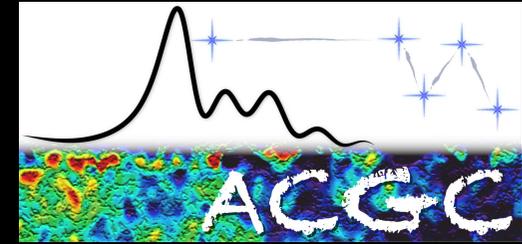




Disk Building Processes in the local Massive HI LIRG HIZOA J0836-43



A prototype for disk galaxies at $z=1$?

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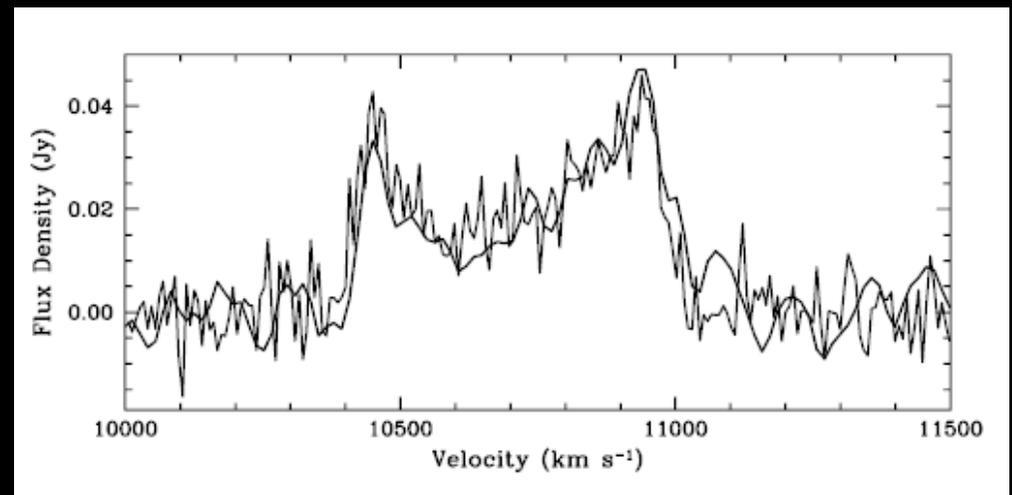
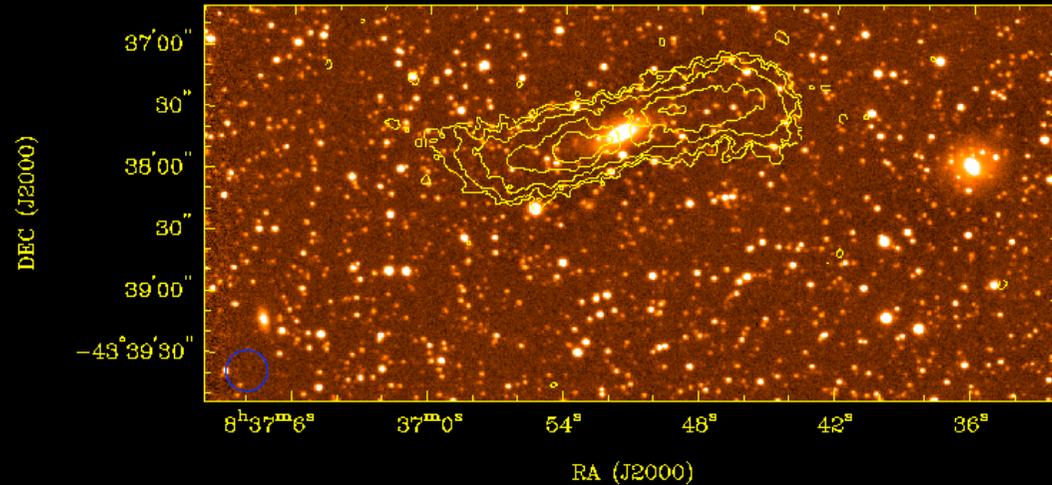
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J. Melbourne (IPAC CalTech)

B. Emonts (ATNF CSIRO)

Discovered in deep Parkes MB HI survey of southern ZOA (& HIPASS)

- $M_{\text{HI}} = 7.5 \times 10^{10} M_{\odot}$
- Velocity width ~ 600 km/s
- $Vel = 10689$ km/s
($\rightarrow D=148$ Mpc)
- HI diameter = 130 kpc
- $SFR_{1.4 \text{ GHz}} = 35 M_{\odot}/\text{yr}$
- Not AGN, Starburst?
- **Similar to Malin 1**
- **But not quiescent ($0.38 M_{\odot}/\text{yr}$) nor LSB (like most giant HI galaxies)**



Donley et al. (2006)

But the galaxy lies in the ZOA; behind thick layer of dust

$A_V = 7.5$ mag

DIRBE;

Schlegel et al (1998)

