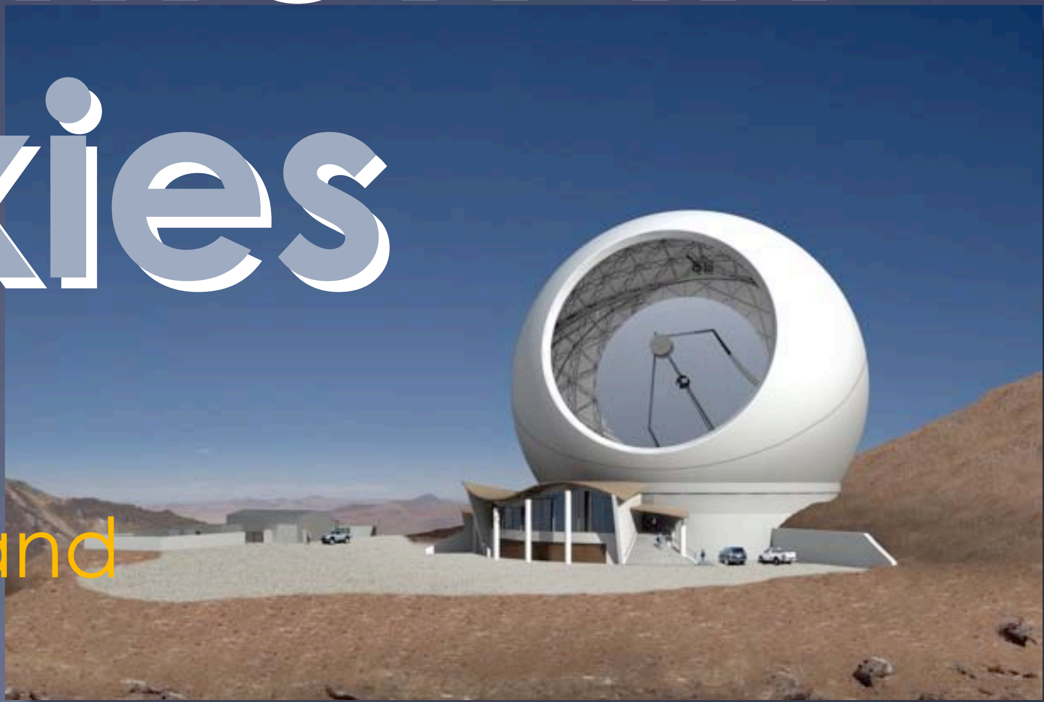
Star Formation in Galaxies



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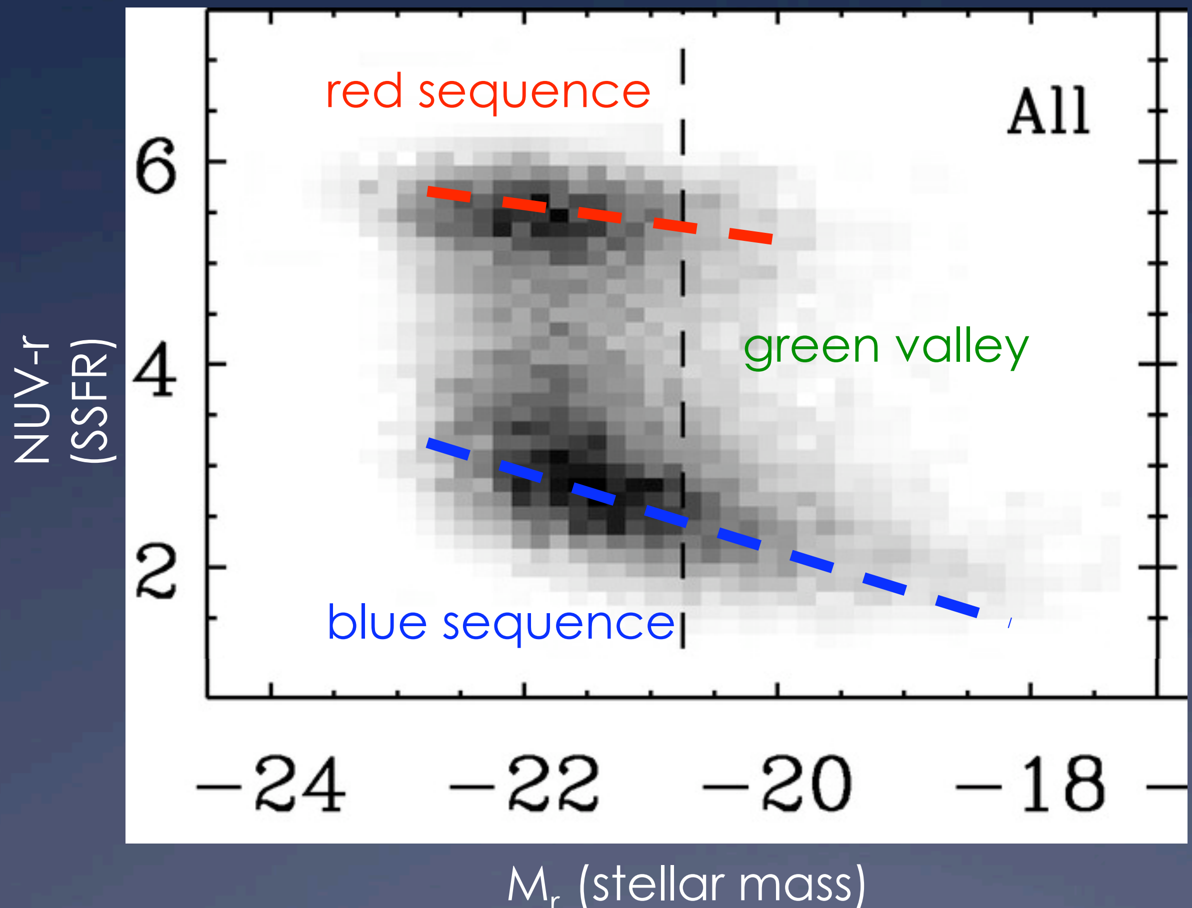
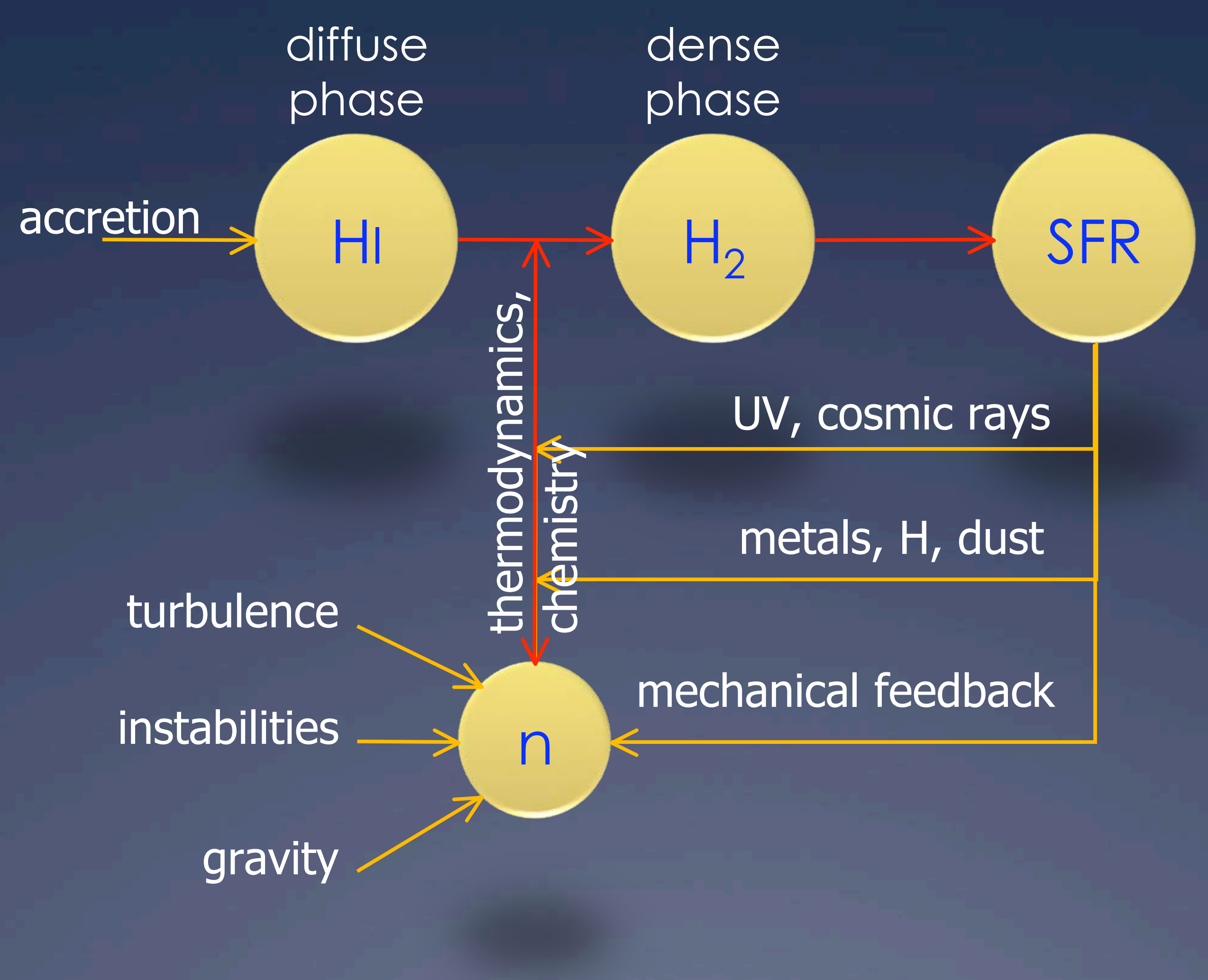
How are galaxies put together?



