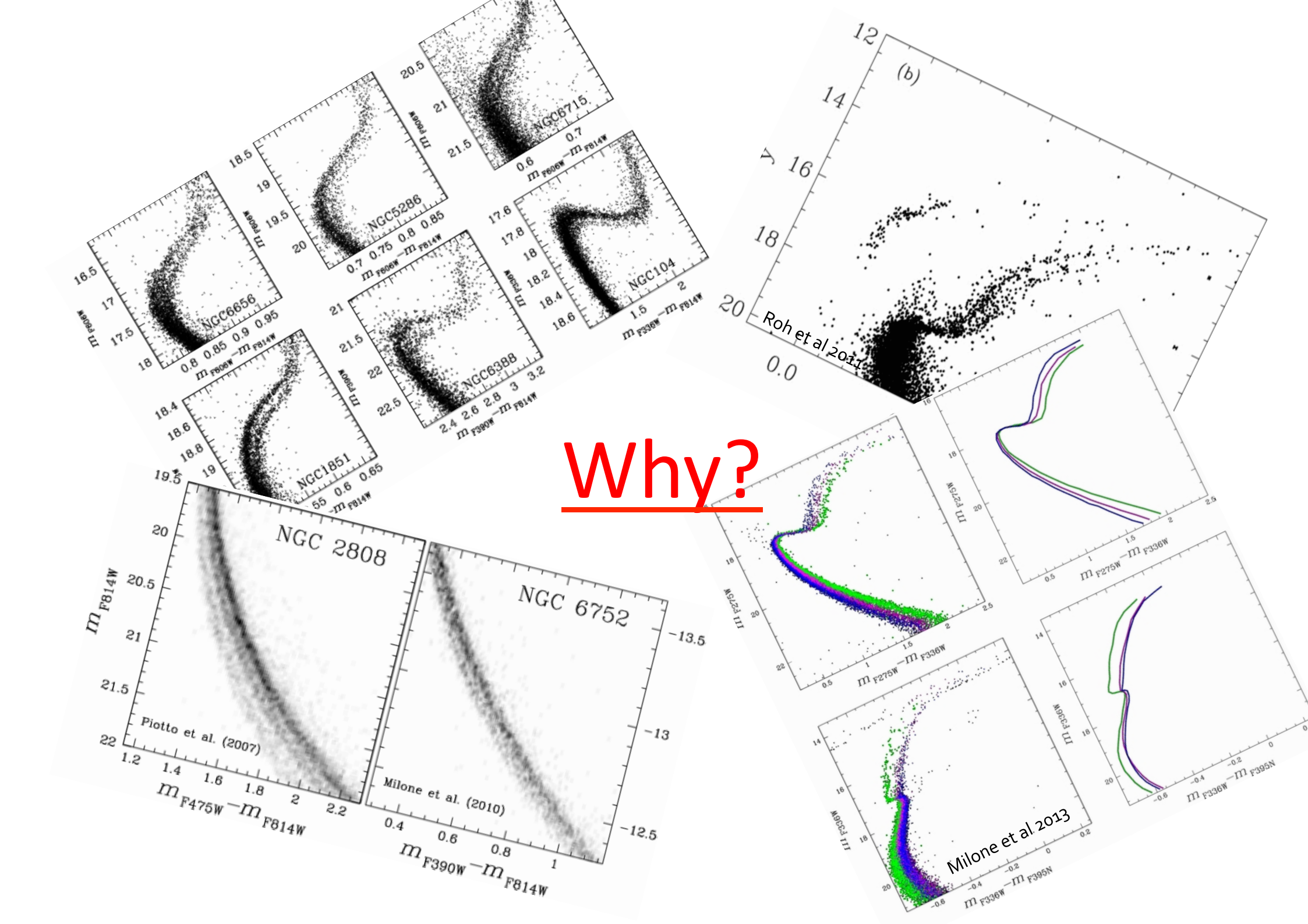
Multiple stellar populations in massive star-burst clusters

Giacomo Beccari

-ESO, Vitacura (Chile)-

De Marchi, G.(ESA), Panagia, N. , Correnti, M. (STScI), Romaniello, M. , Manara, C.F., Testi, L. (ESO)

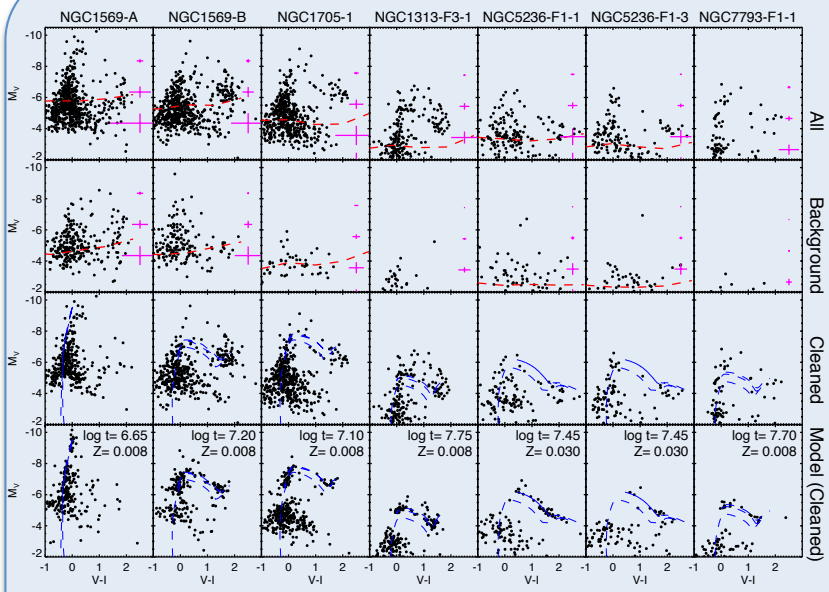

NGC6715
NGC5286
NGC6656
NGC104
NGC6388
NGC1851
(b)
Roh et al 2011
Why?
NGC 2808
NGC 6752
Piotto et al. (2007)
Milone et al. (2010)
Milone et al 2013

Where?

"…multiple populations should be expected in at least some young star clusters, but it is currently not known whether, or to what extent, this phenomenon occurs in observed YMCs."

(review S. Portegies Zwart et al. 2010)

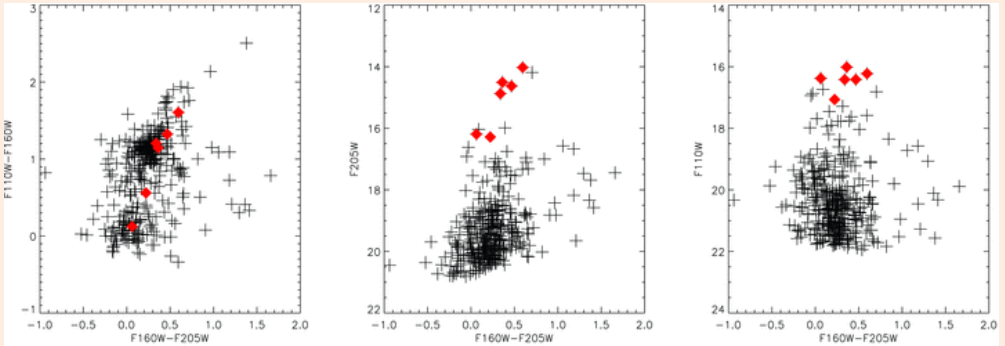
Multiple generations: Intermediate (>100Myr) MC



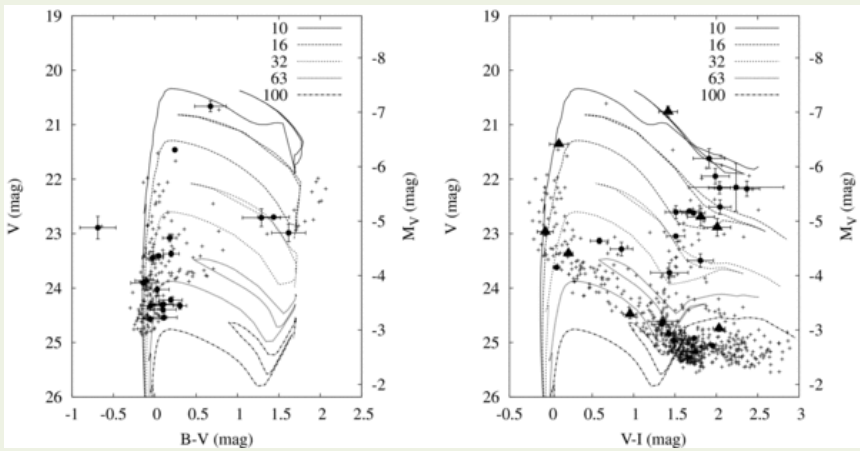
7 YMCs in external galaxies:
Mass:$10^5 M_\odot$–$10^6 M_\odot$
ages 5-50Myr
age spread~30Myr - Larsen et al. (2011)

GMC Type	Observed Signature
Type A	No HII regions
Type B	With HII regions
Type C	With HII regions and < 10 Myr-old YSGs
Type D	With HII regions and 10—30 Myr-old YSGs

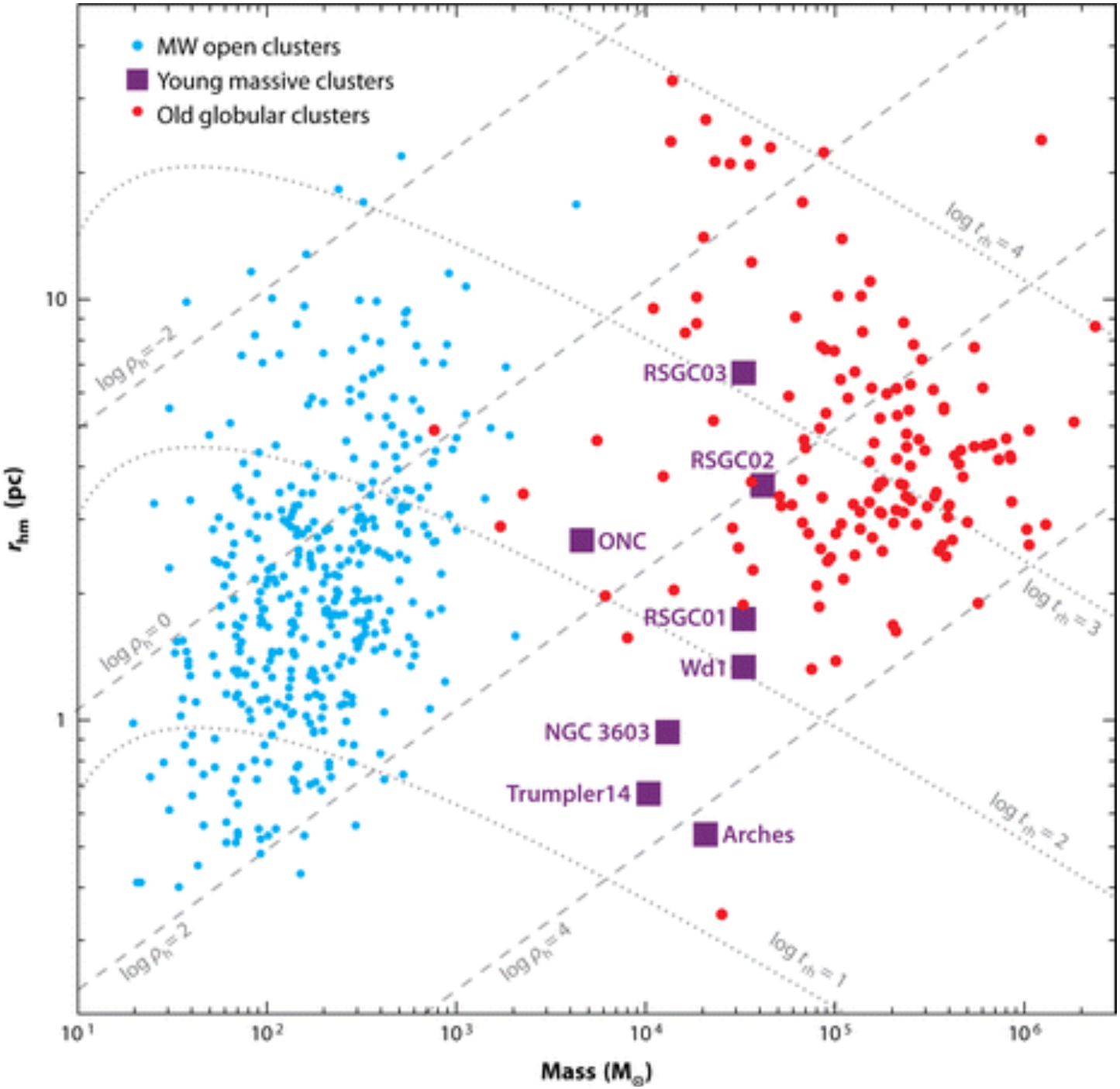
Miura et al. 2010



NGC604 in M33- Mass: $(3.8 \pm 0.6) \times 10^5 M_\odot$
two populations from distinct formation episodes with ages of 3.2 ± 1.0 and 12.4 ± 2.1 Myr - Eldridge & Relaño 2011

