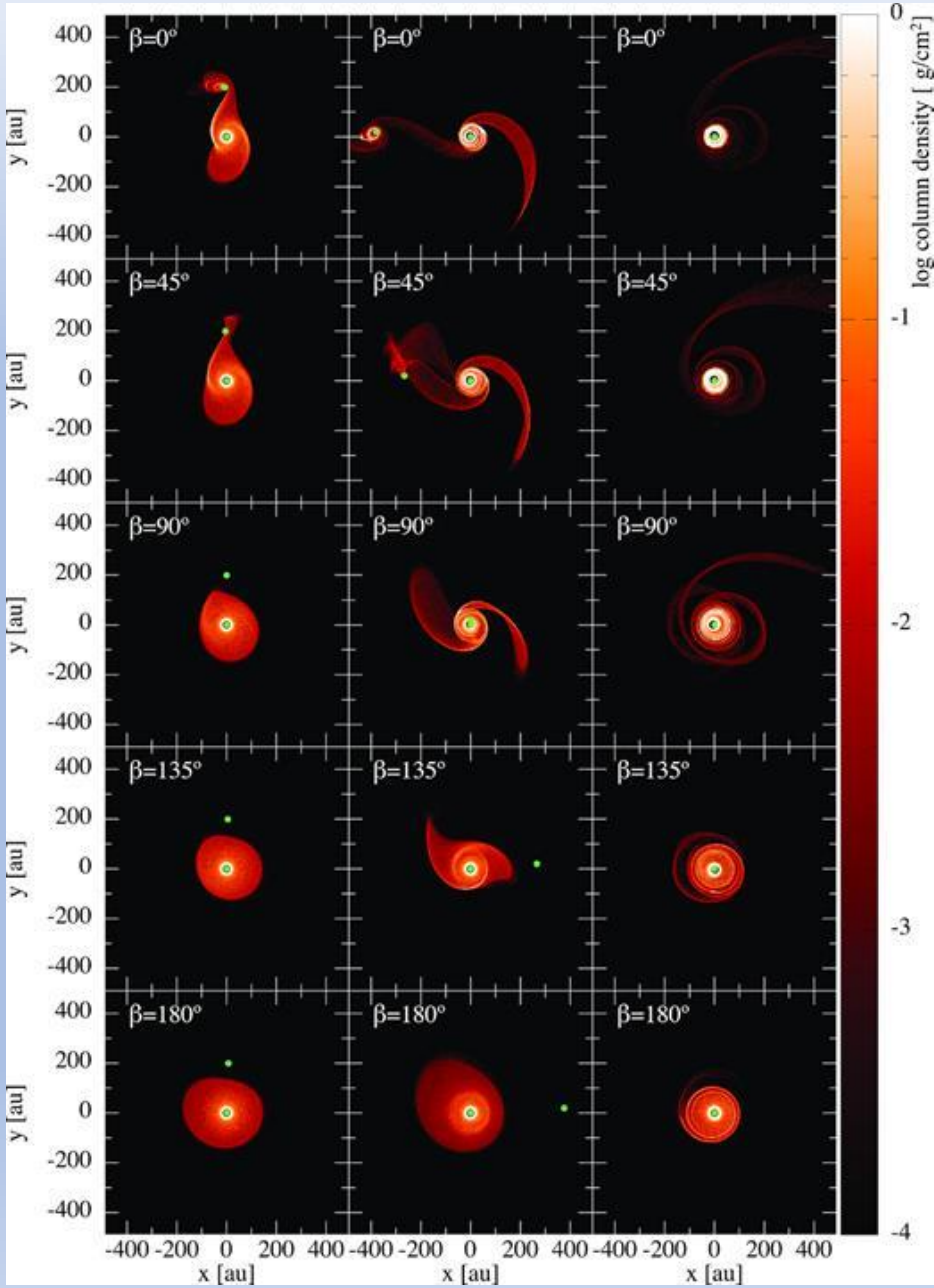
The chemistry of the disc closely resembles that of not irradiated discs.



CLOSE ENCOUNTERS

Gravitational interaction between stars in clusters is enhanced by high stellar density, and it may impact discs:

- **Formation of spirals** *(e.g: Ostriker+1994; Pfalzner+2003)*
- **Disc truncation** *(e.g.: Bhandare+2016, 2019; Winter+2018b)*
- **Formation of warps, inclined disc** *(e.g.: Nealon, Cuello & Alexander 2020)*
- **Transient phenomena** *(Vorobyov+2015, 2020; Cuello+2019)*

