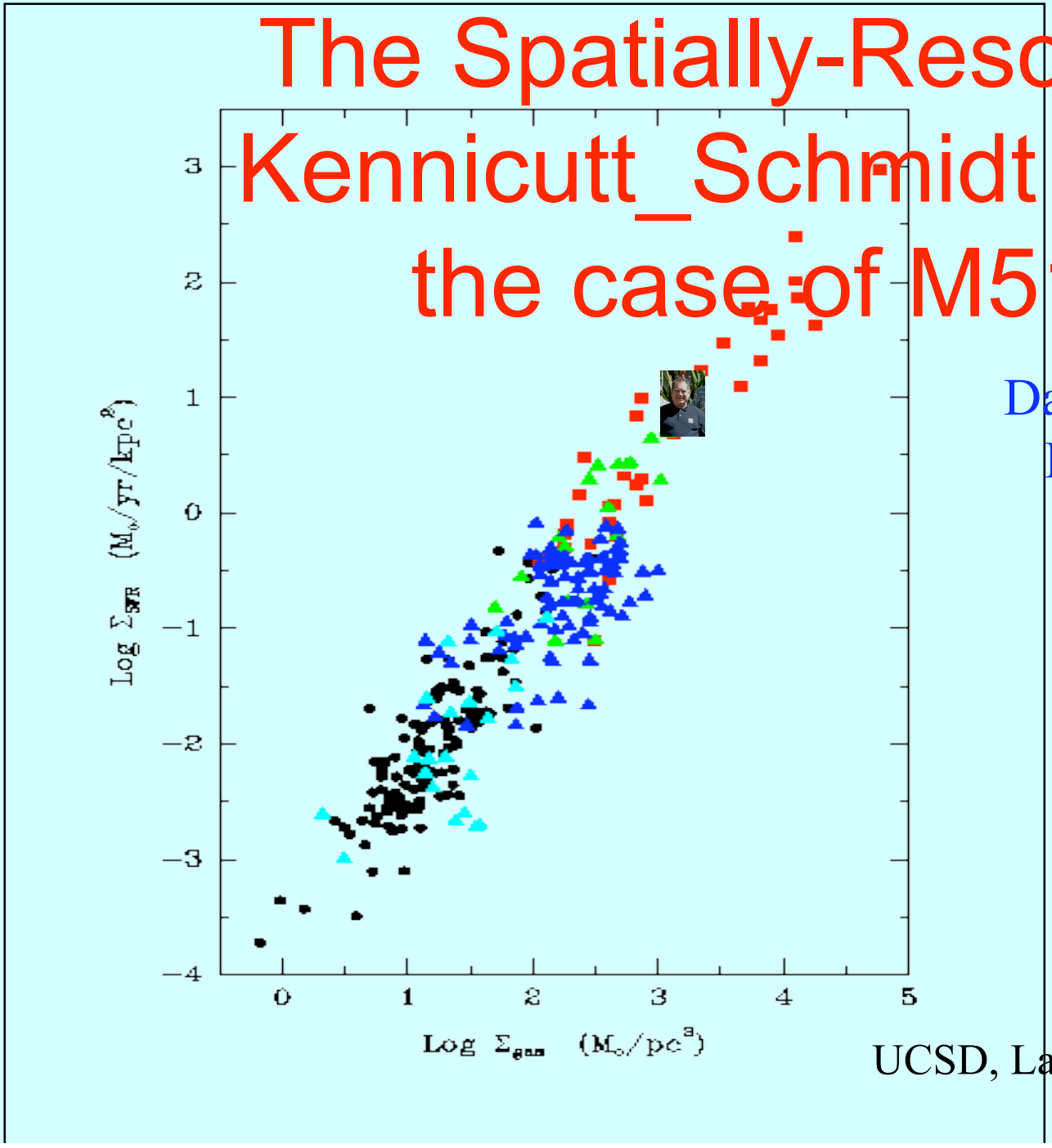
The Spatially-Resolved Kennicutt_Schmidt Law: the case of M51



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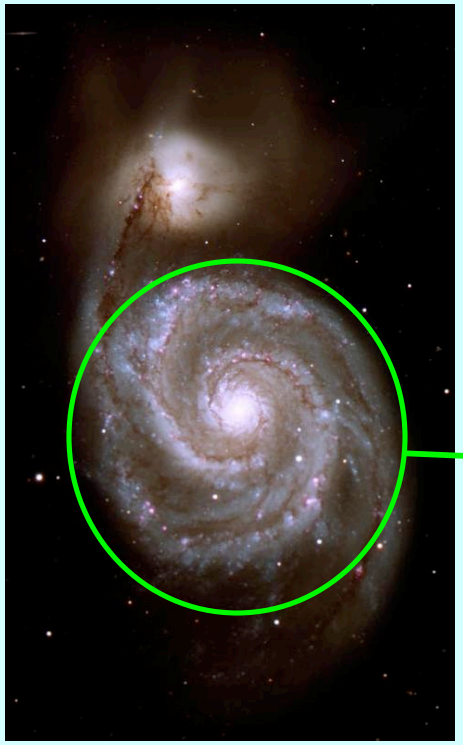
Outline

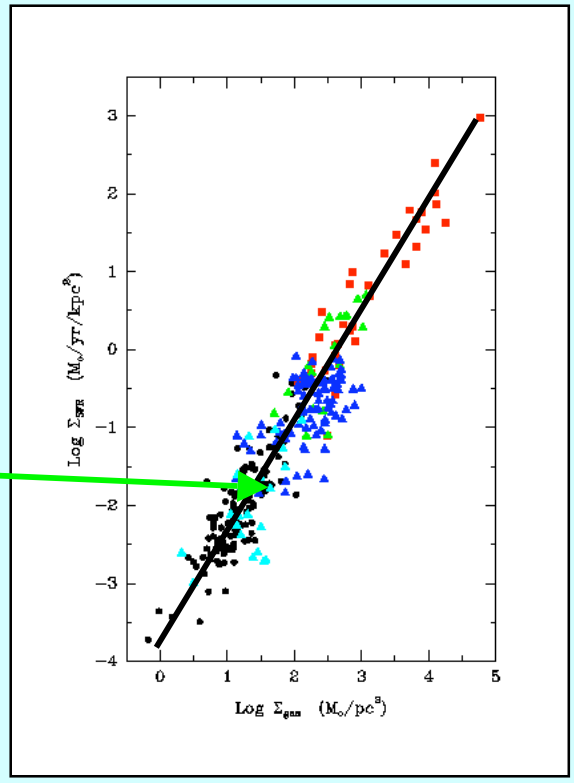
- No much Introduction needed at this point
- Why select M51?
- Results
- Future work

