Probing Nearby Starburst Galaxies with the SMA

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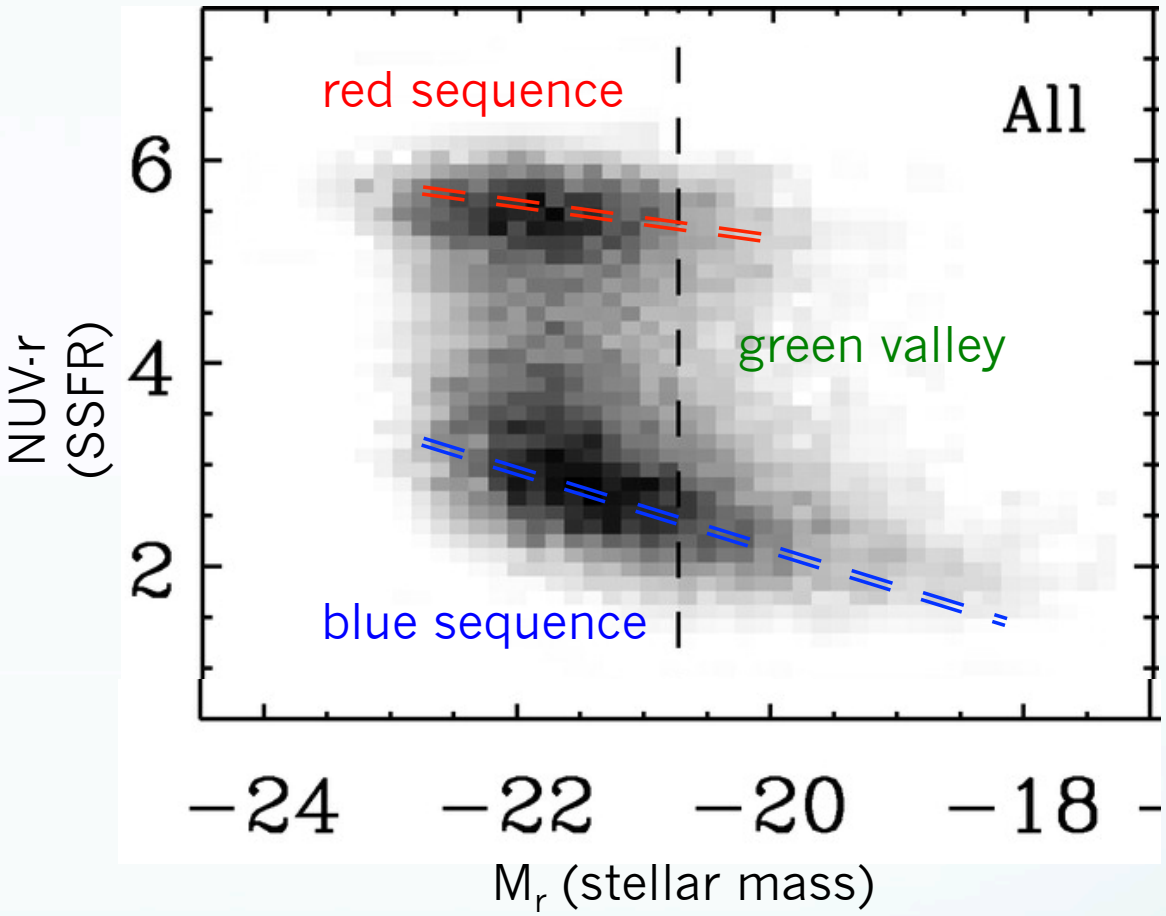
SMA - CfA

Star Formation and Galaxy Evolution

Salim et al. (2007),
Kauffmann et al. (2003)



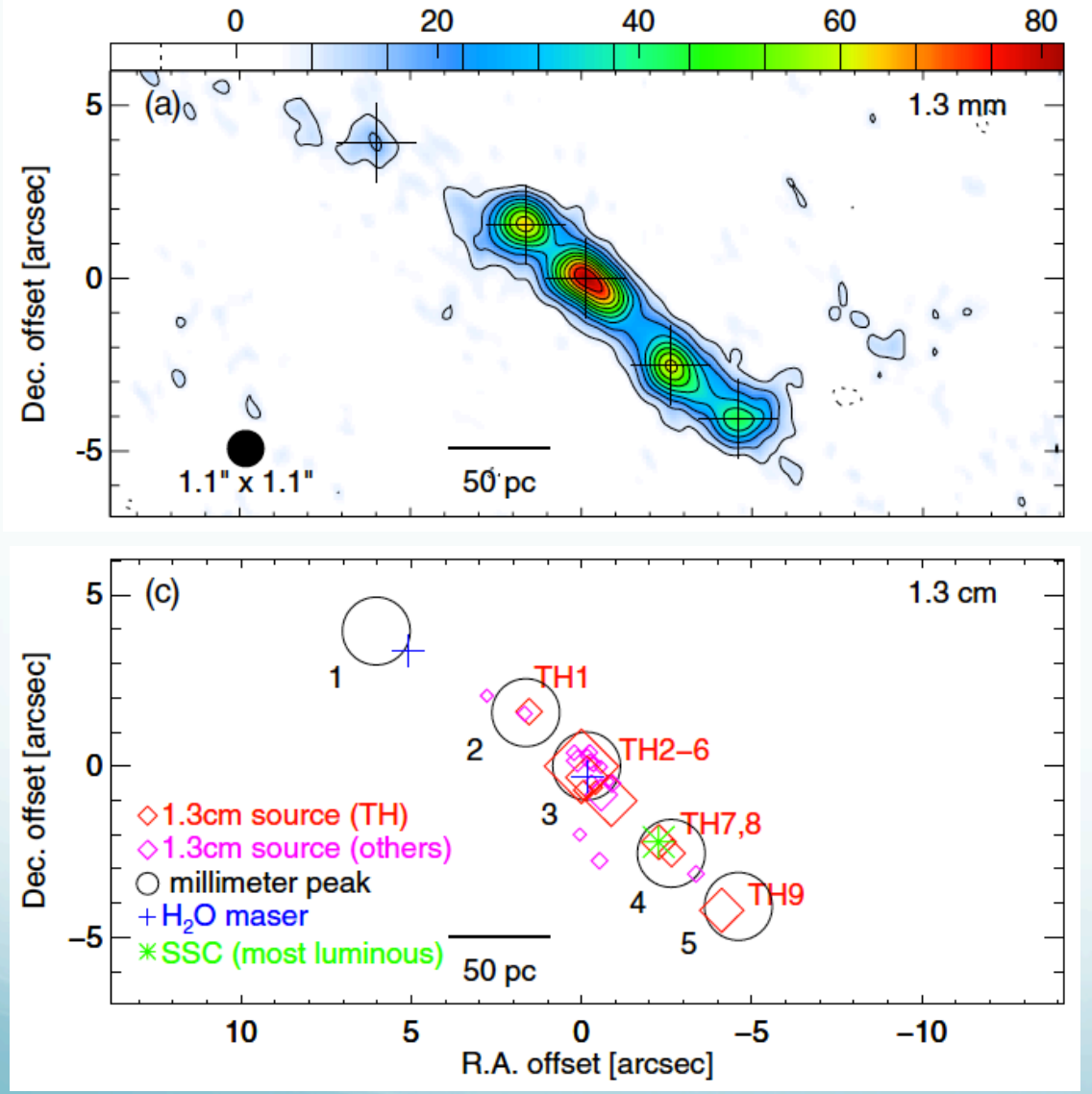
- Two groups: red and dead, and blue and star forming → star formation activity is related to presence/absence of gas!
- What are the relevant physical processes?
- SMA allows us to trace: gas, gas temp, dust continuum, gas velocity, etc!
- Starbursts: different mode of SF, relevant to high-z results

