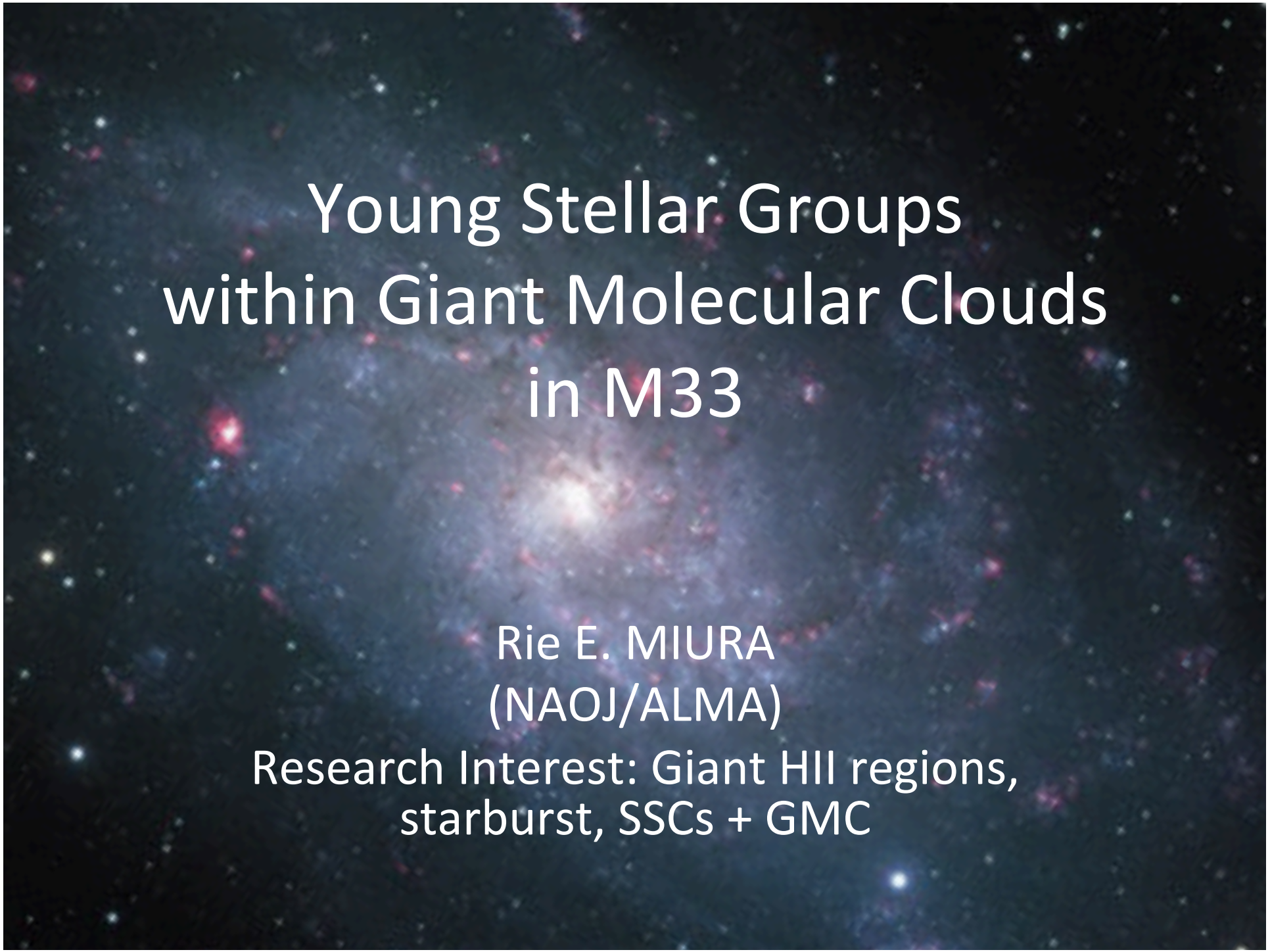

Young Stellar Groups within Giant Molecular Clouds in M33

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Research Interest: Giant HII regions, starburst, SSCs + GMC

Most of stars are born in clusters.

(Lada & Lada 2003)

Most of stars are born in clusters.

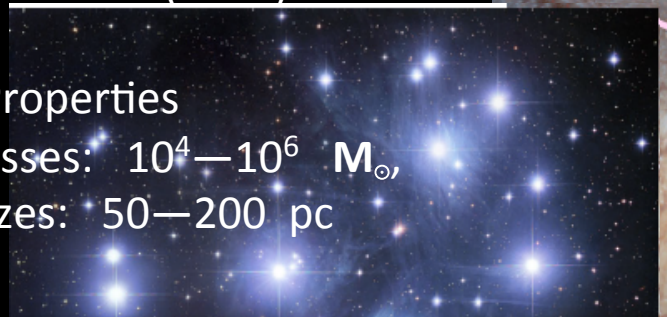
(Lada & Lada 2003)

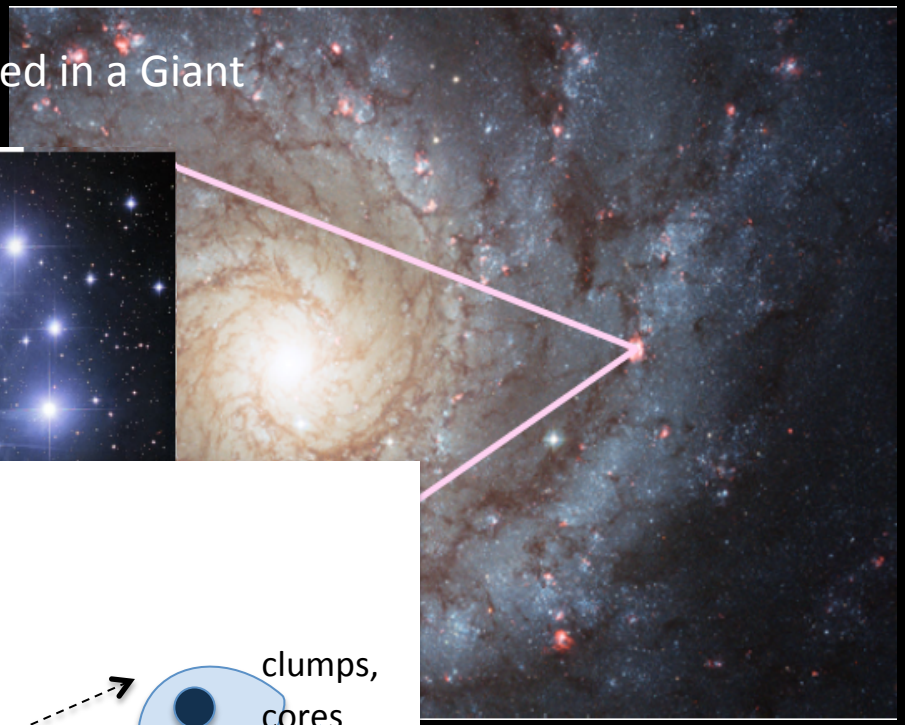
- Massive stars/clusters are formed in a Giant Molecular Cloud (GMC).

