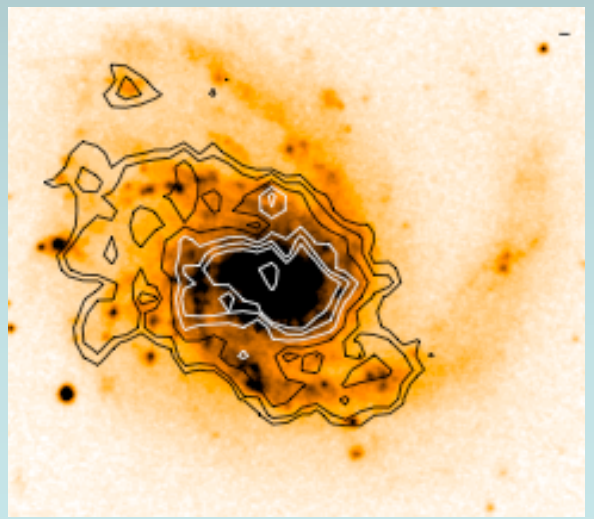
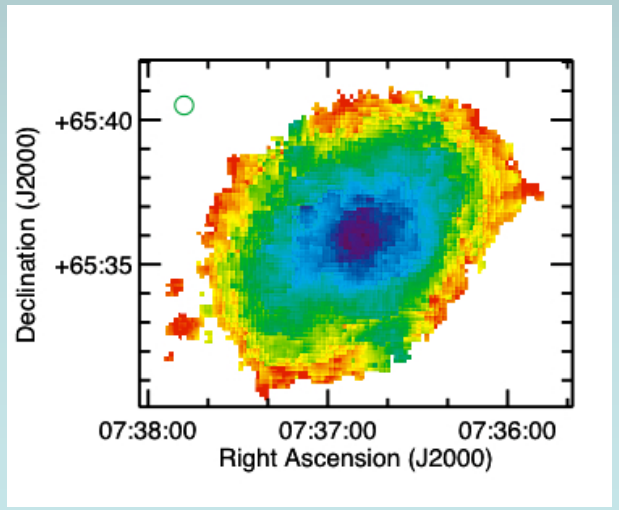
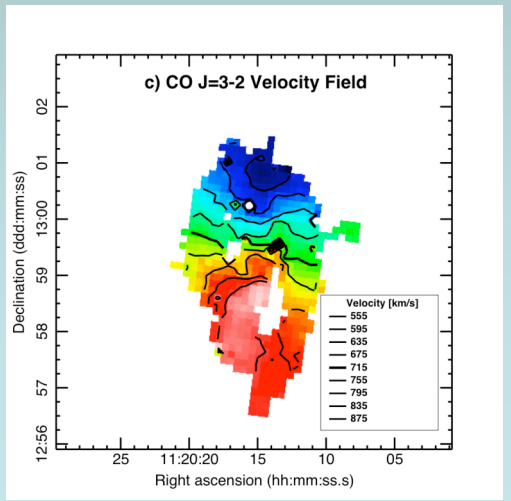
First results from the JCMT Nearby Galaxies Legacy Survey

Chris Wilson,
Brad Warren (McMaster),
George Bendo (Imperial),
and many collaborators







The JCMT Nearby Galaxies Legacy Survey team

- C. Wilson, F. Israel, S. Serjeant (coordinators)
- *B. Warren, E. Sinukoff* (major data processing)
- *G. Bendo,* H. Butner, E. Brinks, S. Courteau, D. Clement, J. Irwin, *J. Gallego, W. Heesen,* J. Knapen, *J. Leech*, H. Matthews, S. Muhle, *A. Mortimer*, G. Petitpas, K. Spekkens, *B. Tan,* R. Tilanus, A. Usero, P. van der Werf, *C. Vlahkis, T. Wiegert,* M. Zhu
- plus ~35 additional collaborators from the UK, Canada, and Netherlands

Outline

- Overview and status of NGLS
- Star formation efficiency in four Virgo and three field spiral galaxies
- Gas-to-dust ratio in NGC 2403
- Very low velocity dispersions in molecular gas
- Global correlation between CO J=3-2 luminosity and star formation rate

The JCMT Nearby Galaxies Legacy Survey: Physical Processes in Galaxies in the Local Universe

- Relative mass and physical properties of different dust components (Galliano et al. 2003)
- How reliable are integrated measurements of physical conditions in galaxies?
- Molecular gas and the gas-to-dust ratio (Neininger et al. 1996)
- Effect of galaxy morphology on the ISM
- Effect of dense cluster environments (Kenney & Young 1989)
- Effect of metallicity on the ISM (Madden et al. 2006)
- The local submillimetre luminosity function (Dunne et al. 2000)

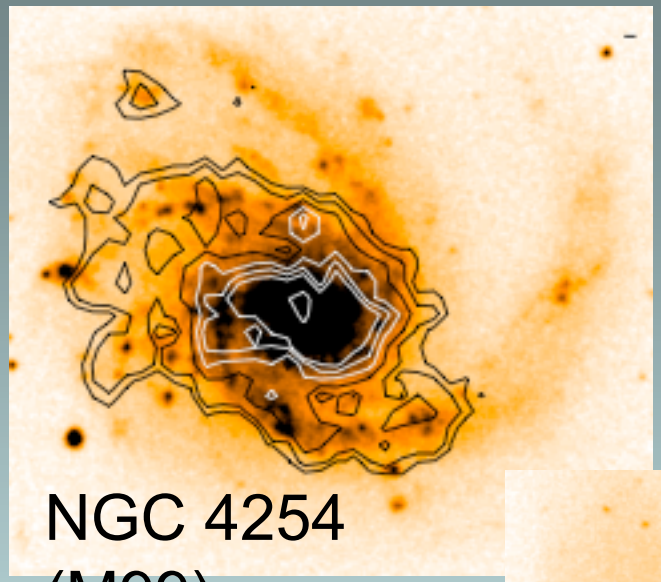
An HI-selected Sample

- 155 galaxies between 2 and 25 Mpc
- HI flux > 6 Jy km/s
- 47 **SINGS galaxies** (Kennicutt et al. 2003)
- 18 HI brightest Irr and E galaxies (HI flux > 3 Jy km/s) + 18 randomly selected spirals in **Virgo Cluster**
- random selection of 72 **field galaxies**
  - D_{25} < 4'
  - Randomly select 18 galaxies in each of 4 morphology bins (E, early S, late S, Irr)

