Mass accretion rates from HST photometry
The case of LH95 in the Large Magellanic Cloud

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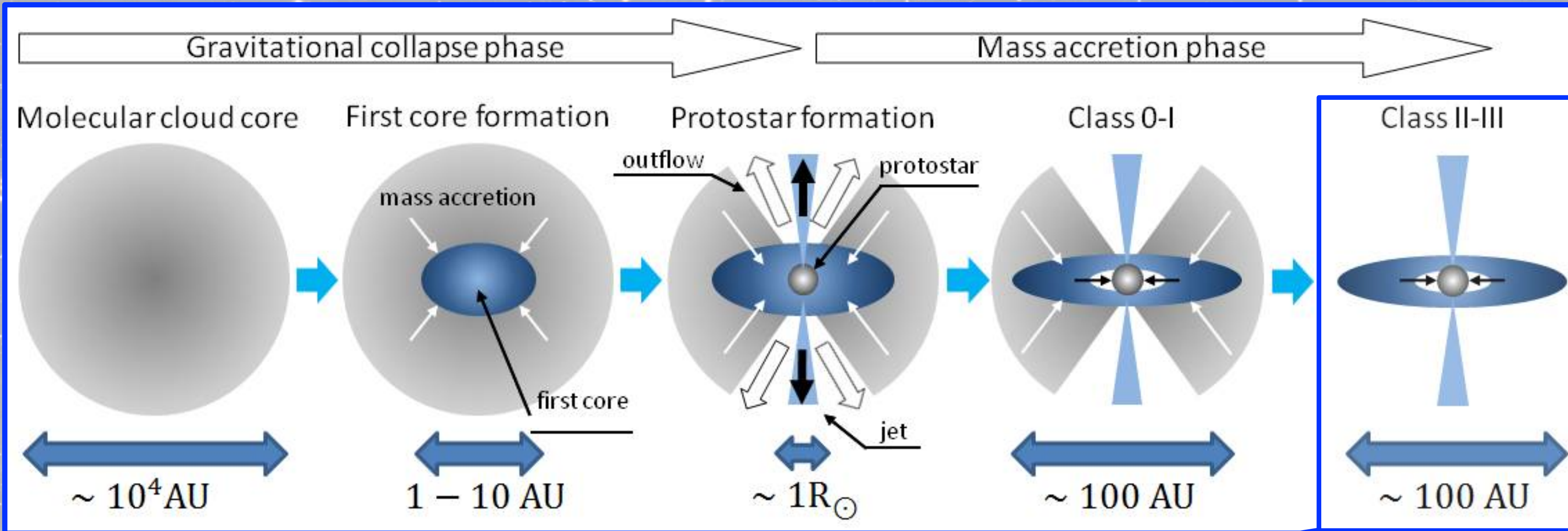
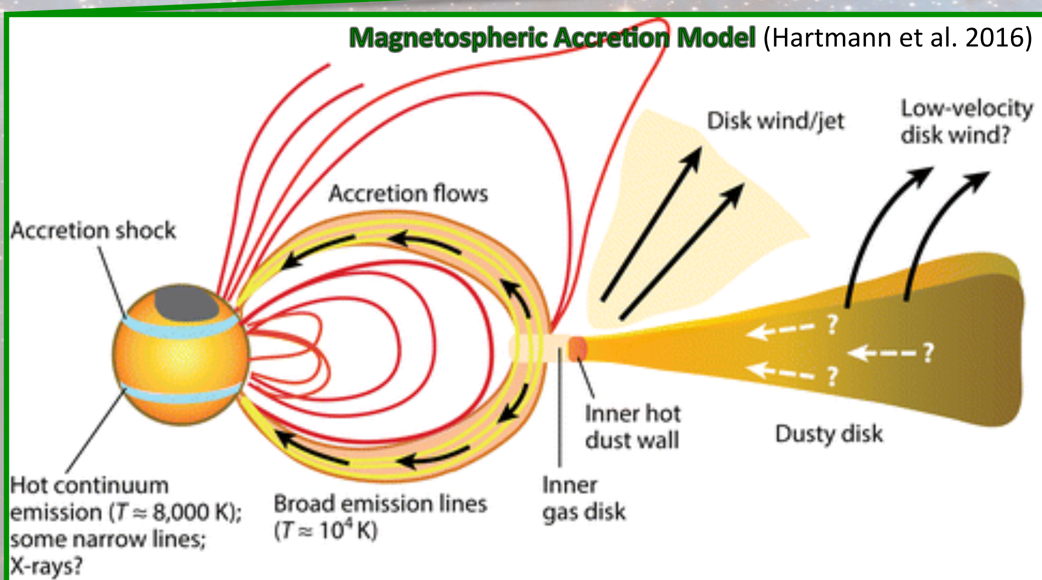
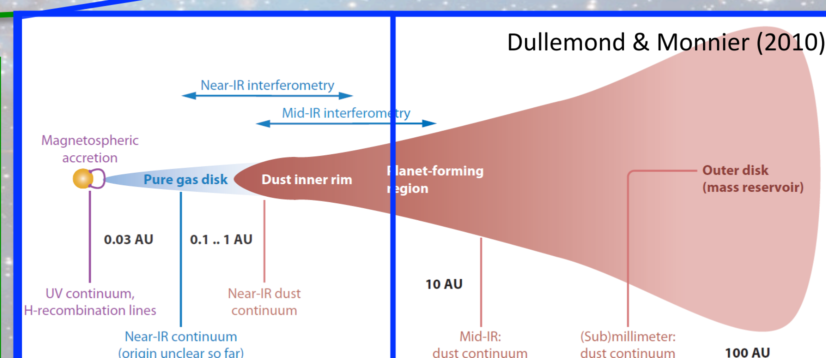
Accretion from a circumstellar disk