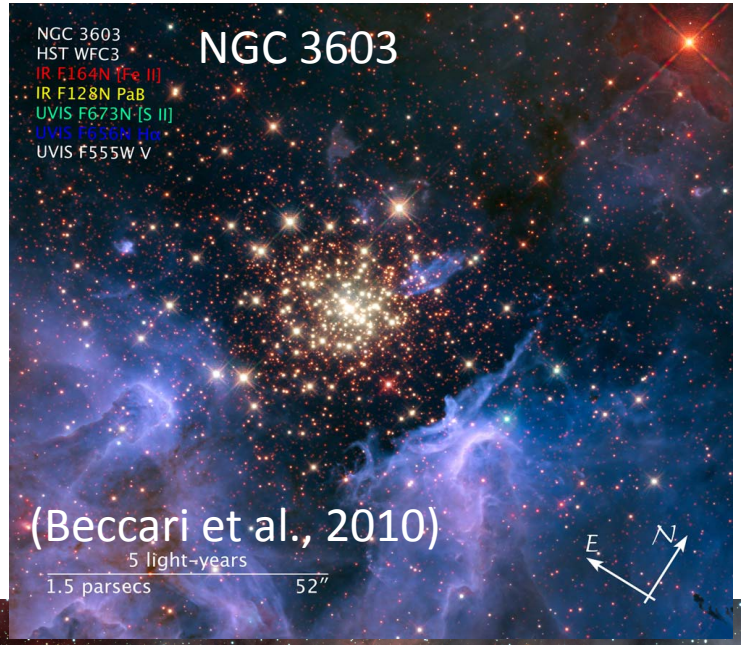


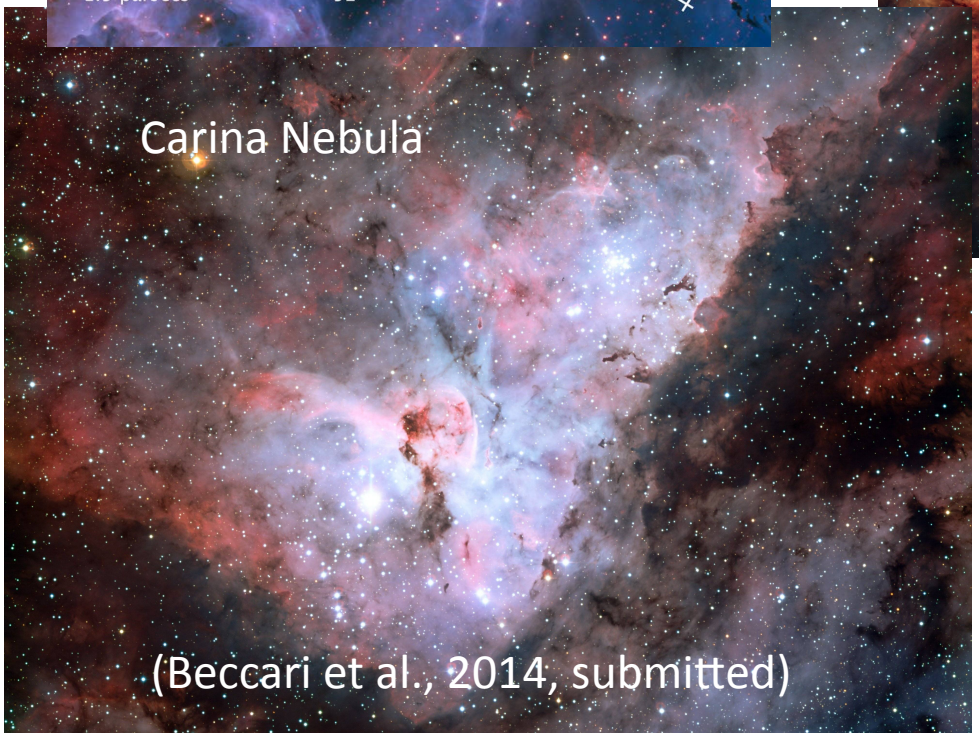
Sandage-96 in NGC2403- Mass: ~$10^5 M_\odot$
a younger population at ~10-16 Myr and an older one at ~32-100 My- Vinkó et al. 2009

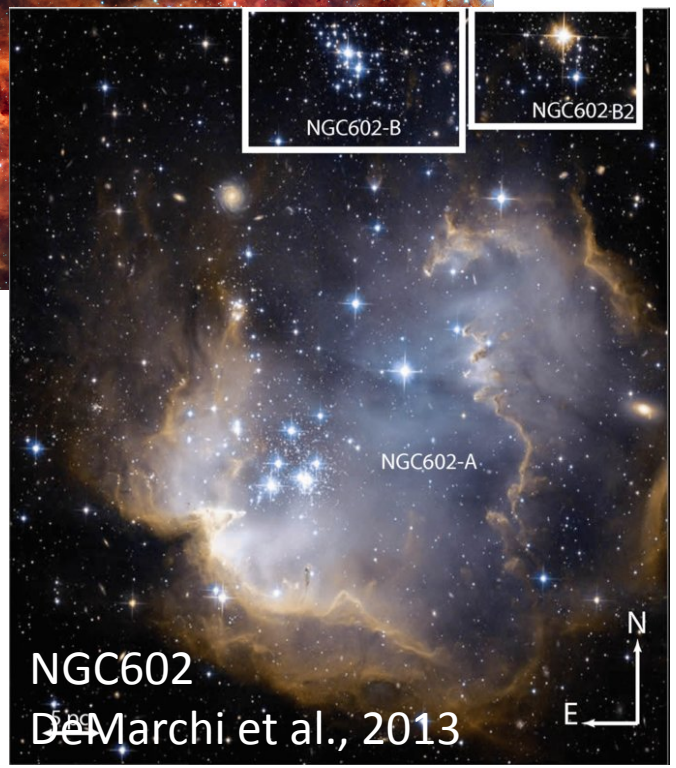


(review S. Portegies Zwart et al. 2010)

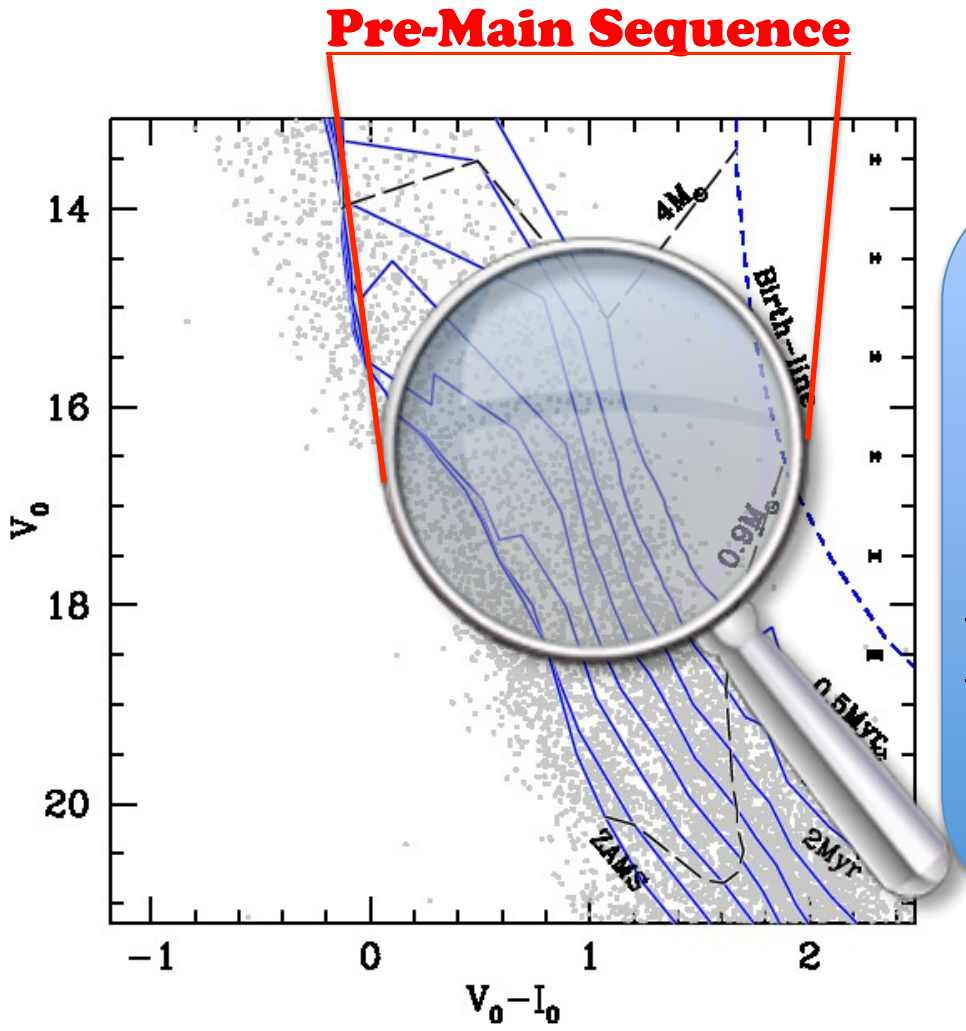
PMS objects in a number of star-burst clusters (MW, LMC, SMC)

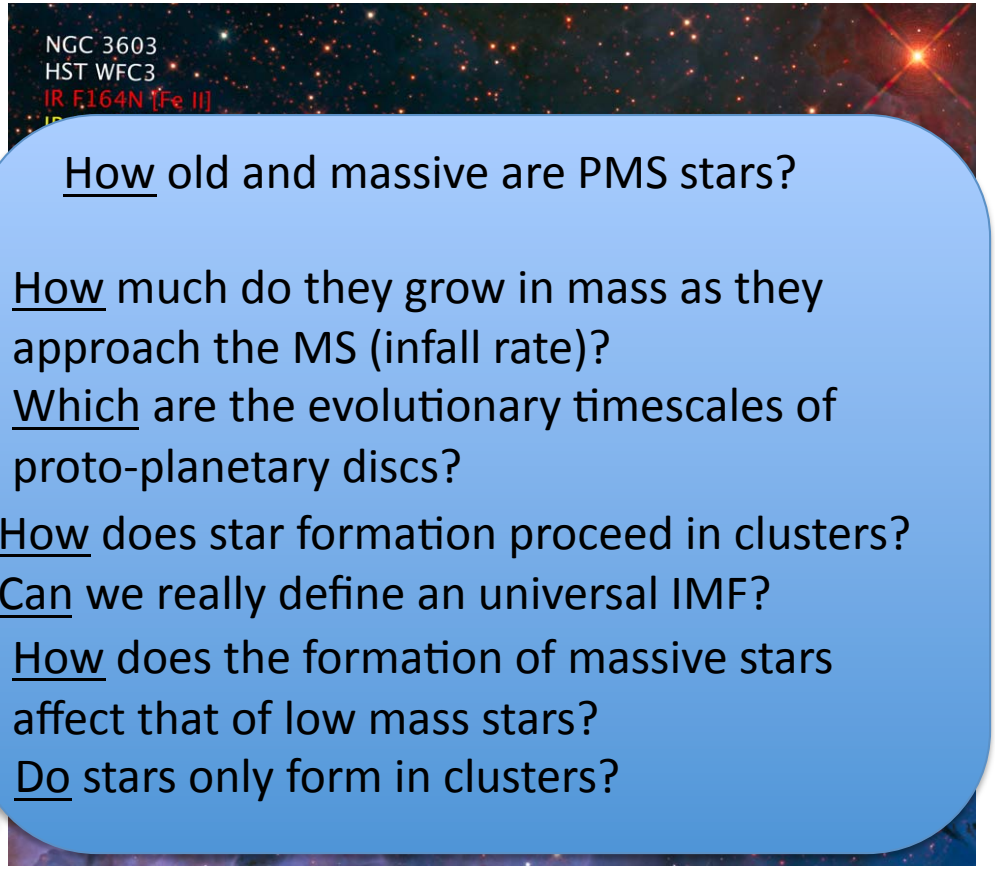






Young (~5-10Myr) MC: tracing the SF through the PMS





How old and massive are PMS stars?

How much do they grow in mass as they approach the MS (infall rate)?
Which are the evolutionary timescales of proto-planetary discs?

How does star formation proceed in clusters?

Can we really define an universal IMF?

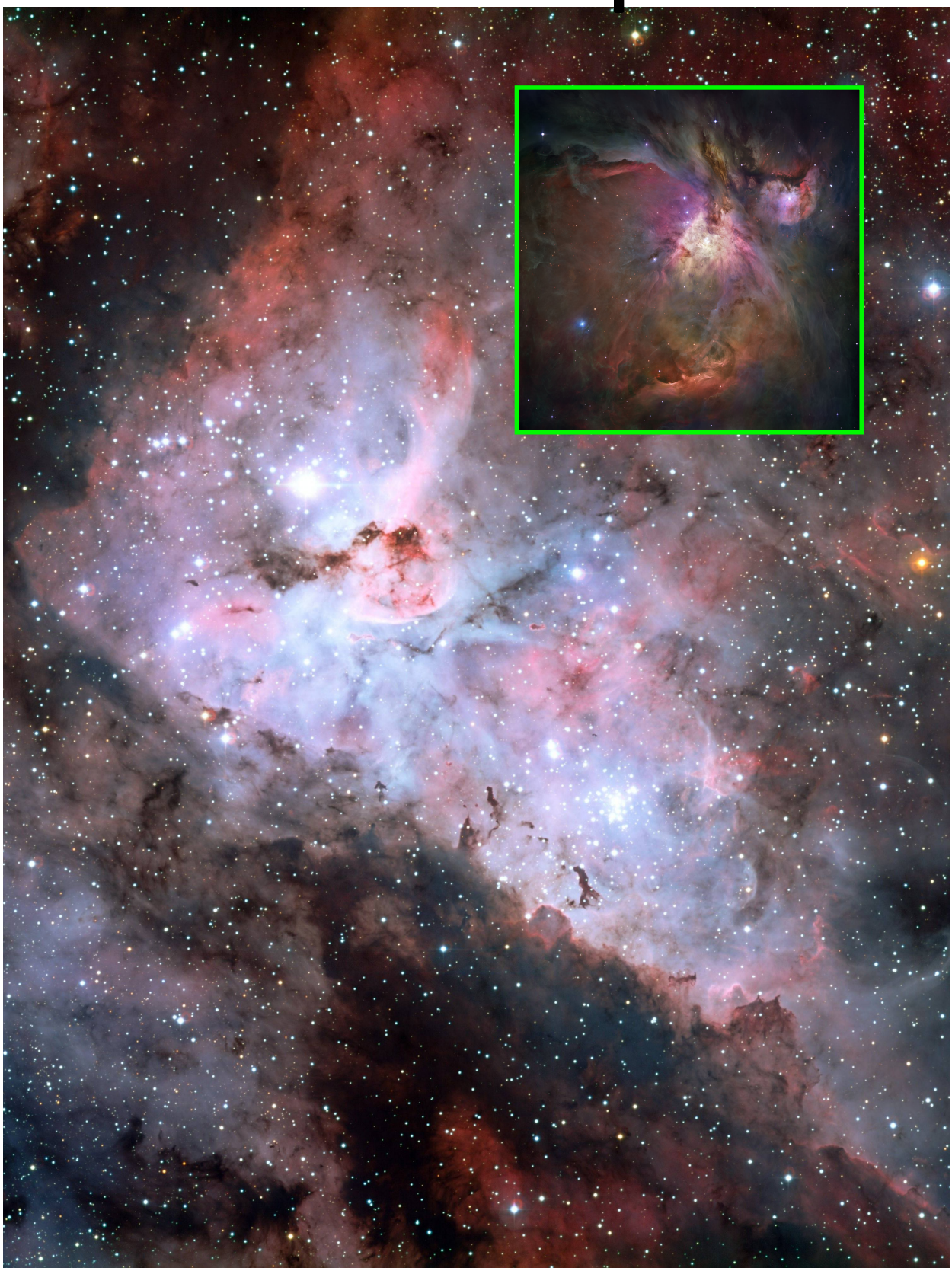
How does the formation of massive stars affect that of low mass stars?

Do stars only form in clusters?