And behind
the Vela SNR

It is optically
~invisible

Observations at
higher λ are
needed to learn
more about this
Galaxy

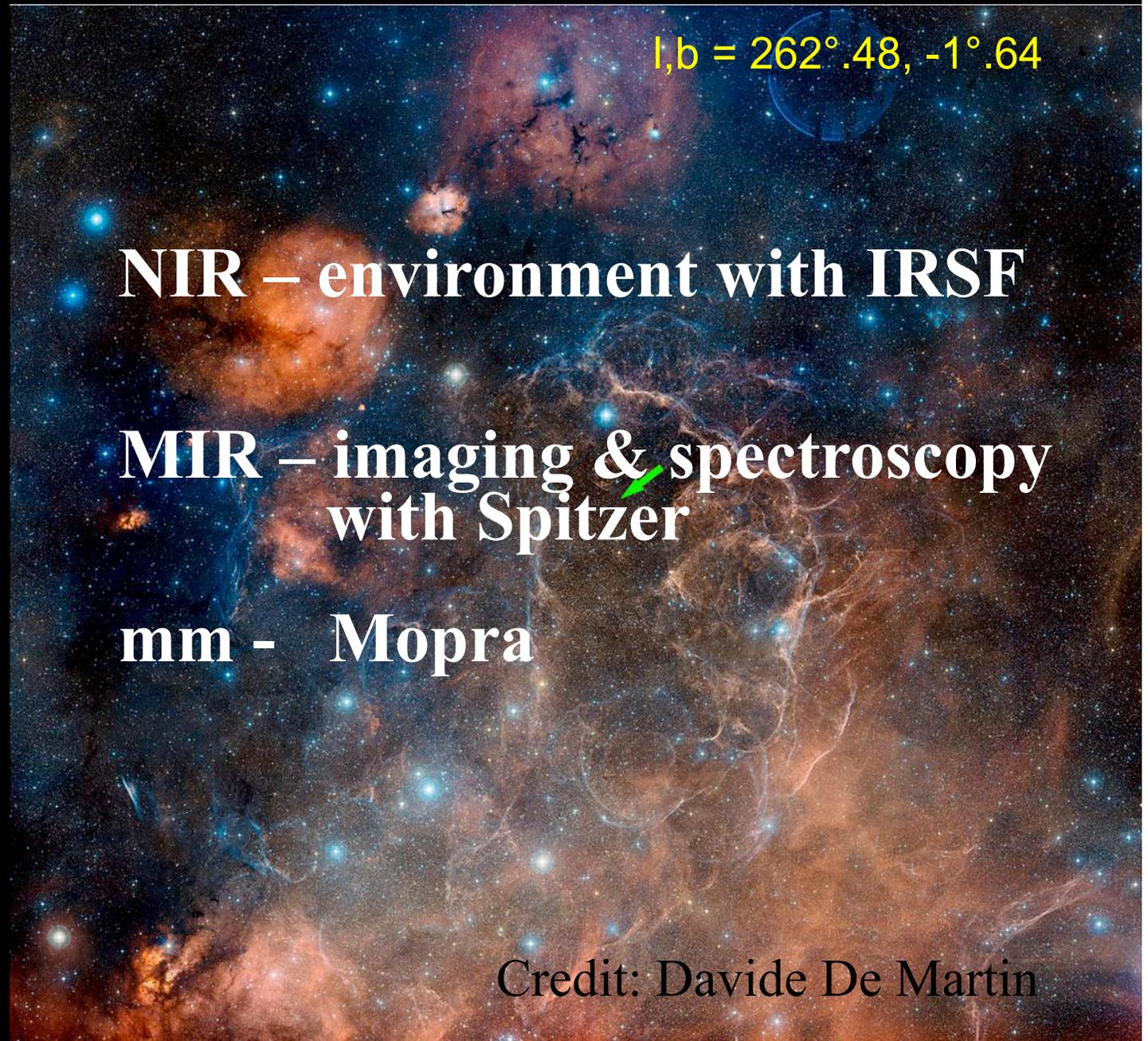
$l, b = 262^\circ.48, -1^\circ.64$

NIR – environment with IRSF

**MIR – imaging & spectroscopy
with Spitzer**

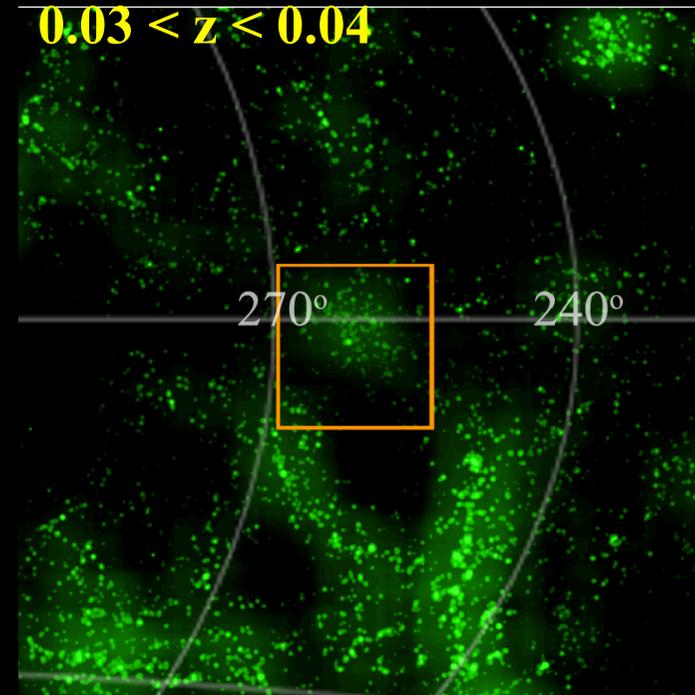
mm - Mopra

Credit: Davide De Martin

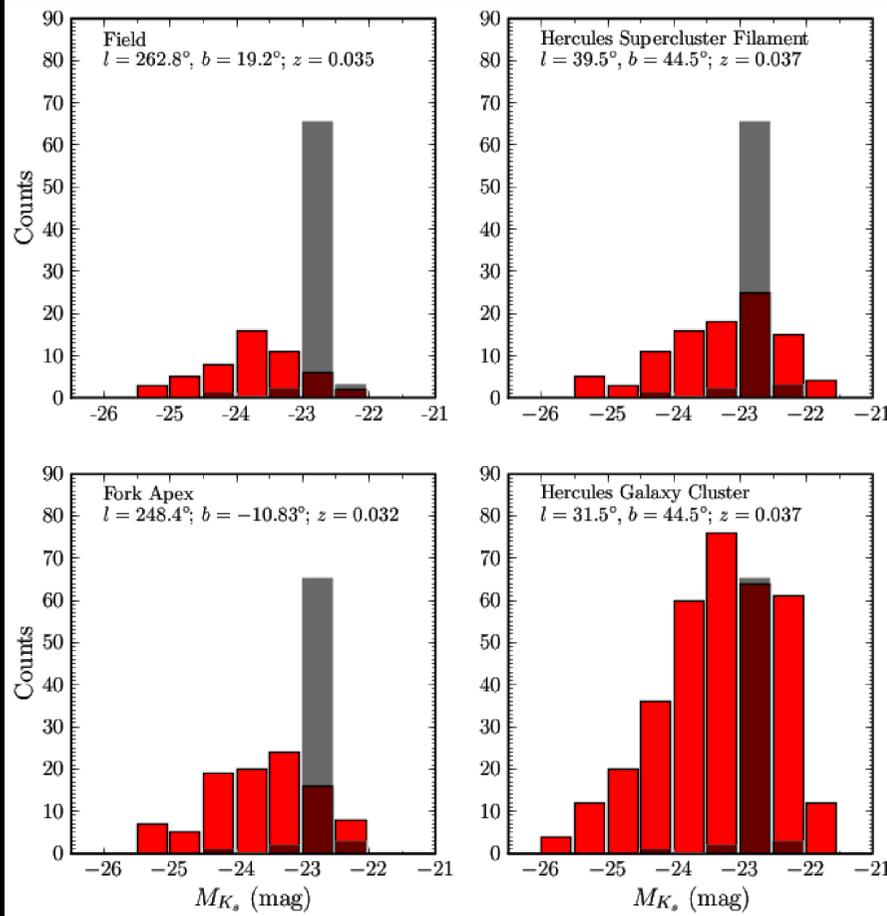


The Environment

NIR (JHK) imaging survey
of $2.24 \square^\circ \rightarrow 404$ galaxies;
phot-z: quiet low density area



→ The galaxy lies in a region underdense in L^* galaxies.