The Empirical Law of SF

In galaxies considered as a whole, the SFR scales with the gas surface density **(Kennicutt 1989, Kennicutt 1998, Kennicutt 2006)**:

$$\Sigma_{SFR} \sim \Sigma_{gas}^{1.4}$$





The Physics behind It…

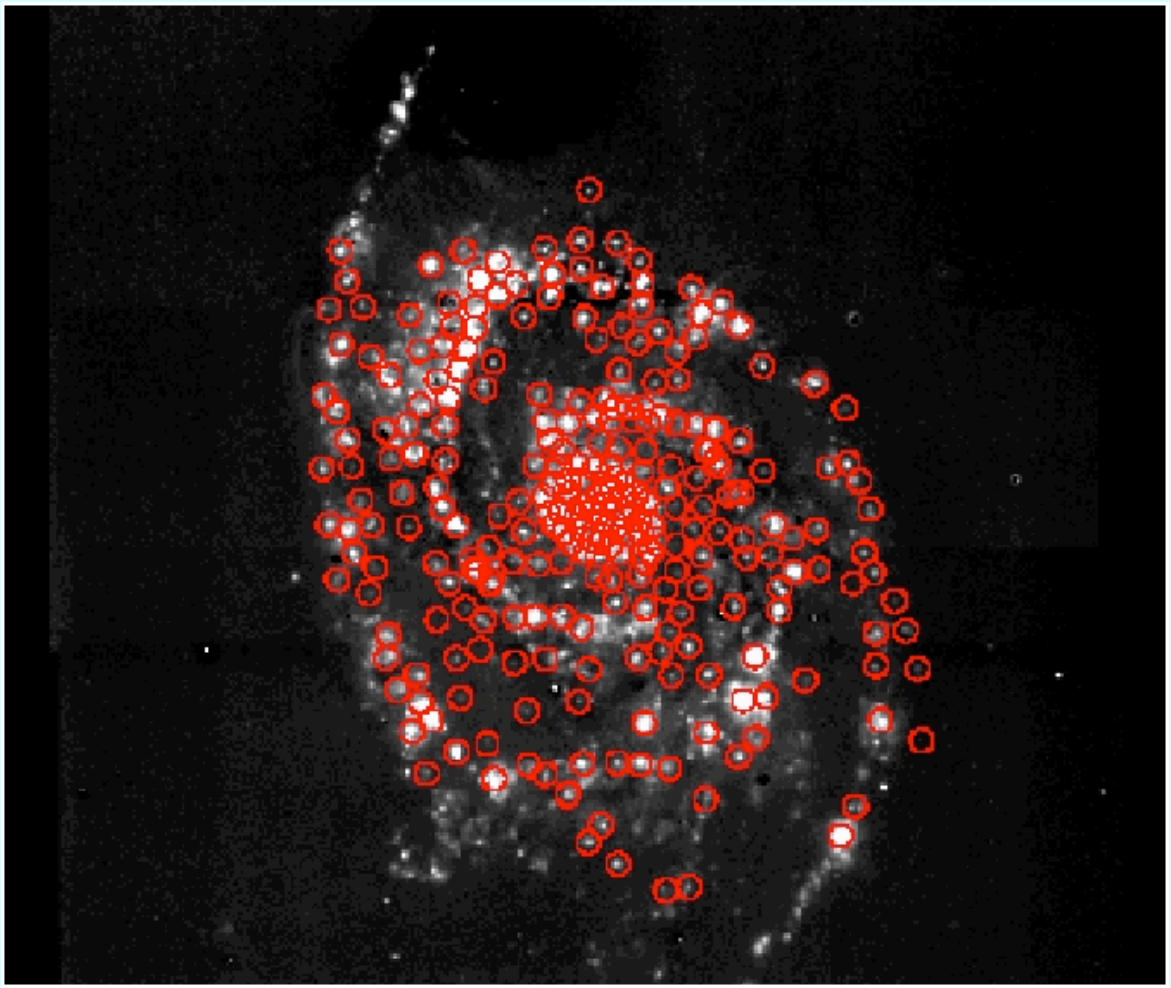
Down to what scales does the KS Law hold?
What is the underlying physical model of the KS Law?

At least two hypotheses:

1. Self-gravitational (small scale): SFR scales with perturbation growth rate in gas disk ($\rho_{SFR} \sim \rho_{gas}^{1.5}$) (Quirk 1972, Larson 1988, 1992)
2. Kinematic (large scale): the relation between SFR density and gas density is mediated by the dynamical (orbital) timescale ($\rho_{SFR} \sim \rho_{gas}\Omega_r f(Q)$ (Wyse & Silk 1989, Silk 1997, Elmegreen 1997))

As multiple models can fit whole galaxies, analysis of local characteristics is needed to progress in our understanding of how star formation is regulated in galaxies

Going Local….



Analyze individual regions in a galaxy, rather than multiple galaxies.

Needed ingredients:

1. Reliable gas density estimates (HI, H2 (CO))
2. Reliable SFR density estimates

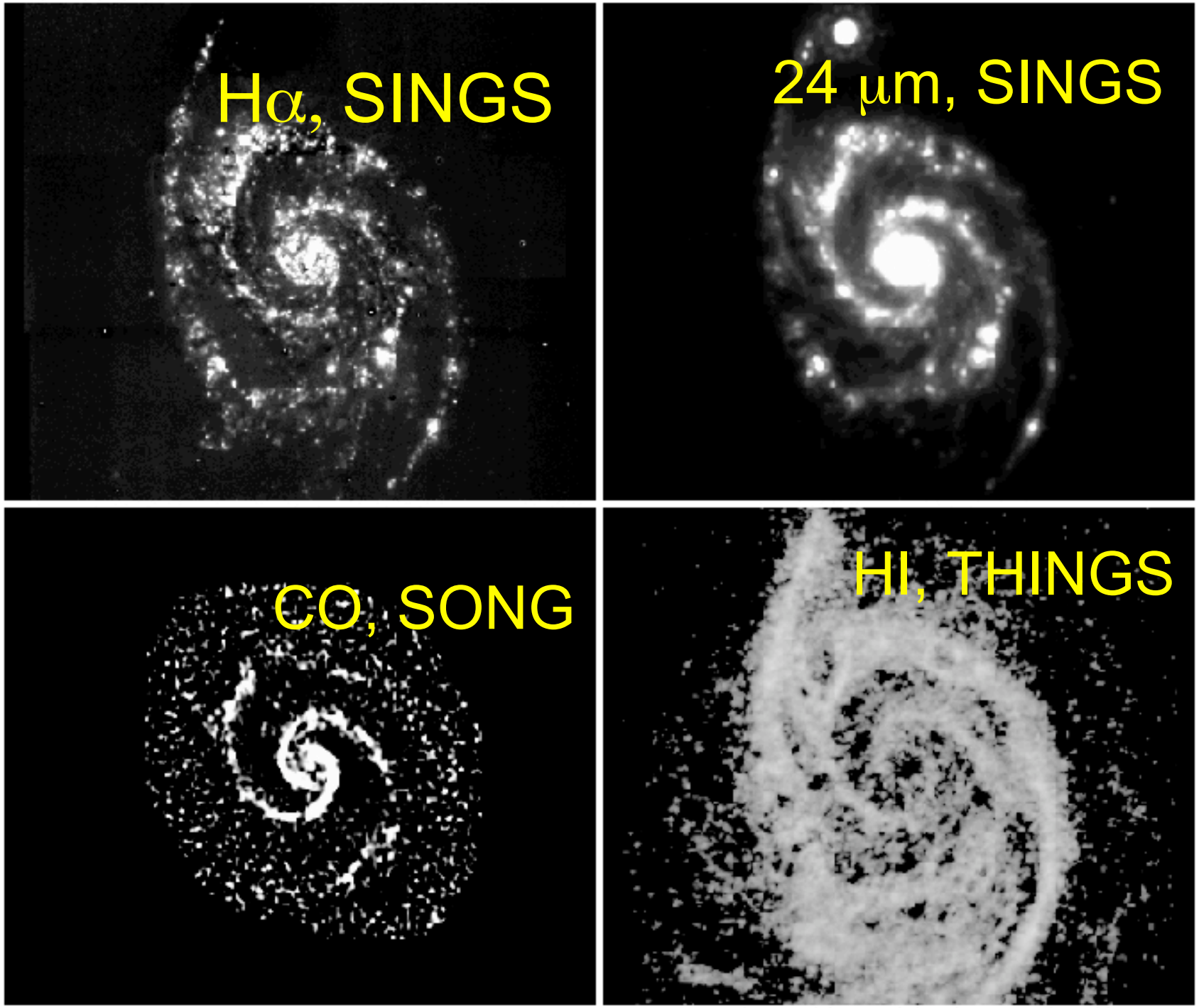
Kennicutt, Calzetti, Walter, et al. in prep.

Why M51?

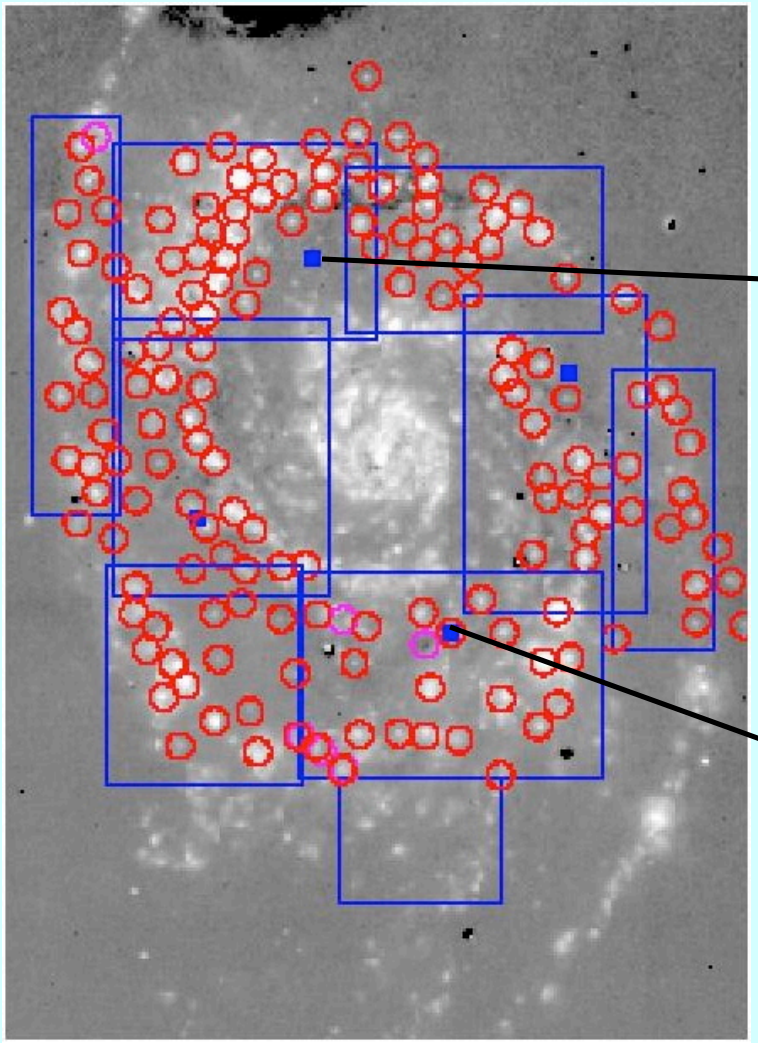
D=8.2 Mpc, almost face-on
small/neglig. metal radial dependence (constant CO/H_2).

M51 has all the ingredients:

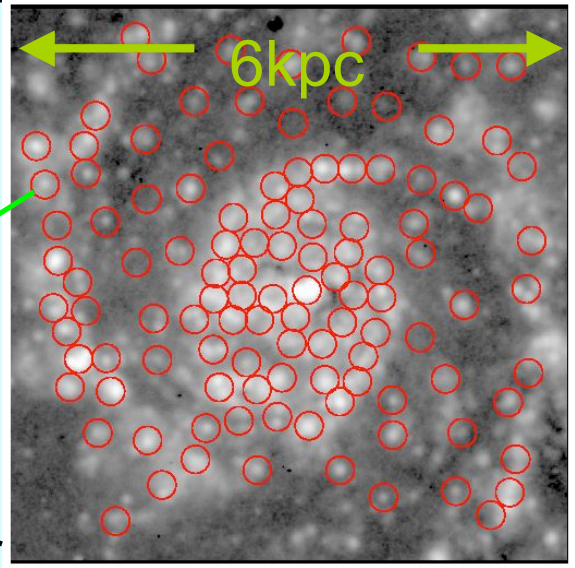
1. High-resolution HI (~6” Walter et al.); high-resolution CO (~6”, BIMA-SONG)
2. Hα; Spitzer (IRAC, MIPS from SINGS), and Pα (inner 6 kpc, Scoville et al. 2001)
3. Nearby: 6”=240 pc ~ HII complexes