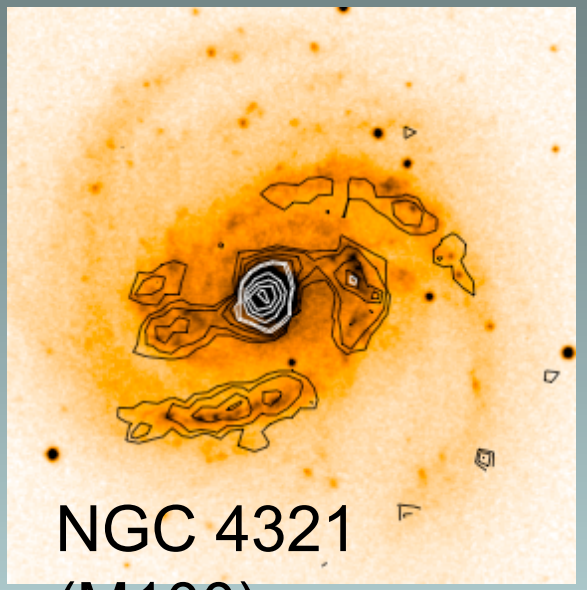
New JCMT data

- CO J=3-2 data cubes
  - Area covered is $D_{25}/2$
  - velocity range of 1000 km/s centered on mean galaxy velocity
  - Sensitivity 19 mK at 20 km/s resolution rms
  - Equivalent to Av = 1 mag or 2×10^{21} H/cm^2 rms
- Awarded 256 hours for CO; currently 84% complete; 124 galaxies observed
- HARP science verification May-Oct 2007
- Survey observing Nov 2007-present

I. Star forming molecular gas in Virgo cluster spirals

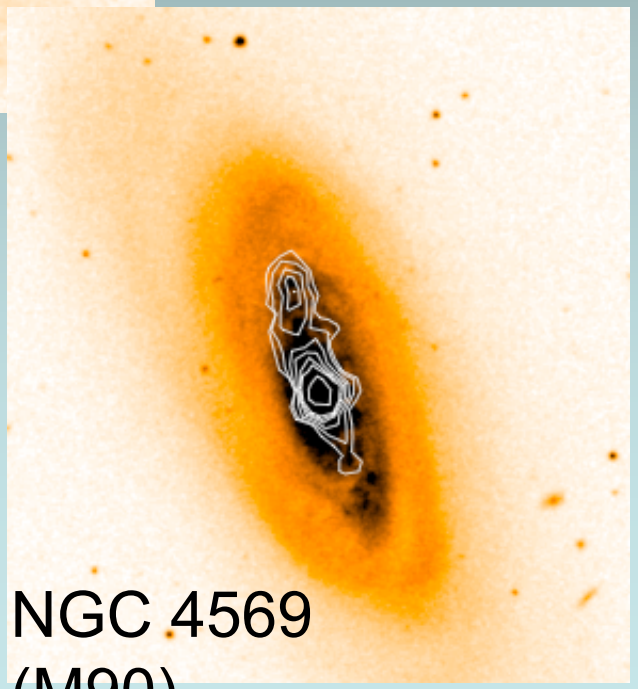


NGC 4254
(M99)

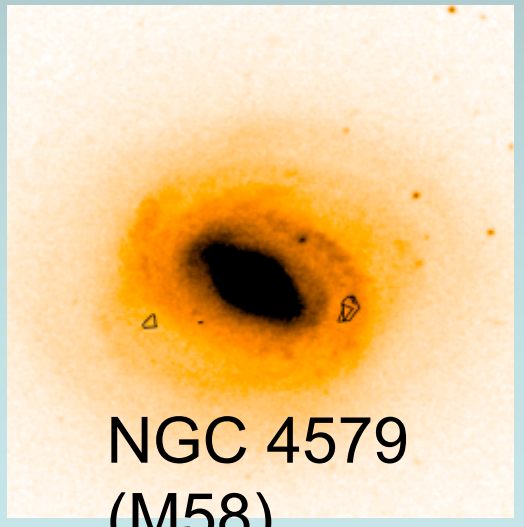


NGC 4321
(M100)

Wilson et al.
2009, ApJ

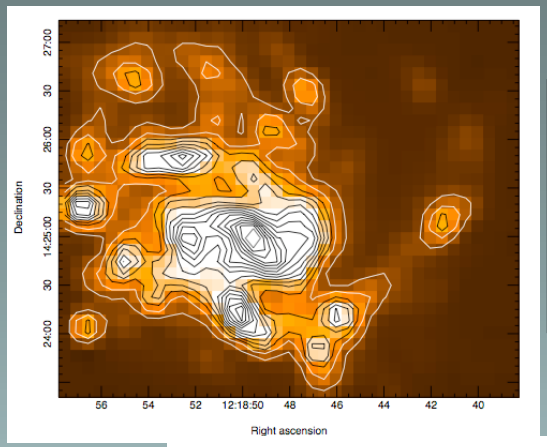


NGC 4569
(M90)

