Star Formation in Interacting Galaxies from VIXENS

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VIRUS-P INVESTIGATION OF THE EXTREME ENVIRONMENTS OF STARBURSTS

Neal Fest, UTexas, April 26, 2013

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Max

VIRUS-P INVESTIGATION OF THE EXTREME ENVIRONMENTS OF STARBURSTS

Last weekly meeting, December 2012

Neal Fest, UTexas, April 26, 2013

VIRUS-P INVESTIGATION OF THE EXTREME ENVIRONMENTS OF STARBURSTS

The Team

PI, A. Heiderman

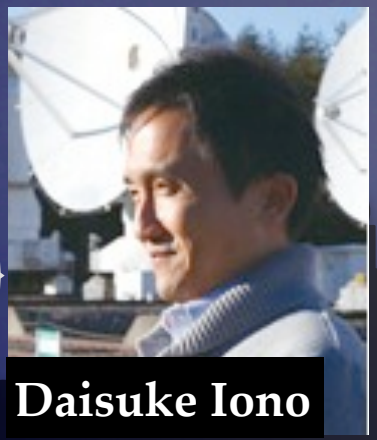
CO-Is:


Neal Evans


Timothy Davis

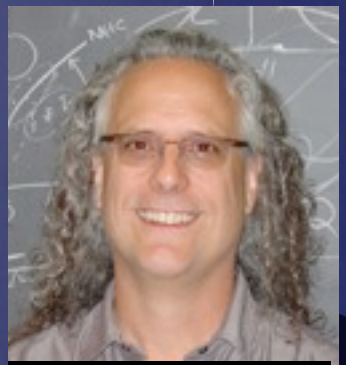

Guillermo Blanc


Remco van den Bosch


Daisuke Iono


Min Yun


Casey Papovich

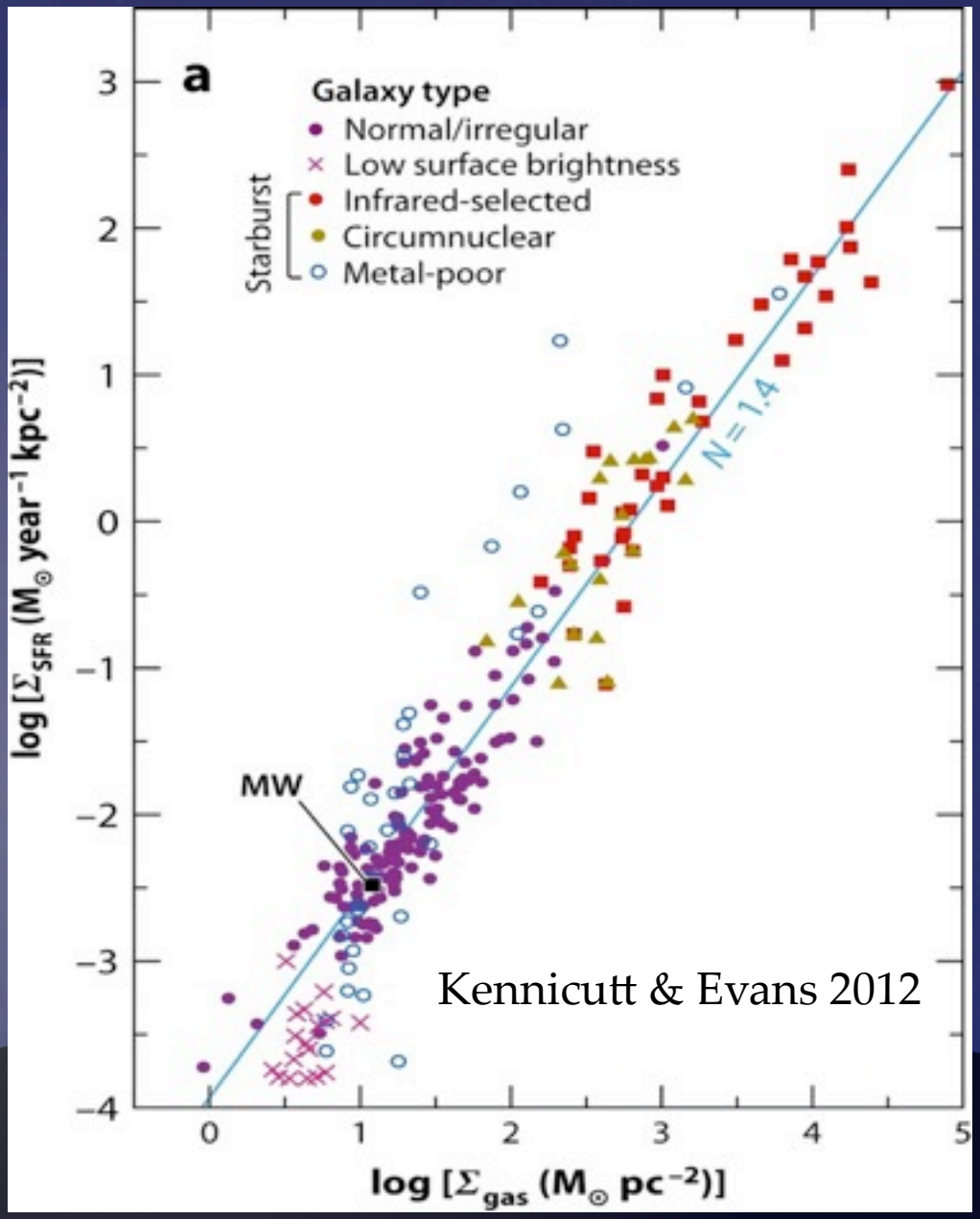

Karl Gebhardt

Extragalactic Relations

- Global system-average scales
  - spirals, starbursts
- Common Parameterization:

$$\Sigma_{SFR} = A\Sigma^{N}_{gas}$$

(Schmidt 1959; Kennicutt 1998)



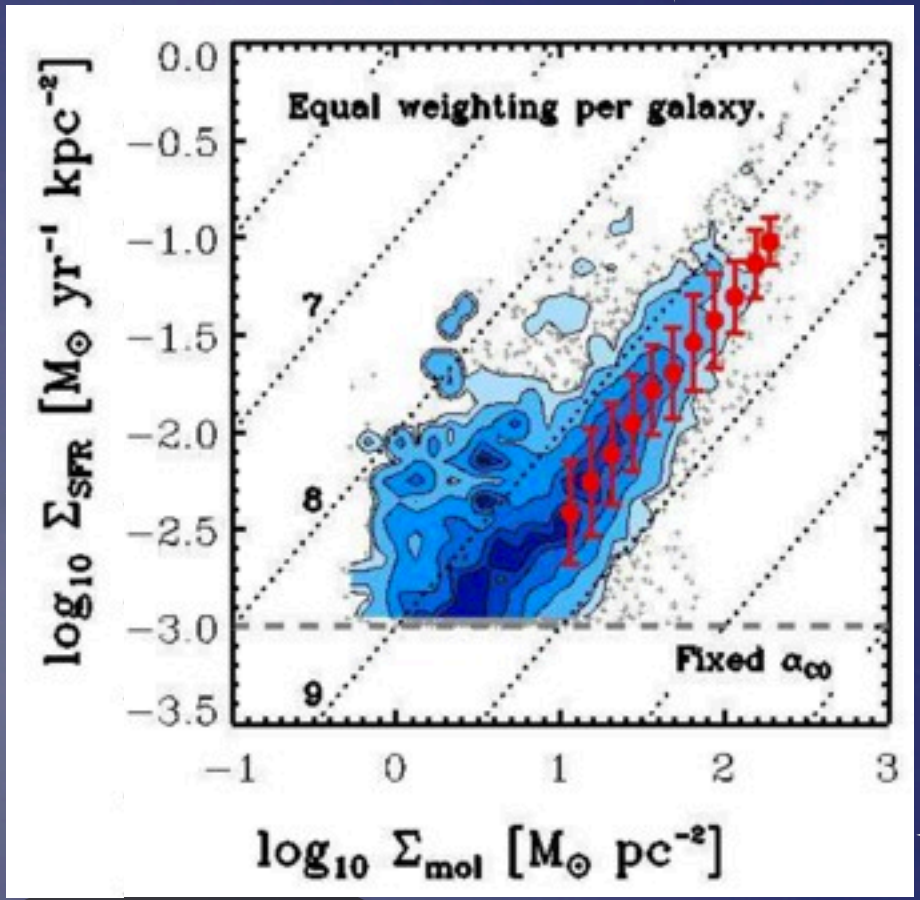
Kennicutt & Evans 2012

Extragalactic Relations

- 1 kpc scale regions in nearby spiral galaxies
- Common Parameterization:

$$\Sigma_{SFR} = A\Sigma^{N}_{gas}$$

(Schmidt 1959; Kennicutt 1998)

