Star formation in the Local Group as seen by low-mass stars

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Motivations

• Solar mass stars account for most of the star formation in galaxies

• Low mass stars can form in small clouds as well as in big ones

• Need to probe diverse environments, Magellanic Clouds crucial for metallicity

• At redshift z~2, environment was similar to Magellanic Clouds
Spectroscopic search

![Graph showing spectroscopic search and signs of accretion]
Until JWST only feasible in the Milky Way
In the meanwhile…

New simple method combines HST broad- \((V, I)\) and narrow-band \((H\alpha)\) photometry and allows us to:

- identify all objects with \(H\alpha\) excess emission
- derive accretion luminosity and mass accretion rates
- for hundreds of stars simultaneously

De Marchi, Panagia & Romaniello 2010, ApJ, 715, 1
Beccari, Spezzi, De Marchi et al. 2010, ApJ, 720, 1108
De Marchi, Panagia & Sabbi 2011, ApJ, 740, 10
De Marchi, Panagia, Romaniello et al. 2011, ApJ, 740, 11
Spezzi, De Marchi, Panagia et al. 2012, MNRAS, 421, 78
De Marchi, Beccari & Panagia 2013, ApJ, 775, 68
Beccari, De Marchi, Panagia et al. 2015, A&A, 574, A44
De Marchi, Panagia, Beccari 2017, ApJ, submitted
H$_\alpha$ photometry

De Marchi, Panagia & Romaniello 2010
De Marchi et al. 2011b

LMC (SN 1987A)
gives $L(H_\alpha)$
$H_\alpha$ photometry

within $r < 20$ pc

~1,100 stars
Hα photometry

De Marchi, Panagia, Sabbi, et al. (in prep)

within $r < 120$ pc
$\sim 44,000$ stars
PMS stars in CMD

De Marchi, Panagia, Sabbi, et al. (in prep)
PMS stars in CMD

De Marchi, Panagia, Sabbi, et al. (in prep)
Multiple generations ubiquitous

- Multi-generation pattern always seen, $\Delta t \sim 10$ Myr
- Older PMS stars always more widely distributed

Beccari et al. 2010

De Marchi et al. 2013b
Different spatial distribution

- Multi-generation pattern always seen, $\Delta t \sim 10$ Myr
- Older PMS stars always more widely distributed
Accretion evolution with time

De Marchi, Panagia, Beccari 2017

R 136

$\log M_{\text{acc}} \ [M_\odot \, \text{yr}^{-1}]$

$\log \text{age} \ [\text{yr}]$

$4 M_\odot$

$3 M_\odot$

$2 M_\odot$

$1 M_\odot$
Accretion evolution with time

Sicilia-Aguilar et al. 2006; 2010

Hartmann et al. 1998
Accretion evolution with time

De Marchi, Panagia, Beccari 2017

Log $M_{\text{acc}} [M_\odot \text{ yr}^{-1}]$ vs Log age [yr]
Accretion evolution with time

- **R 136**

\[ \log M_{\text{acc}} \text{ [M}_\odot \text{ yr}^{-1}] \]

- **a) 0.5–1.1 M\(_\odot\)**
  \[ \alpha = -0.58 \pm 0.03 \]
  \[ Q = -7.30 \pm 0.20 \]

- **b) 1.1–1.5 M\(_\odot\)**
  \[ \alpha = -0.36 \pm 0.05 \]
  \[ Q = -7.15 \pm 0.34 \]

- **c) 1.5–2.0 M\(_\odot\)**
  \[ \alpha = -0.21 \pm 0.04 \]
  \[ Q = -6.84 \pm 0.31 \]

- **d) 2.0–4.0 M\(_\odot\)**
  \[ \alpha = -0.41 \pm 0.07 \]
  \[ Q = -6.48 \pm 0.43 \]
Accretion evolution with time

\[
\log \dot{M}_{\text{acc}} \simeq 0.9 \log m - 0.6 \log t + c
\]

\[
c = \log \dot{M}_{\text{acc}} - 0.9 \log m + 0.6 \log t
\]
Accretion rate and metallicity

\[ c \propto Z^{-1/3} \]  

\[ \log \dot{M}_{\text{acc}} \approx \log m - 0.6 \log t + c \]  

\[ \frac{dN}{dm} \propto m^\alpha \left[ 1 - e^{-\left( m/m_c \right)^\beta} \right] \]  

\[ t_{\text{dis}} \propto t_{\text{rh}} t_{\text{1}}^{-x_{\text{cr}}} \]  

\[ t_{\text{dis}} = t_{\text{0}} M_{\text{ini}}^{0.62} \]  

\[ m_c \approx 0.15 + 0.5 \times \left( t_{\text{dyn}} \right)^{3/4} \]  

De Marchi, Panagia & Beccari 2017
Spectra of ~100 stars per field, easy with NIRSpec

R~1000–2700, 1.7 – 3.0 μm, include Paα, Brβ, Brγ

Rich sample of younger and older PMS stars
Summary

- Tarantula nebula hosts lots of PMS stars (~44000), most are older than R136
- Multi-generation patterns common, $\Delta t \sim 10$ Myr, younger generations always more concentrated
- Mass function variations across SF regions
- Mass accretion rate depends on metallicity, at low metallicity stars accrete more and longer, sizeable mass fraction accreted during PMS phase
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We have developed and successfully tested a new self-consistent method to reliably identify pre-main sequence (PMS) objects actively undergoing mass accretion in a resolved stellar population, regardless of their age. The method does not require spectroscopy and combines broad-band V and I photometry with narrow-band Hα imaging to: (1) identify all stars with excess Hα emission; (2) derive their Hα luminosity \( L(\text{H}\alpha) \); (3) estimate the Hα emission equivalent width; (4) derive the accretion luminosity \( L_{\text{acc}} \) from \( L(\text{H}\alpha) \); and finally (5) obtain the mass accretion rate \( M_{\text{acc}} \) from \( L_{\text{acc}} \) and the stellar parameters (mass and radius). By selecting stars with photometric accuracy in Hα better than 15%, the statistical uncertainty on the derived \( M_{\text{acc}} \) is typically <17%...