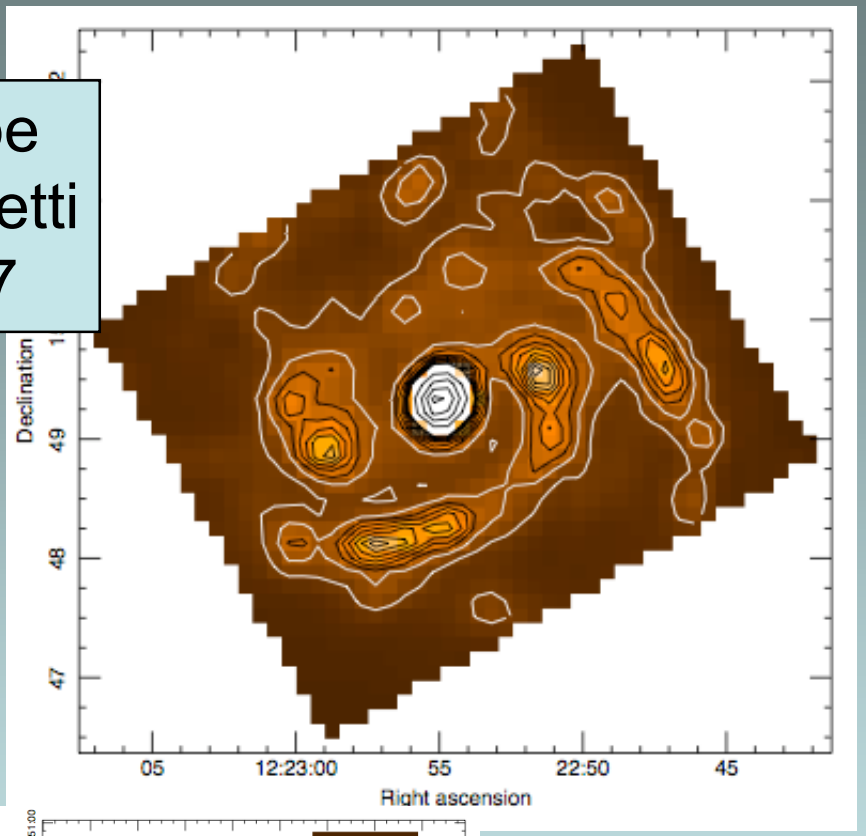


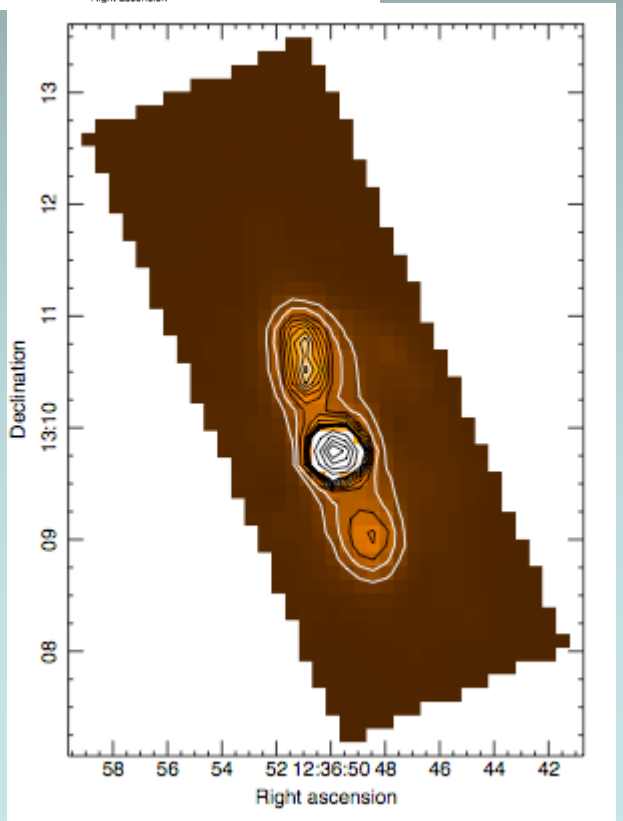
NGC 4579
(M58)