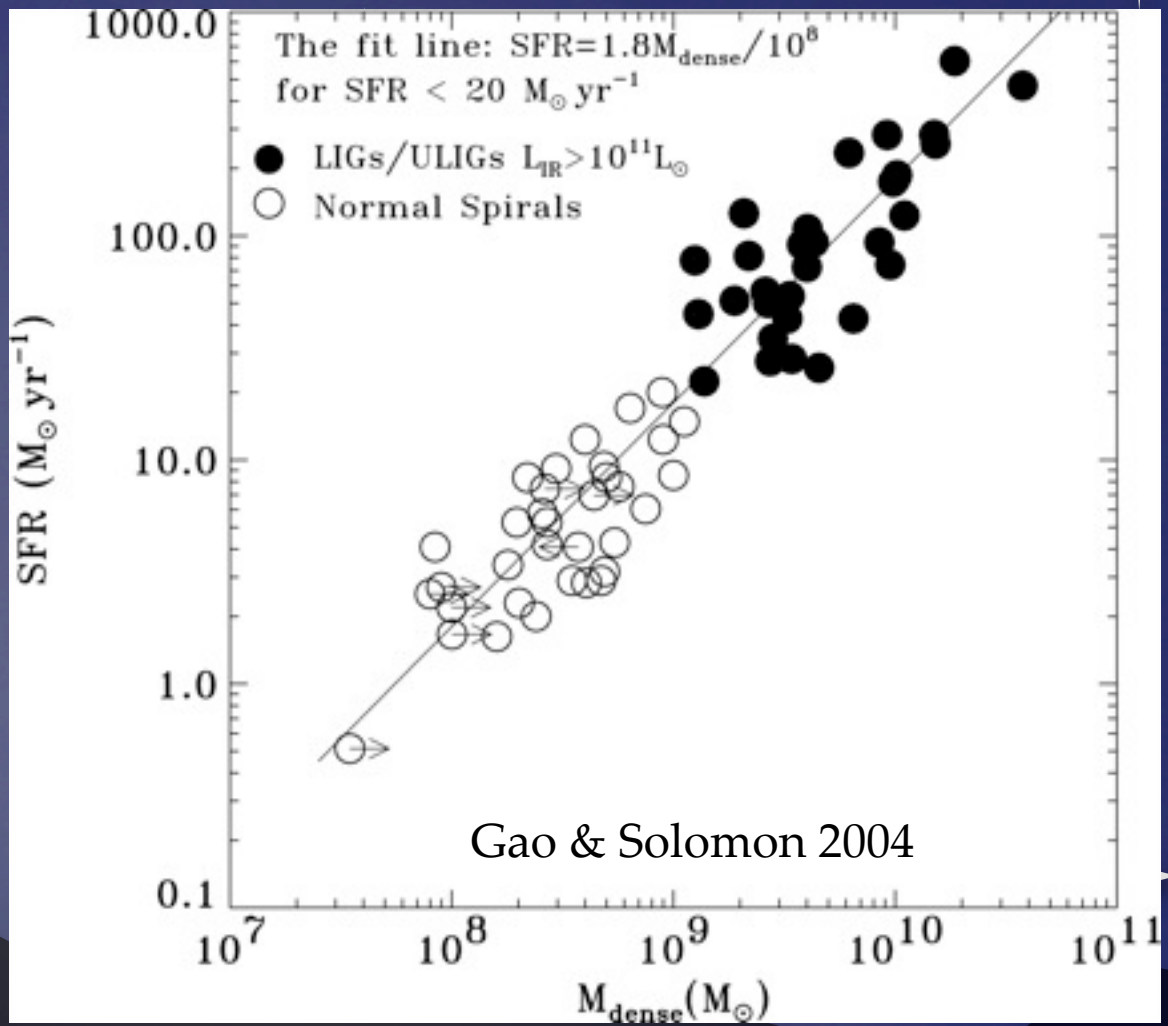


Leroy et a. 2013

Extragalactic Dense Gas Relation

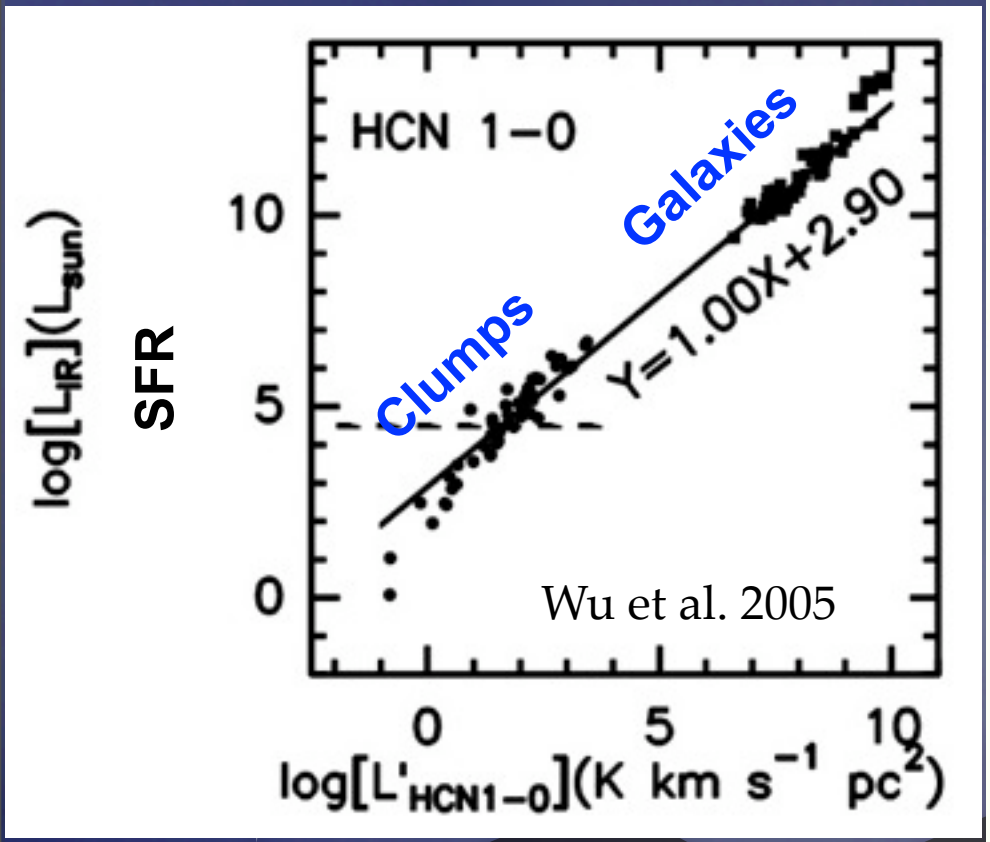
- Dense gas (traced by HCN)
- SFR ∝ amount of dense gas

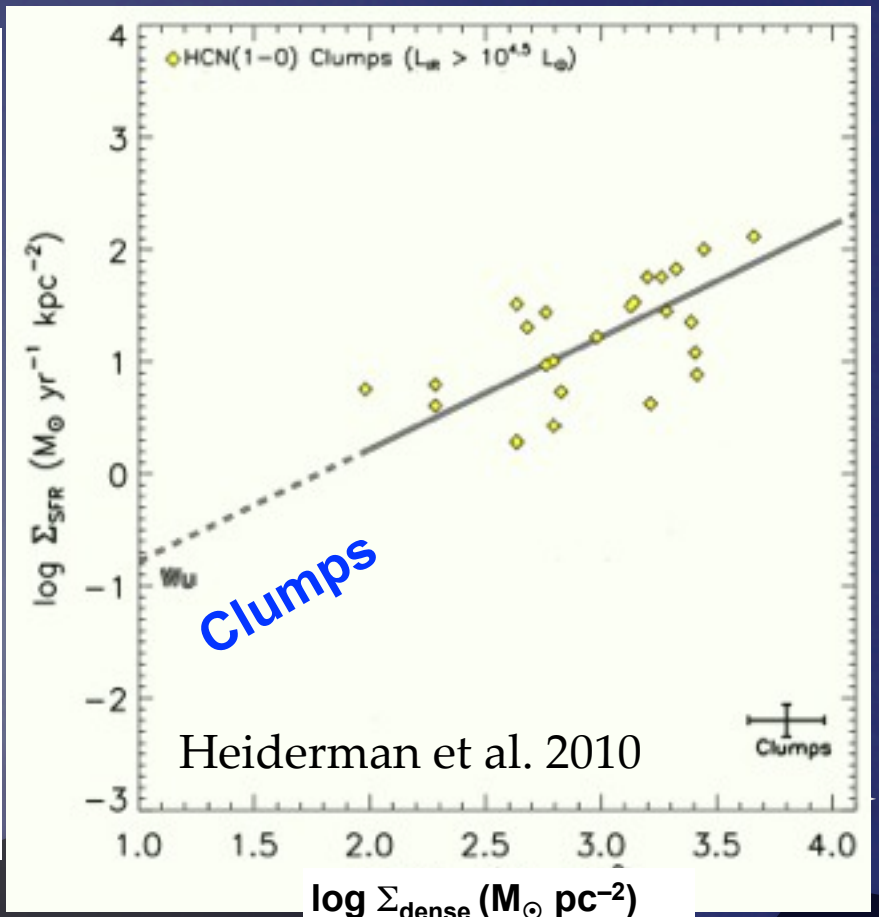
SFR ∝ M_{dense}



Extragalactic + Galactic Dense Gas Relation

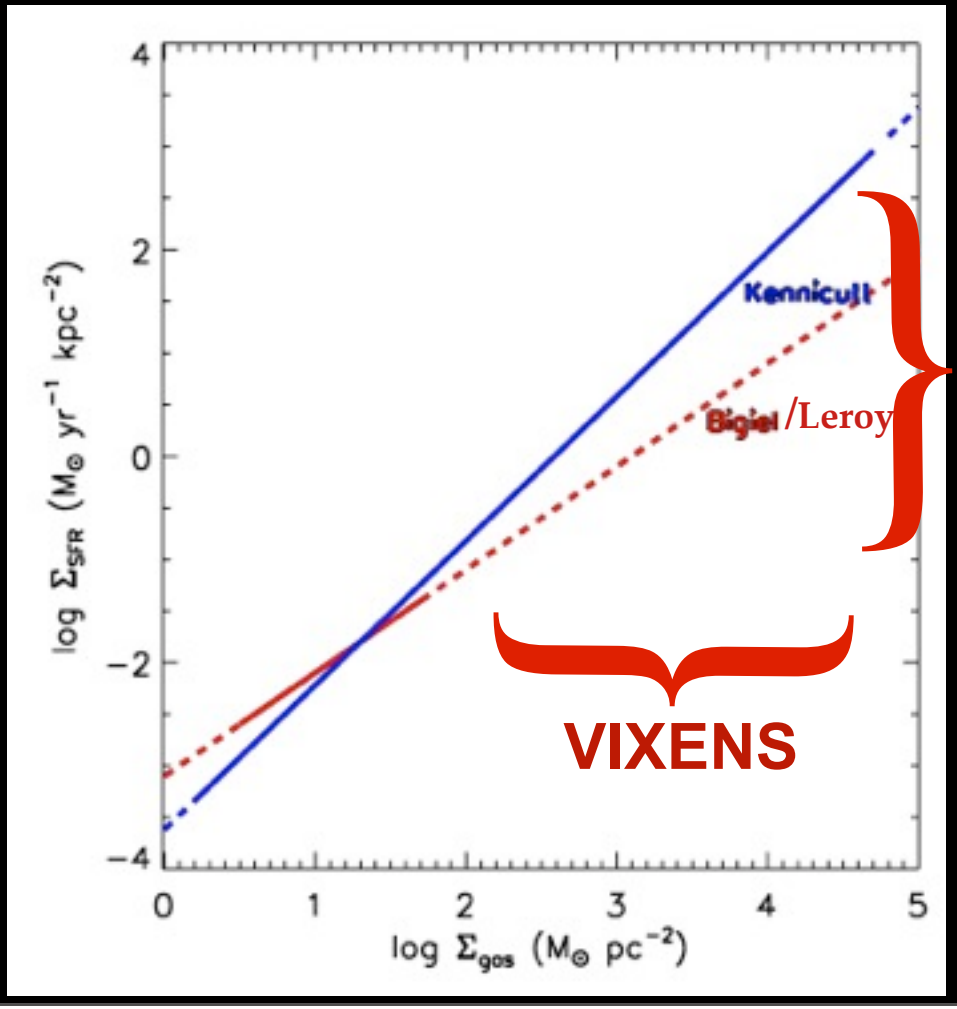
- Extragalactic relation extends to Galactic massive clumps





VIRUS-P INVESTIGATION OF THE EXTREME ENVIRONMENTS OF STARBURSTS

- Kennicutt 1998: global integrated measurements in spirals & starbursts
- Bigiel et al. (2008); Blanc, Heiderman et al. (2009; VENGA), Leroy et al (2013): spatially resolved regions in 'normal' spirals
- VIXENS: spatially resolved star formation in interacting/starburst galaxies at *high* Σ_{gas} , Σ_{SFR}