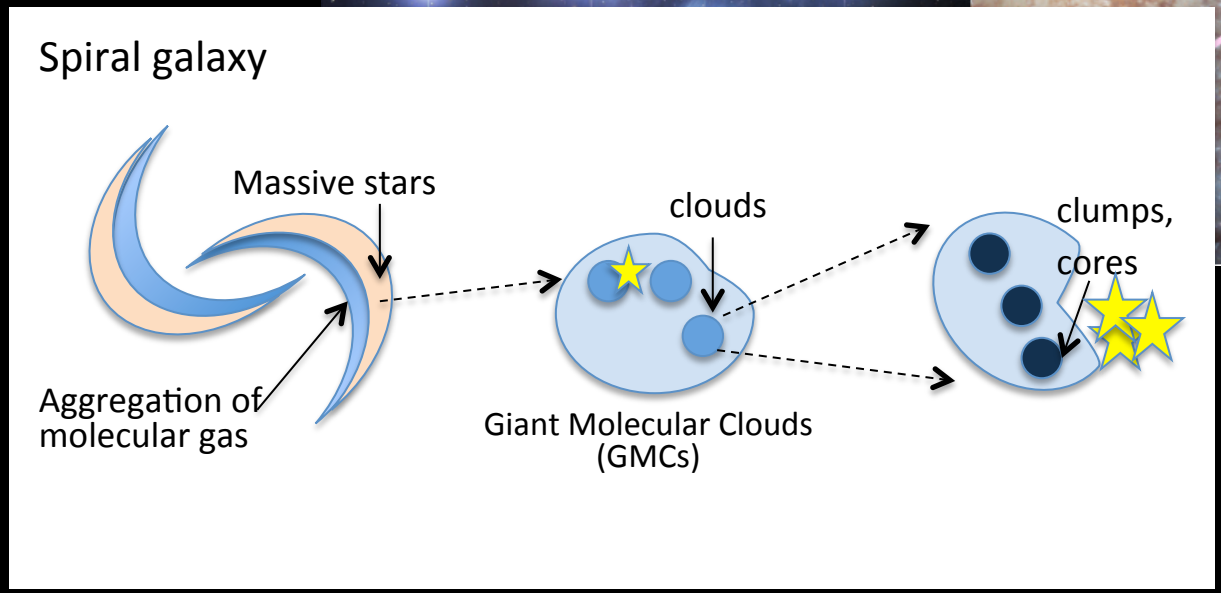
- GMC Properties

GMC masses: 10^4—10^6 $M_\odot$,

Sizes: 50—200 pc



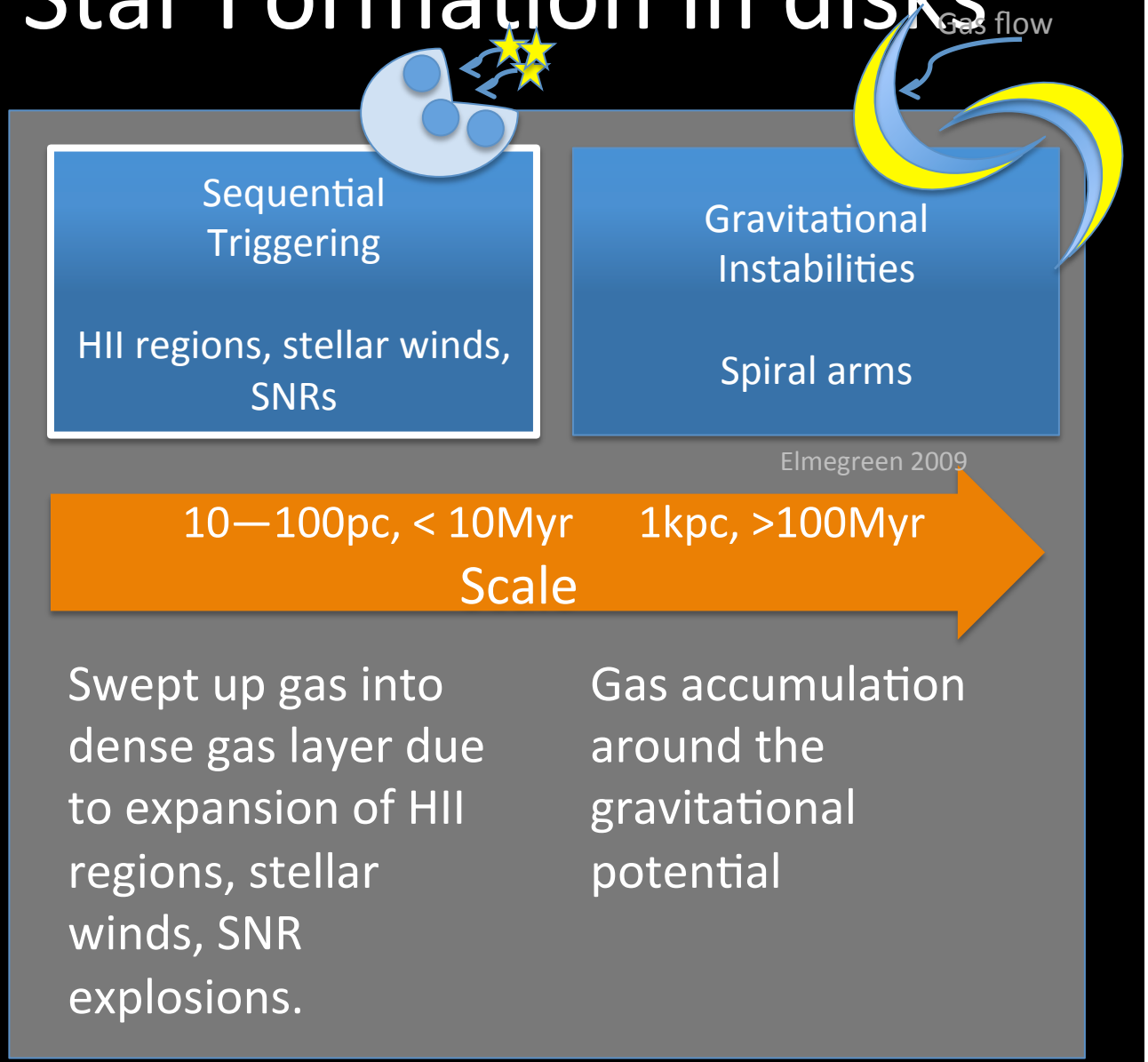




Triggered Star Formation in disks

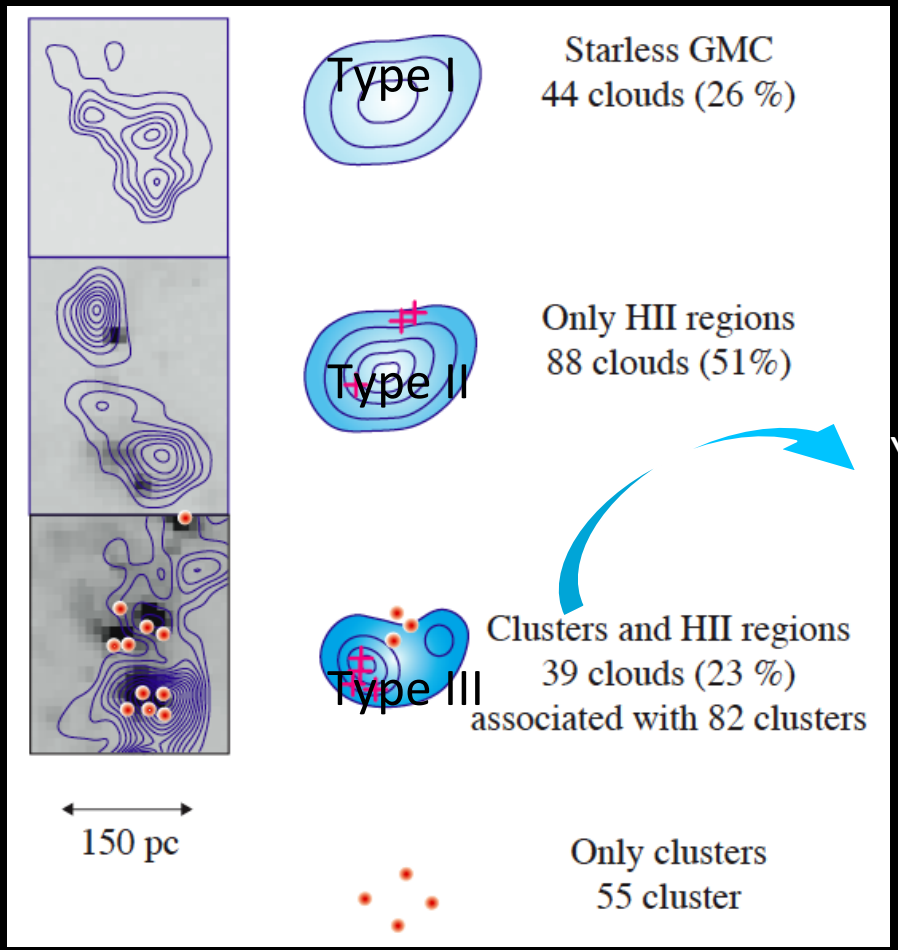
Mechanism for massive SF requires large-scale processes (Elmegreen 2004).

