Metallicity and Star Formation: The Resolved Schmidt Law in the Magellanic Clouds

(and throughout the blue sequence)

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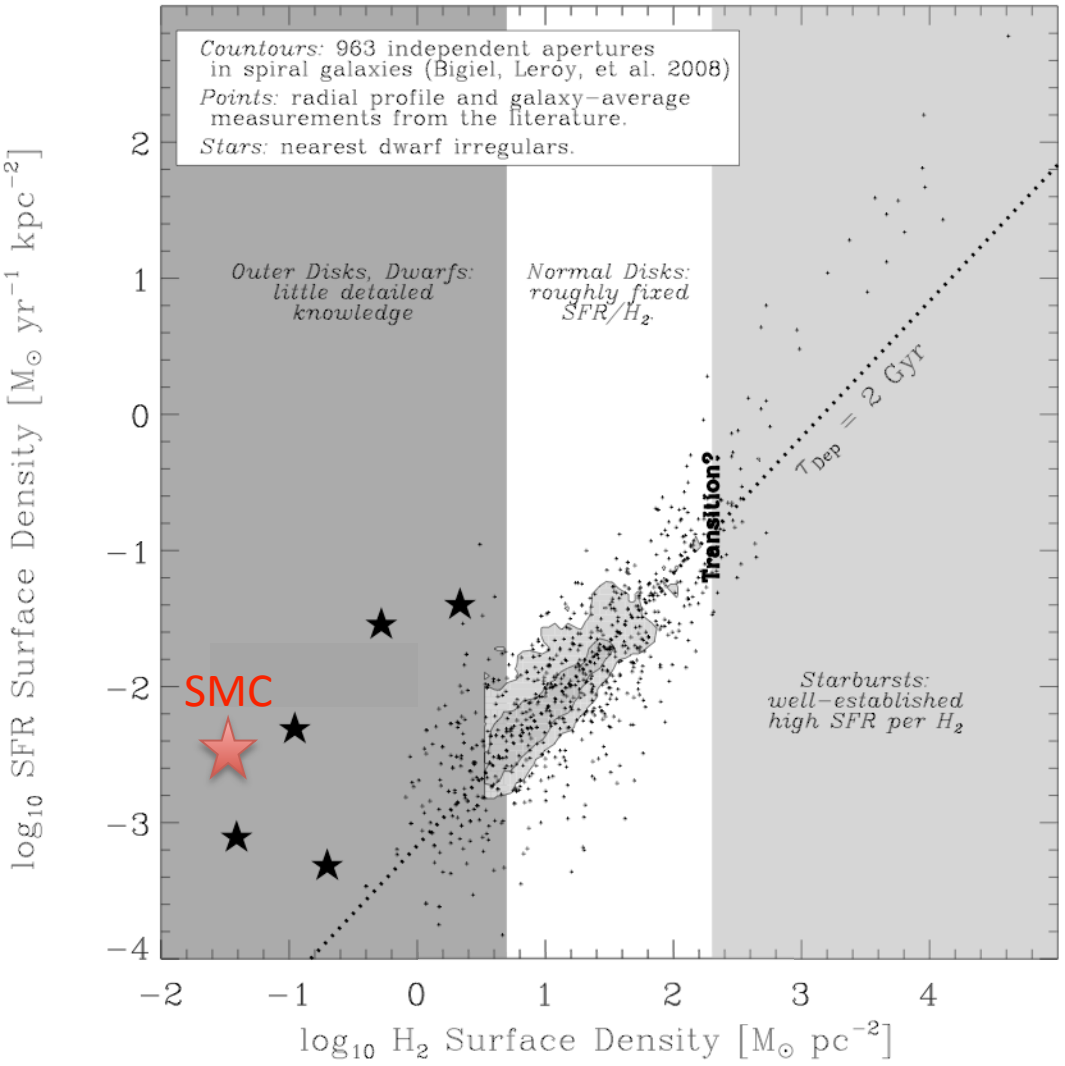
Background: low metallicity and the SF law

- *Low metallicity local dwarf galaxies and outer galaxy disks are some of the most discrepant objects when placed on the **molecular** star formation law (c.f., RCK's talk)*

- *I will argue that this is mostly a result of imperfect estimates of H_2 surface densities*



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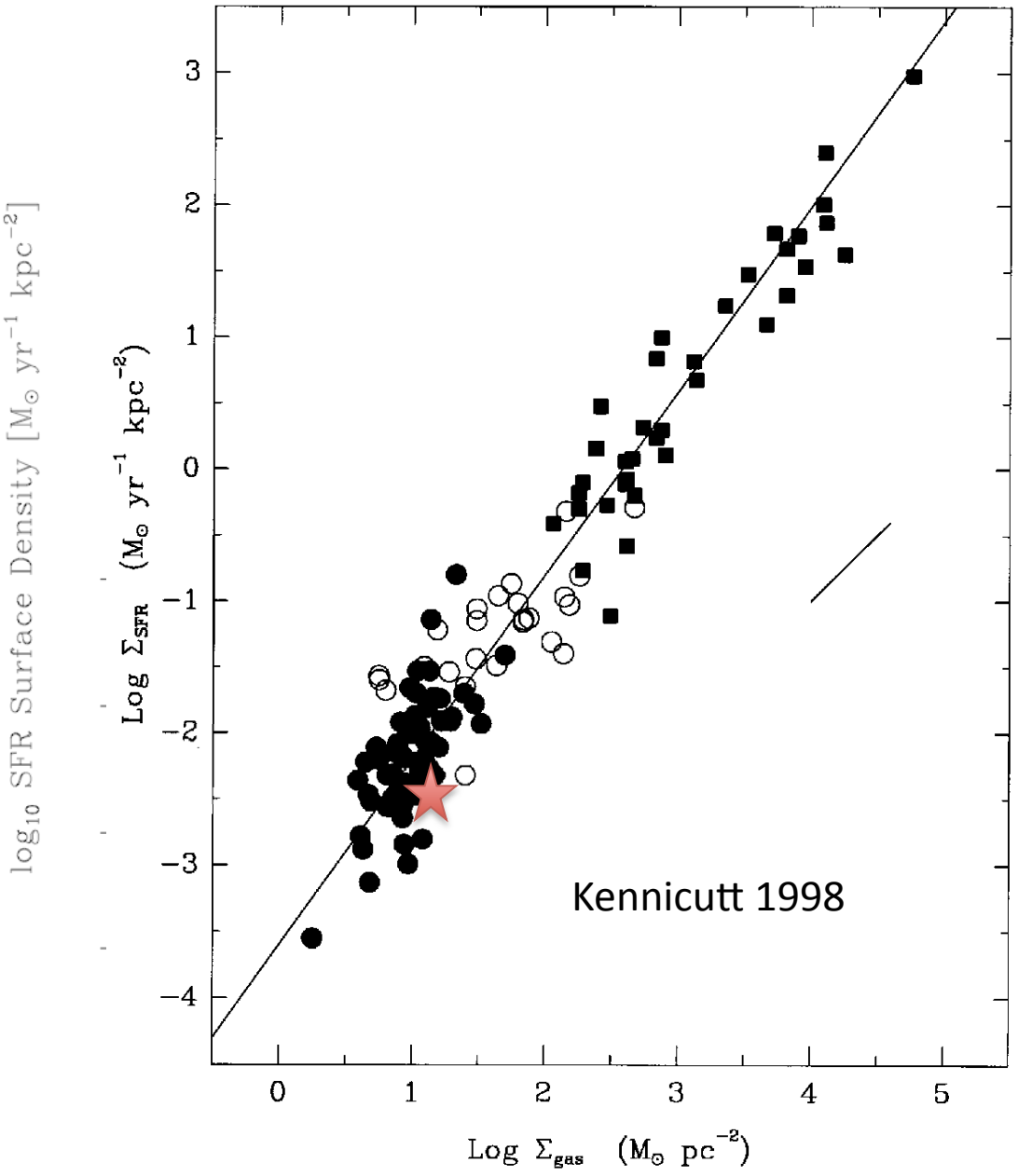
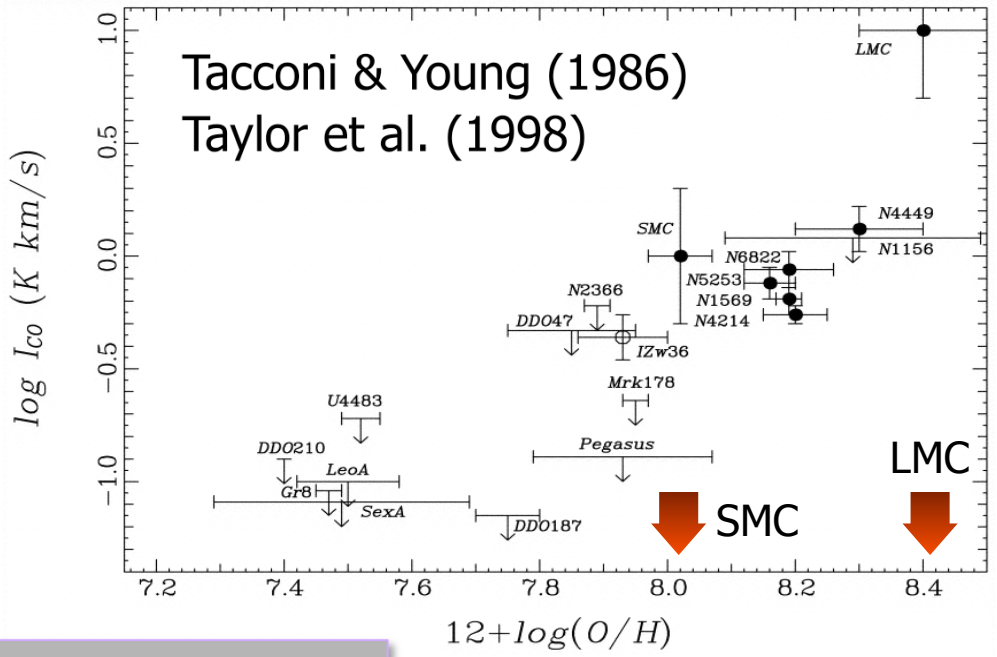
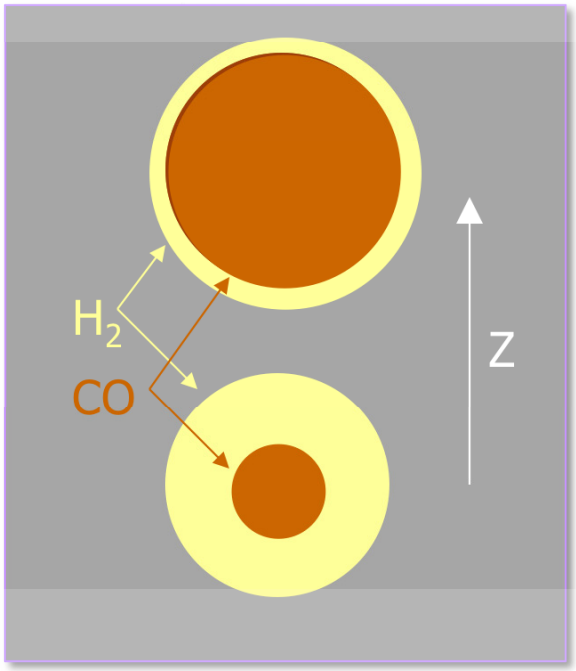