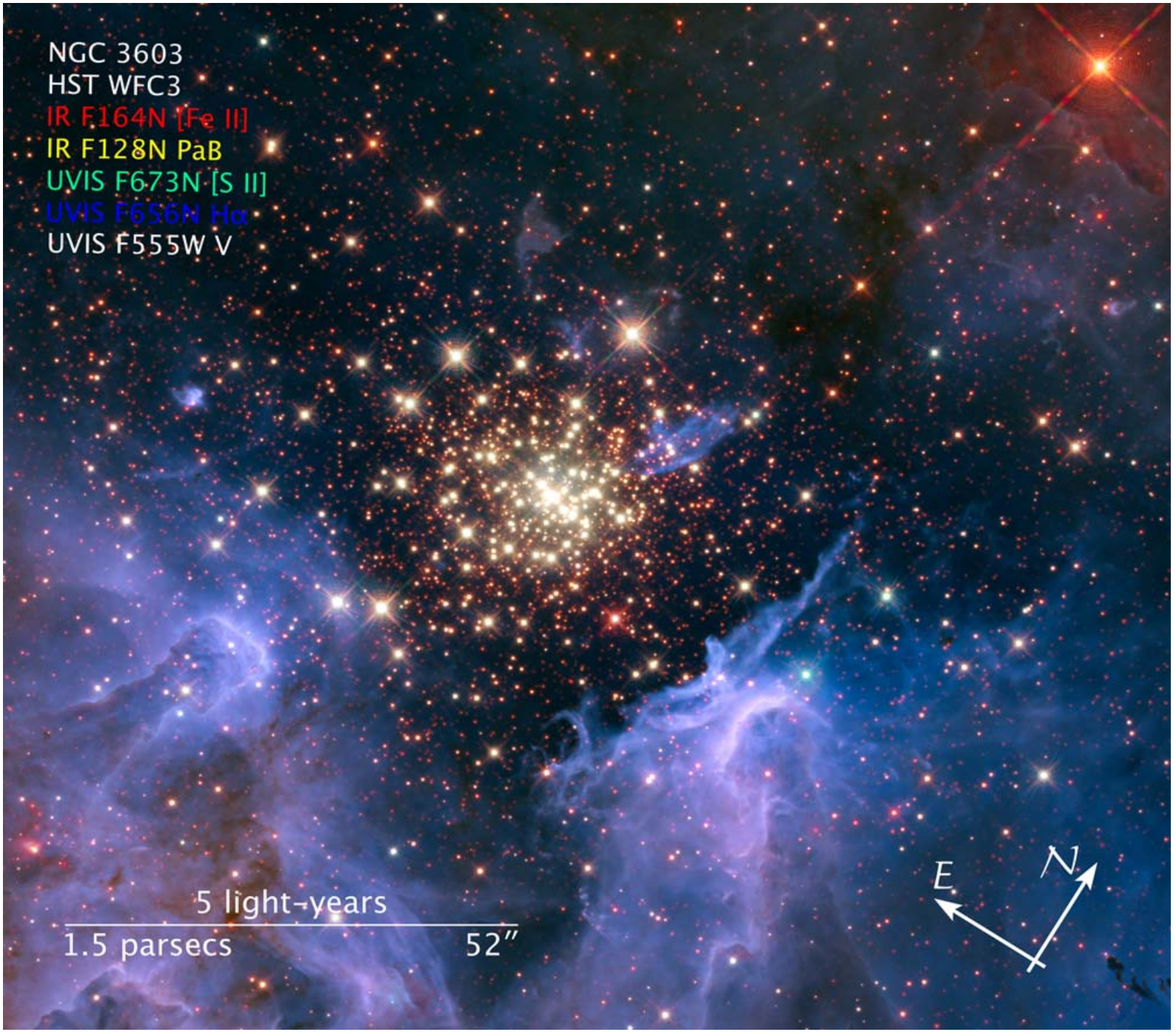

Orion
30’ = 4 pc


0.05 pc

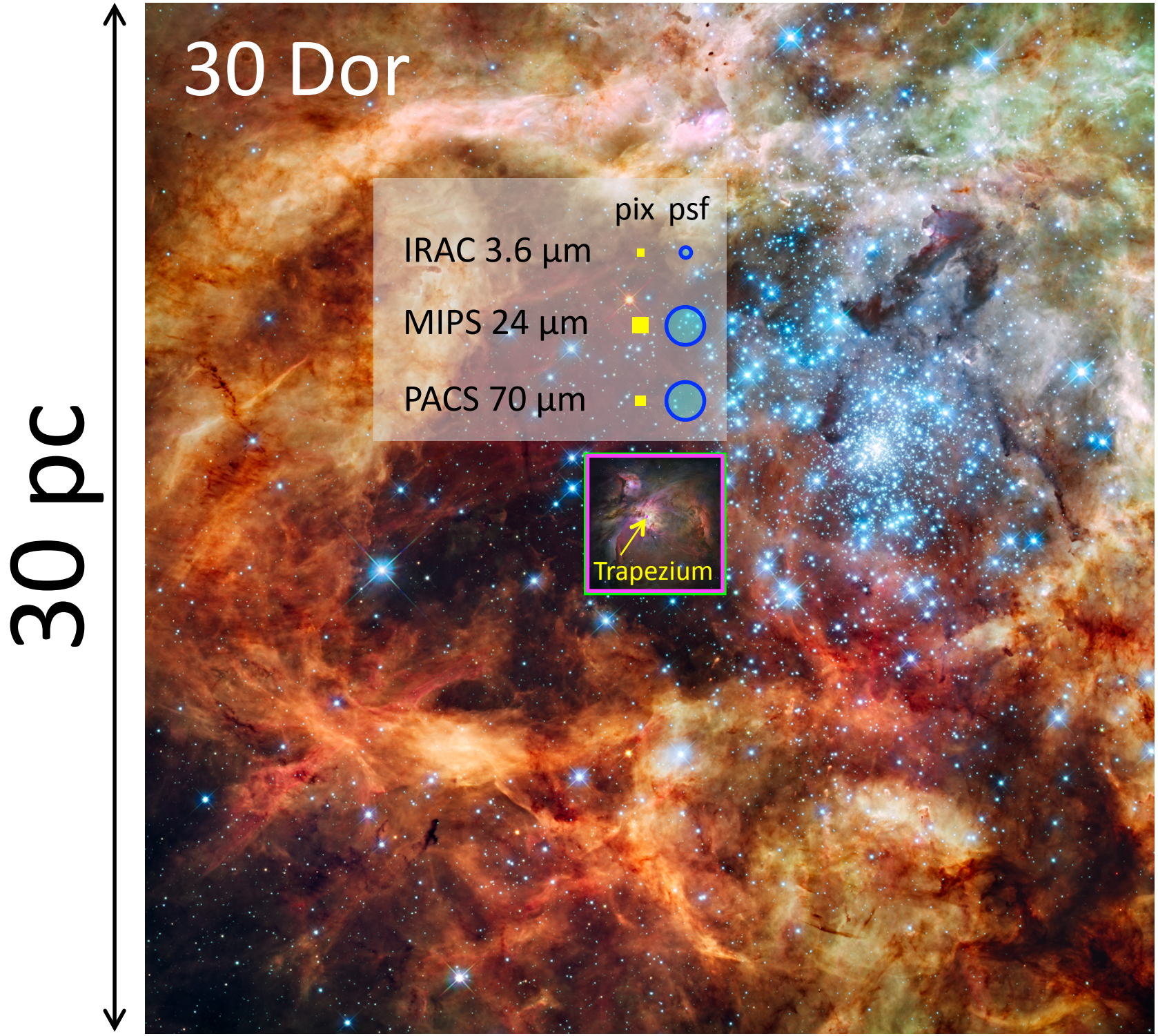
30’ = 26pc

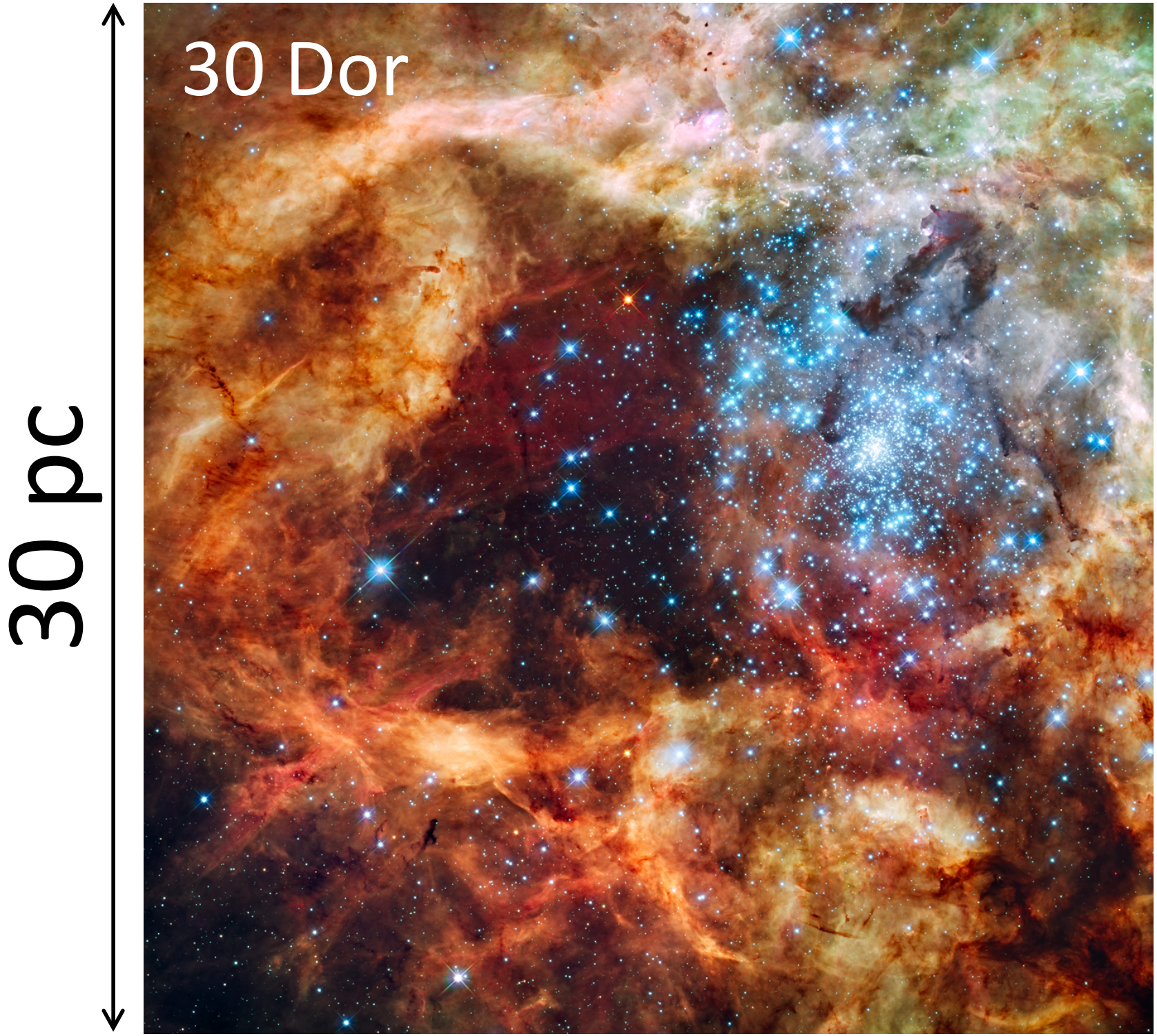


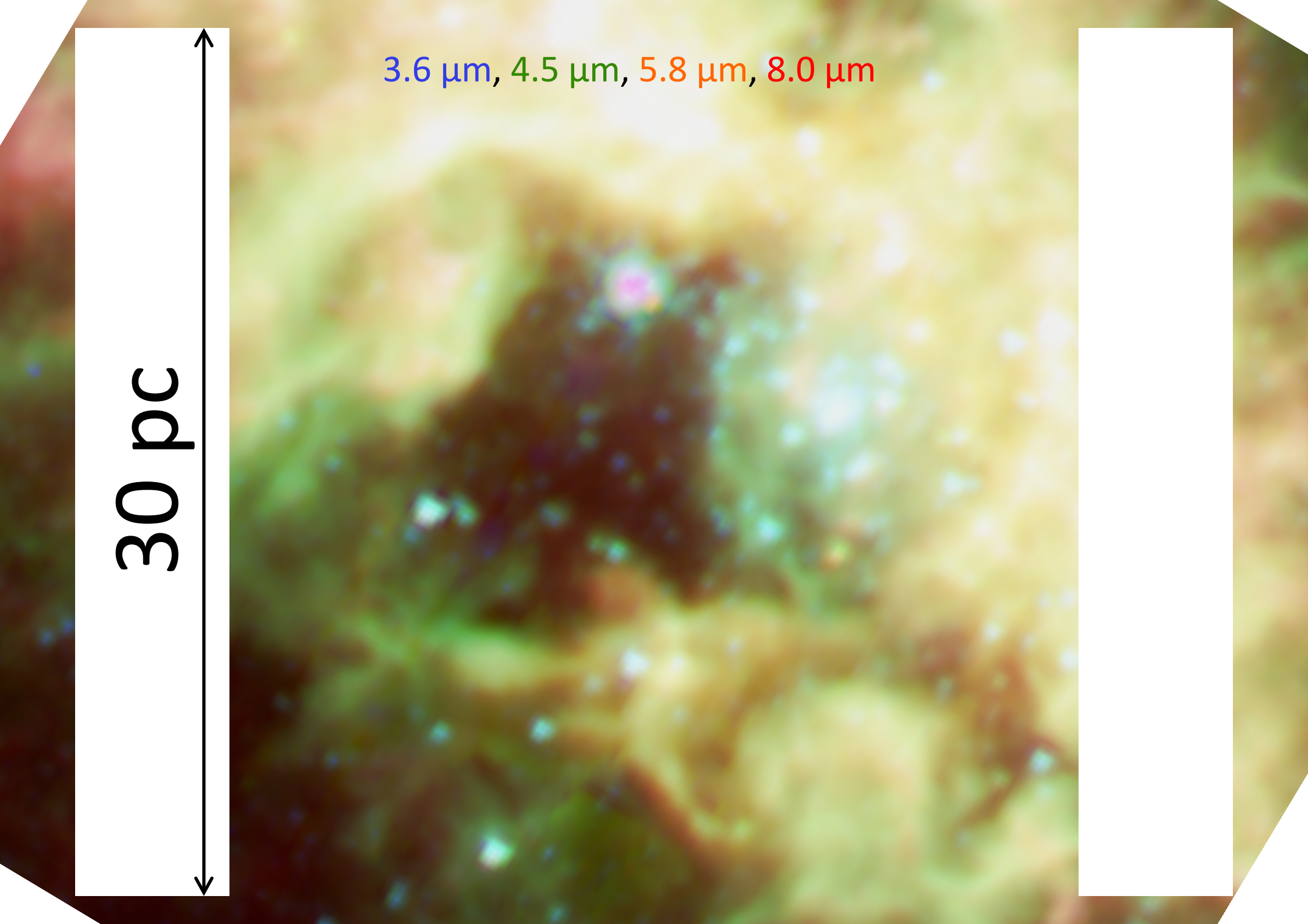
2.5′ = 5pc


NGC 3603
HST WFC3
IR F164N [Fe II]
IR F128N PaB
UVIS F673N [S II]
UVIS F656N Hα
UVIS F555W V
5 light-years
1.5 parsecs
52″
E
N