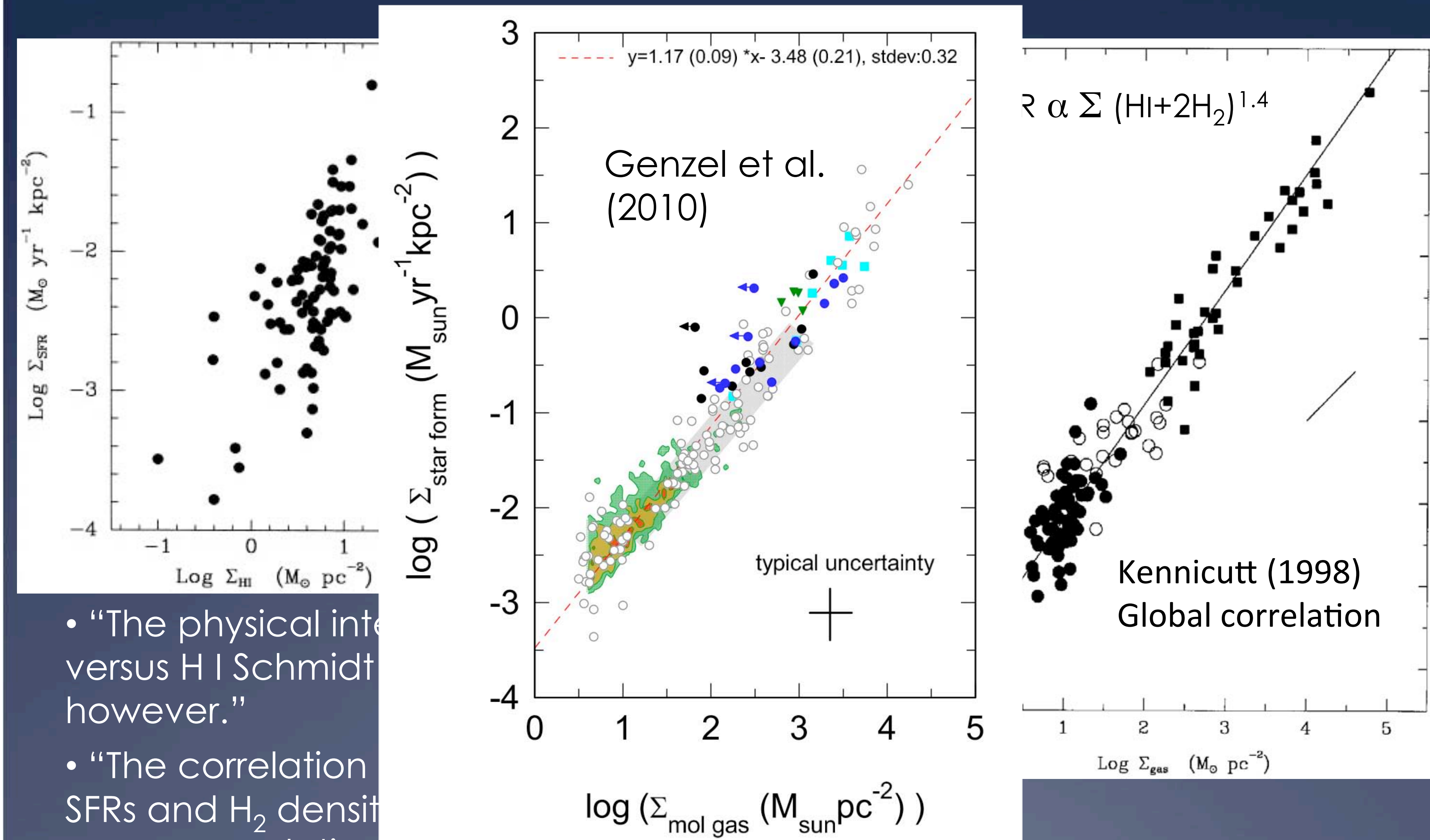
Salim et al. (2007),
Kauffmann et al. (2003)

- Two groups: red and dead, and blue and star-forming
- Star formation activity is related to the presence (or absence) of gas
- What are the relevant physical processes?