Background: CO is a flawed tracer of molecular gas

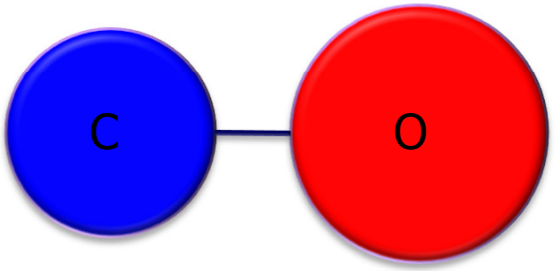
- *Surveys show that HI-rich dwarfs are faint in CO*
- *Despite strong (mass-normalized) star formation activity, no galaxies with Z< 1/5 $Z_\odot$ have been detected*
- *Usually attributed to enhanced photo-dissociation of CO, due to diminishing dust UV shielding*

Maloney & Black (1988); Lequeux et al. (1994); Bolatto et al. (1999); Röllig et al. (2006)





Ground quadrupole transition energy ~ 500 K



Background: a different way to trace H_2

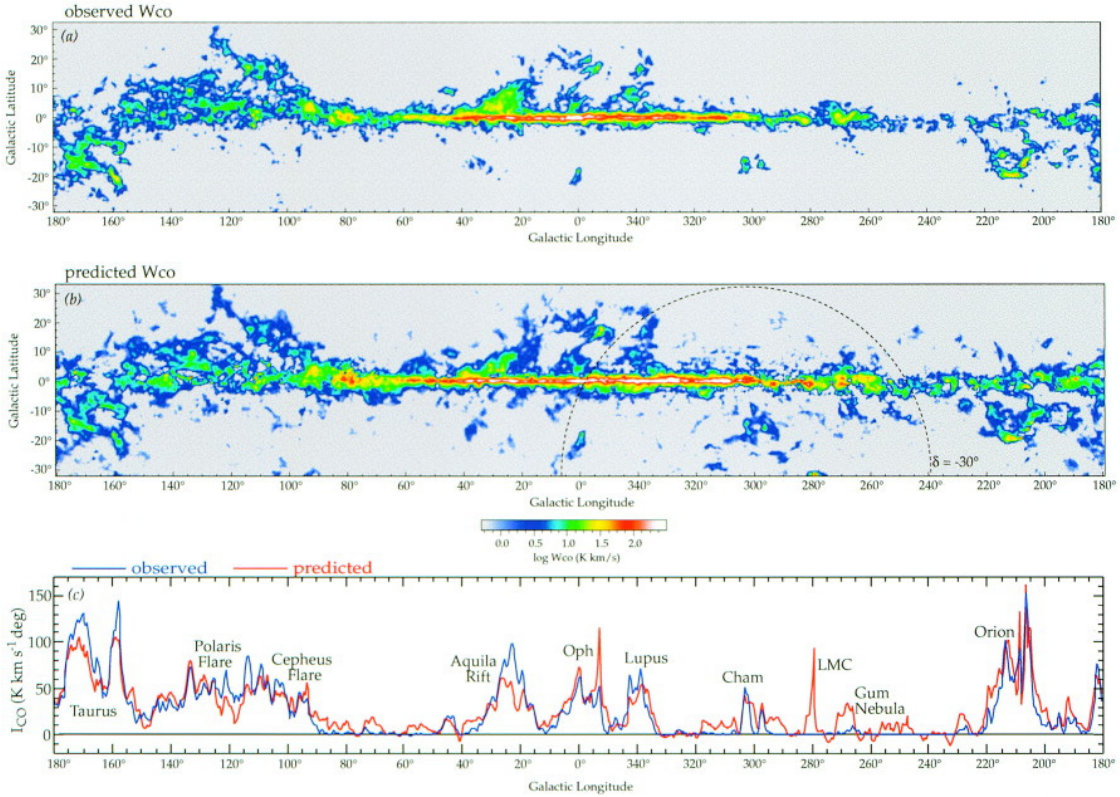
CO is expected to be biased at low metallicities . FIR dust emission offers another view.

Traces the total gas (HI + H_2) column.

Probably better, at least 'differently biased.'

In the Galaxy, matches Gamma Ray and CO results very well (Dame, Hartmann, & Thaddeus 2001).

In the SMC, IRAS suggests much more H_2 than seen from CO (Israel 1997)



Method:

$$\Sigma_{H2} = (\Sigma_{dust} \times DGR^{-1}) - \Sigma_{HI}$$

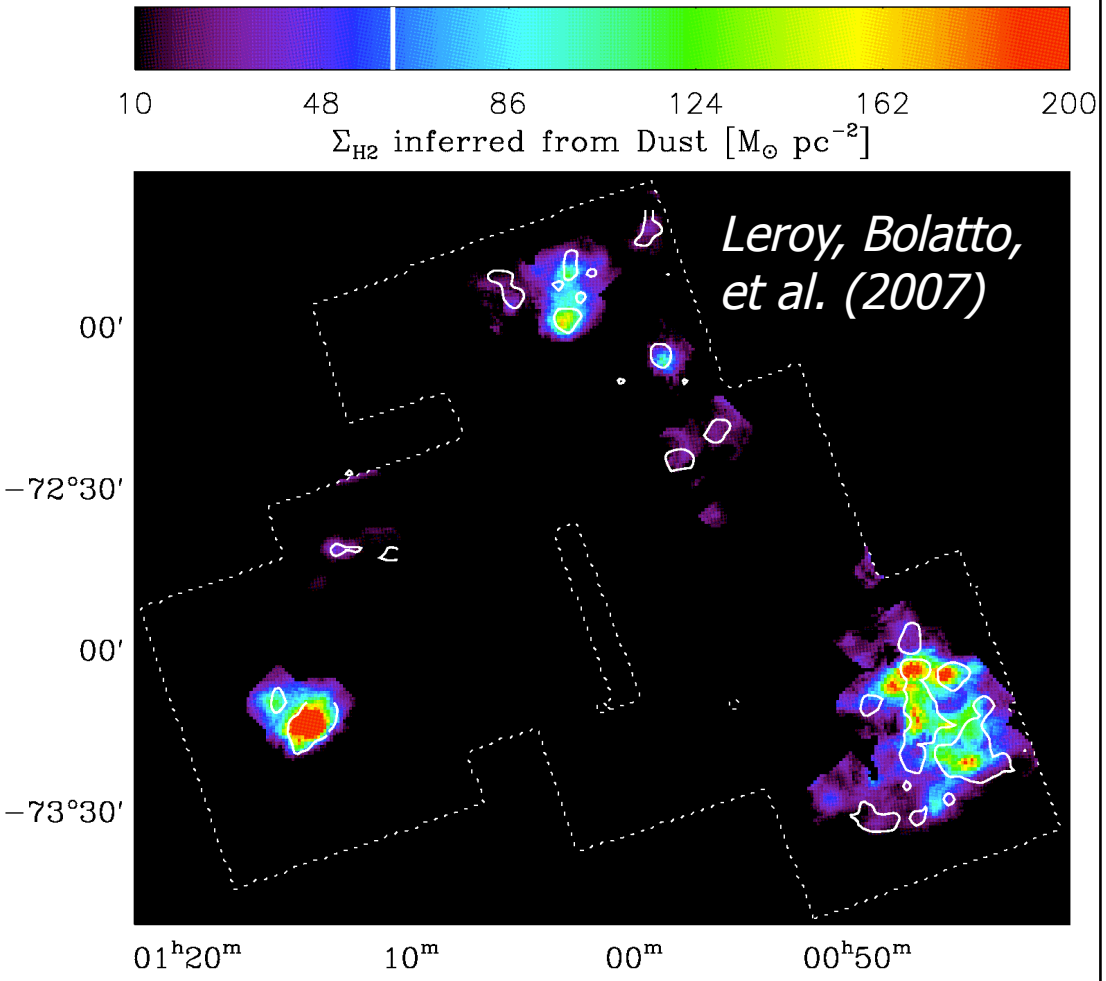
*Estimate the **dust surface density** from τ using FIR emission (need two bands to make a temperature estimate).*

*Measure the **dust-to-gas ratio** from the ratio of dust to atomic gas away from the molecular line emission but near enough to calibrate out galactic variations.*

*Straightforward to determine from **21 cm** observations, modulo optical depth effects (estimates exist for the Magellanic Clouds).*