VIXENS IFU Survey: Testing SFR-gas Relations at high Σ_{gas}, Σ_{SFR}

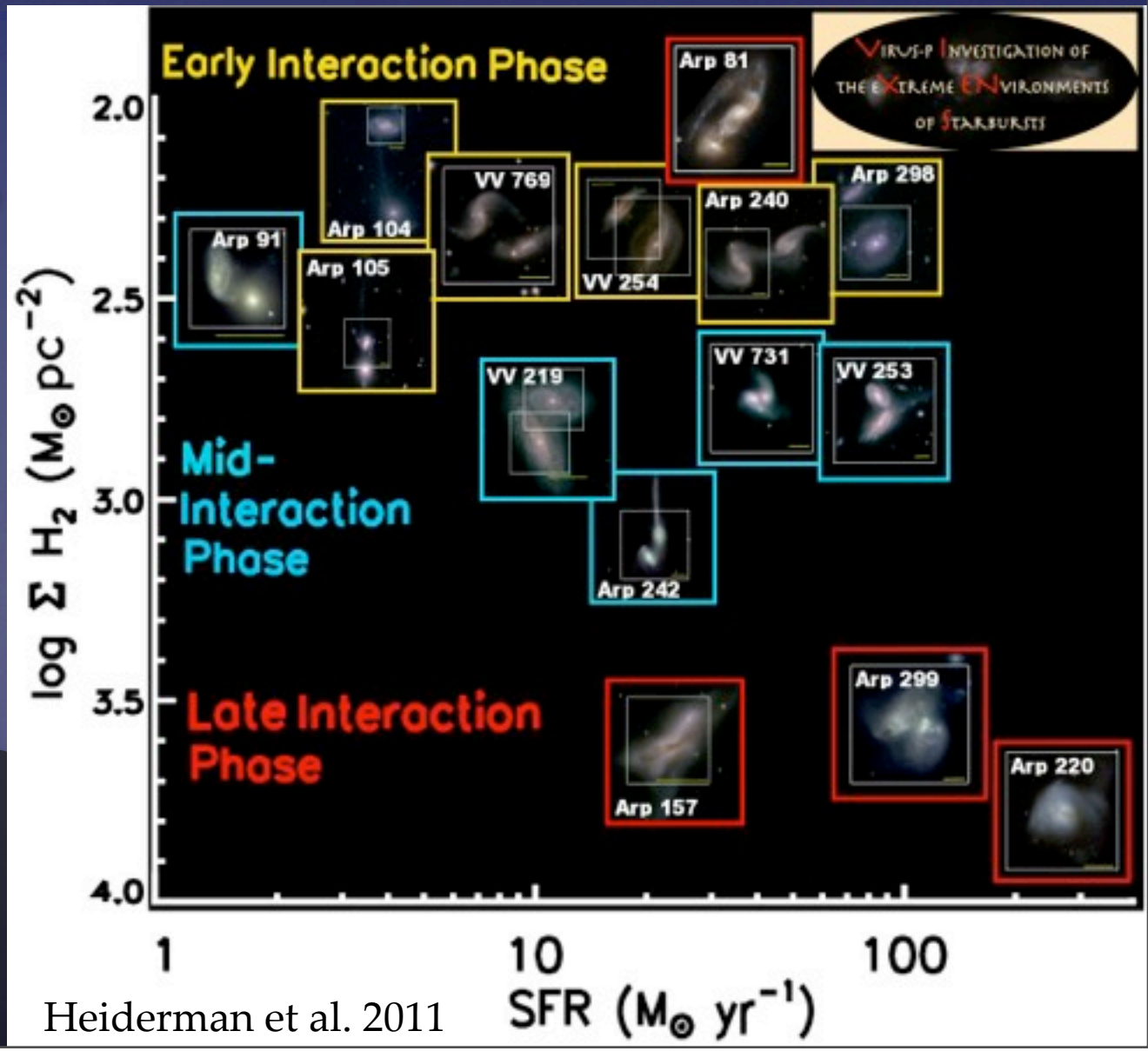
- Goal: Investigate the ~0.1-1 kpc resolved SFR-gas (S-K) relation at *high* Σ_{gas} (>100 $M_\odot$ pc^{-2}) & Σ_{SFR} (>~10 $M_\odot$ yr^{-1}) as a *function of interaction phase*

- Ancillary Data:

Gas: CO(1-0)/ CO(3-2)/HCN(1-0)/ HI

SFR: Hα/24μm/FUV

Dust: 350um



Heiderman et al. 2011

Late Interaction Stage Merger Arp 299

Gas tracers:

- CO(2-1)
- CO(3-2)
- HCN(1-0)
- HCO^+(1-0)
- HI

Star Formation tracers:

Hα

24μm

Paα

N

E

IC 694

A

C'