Credits: Tsukamoto



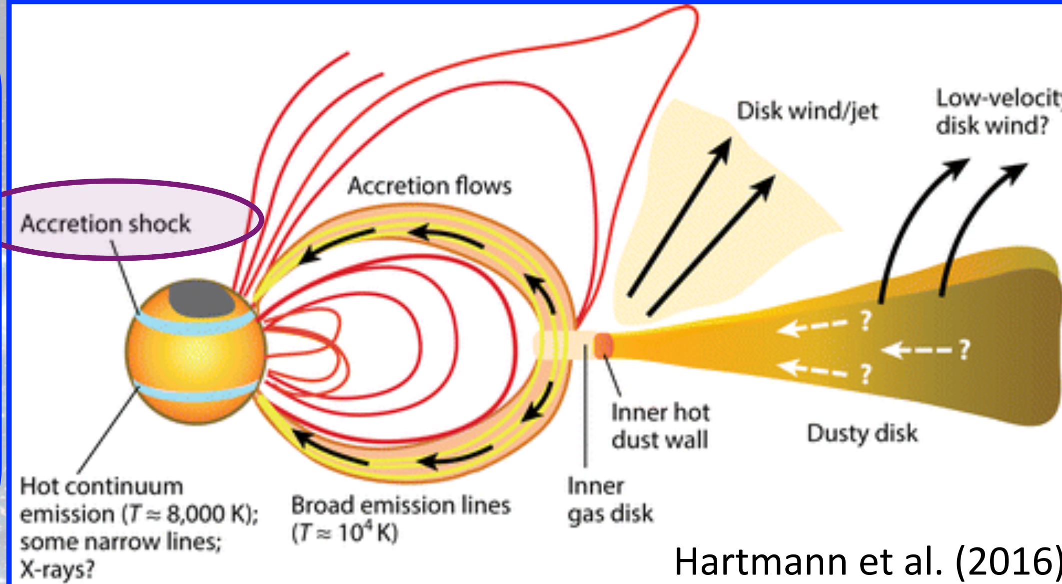


Talk by Carlo Manara & Laura Venuti

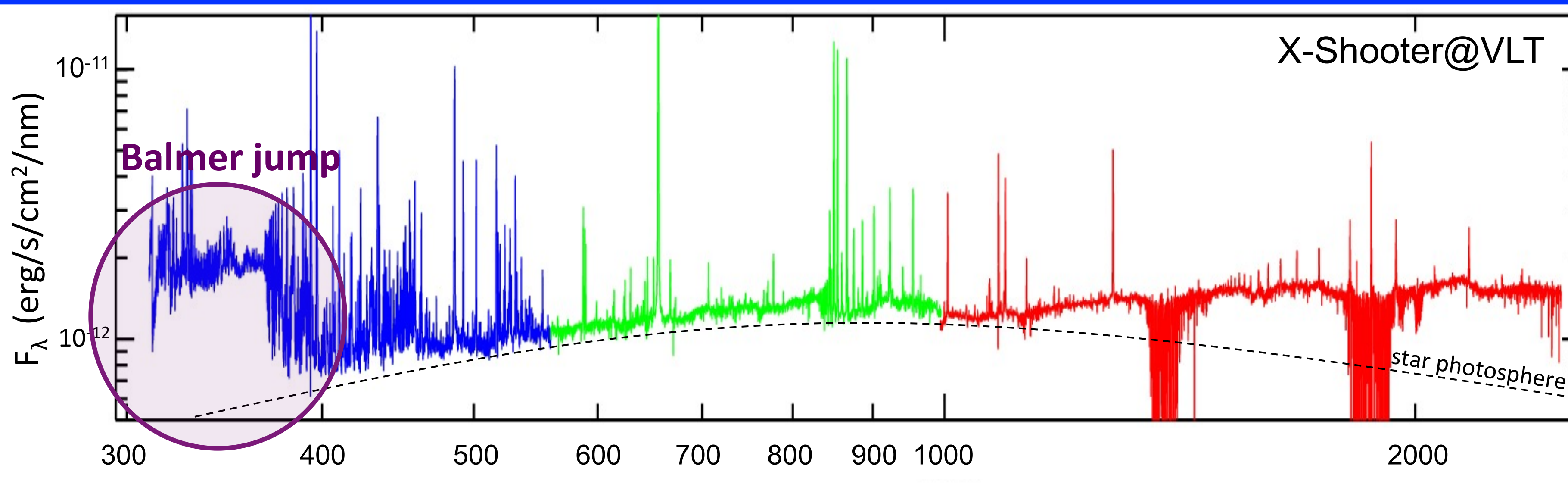
Signature of accretion process

Multiple Tracers from UV to NIR

- UV-optical continuum excess emission: **Accretion shock**



Hartmann et al. (2016)



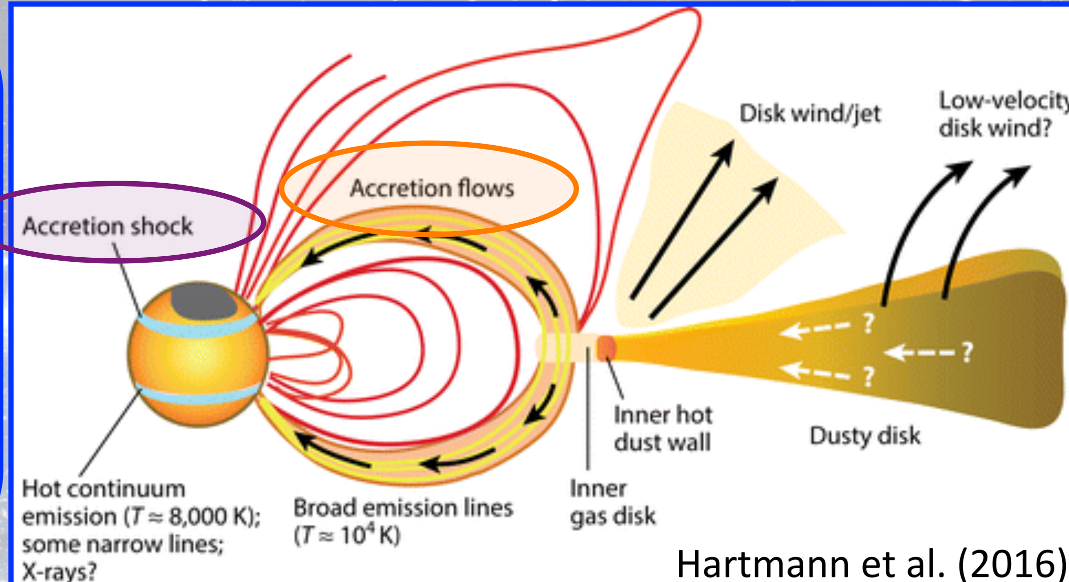
Credits: Antoniucci

Alcalá et al. (2014, 2017)

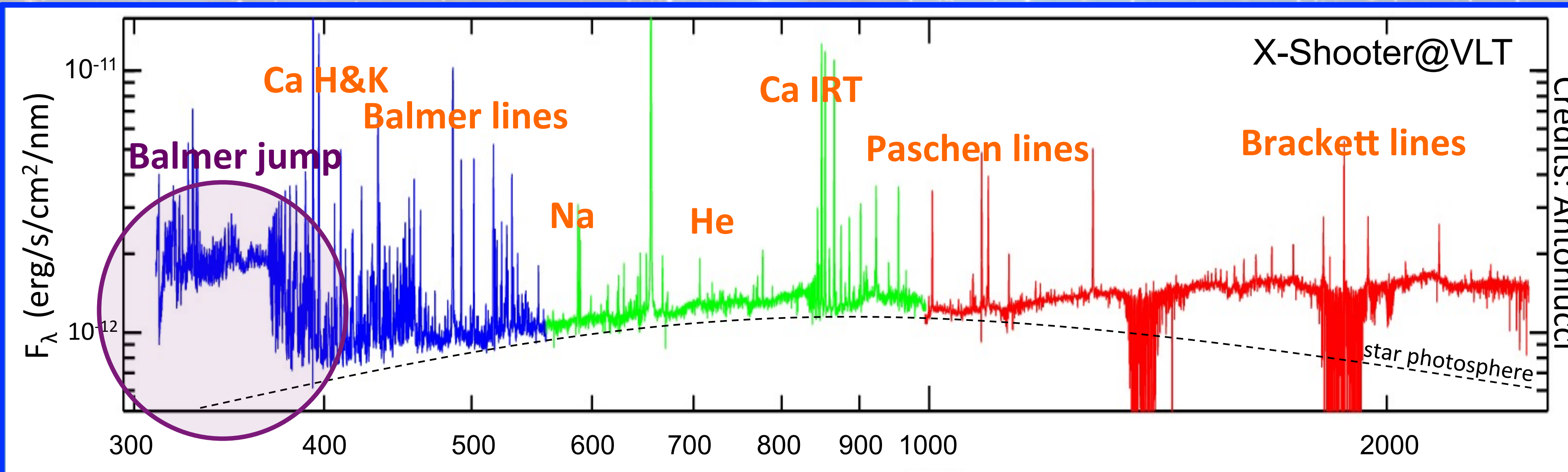
Signature of accretion process

Multiple Tracers from UV to NIR

- ✧ UV-optical continuum excess emission: **Accretion shock**
- ✧ Excess (permitted) line emission (H, He, Ca, Fe, Ti, Na, …): **Accretion flows** (& Winds)



Hartmann et al. (2016)



Alcalá et al. (2014, 2017)

Methods to derive accretion properties

Primary/Secondary diagnostics

- ✧ UV-optical continuum excess $\Longrightarrow$ $\mathbf{L_{acc}}$ (e.g., Herczeg & Hillenbrand 2008, Rigliaco et al. 2012, Alcalá et al. 2014, 2017)
- ✧ Emission lines from infalling gas (e.g., Alcalá et al. 2017)
  - $\log L_{acc} = 1.05 \log L_{H15} + 3.43$ **UV**
  - $\log L_{acc} = 1.25 \log L_{He6678} + 4.70$ **VIS**
  - $\log L_{acc} = 1.19 \log L_{Br\gamma} + 4.02$ **NIR**

Some caveats

- ✧ When L_{acc}-L_{line} relations are used: **asynchronous measurements**, emission lines can trace also winds and chromospheric activity, etc.
- ✧ These methods require spectroscopy, laborious, hence **only some hundreds objects** have measured L_{acc} and $\dot{M}_{acc}$
- ✧ Most regions studied so far are **nearby**, cover a limited range of age, solar metallicity (e.g., Taurus-Auriga, Ophiucus, Lupus, Orion)

What about other environments?