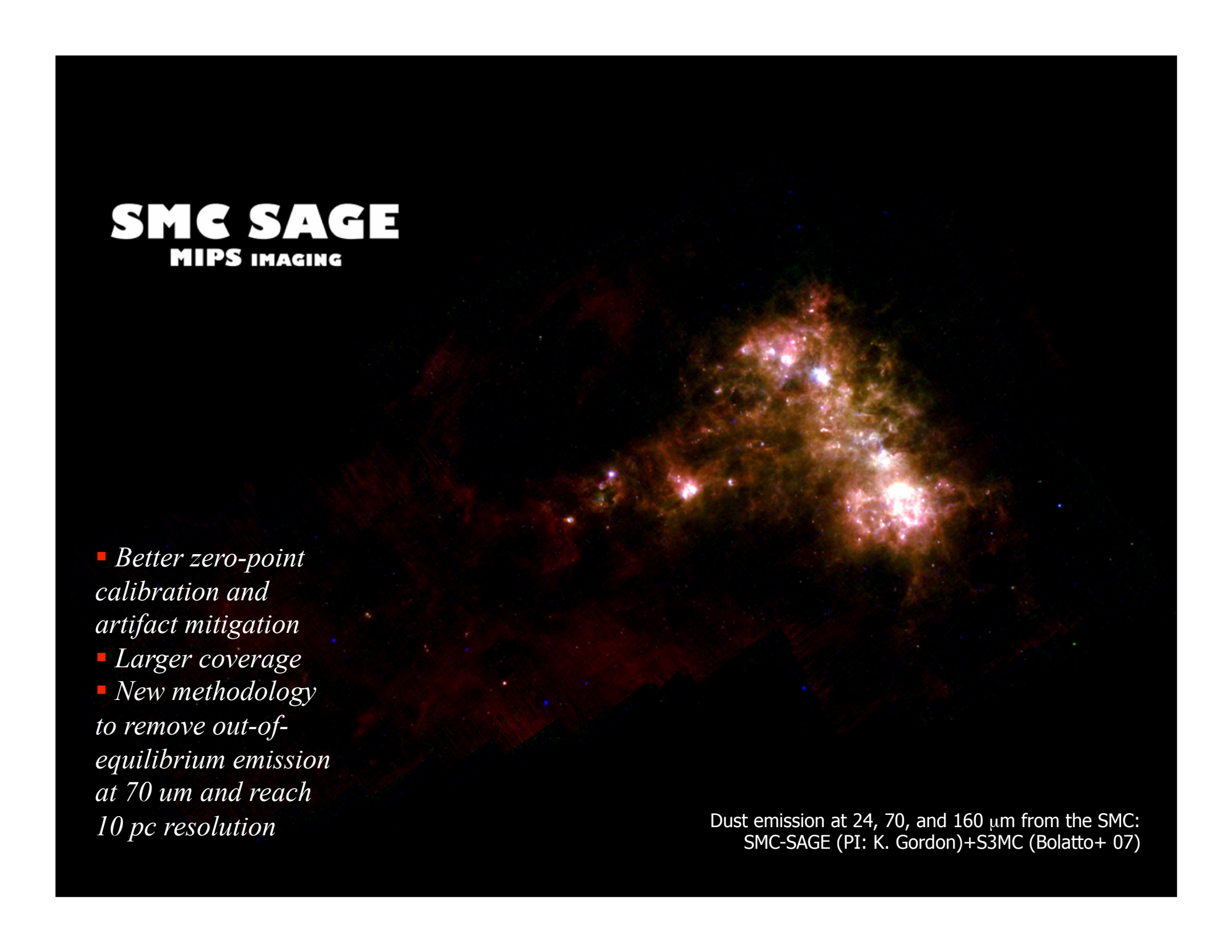
Background: Results from 2007 analysis using S^{3}MC

- *Using 100 and 160 um to avoid influence of stochastic heating. Limited to ~4' (80 pc) by IRAS.*
- *Using Dale & Helou (2000) models to account for multiple temperature comps.*
- *DGR determined locally.*
- ***Conclusions**: Large Xco correction (30-60 times Galactic). M_{H2}~3x10^7 M_{sun} total molecular mass, compared to M_{HI}~2x10^8 M_{sun}. Similar pressure relation as large spirals.*



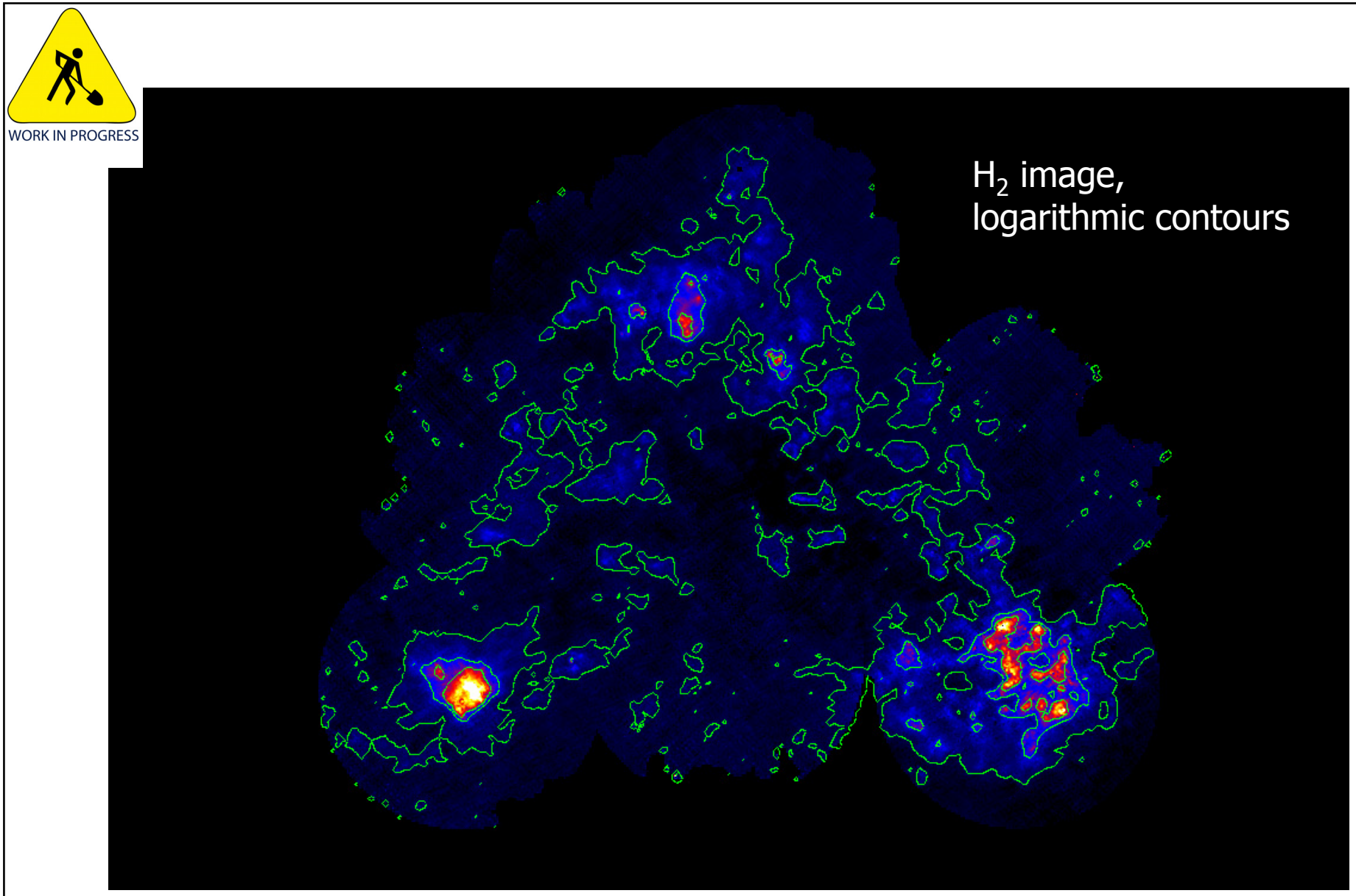
SMC SAGE

MIPS IMAGING

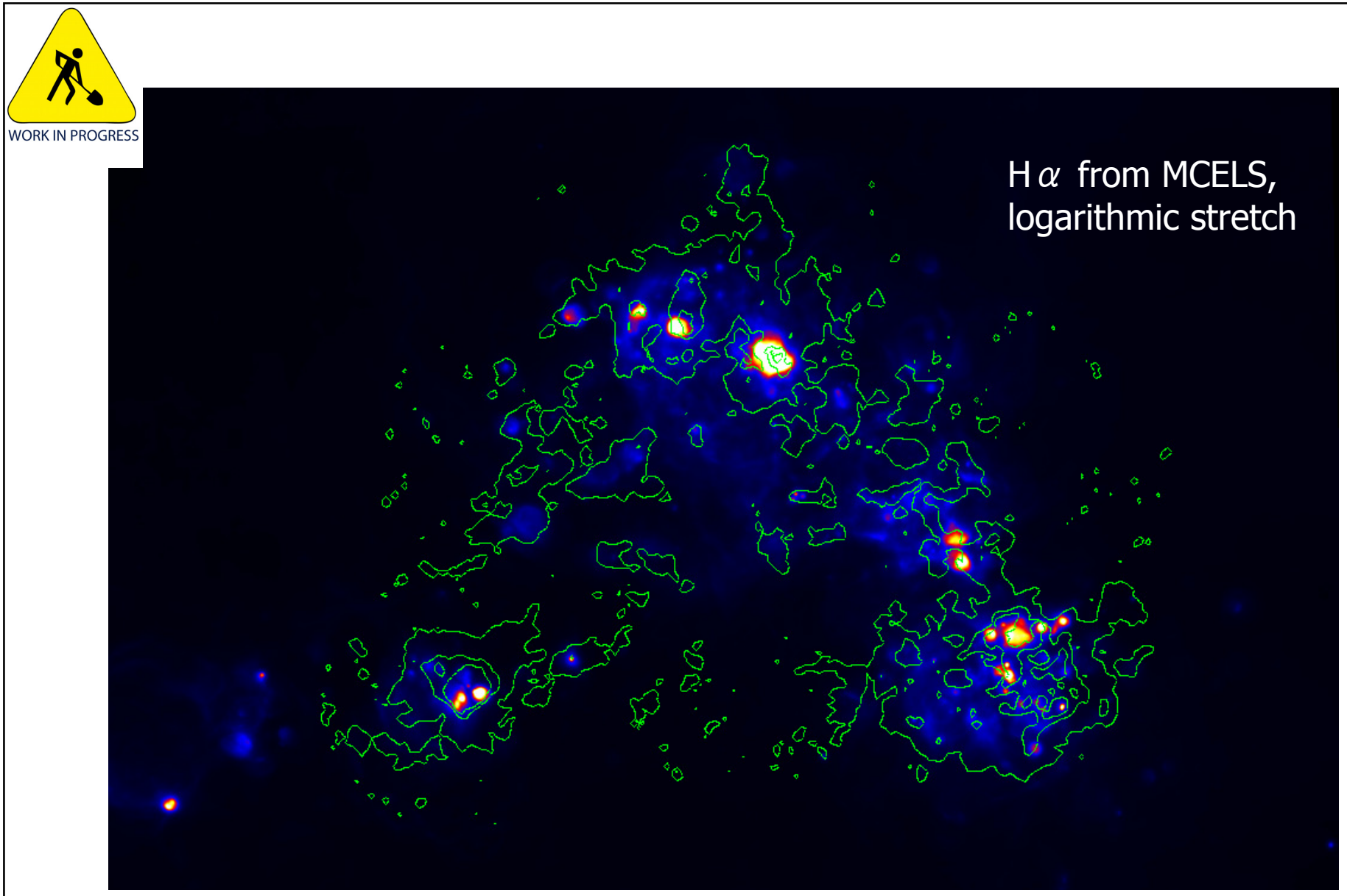


- *Better zero-point calibration and artifact mitigation*
- *Larger coverage*
- *New methodology to remove out-of-equilibrium emission at 70 um and reach 10 pc resolution*