NGC 253

- Active starburst in central ½ kpc
- SFR ~ 5 M_{sun}/year
- 3.5 Mpc away

Image: R. Jay GaBany

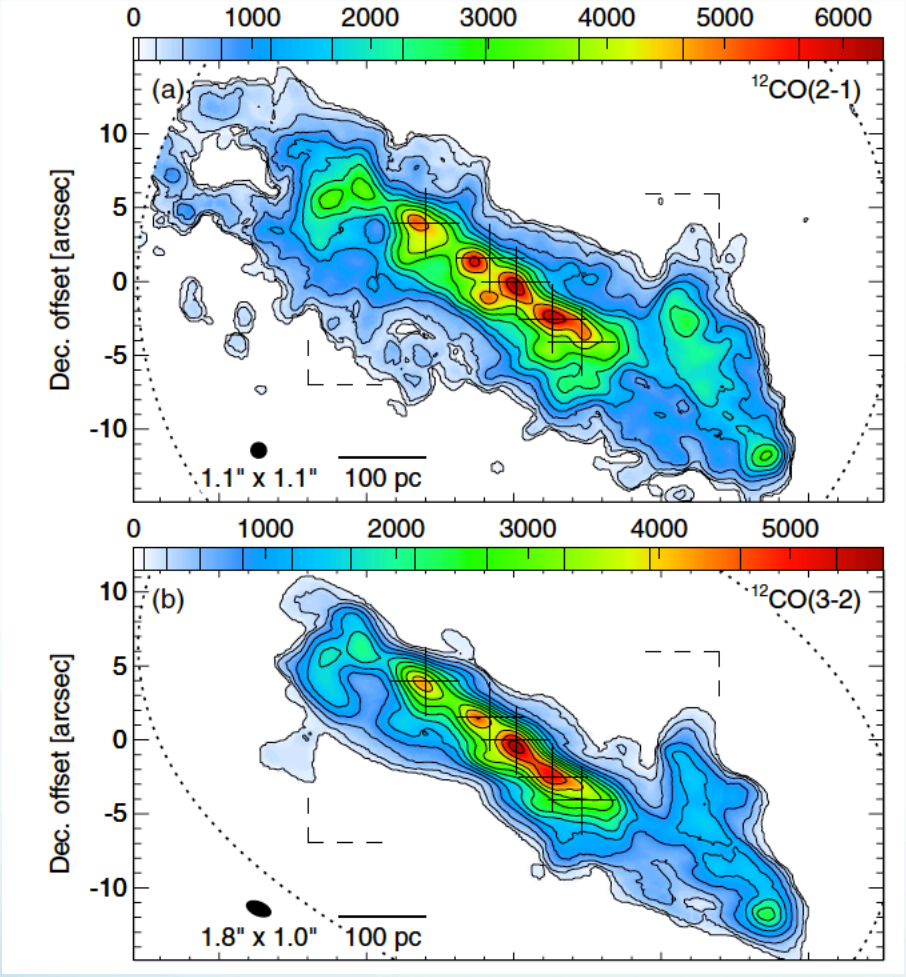
Association of Continuum Sources

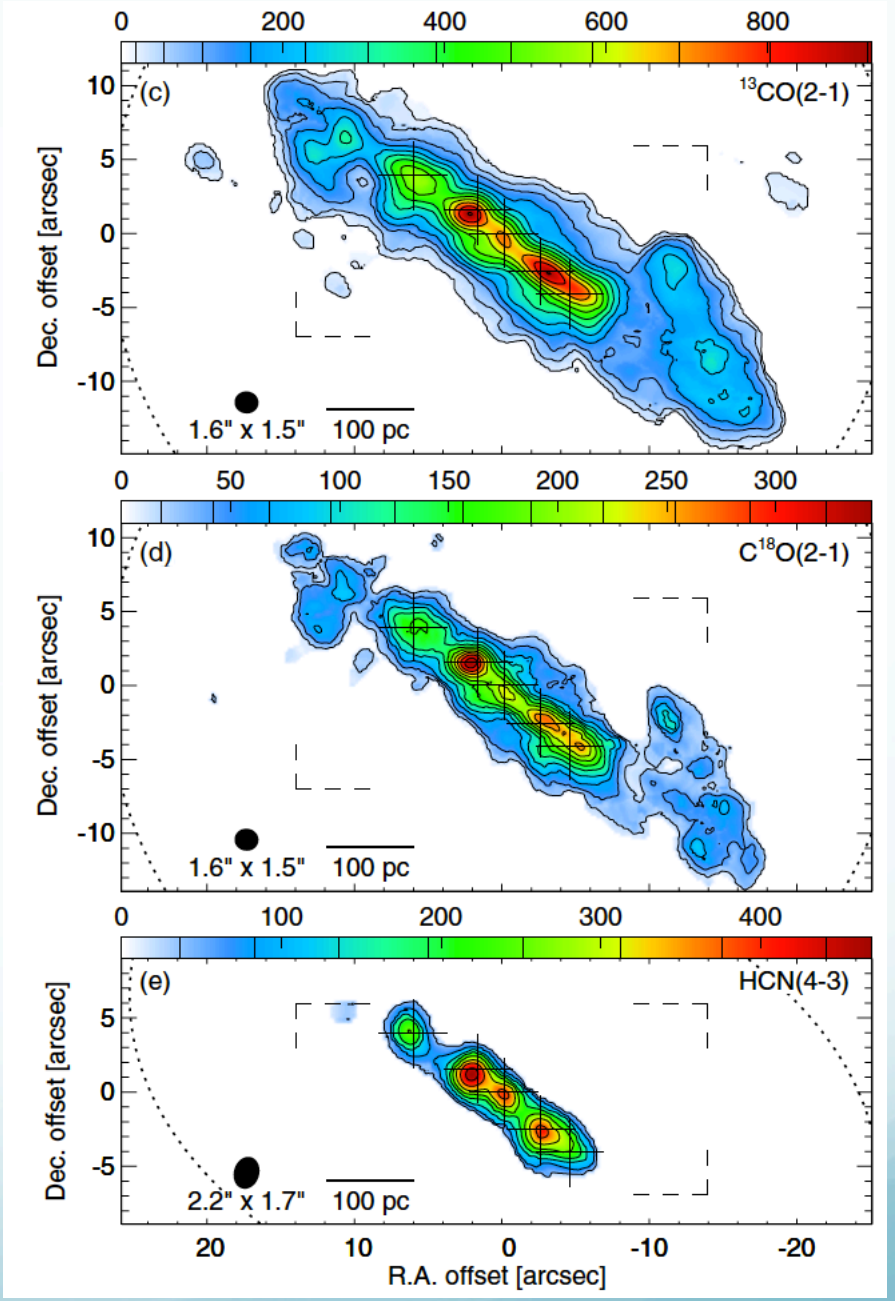


- 1-2” resolution = 20-40pc
- 5 continuum clumps associated with compact cm sources → massive star formation
- Continuum emission is most likely thermal