Low Metallicity SFRs

- ✧ Many stars in the Universe formed at redshift z≈2 (e.g., Madau & Dickinson 2014), when metallicity was ≲1/3 $Z_{\odot}$, like in the Magellanic Clouds (De Marchi et al. 2017), but…
- ✧ Spectroscopy of individual stars in MCs hampered by crowding (VLT observations attempted, but limit is angular resolution)

Photometric Method

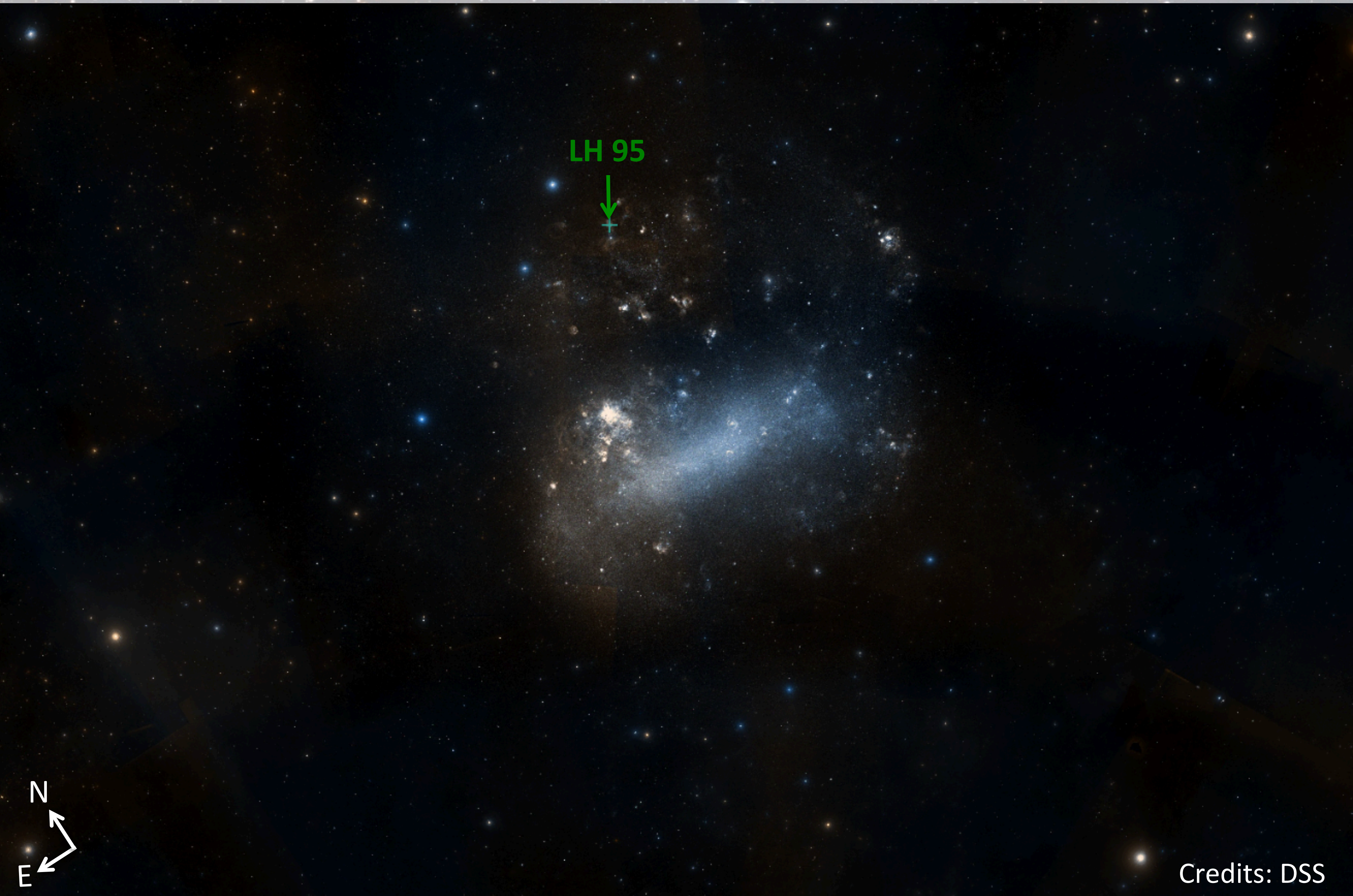
(Tested by De Marchi et al. 2010 in the LMC)

- ✧ It combines broad-band V,I and narrow-band Hα HST photometry, allowing to:
  - **Identify** stars with Hα excess emission
  - Derive their $\mathbf{L_{acc}}$ and $\mathbf{\dot{M}_{acc}}$
  - For **hundreds** of stars **simultaneously**!
- ✧ Applied in several regions of the LMC (De Marchi et al. 2017; Spezzi et al. 2012), SMC (De Marchi et al. 2011, 2013), MW (Beccari et al. 2010, 2015; Zeidler et al. 2016) and confirmed spectroscopically (e.g., Barentsen et al. 2011)

The case of LH95

- ✧ One of nine regions in the MW, LMC, SMC **observed with HST** and representative of different environments (metallicity, star formation rate, density, content of massive stars, etc.)
- ✧ Located **North of the LMC** (Lucke & Hodge 1970), low in density (≈0.06 $M_{\odot}/pc^3$), with a few blue stars (Kontizas et al. 1994), low reddening (Gouliermis et al. 2002)
- ✧ Debated evidence of **age spread** (Da Rio et al. 2010) and **clustering** (Gouliermis et al. 2007)

The case of LH95



The case of LH95

HST Observations

LH 95

Credits: Gouliermis

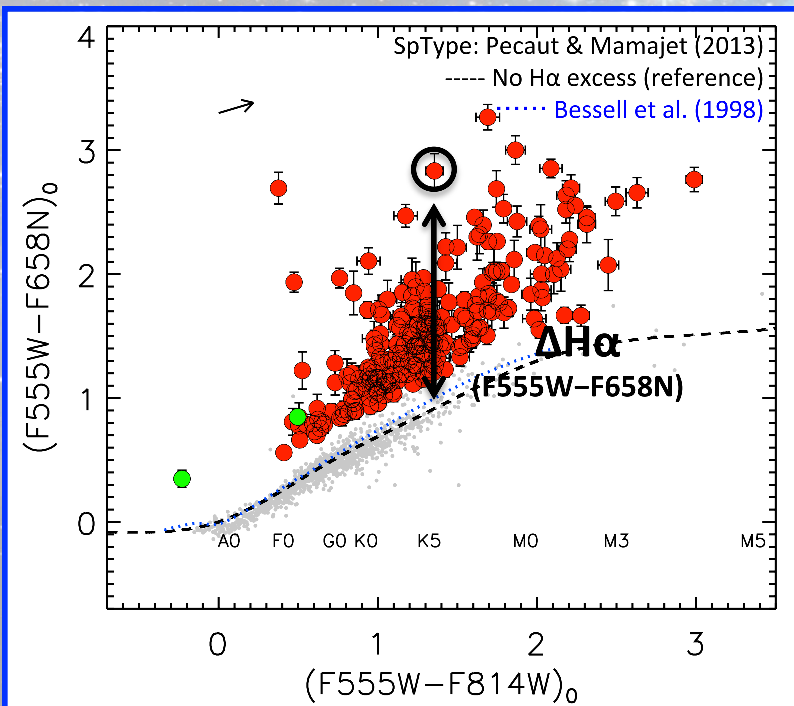
- ACS/WFC photometric data in three bands:
  - **F555W** (**V** band)
  - **F658N** (**Hα** band)
  - **F814W** (**I** band)
- Among the **deepest** observations ever taken toward LMC