Dust emission at 24, 70, and 160 μm from the SMC:
SMC-SAGE (PI: K. Gordon)+S3MC (Bolatto+ 07)



Fraction of obscured SF according to the Calzetti et al. (2007) calibration is localized and small: we use Hα +24 um but **most** of the correlation comes from Hα



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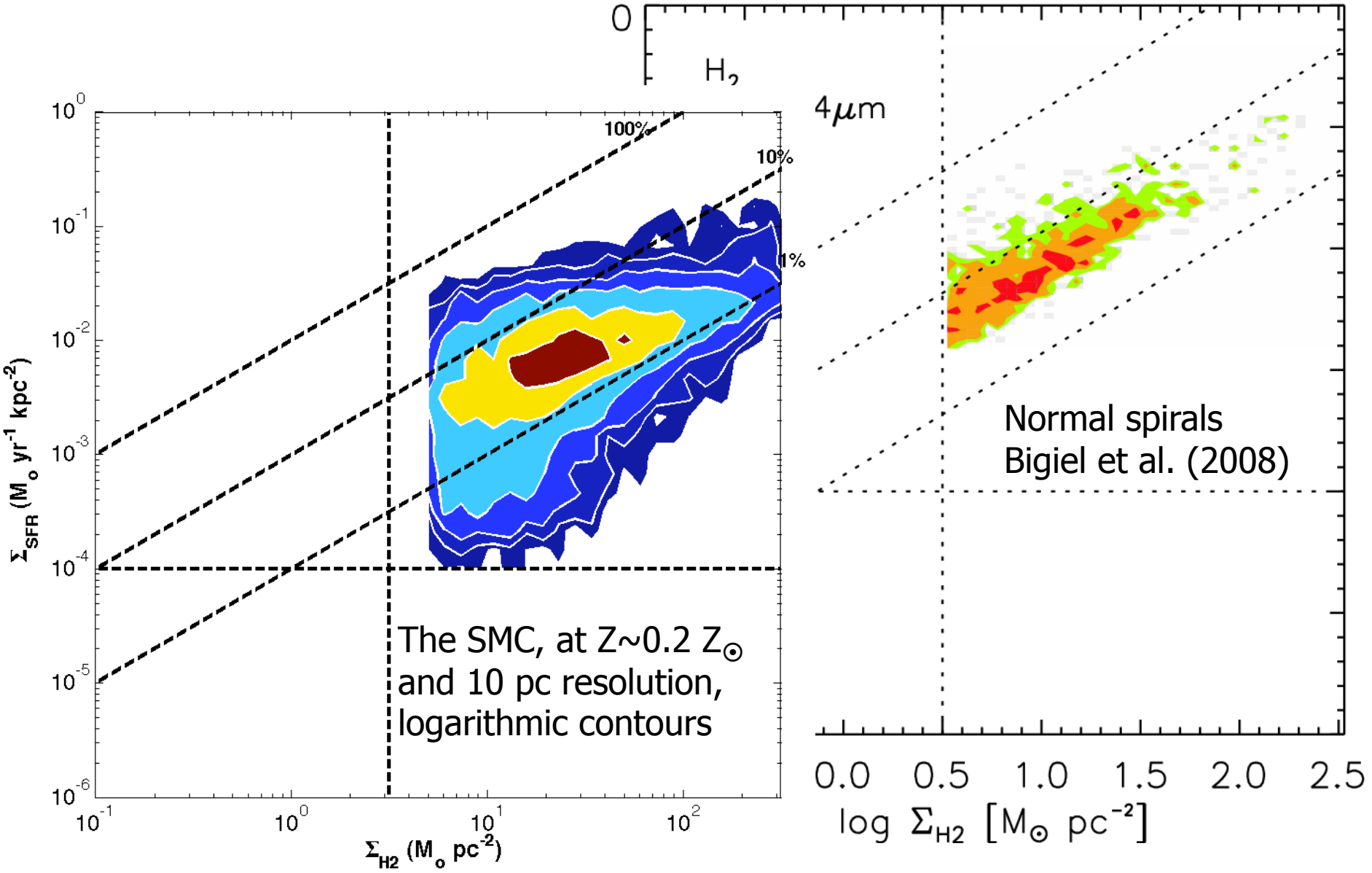
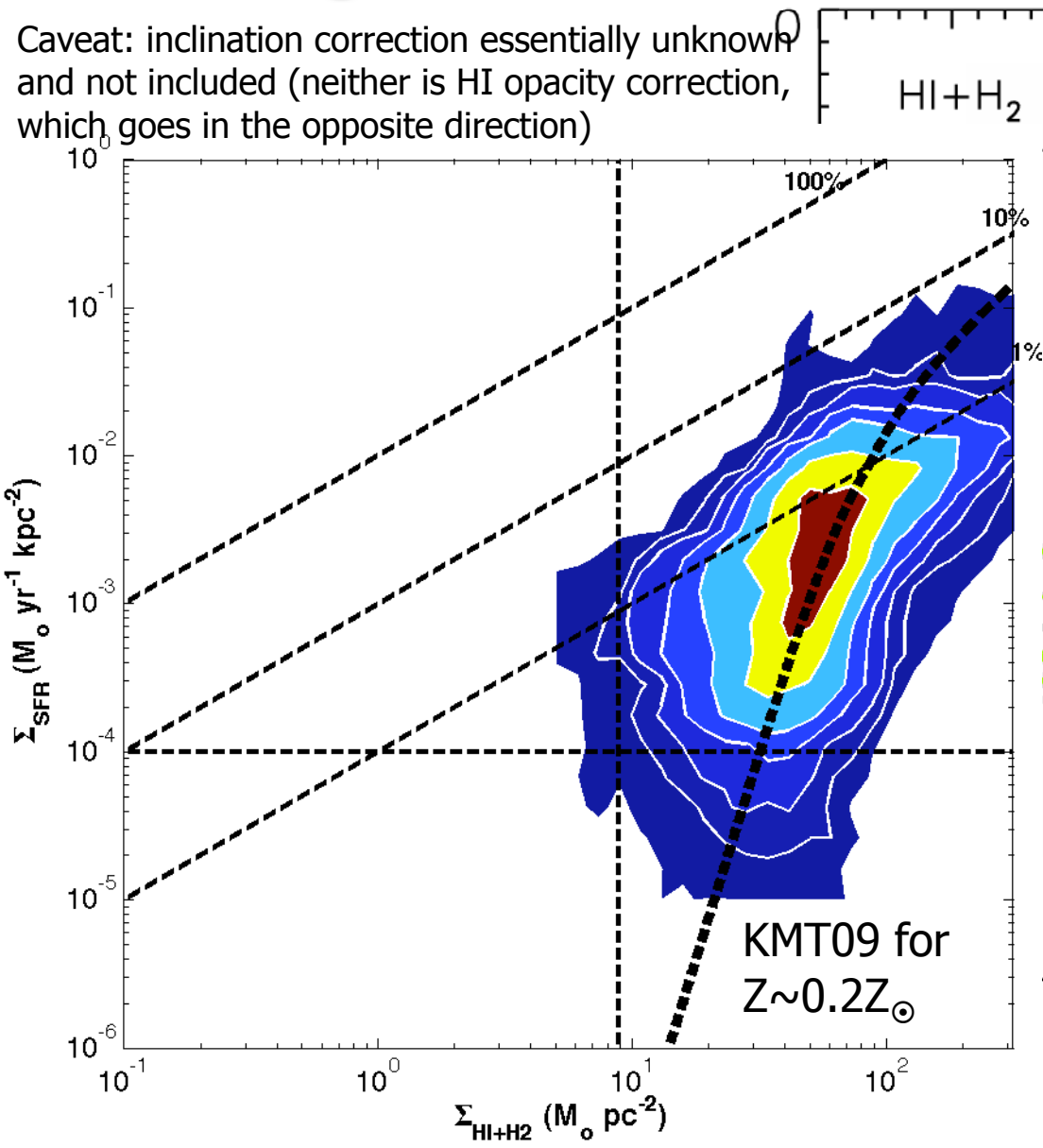
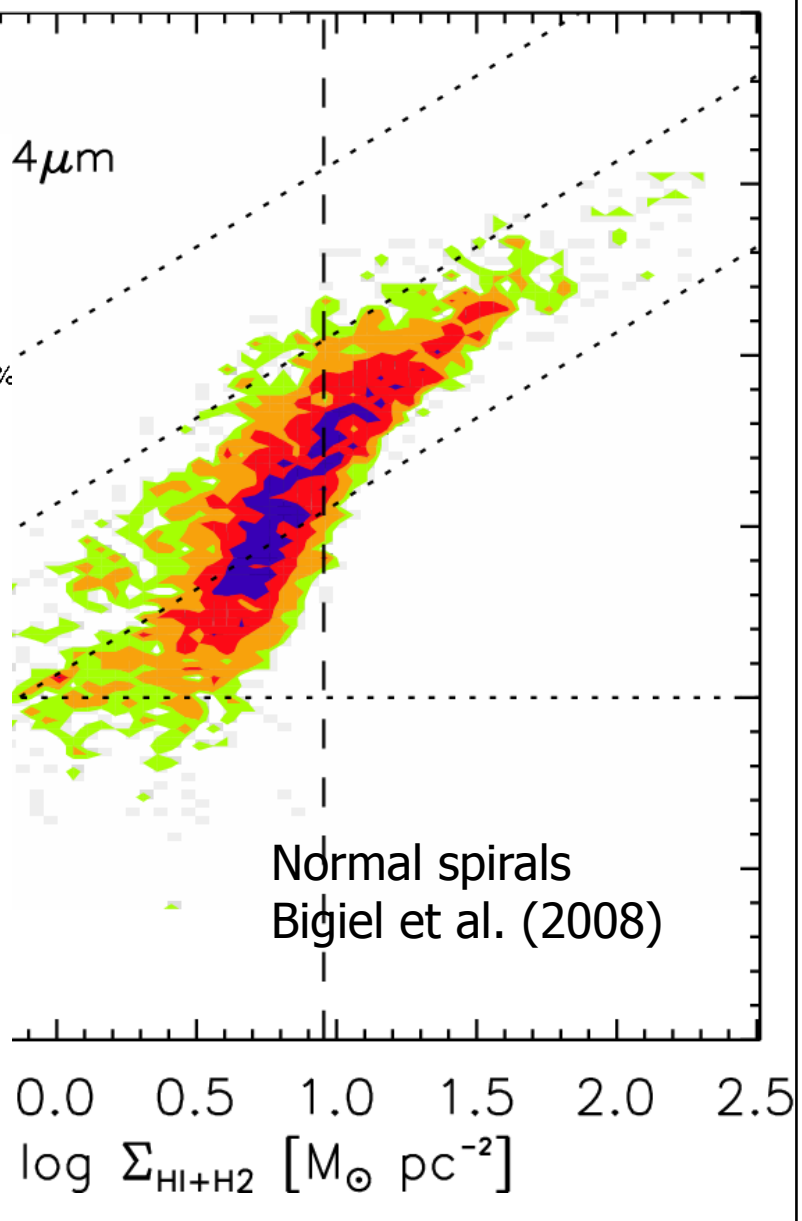
The H_2 Schmidt law in the SMC