Among triggered SF processes in disks, sequential SF is important, because they are similar spatial and time scale to GMCs.



GMC Evolution

- Extensive studies of evolution of GMC have been carried out in LMC (e.g. Fukui et al. 1999,Mizuno et al. 2001,Yamaguchi et al. 2001, Kawamura et al.2009).



(Kawamura+2009)

7 Myr

14 Myr

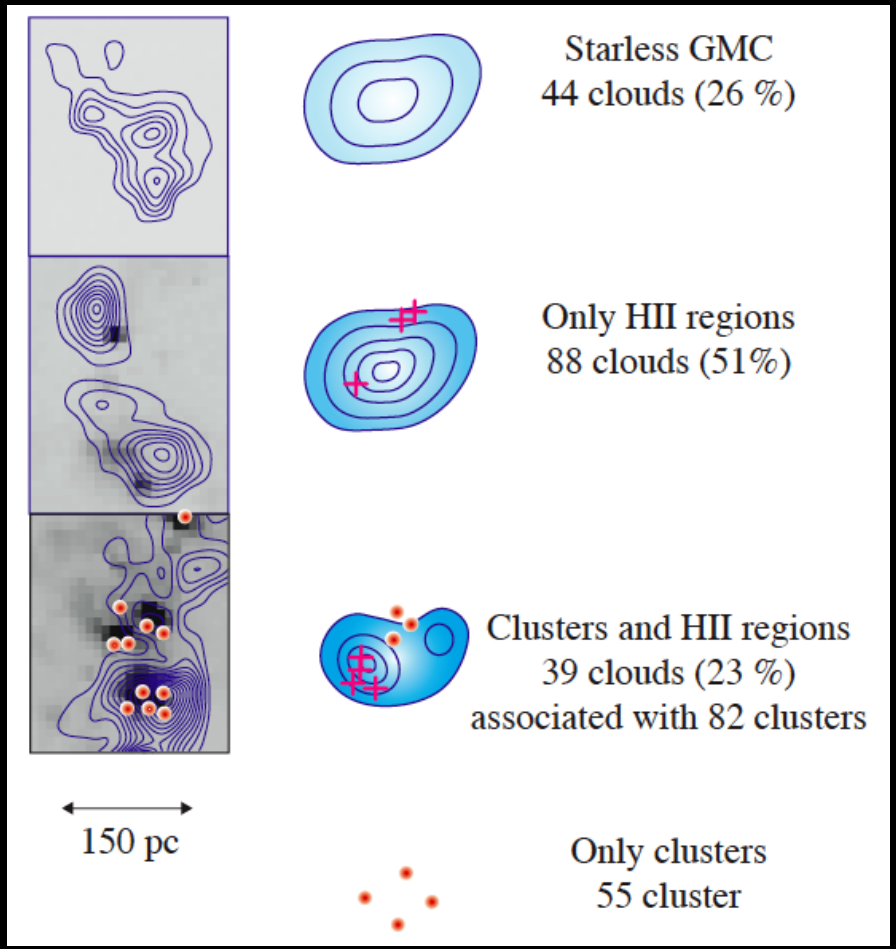
Young Cluster (<10 Myr)

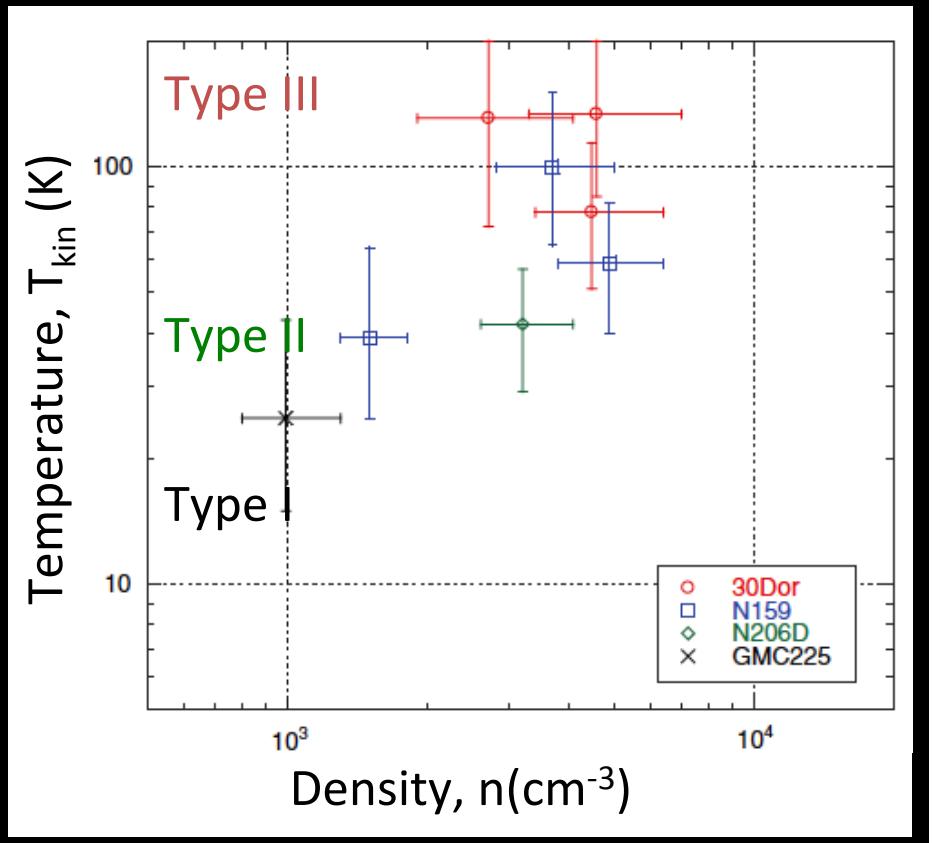
6 Myr

4Myr

Lifetime:
~ 30 Myr
(e.g. Williams & McKee 1997, Yamaguchi et al. 2001, Kawamura et al. 2009)