The gas-star formation relation in galaxies

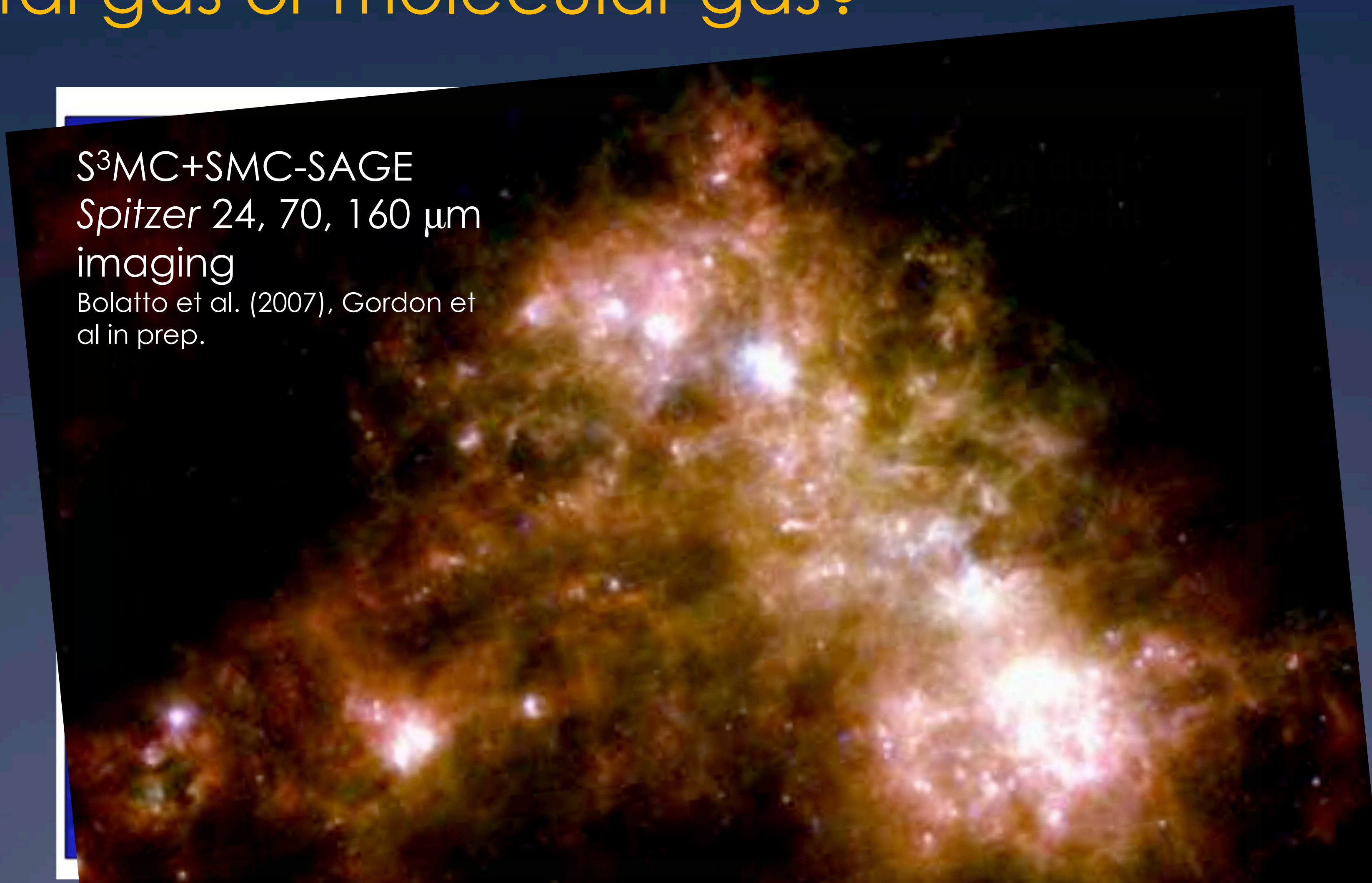


The Star Formation Law



- "The physical inte versus H I Schmidt however."
- "The correlation SFRs and H_2 densit a poor correlation between the SFR and molecular gas densities is unexpected"

Total gas or molecular gas?



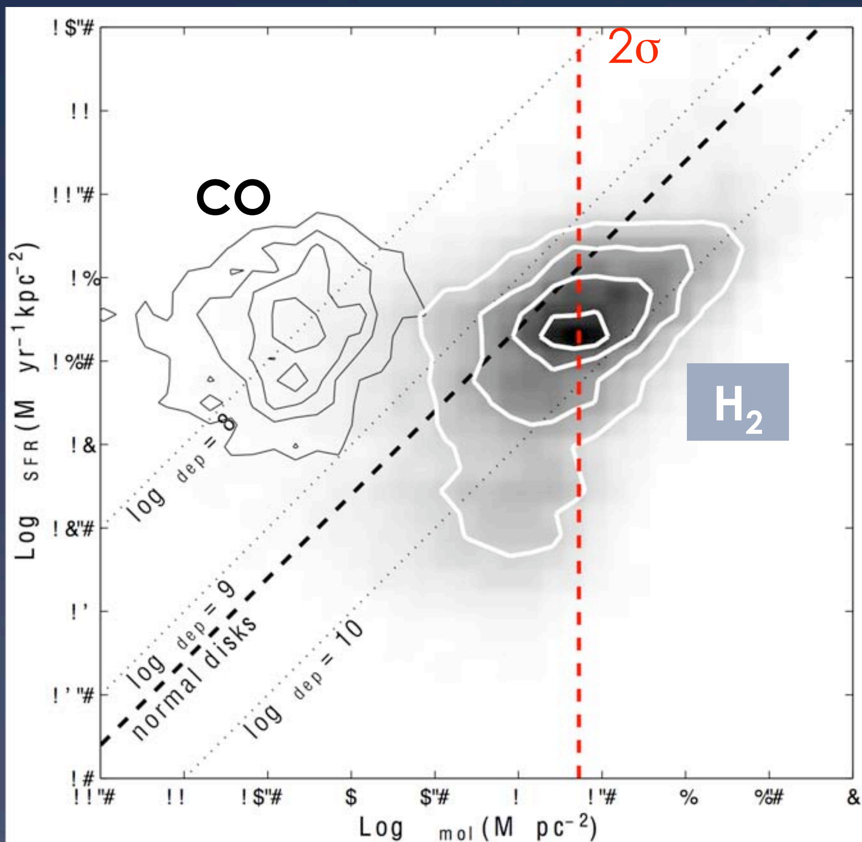
- Better asked in a HI-dominated system
- We use the SMC as a laboratory. Bypass the CO and Xco using dust as the H_2 tracer (Israel 1997; Dame et al. 2001)

Leroy, Bolatto, et al. (2007, 2009,2010); Bolatto, Leroy, et al. in prep.