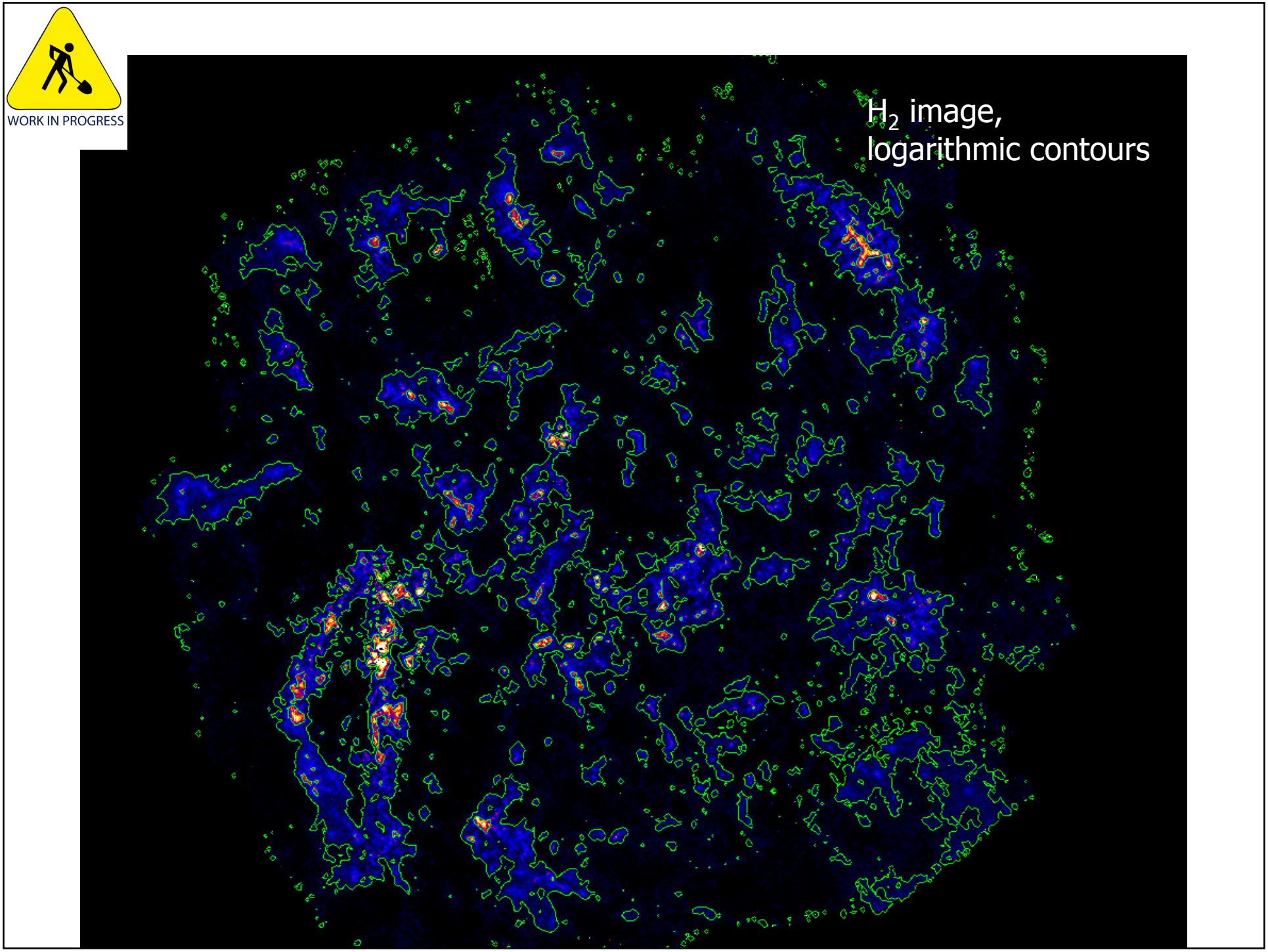


The total gas Schmidt law in the SMC

Caveat: inclination correction essentially unknown and not included (neither is HI opacity correction, which goes in the opposite direction)