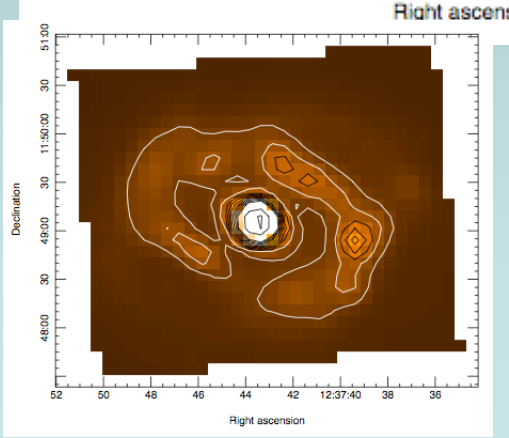
“Star formation rates” = 24 μm + Hα



SFR recipe from Calzetti et al. 2007

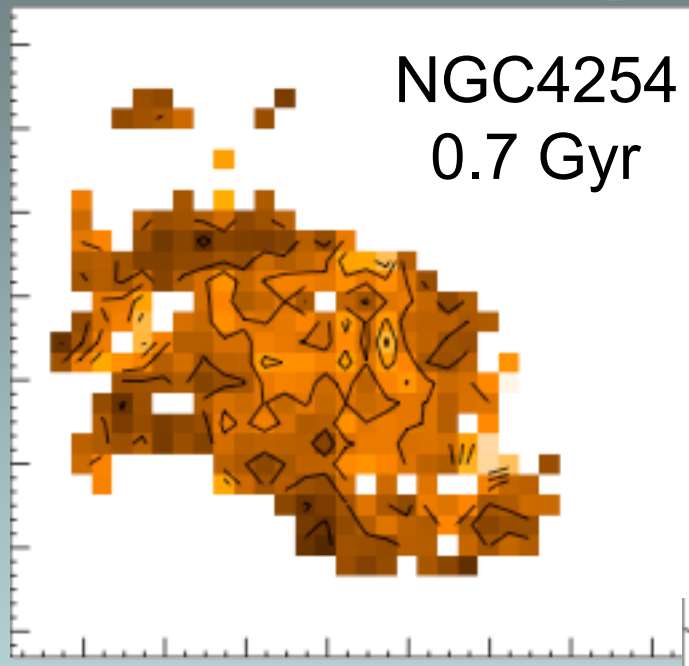


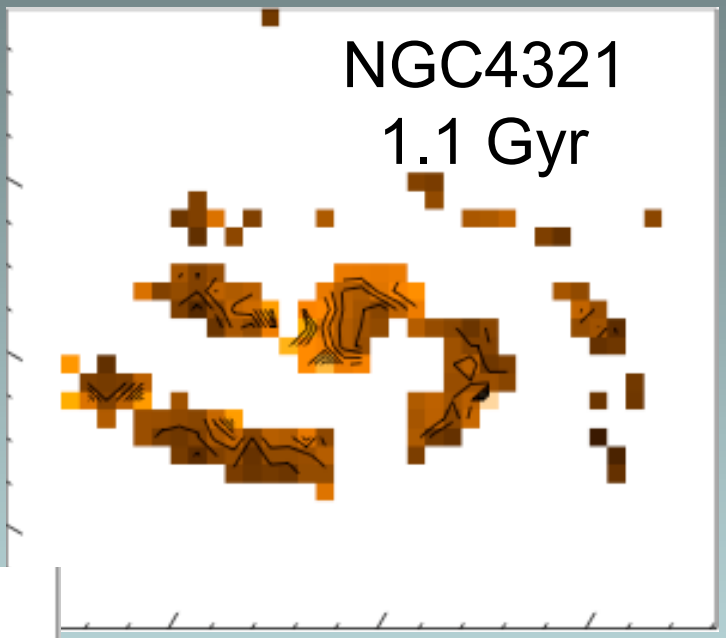


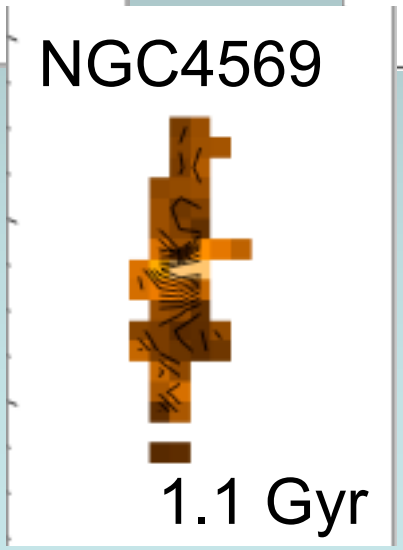


All images are on same colour scale

Gas depletion time = 1/SFE







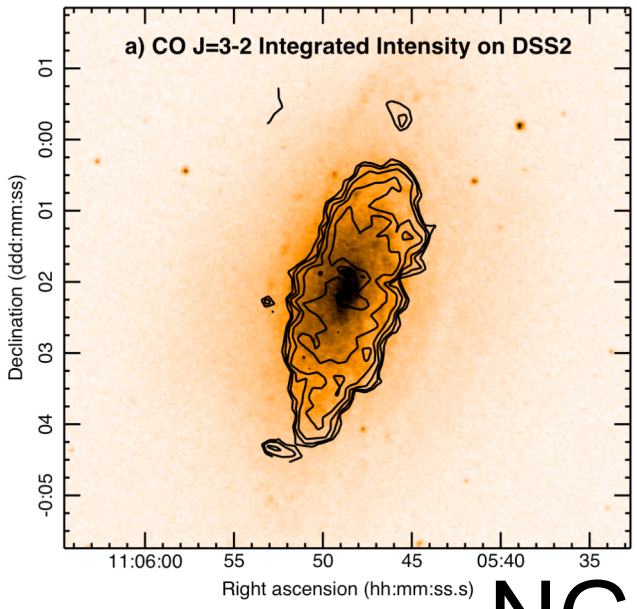
$t_{gas} = M_{mol}/SFR$

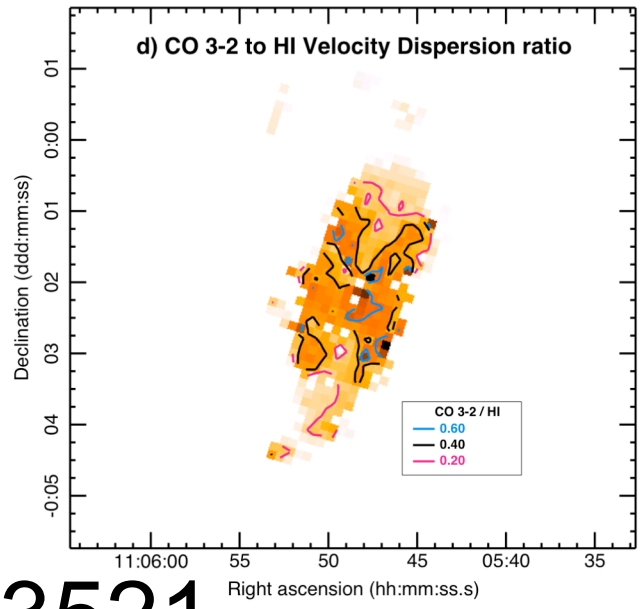
Quite uniform gas depletion times when CO J=3-2 used to trace mass of molecular gas

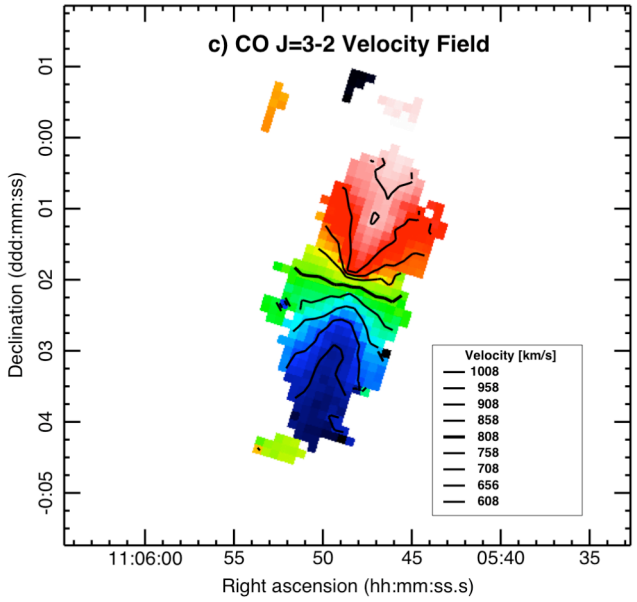
II. Star Formation Efficiency versus gas surface density (Warren et al. 2009, submitted)

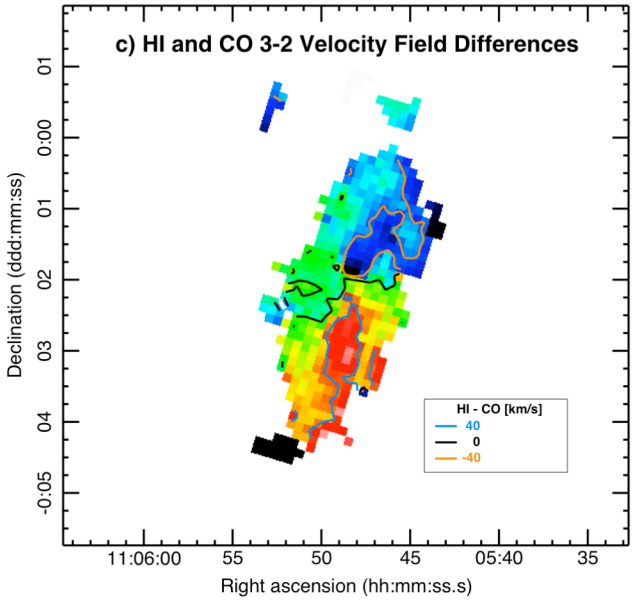
- Three large field spirals from NGLS
- All with complementary high-resolution HI data from THINGS (Walter et al. 2009)
- Star formation efficiency, molecular gas fraction, total gas surface density, kinematic differences