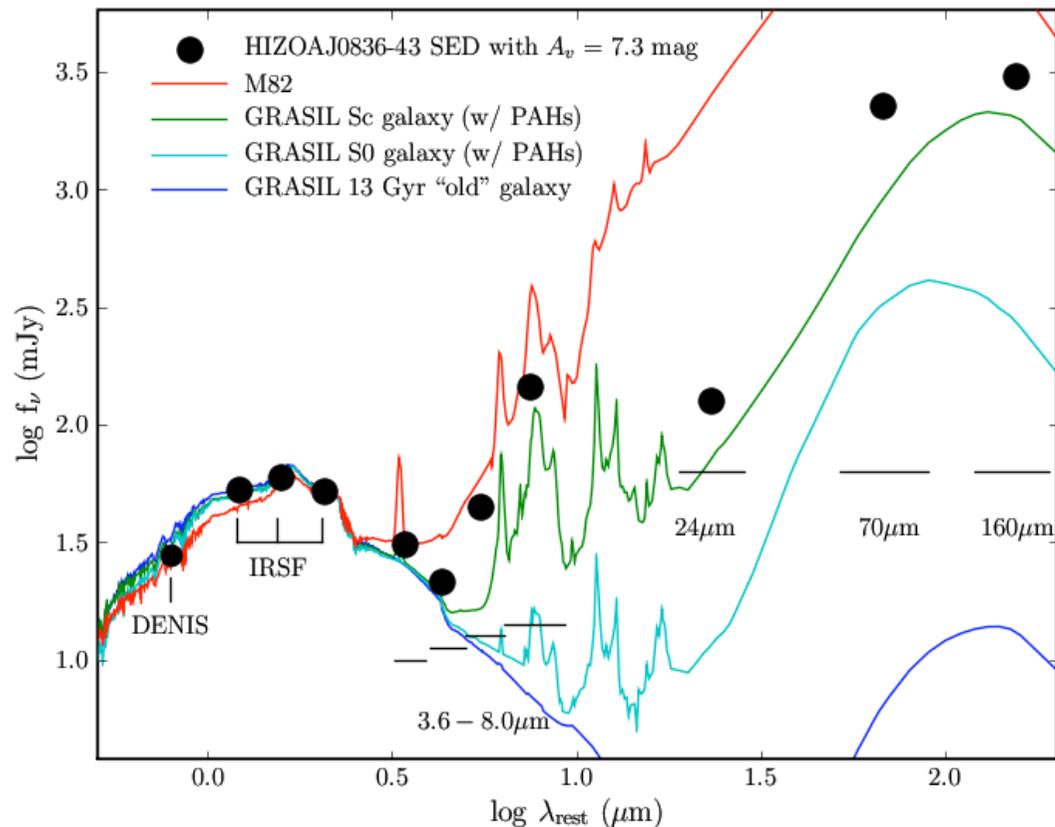


This may have allowed its formation and survival, enabling it to evolve in the unusual LIRG

← Grey: galaxies in 10Mpc volume around HIZOA

SED of HIZOA J0836-43: NIR, IRAC, MIPS

- $L_{\text{TIR}} = 1.2 \times 10^{11} L_{\odot} \rightarrow$ Luminous Infrared Galaxy (LIRG)
- $\text{SFR} = 20.5 M_{\odot}/\text{yr}$ (Kennicutt 1998)



Cluver, Jarrett et al. ApJL (2008)

- resembles Sc-galaxy

• Note: not S0/Sa as from NIR imaging/photometry

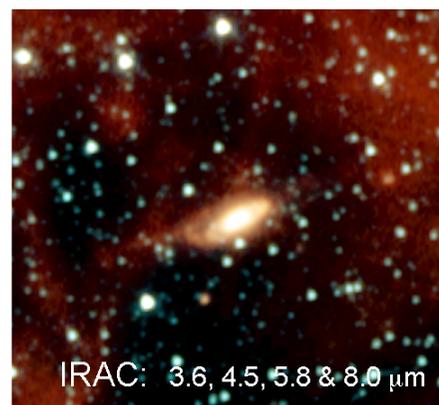
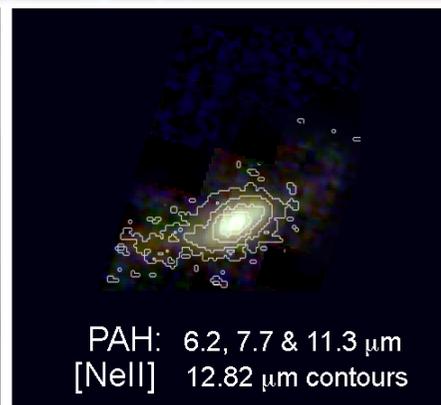
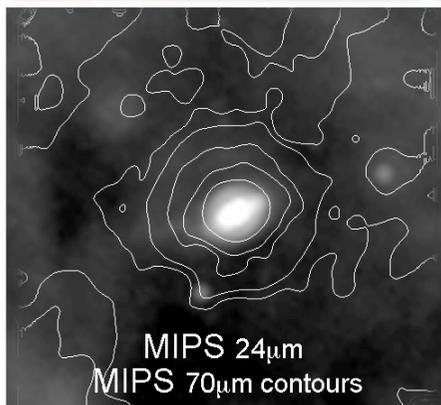
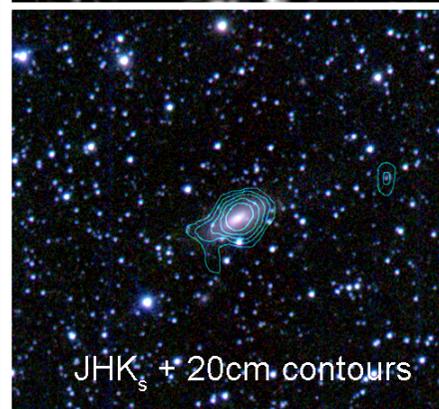
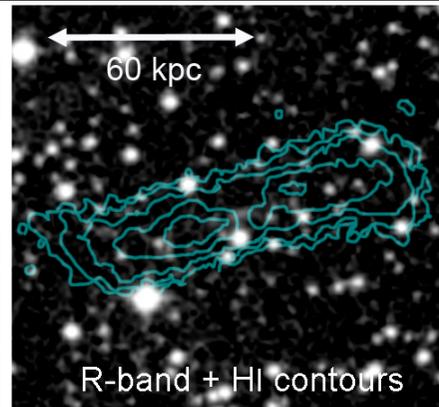
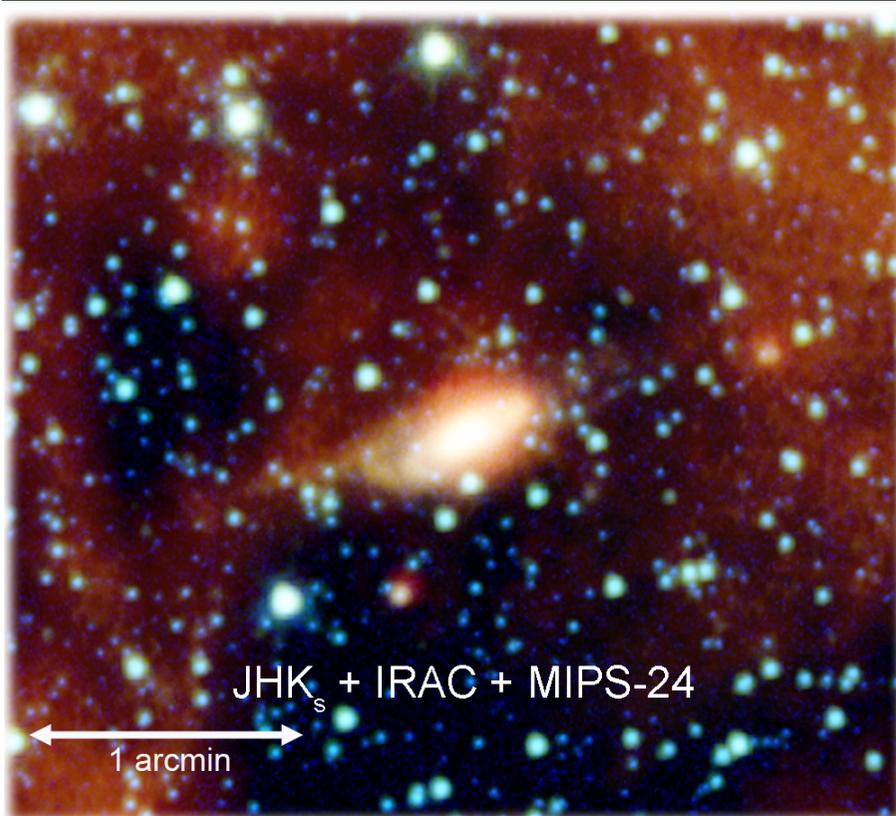
- strong MIR emission (5-8 μm) \rightarrow but PAH's