Orion
30’ = 4 pc

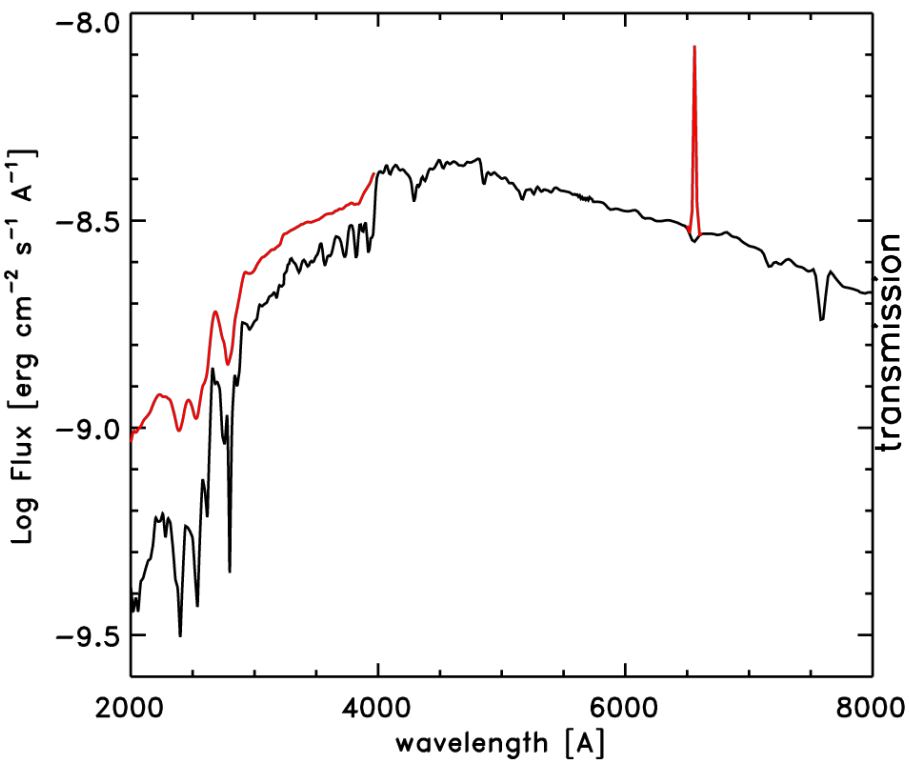

30 Dor
pix psf
IRAC 3.6 µm
MIPS 24 µm
PACS 70 µm
Trapezium
30 pc

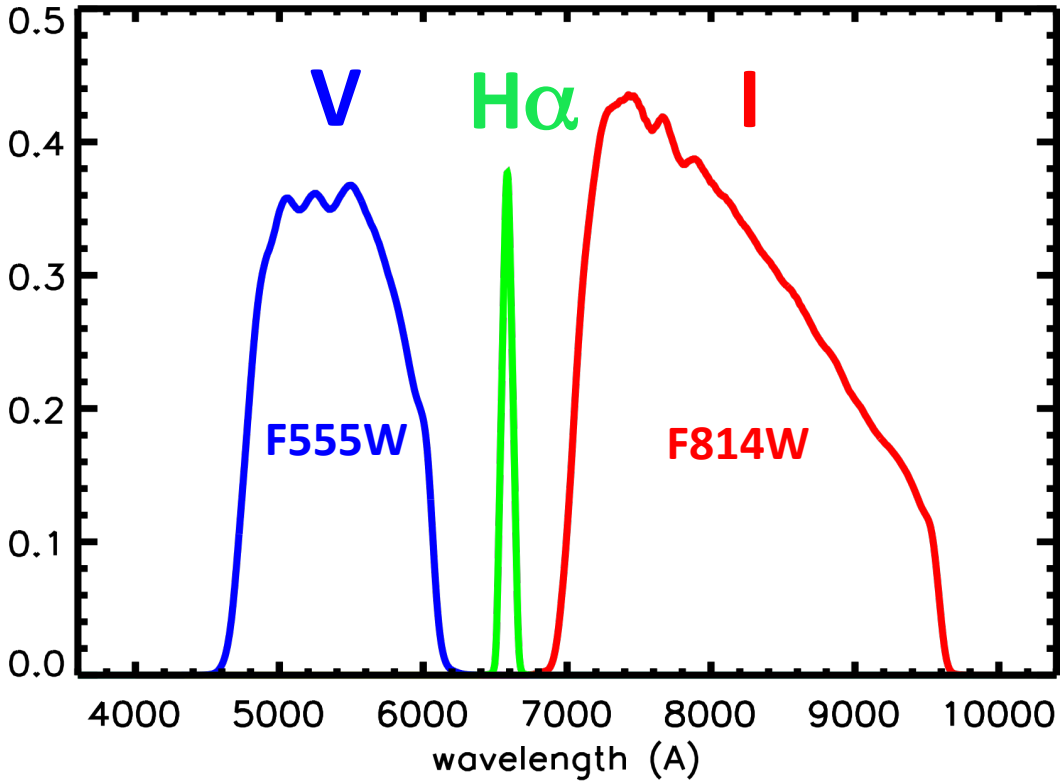

30 Dor
30 pc


3.6 µm, 4.5 µm, 5.8 µm, 8.0 µm
30 pc

=How?=(1) Photometry

Typical signature:
UV, IR and Hα excess emission



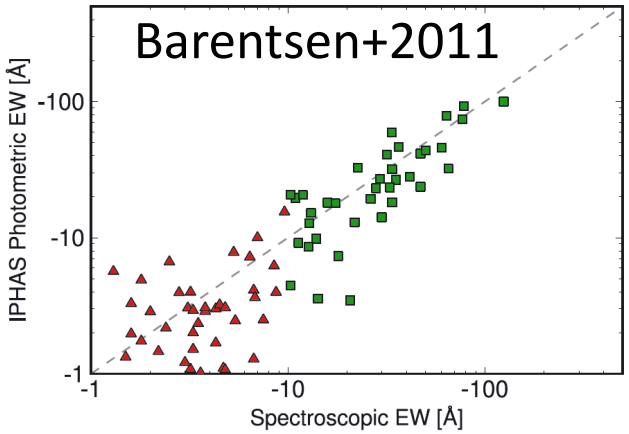


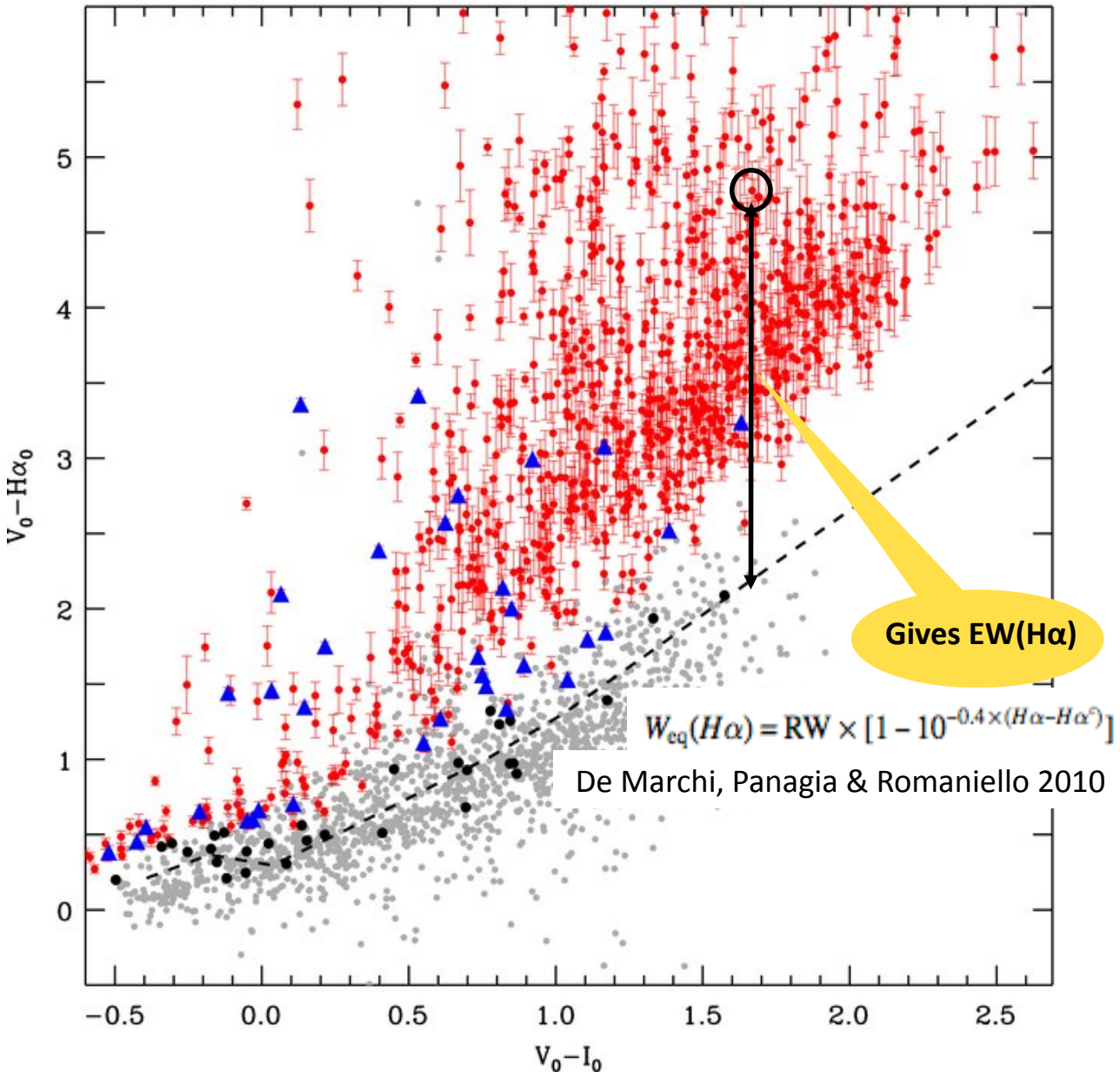
=How?=(2)

Beccari et al. 2010, ApJ, 720, 1108

Stars with no Hα excess

Stars with Hα excess (distance in V-Hα from emp.law.> 5 combined V and Hα color error



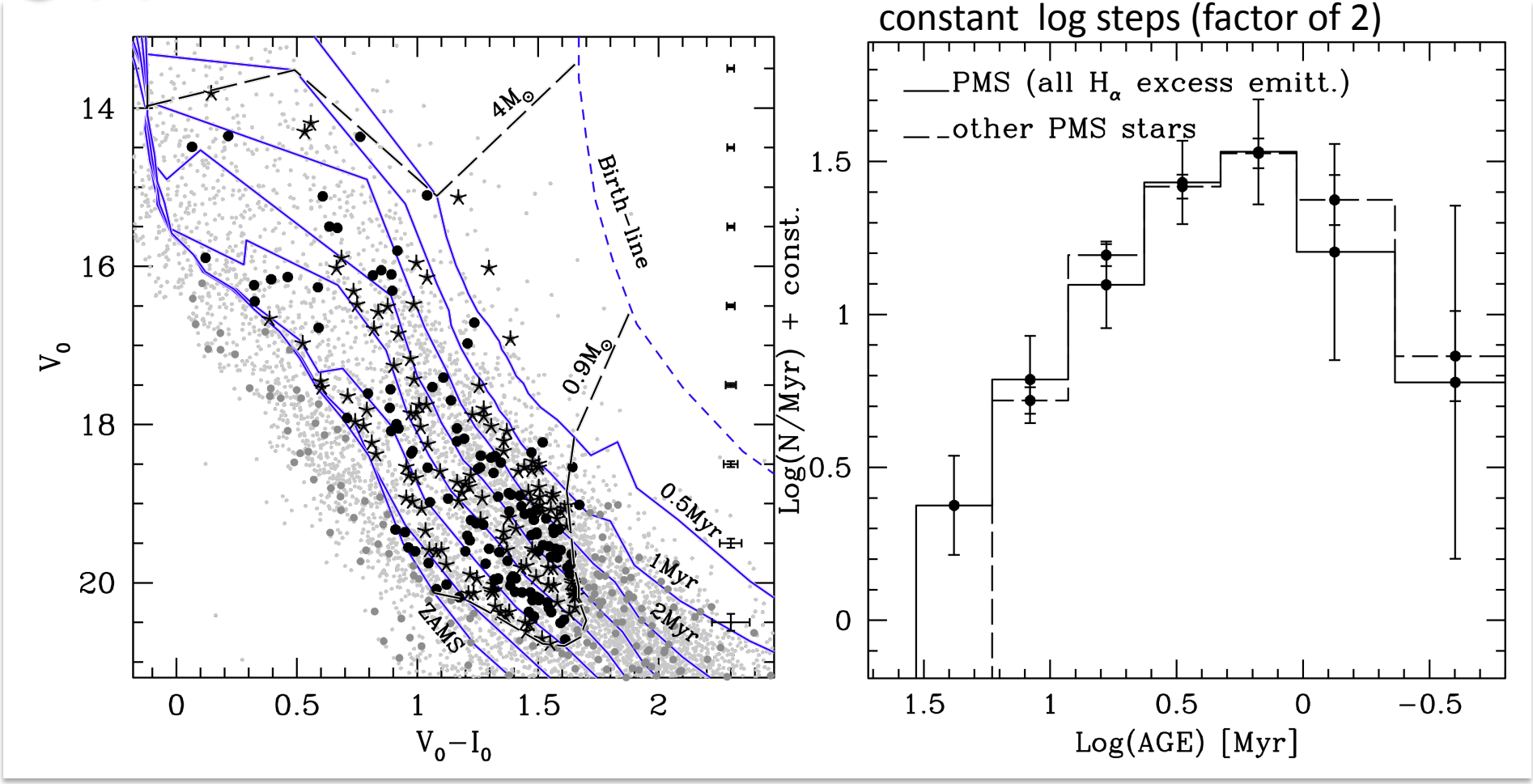


EW(Hα)>20AA !no chromosphere activity (CA)!