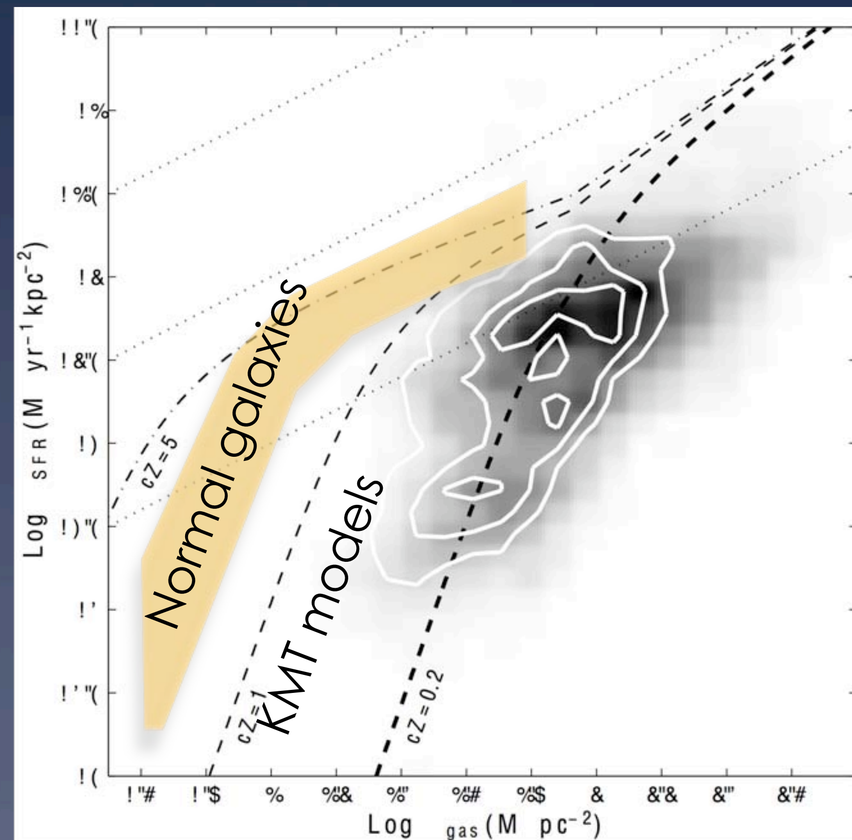
Relations for H_2 and total gas

SFR

Molecular Gas



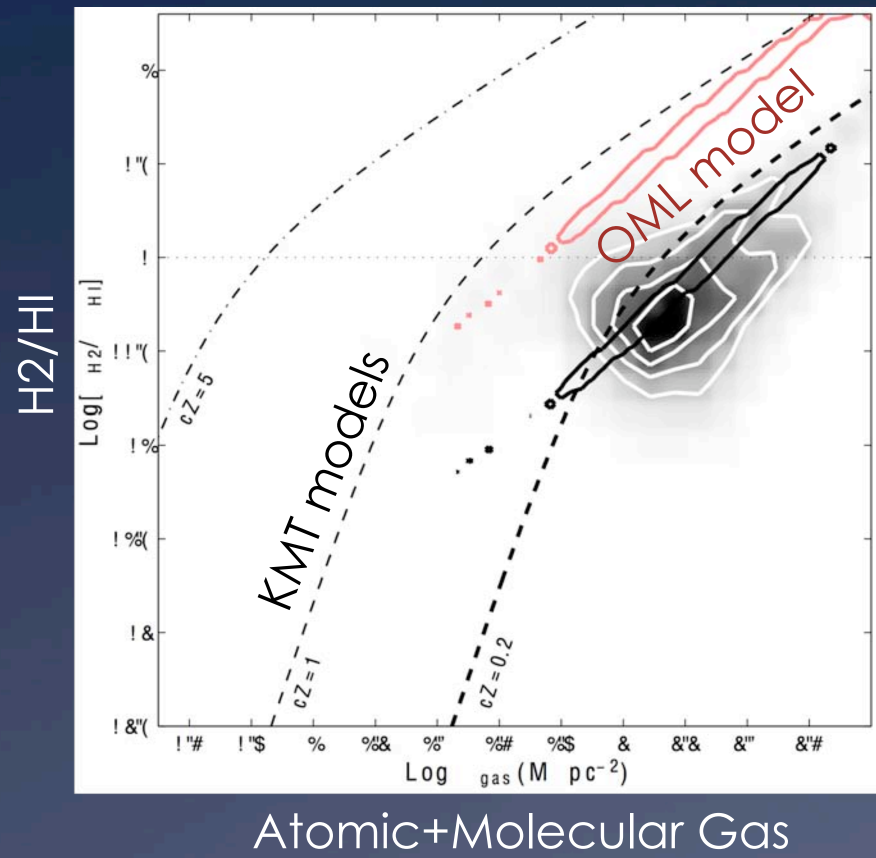
Atomic+Molecular Gas



- The SMC is "normal" in H_2 vs. SFR
- The SMC is vastly underperforming in total gas vs. SFR
    - Similar problem at high-z, see Wolfe & Chen (2006)
- Krumholz et al. (2009, KMT) models with HI→H_2 set by PDR balance fit the data

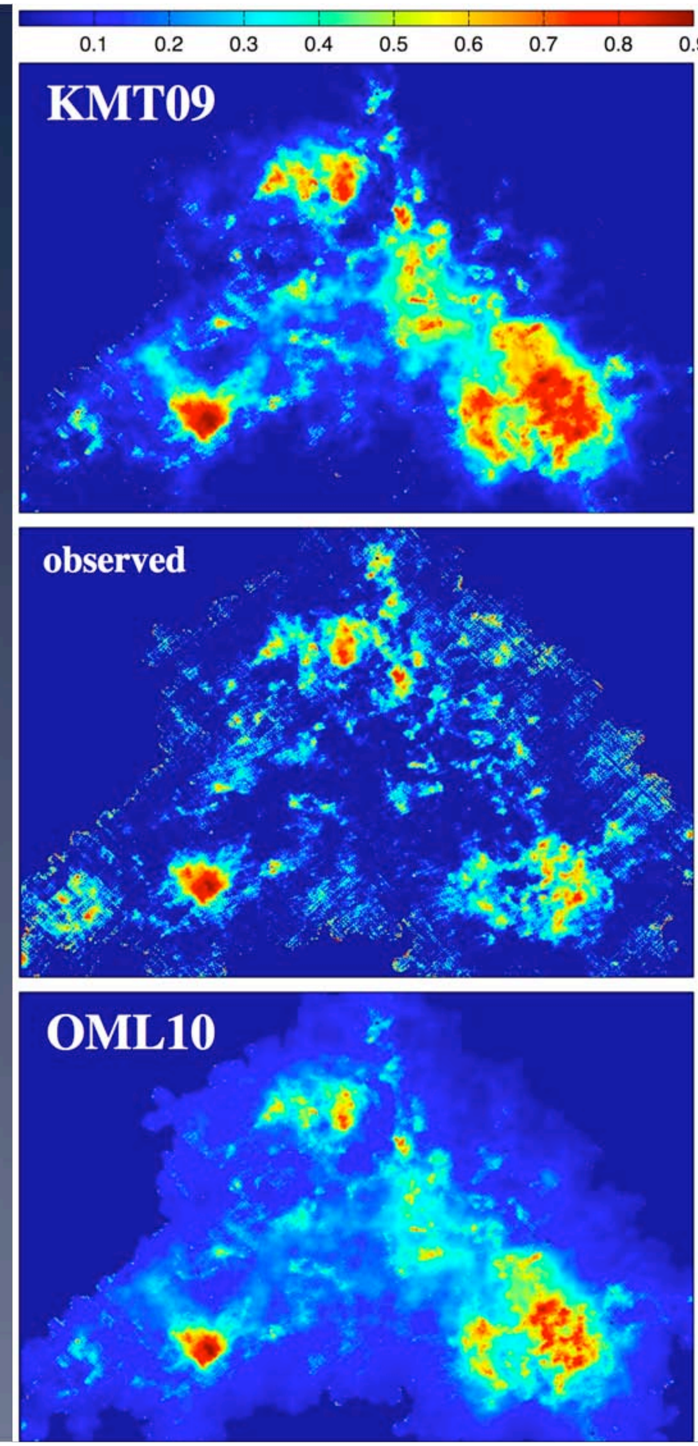
Bolatto, Leroy, et al. in prep.