- strong emission from cold dust ($\lambda > 60 \mu\text{m}$)

• But it does not match starburst (see M82)

Various composite images of HIZOA J0836-43

Cluver et al. ApJ 2010



Opt: nearly invisible

NIR: prominent bulge;
20cm extended

MIR: extended SF disk
Similar to 20cm

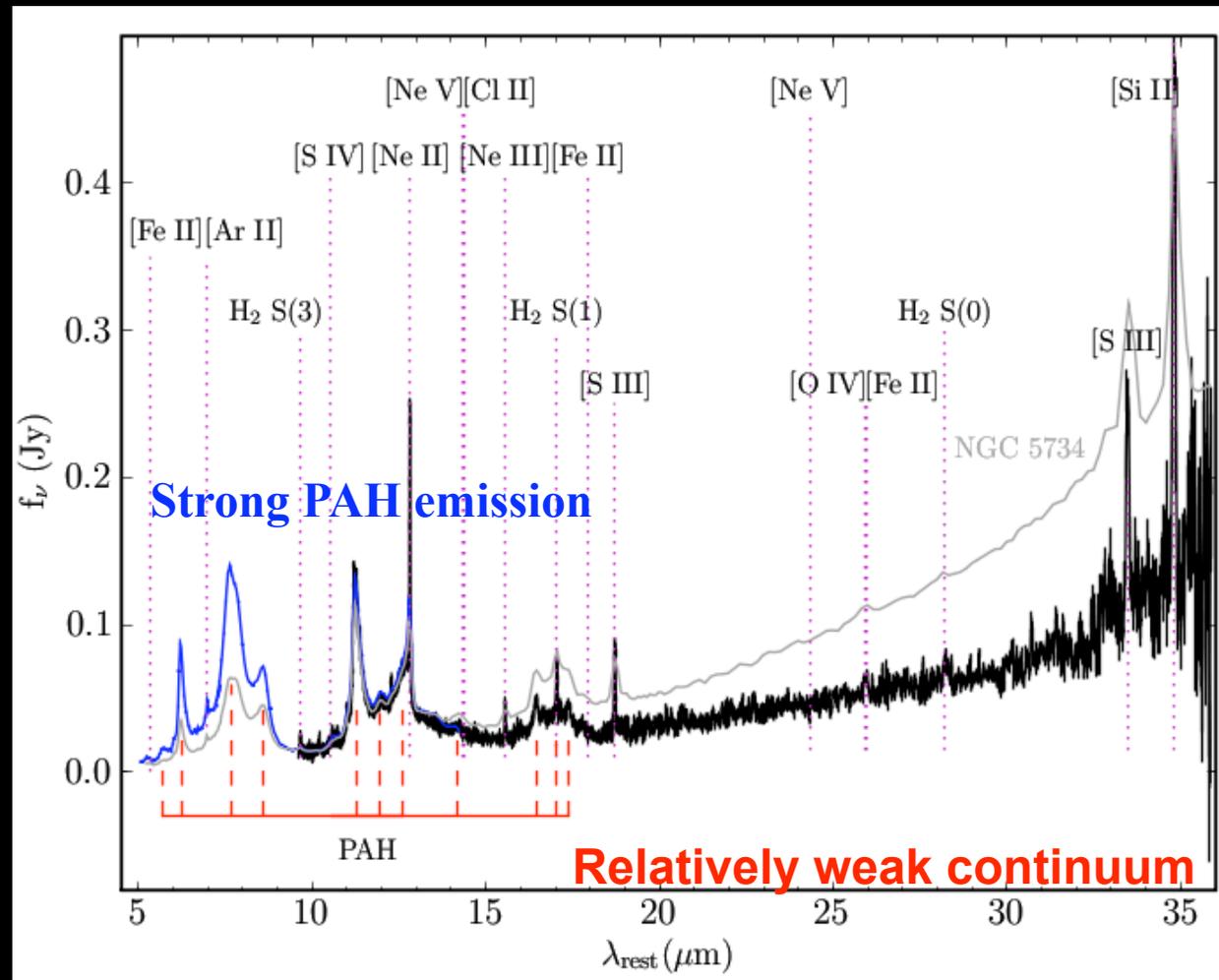
Extended SF also
strong in PAHs
(6.2, 7.7, 11.3)

And [NeII]

→ All SF indicators
extend beyond the
old evolved stellar
pop. → 50kpc SF disk

Spitzer IRS Spectroscopy (MIR) of nucleus

Combined SL (5-14 μm) + SH (10-20 μm) + LH (19-38 μm)



- Strong excited nebular lines

Typical of SF/SB regions
but also of PDR (RN)