=How?=(3)

PMS (Ha excess emitters)

Solid line: age distribution with constant log steps (factor of 2)



Beccari et al. (2010)

Stars physical parameters for more that 1000 PMSs

- **Hα luminosity $L_{H\alpha}$ gives accretion luminosity L_{acc} via relationship calibrated using spectroscopic data** (e.g. Dahm 2008)

$$\text{Log}\,(L_{acc}) = \text{Log}\,(L_{H\alpha}) + (1.72 \pm 0.25)$$

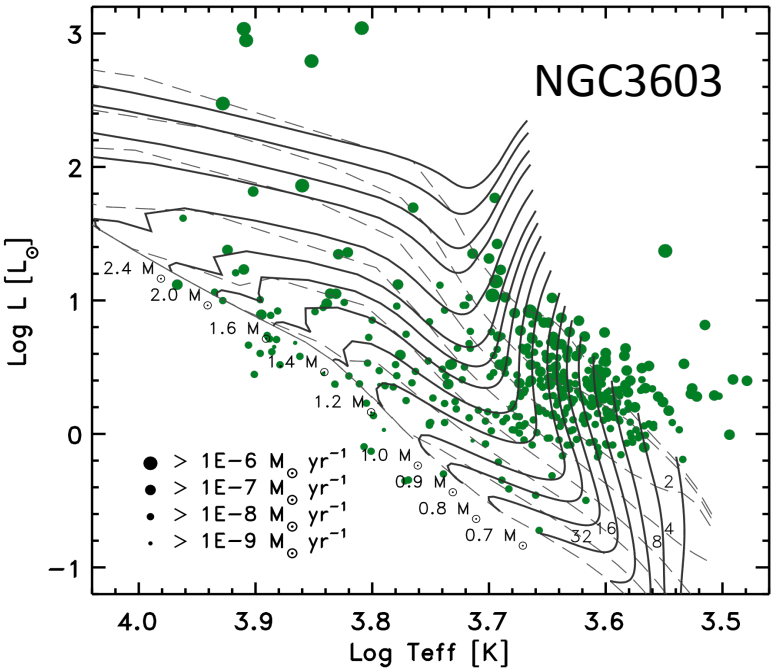
- **Mass $M_\star$ radius $R_\star$ and age $t_\star$ from PMS isochrones in HR diagram**

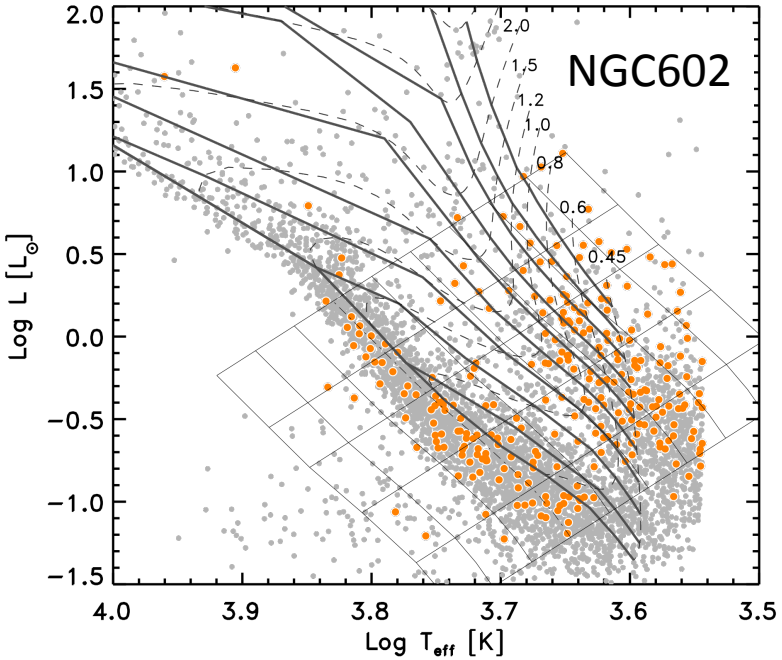
- **Free fall equation gives mass accretion rate $\dot{M}$**

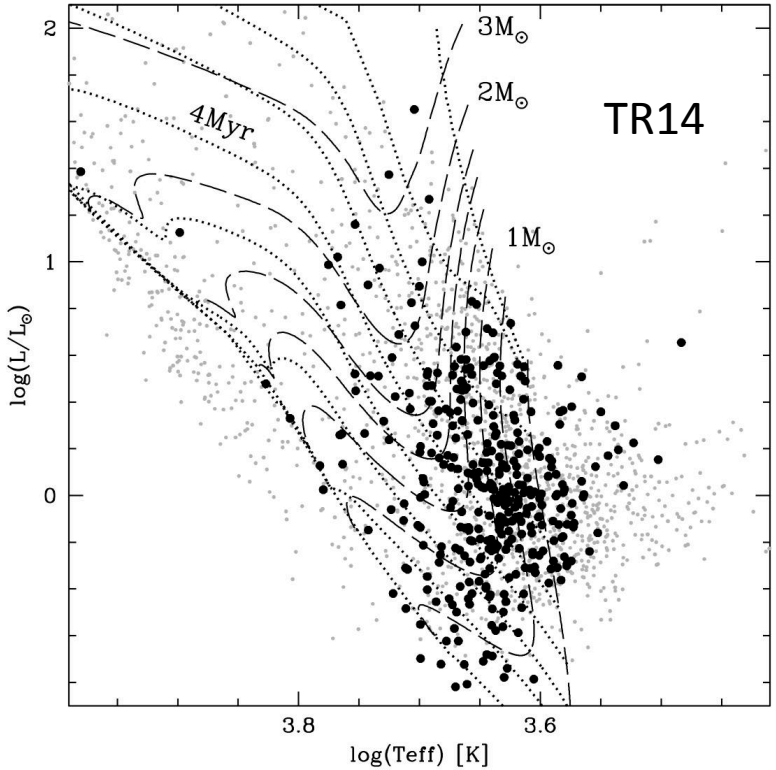
$$L_{acc} \simeq \frac{GM_*\dot{M}}{R_*}\left(1 - \frac{R_*}{R_{in}}\right)$$

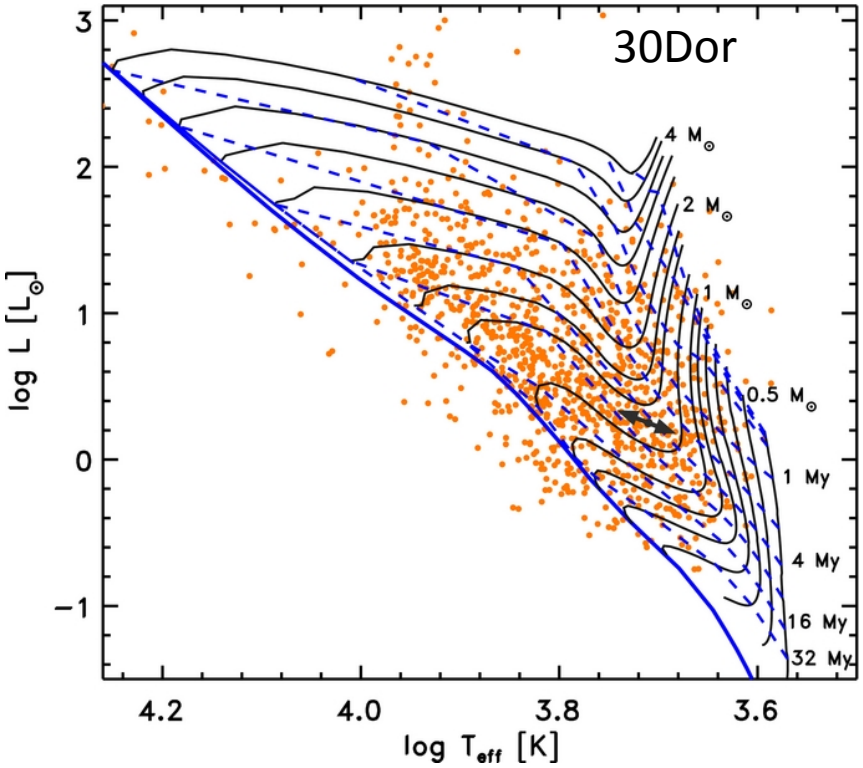
- **We can study how star formation has proceeded in space and time**

Results (1):10-30Myr age spreads


NGC3603
Log L [L⊙]
Log Teff [K]
2.4 M⊙
2.0 M⊙
1.6 M⊙
1.4 M⊙
1.2 M⊙
1.0 M⊙
0.9 M⊙
0.8 M⊙
0.7 M⊙
> 1E−6 M⊙ yr⁻¹
> 1E−7 M⊙ yr⁻¹
> 1E−8 M⊙ yr⁻¹
> 1E−9 M⊙ yr⁻¹

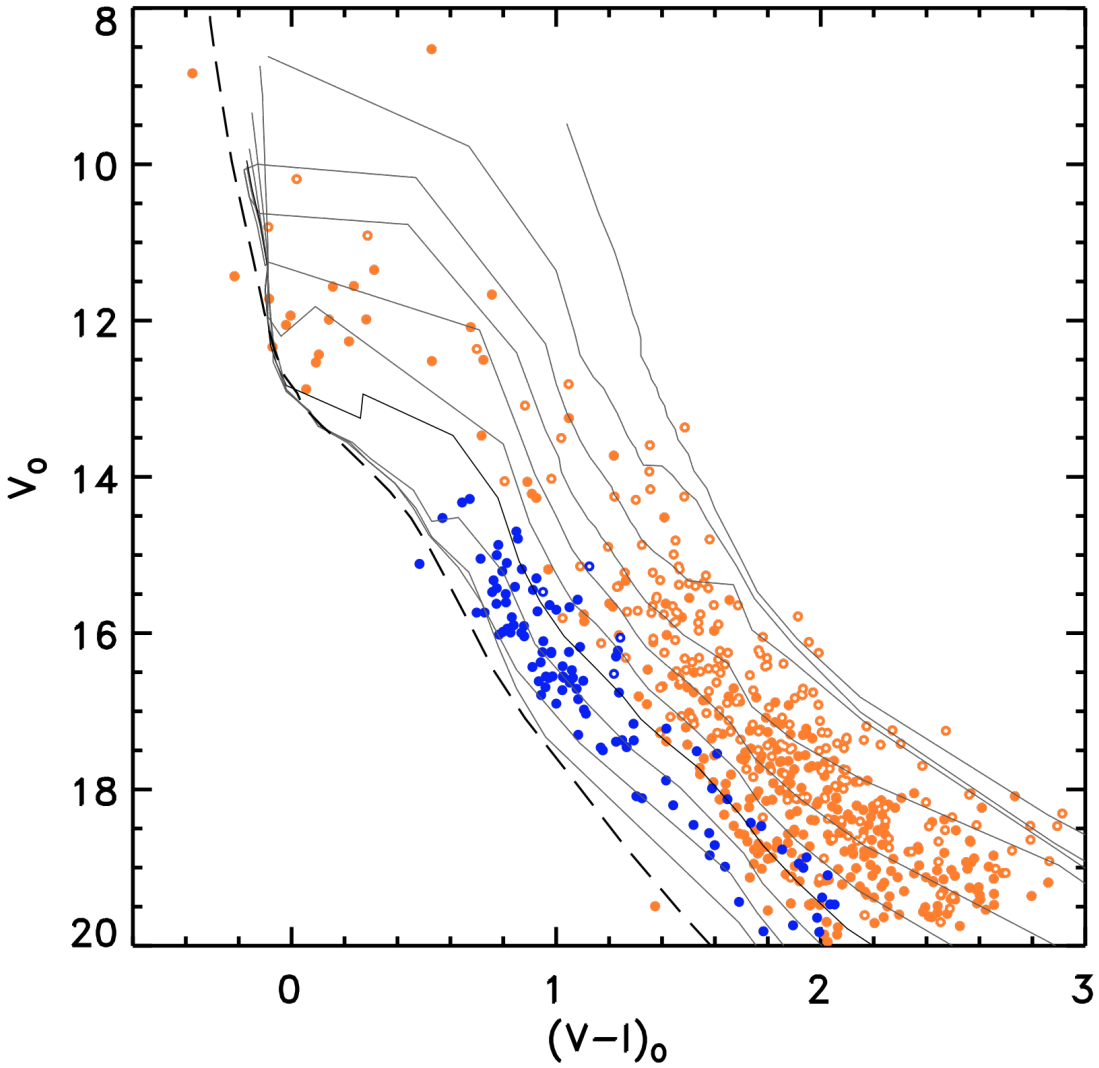

NGC602
Log L [L⊙]
Log T_eff [K]
2.0
1.5
1.2
1.0
0.8
0.6
0.45


TR14
log(L/L⊙)
log(Teff) [K]
3M⊙
2M⊙
1M⊙
4Myr

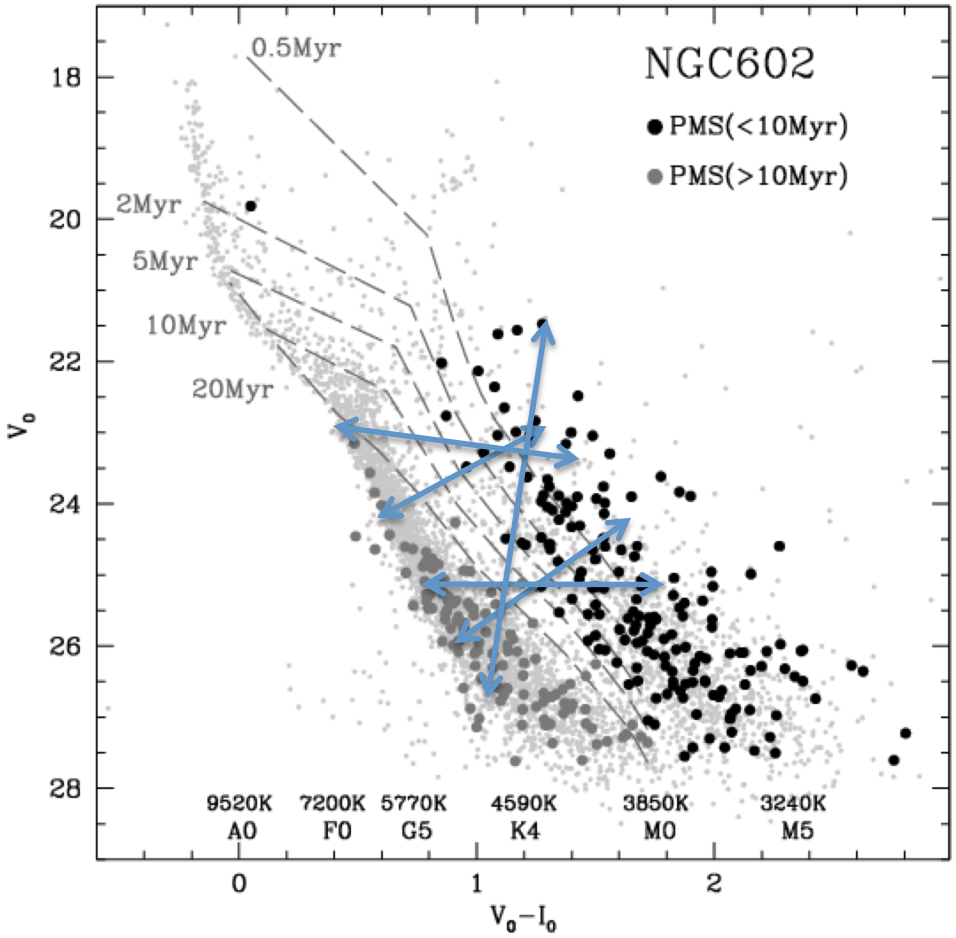

30Dor
log L [L⊙]
log T_eff [K]
4 M⊙
2 M⊙
1 M⊙
0.5 M⊙
1 My
4 My
16 My
32 My

Older stars with NIR excess in M16

De Marchi et al. 2013



Results (2):Different generations have different spatial distribution



Uncertainties:

OBSERVATIONAL

Photometric errors

Differential extinction

Disc inclination

Unresolved binaries

Stellar variability

THEORETICAL

Birth-line position

Mass accretion rates

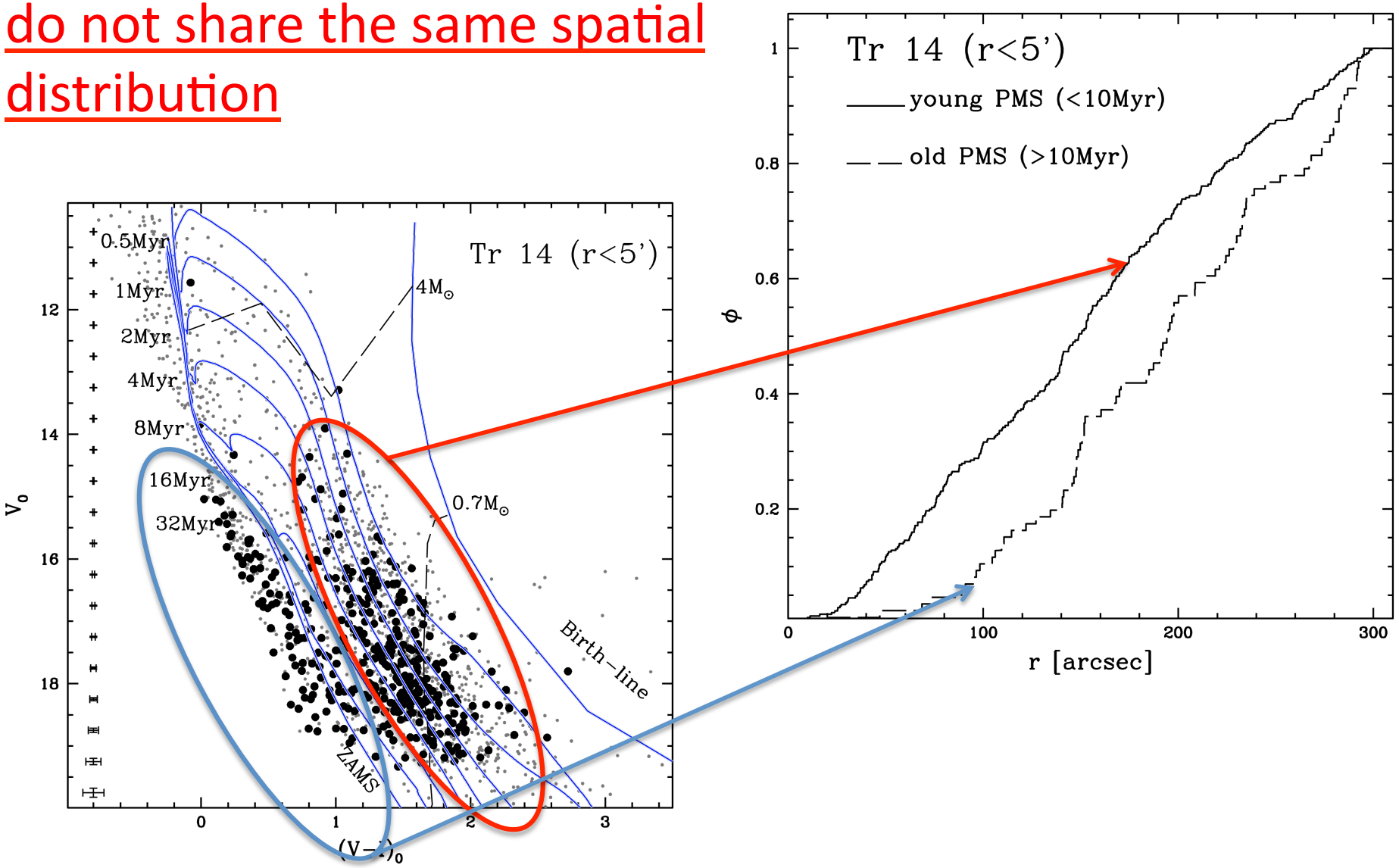
Stellar rotation rates

Massive and episodic accretion

see rev. Preibisch 2012

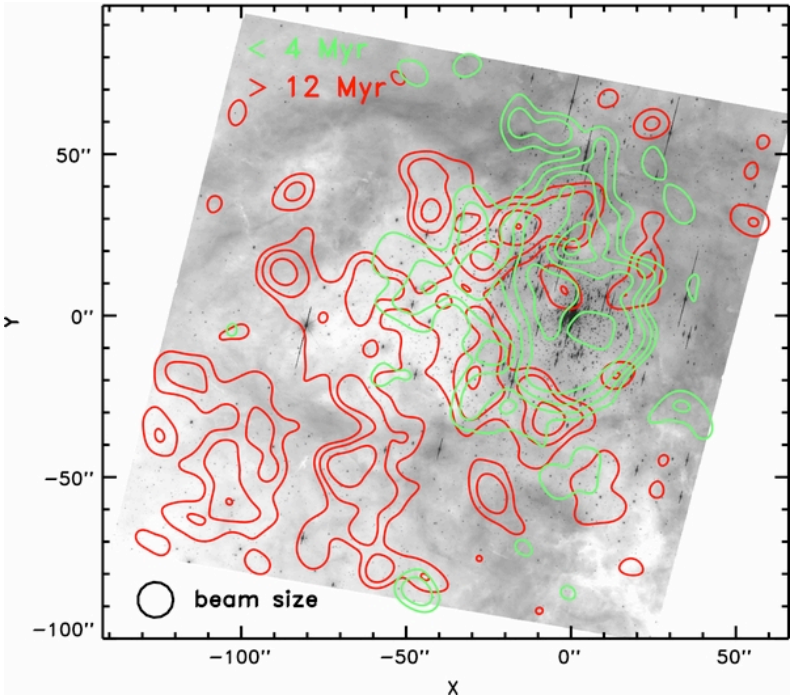
Young and Old generations

do not share the same spatial distribution

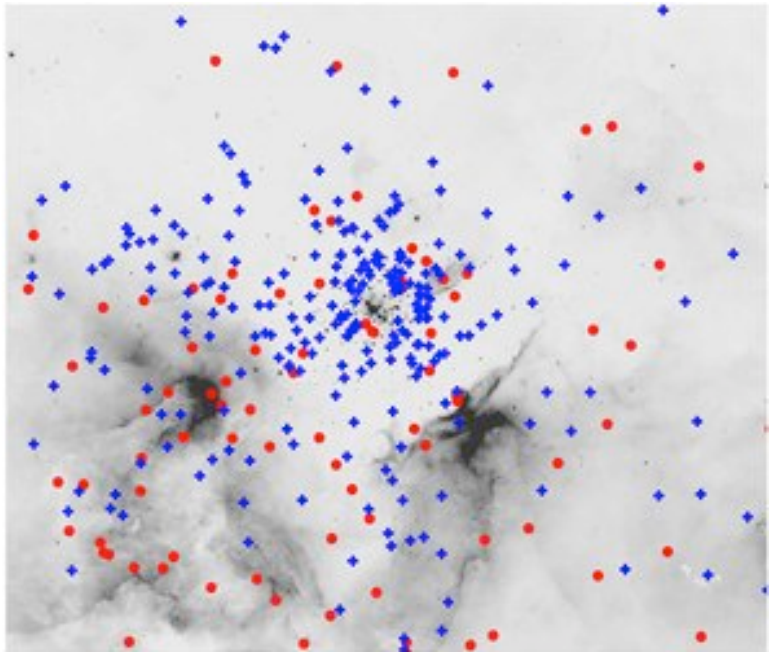


Beccari et al. (2014) A&A submitted

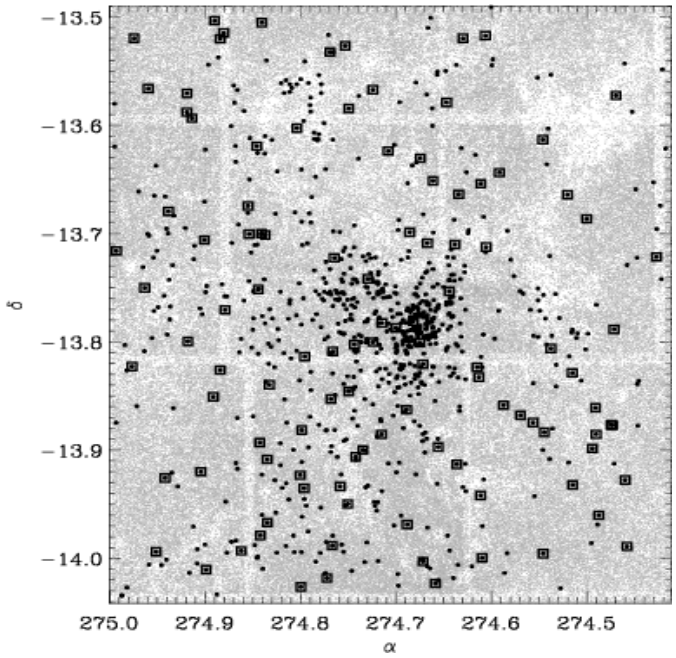
30 Dor - De Marchi et al. 2011b



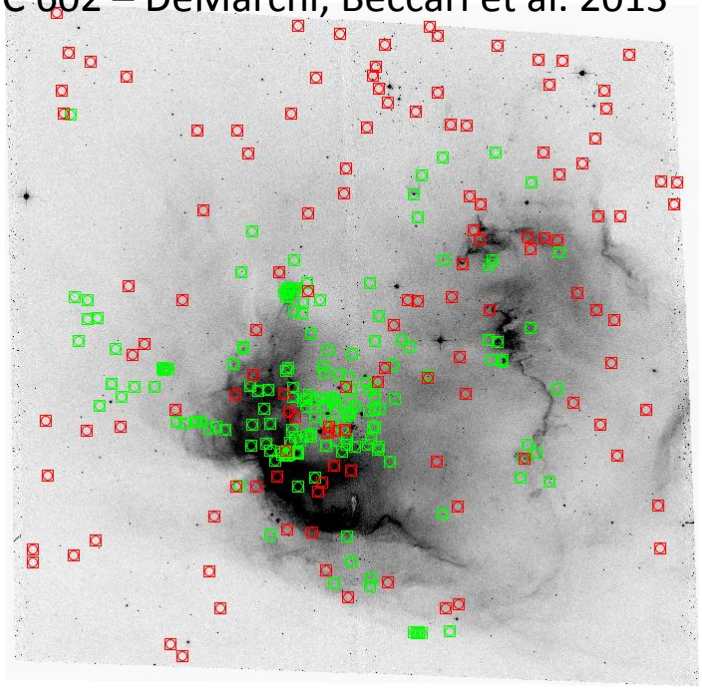
NGC 3603 - Beccari et al. 2010

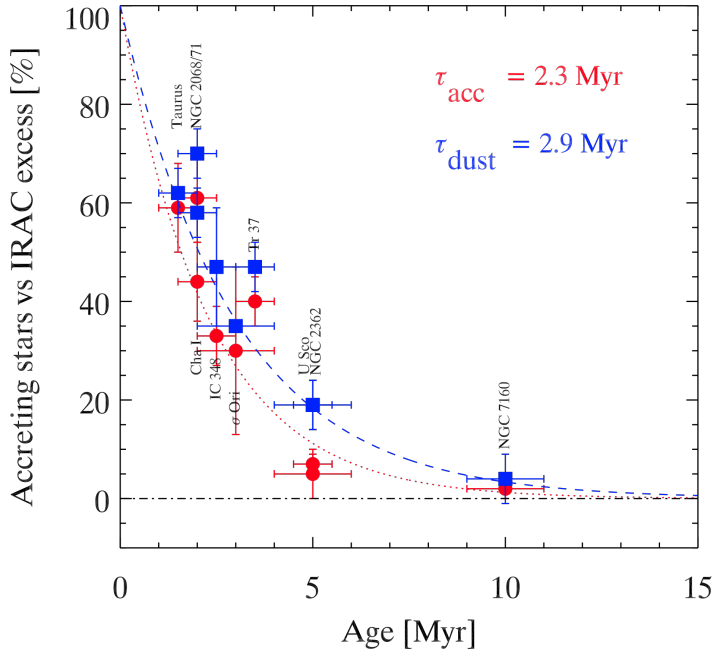


EAGLE NEBULA Guarcello 2010, A&A, 521, 18



NGC 602 – DeMarchi, Beccari et al. 2013





Fedele et al. 2010

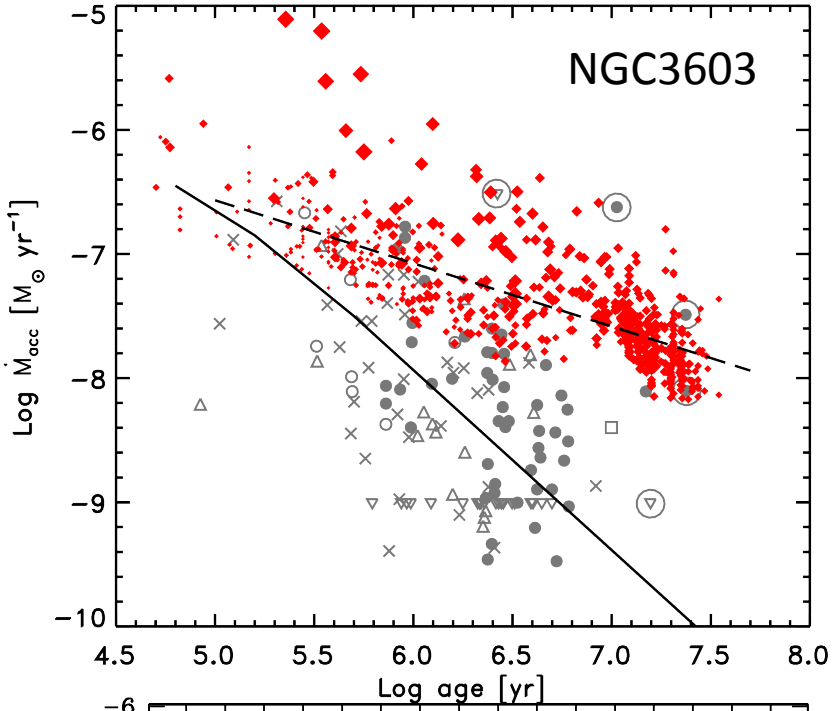
Results (3):Evolution of Macc(t,M$_*$,Z)