Molecular fraction and pressure

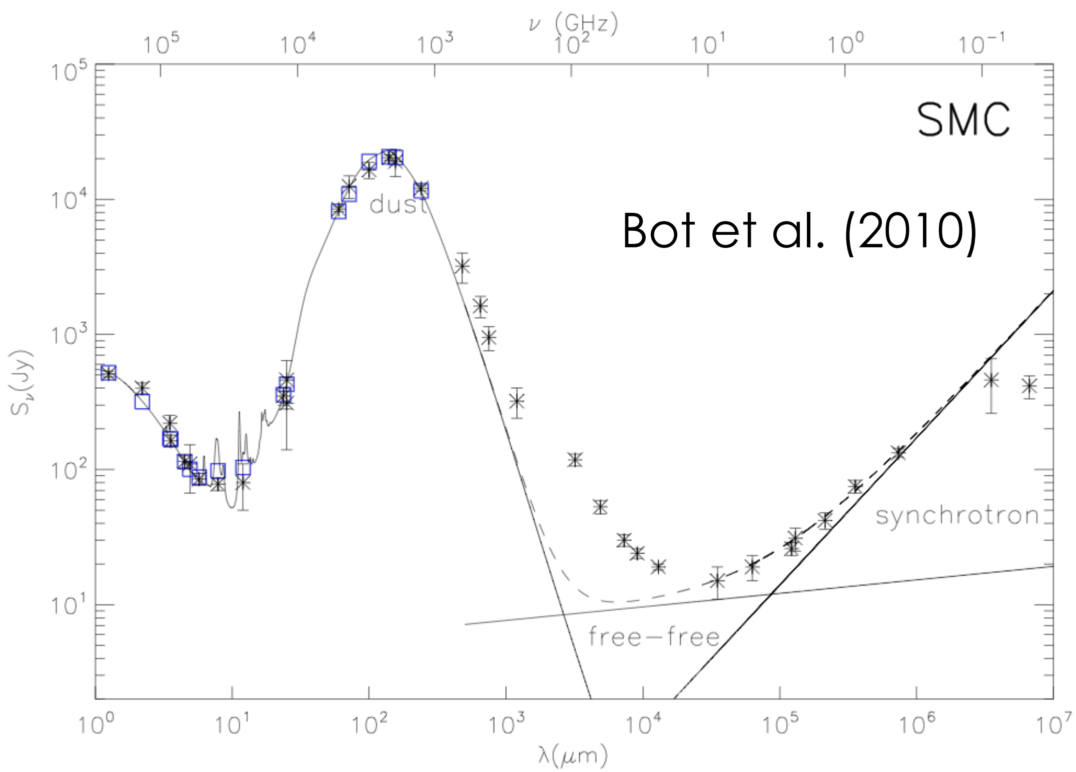


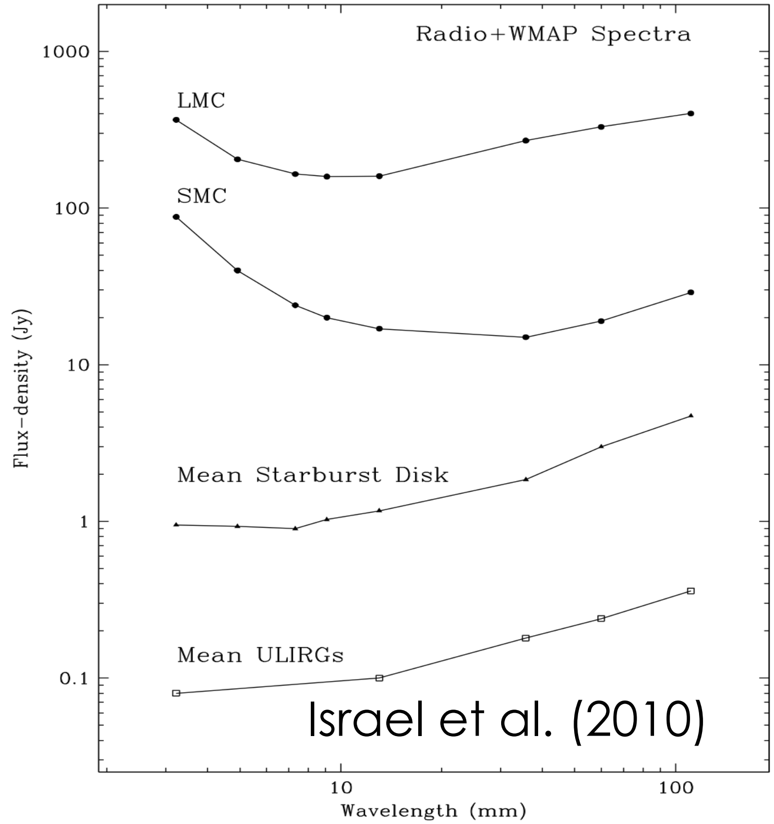
- Data are fit very well by OML10, after including the effect of dust-to-gas on UV propagation
- The core of OML10 is thermodynamic pressure equilibrium