C

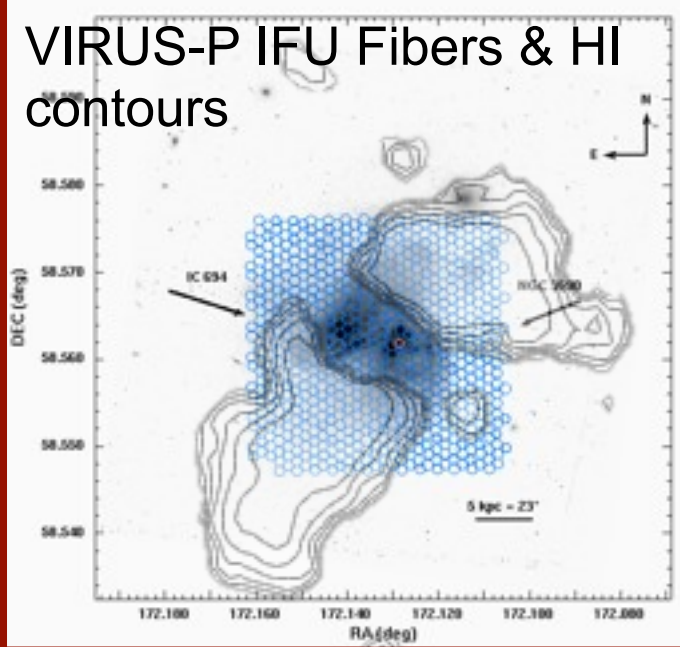
B1

NGC 3690

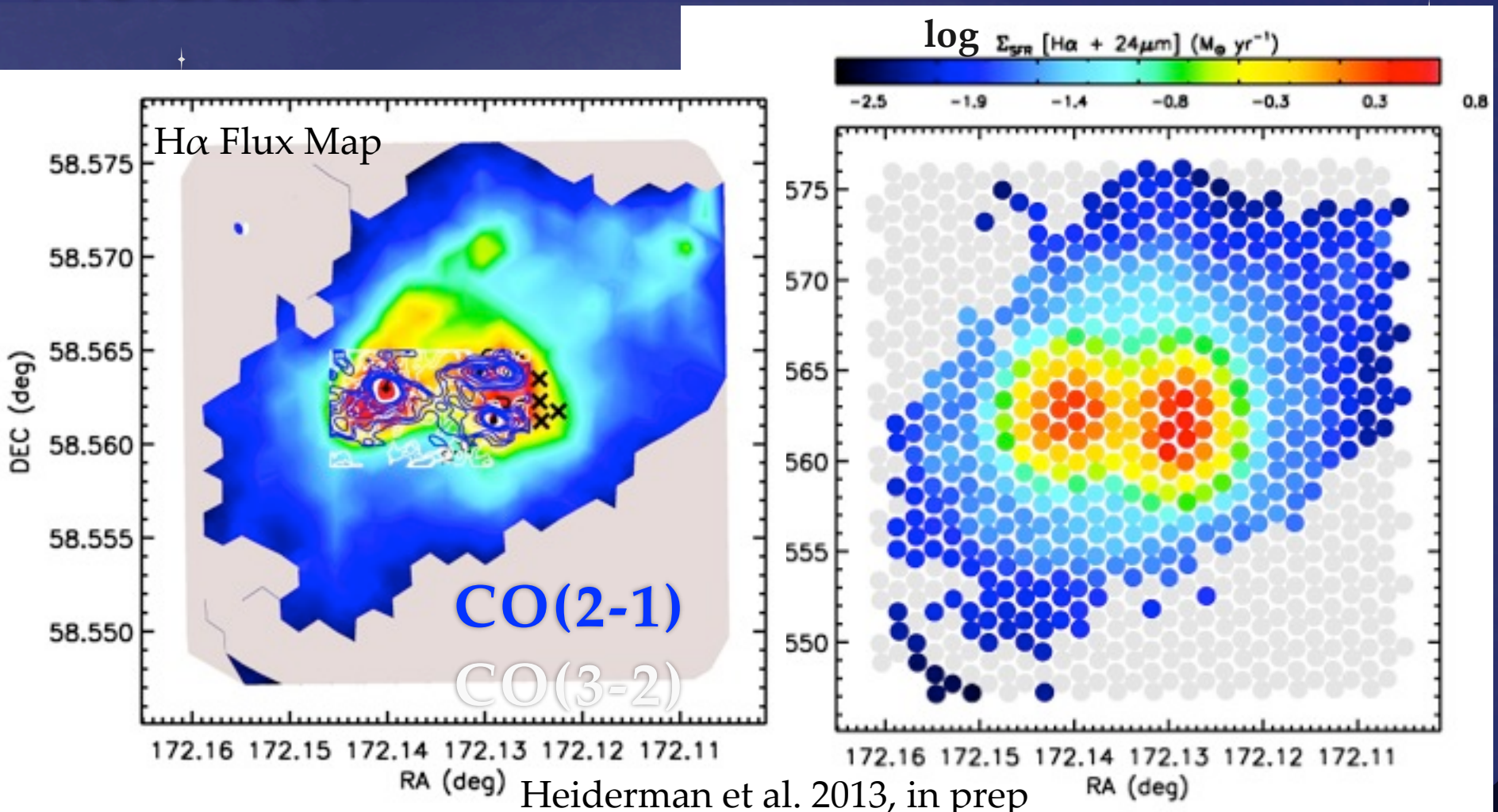
HST 814W

1 kpc

VIRUS-P IFU Fibers & HI contours



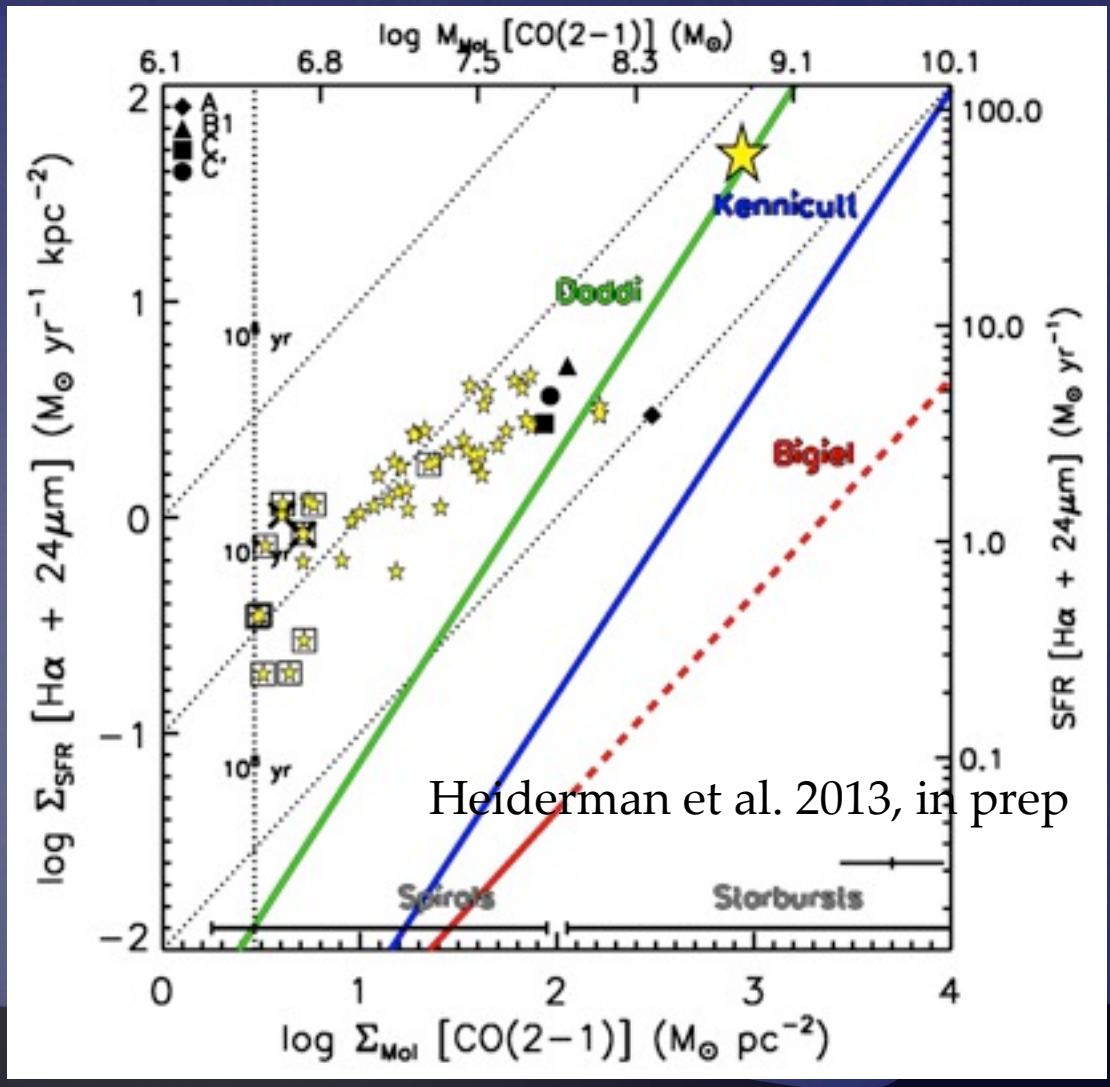
SFR- MoI Gas Surface Density Relation



Heiderman et al. 2013, in prep

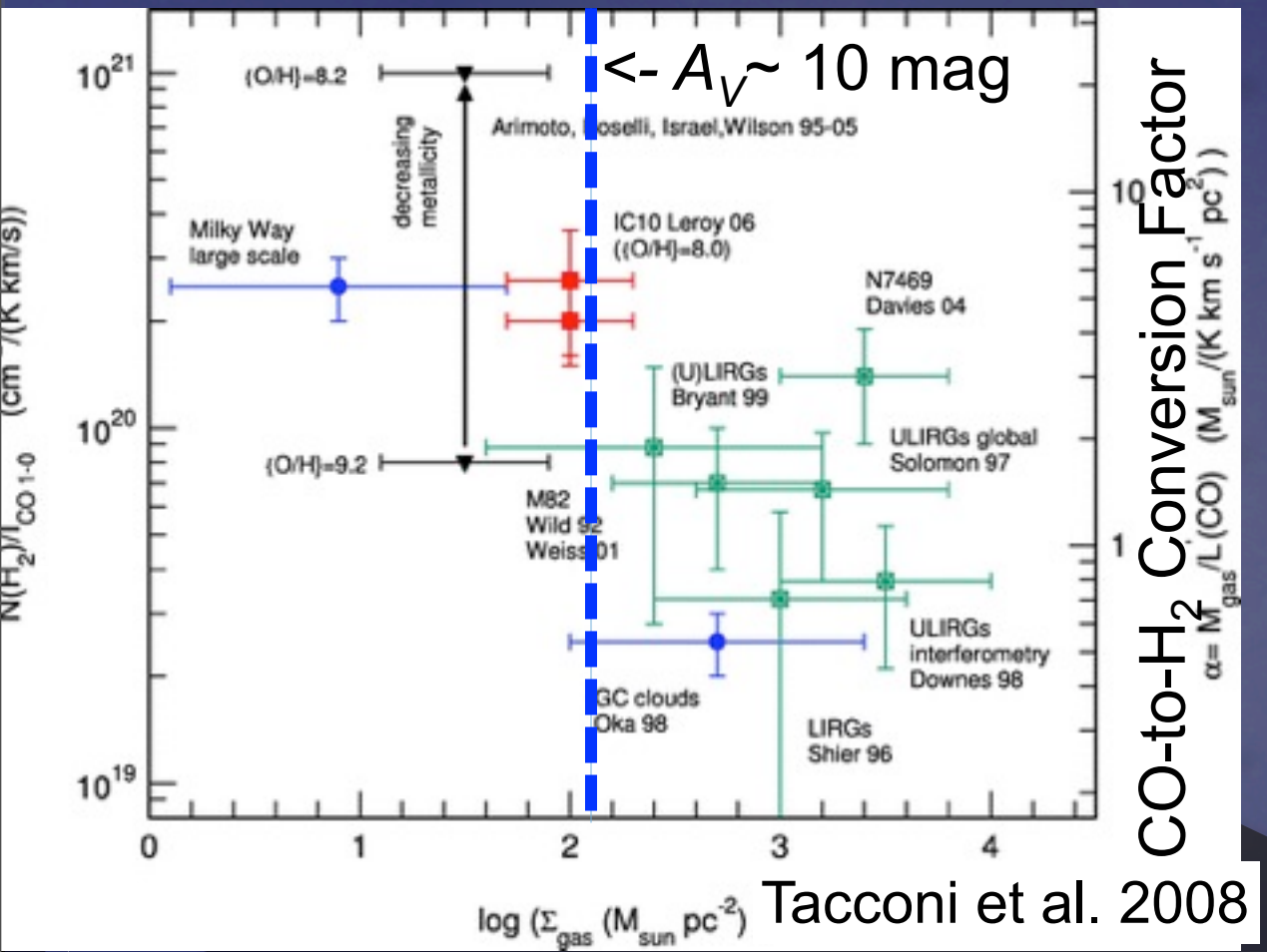
SFR-MoI Gas Relation ~1.3 kpc scales

- Using a starburst-like CO-to-H_2 conversion factor (α_{CO}) value for Arp 299 (Sliwa et al. 2012) and CO(2-1)
- regions lie well above extragalactic relations, even high-z mergers



Heiderman et al. 2013, in prep

CO-to-H_2 Conversion Factor α_{CO} Decreases at High Σ_{gas}



Tacconi et al. 2008

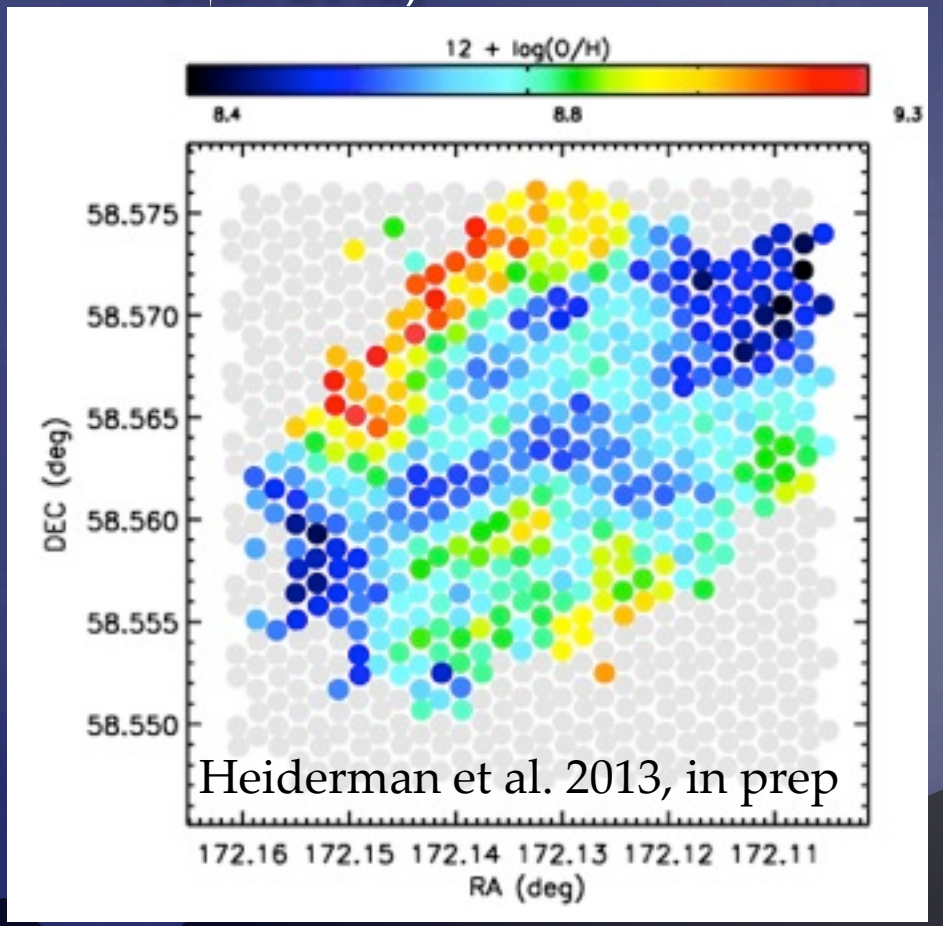
Conversion factor decreases with increasing Σ_{gas}

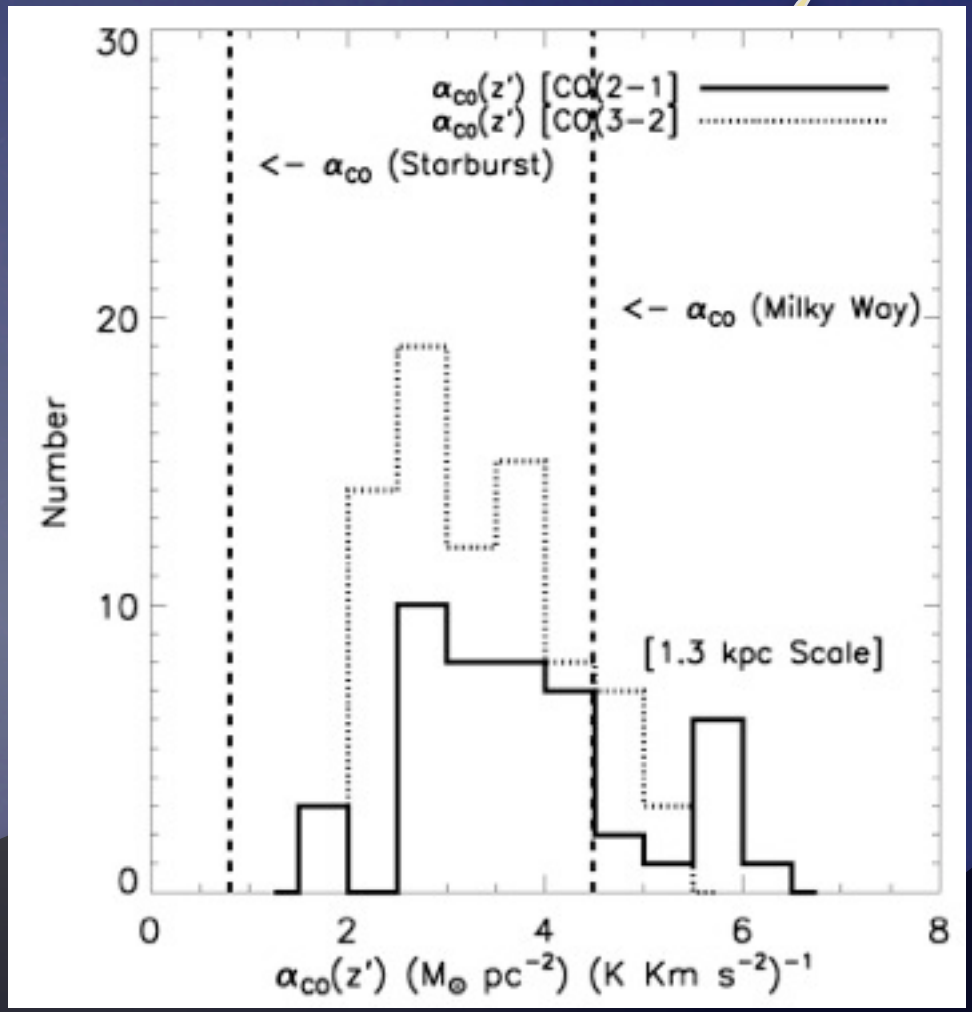
At A_V~10 mag (Σ_{gas} ~150 $M_\odot$ pc^{-2}), sharp decrease is seen