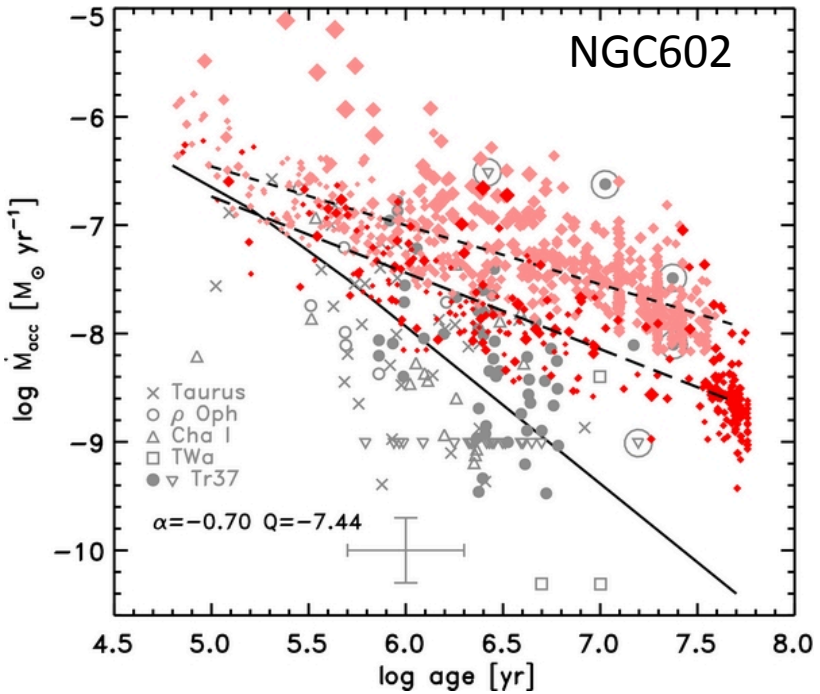
t = ~0Myr to ~30 Myr

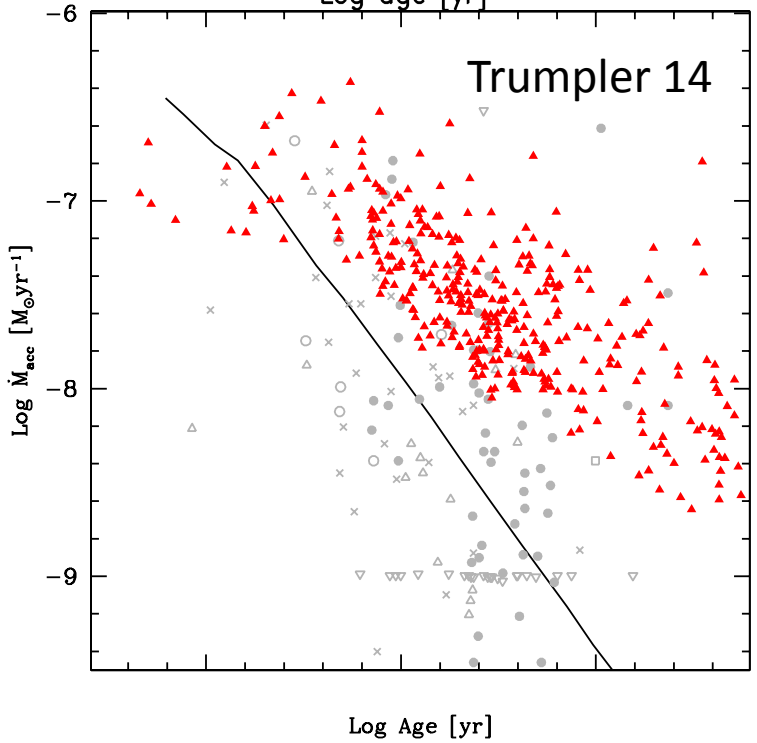
M$_*$= ~0.8Msun to ~3 Msun

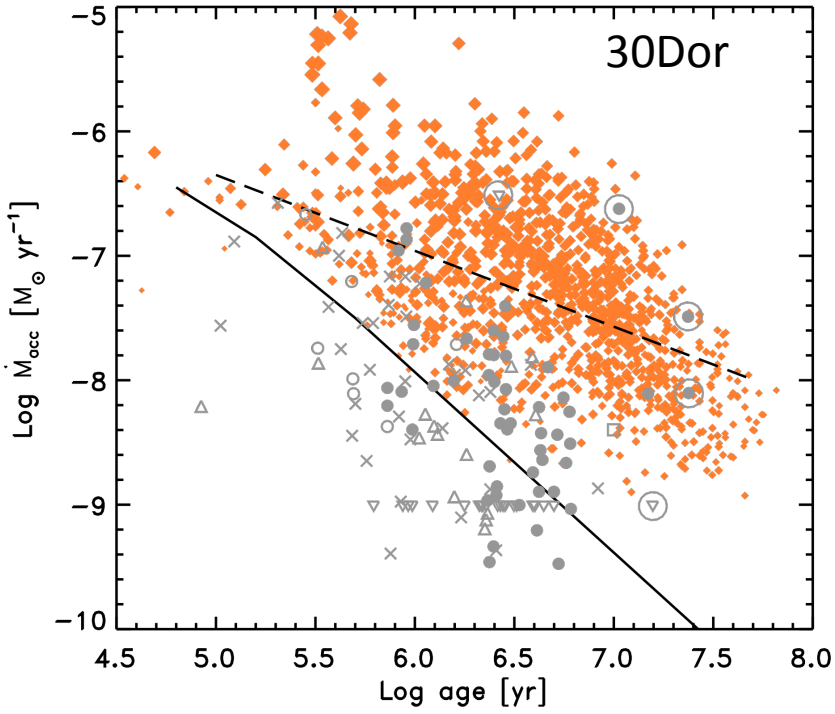
Z = 0.002 (SMC) - 0.007 (LMC) - 0.019 (MW)

$$\log \dot{M}_{\rm acc} = a \times \log t + b \times \log m + c$$

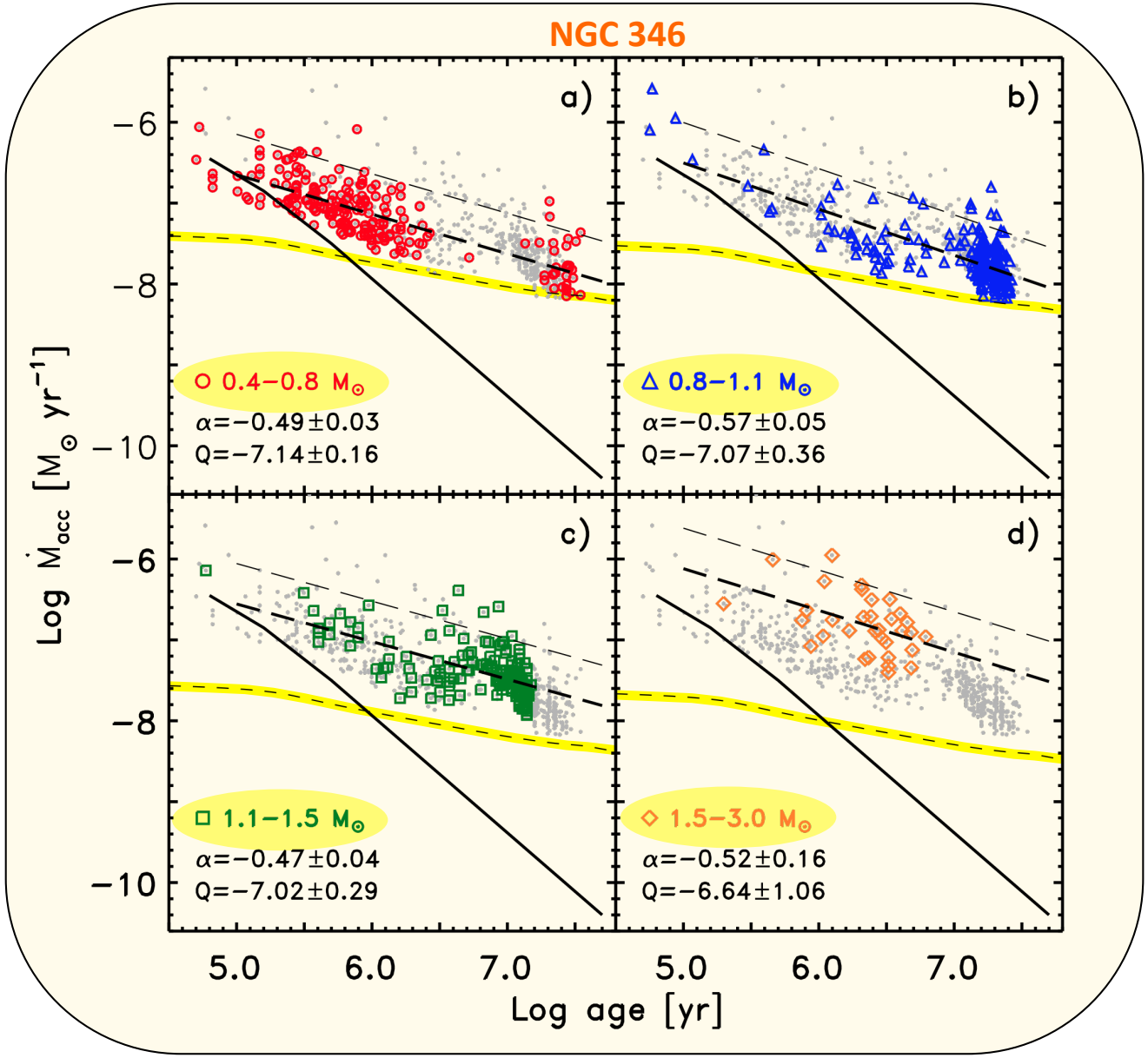

NGC3603
Log $\dot{M}_{acc}$ [$M_\odot$ yr^{-1}]
Log age [yr]


NGC602
log $\dot{M}_{acc}$ [$M_\odot$ yr^{-1}]
log age [yr]
Taurus
ρ Oph
Cha I
TWa
Tr37
α=−0.70 Q=−7.44

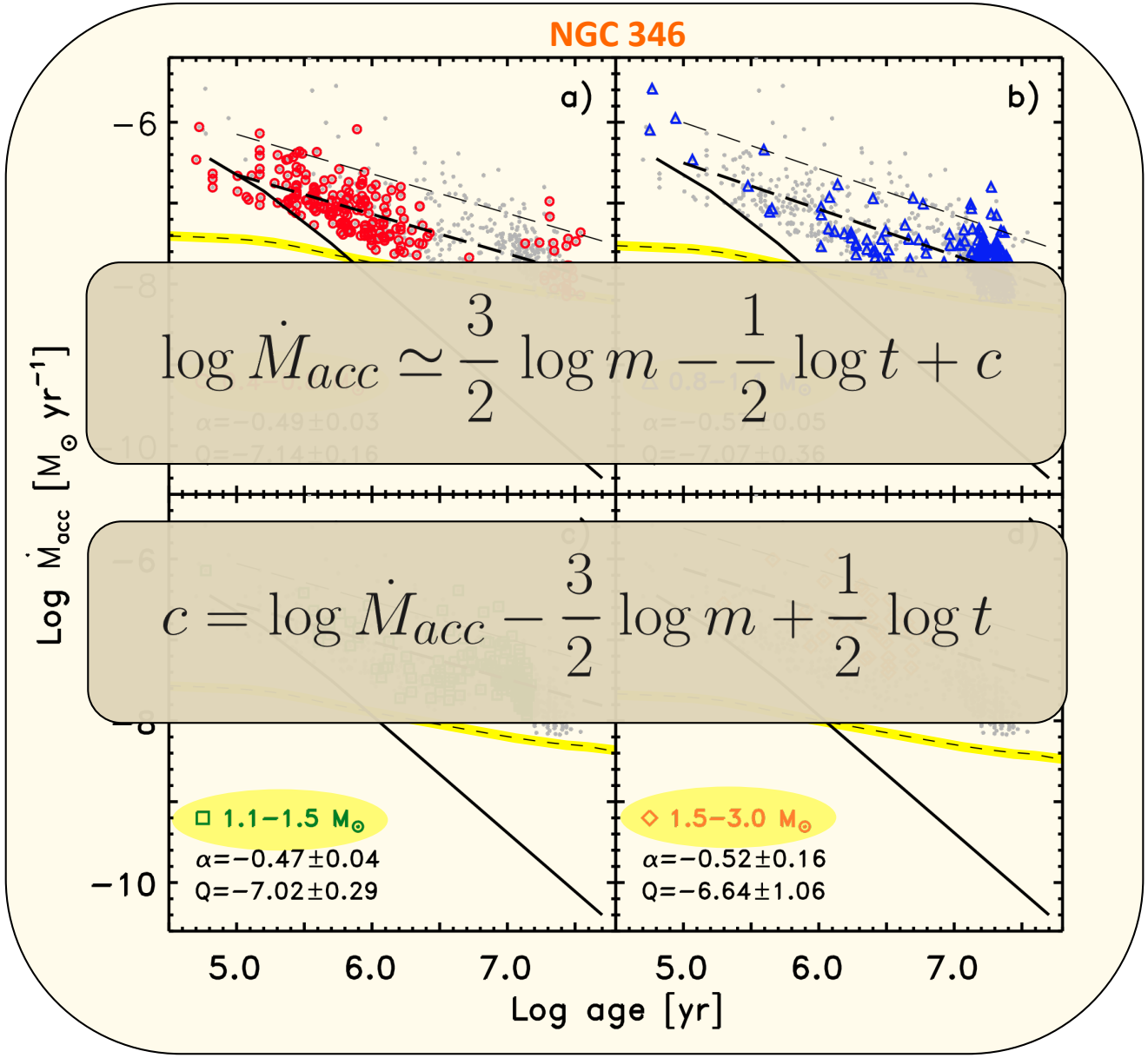

Trumpler 14
Log $\dot{M}_{acc}$ [$M_\odot$yr^{-1}]
Log Age [yr]


30Dor
Log $\dot{M}_{acc}$ [$M_\odot$ yr^{-1}]
Log age [yr]