Ostriker, McKee, & Leroy 2010



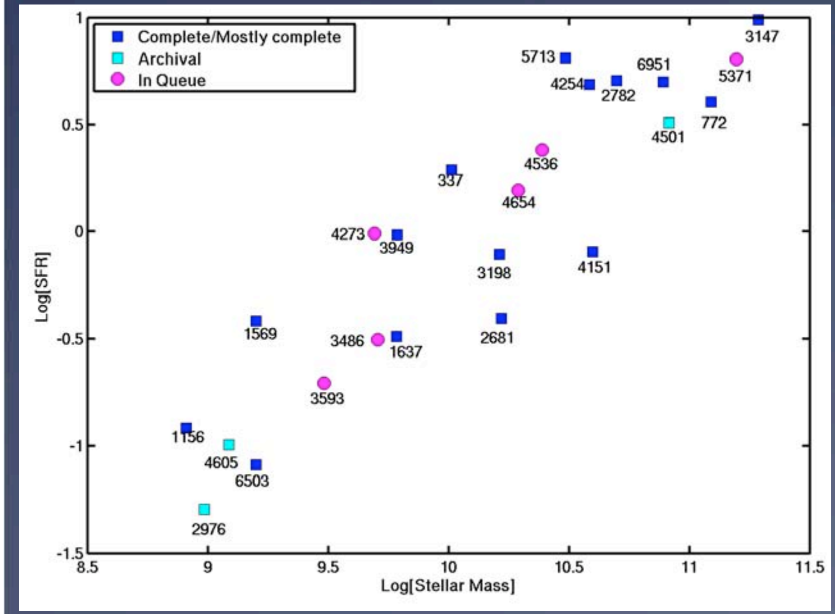
Dust properties at submm/mm wavelengths



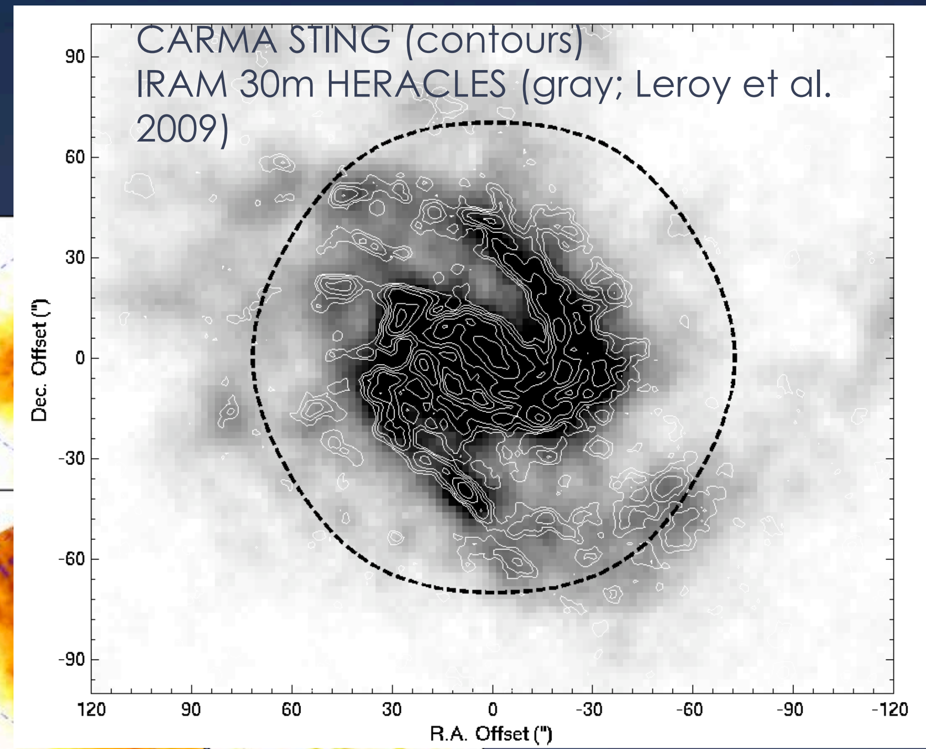


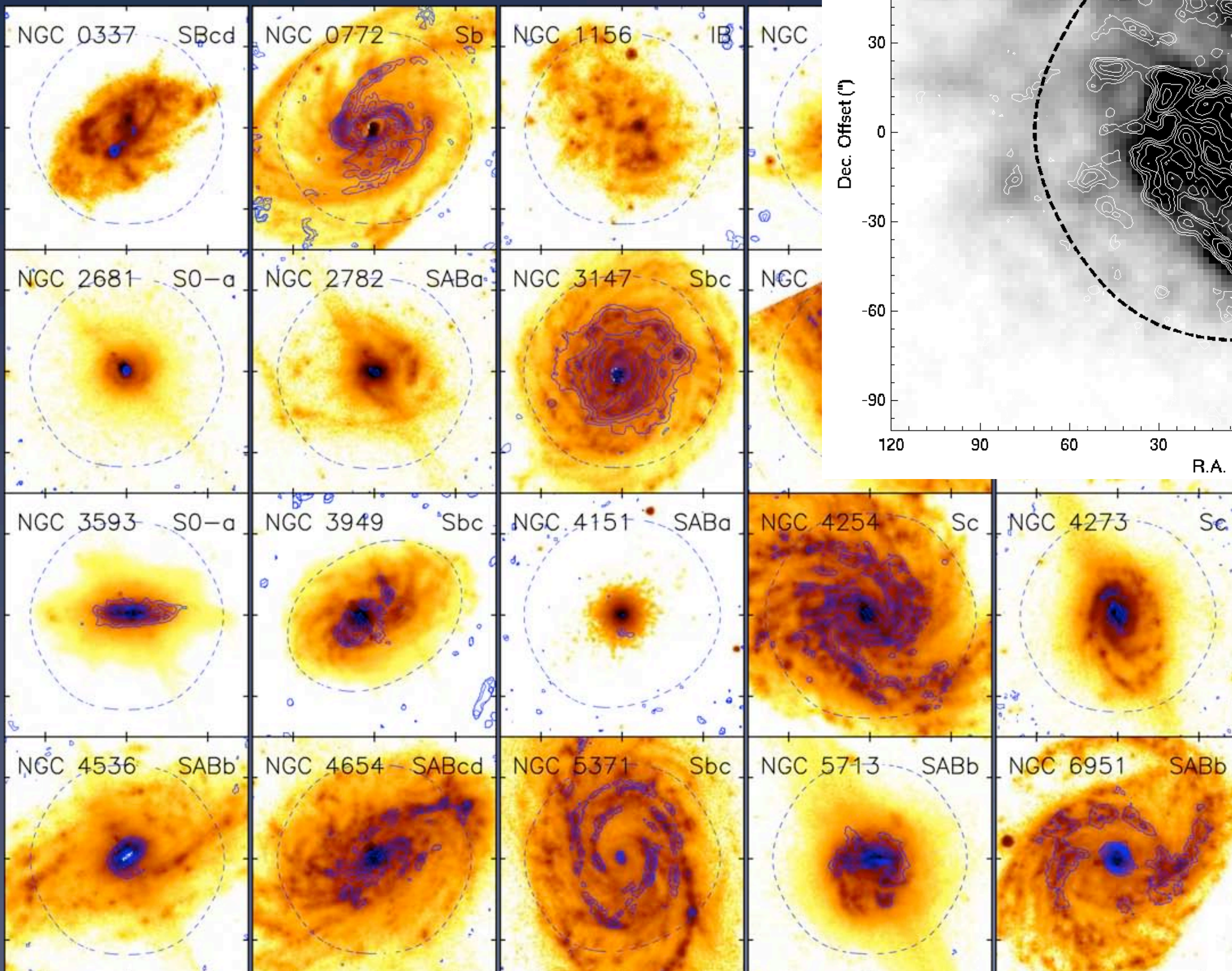
- There are consistent observations of submm excess, perhaps associated with low metallicity (e.g., Galliano et al. 2005)
- Very cold dust? Exotic dust properties? Spinning dust?
- The excess starts to pick up at Herschel's SPIRE longest band