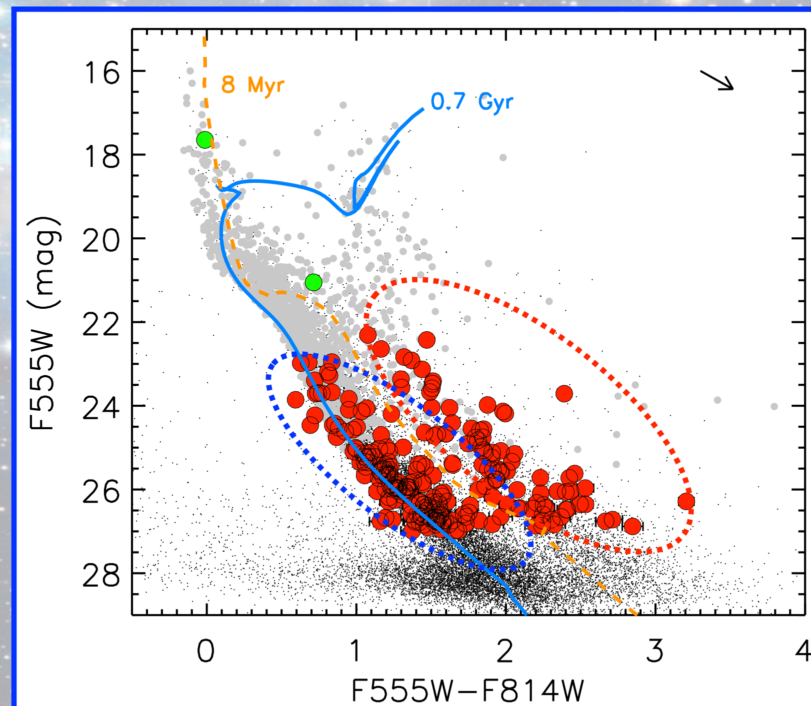
Credits: DSS

The Method

Identification of PMS candidates

- Initial catalogue of 24515 sources (black dots)
- Selection of stars with δ_{555}, δ_{658}, δ_{814}<0.05 mag (1294 most probable old MS; grey dots, dashed line)
- Within the targets with δ_{555}, δ_{814}<0.1 mag, δ_{658}<0.3 mag: **ΔHα > 4σ** (247 bona fide PMS; red circles)

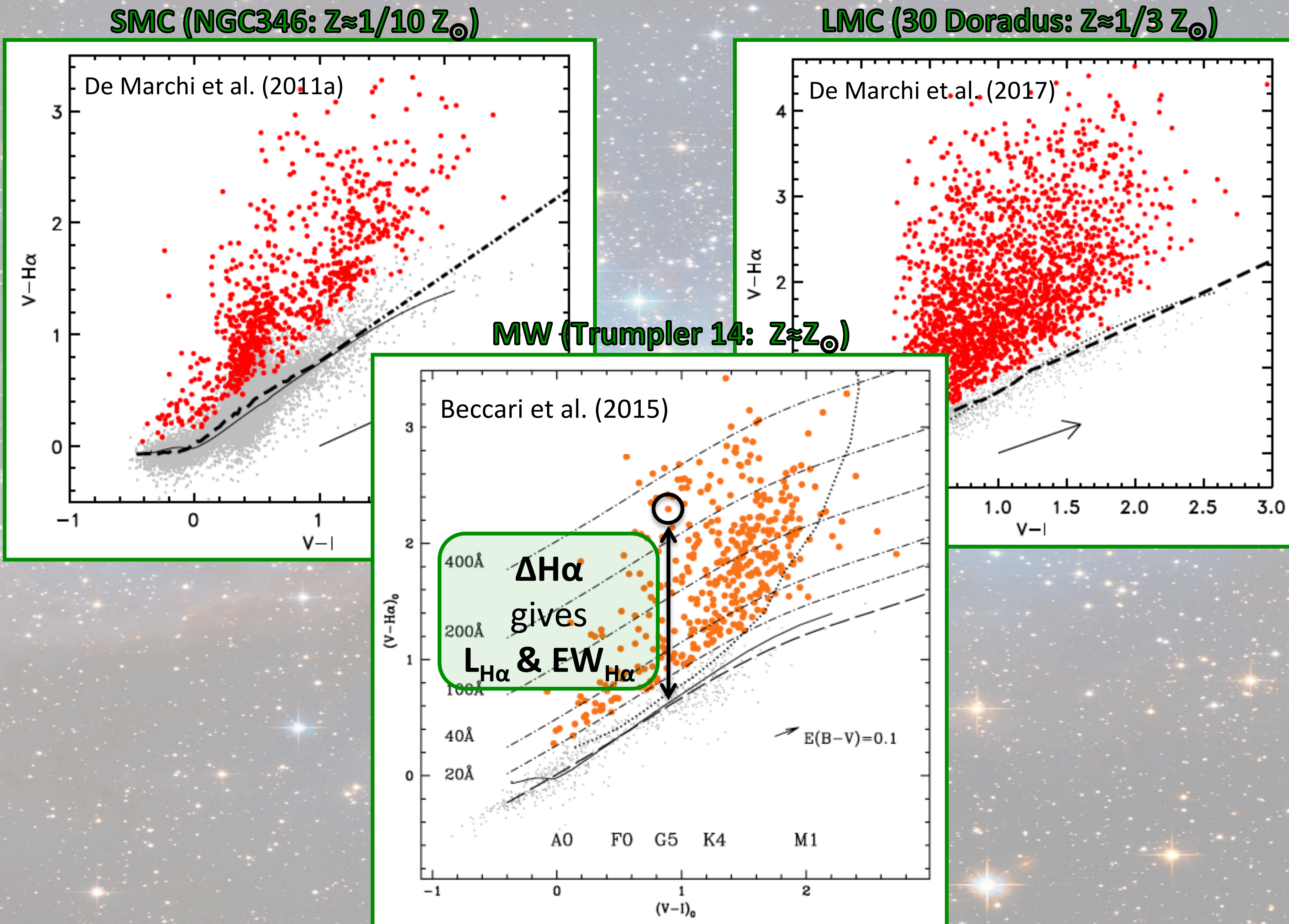




KB, De Marchi, Panagia, Beccari 2018, in prep

- **245 low-mass PMS candidates**
- Evidence of **two populations** (**'Younger'** < 8 Myr; **'Older'** > 8 Myr)