Hα, SINGS
24 μm, SINGS
CO, SONG
HI, THINGS

Measuring SFRs



Pα, our `unbiased' SFR indicator, available only within inner ~6 kpc



~ 500 pc

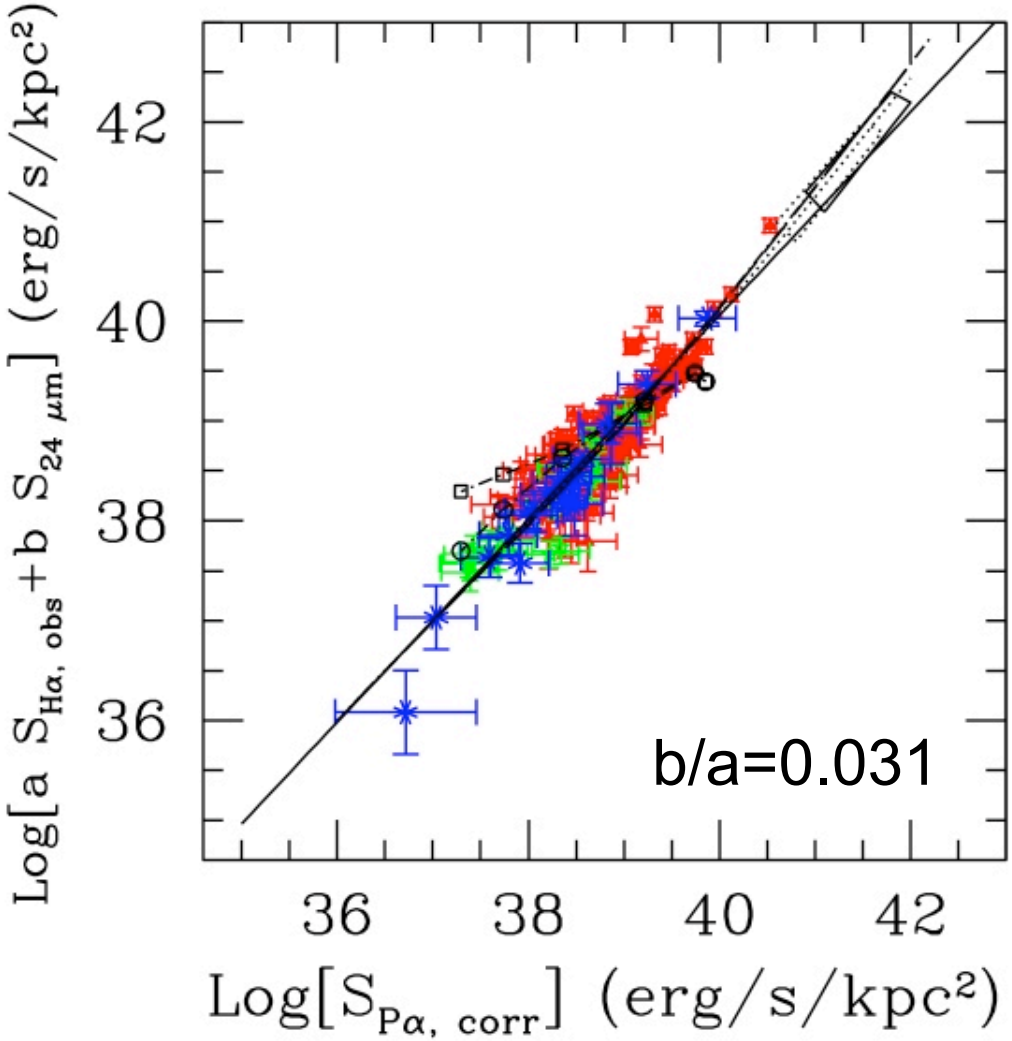
Need to use an additional SFR indicator

A Robust Measure of SFR

Exploit the availability of both optical and IR (MIPS24) data

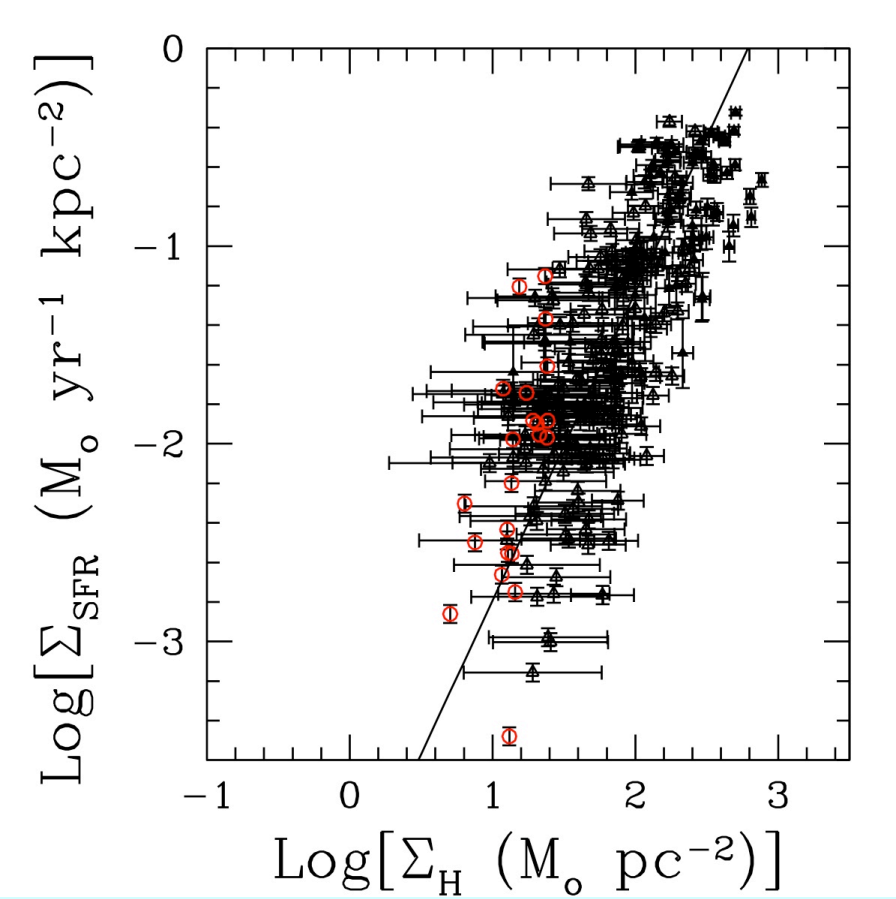
$L(H\alpha)$ = unobscured SF
$L(24\mu m)$ = obscured SF
$L(Pa\alpha)_{corr}$ = `unbiased' SFR indicator