Sakamoto et al. 2011

^{12}CO, ^{13}CO, $C^{18}O$, HCN



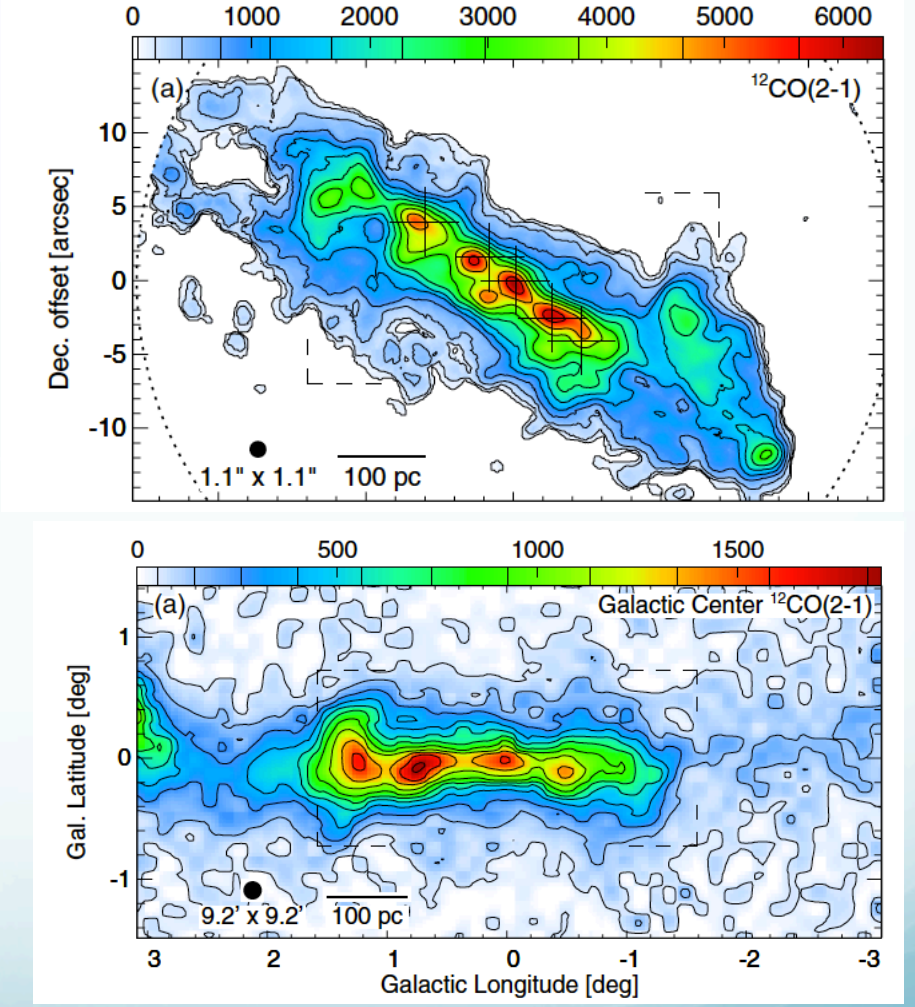


- CO optically thick up to J=3 level
- T~50K, size~20pc, mass~10^7 M_{sun}

Sakamoto et al. 2011

Comparison with the Milky Way

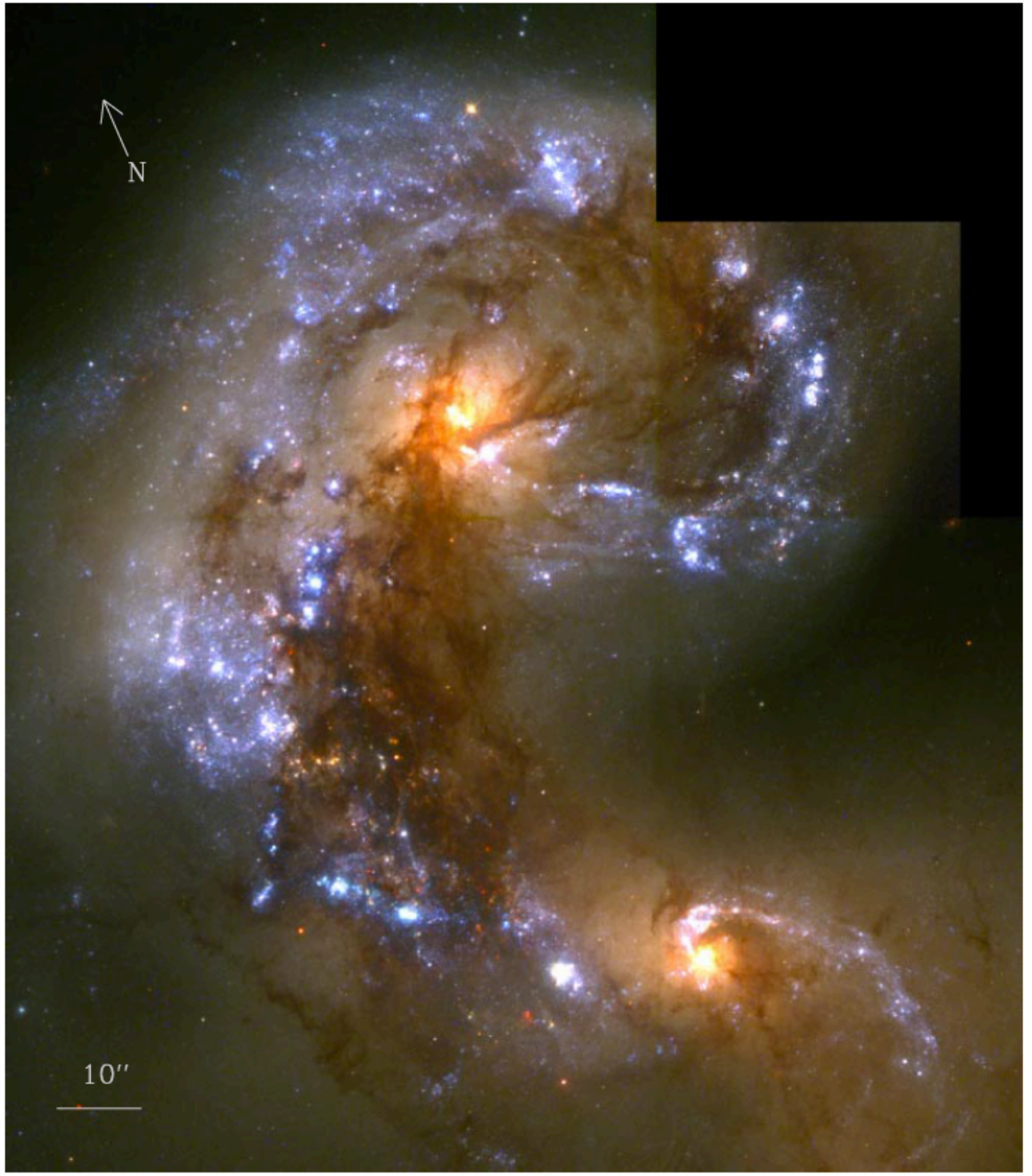
- Similar 20pc resolution for both maps
- Sizes at half-max CO intensity about the same (0.5x0.1 kpc^2)
- Several prominent peaks 20-50pc in size
- Higher HCN/CO ratios at peak than surrounding area
- Clouds in NGC 253 have CO intensities (peak & integrated) 3 to 4x higher than MW → higher masses and column densities in 20pc than MW



Sakamoto et al. 2011

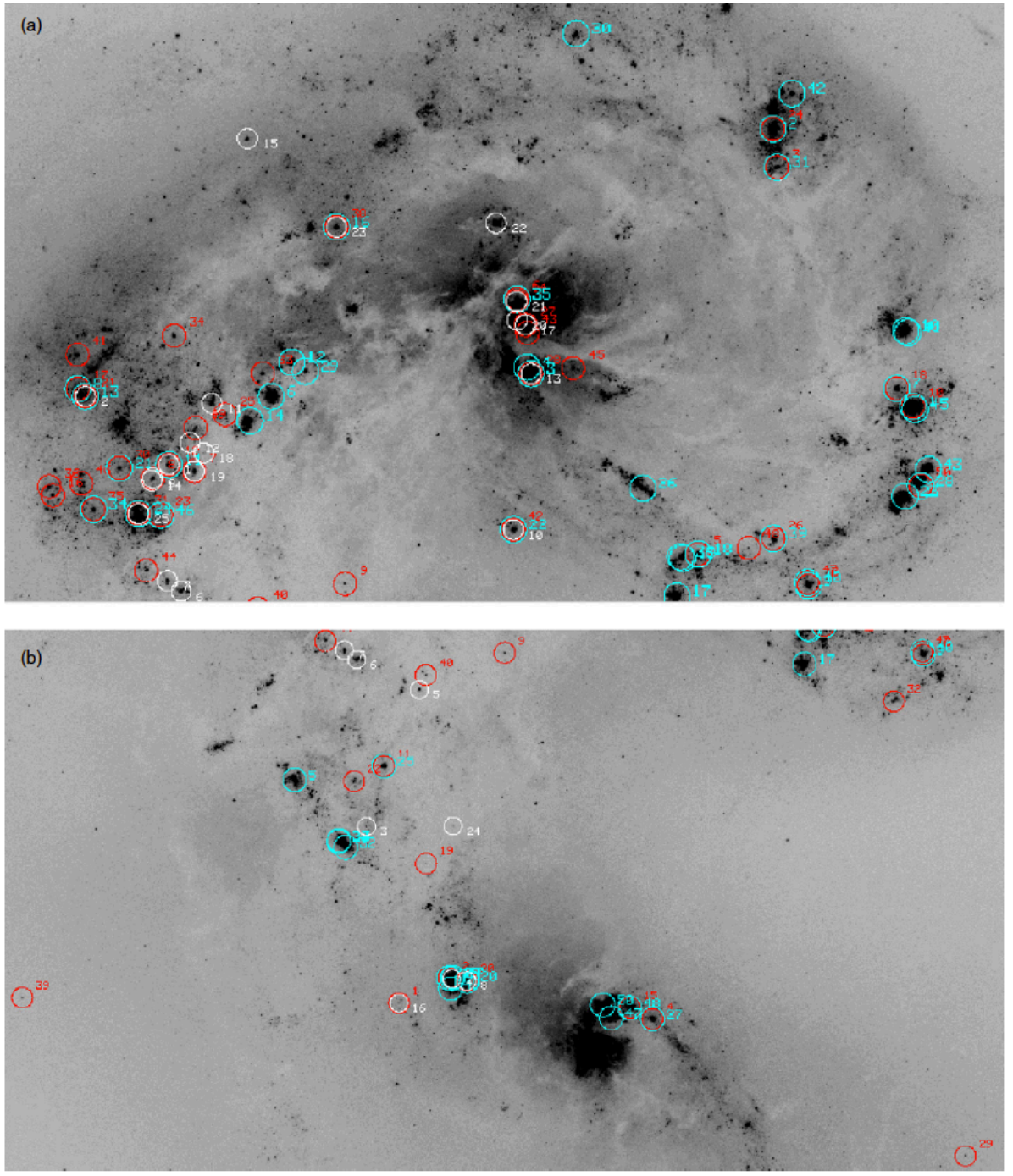
The Antennae

- Starburst from merging of NGC 4038 and NGC 4039
- ~19.2 Mpc away



HST WIFPC2 true-color (UBVI) image of the Antennae Galaxies (Whitmore et al. 1999)