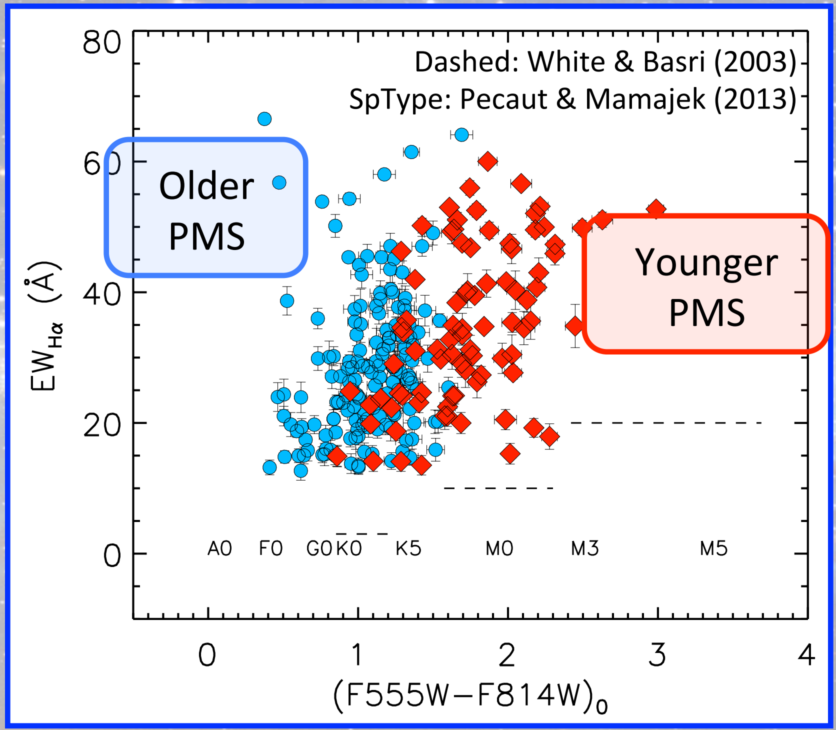
Previous Results in the Local Group



From Hα colour excess to $EW_{H\alpha}$ and $L_{H\alpha}$

$\Delta H\alpha \longrightarrow EW_{H\alpha}$ Instrumental phot. properties (ACS website)

$\langle EW_{H\alpha} \rangle \approx 30$ Å



245 probable low-mass accretors (lower limit)

KB, De Marchi, Panagia, Beccari 2018, in prep

$\Delta H\alpha \longrightarrow L_{H\alpha}$

Instrumental phot. properties (ACS website)
d=51.1±1.2 kpc (Panagia 1999)

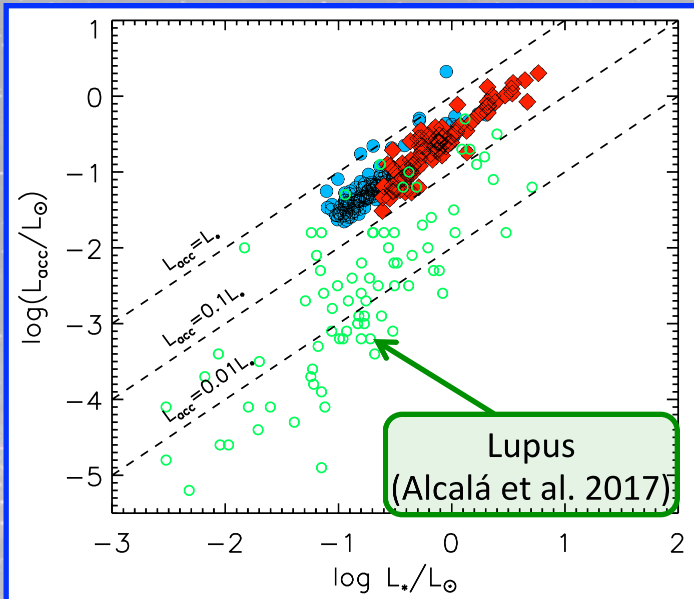
$\langle L_{H\alpha} \rangle \approx 0.2 \times 10^{-2} L_\odot$

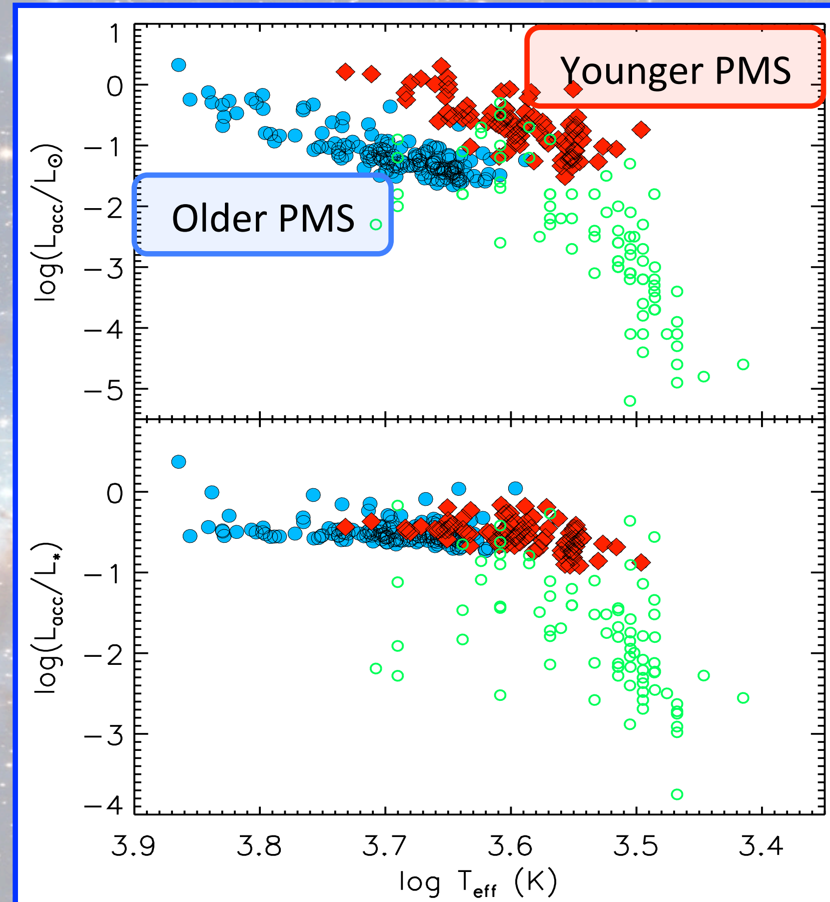
$$\log L_{acc}/L_\odot = (1.13 \pm 0.05) L_{H\alpha}/L_\odot + (1.74 \pm 0.19)$$

(Alcalá et al. 2017)

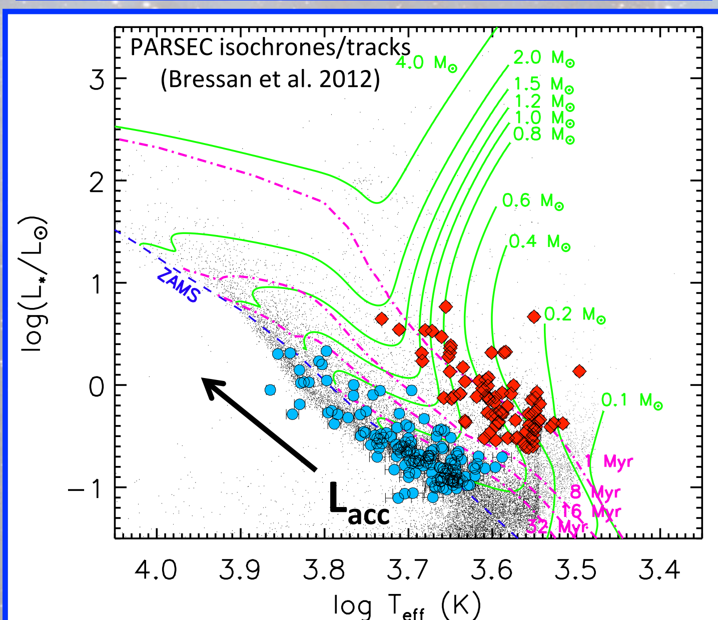
Accretion vs Stellar Parameters

(Luminosity and Effective Temperature)





KB, De Marchi, Panagia, Beccari 2018, in prep



- ✧ **L_{acc} increases with $L_\star$** ($0.1\ L_\star < L_{acc} < L_\star$)
- ✧ L_{acc} higher at **lower Z**
- ✧ **L_{acc} decreases with T_{eff}** while $L_{acc}/L_\star \sim$ flat (see also Manara et al. 2013)
- ✧ **Bimodal distribution**