WORK IN PROGRESS
H_2 image,
logarithmic contours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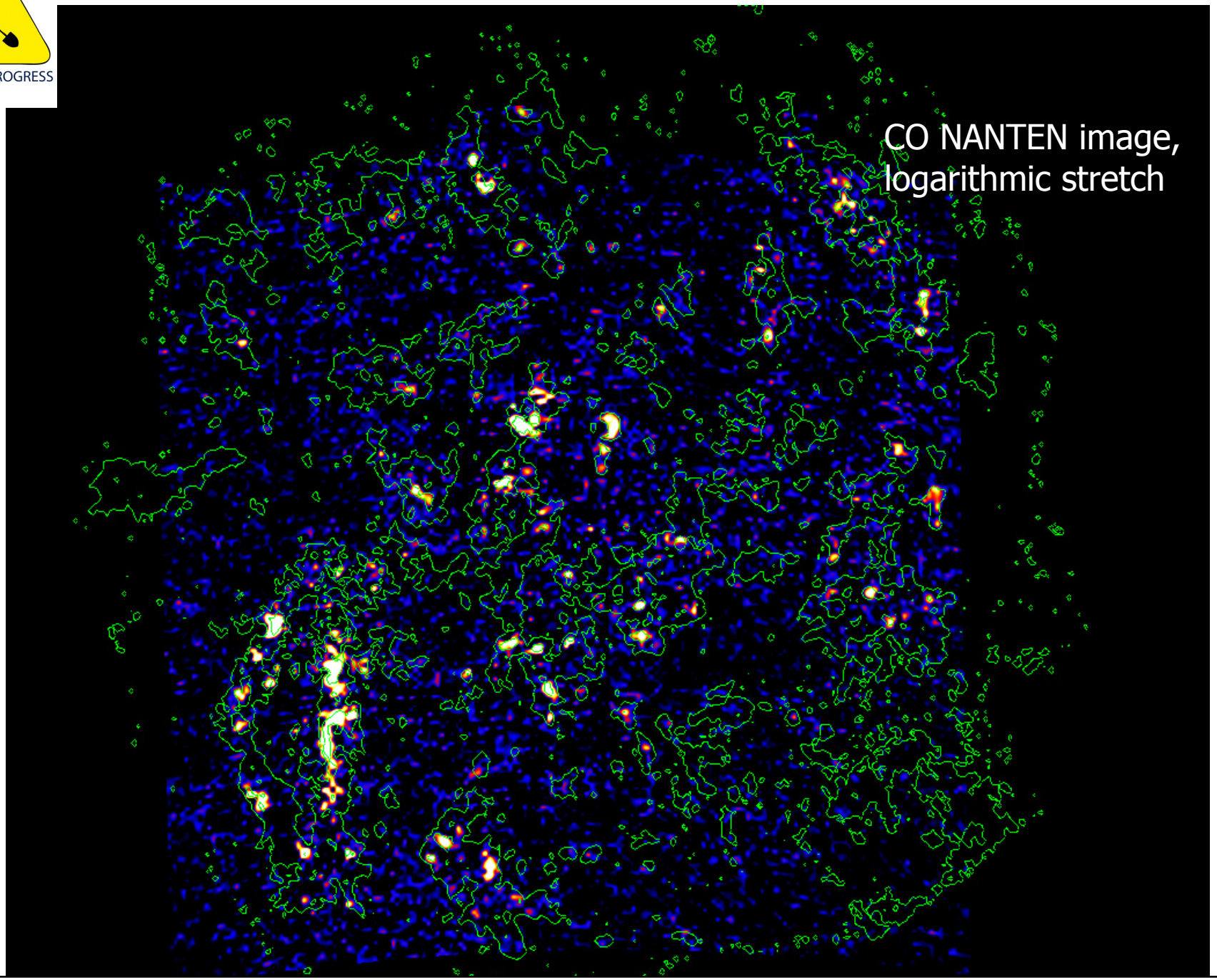
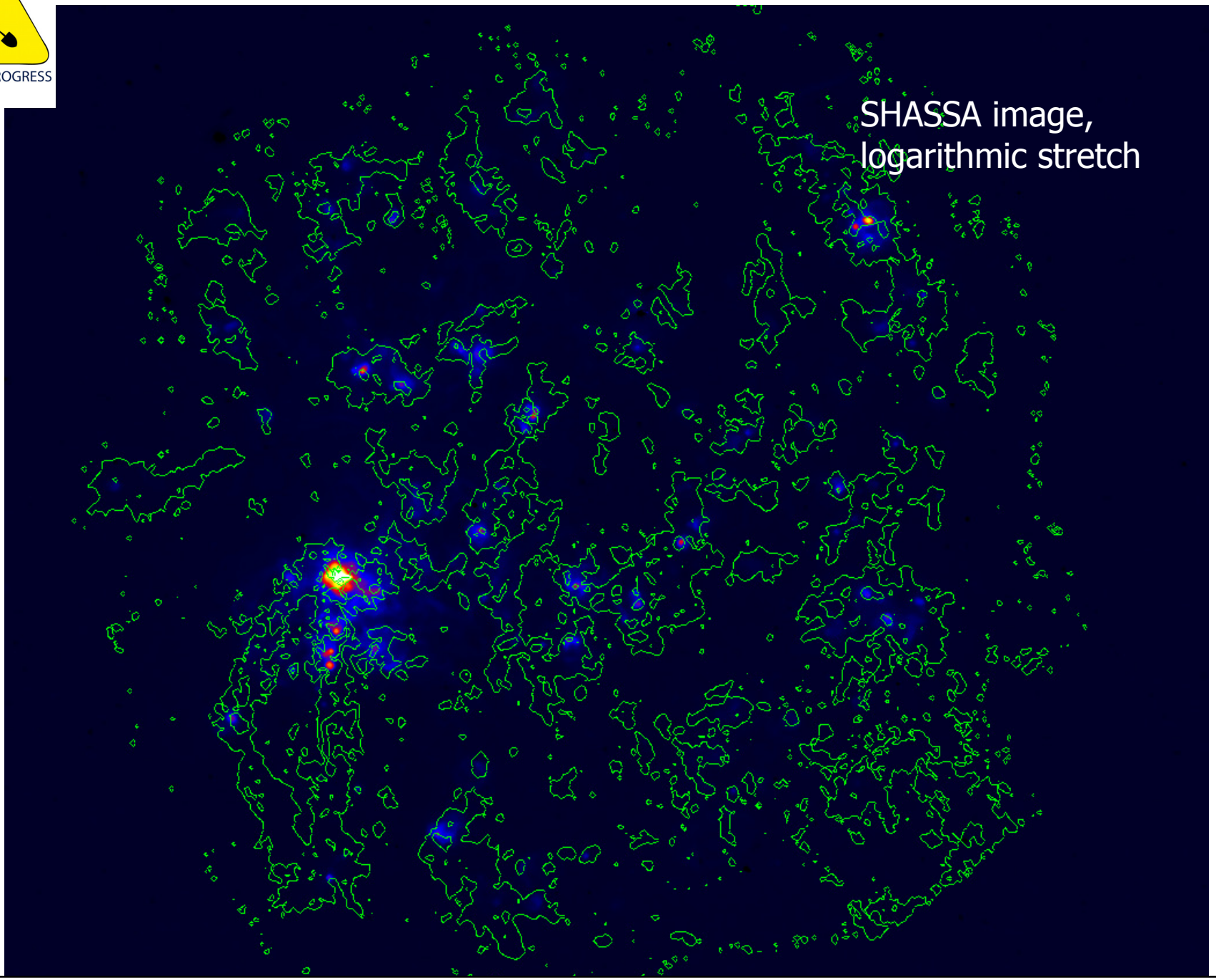
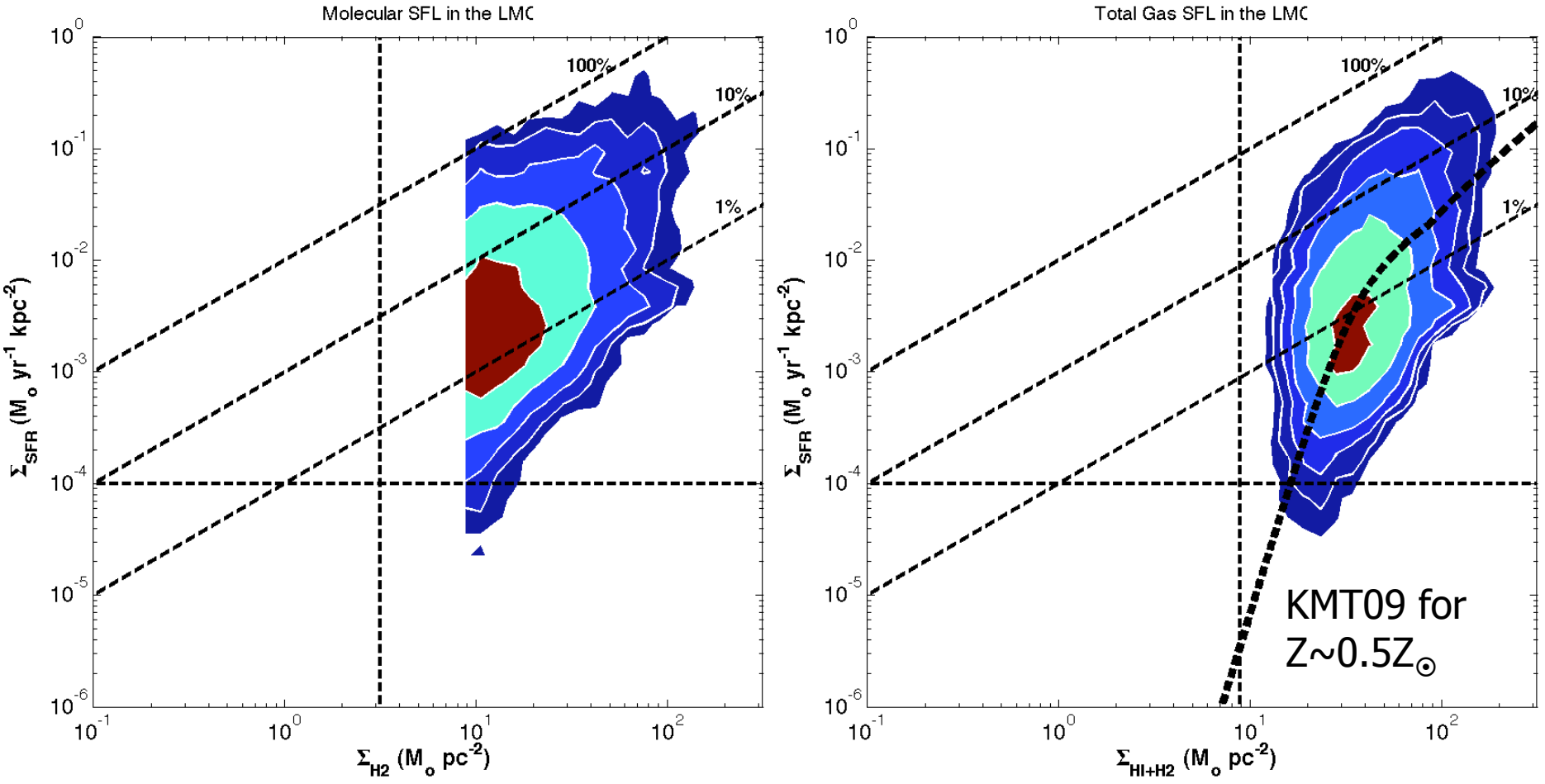