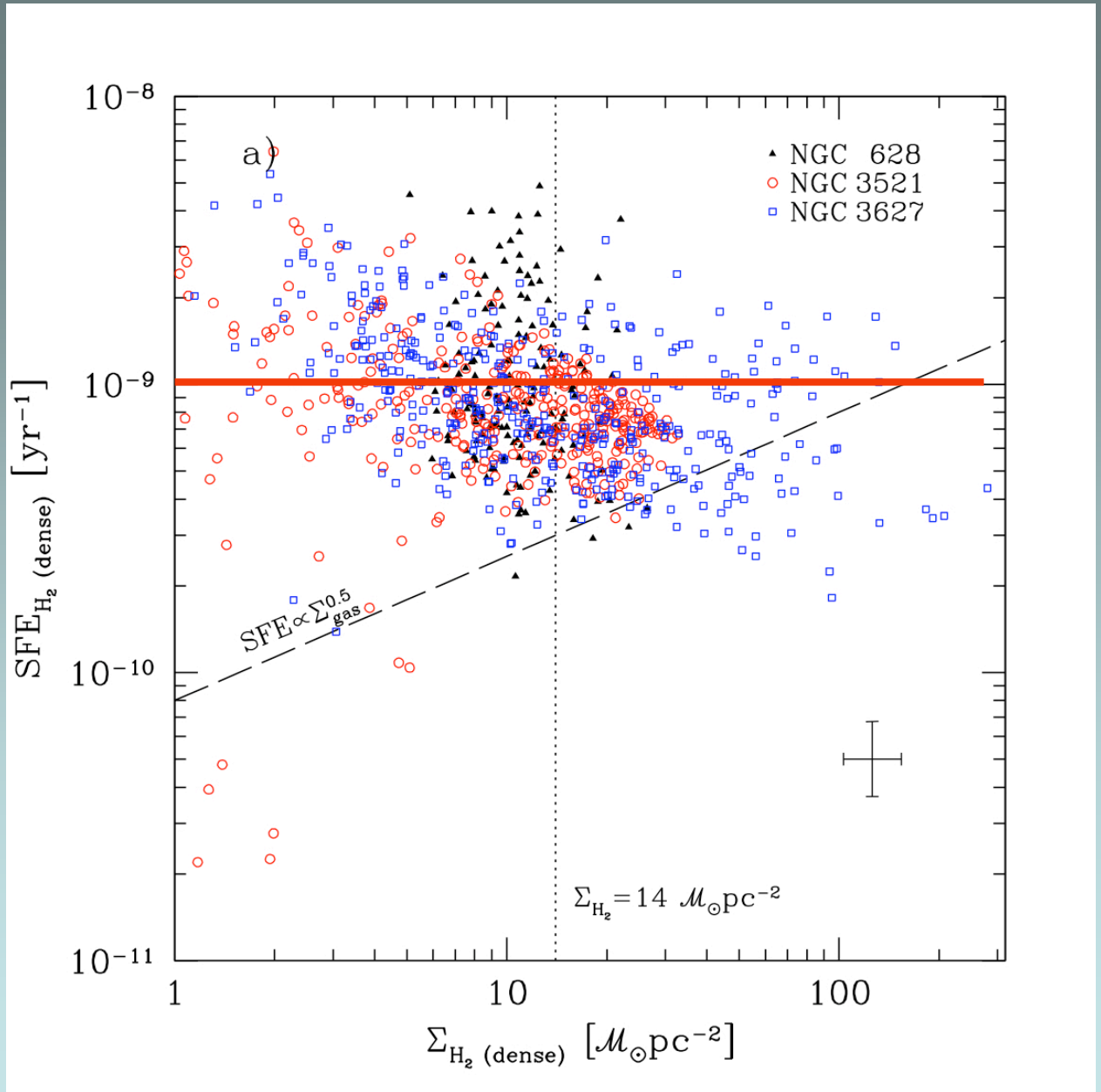
NGC3521


a) CO J=3-2 Integrated Intensity on DSS2
Declination (ddd:mm:ss)
Right ascension (hh:mm:ss.s)