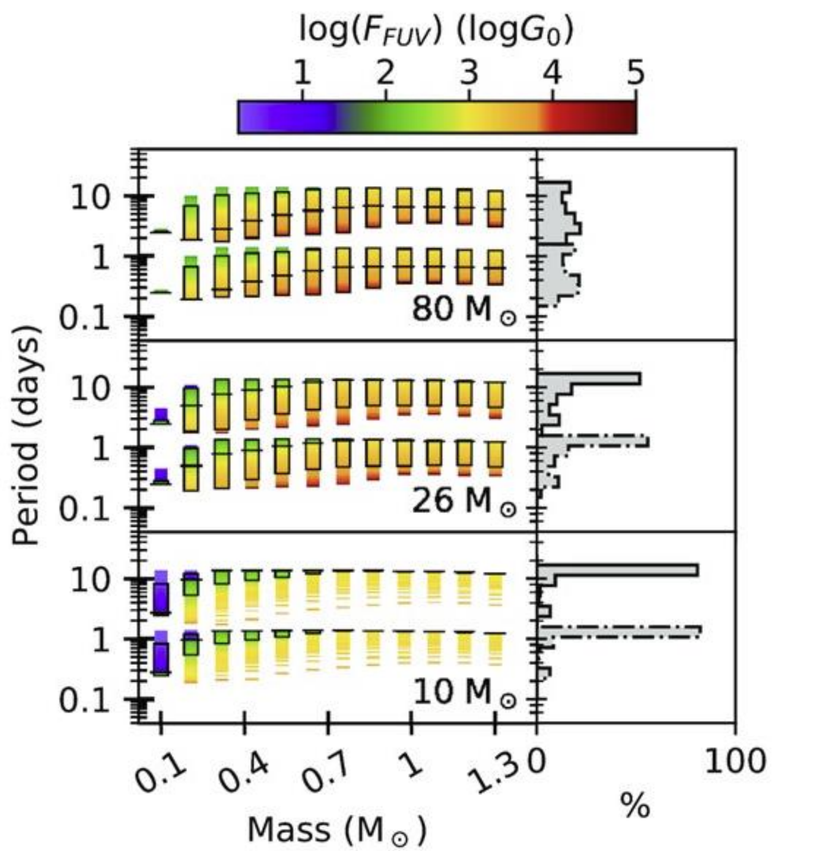


Fly-by simulations (Cuello+2019, 2020)

FEEDBACK ON STELLAR EVOLUTION

Studies report possible variations of the IMF due to the surrounding environment, but no conclusive results presented to date *(Bastian+2010, Offner+2013)*

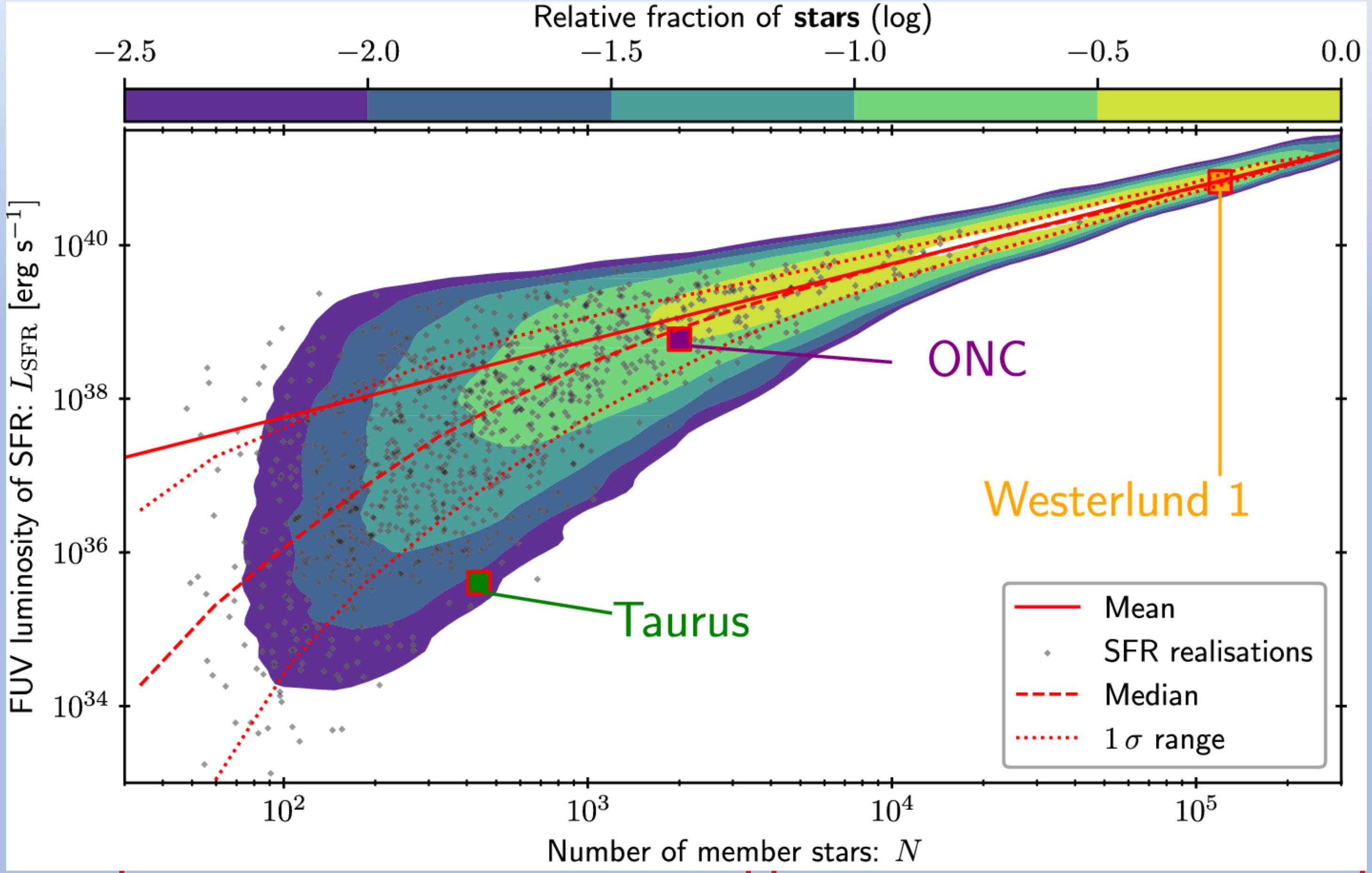
Shallower than Salpeter 1995	Consistent with Salpeter 1995
Arches *(Figer+1999; Kim+2007; Espinoza +2009)*	Westerlund 1 *(Brandner+2008; Gennaro +2011; Andersen+2017)*
NGC6303 *(Eisenhauer+1998; Sung & Bessell 2004; Stolte+2006)*	30 Doradus and R136 *(Hunter+1995, 1996, 1998; Andersen+2009)*
Westerlund 1 *(Lim+2013)*	Trumpler 14 and 16 *(Hur+2012)*
30 Doradus *(Sirianni+2000)*	Westerlund 2 *(Hur+2014)*
Quintuplet Cluster *(Hußmann+2012)*	



Roquette+2021: spin-evolution model (Matt+2015) + disc locking + disc photoevaporation model (Winter+2020).