Unlikely CO conversion factor is bimodal over all star forming environments

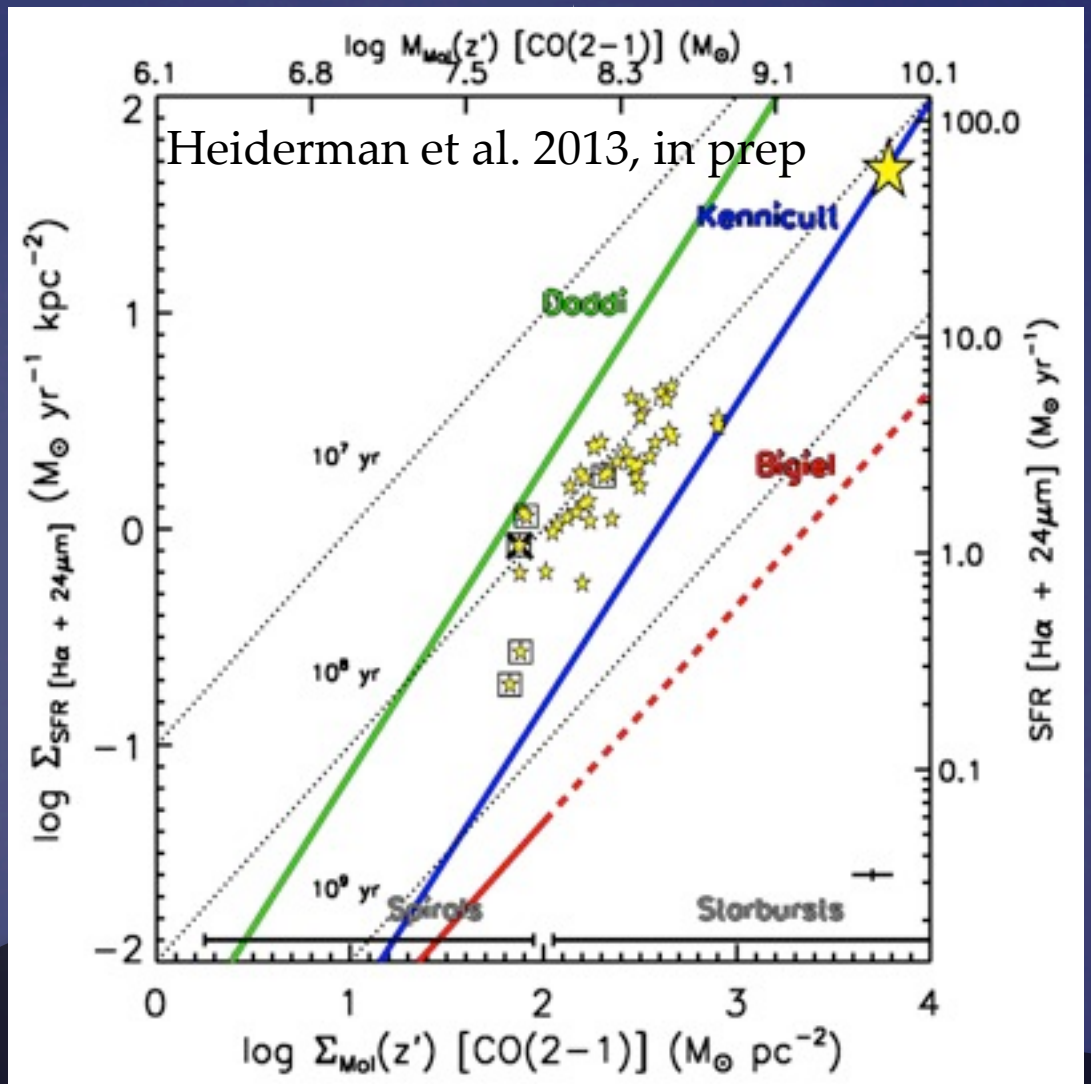
Testing α_{CO} in Arp 299 as a Function of I(CO) and Metallicity

- $\alpha_{CO}(z)$ decreases as I(CO) increases (Narayanan et al. 2012)



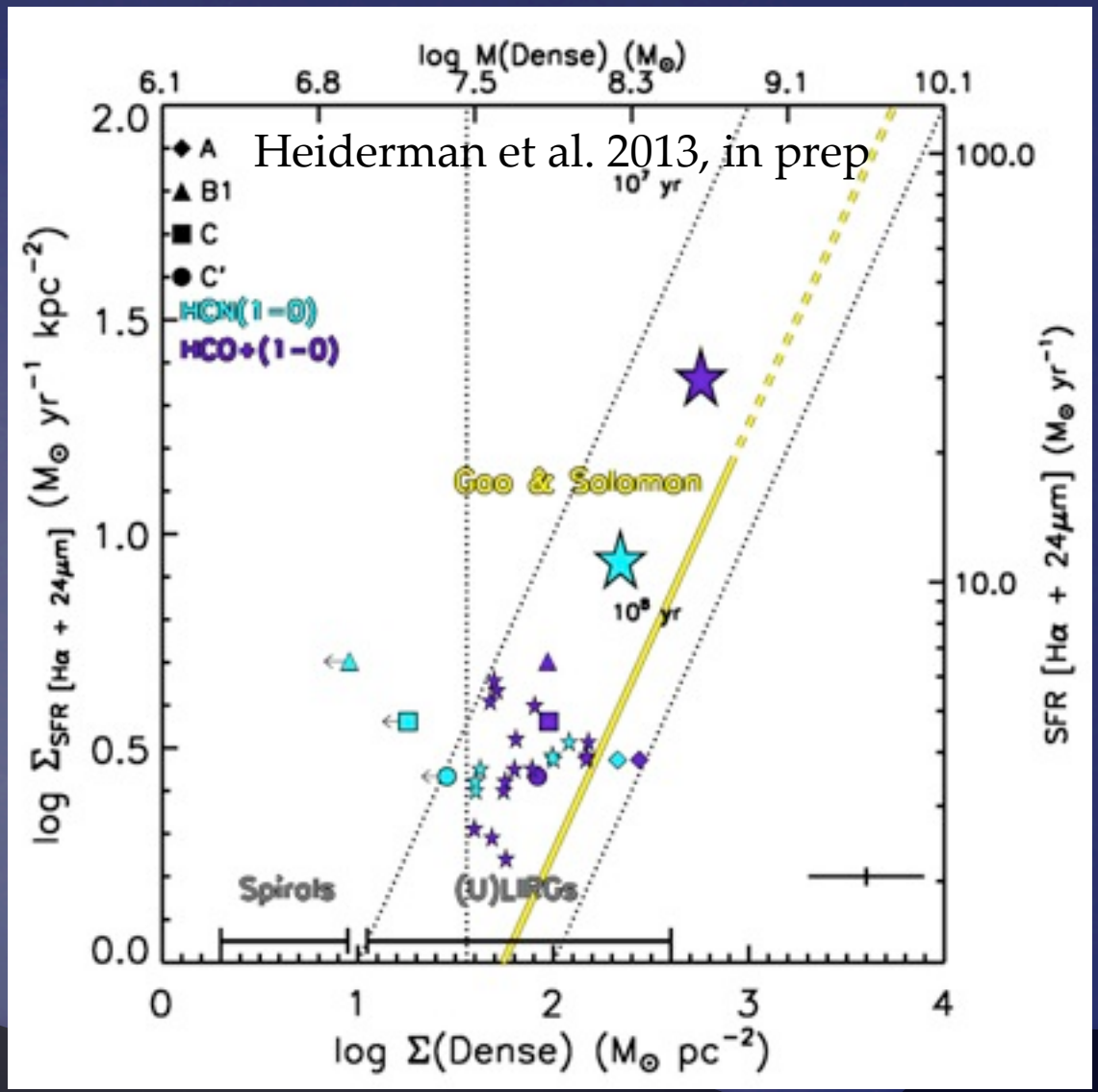


SFR-MoI Gas Relation Using $\alpha_{CO}(z)$



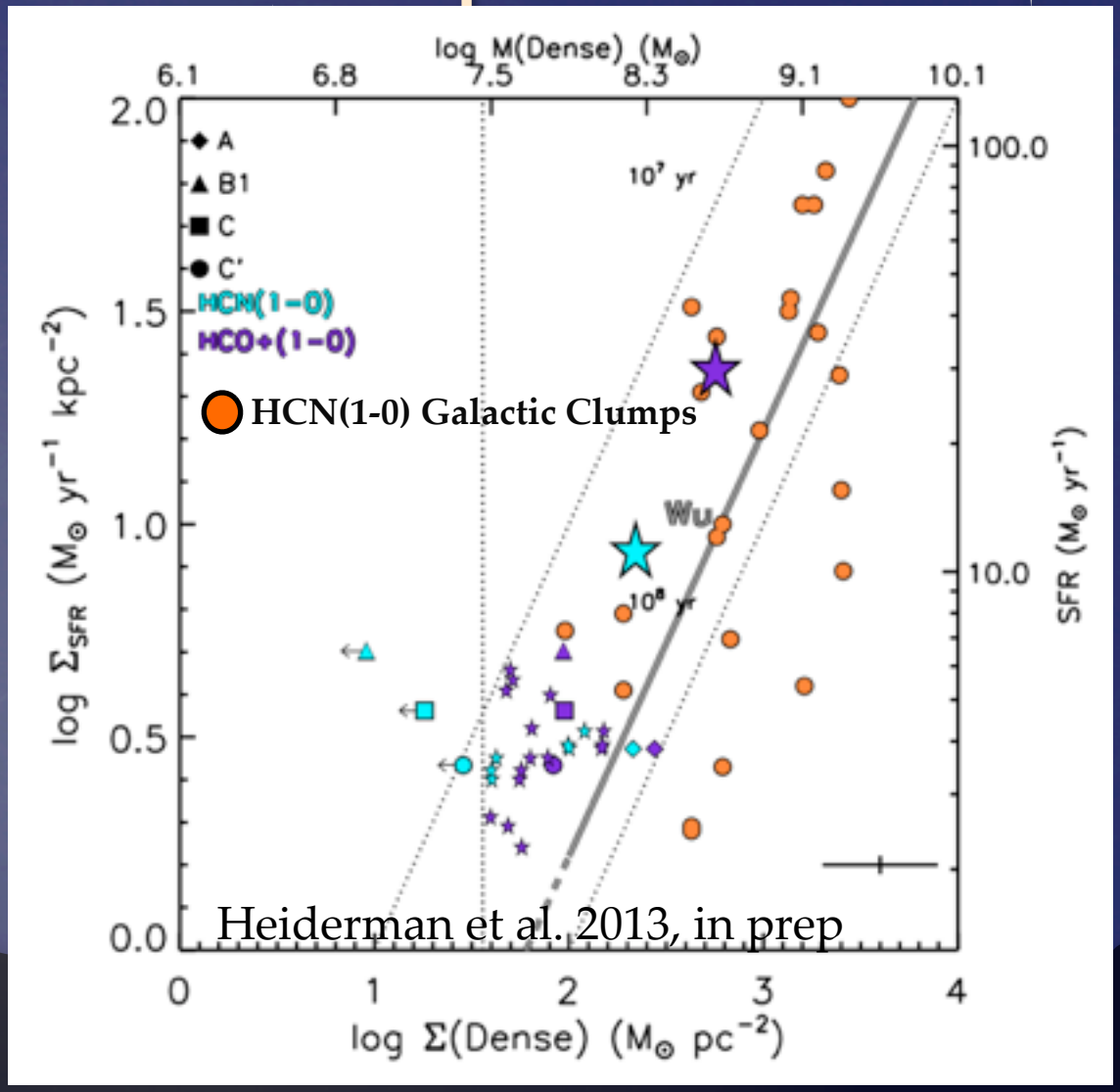
SFR-Dense Gas Relation ~1.3 kpc scales

- HCN & HCO^+ to dense gas conversion factor 50% lower than Gao & Solomon 2004
- Dense gas relation in Arp 299 also lies above the integrated relation