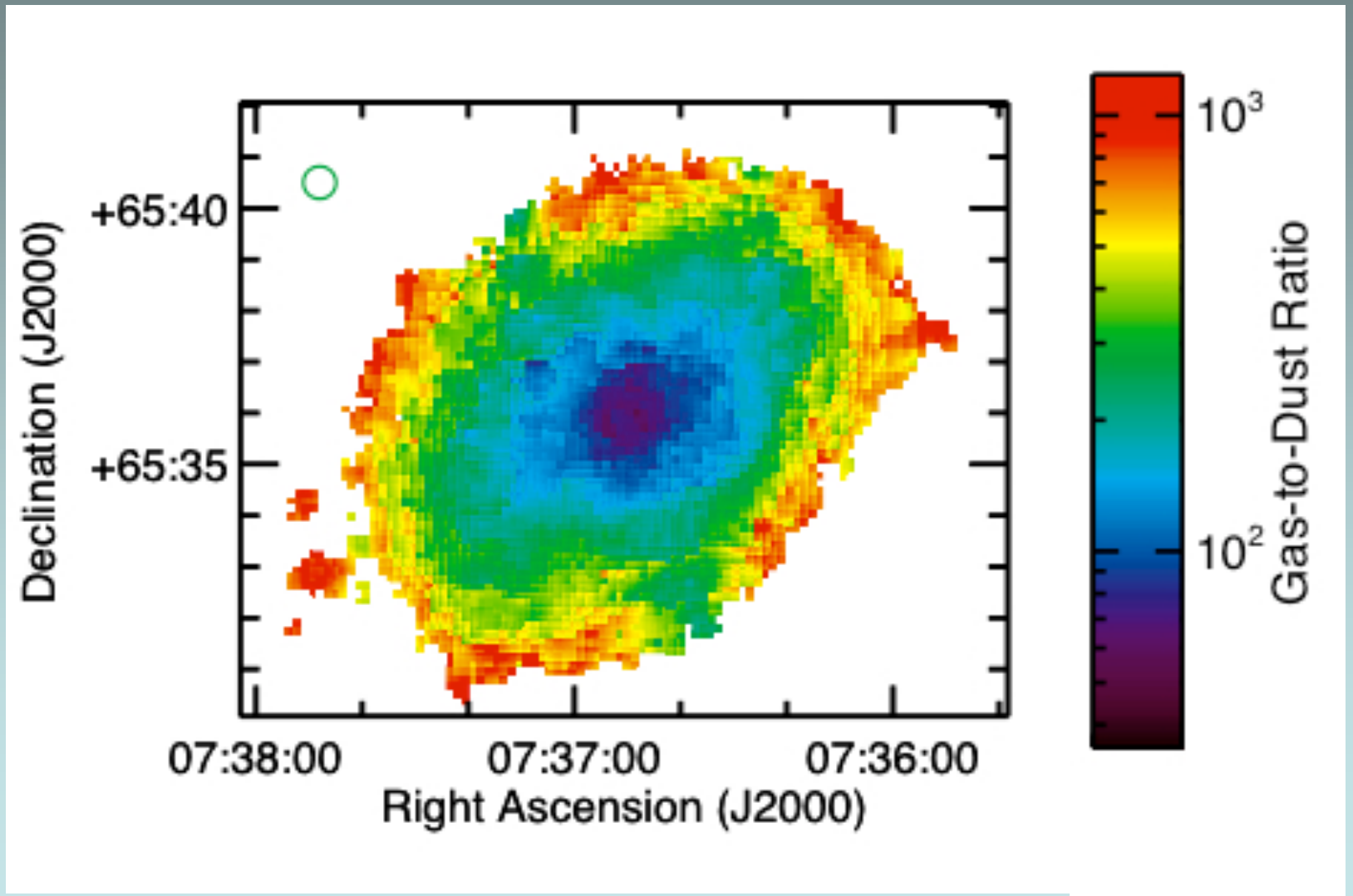

d) CO 3-2 to HI Velocity Dispersion ratio
CO 3-2 / HI
0.60
0.40
0.20
Declination (ddd:mm:ss)
Right ascension (hh:mm:ss.s)


c) CO J=3-2 Velocity Field
Velocity [km/s]
1008
958
908
858
808
758
708
656
608
Declination (ddd:mm:ss)
Right ascension (hh:mm:ss.s)

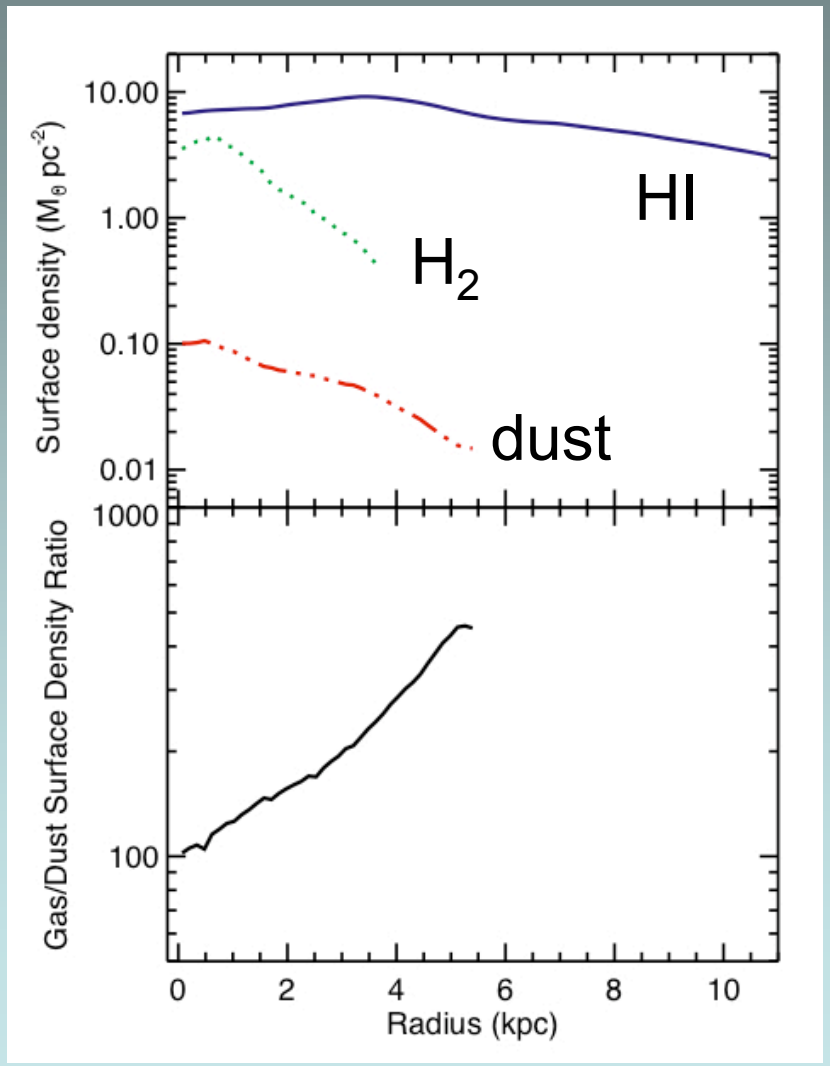

c) HI and CO 3-2 Velocity Field Differences
HI - CO [km/s]
40
0
-40
Declination (ddd:mm:ss)
Right ascension (hh:mm:ss.s)