Molecular gas through the blue sequence



Detailed studies of the Star Formation Law



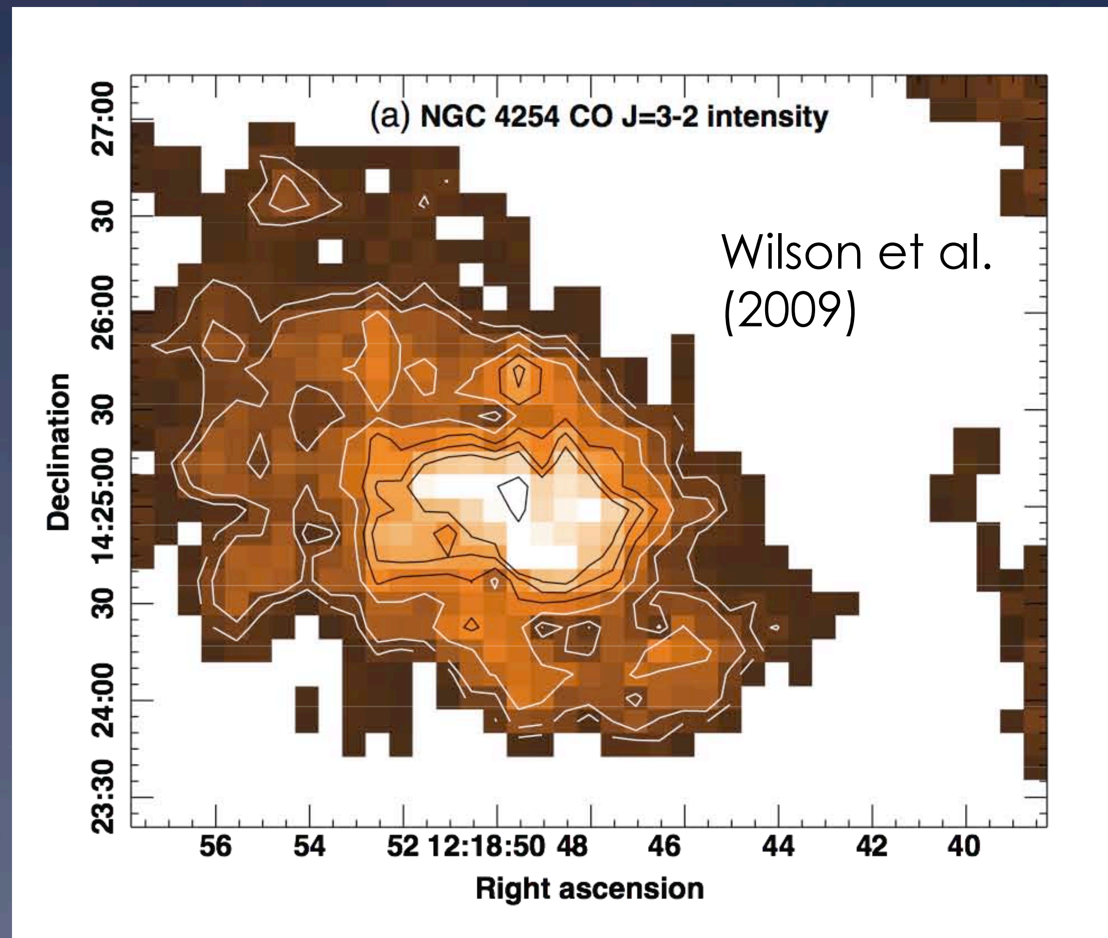


Is the relation between H_2 gas and SFR nonlinear or linear?

(Rahman, Bolatto, Wong, et al. 2010)

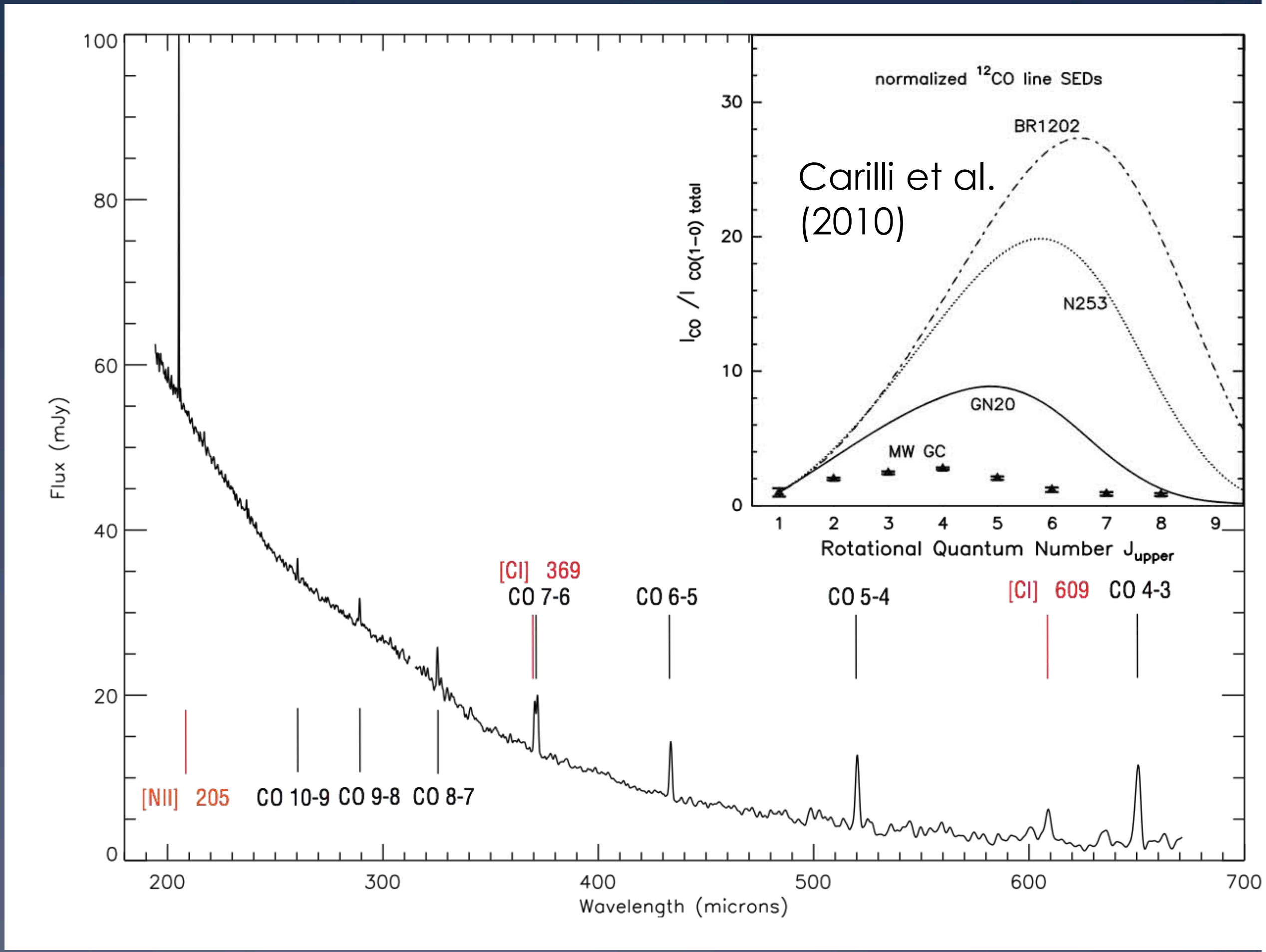
Molecular gas or dense gas?