CO NANTEN image,
logarithmic stretch

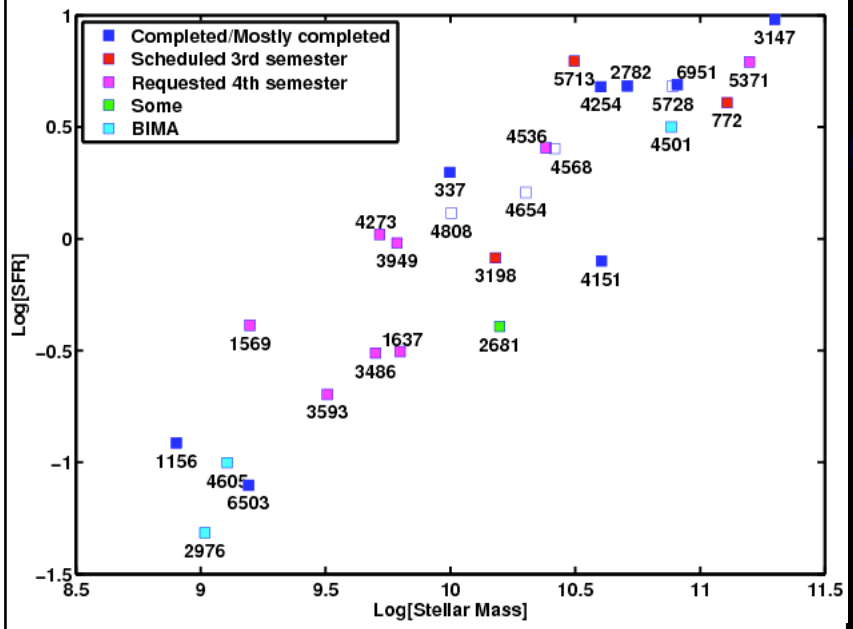

WORK IN PROGRESS


SHASSA image,
logarithmic stretch

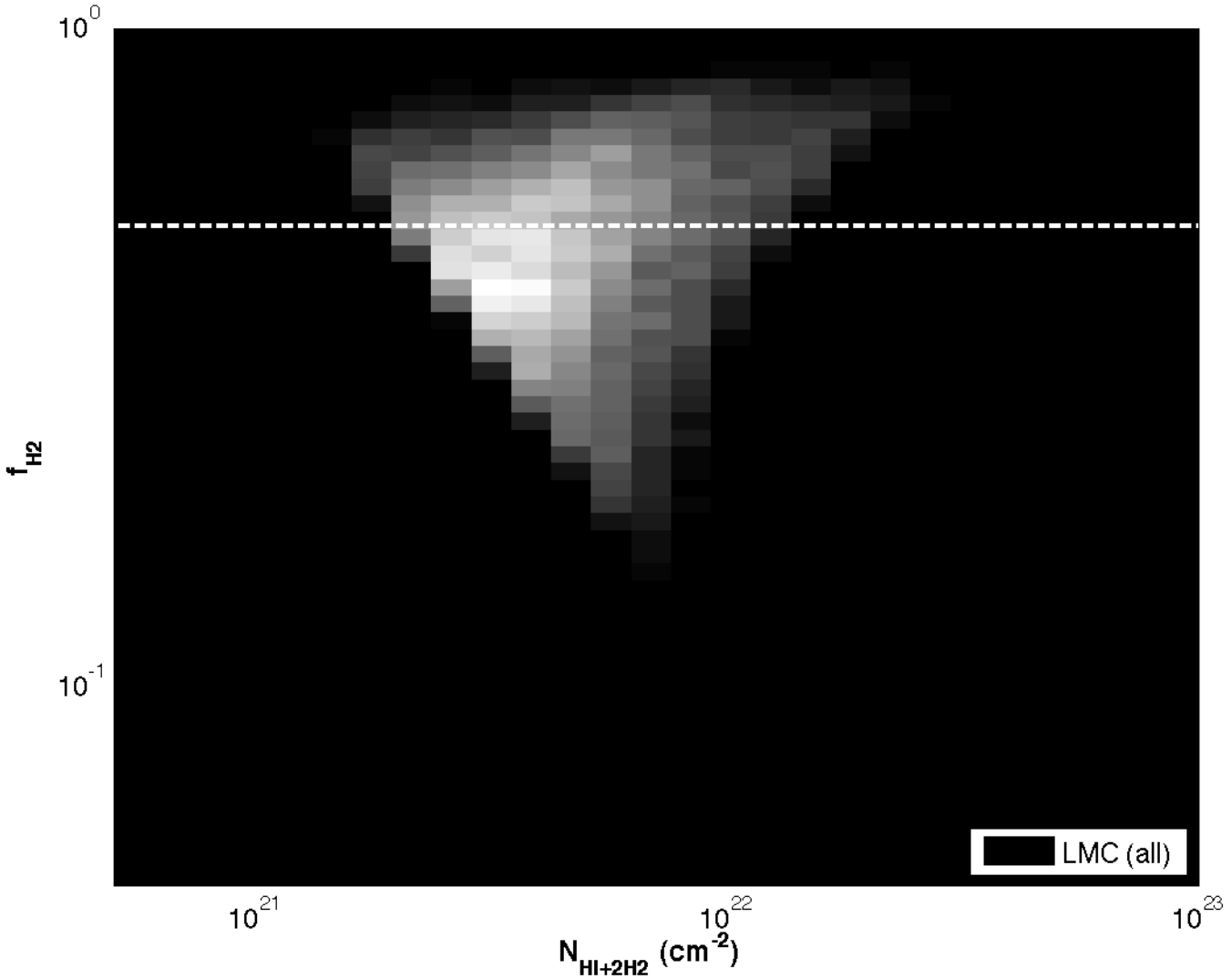
The Schmidt law in the LMC



A systematic sampling of the blue sequence



The resolved molecular fraction in galaxies



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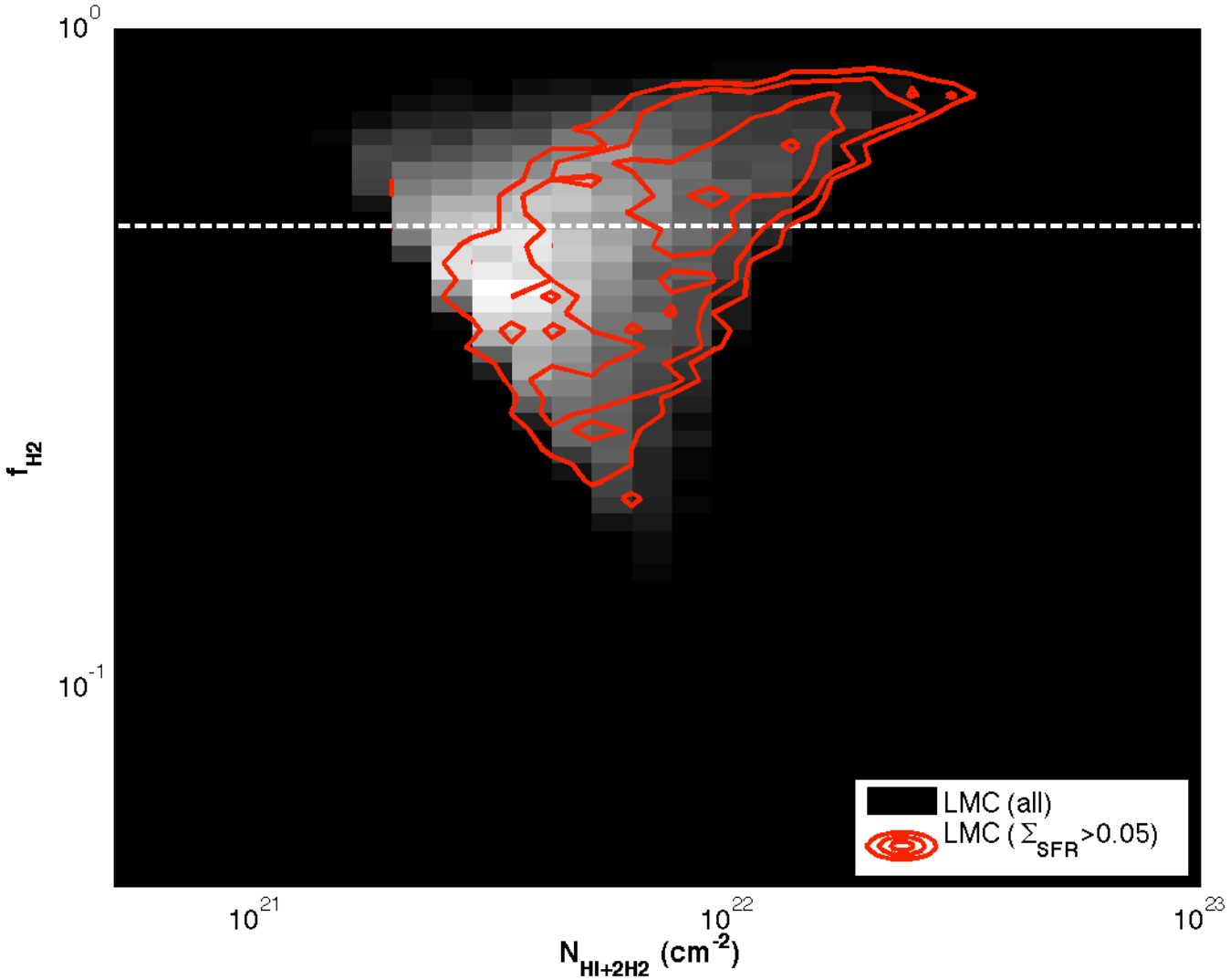

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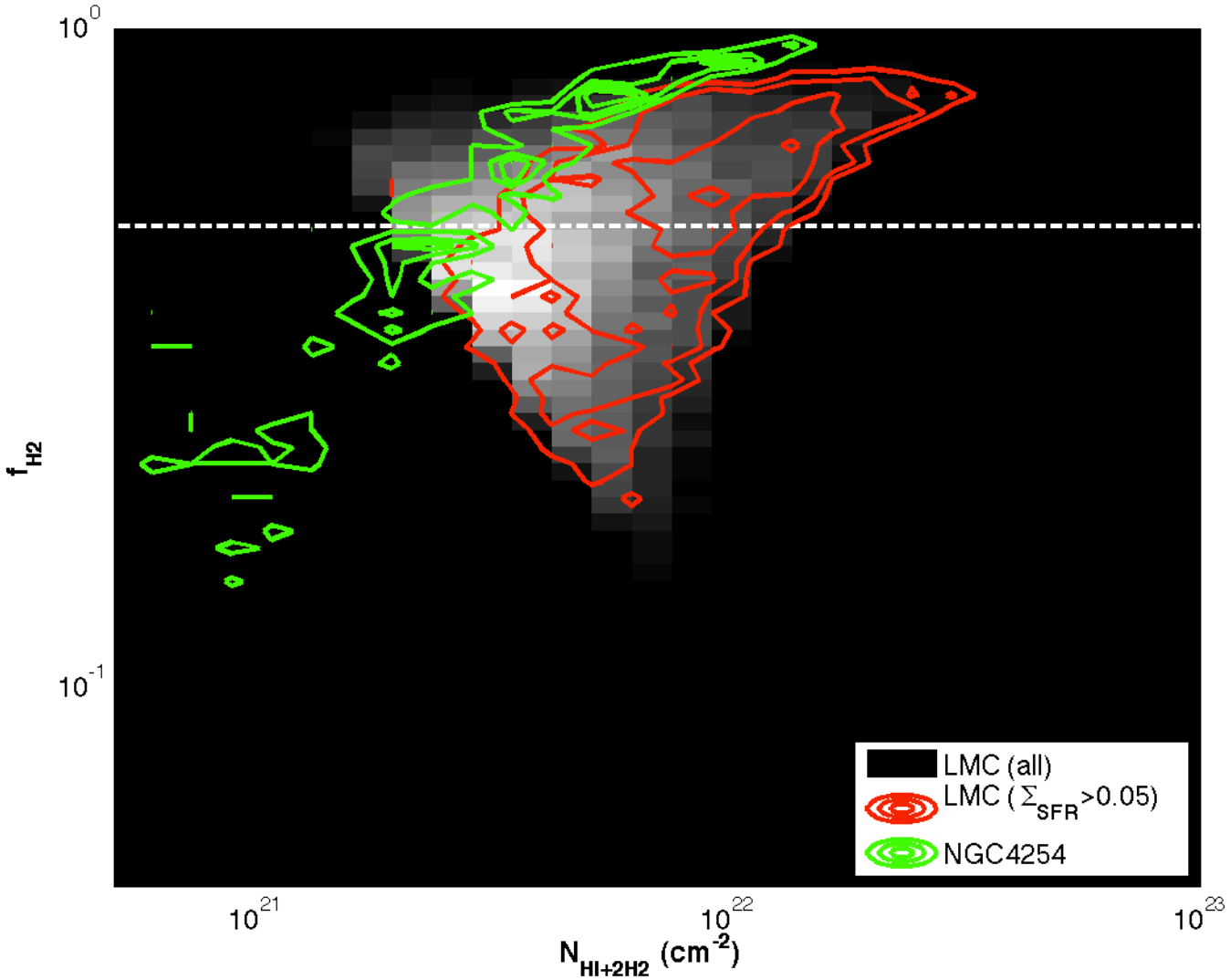