SFR-Dense Gas Relation Arp 299 vs. Galactic Clumps

- ~1.3 kpc regions in Arp 299 also lie near Galactic massive dense clumps



Summary

VIRUS-P INVESTIGATION OF THE EXTREME ENVIRONMENTS OF STARBURSTS

- **VIXENS** will test spatially resolved SFR-gas relations in interacting/ starburst galaxies as a *function of interaction phase*

Arp 299 Results:

- SFR- MoI gas surface density relation on 1.3 kpc scales in late-stage merger Arp 299 lie above known relations
  - More work needed on CO-to-H2 conversion factor, likely variable with interaction phase

- SFR- Dense gas surface density relation on 1.3 kpc scales similar Galactic clumps

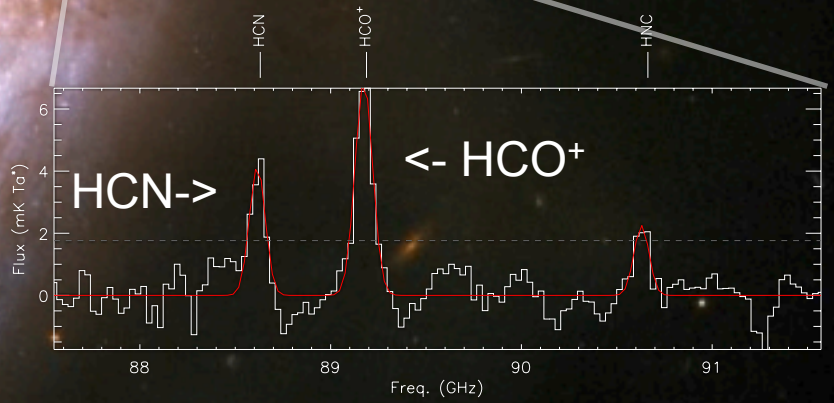
Additional Slides

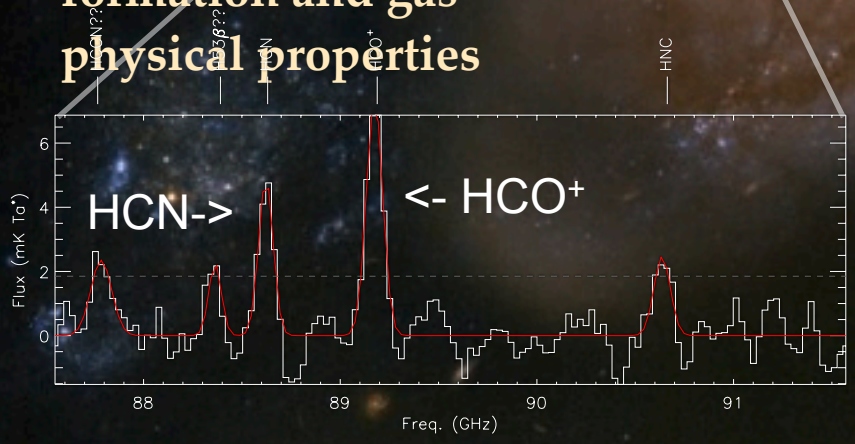
Exploring SFR-*dense* gas relations with VIXENS

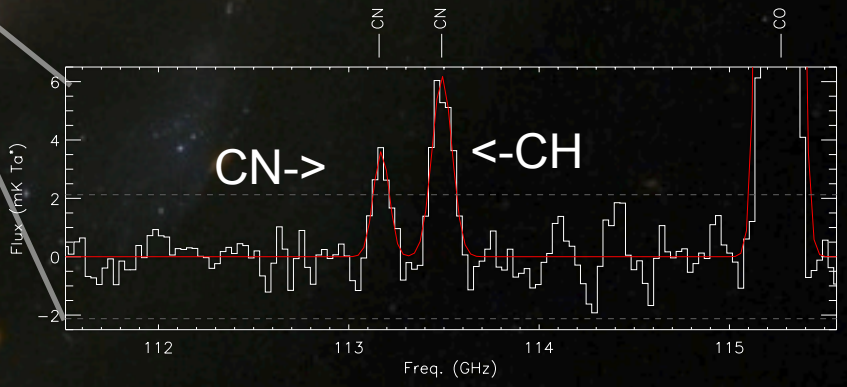
- **VIXENS IRAM & Nobeyama line surveys of *dense* (≥10^4 cm^{-3}) gas tracers (HCN, HCO^+, HNC, CS) (P.I., Timothy A. Davis, ESO)**

- **Investigating star formation and gas physical properties**

Arp 299

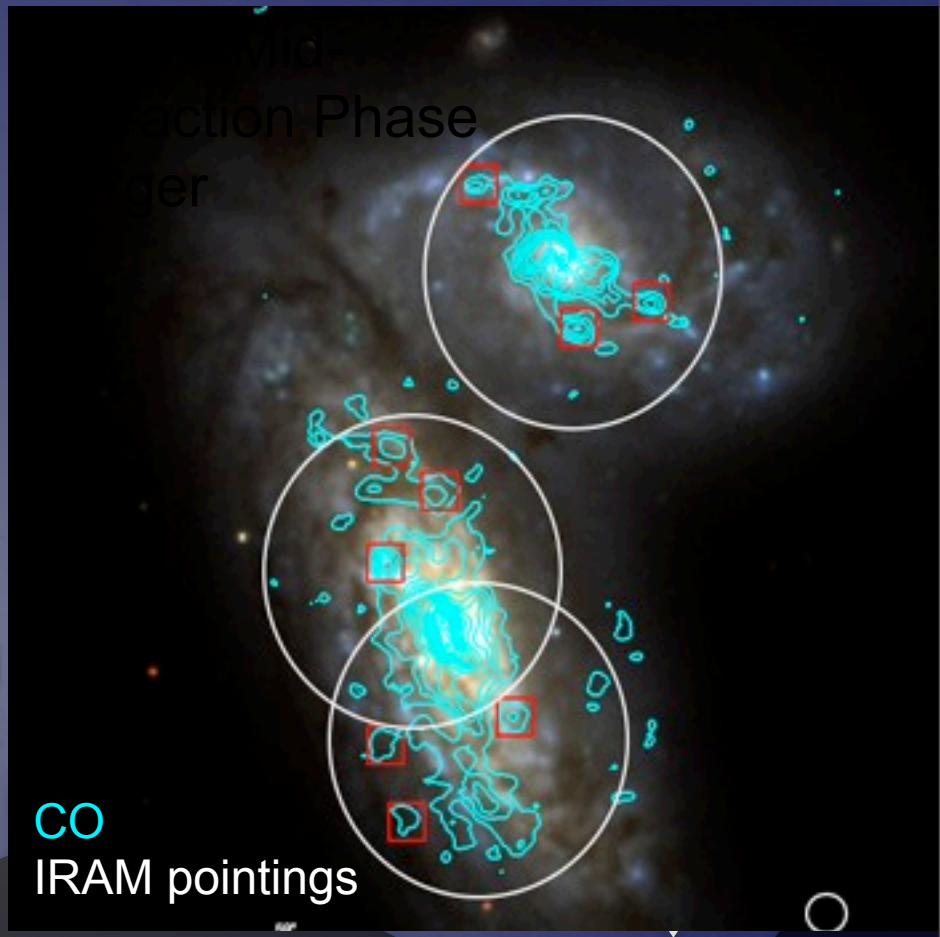






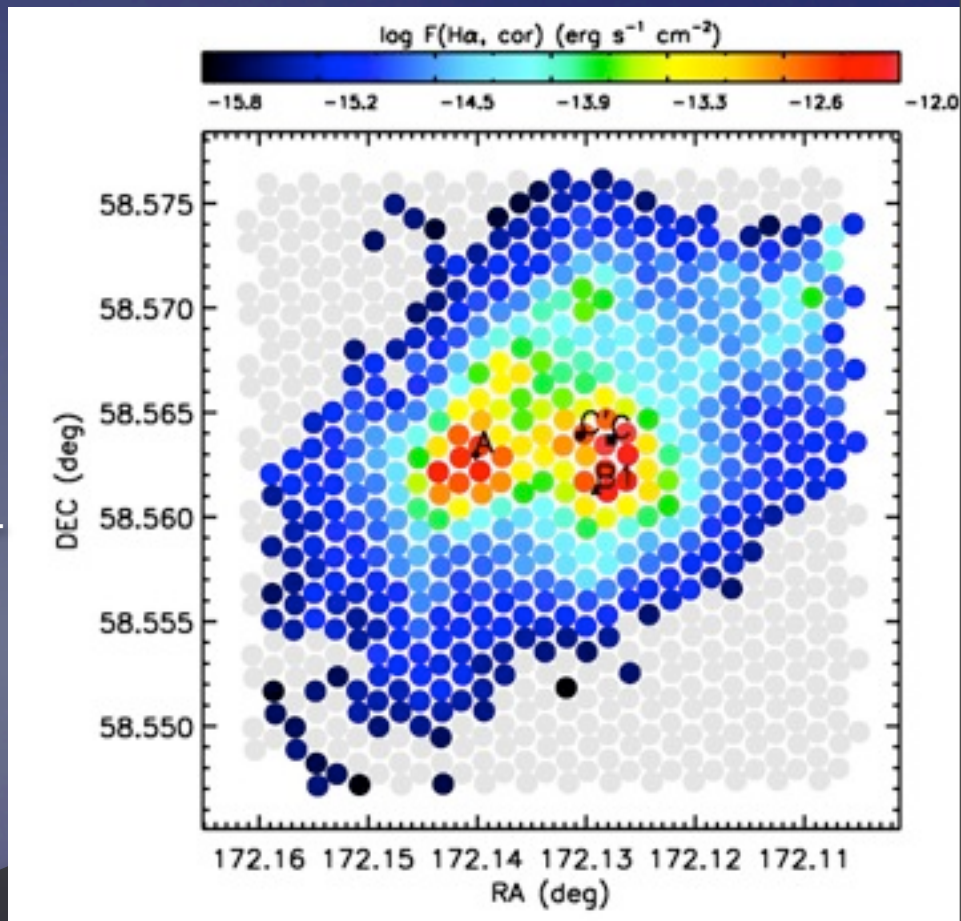
Exploring SFR-*dense* gas relations with VIXENS

- VIXENS IRAM & Nobeyama line surveys of *dense* gas tracers (HCN, HCO^+, HNC, CS)
- CARMA/PdBI/ALMA followup maps
- VIXENS IFU + Sharc II/Herschel IR images observations -> accurate SFRs
- Spatially resolved dense gas and star formation relations
- Compare to Galactic surveys (Wu et al. 2010 + others)