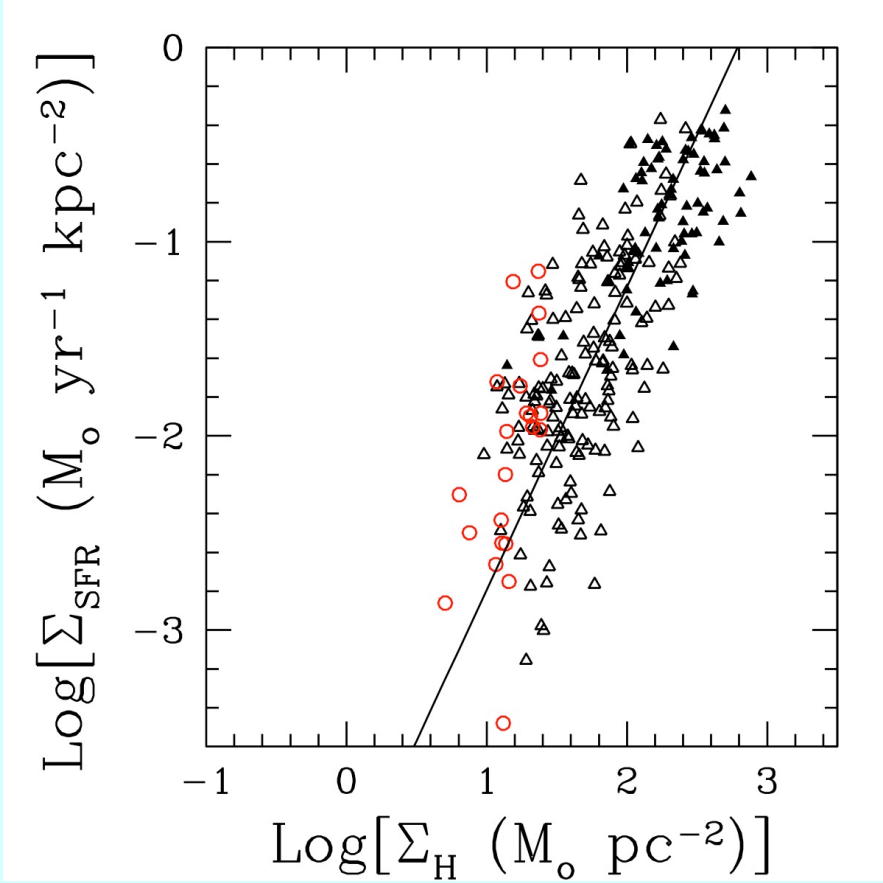
Used 220 HII knots in 33 SINGS galaxies



Kennicutt et al. 2007
Calzetti et al. 2007

Local KS Law

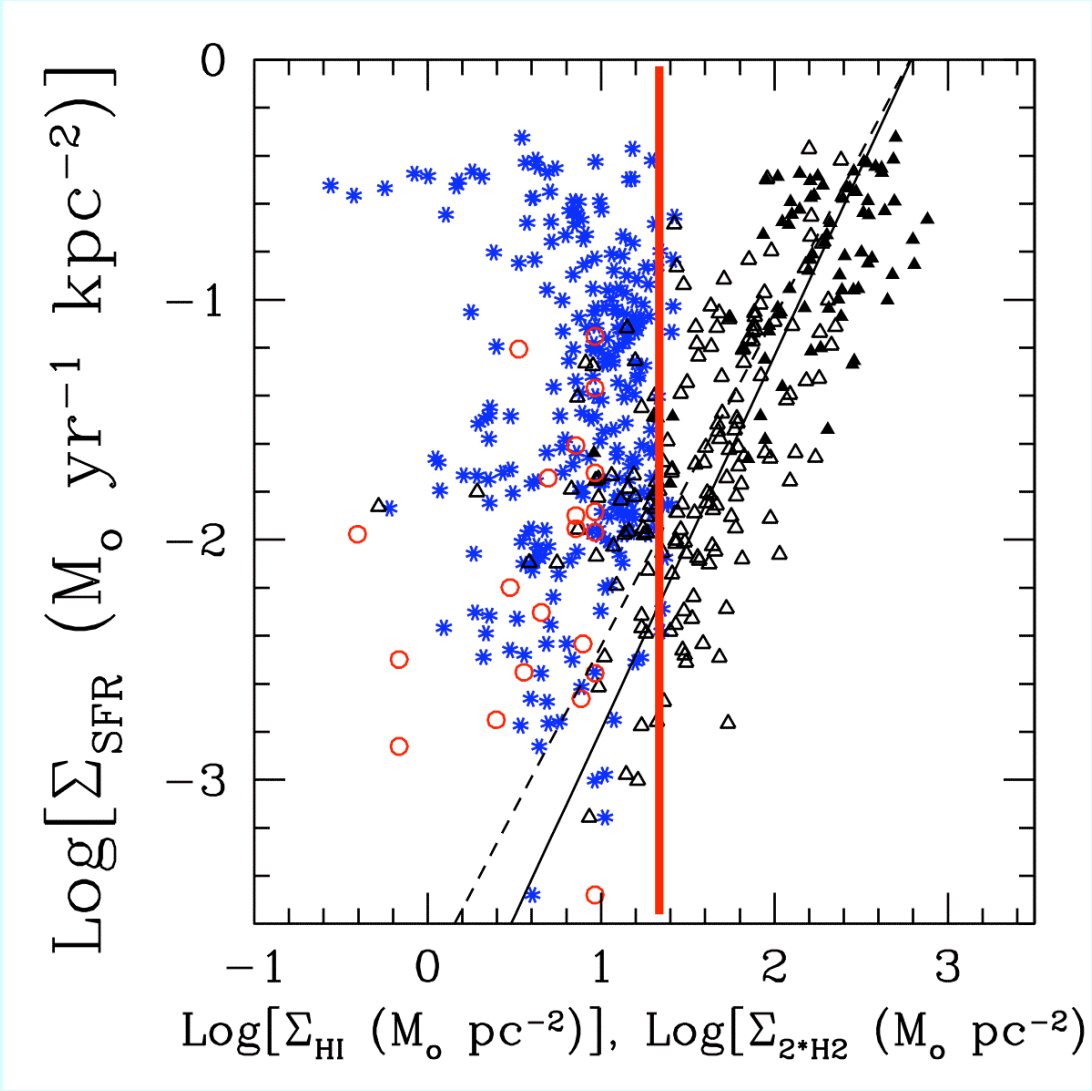




