Where is the ISM Good At Forming Stars?

Adam Leroy (MPIA)
Fabian Walter (MPIA)
Frank Bigiel (UC Berkeley)
The THINGS and HERACLES teams

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- **What we're trying to do:**
  - **HERACLES, THINGS et al.**
- Two easy answers:
  - "phase" (HI vs. H_2)
  - radius
- A deeper look:
  - dust-to-gas ratio (metallicity)
  - hydrostatic pressure
  - gravitational instability
  - spiral structure

The HERA CO-Line Extragalactic Survey

HERACLES

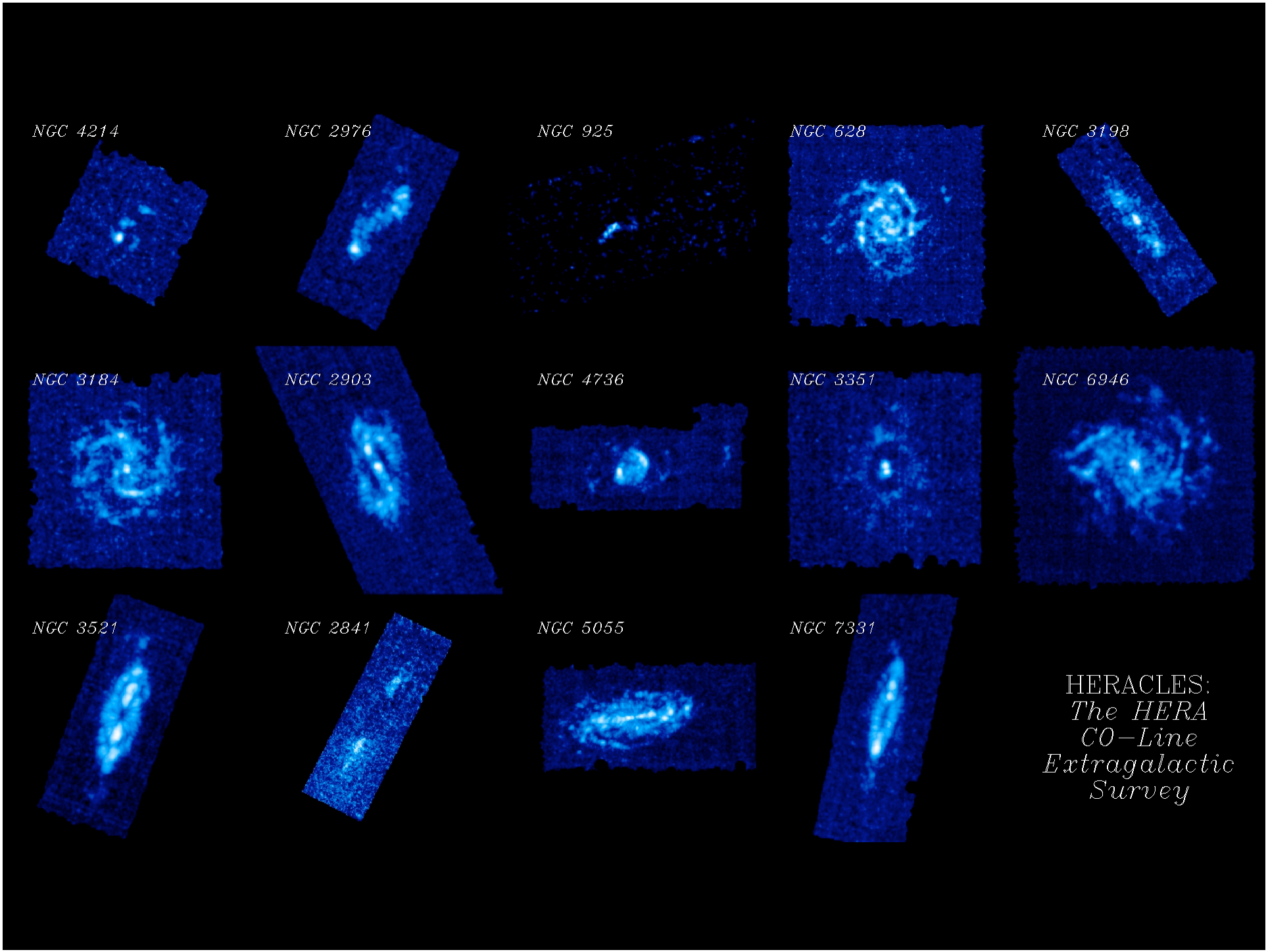
Leads: A. Leroy & F. Walter

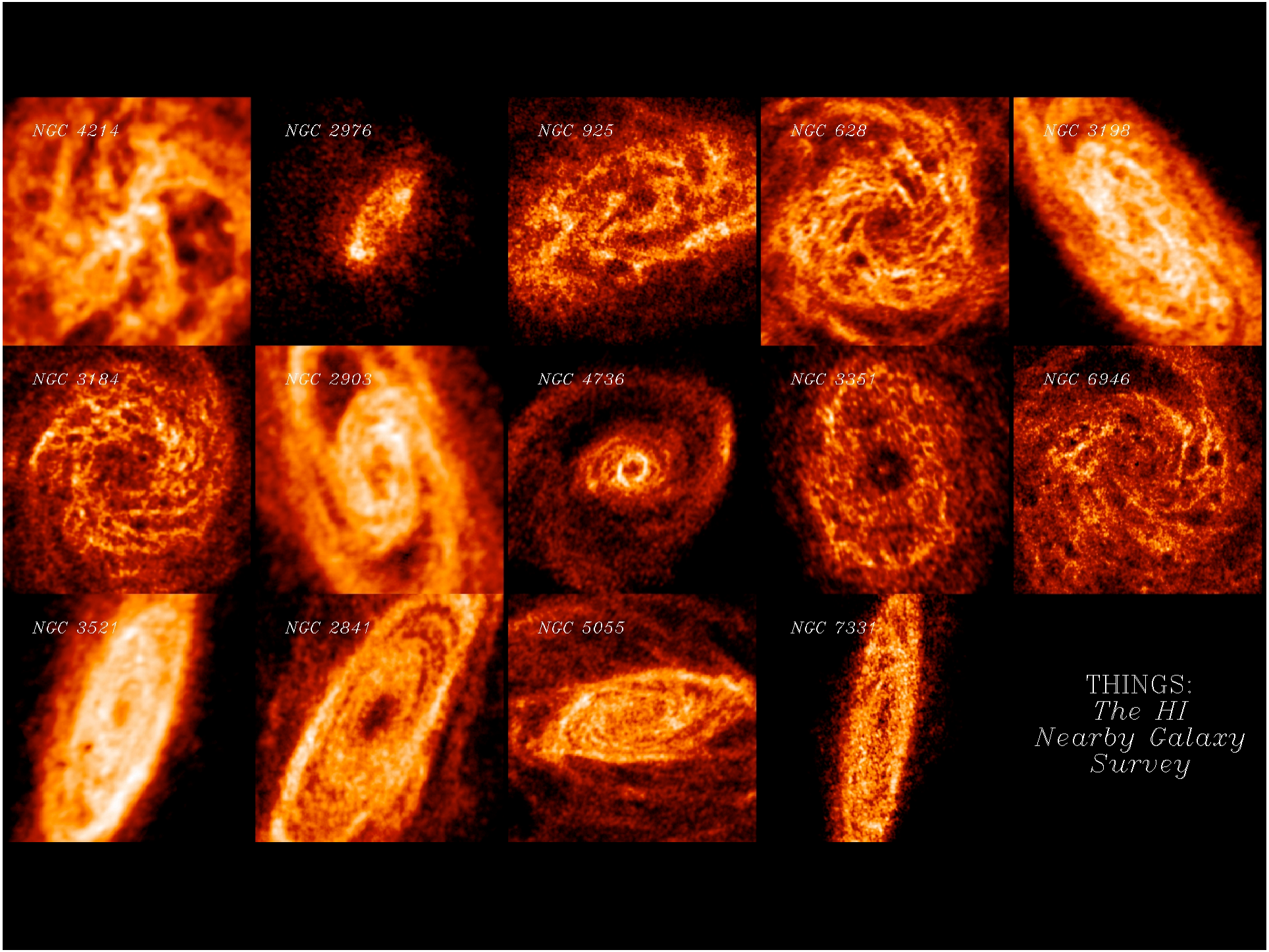
Team: F. Bigiel, E. Brinks, W.J.G. de Blok, G. Dumas, D. Calzetti, R. C. Kennicutt, C. Kramer, H-W Rix, E. Schinnerer, A. Schruba, K.-F. Schuster, A. Usero, A. Weiss, H. Wiesemeyer