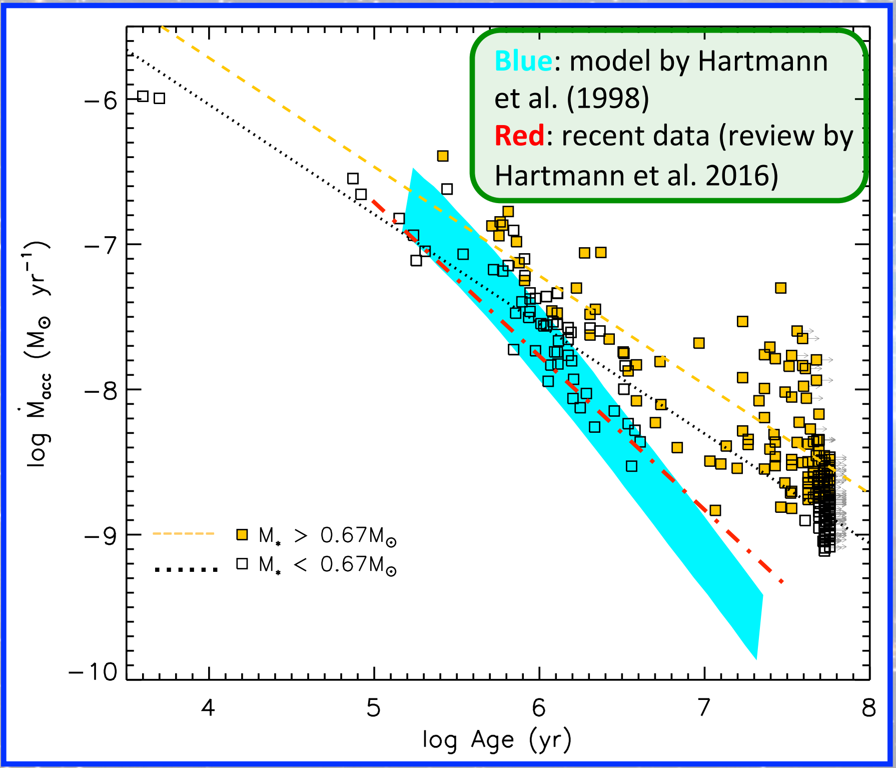
Accretion evolution with Time & Mass

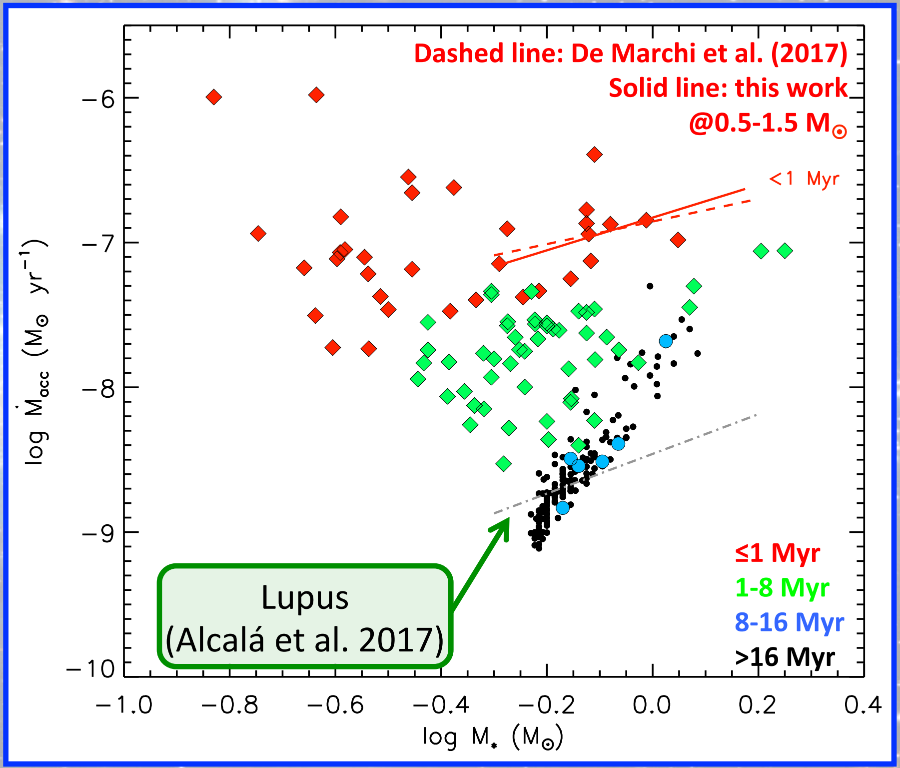
Hartmann (1998)

$$\dot{M}^{H\alpha}_{acc} = \left(1-\frac{R_*}{R_{in}}\right)^{-1}\frac{L^{H\alpha}_{acc}R_*}{GM_*}$$

$M_\star$, $R_\star$ stellar mass and radius
$R_{in} \approx 5R_\star$ disk inner radius
G universal gravitational constant

KB, De Marchi, Panagia, Beccari 2018, in prep

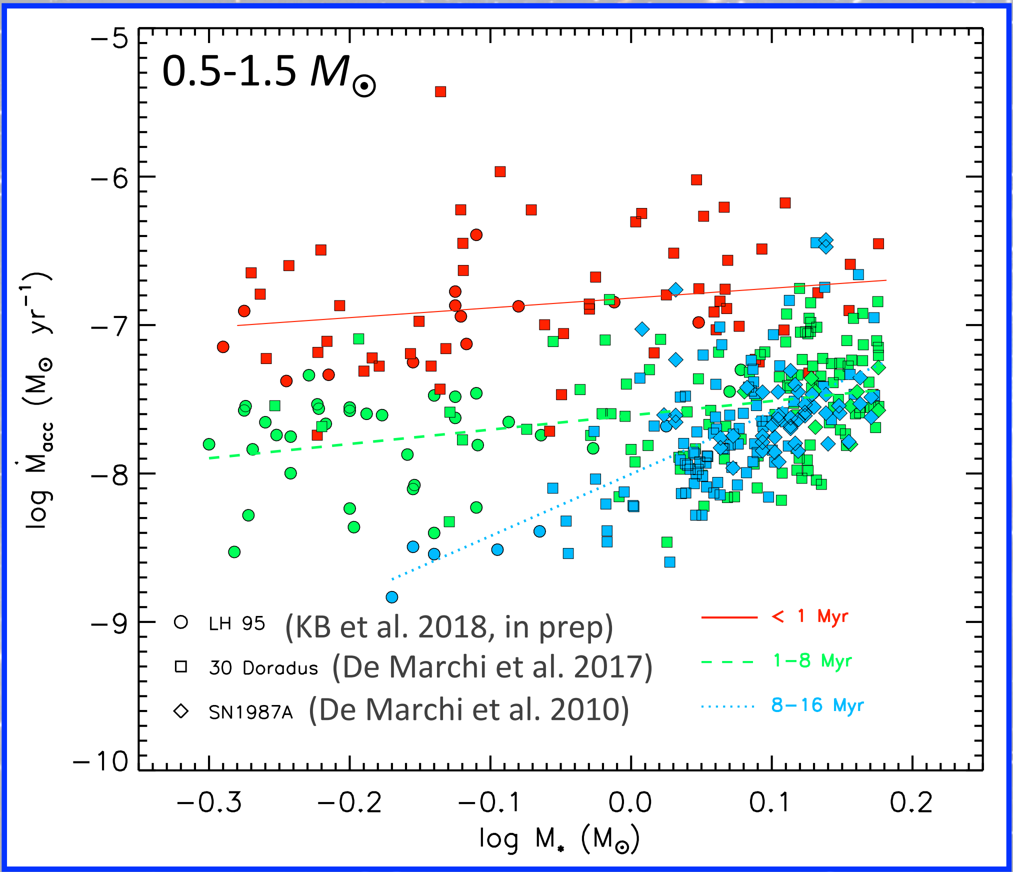




- ✧ **Higher mass** have **higher $\dot{M}_{acc}$** at all ages
- ✧ $\dot{M}_{acc}$ **decreases** more **slowly** with **time** at **lower Z**
- ✧ $\dot{M}_{acc}$ higher for **younger** stars
- ✧ **Slope** of the $\dot{M}_{acc}$-$M_\star$ relationship **changing** according to age and **similar for MW and extra-Galactic SFRs**