Fast disc dispersal at high G_0 in low-mass stars produces more rapid rotators

WHY WE HAVE TO LOOK AT SUPERMASSIVE YOUNG CLUSTERS



Young supermassive star clusters (>10^4 $M_\odot$) are dominated by the richest ensemble of massive stars known and very high stellar density

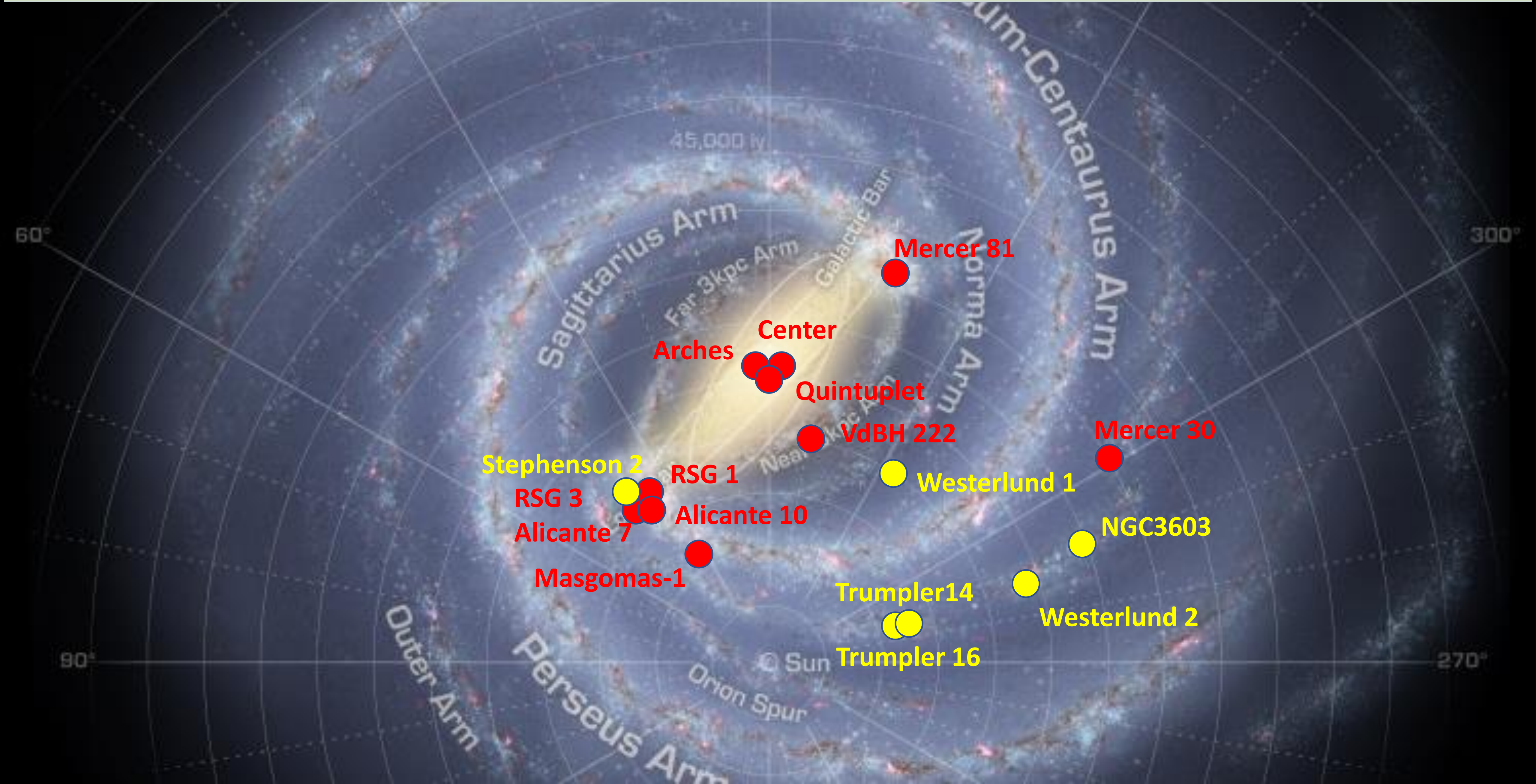
They allow us to extend our knowledge of star and planet formation and early evolution to the starburst environment

FUV field intensity vs. stellar population in stellar clusters. (Winters+2022)