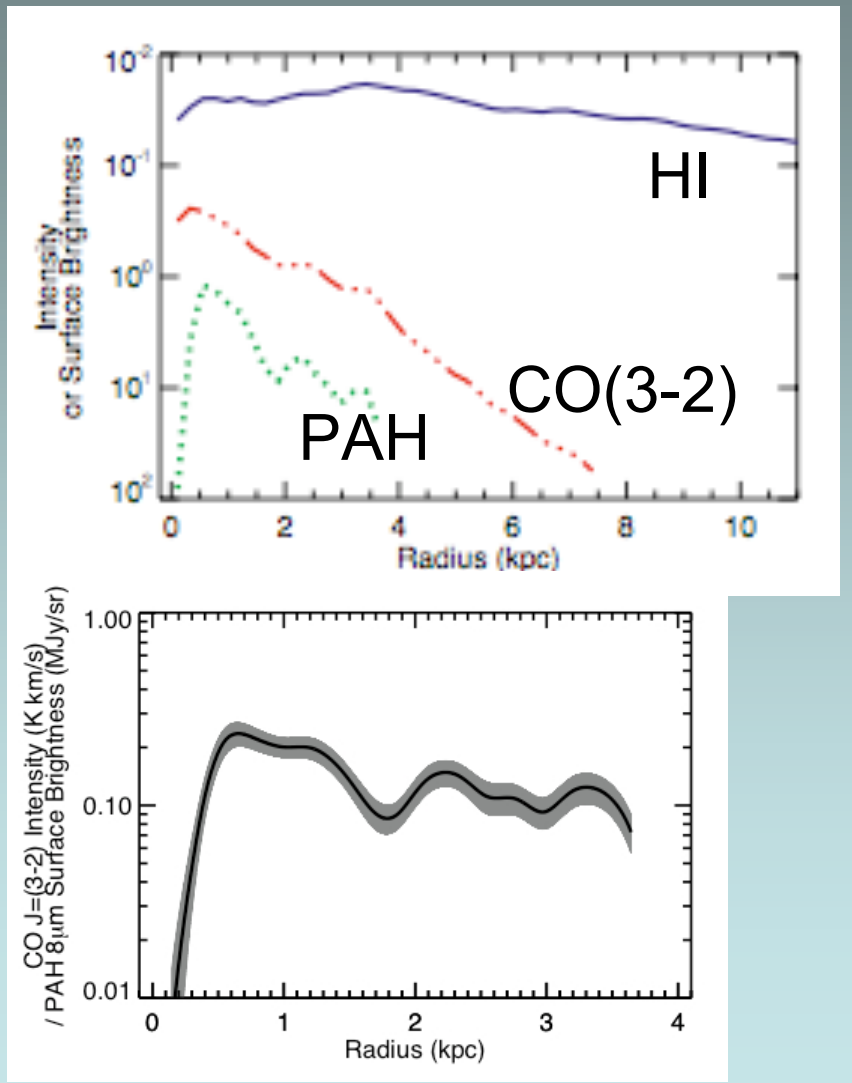

a)
NGC 628
NGC 3521
NGC 3627
10^{-8}
10^{-9}
10^{-10}
10^{-11}
$\mathrm{SFE}_{\mathrm{H_2}\ (\mathrm{dense})}\ [\mathrm{yr}^{-1}]$
$\mathrm{SFE} \propto \Sigma^{0.5}_{\mathrm{gas}}$
$\Sigma_{\mathrm{H_2}} = 14\ \mathcal{M}_{\odot}\mathrm{pc}^{-2}$
1
10
100
$\Sigma_{\mathrm{H_2}\ (\mathrm{dense})}\ [\mathcal{M}_{\odot}\mathrm{pc}^{-2}]$