Accretion evolution with Time & Mass

The LMC



Multivariate regression fit:

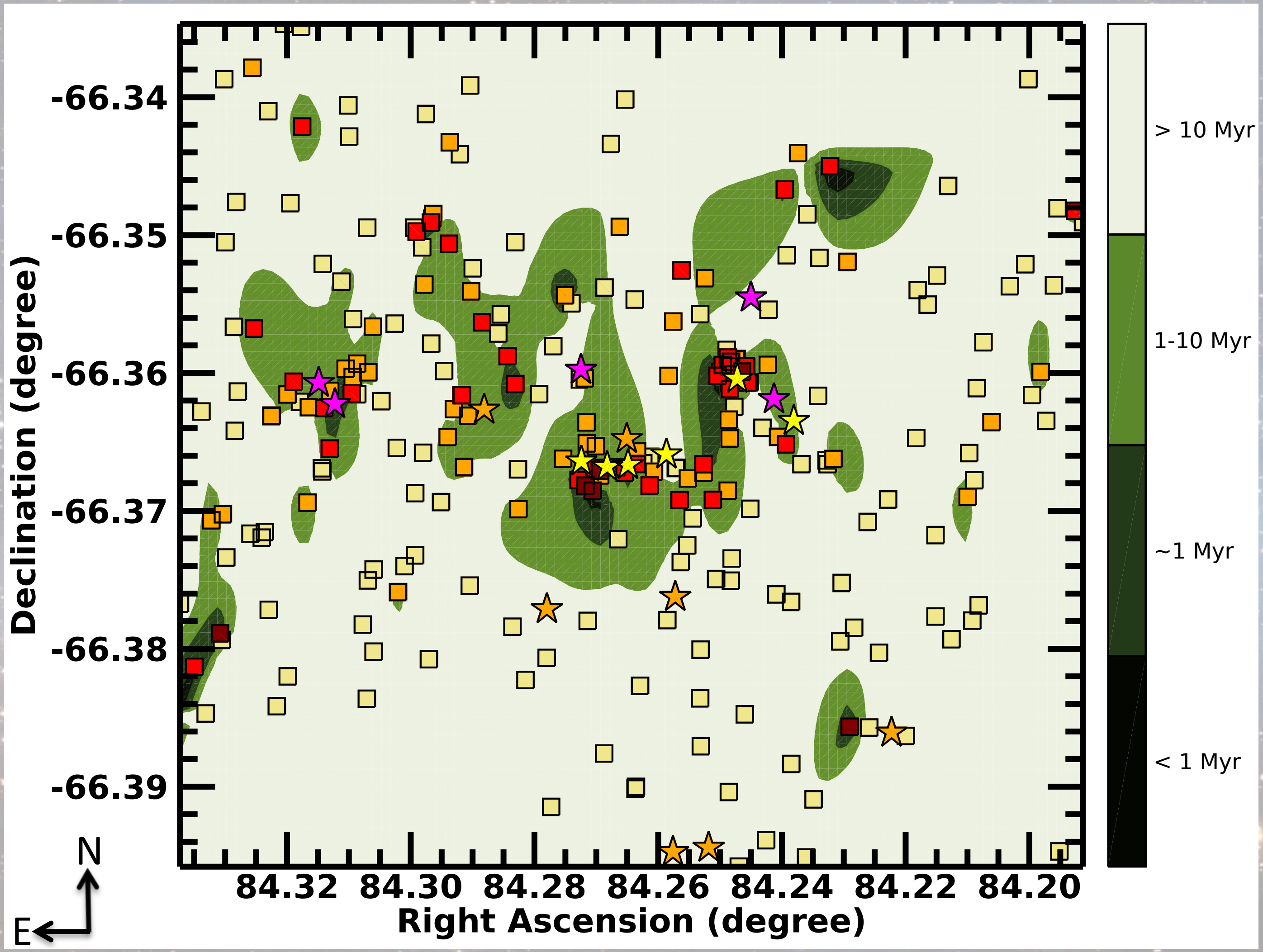
$$\log \dot{M}_{acc} \approx a \log t + b \log M_\star + c$$

a≈−0.6
b≈0.8

- **Similar findings in the Local Group** (MW, LMC, SMC; De Marchi et al. 2017)
- ***"c"* is not a constant** (dependence on other environmental parameters: metallicity, gas density, magnetic field, etc.; De Marchi et al. 2017)
- Stronger constraints from **JWST**

Multiple generations

Spatial distribution of accreting PMS stars

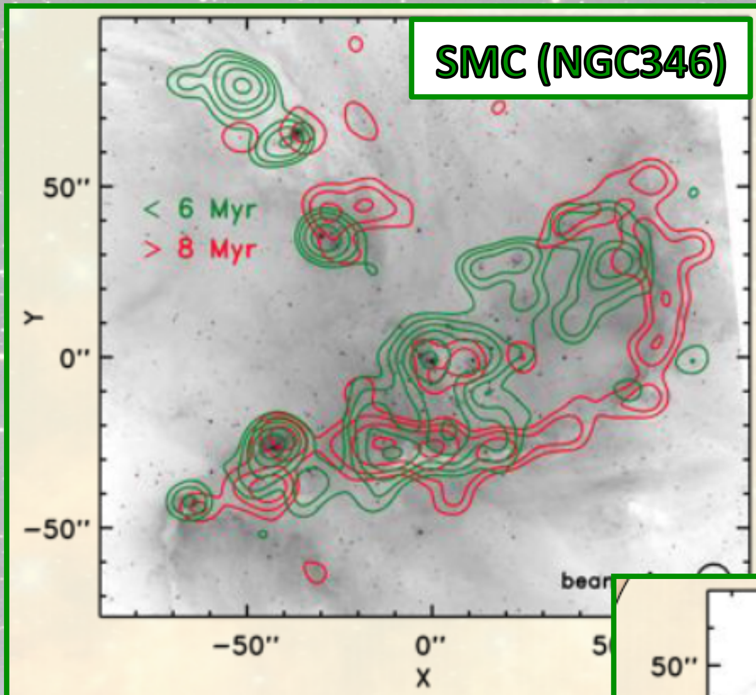


Massive stars:
- Gouliermis et al. (2002)
- Da Rio et al. (2012)
- Cutri et al. (2003)