GMC Evolution and Dense/Warm gas



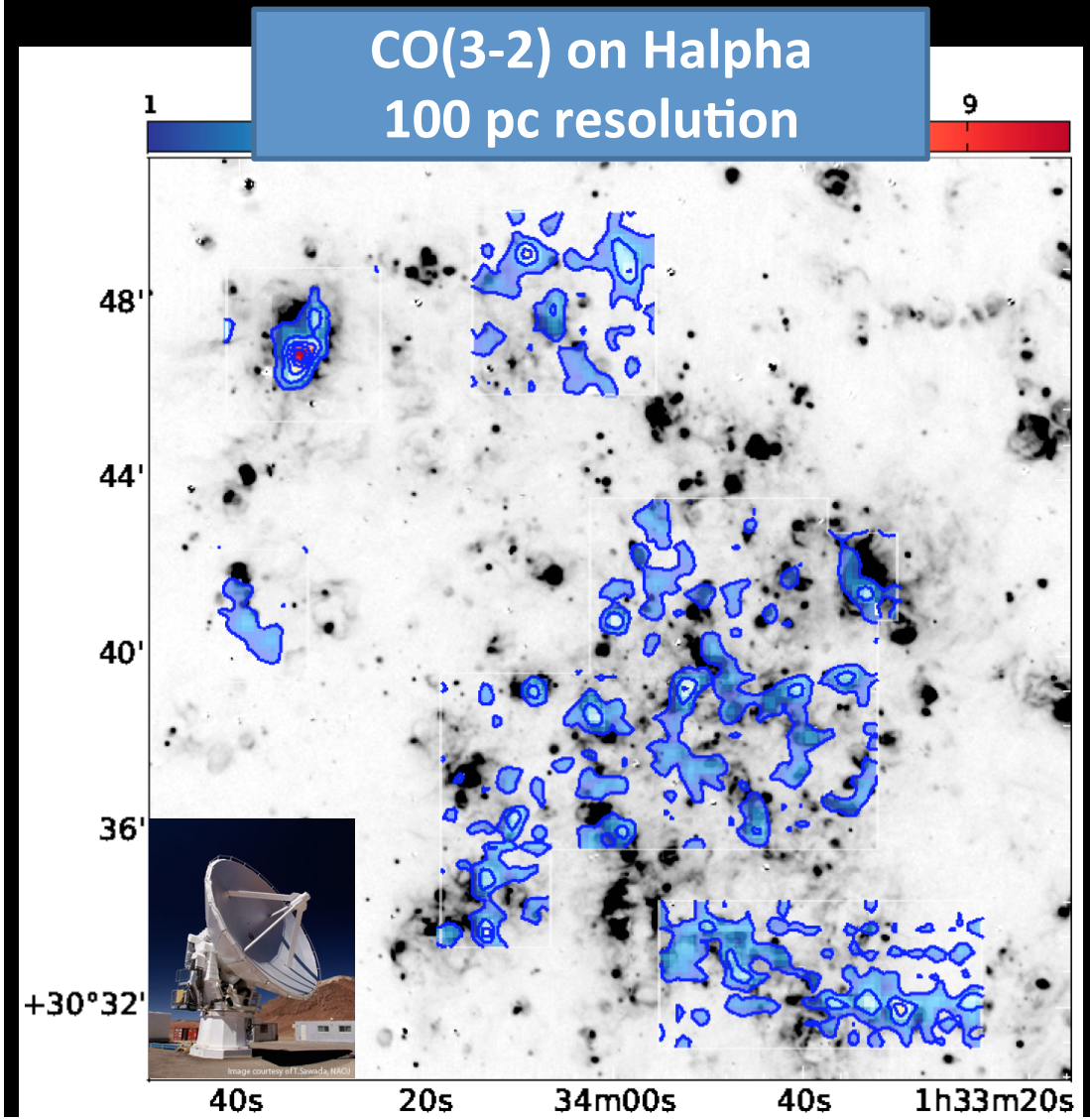


- The kinetic temperature and density generally increase as GMC evolves (e.g. Minamidani et al. 2008, 2011).

TARGET | Nearby Spiral Galaxy M33

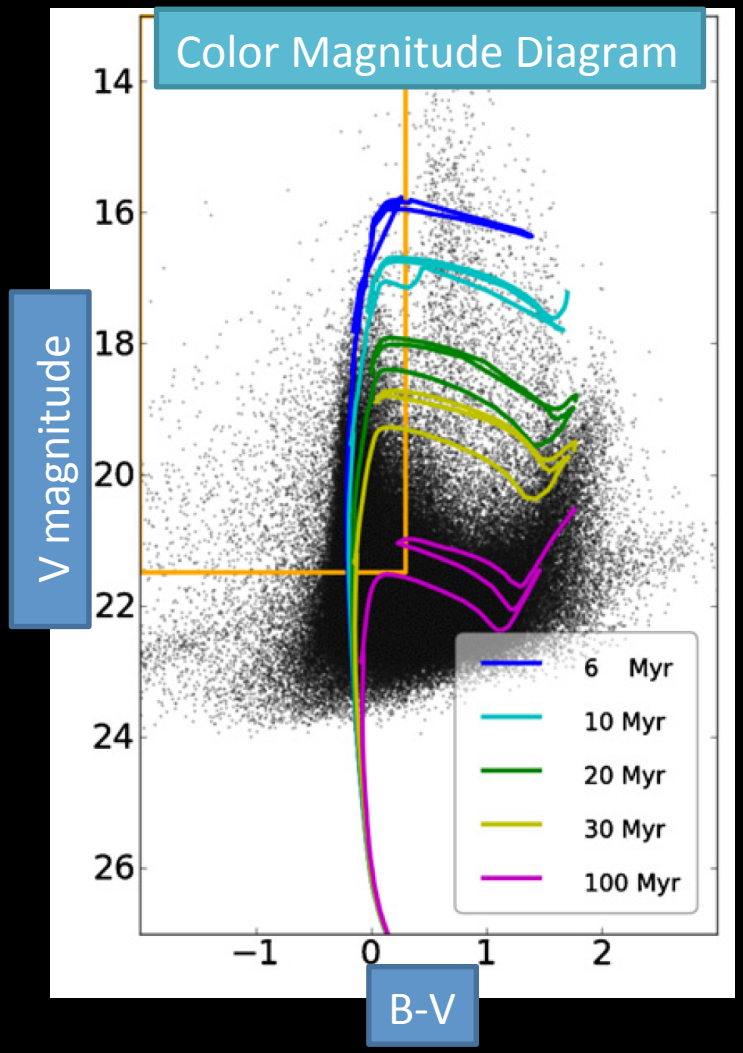
- Close to us (D=840kpc)
- Favorable inclination (i=51^{o})
- Plenty of massive star forming region unlike MW.
- All samples are at the same distance, unlike MW.

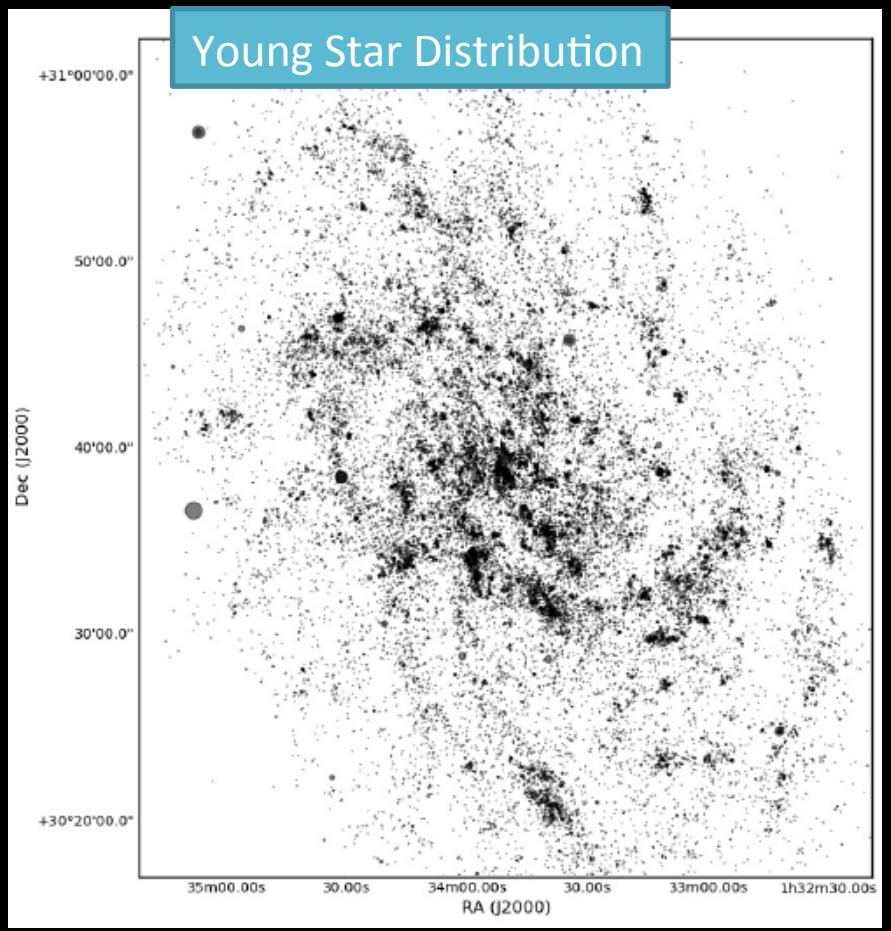
M33 CO(3-2) Catalog



- Our CO(3-2) data covers 87% of CO(1-0) based molecular gas.
- Wide Field (136 arcsec^2) & High sensitivity (dV=2.5km/s) mapping using ASTE.
- 87 GMCs are identified by CPROPS (Rosolowsky+06).
- Size: 12—157 pc;
  Mass: 0.2—89.2x10^{5}Mo.