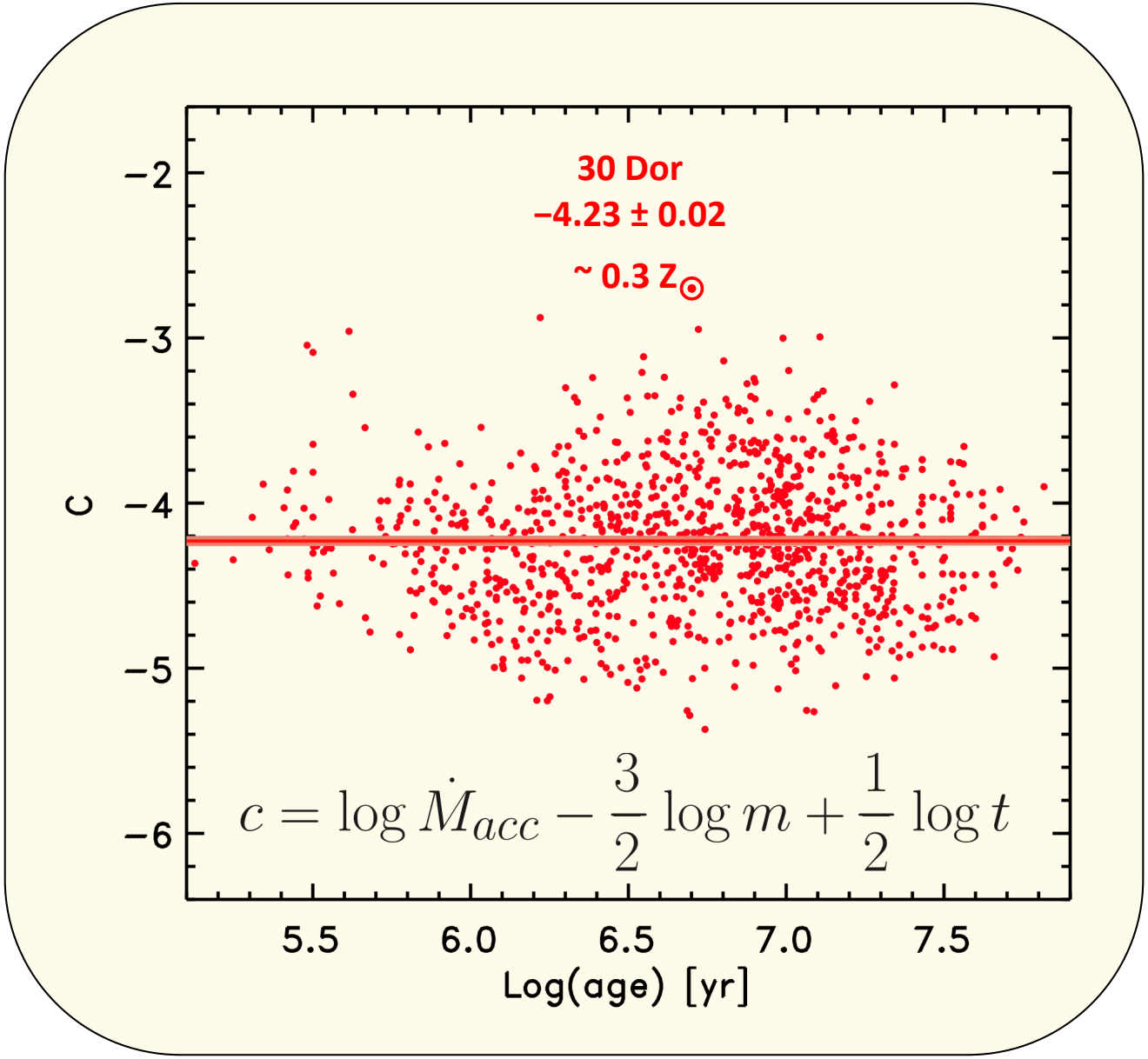
Accretion evolution with time & mass



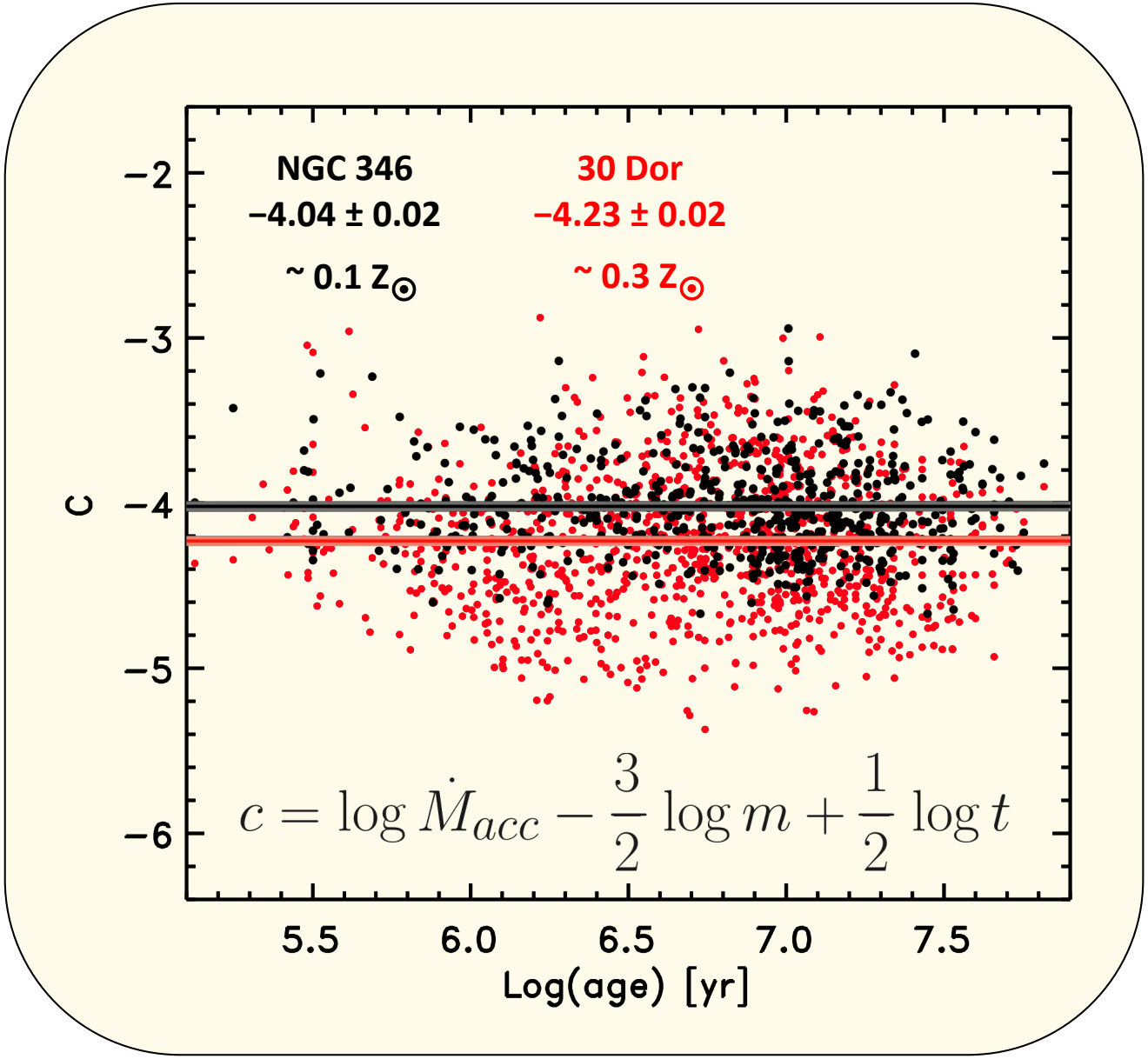
Accretion evolution with time & mass



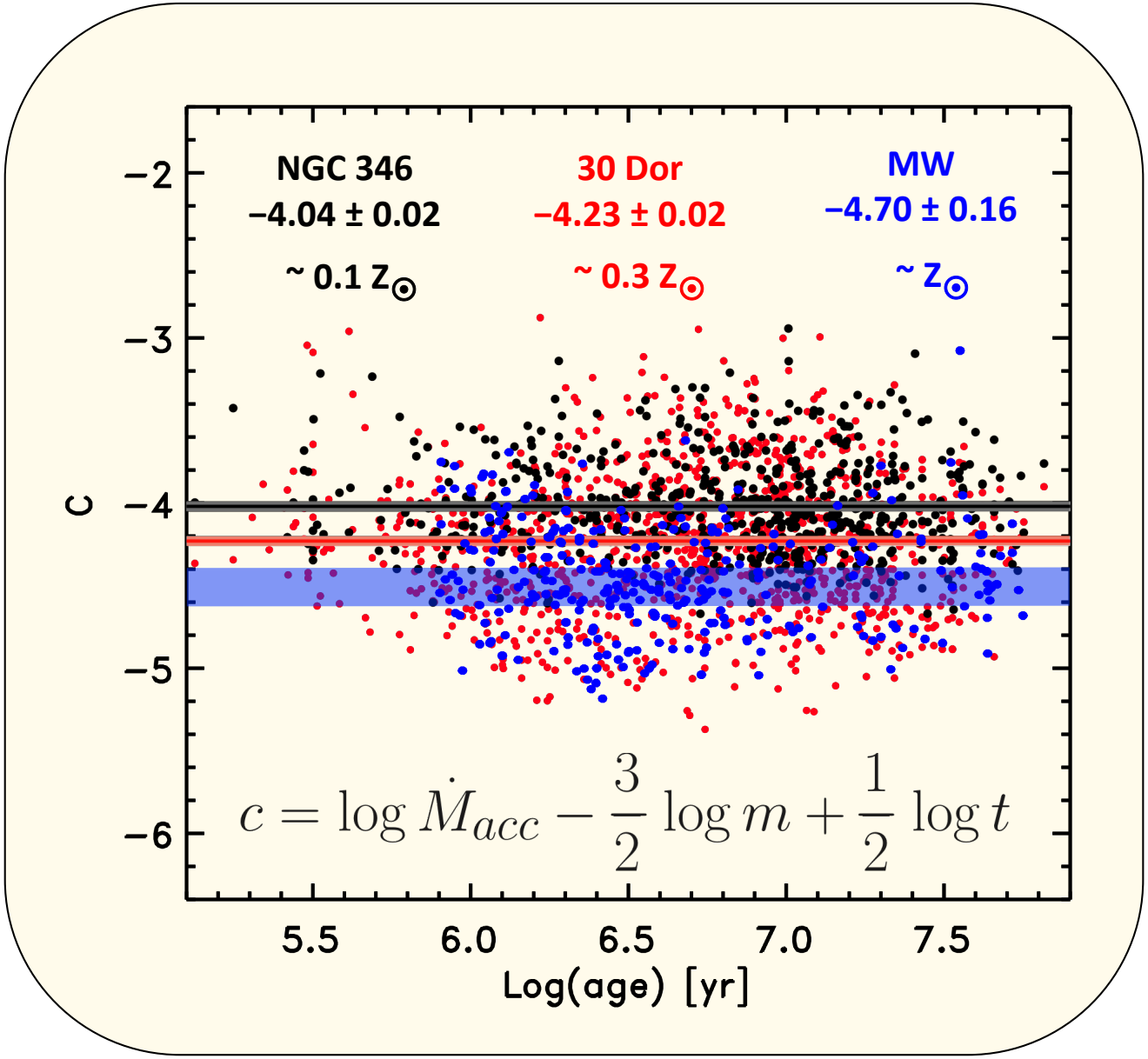
Accretion rate and metallicity



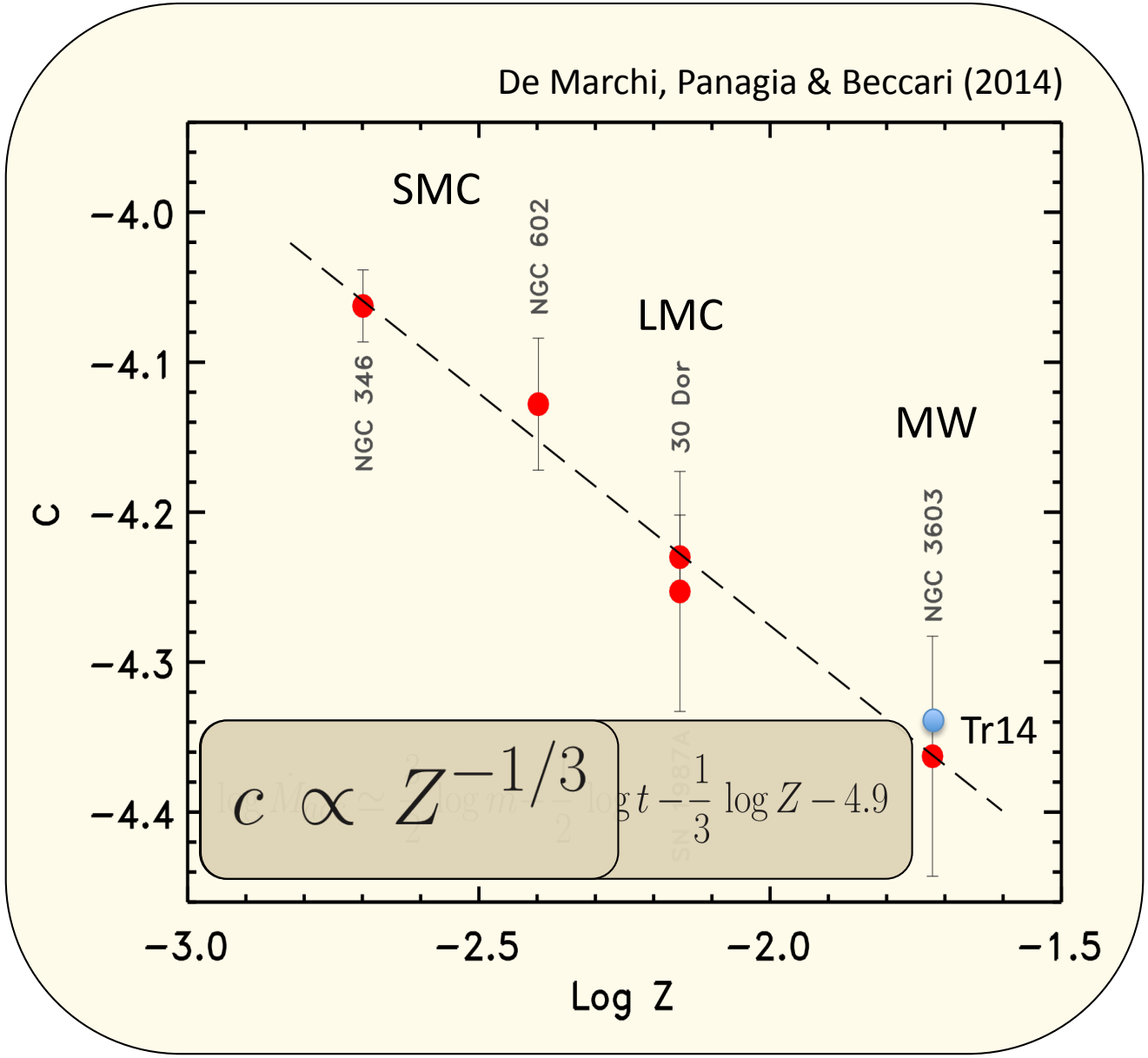
Accretion rate and metallicity



Accretion rate and metallicity



Accretion rate and metallicity




Star formation ... made in Europe
www.starformation.eu
Reader
JWST webinar
RSSD
two-body
SMAC
TSE
Intranet
IDL Help
Simbad
Dictionaries
Scholar
astro-ph
ADS
Calendar
Google
star formation
made in europe
Guido De Marchi
Nino Panagia
Martino Romaniello
Giacomo Beccari
Francesco Paresce
Loredana Spezzi
Elena Sabbi
Marco Sirianni
Morten Andersen
recent papers
older papers
people
mail
Home
Recent papers
Paper I
Paper II
Paper III
Paper IV
Paper V
STScI May Symposium
Paper VI
Paper VII
Paper VIII
Paper IX
Older papers
2004
2002
2000
1998
1994
Introduction
We are a group of European scientists
provides a selection of our papers. Some are
published, others have been
written. You can scroll down or use the
navigation bar on the
papers that you want to see. If you want to know more about a paper,
please write to us at
www.starformation.eu
papers
Paper I (2010)
Photometric determination of the mass accretion rates of pre-main sequence stars. I. Method and application to the SN1987A field
Guido De Marchi (ESA), Nino Panagia (STScI, INAF-CT, Supernova Ltd), Martino Romaniello (ESO)

Conclusions

- **Multiple generations always seen, Δt ~ 10 Myr**

  LMC: 30 Dor, SN 1987A, NGC 1850
  SMC: NGC 346, NGC 602
  MW: NGC 3603, M16, Trumpler 14 (Carina Nebula)
  Star formation episodes not spatially correlated

  Younger generation usually more concentrated

- **At low Z accretion process stronger and longer**

$$\log \dot{M}_{acc} \simeq \frac{3}{2} \log m - \frac{1}{2} \log t - \frac{1}{3} \log Z - 4.9$$

  important constraints for theory of star formation

➔ We have 24 HST orbits (WFC3) and 7 nights at 2.2ESO/MPI (WFI)+ FLAMES spectra to perform a survey of YMC in the Hα