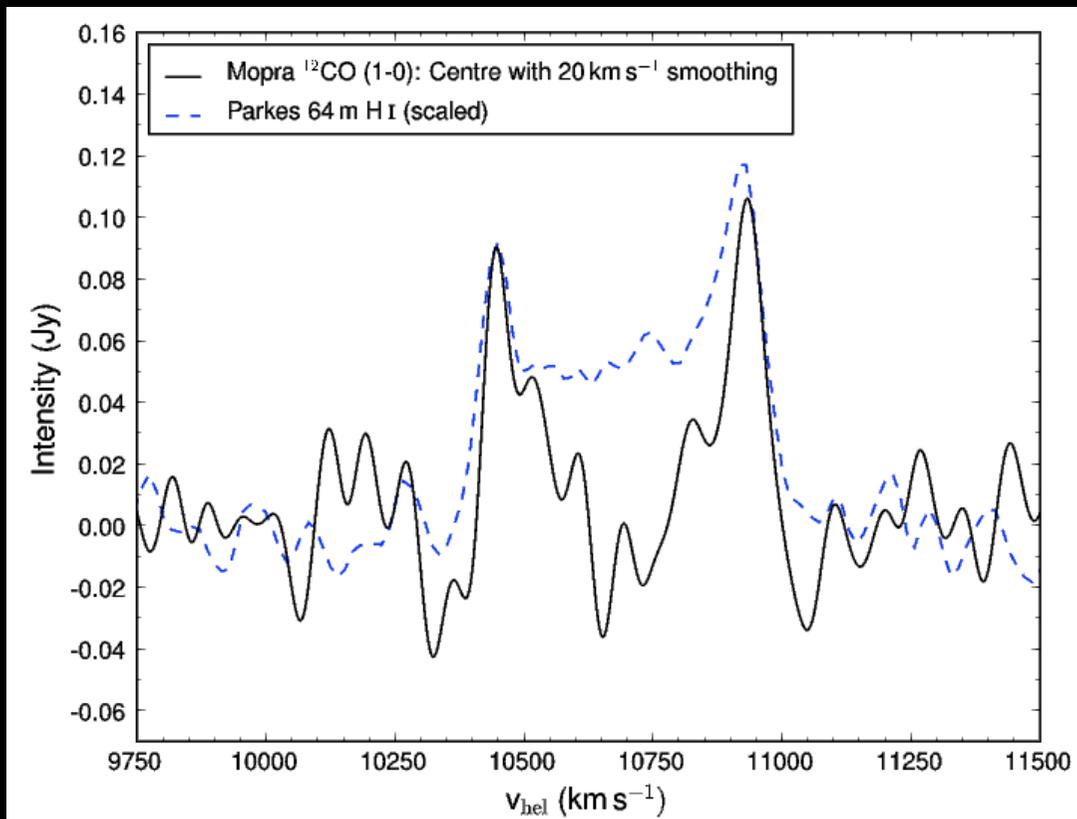
- But no [Ne V] & [O IV]
→ AGN absent (or weak)
- Strong PAH Emission
→ extended > nucleus
but weak MIR continuum
- weak rotational H₂ lines
 - T ~ 330K
 - M = 1.3 × 10⁷ M_⊙

Cluver et al. ApJ (2010)

CO observations using Mopra (2009,2010)

What about cold molecular gas? *Observed: very little warm H₂-gas*

→ Prediction: from L_{FIR} → M_{gas} = 1.3 x 10¹⁰ M_⊙



- Rapidly rotating mol disk

- No low velocity gas

- M_{cold gas} = 3.9 x 10⁹ M_⊙

→ lower than predicted

- M(HI) / M(H₂) = 5 %

- f_{mol gas} = 8%

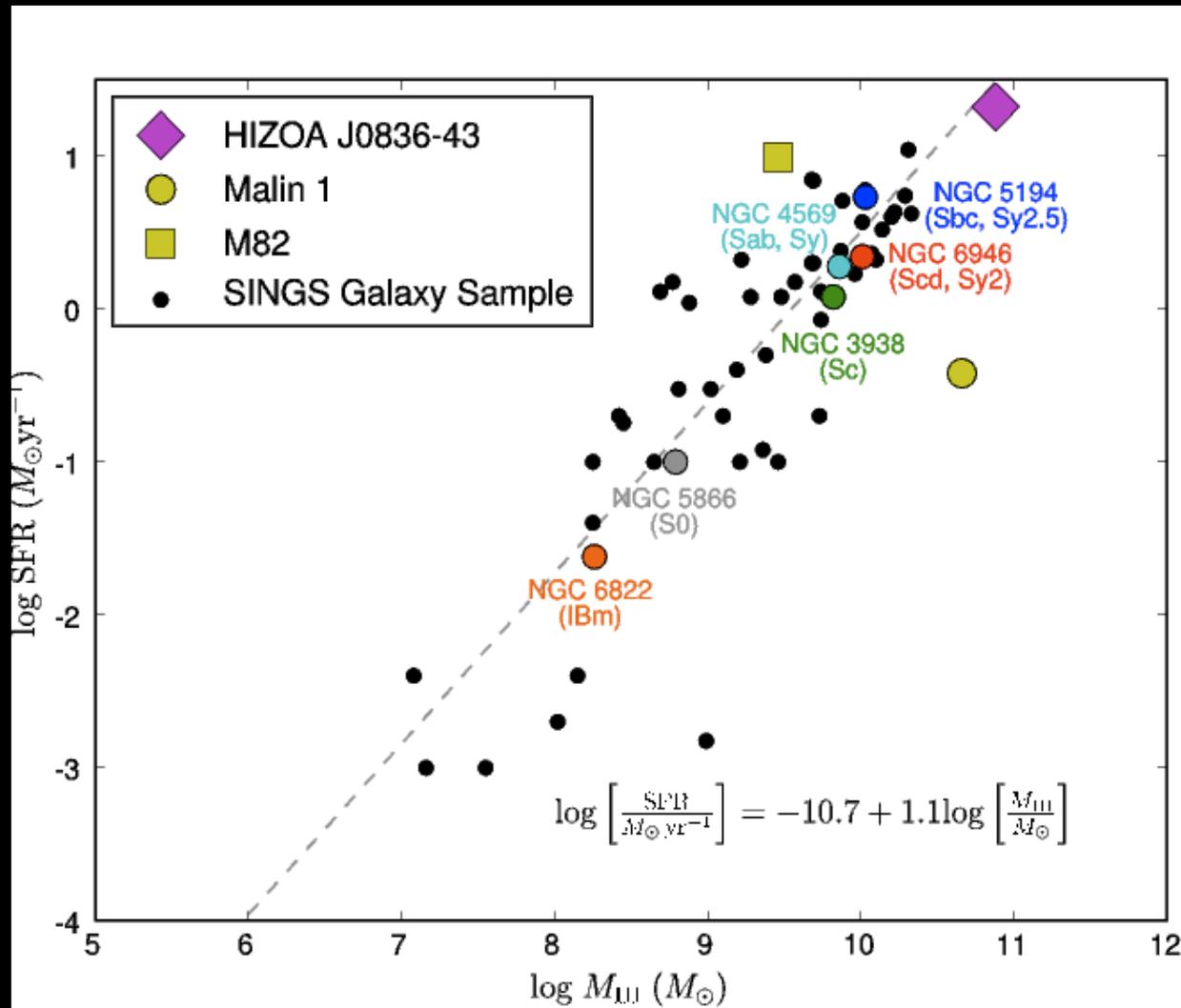
- Gas fraction = 64 %

*Central pointing, 16.6 hrs, beam 30"; entire disk 1'
Most of gas in beam; lower limit for mass estimate*

What's the connection?