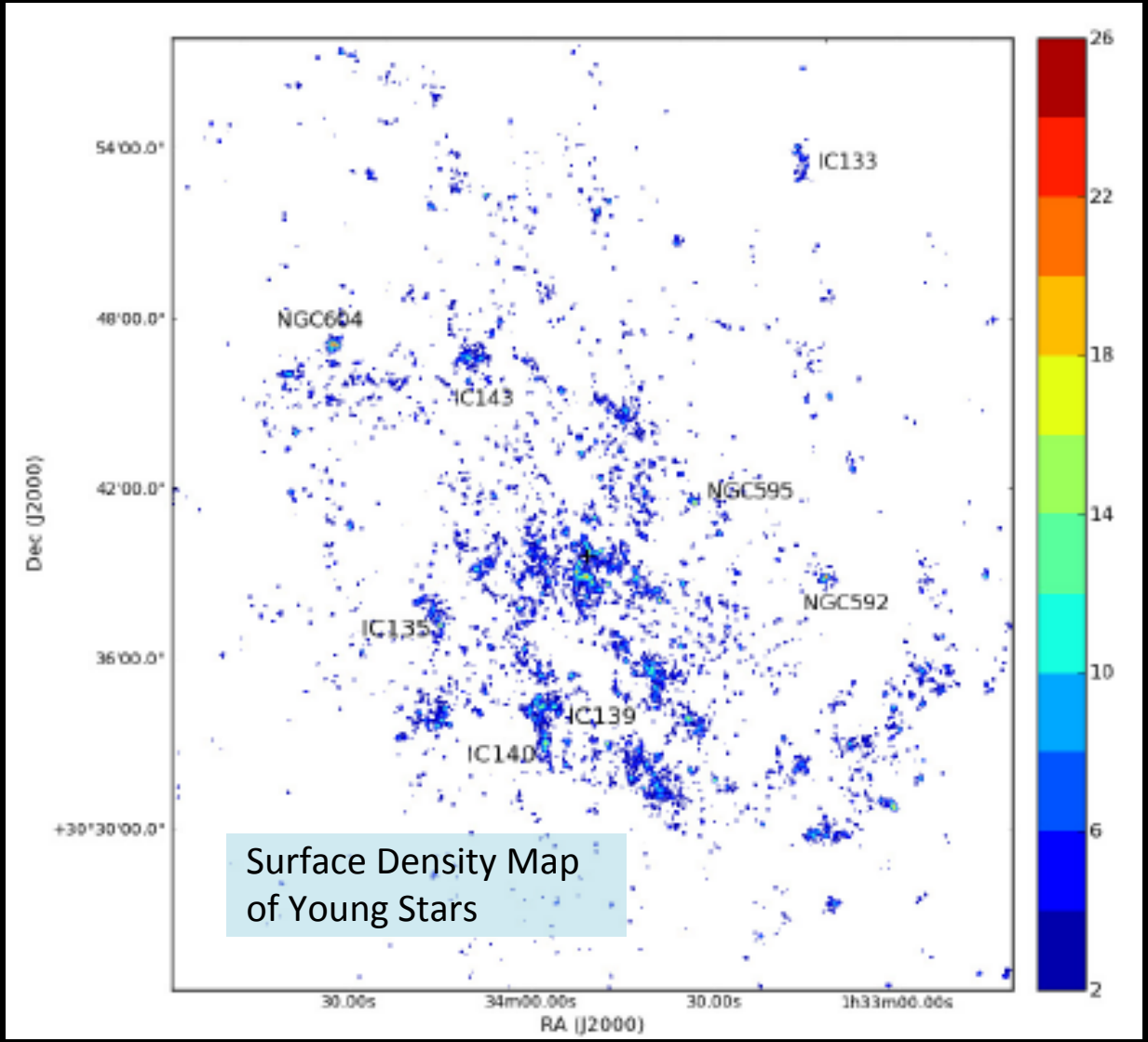
Young Star Distributions in M33





Young Stellar Groups (YSGs)
= concentration of young (<100Myr) stars;
clusters or OB associations

Young Stellar Group (YSG)



Surface Density Map of Young Stars

Excess (n*>5 stars/ 30pc^2 area) of surface density of young stars
→ defined as "clusters"

- Excess of stellar density along spiral arms
- 93 YSGs were identified.
- size 27—91pc
- mass $10^{3.5}$—$10^{4.7}$Mo

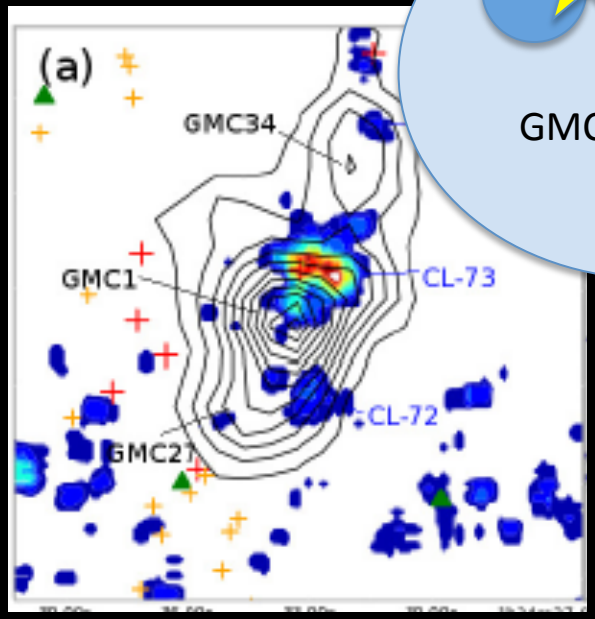
Methodology for GMC Classification

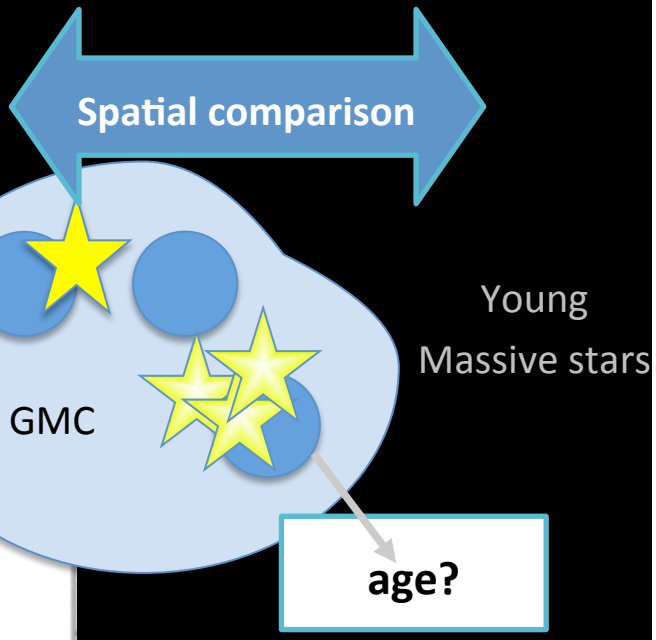
1) Create a new GMC catalog using CO(3-2)
2) Build young cluster catalog using photometric data (Massey et al. 2006)
3) Estimate cluster ages

   Classify GMCs in relation to:

   - Age of cluster
   - HII regions

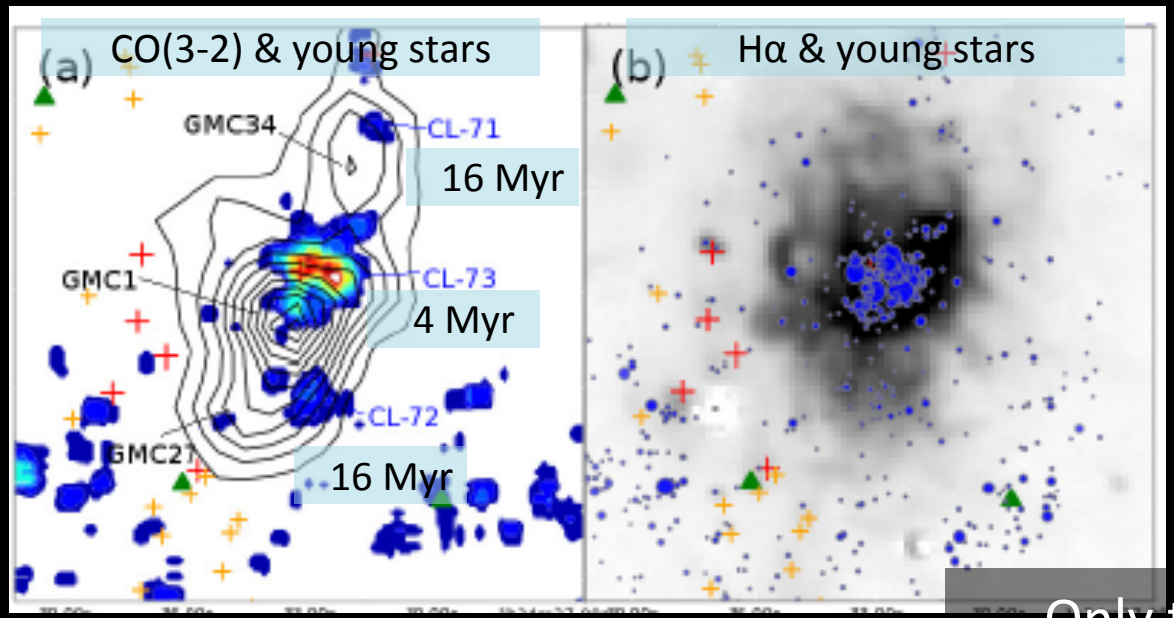
   (Courtes et al. 1987, Hodge et al. 1999)



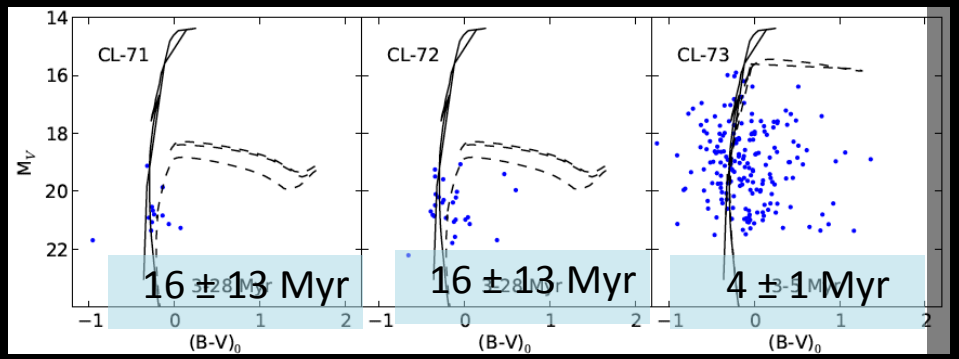


GMC classification

Example: NGC604 region



Contour: CO(3-2)
Color contour : Young stars
Gray scale: Hα
+ : HII region
▲: 24μm sources



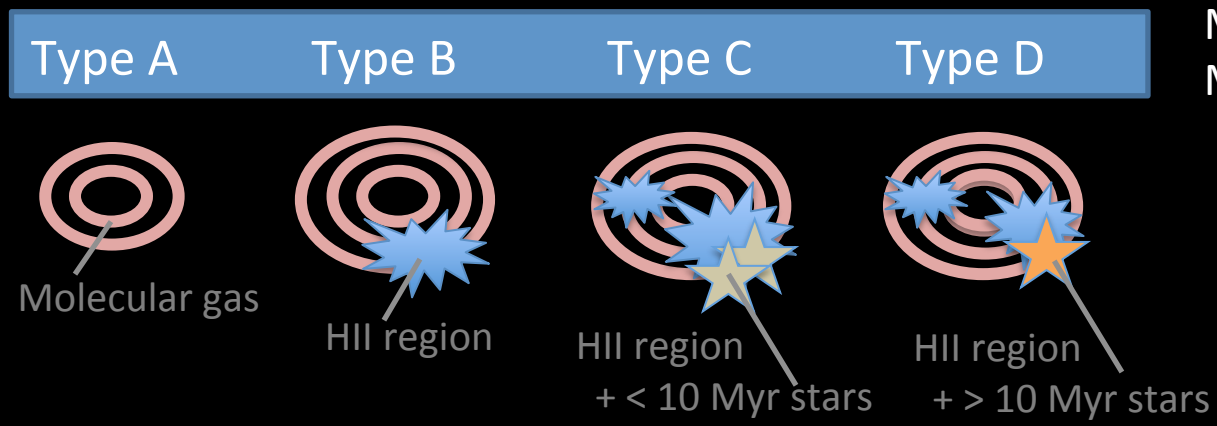
CMD for the three clusters in NGC604

- Only the clusters/HII regions within the extent of a GMC are treated as the associated clusters with a GMC.
- Example of classification:

- GMC-1 HII regions and < 10Myr old clusters.

GMC classifications and lifetime

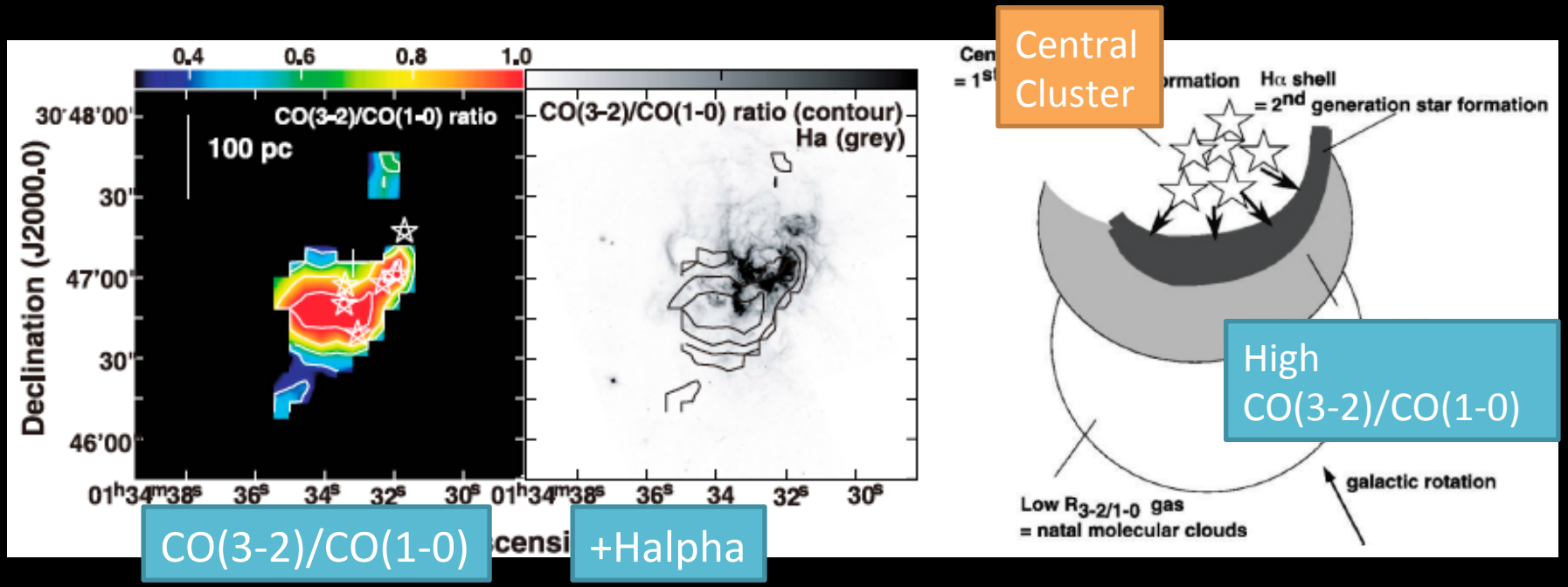
GMC Type	Observed Signature	Number of GMCs	Time Scale (Myr)
Type A	No HII regions	2 (2%)	1
Type B	With HII regions	16 (20%)	3—7
Type C	With HII regions and < 10 Myr-old YSGs	34 (42%)	5--10
Type D	With HII regions and 10—30 Myr-old YSGs	29 (36%)	8--17



Miura et al. 2012
Miura et al. in prep.