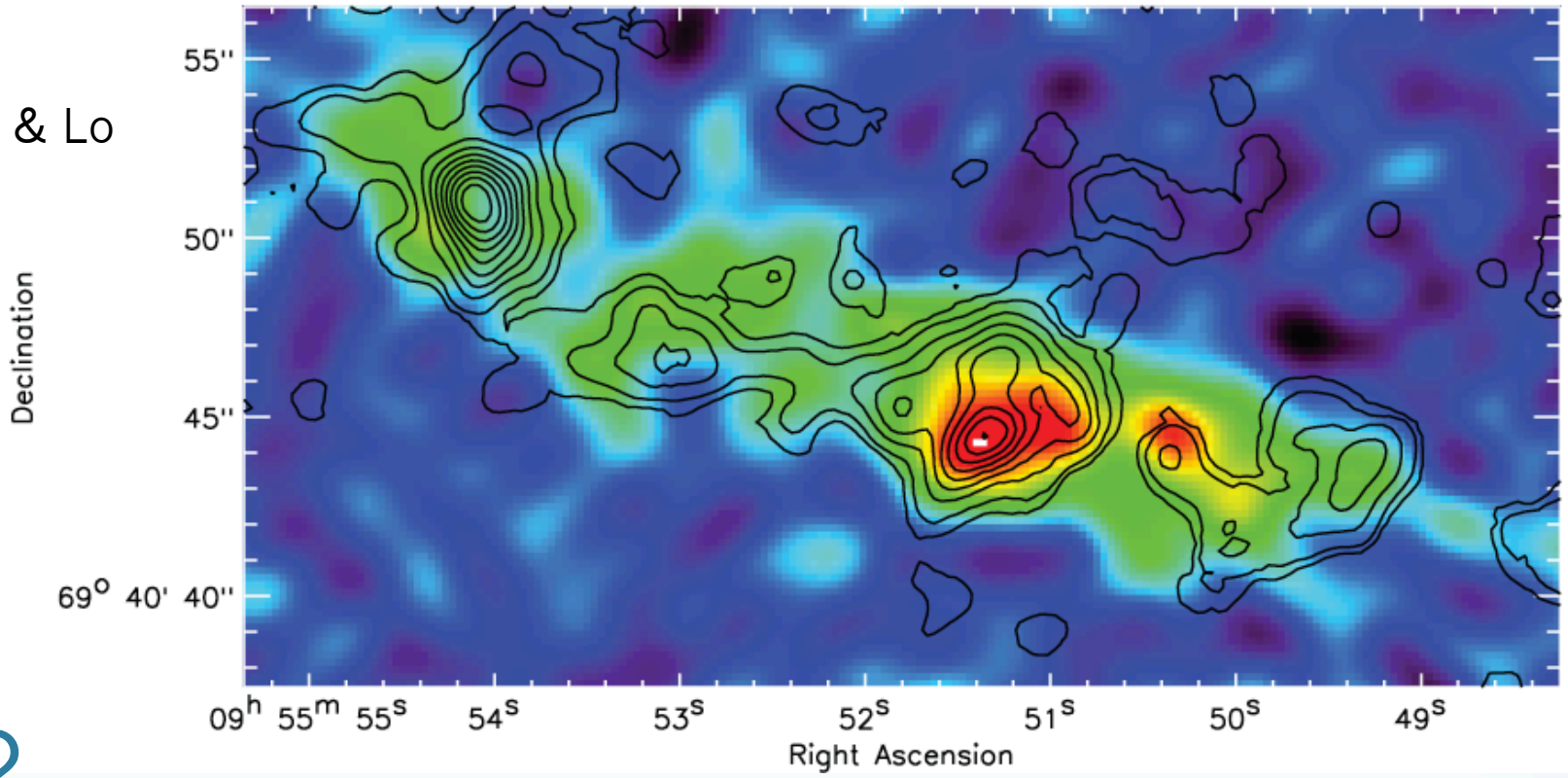
- Super Star Clusters: predominantly found in starbursts and dwarfs
- Different mode of star formation?



- Blue: 50 most luminous clusters
- Red: 50 most massive clusters
- White: 25 most IR-bright clusters