III. Gas to dust mass ratio in NGC2403 (Bendo et al., in prep.)



Radial profiles of gas and dust

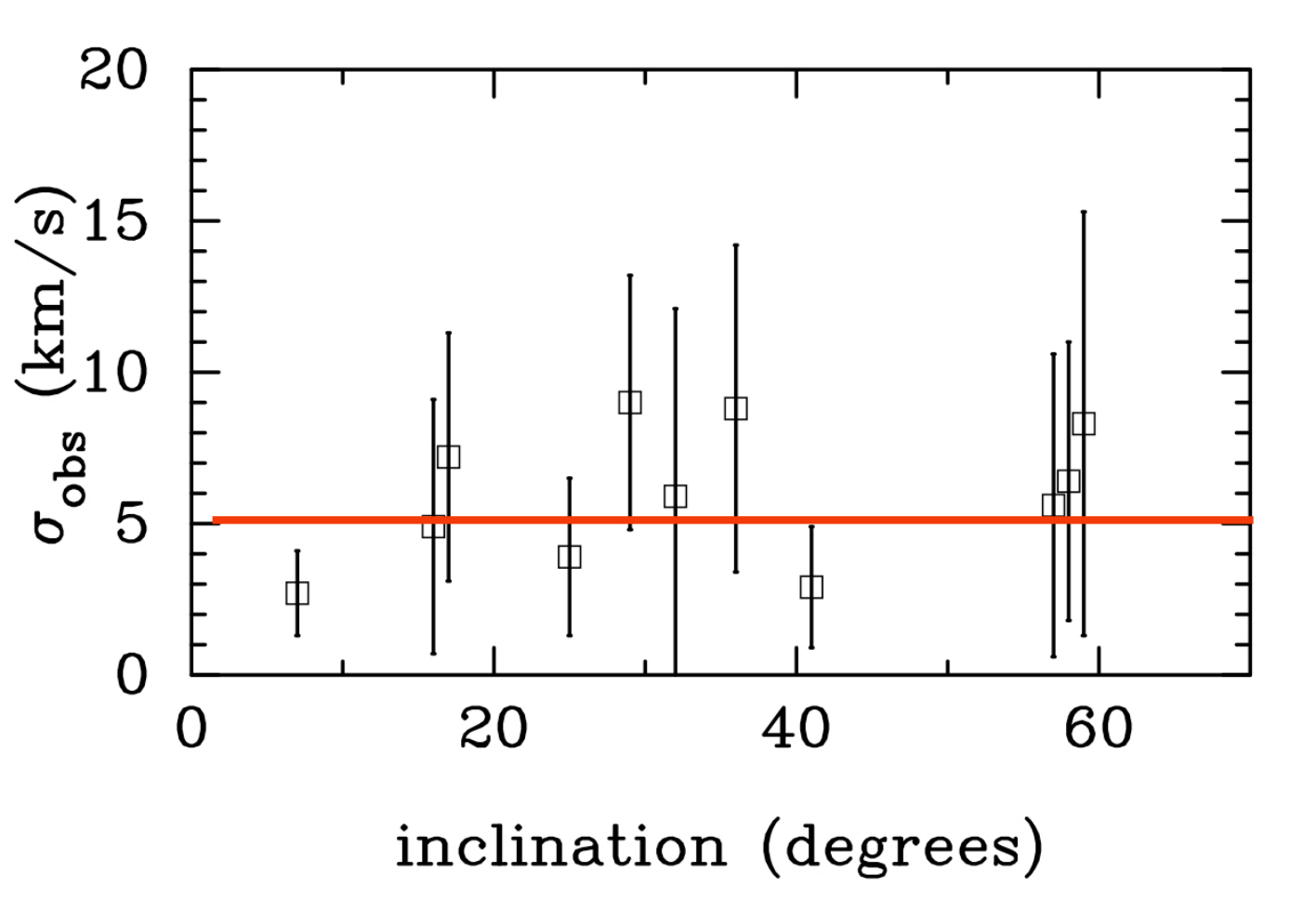




IV. Velocity dispersions in the molecular interstellar medium (C. Wilson et al., 2009, in prep)

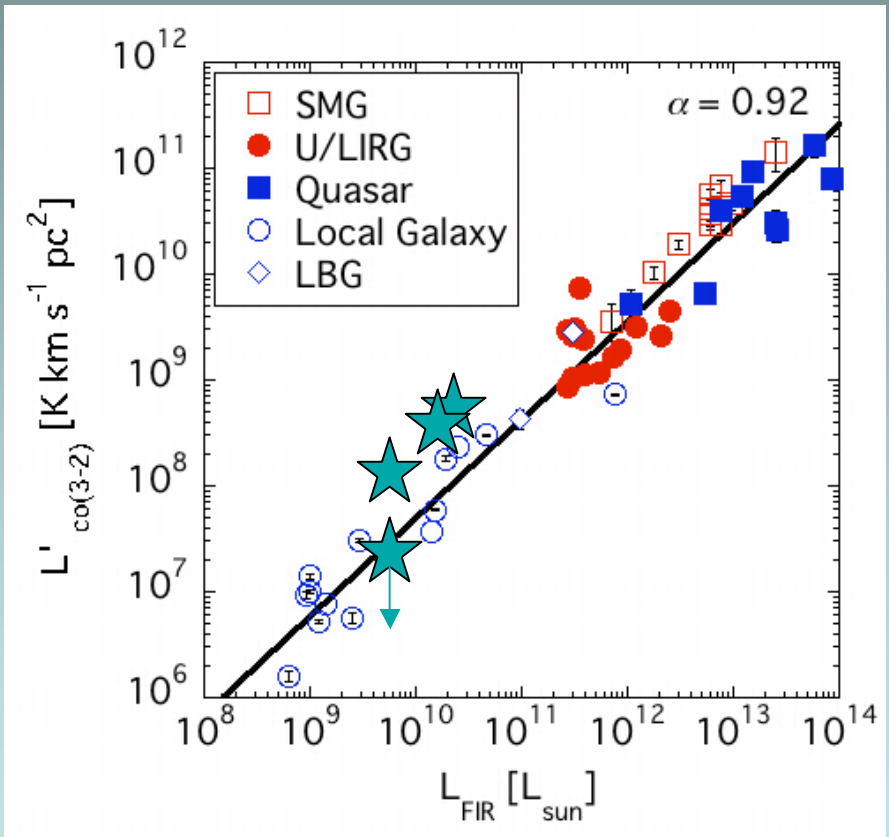
- Gas velocity dispersion is an important input to the Toomre criterion for disk stability $Q = \sigma_g \kappa / \pi G \Sigma_g$
- HI velocity dispersion 10+/-2 km/s at r_{25} (higher in interior,Tamburro et al. 2009)
- Measurements of σ_g in molecular component are rare

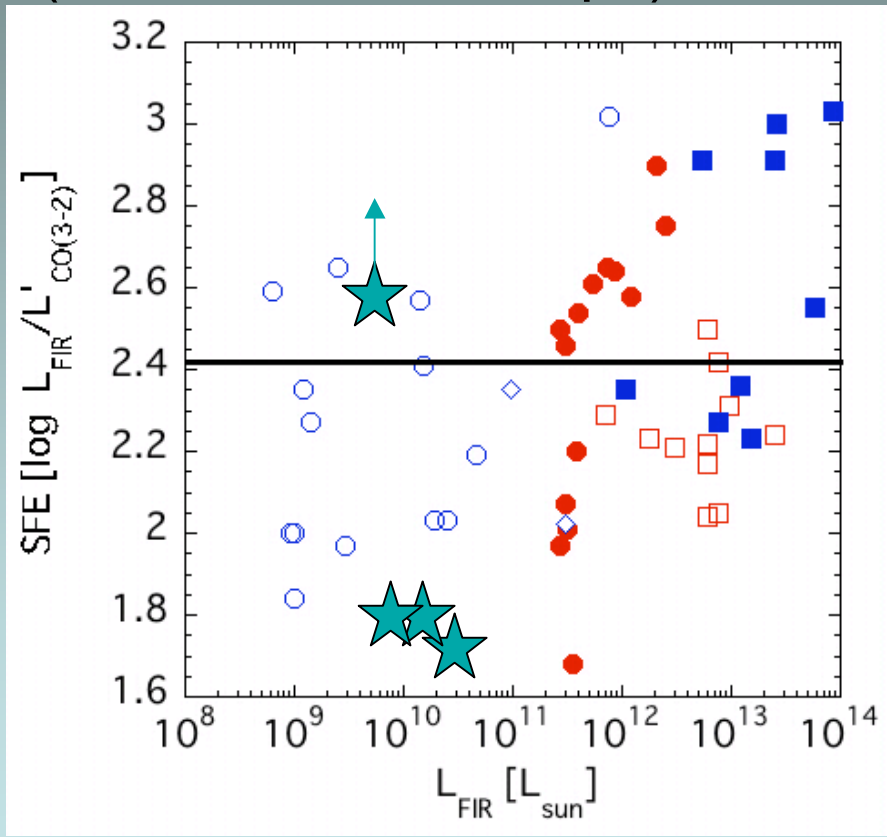
Velocity dispersion in molecular gas only ~5 km/s



A linear correlation between CO J=3-2 and far-infrared luminosity

(Iono et al. 2009, ApJ)





- Slope (0.92+/-0.03) is similar to HCN (Gao & Solomon 2004) and significantly steeper than CO(1-0) (Yao et al. 2003)

First Results from the Nearby Galaxies Legacy Survey

- Analysis of 7 large spirals suggests CO J=3-2 is an excellent tracer of dense molecular gas directly involved in star formation
- gas-to-dust ratio varies with radius in NGC 2403; perhaps due to the metallicity gradient
- Very low (5 km/s) velocity dispersions in the dense molecular gas, much smaller than HI
- deep CO J=3-2 images for 124 galaxies so far; *31 more galaxies and SCUBA-2 850 and 450 micron data still to come!*

The JCMT Nearby Galaxies Legacy Survey: Papers

I. Star-forming molecular gas in Virgo Cluster spiral galaxies, Wilson et al., 2009, ApJ, 693, 1736

II. Warm molecular gas and star formation in three field spiral galaxies, Warren, Wilson, Israel, et al., 2009, ApJ, submitted

III. The relations among PAHs, cold dust, molecular, and atomic gas in NGC 2403, G. Bendo, Wilson, Warren et al., 2009, MNRAS, in prep.

IV. Very low velocity dispersions in the molecular interstellar medium of spiral galaxies, C. Wilson, Warren, et al., 2009, MNRAS, in prep.