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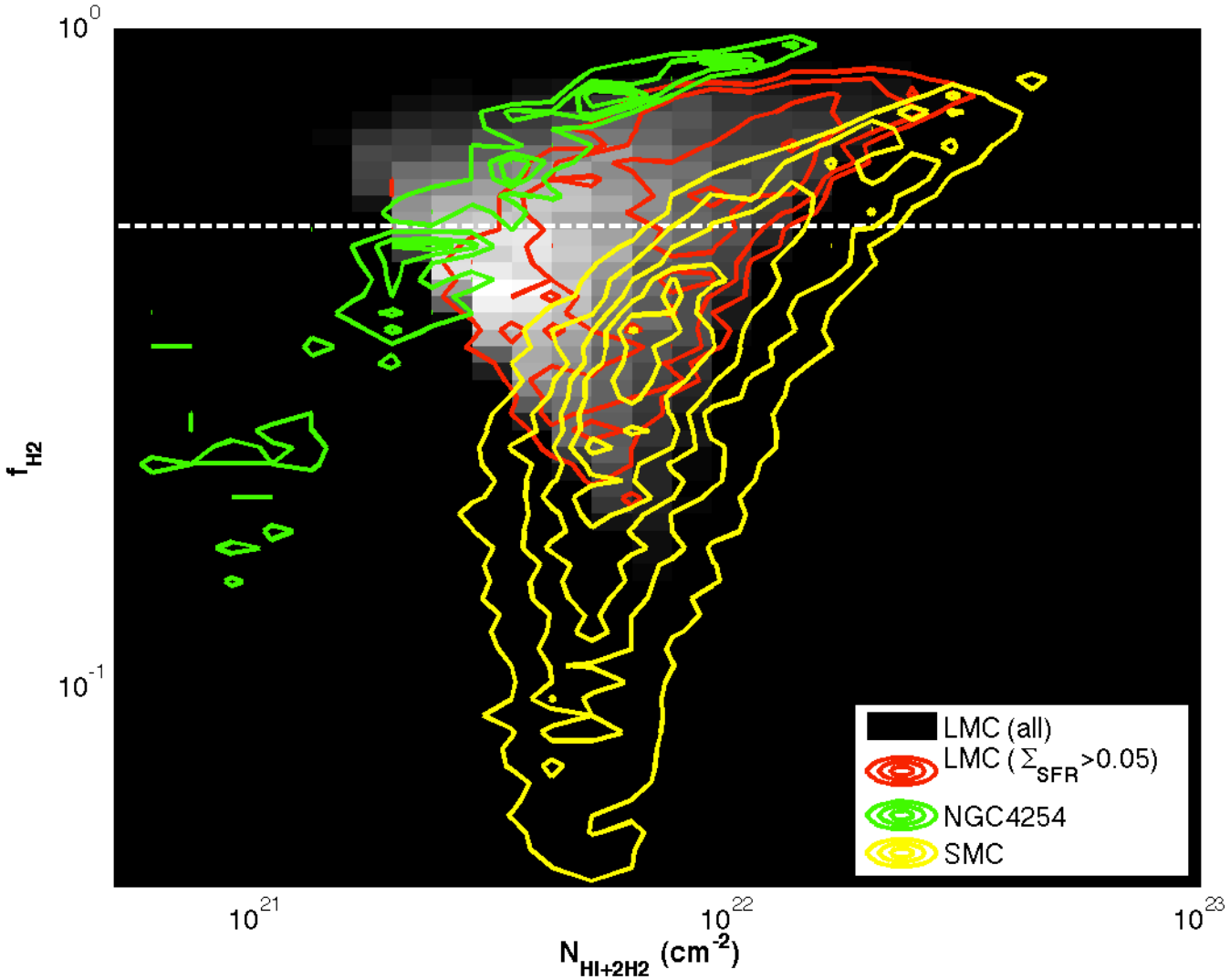

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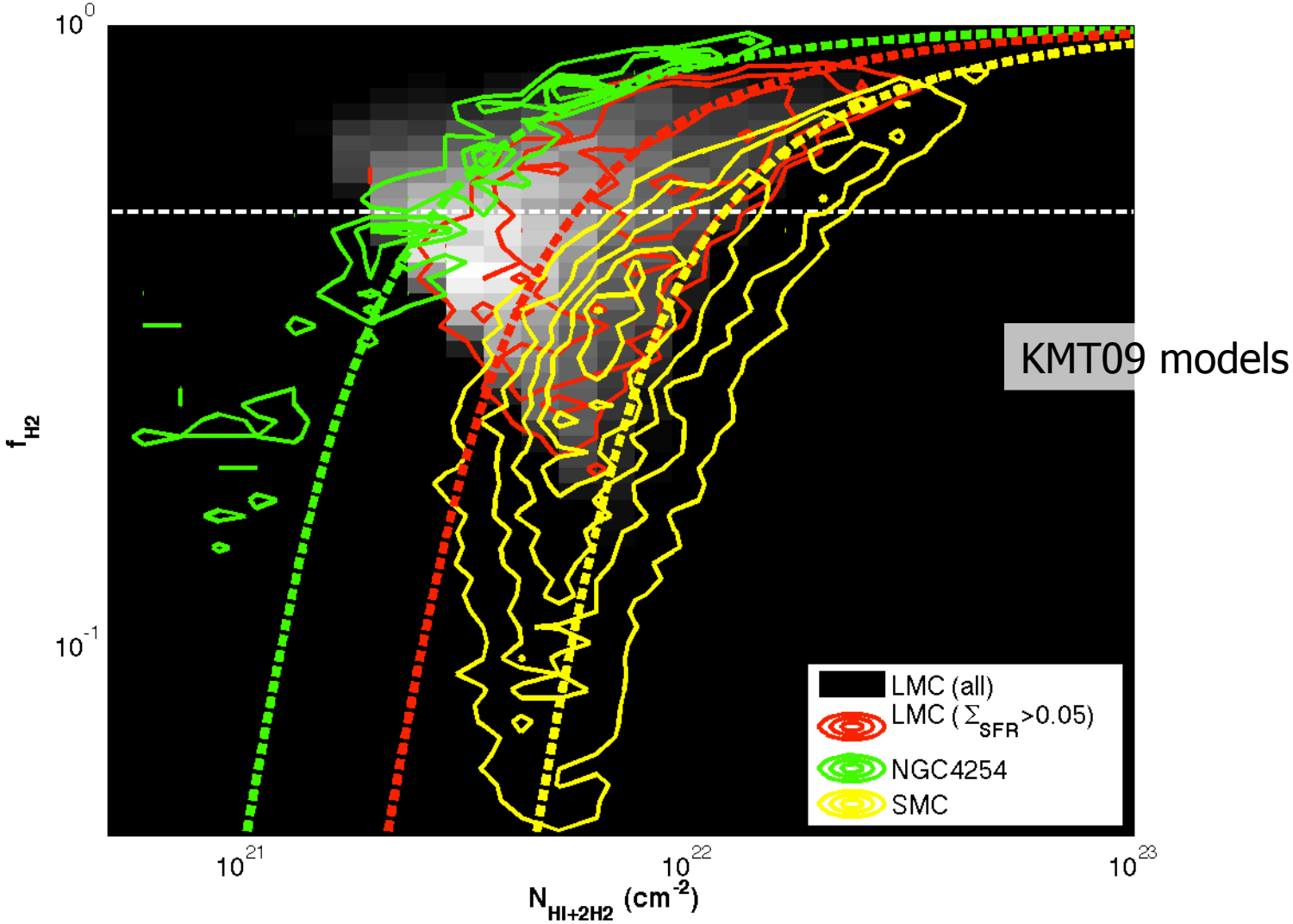


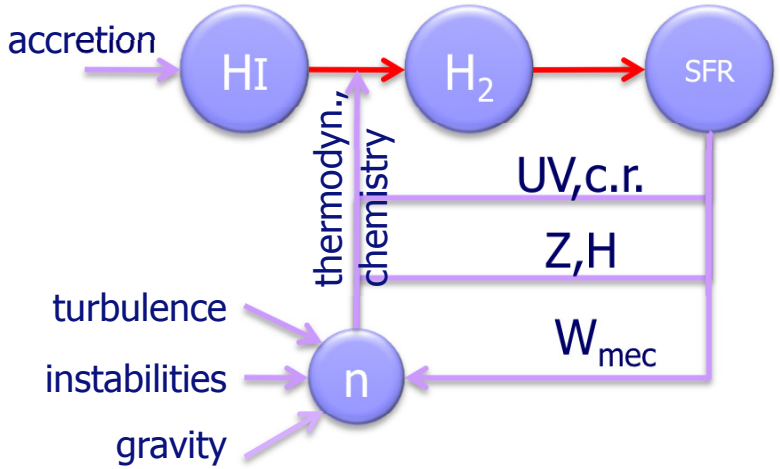
KMT09 models

Conclusions: Metallicity and Star Formation

1. At least in the case of the SMC, the **driver for the SFR is the H_2 fraction**:
   - The molecular SFL is very similar to large spirals
   - The total gas SFL is radically different: higher saturation value for Σ_{HI}
   - Good news for Dawn Erb and other fans of SFR->M_{H2} at low Z
   - Explains results for DLAs too (Wolfe & Chen 2006)

2. **Caveat astrologus**: beware of CO in outer disks/low metallicity
   - Yes, we will measure it (ALMA, etc), but what does it mean?

3. **What is the "prime mover"**?



4. **How does translucent H_2 participate in star formation**?
   - Isn't large Av necessary for decoupling and collapsing?
   - Aren't molecular lines needed for cooling?