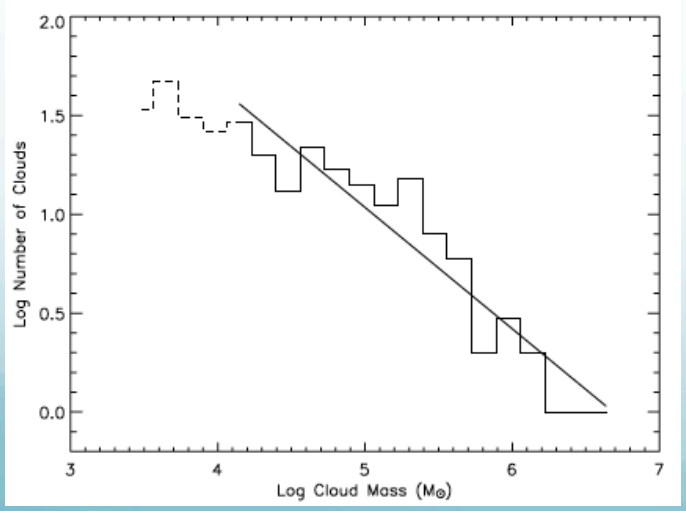
Whitmore et al. 2010

Keto, Ho, & Lo 2005



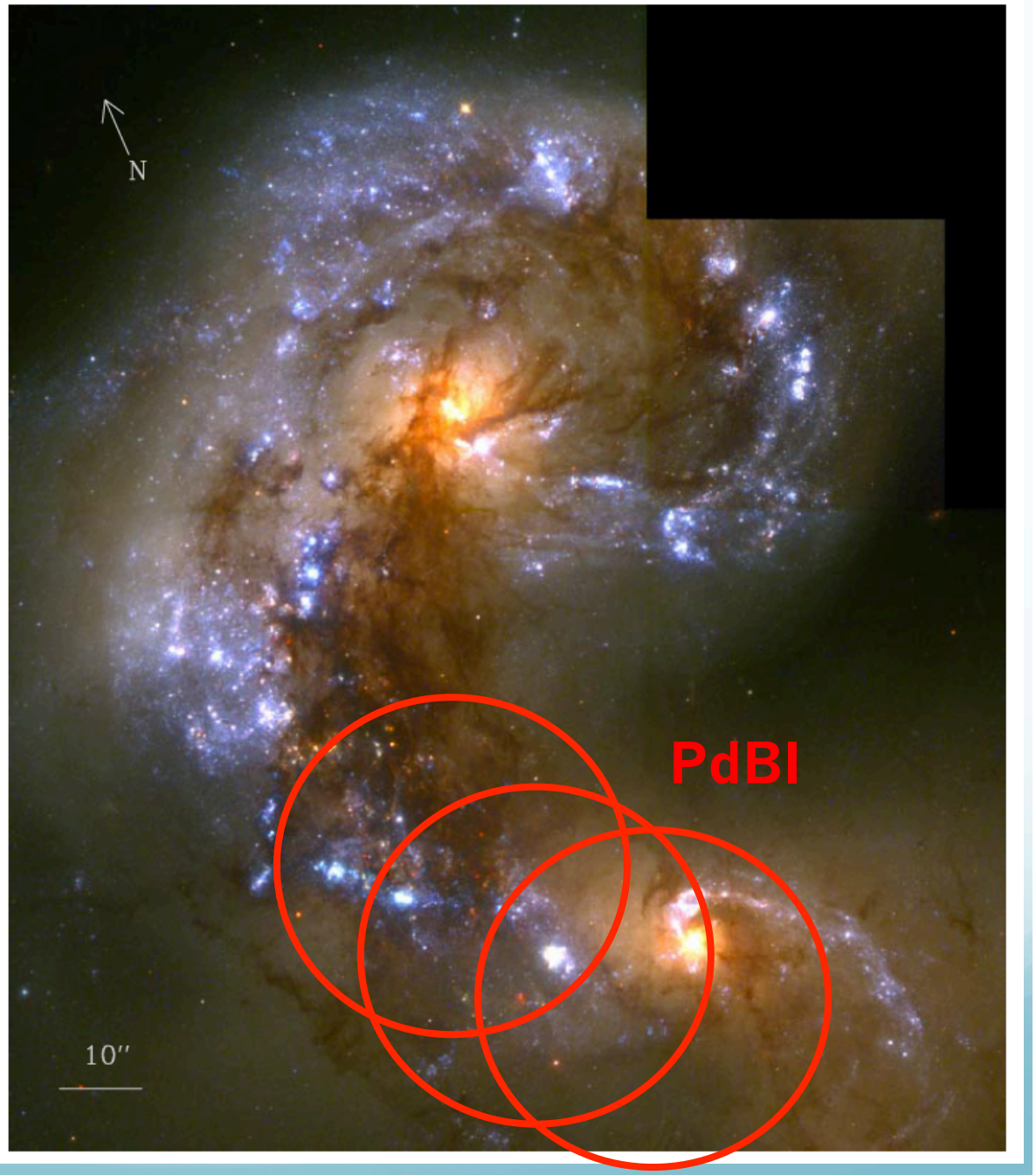
M82

Contours: CO(2-1), color: 100 GHz radio continuum



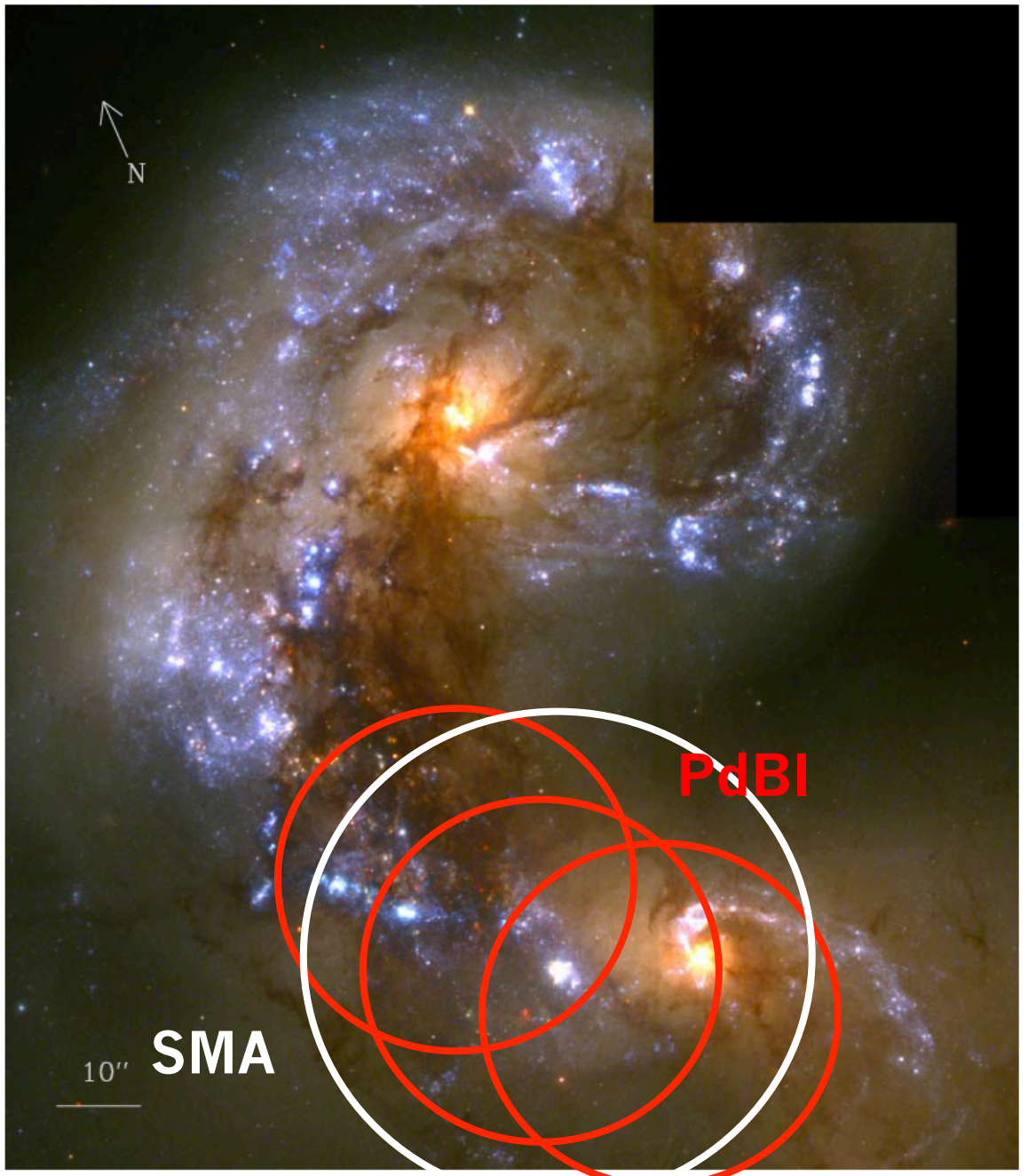
- Molecular cloud mass spectrum similar to that of young star clusters
- SN & HII regions surround large clouds -> outside in formation from external pressure
- Spectra of clouds suggest shock-driven compression

- Focus on the “overlap” region where shock compression is expected
- 3 pointings from the Plateau de Bure Interferometer at ~1” resolution (~100 pc)

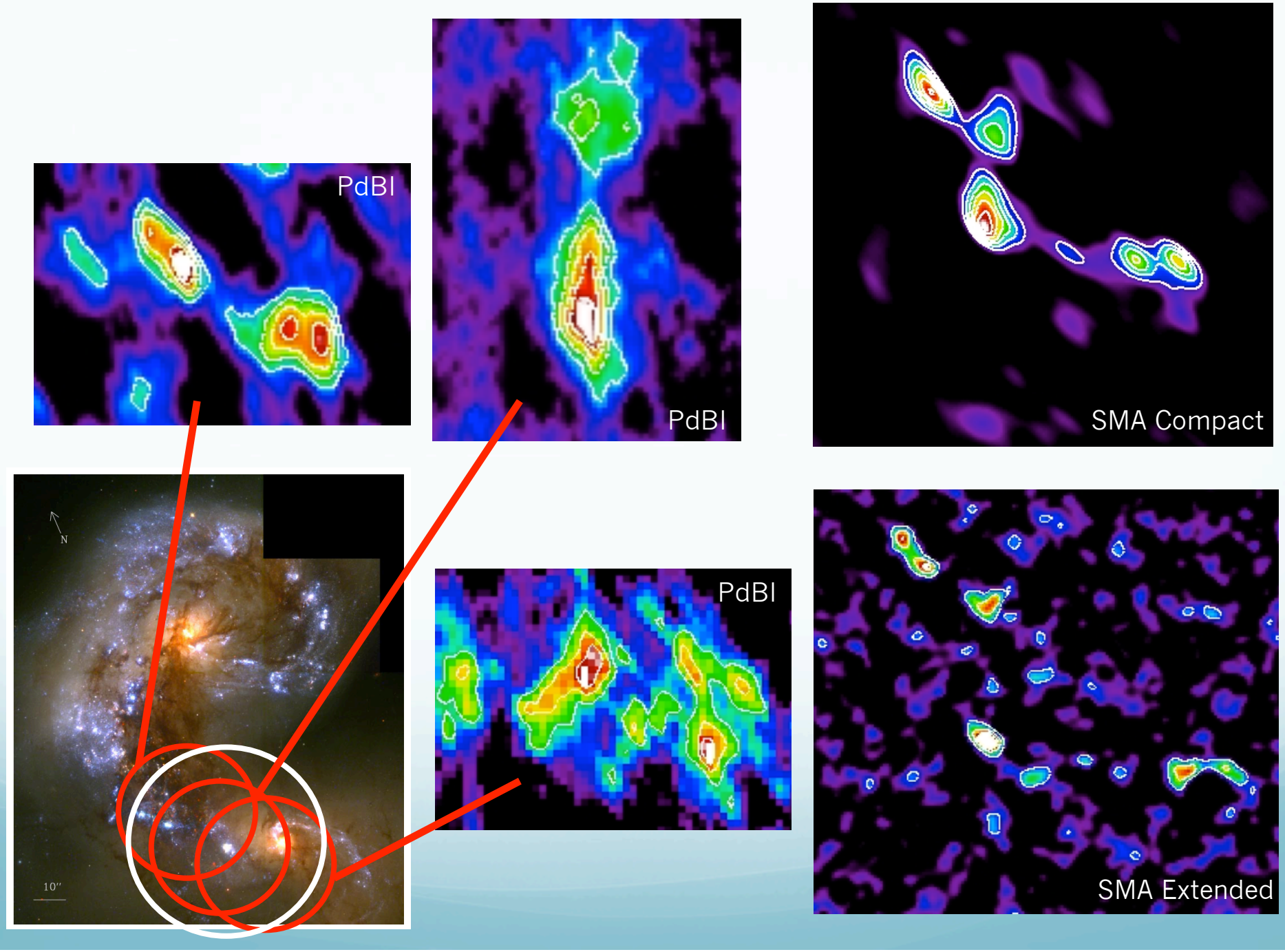


Wei, Keto, & Ho, in prep.