- Lots of stars + lots of gas + building
- $M^* = 4.4 \times 10^{10} M_{\odot} + M_{\text{HI}} = 7.5 \times 10^{10} M_{\odot} + M_{\text{H}_2+\text{He}} = 3.9 \times 10^9 M_{\odot}$
- $\text{SFR} = 20.5 M_{\odot}/\text{yr}$ & $\text{sSFR} = 0.47 \text{ Gyr}^{-1}$
- Gas Fraction > 0.64 & Molecular Gas Fraction ~ 0.08
 - vigorously star-forming extended stellar disk (inside-out)
 - Properties as scaled-up version of local disk galaxies
- How does this compare to other local SF disk galaxies?
- How does this compare to more distant systems?
- What we can say about the star formation processes, bimodality?

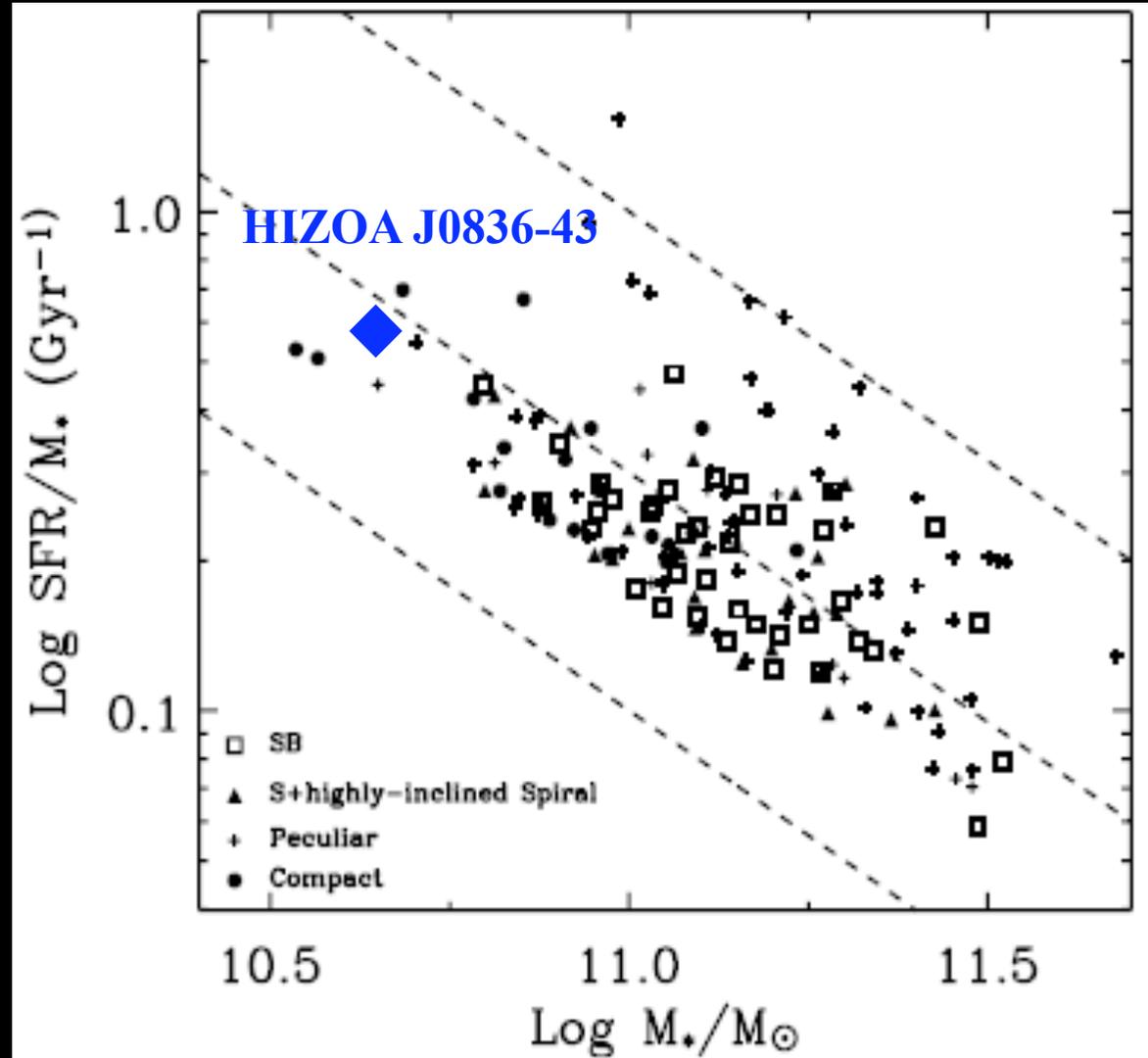
Comparison to SINGS galaxies



(Dale et al. 2009)

Comparison to sample of local LIRG's ($z < 0.1$)

(Wang et al.; 2006)



$$M_* = 4.4 \times 10^{10} M_\odot$$

(using Bell et al.; 2003)