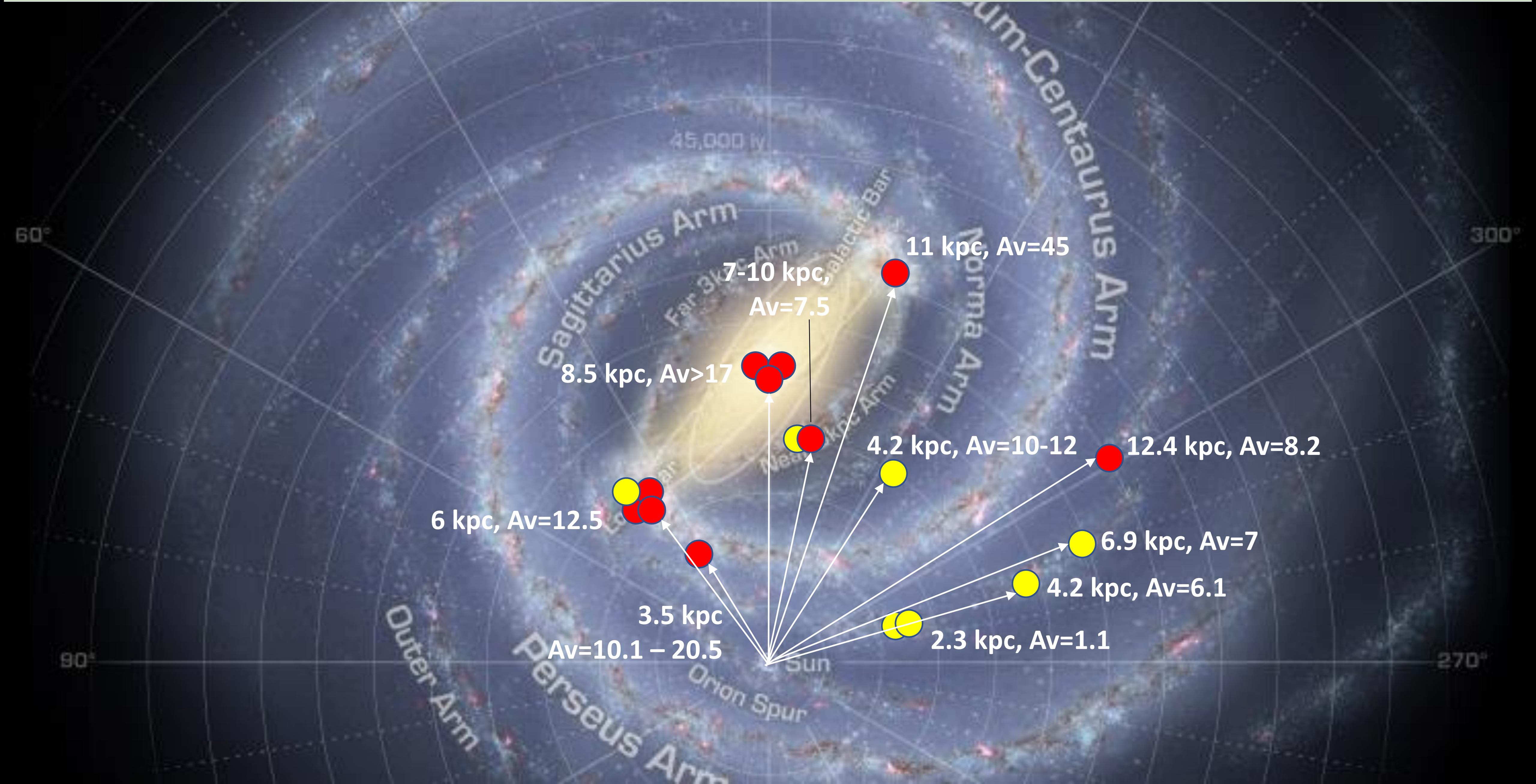
Low- and Intermediate mass clusters
Solar neighbourhood

Massive and supermassive clusters

SUPERMASSIVE STAR CLUSTERS IN THE MILKY WAY



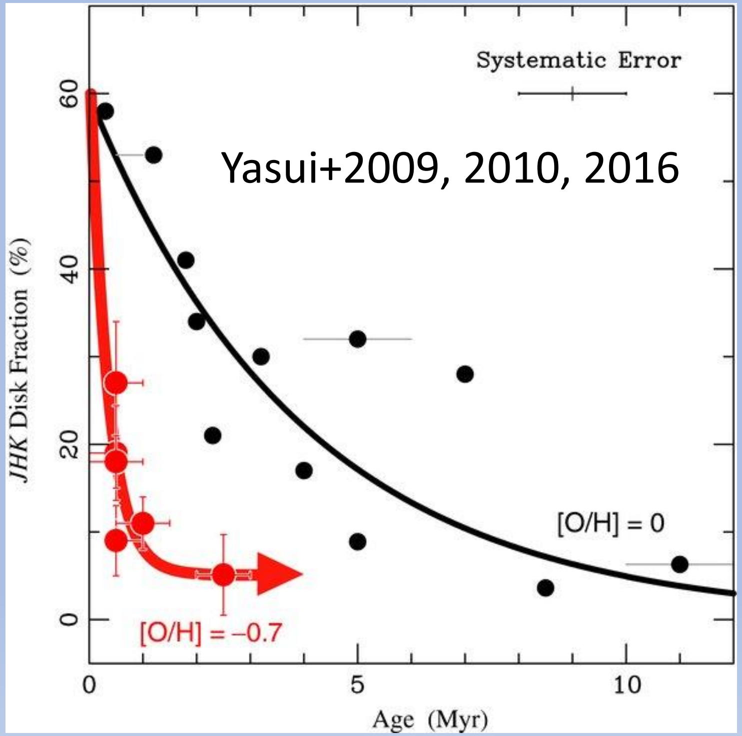
SUPERMASSIVE STAR CLUSTERS IN THE MILKY WAY