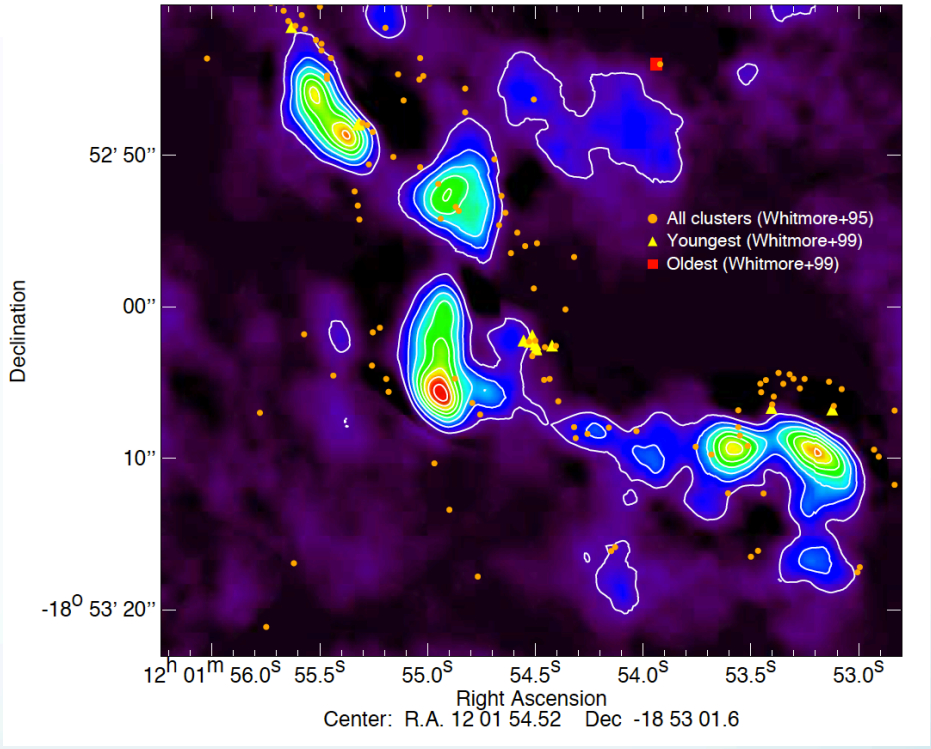
- Focus on the “overlap” region where shock compression is expected
- 3 pointings from the Plateau de Bure Interferometer at ~1” resolution (~100 pc)
- 2 pointings from SMA compact and extended arrays.



Wei, Keto, & Ho, in prep.

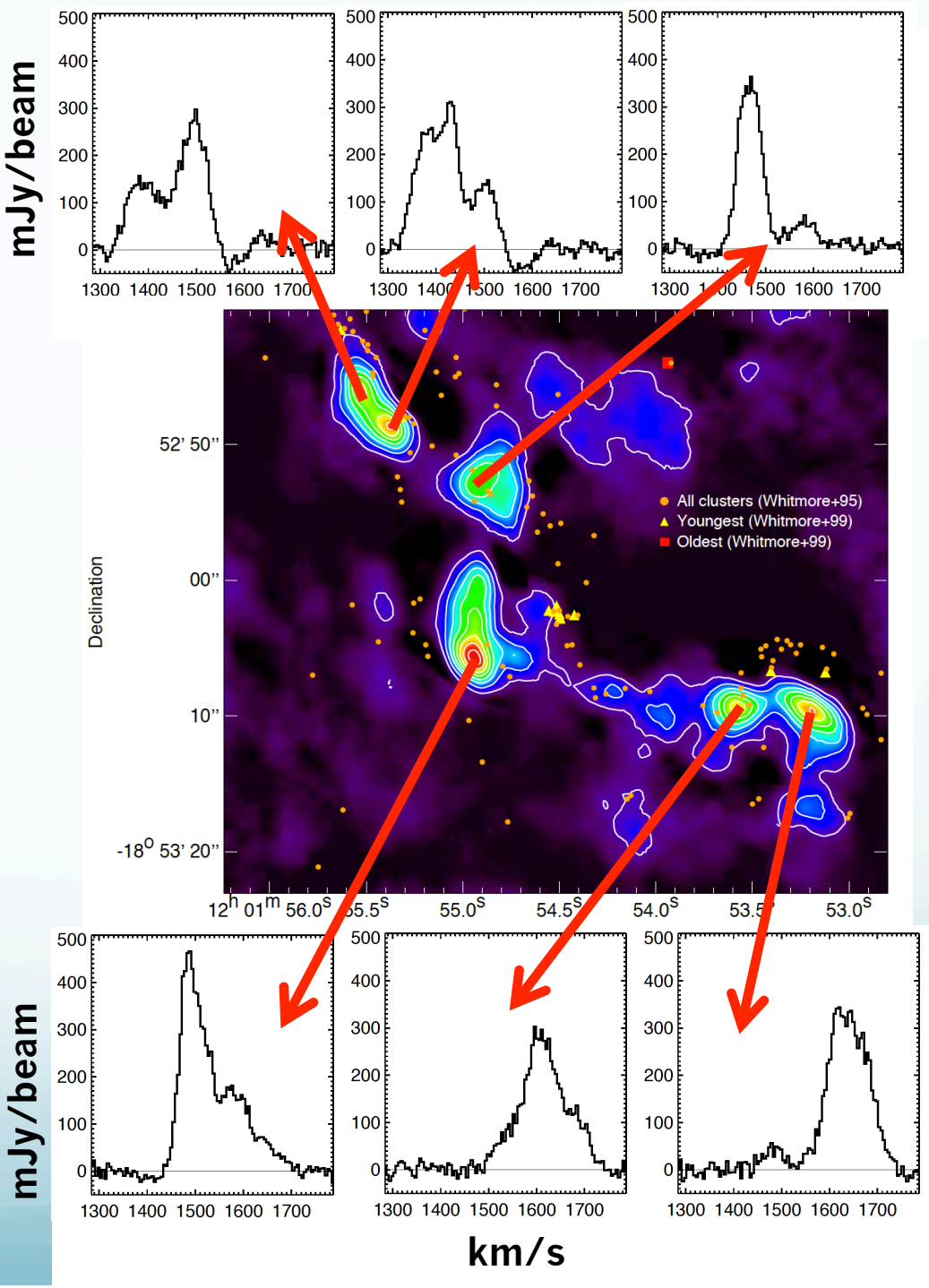

PdBI
PdBI
SMA Compact
N
10″
PdBI
SMA Extended

- Combined SMA and PdBI CO(2-1) map at ~2” resolution = 200 pc
- Super star clusters identified by Whitmore et al. surround the CO emission



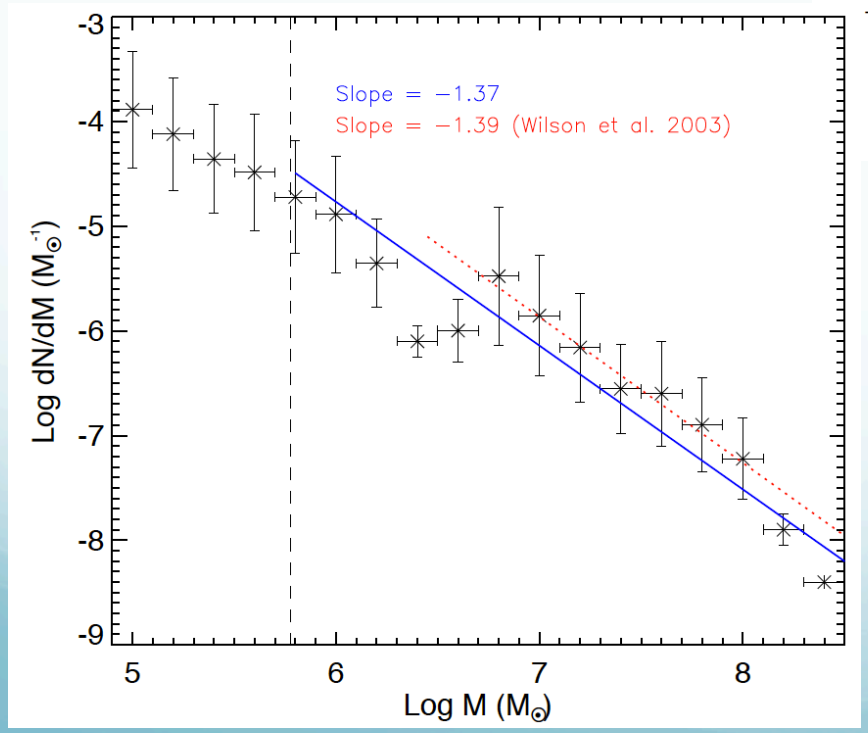
Wei, Keto, & Ho, in prep.

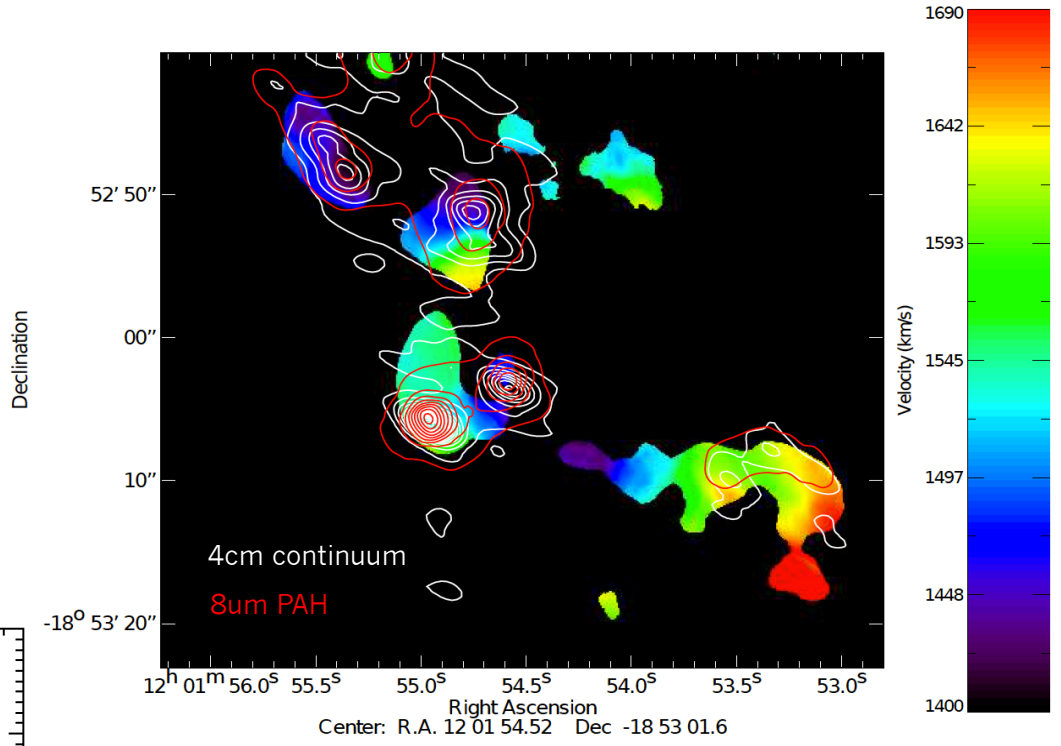
- Combined SMA and PdBI CO(2-1) map at ~2” resolution = 200 pc
- Super star clusters identified by Whitmore et al. surround the CO emission
- Spectra extracted from individual peaks appear complex