- implies young stellar-building phase

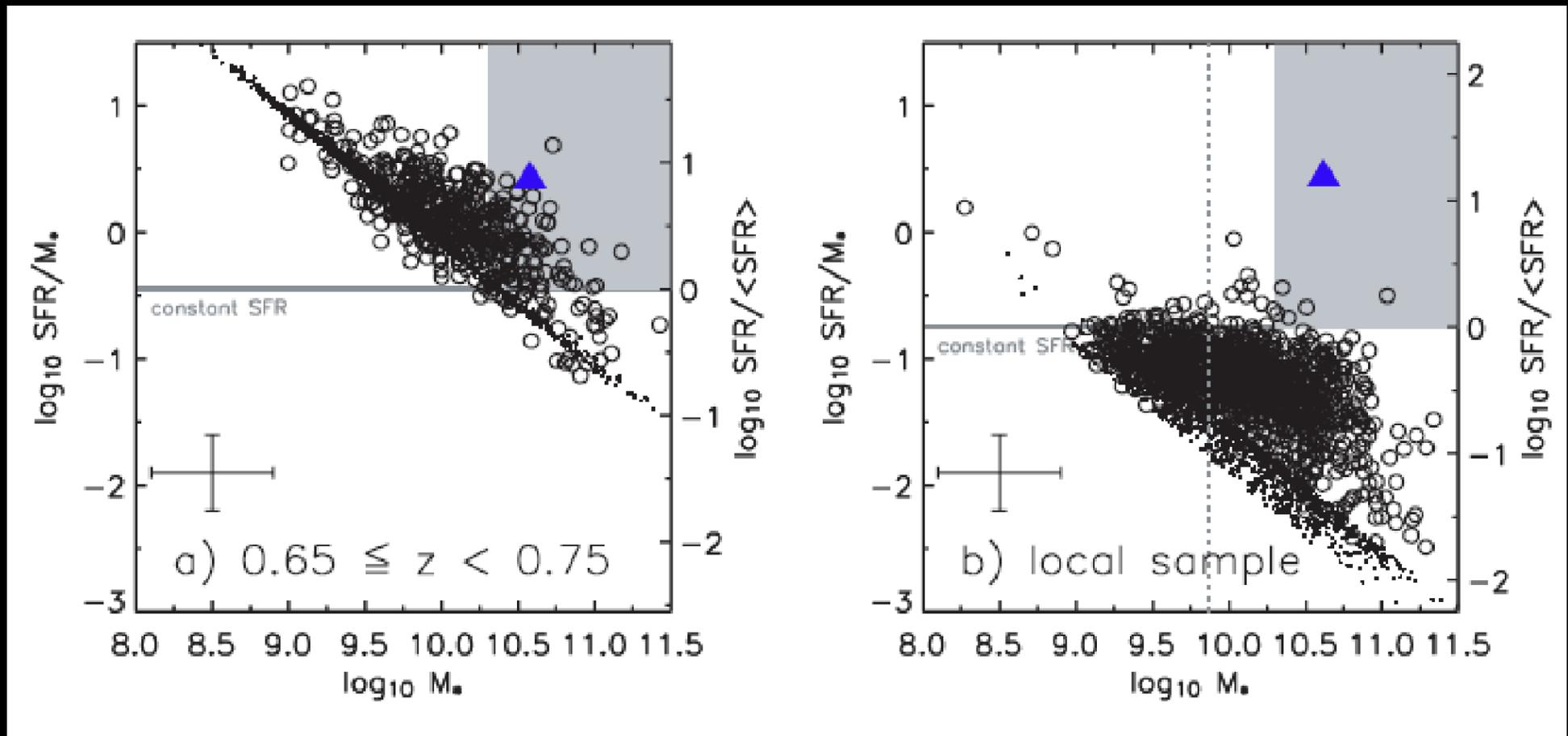
- $s\text{SFR} = 0.47 \text{ Gyr}^{-1}$

- can double stellar mass in 2Gyr

(hashed lines indicate SFR of $10, 30, 100 M_\odot/\text{yr}$)

Comparison to higher redshift SF Galaxies

HIZOA J0836-43 is building stellar mass...

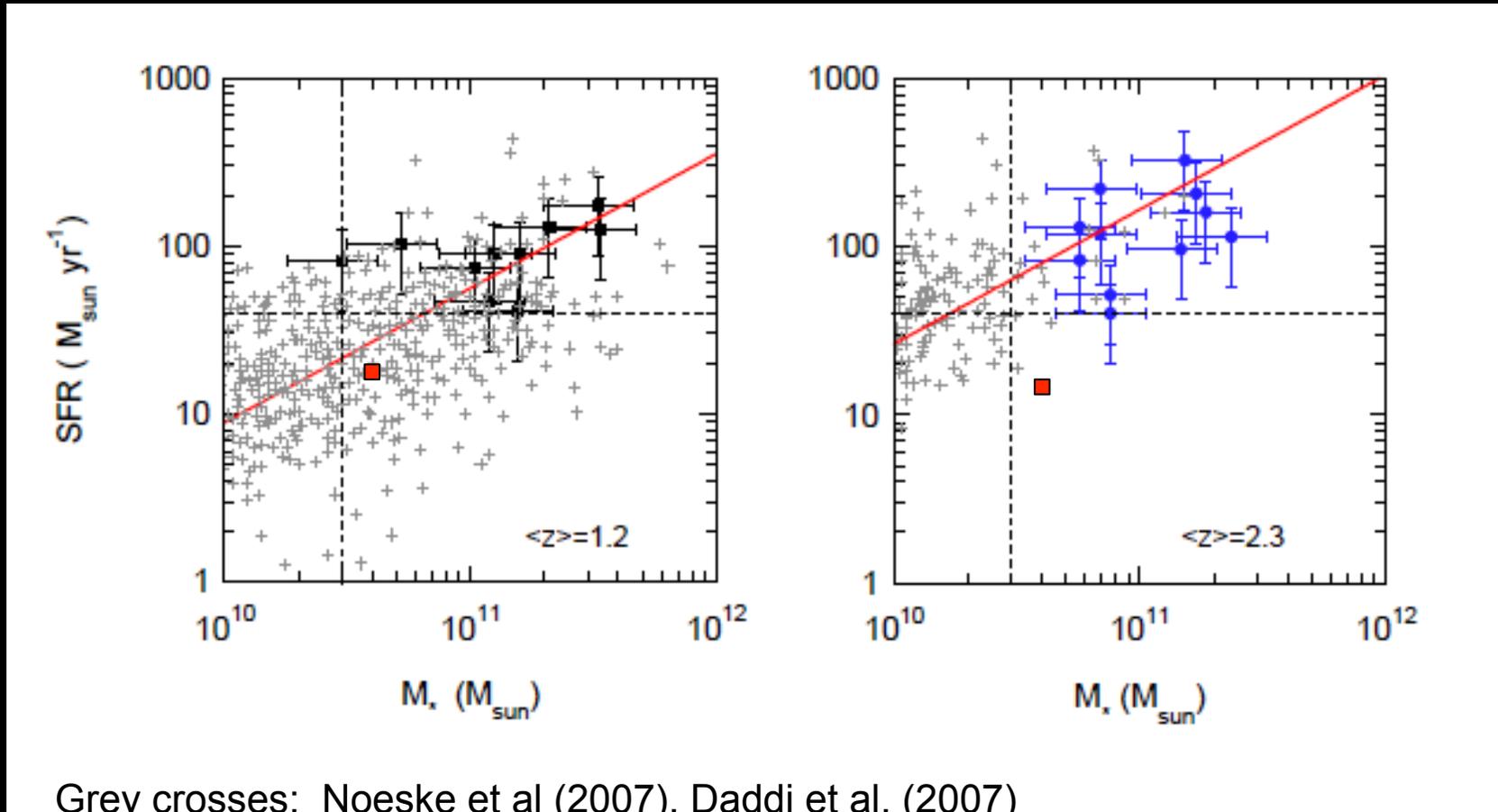


Bell et al. (2005)