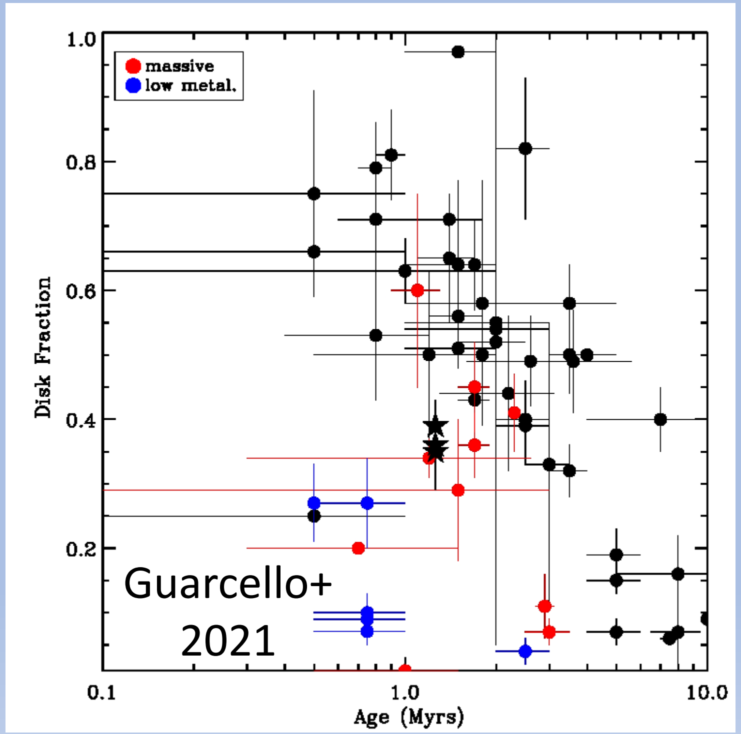


DISCS AT LOW METALLICITY

Disc accretion depends on metallicity, since disc ionization is expected to be more efficient at low metallicity because of the low dust opacity.

FUV penetration strongly depends on the amount of dust in the disk, resulting in a more efficient heating and thus more rapid photoevaporation (Nakatani+2018). Theoretical works suggest disks lifetime decreases with the dust opacity (Gorti & Hollenbach 2009).





Observational evidence from photometric studies supporting a lower disc fraction in Galactic SFRs at low metallicity in the outer Galaxy (left) and in the young cluster Dolidze 25 (right)

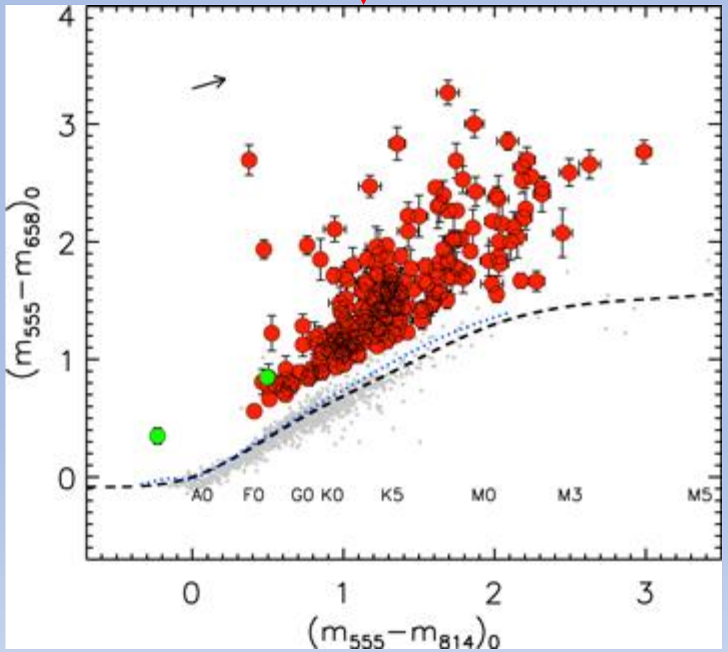
Disc fraction at low metallicity

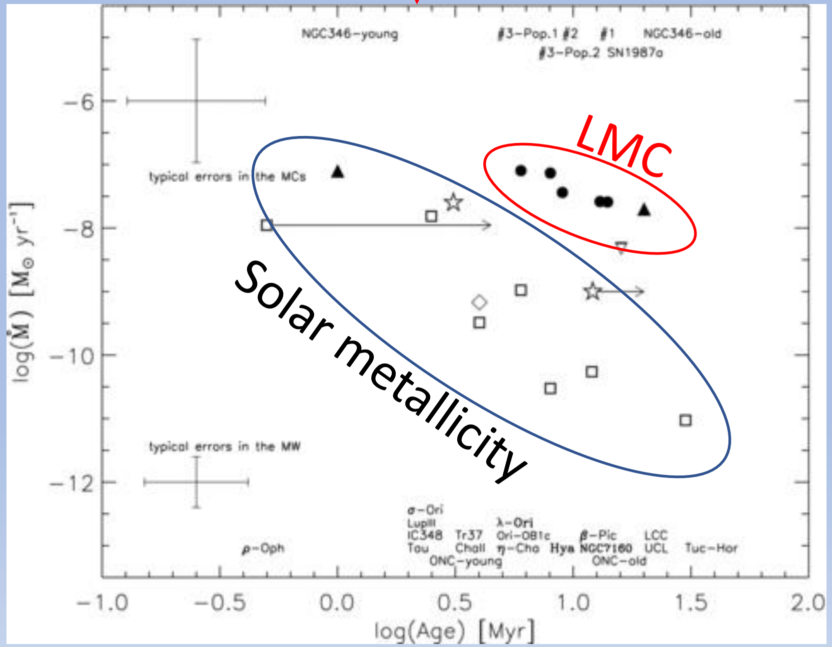
STUDIES IN THE MAGELLANIC CLOUDS

Longer accretion timescale reported in the Magellanic Clouds.
(Spezzi+2012, de Marchi+2017, Biazzo+2019)

Accreting stars are selected with photometric diagrams including narrow Hα filters.
Confirmed spectroscopically with NIRSpec *(de Marchi+2024)*

Accretion rates decrease more slowly than in other SFRs.