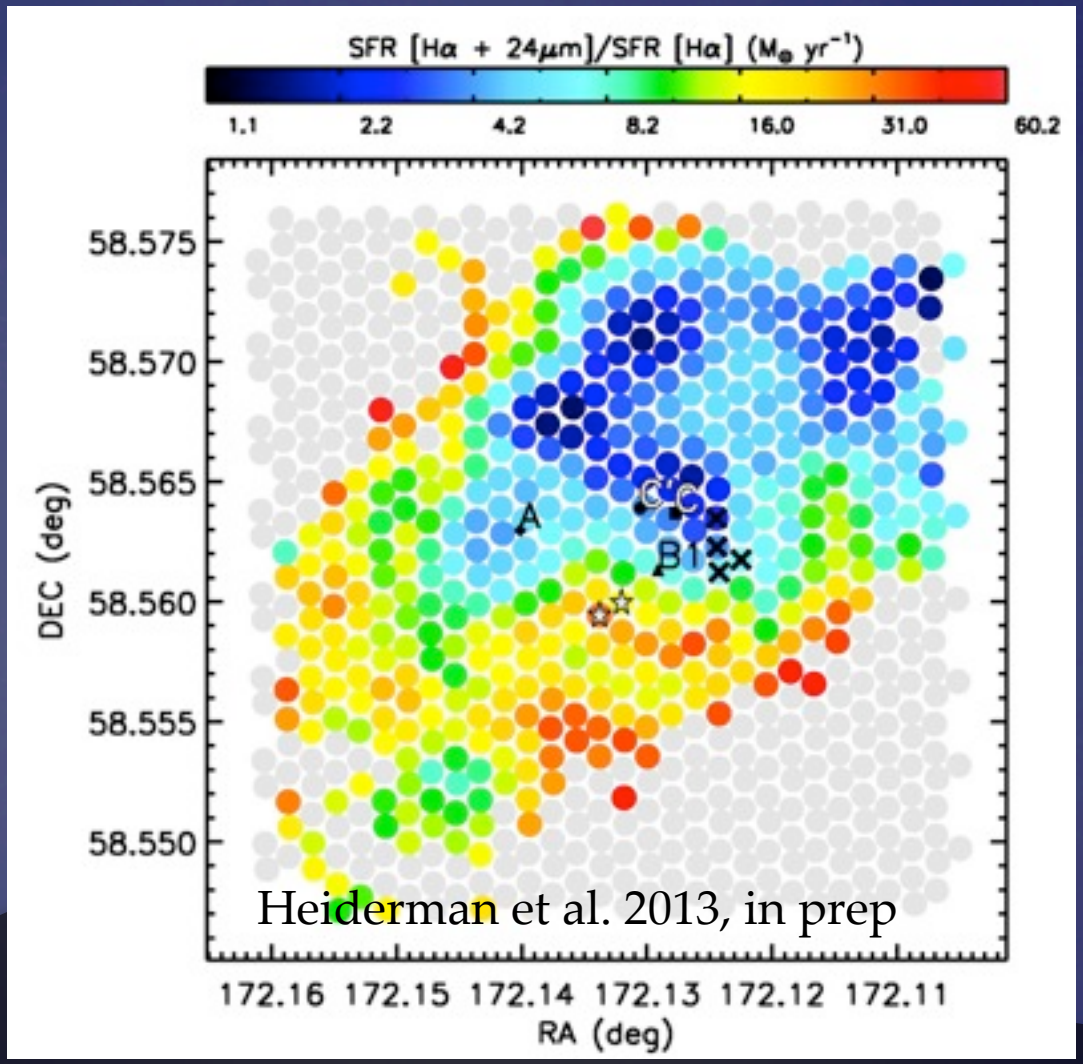


Comparison of System Wide SFRs

- SFR [Hα] = 19±1 $M_\odot$ yr^{-1}
- SFR [24μm] = 44±6 $M_\odot$ yr^{-1}
- SFR [IR] = 77±5 $M_\odot$ yr^{-1} (IRAS)
- SFR [Hα+24μm] = 90±10 $M_\odot$ yr^{-1}



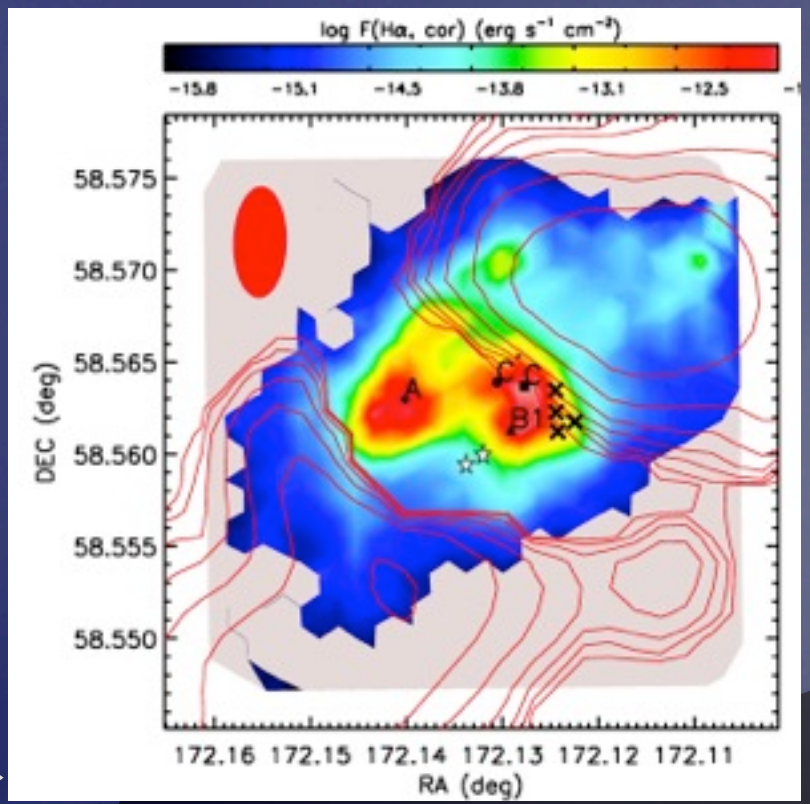
Hα Reliable Star Formation Tracer in Outer Regions

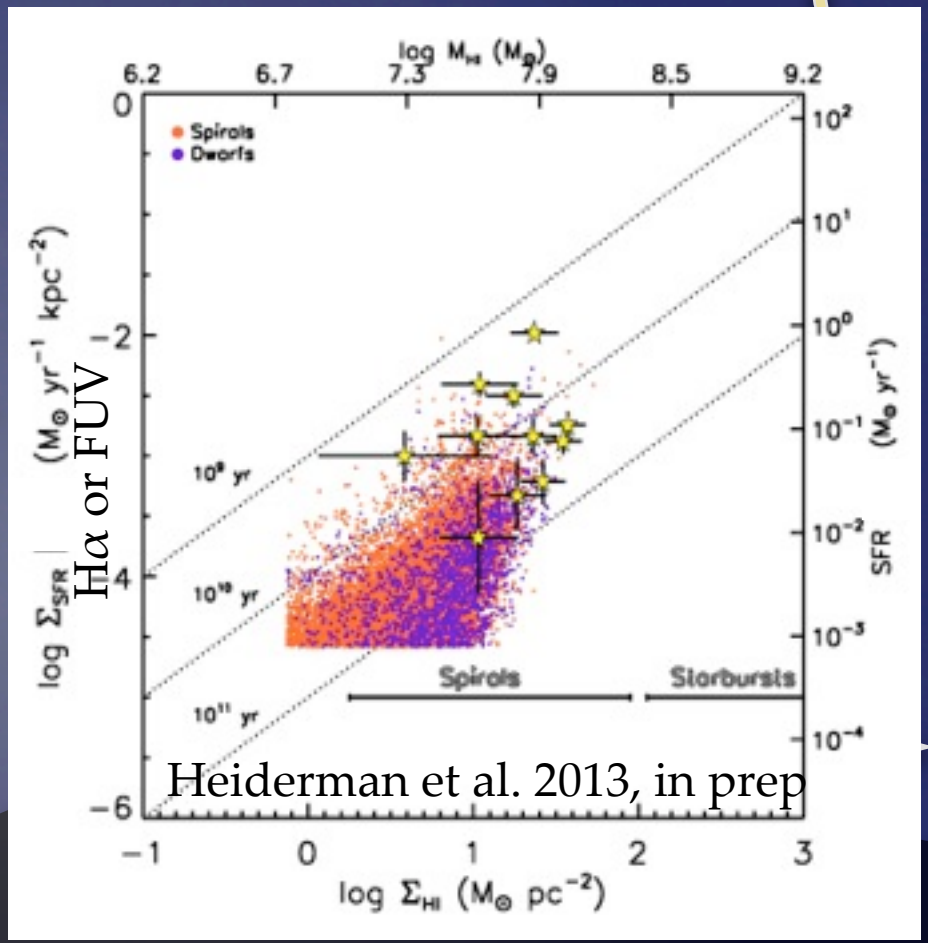


Heiderman et al. 2013, in prep

Star Formation Efficiency in Outer Regions ~4.7 kpc scales

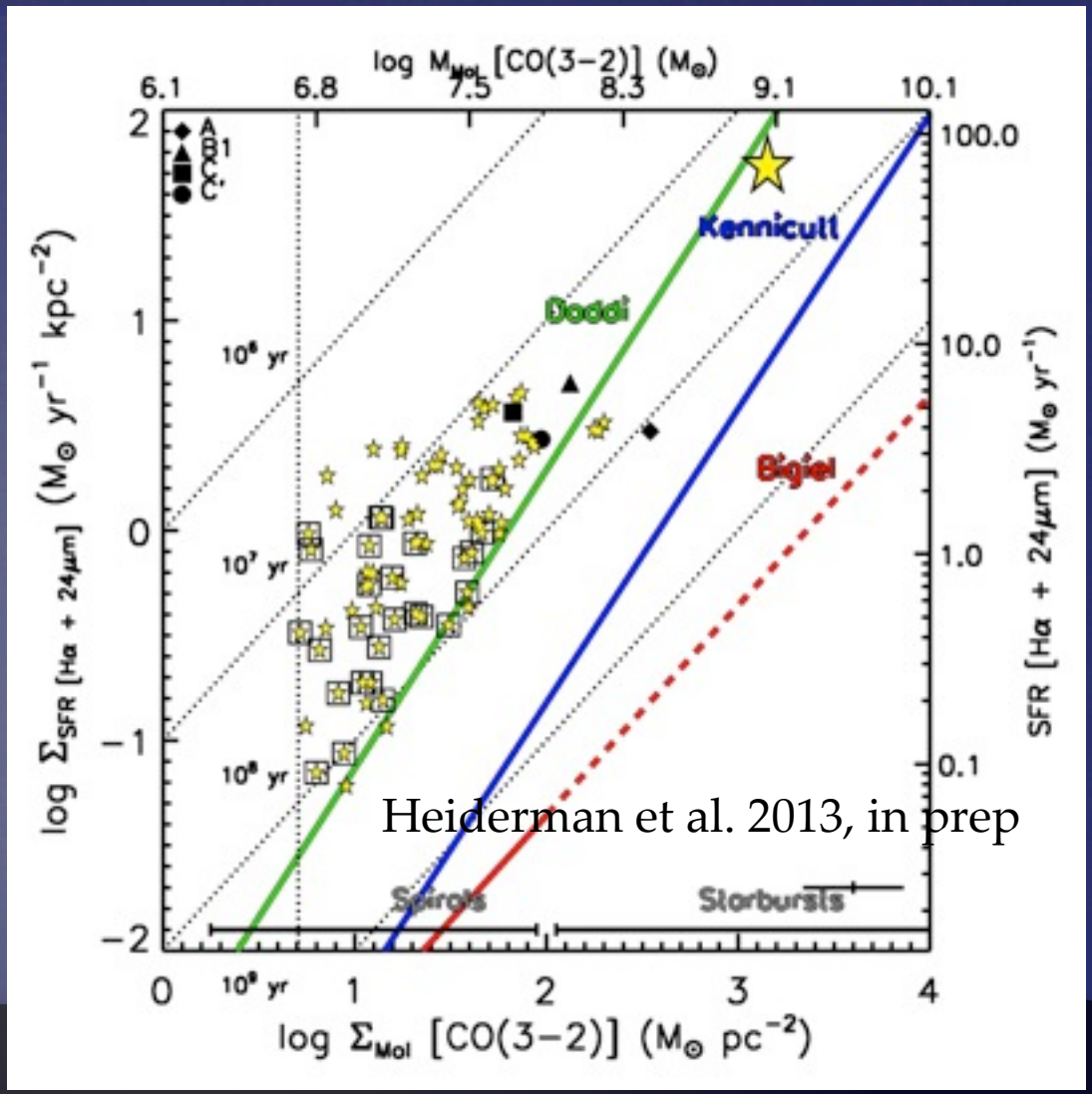
- The SFR per unit gas mass is a factor of ~6 higher on average higher than spirals and dwarfs from Bigiel et al. 2010