- We know that star formation is, globally, better correlated with dense gas tracers in ULIRGs (Gao & Solomon 2004)
- In MW GMCs, star formation happens in dense cores
- Observations in nearby galaxies suggest the SFR-CO (3-2) is tighter than with CO (1-0)
- Density or temperature effect?
- Can we measure actual gas densities?



Panchromatic studies

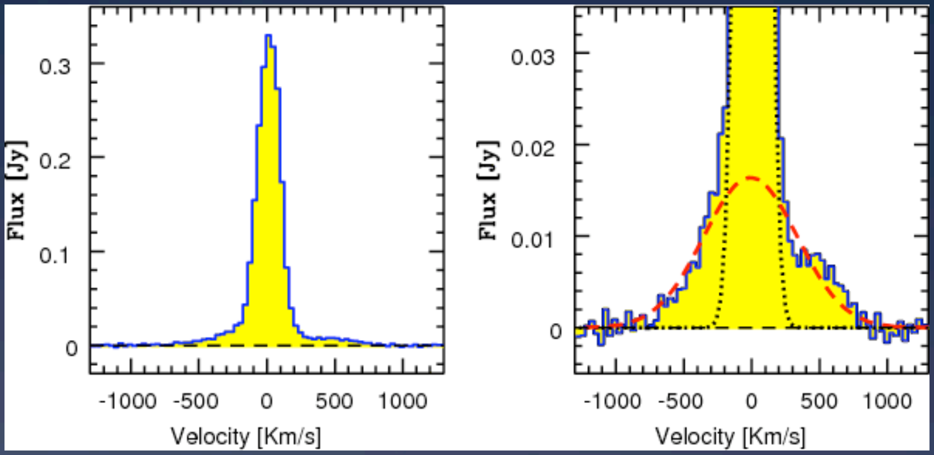
- Access to the full rotational ladder with good calibration and spatial resolution
- Density, temperature, and column density
- Access to some "optically thin" transition is key
- Energy sources in the molecular ISM (dynamical heating, cosmic rays, e.g. Bradford et al. 2003)
- Allows us to bypass the Xco crutch
- Needs to be spatially resolved
- Redshifted FIR lines like [CII], [NII], and [OI]

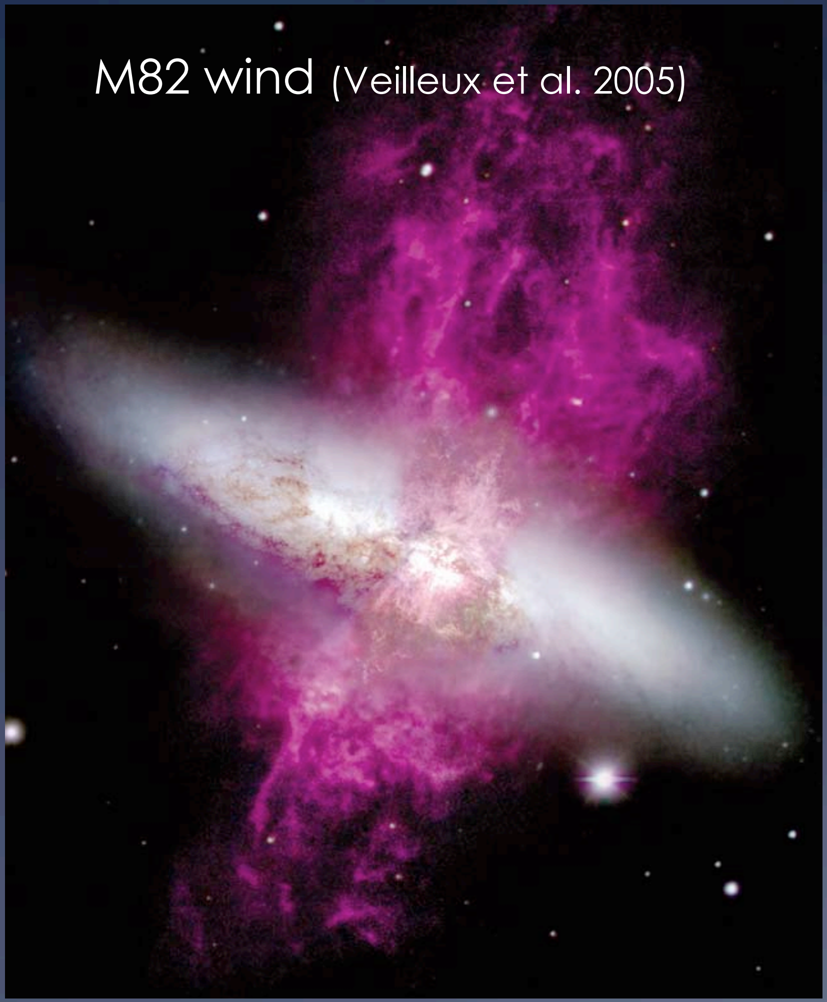


SPIRE FTS spectrum of IC342

Feedback

CO 1-0 wind in Mrk 231
(Feruglio et al. 2010)





- Pollution of the ISM, galaxy mass function fall-off at large masses, solution to overcooling problem
- There is molecular gas entrained in Galactic outflows, maybe enough to shut down SF
- Low SB material. If it is optically thin, it will be brighter in the higher J transitions

CCAT science: complementing ALMA

* Large format detector arrays
* Ultra-wide bandwidth techniques
* Low surface brightness: only a small fraction of ALMA's collecting area is in short baselines

* *Submm continuum*
  * Tracing molecular gas where CO fails
  * Submm excess: dust properties, very cold dust?
  * SFR estimates from dust modeling

* *Spectroscopy*
  * Multitransition studies, redshifted FIR transitions
  * Outer galaxy disks, dwarf galaxies, tails
  * Molecules in winds
  * Physical state of the gas
  * The "other parameters" in the Star Formation Law
  * Gas masses without Xco