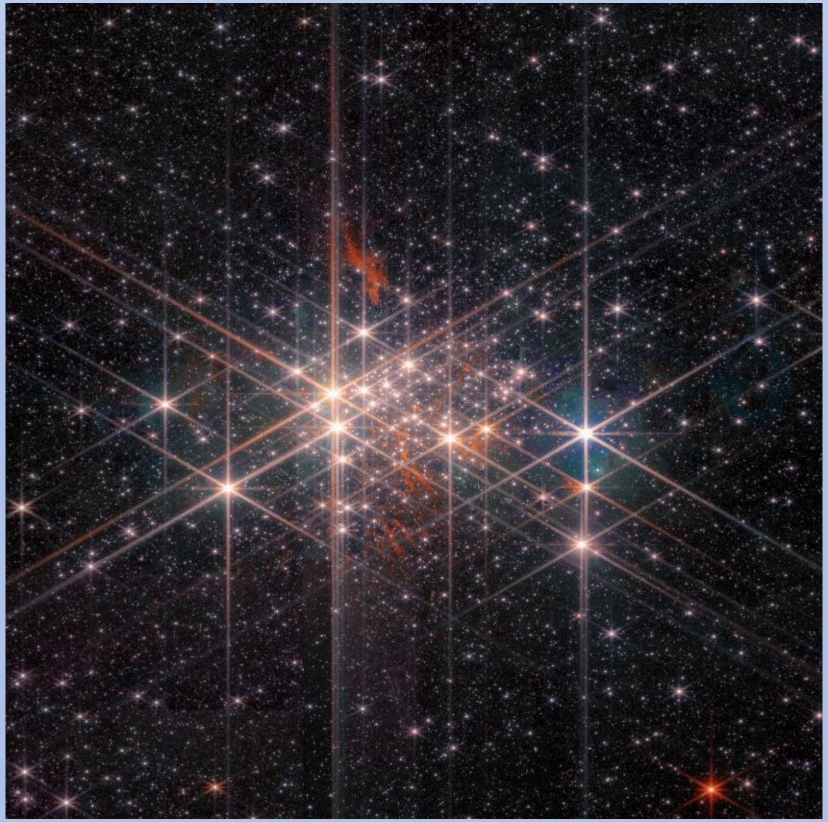


These can be due to:

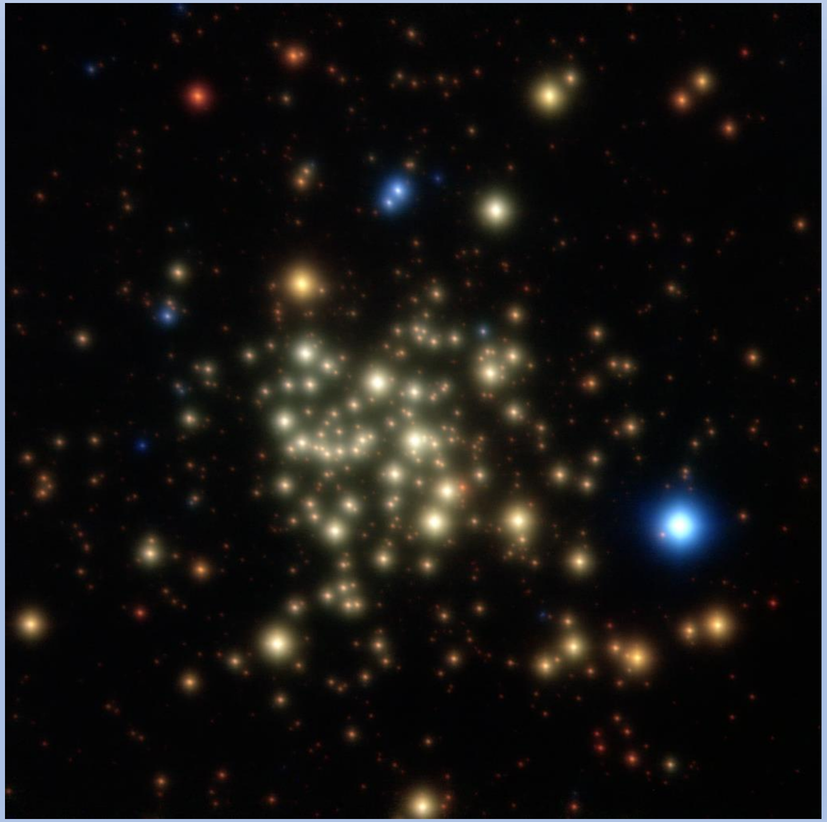
- Weaker radiation pressure on the inner disk;
- Lower disk opacity which reduces disk temperature, smaller viscosity and thus larger viscous timescale;
- Slower formation of solid bodies.

HOW SHARP WILL OBSERVE DISTANT MASSIVE/LOW-Z SFRs

Test cases considered: M5, K5 and G5 spectral models (PARSEC isochrones to account for age and obtain magnitudes) in the following clusters:



Westerlund 1 (NIRCam)
5Myrs, 4230 pc, AJ=2.9

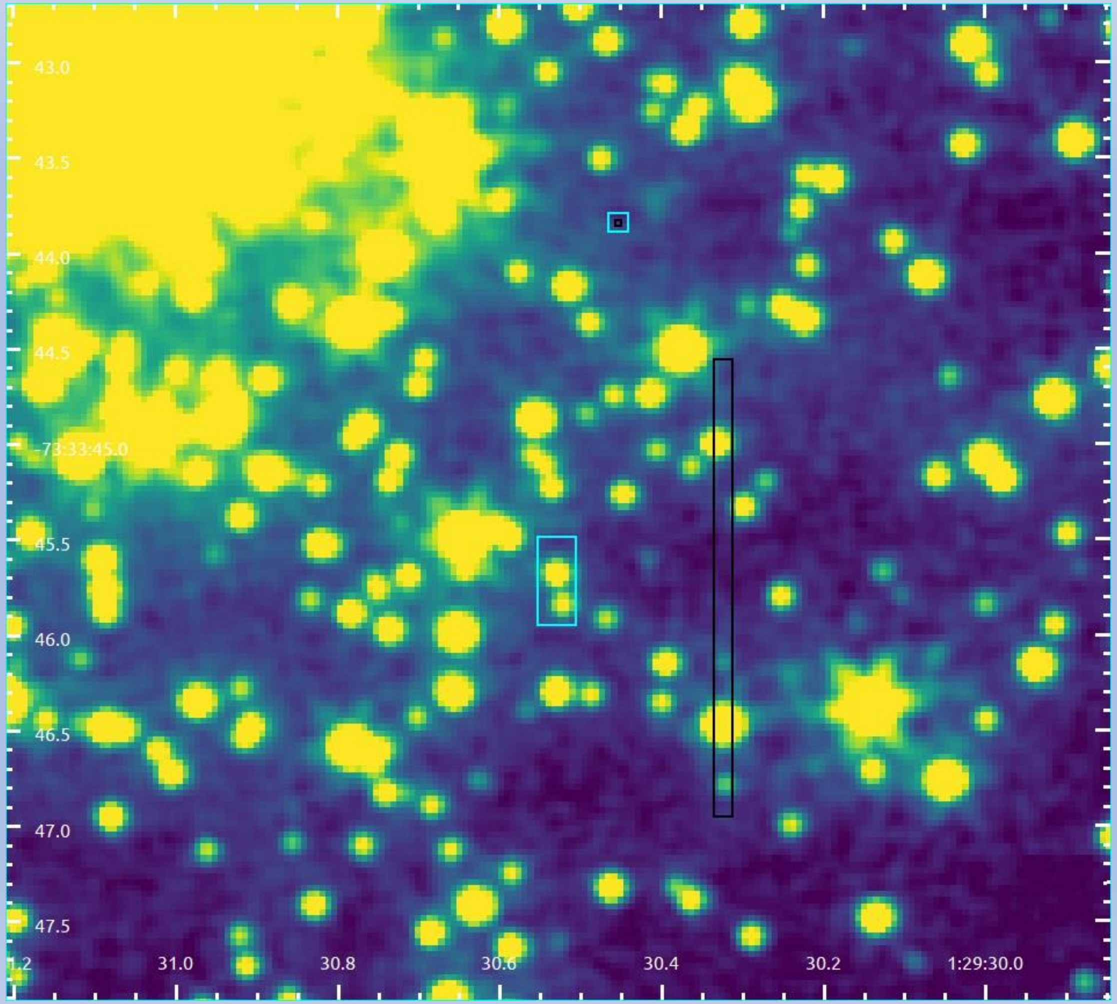


The Arches Cluster (VLT)
2Myrs, 8500 pc, AJ=5.8

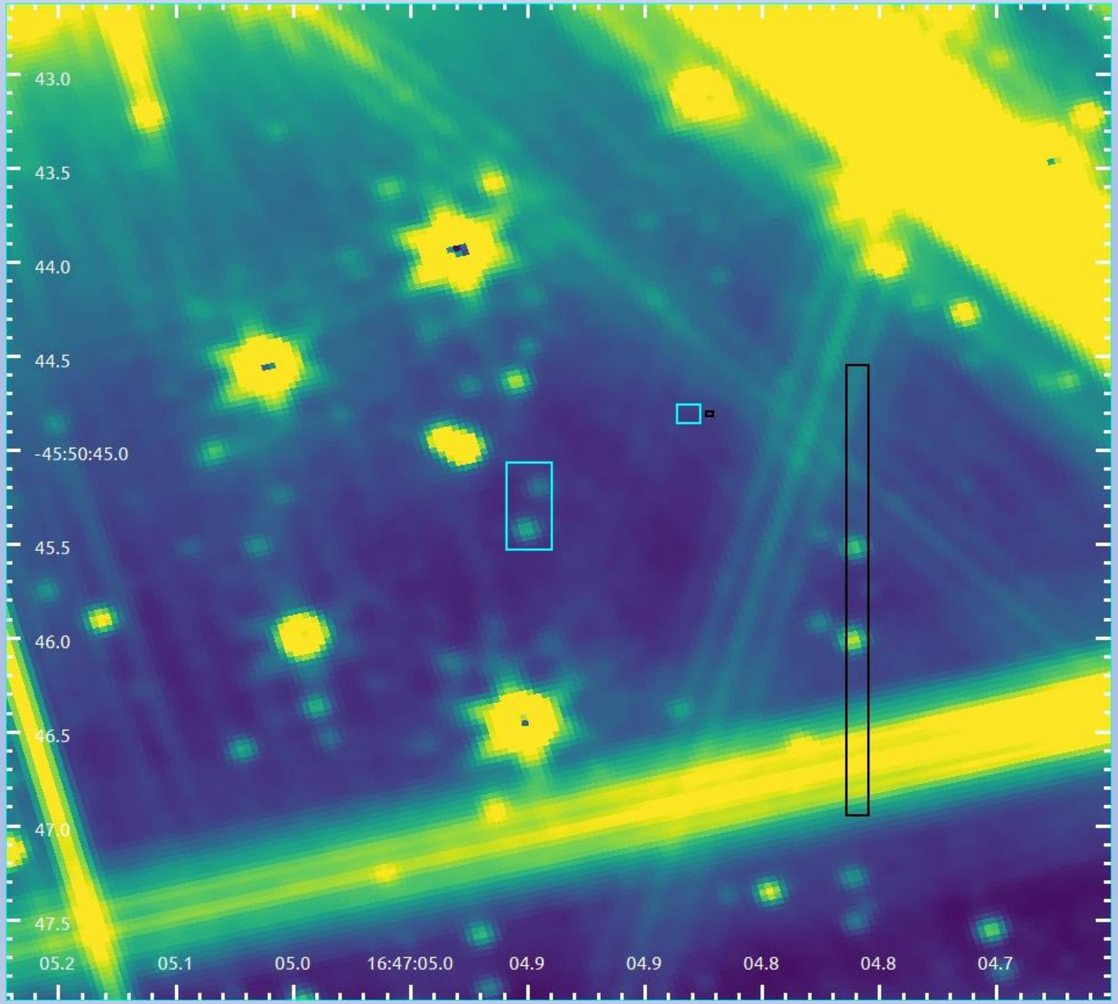
NGC602 (HST)
1Myrs, 60000 pc, AJ=0.03

SHARP vs. NIRSpec, SPATIAL RESOLUTION

Comparison between the pixel scale and the size of the SHARP slit and one NIRSpec MSA element using NIRCam images, F150W filter