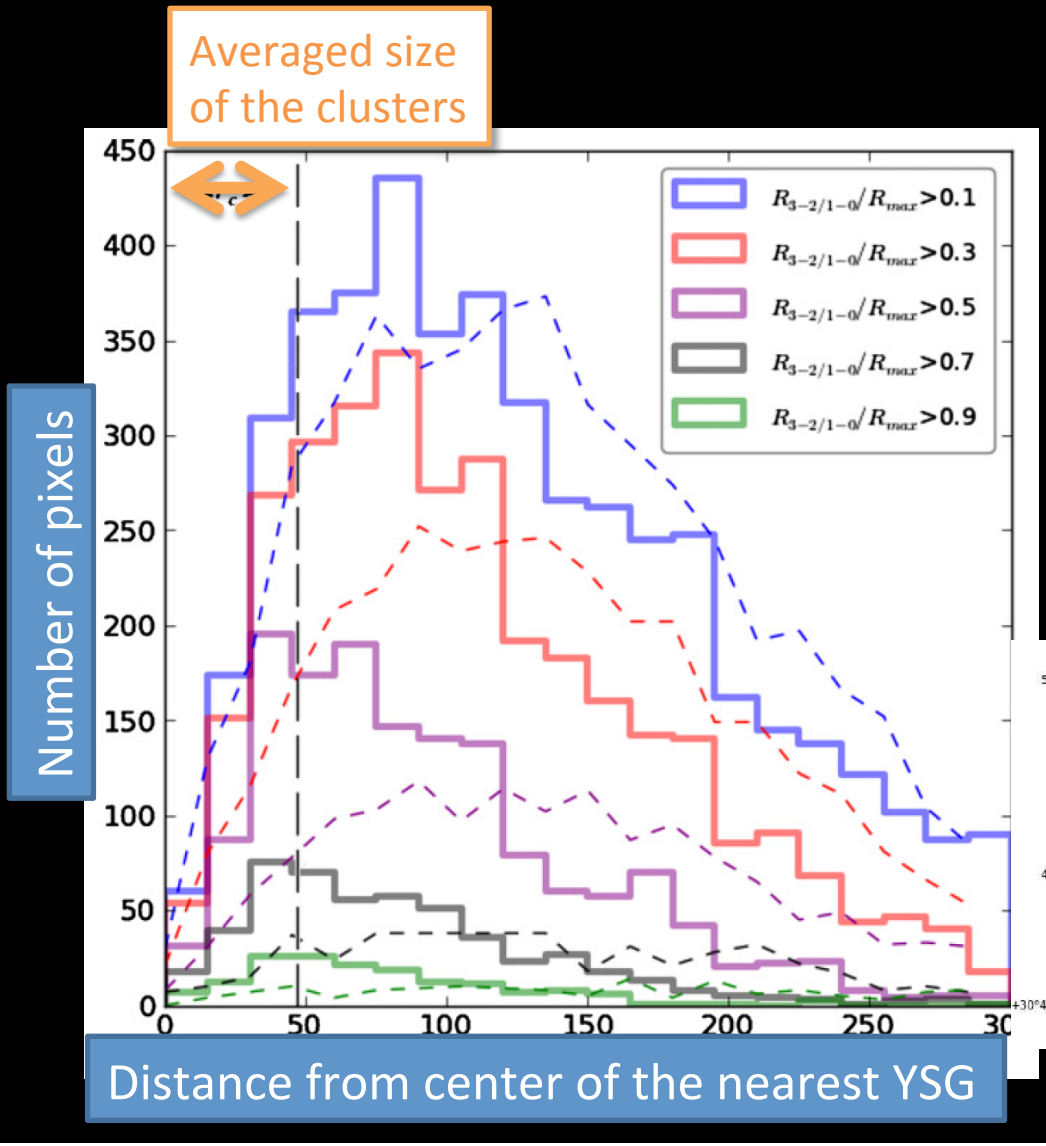
Enhanced $R_{3\text{-}2/1\text{-}0}$ around SF regions

- $R_{3\text{-}2/1\text{-}0}$ ≡ CO(3-2)/CO(1-0) ~ Dense gas fraction
- Example: Giant HII region NGC604 in M33