258 regions in M51

Best fit slope = 1.56

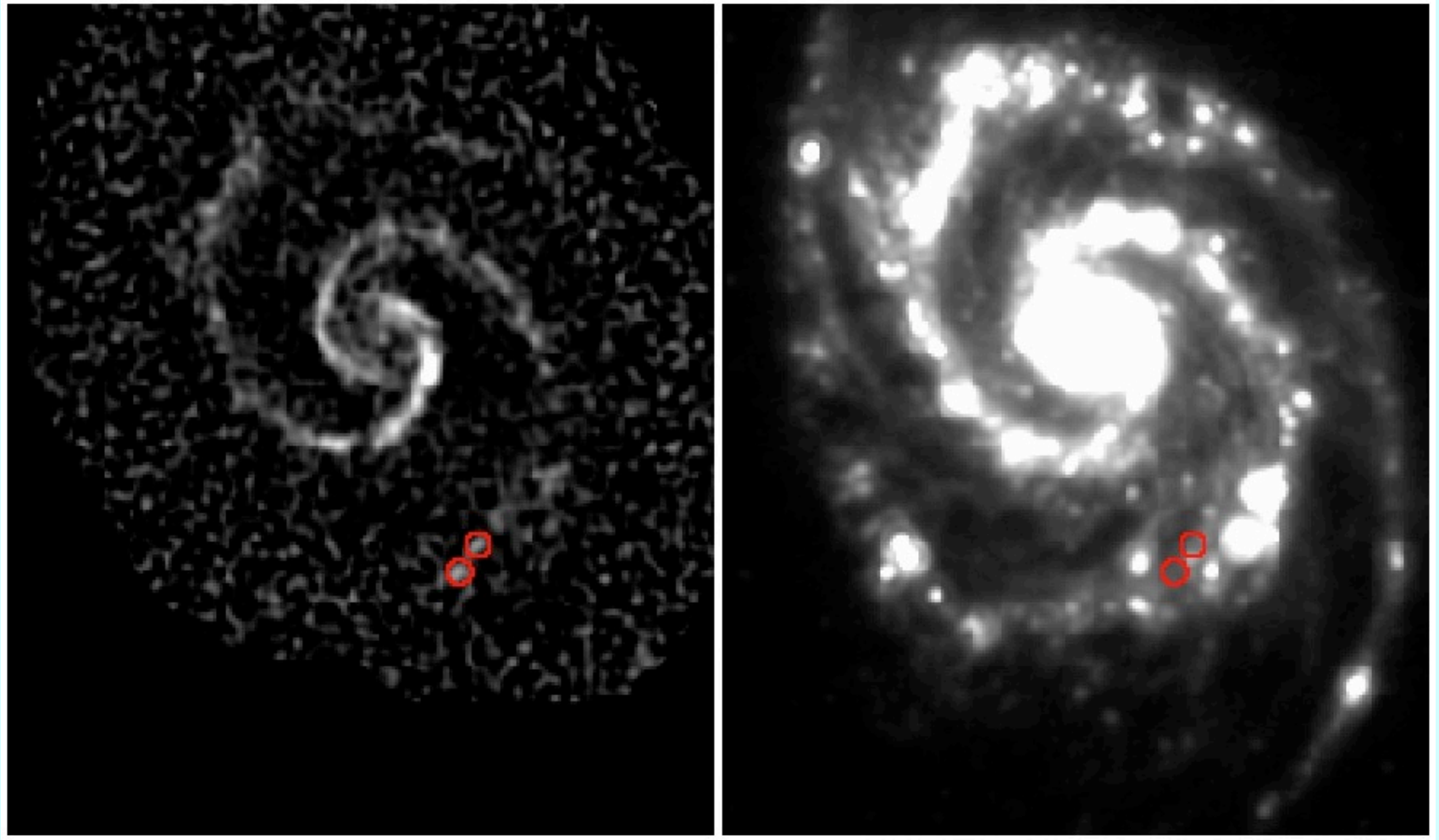
HI versus H_2



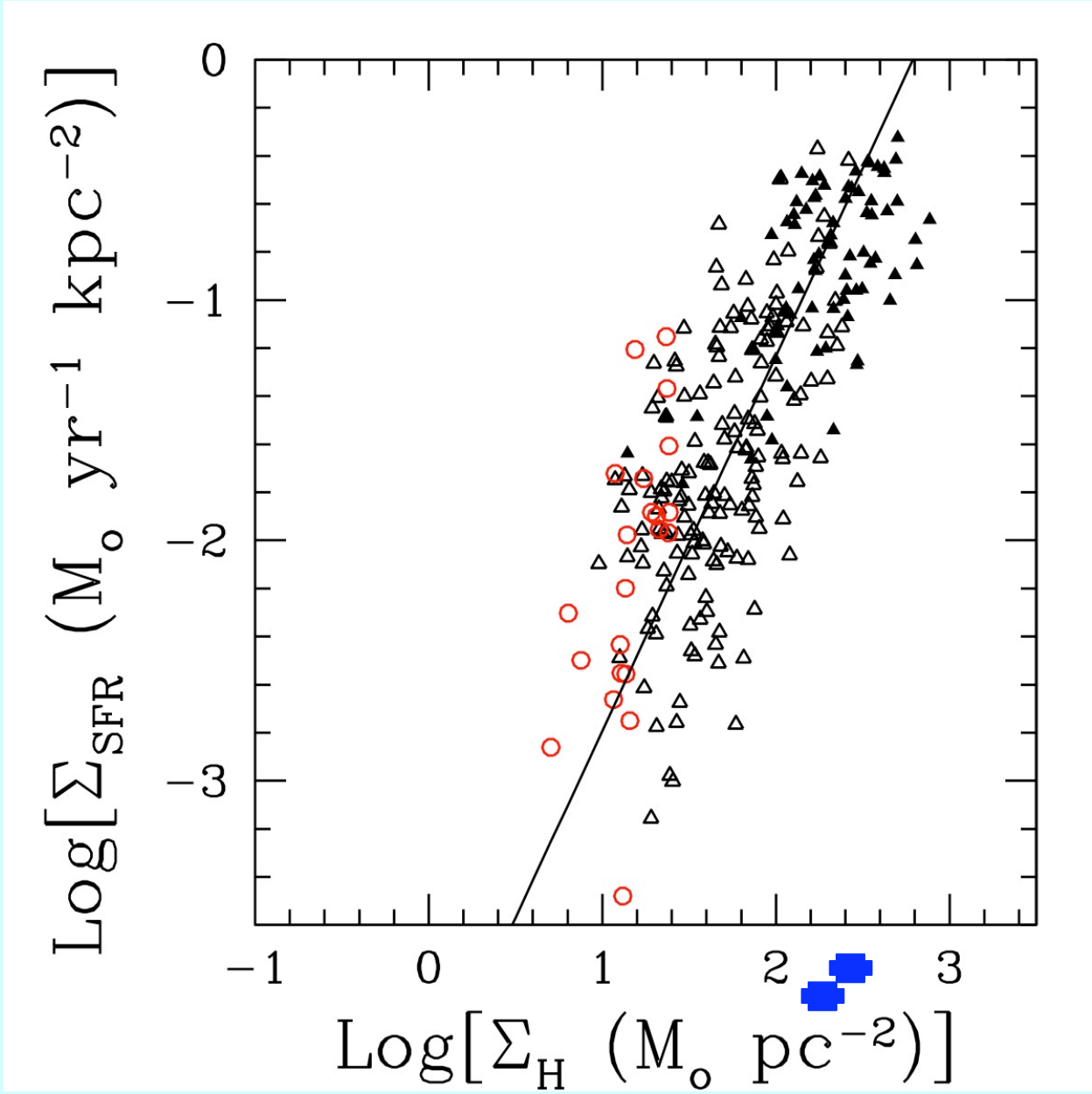
SFR correlates with H_2, but not with HI in M51