→ HIZOA J0836-43 is more similar to the $z \sim 0.7$ galaxies than local star forming galaxies

Gas-Star Formation relation over Cosmic Time

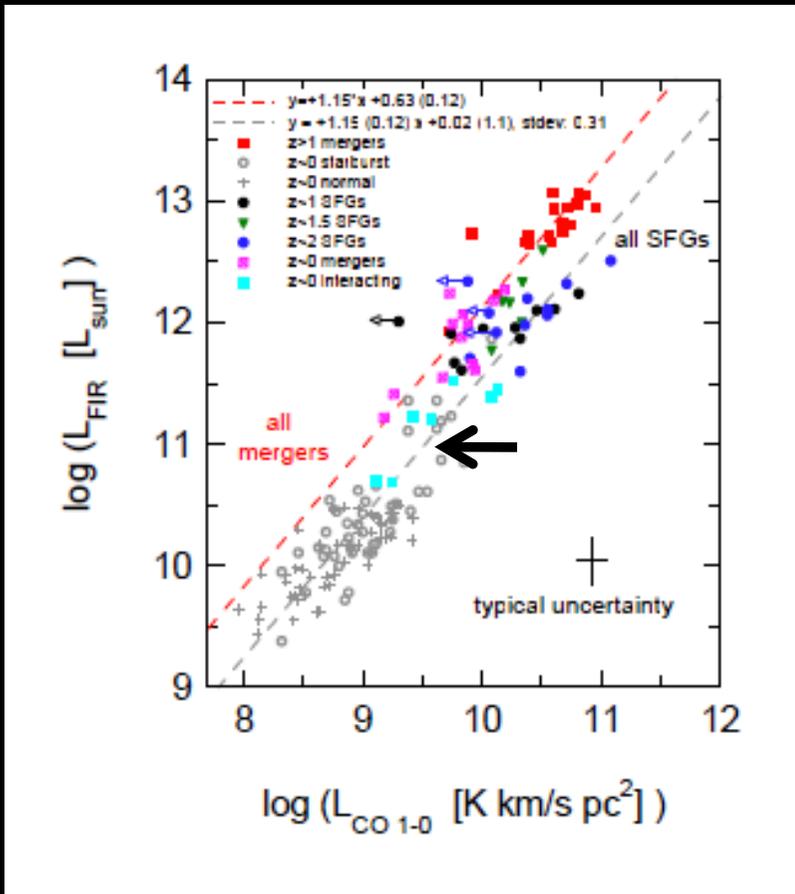
Genzel et al. (2010)



$$\text{SFR} = 150 (M_{\star} / 10^{11})^{0.8} ([1+z]/3.2)^{2.7} \quad (\text{Bouché et al. 2010})$$

20.5 M_{\odot} /yr corresponds to $z \sim 0.95$

Molecular gas fractions and star formation mechanisms



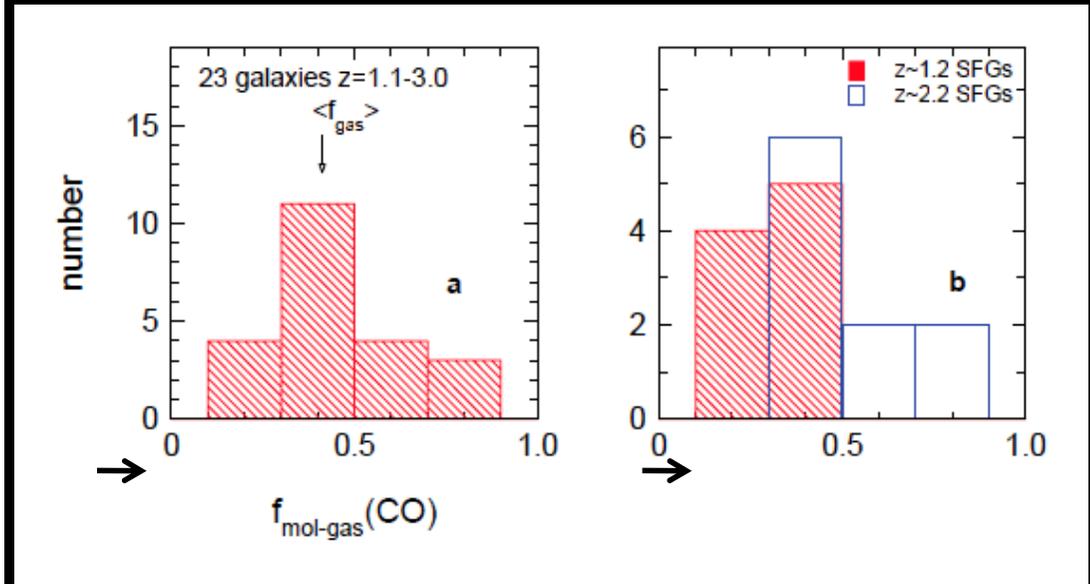
Genzel et al. (2010)

34% @ z~1.2 (update 45%)

44% @ z~2.2 (update 56%)

HIZOA (from CO): $3.9 \times 10^9 M_{\odot}$

→ 8.8 % (lower limit)



Tacconi et al. (2010)

→ HIZOA lies on the line of actively starforming galaxies,

→ and not on the line of major merger

Main points: a local LIRG

- **Rapidly rotating HI and CO (molecular gas) disk**

- “large gas reservoir”; is it accreting?

- **Old bulge + ‘new’ (forming) stellar disk**

- not a major merger

- instead it is a "disk" starburst --> we see clear *inside-out* disk building

- consistent to higher z : larger SFR is due to larger gas reservoirs

- **Similarities to * $z \sim 1$ * (gas content, stellar mass, SFR)**

- study mechanism of "big disk" star formation (inside-out formation)

- at an observationally feasible distance ($z \sim 0.036$)

- compared to distant disks at *epoch of peak stellar building*

Future Plans

- **ATCA : long baselines = higher angular resolution**
 - Distribution and kinematics of HI (and warp)
 - Probe interface between H₂ and HI
 - **→ DONE (Feb 2011)**
- **Herschel Proposal**

Further Details:

- *Cluver et al. 2008 ApJL 686, L17 (arXiv:0808.4040)*
- *Cluver et al. 2010 ApJ 725, 1550 (arXiv: 1010.3550)*

Further questions:

- *Michelle Cluver at : mcluver@ipac.caltech.edu*