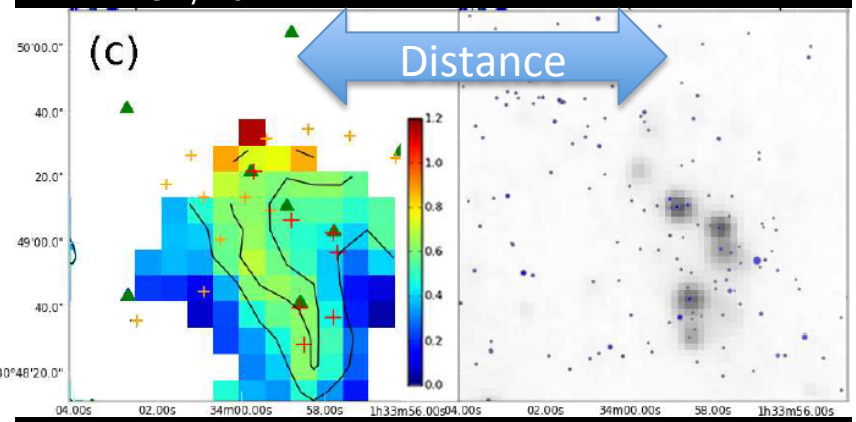
Tosaki, Miura et al. 2007

Offset from $R_{3\text{-}2/1\text{-}0}$ and massive SF sites

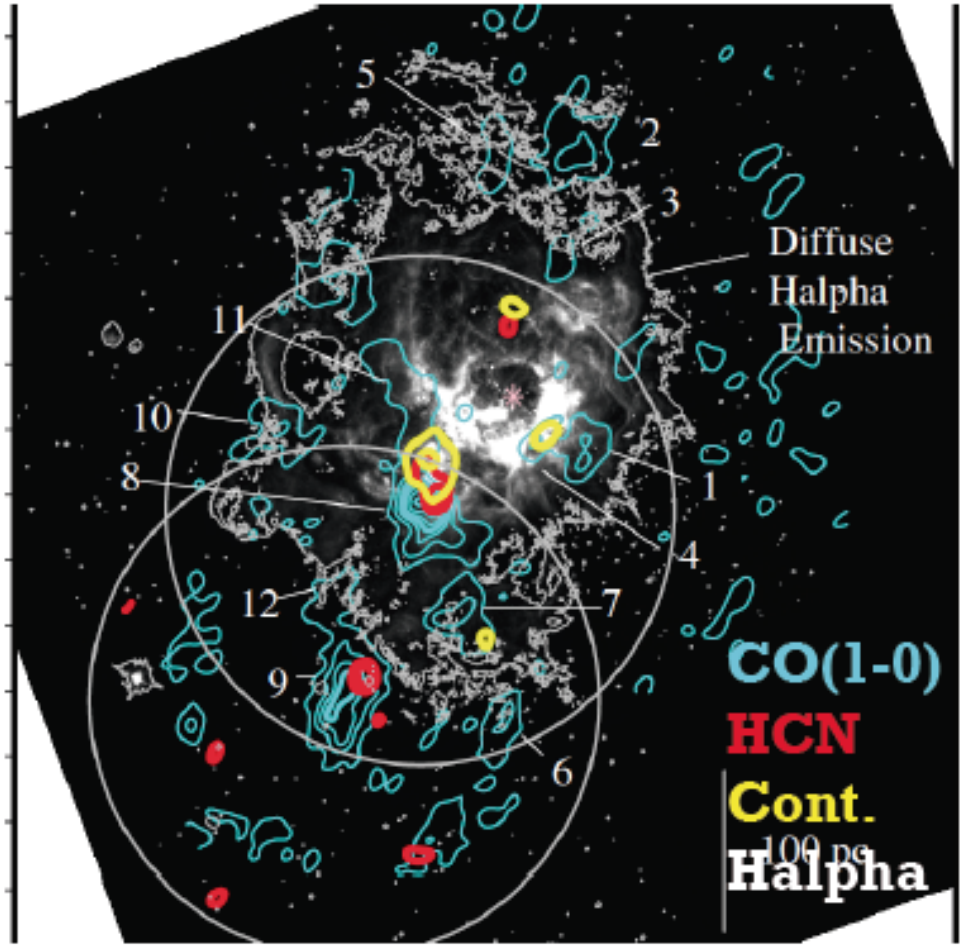


- High $R_{3\text{-}2/1\text{-}0}$ enhanced at vicinity of SF regions
- But the $R_{3\text{-}2/1\text{-}0}$ peaks do not coincide with SF region

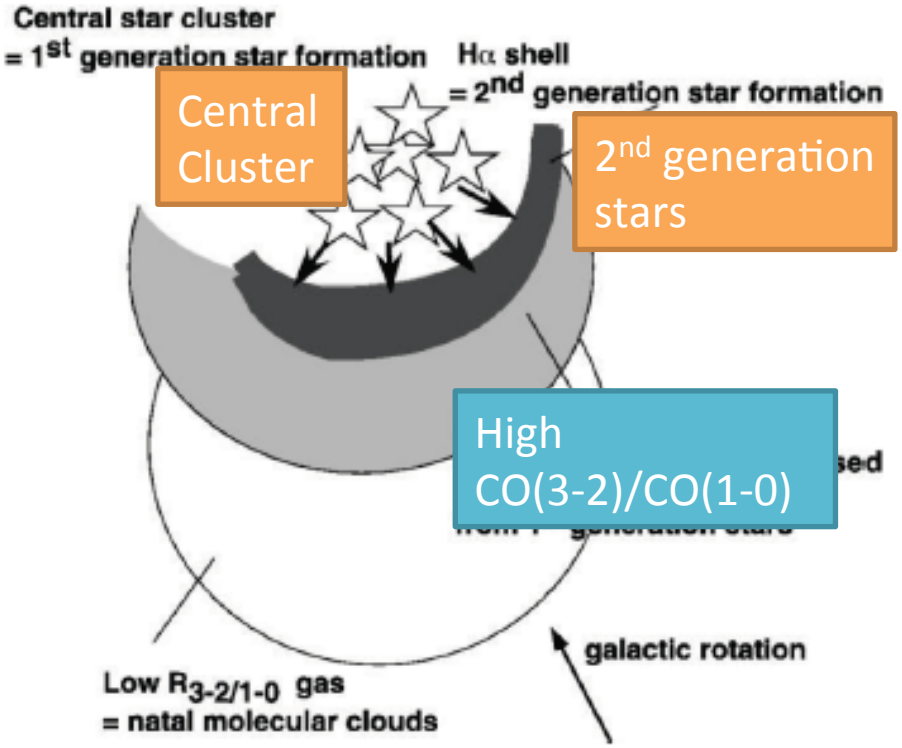
[$R_{3\text{-}2/1\text{-}0}$] [Ha: massive SF sites]



Sequential SF in NGC 604



NMA ~10pc resolution
(Miura et al. 2010)

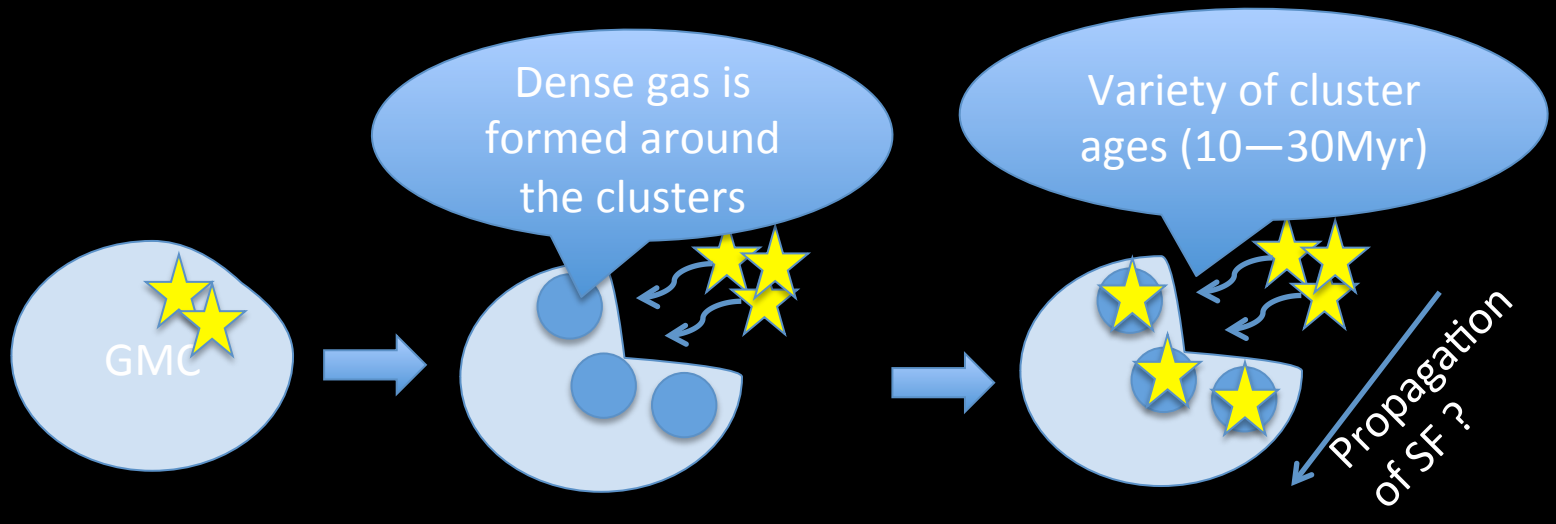


- Triggered SF by the expansion of HII regions from the 1st generation stars ?

Miura et al. 2010

GMC Evolutions and SF propagation

- Association of both 10—30Myr-old YSGs and HII regions (<10Myr) suggests that massive SF CONTINUOUSLY occurs inside a GMC.
- Enhanced dense gas fraction (traced by $R_{3\text{-}2/1\text{-}0}$) around massive SF sites => dense gas formation is preferentially located around previously generated stars, and the next generation of SF occurs in such dense gas.
- Massive SF gradually propagates outward in the GMC.



Summary

1. For the first time M33 GMCs are classified into four types according to the spatial correlation with massive SF sites and the cluster ages. This is interpreted as GMC evolutions.
2. Dense gas fraction traced by $R_{3\text{-}2/1\text{-}0}$ is enhanced around the massive SF sites, which suggest propagation of SF in the GMCs.
3. The lifetime of GMC with over 10^5Mo is estimated 20—40 Myr.
4. We will do survey embedded cluster forming regions with ALMA/ Subaru telescope.