`Upper limit' to HI density

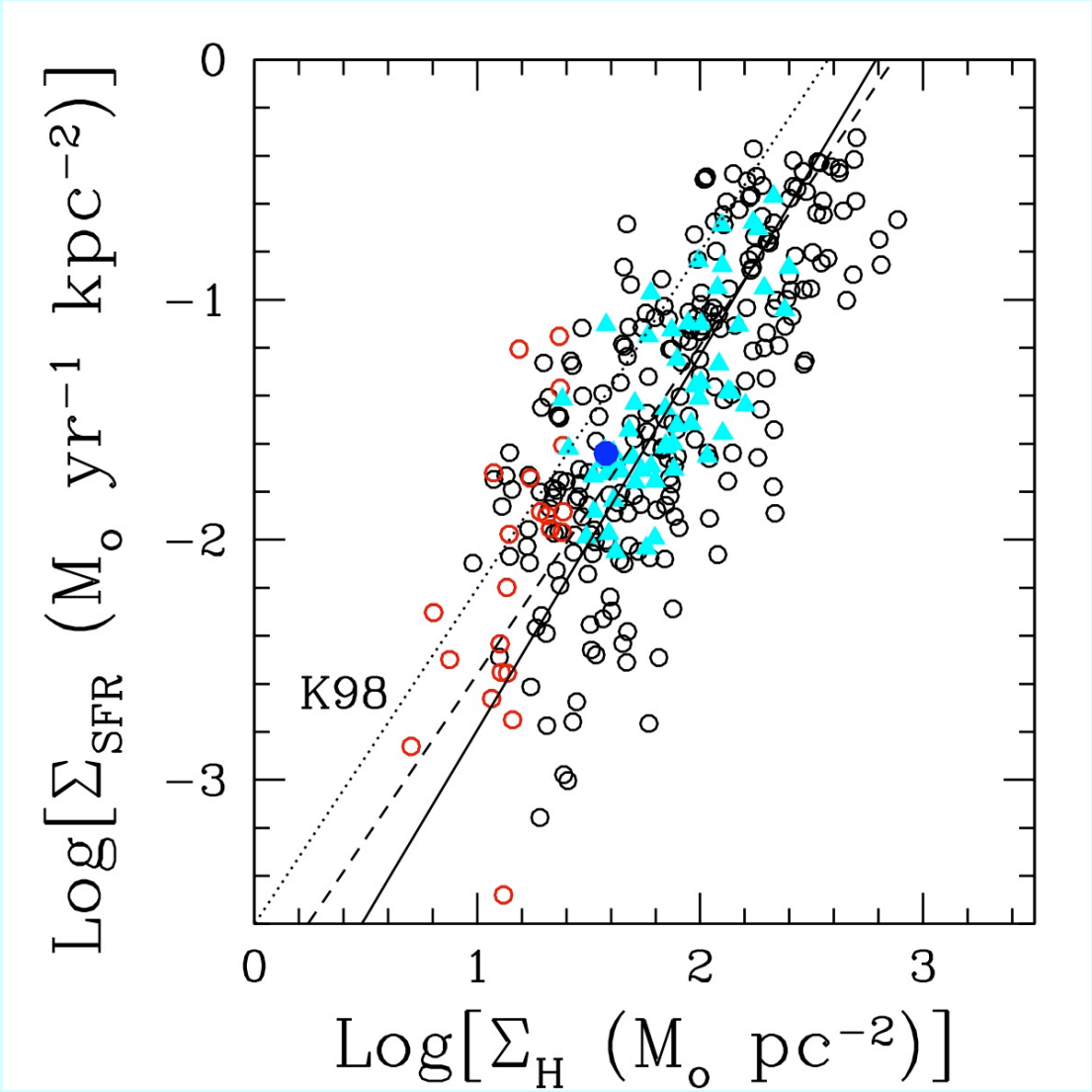
Gas with no SFR…



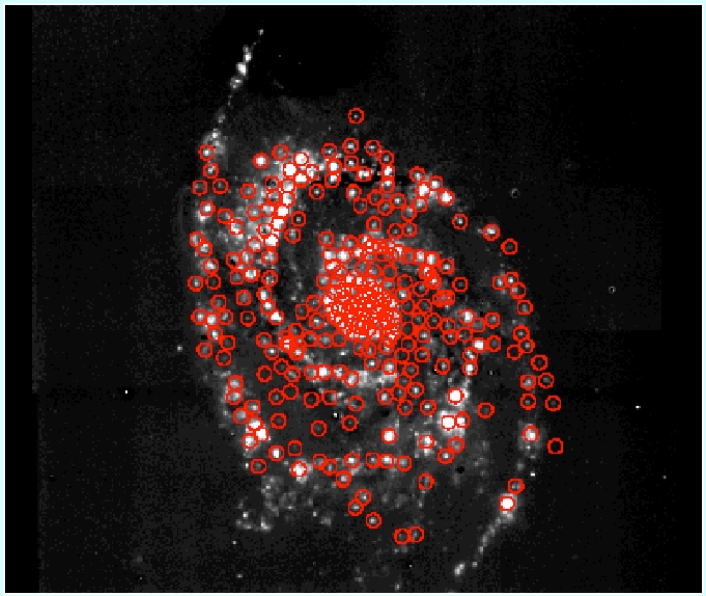
Identified at least two regions with gas, but only upper limits on SFR