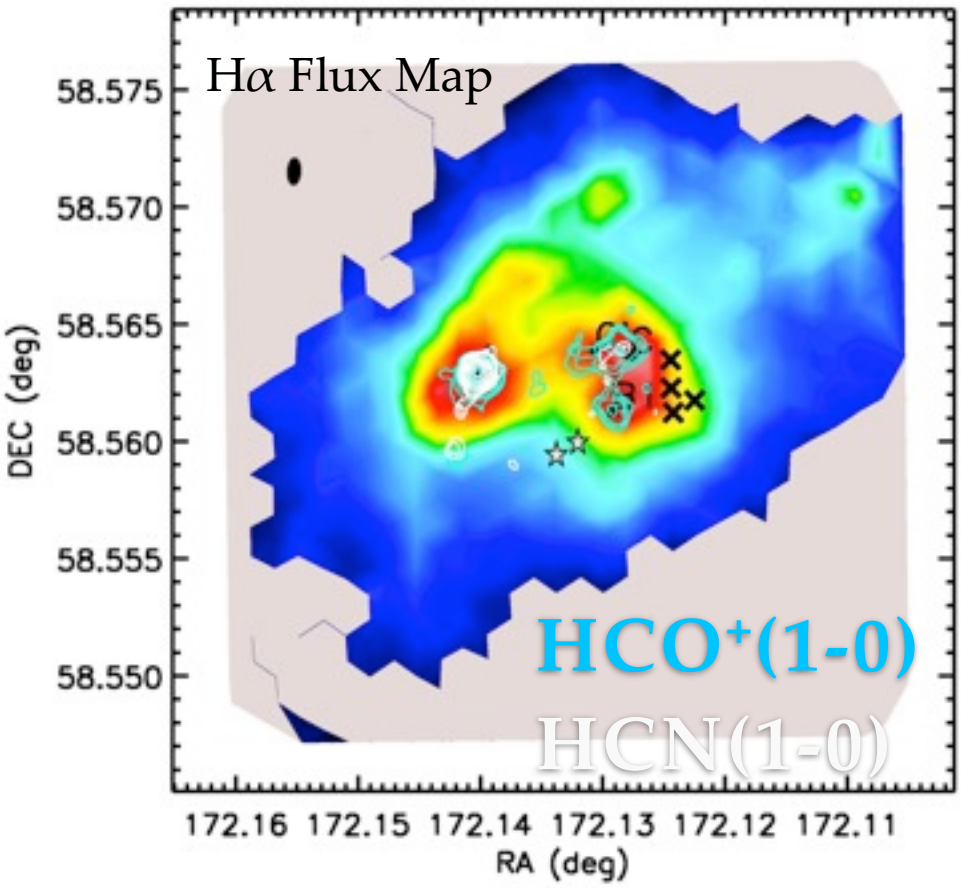


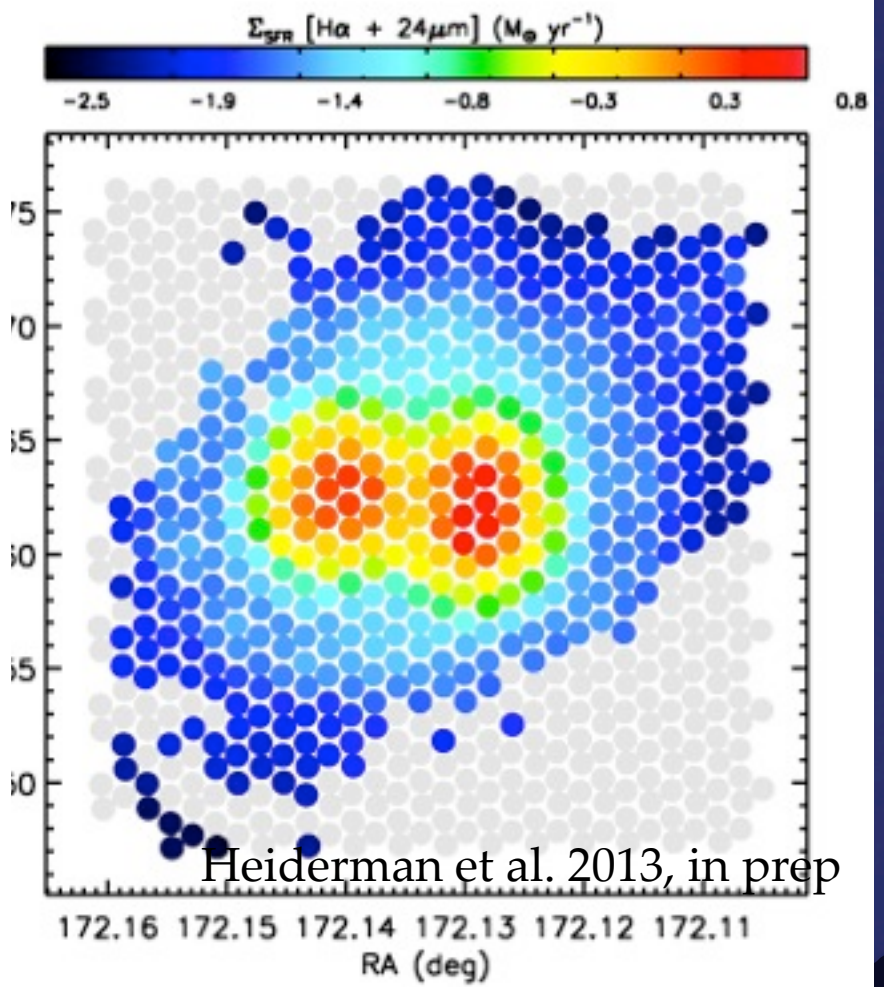
SFR-MoI Gas Relation ~1.3 kpc scales

- Using a starburst-like CO-to-H_2 conversion factor (α_{CO}) value for Arp 299 (Sliwa et al. 2012) and CO(3-2)
- Similarly regions lie well above known relations



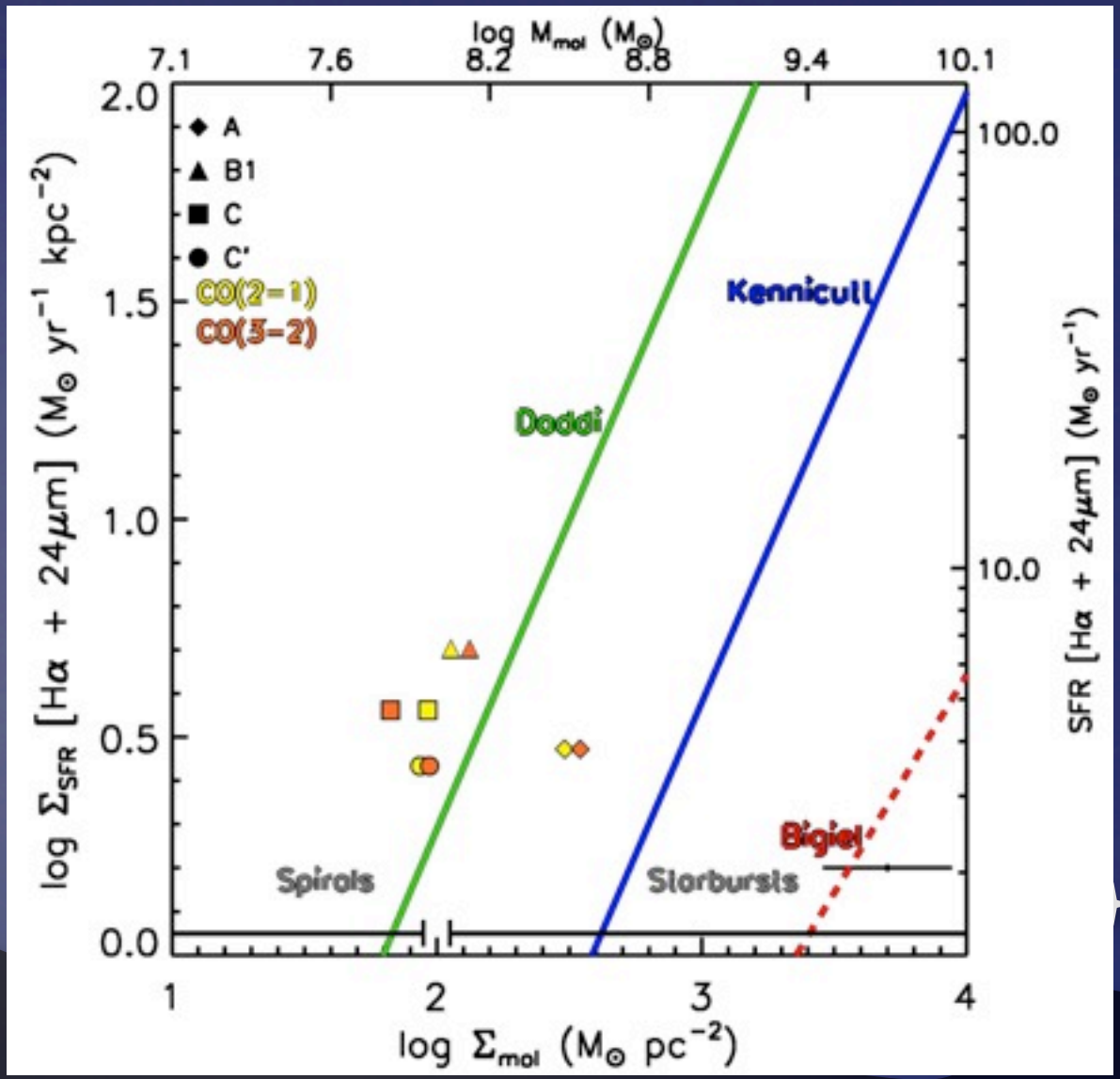
SFR- Dense Gas Surface Density Relation





Heiderman et al. 2013, in prep

SFR-Mol Gas Relation in Nuclear Regions



SFR-Dense Gas Relation in Nuclear Regions