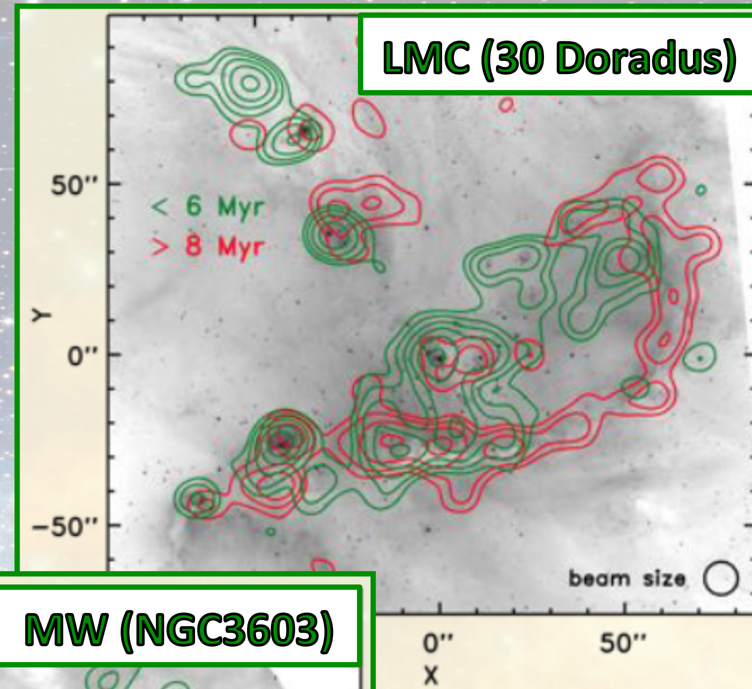
- $\log\dot{M}_{acc} > -6.7\ M_\odot/yr$
- $-7.5 < \log\dot{M}_{acc} < -6.7\ M_\odot/yr$
- $-8.3 < \log\dot{M}_{acc} < -7.5\ M_\odot/yr$
- $\log\dot{M}_{acc} < -8.3\ M_\odot/yr$

✧ **Younger** and most **accreting** objects are **clumped (~5 pc)**
✧ **Older** and less accreting PMS are more **widely distributed**

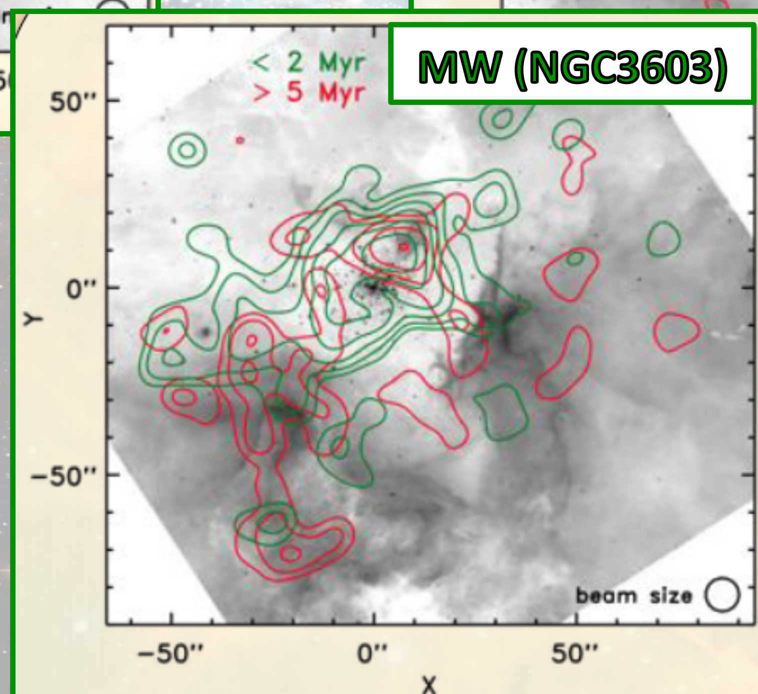
Multiple generations in the Local Group



De Marchi et al. (2011a)



De Marchi et al. (2011b)



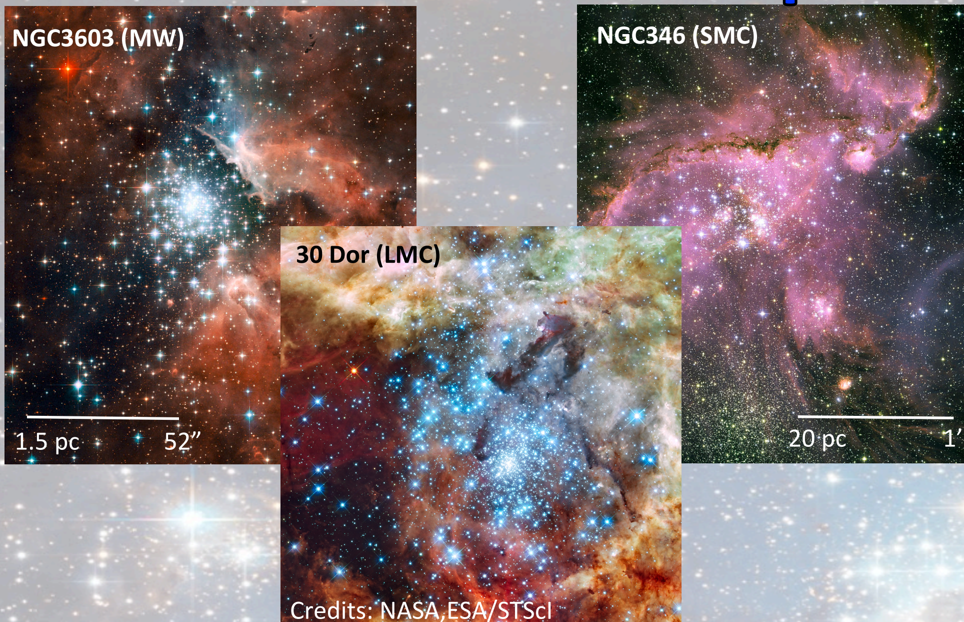
Beccari et al. (2010)

- ✧ **Multi-generation pattern of young populations is common in the Local Group**
- ✧ Older PMS stars always more widely distributed with velocity dispersion of ~ km/s

Credits: De Marchi

Future Perspectives with JWST

Launch: n.e.t. May 2020



NIRSpec GTO

"Star formation in the Local Group"

(15 hours)

https://www.cosmos.esa.int/web/jwst/jwst-esa

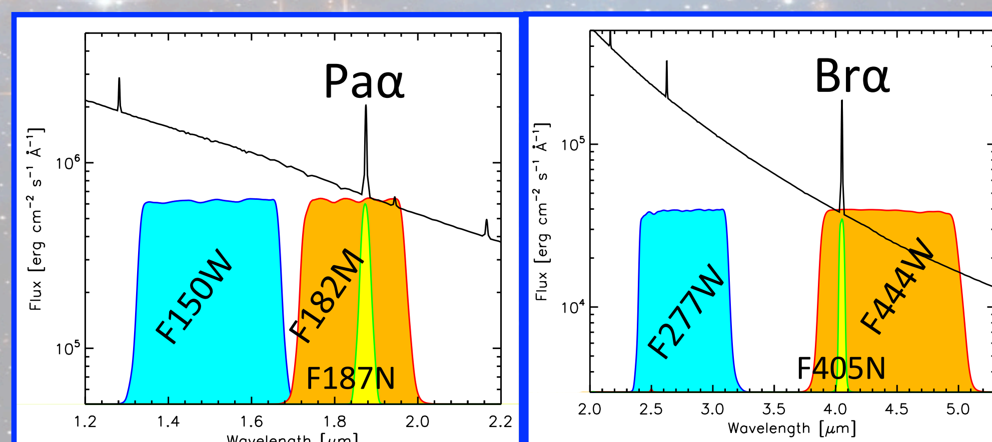
Team: **<u>Guido De Marchi (PI)</u>**, Pierre Ferruit, Catarina Alves de Oliveira, Tracy Beck, Giovanna Giardino, Roberto Maiolino, James Muzerolle, Nino Panagia, Katia Biazzo

Challenges

✧Simultaneous **Paα, Brγ, Brβ** for the first time (+ coordinated NIRCam obs. in broad-/narrow- **Paα** and **Brα** bands)

✧Nature of **accretion process** in three known massive clusters of the Local Group

✧How accretion depends on **$M_\star$, Age, Z** (+ **gas kinematics**)



Credits: De Marchi

Talk by Alessio Caratti o Garatti

THANKS FOR YOUR ATTENTION!