Wei, Keto, & Ho, in prep.

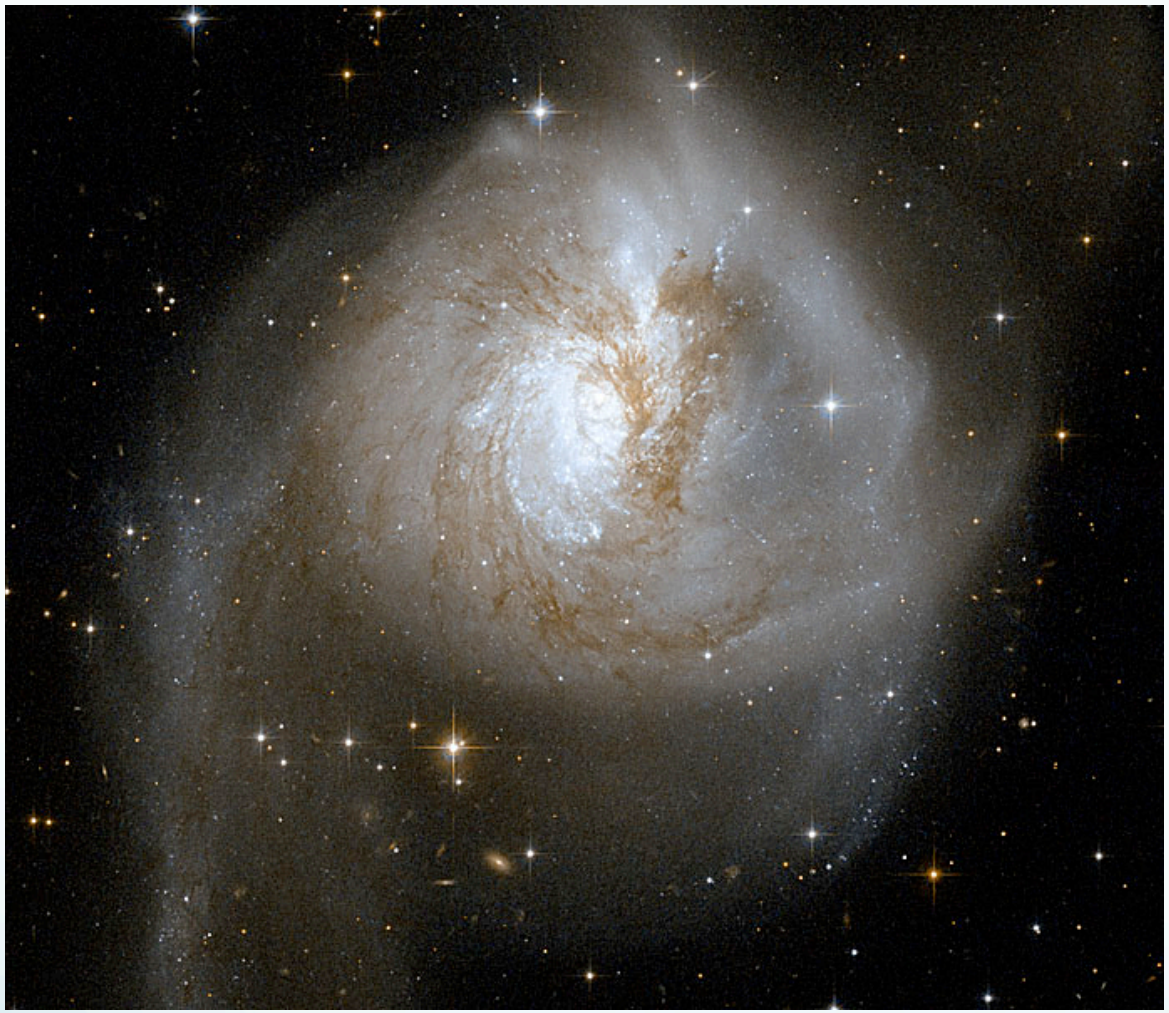
- Differential mass function of clouds extracted by CLUMPFIND consistent with previous work
- Reach down to lower cloud masses than previous work





- Comparison between velocity field and star formation tracers → little correlation between large velocity gradients and peak SF
- Resolution issue?

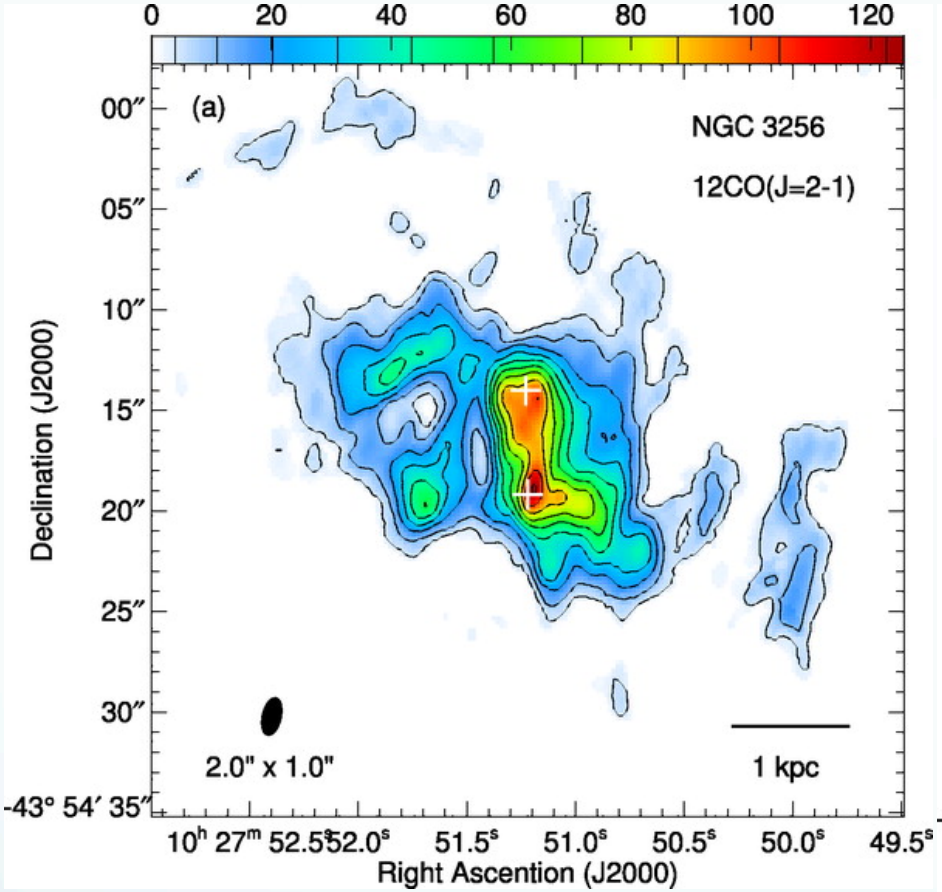
Wei, Keto, & Ho, in prep.