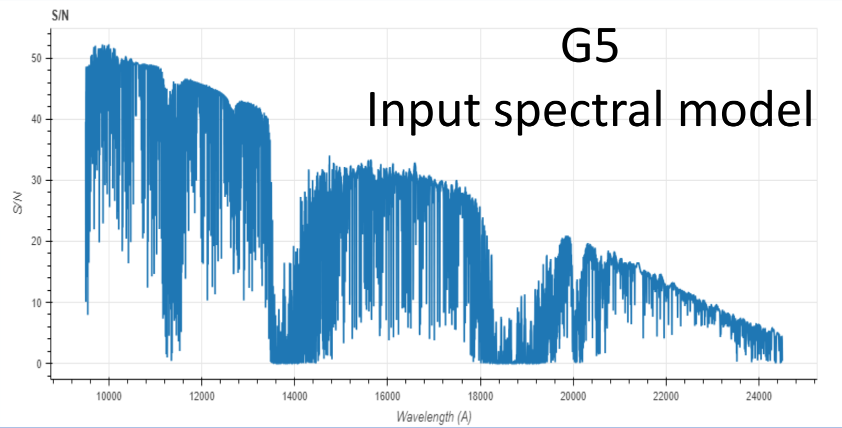


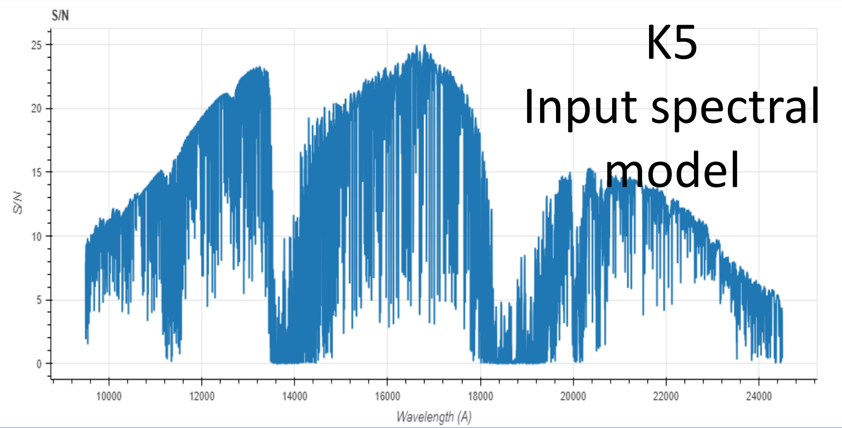
NGC602

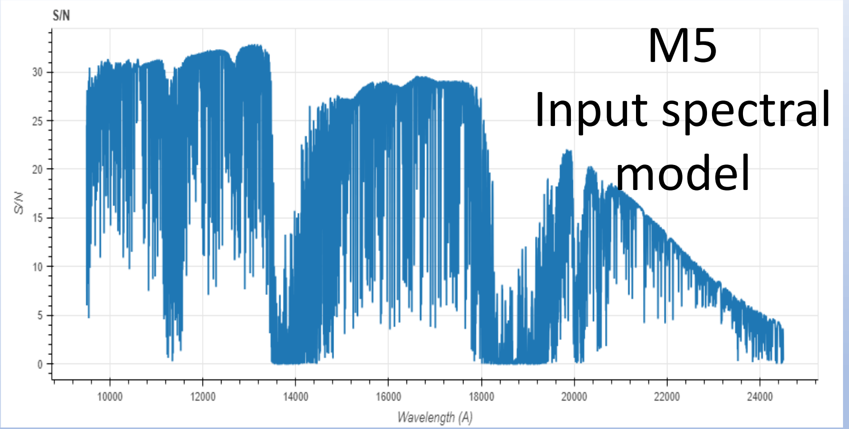


Westerlund 1

SHARP vs. NIRSpec (G235H/F170LP, R=2700), SNR







SHARP (SNR=10 in K band):

Wd1: 2x30sec

NGC602: 10x30sec

Arches: 86x30 sec

NIRSpec SNR (with same exposure)

Wd1: 1x1, SNR=0.11

NGC602: 7x1, SNR=10.1

Arches: 10x6, SNR=74

SHARP (SNR=10 in K band):

Wd1: 17x30sec

NGC602: 138x30sec

Arches: 999x30 sec

NIRSpec SNR (with same exposure)

Wd1: 12x1, SNR=28.4

NGC602: 10x9, SNR=8.7

Arches: 20x35, SNR=60.8

SHARP (SNR=10 in K band):

Wd1: 24x30sec

NGC602: 249x30sec

Arches: 999x30 sec

NIRSpec SNR (with same exposure)

Wd1: 12x1, SNR=16

NGC602: 10x17, SNR=4.6

Arches: 20x35, SNR=37.5

CONCLUSIONS

It is important to extend our knowledge of star and planet formation and early evolution to very massive and low-Z star-forming environments

However, they are typically distant, highly extinguished, and very crowded. High sensitivity and extreme spatial resolution is required

SHARP can be a game-changer in the study of most distant and crowded massive SFRs

THANK YOU!