0
−1
−2
−3
−1
0
1
2
3
Log[Σ_SFR (M_o yr^−1 kpc^−2)]
Log[Σ_H (M_o pc^−2)]

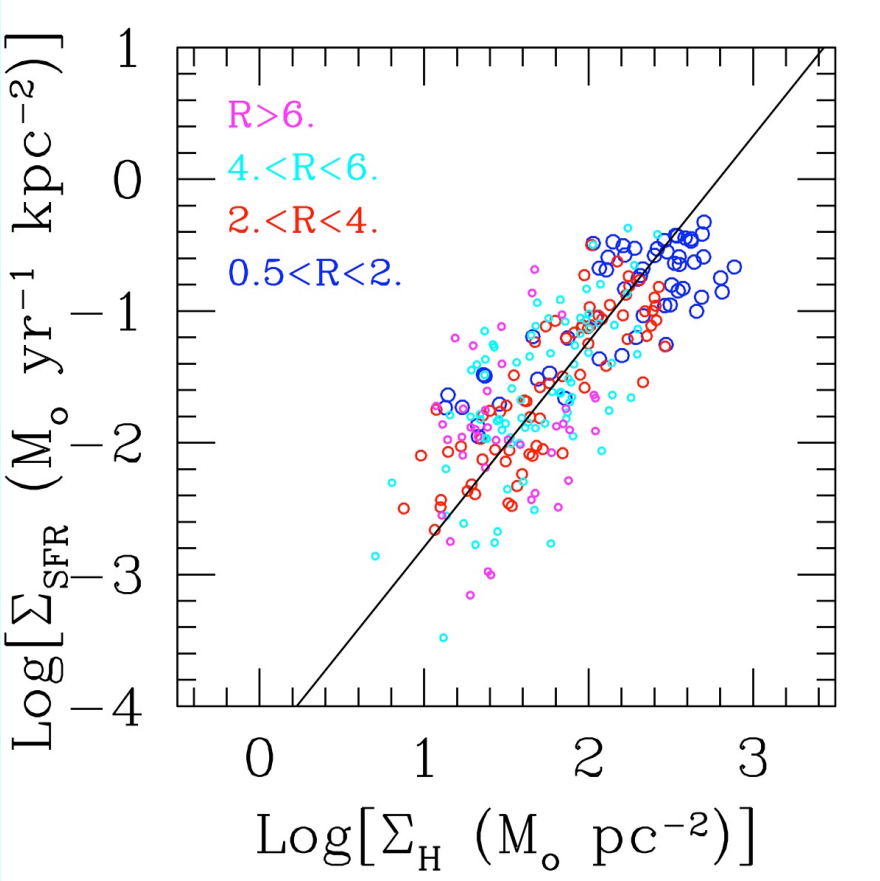
Local versus Global

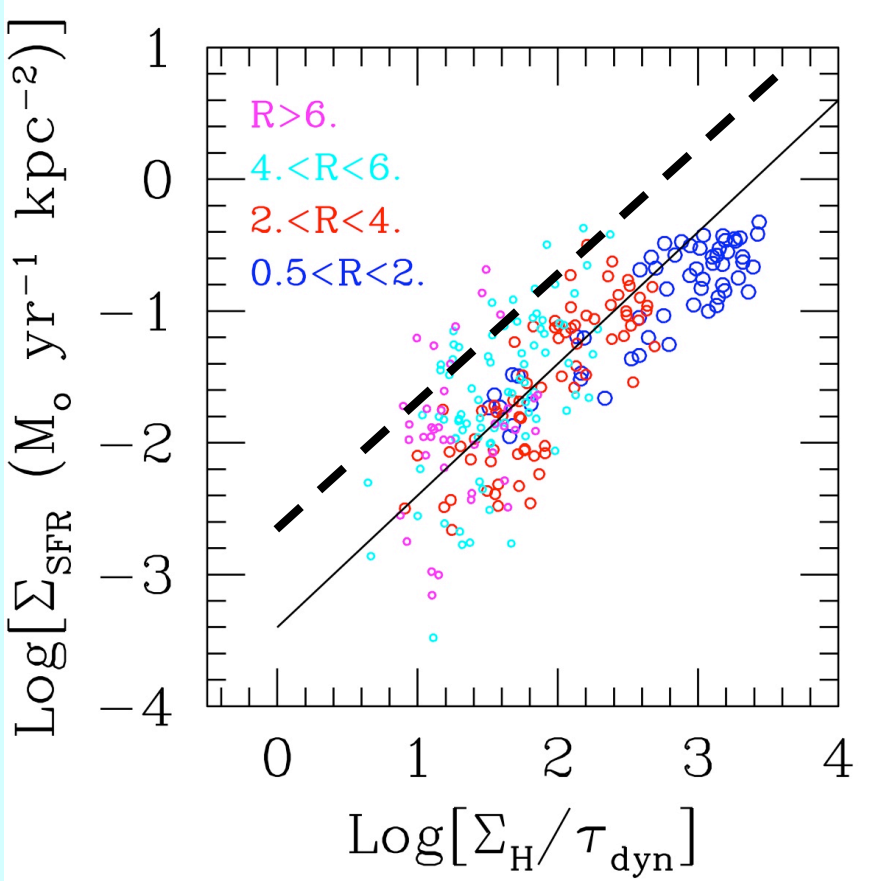


The shift between the `local'and `global' Laws is an effect of the averaging process across the galaxy's disk



Comparing Models





$\tau \sim 1/\Omega_r$

The gas density divided by the orbital time does not appear to produce a linear relationship, and is ~0.7 dex offset from the global Law.

Conclusions

- KS Law holds down to small scales, 500 pc (tentatively tested down to 300 pc, ~ the size of HII complexes), with a slope ~1.5
- The KS Law is due to H_2 in M51 (HI does not show a correlation with the SFR)
- Consistent with Global KS Law, once differences in the averaging procedures are included
- The weighting of the gas density by the orbital timescale produces a relation that is non-linear (in log-log scale) with the SFR density, and is more markedly offset from the global KS law.
- Near Future: About 15 SINGS galaxies covering a range of types and gas disk properties, have CO, HI, Ha, and 24 mm data, and will be analyzed.