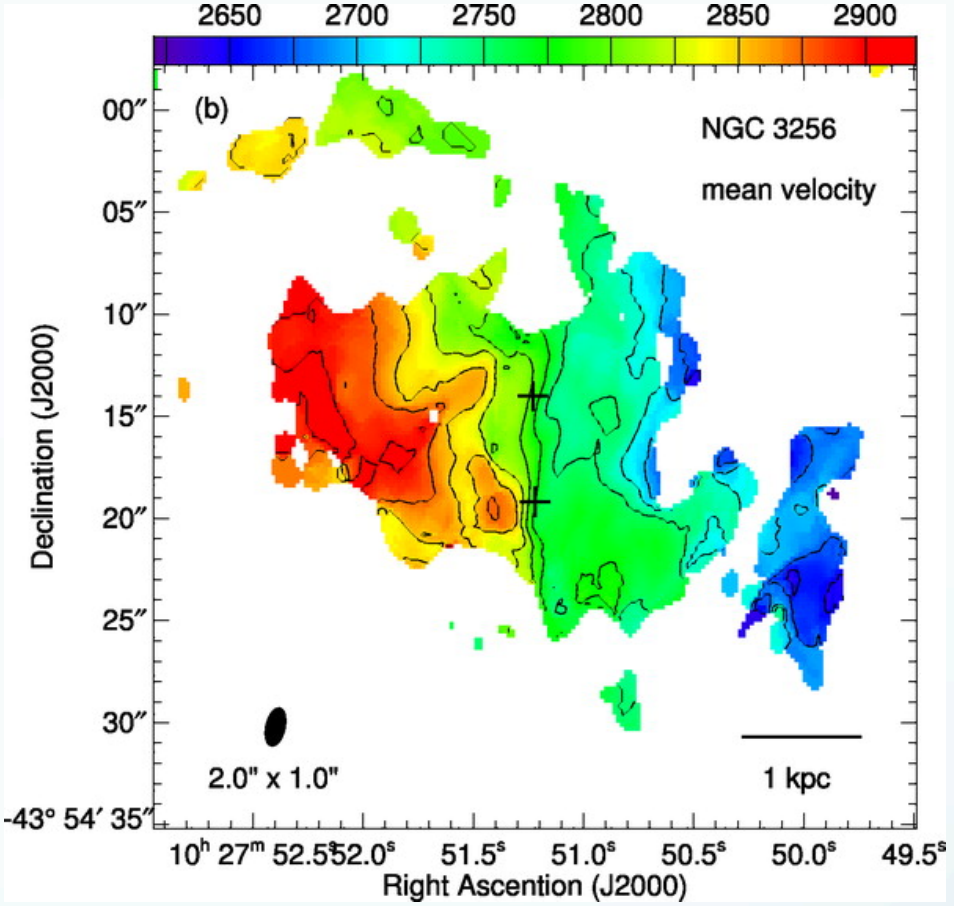


- Luminous Infrared Merger
- Late-stage merger, but not yet complete: double nuclei
- 35 Mpc away

NGC 3256

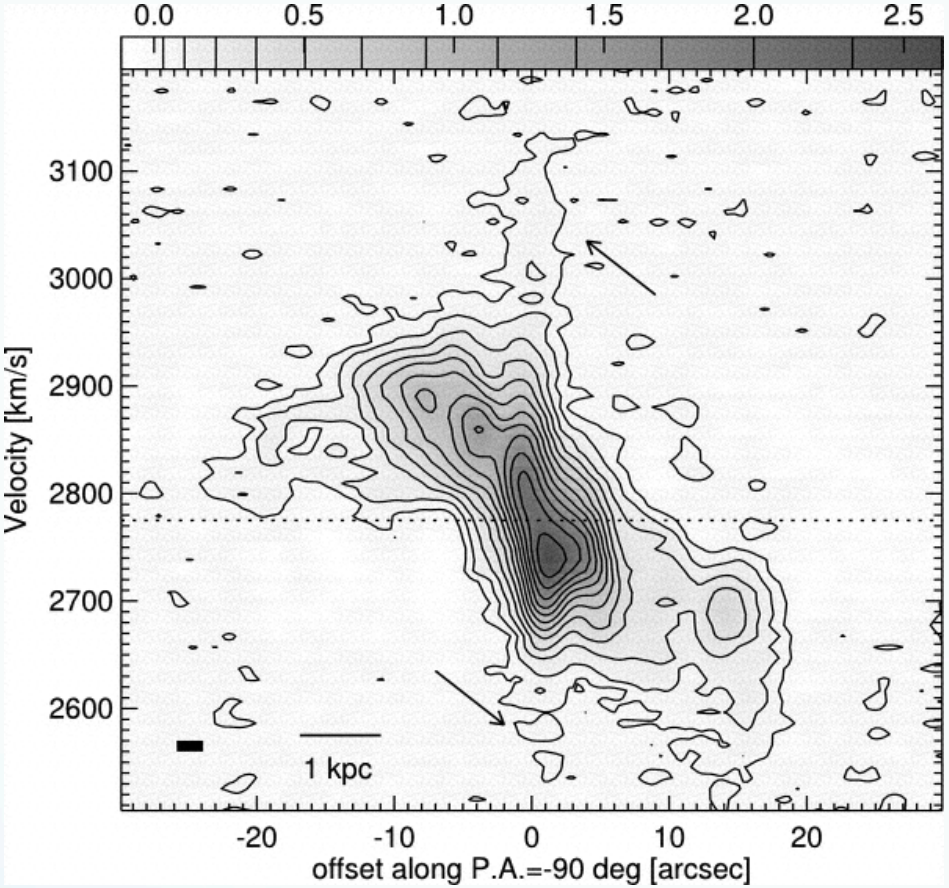
HST ACS (B&I) image
(NASA, ESA, Hubble Heritage Team, & A. Evans)

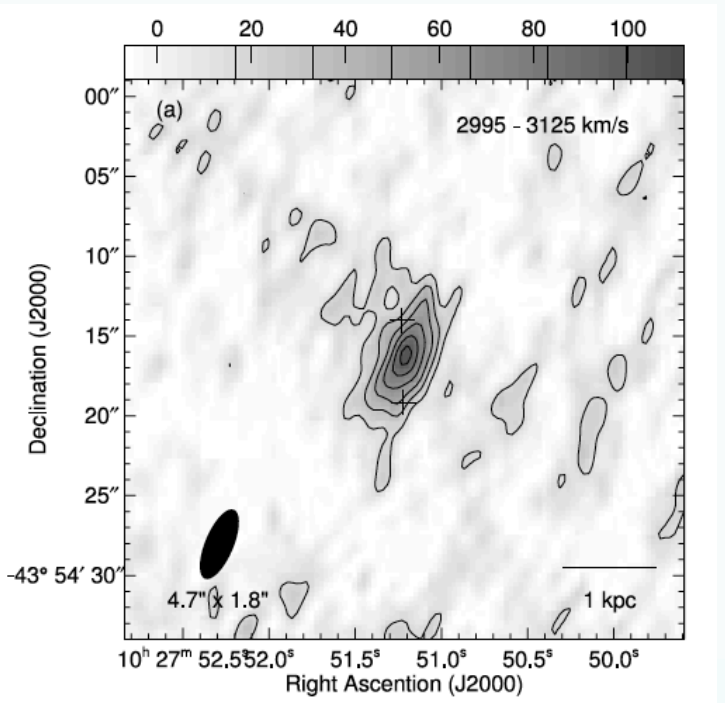


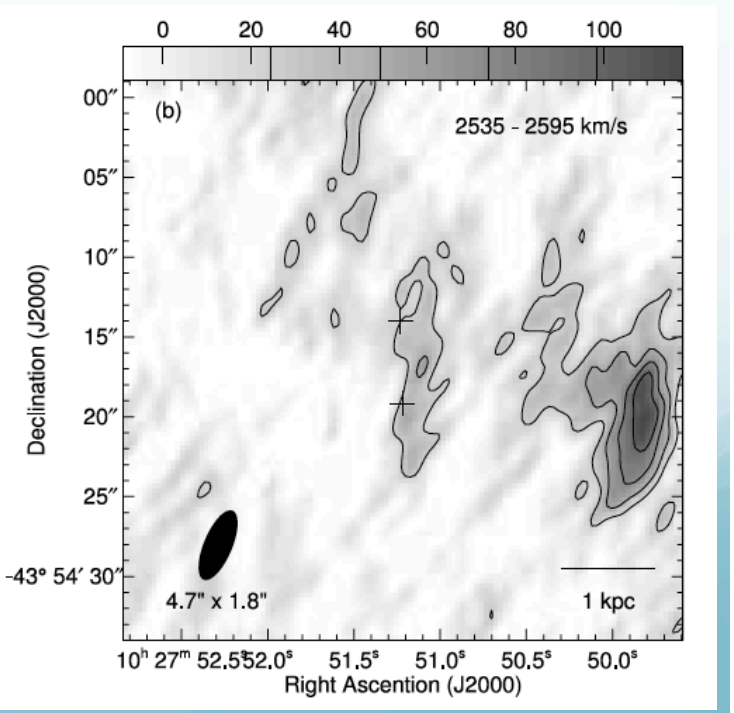


- High resolution SMA imaging reveals compact gas and steep velocity gradient around the nuclei --> small gas disks?

Sakamoto et al. 2006







- High velocity molecular gas in the center = molecular outflow due to superwind from starburst

Sakamoto et al. 2006

Conclusions

- Higher resolution observations with SMA: resolve interesting structures (i.e., GMCs, mini-disks)
- Allows us to quantify density, temperature, and column density of gas in starburst environments
- Understanding of local starbursts help us interpret results at high redshift