- IRAM 30m maps of CO J = 2→1 line (~500h)
- Targets heavily overlap THINGS, SINGS, GALEX, etc.
- 44 galaxies: from dwarfs to starbursts and massive spirals
- Very wide-field (~ r_{25}) and sensitive (σ ~ 2 M_{sun} pc^{-2})

First Maps: Leroy et al. (2009)

HERACLES


NGC 4214
NGC 2976
NGC 925
NGC 628
NGC 3198
NGC 3184
NGC 2903
NGC 4736
NGC 3351
NGC 6946
NGC 3521
NGC 2841
NGC 5055
NGC 7331
HERACLES:
The HERA
CO-Line
Extragalactic
Survey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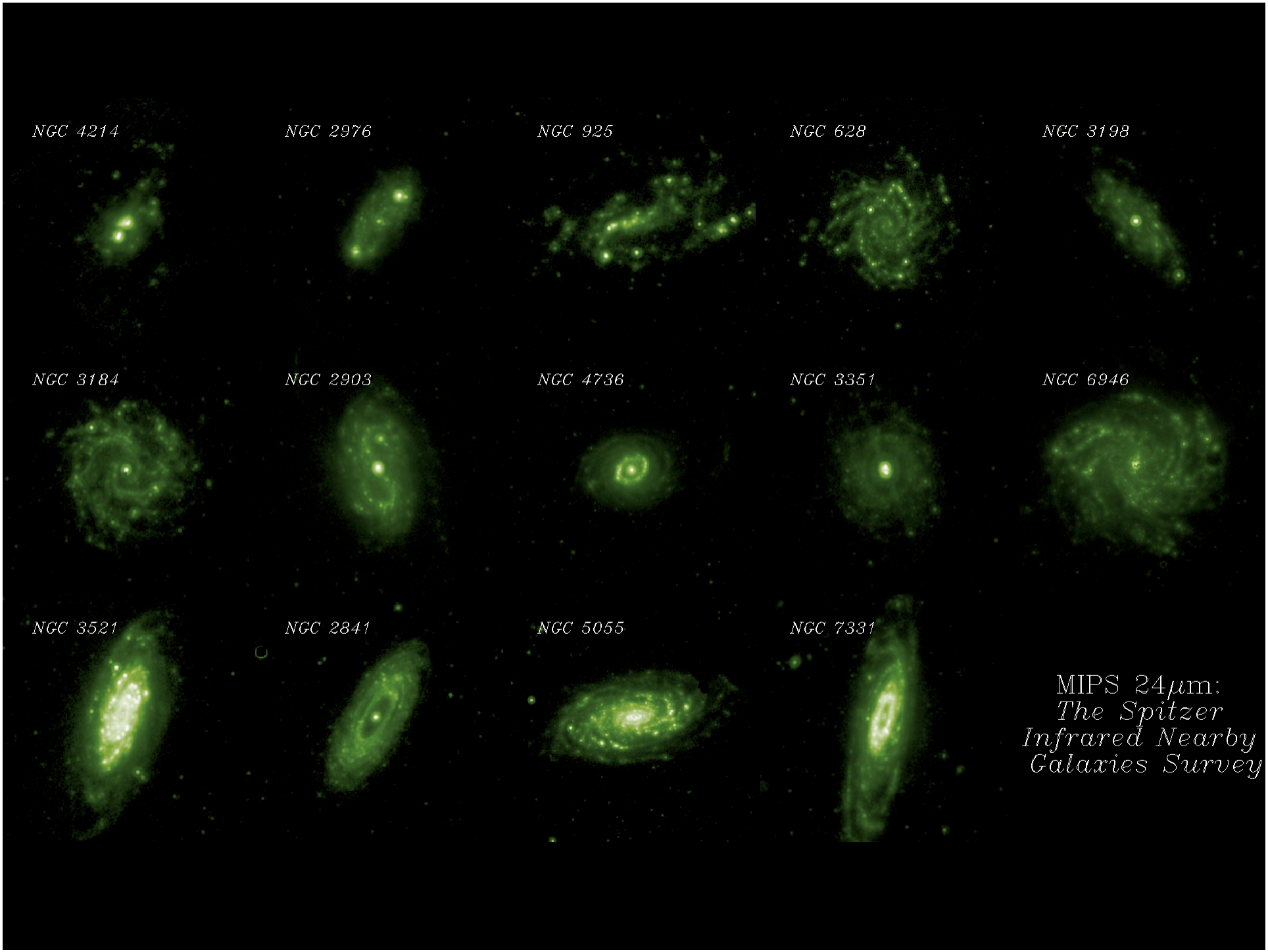
NGC 3184
NGC 2903
NGC 4736
NGC 3351
NGC 6946
NGC 3521
NGC 2841
NGC 5055
NGC 7331
THINGS:
The HI
Nearby Galaxy
Survey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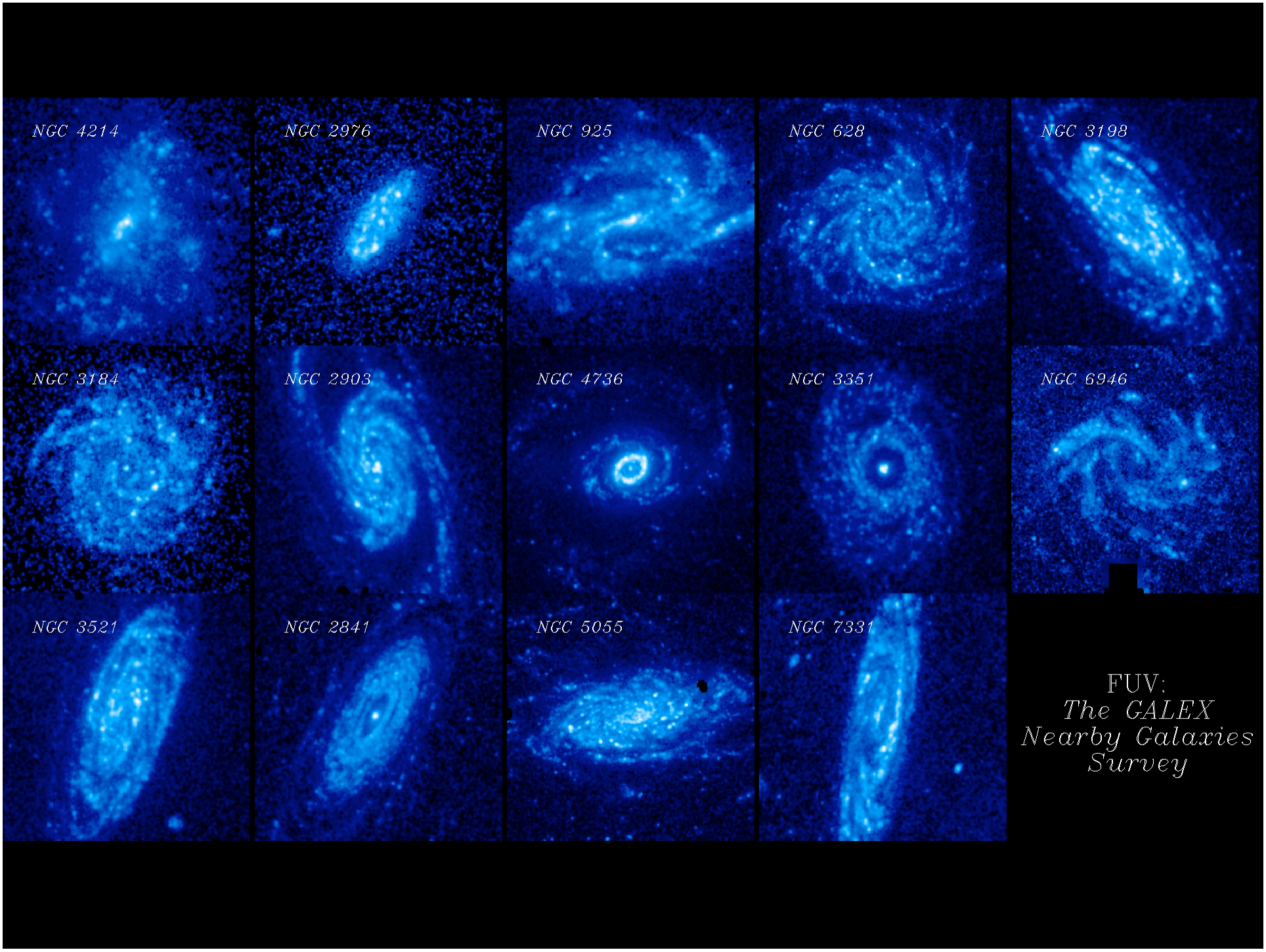
NGC 3521
NGC 2841
NGC 5055
NGC 7331
MIPS 24μm:
The Spitzer
Infrared Nearby
Galaxies Survey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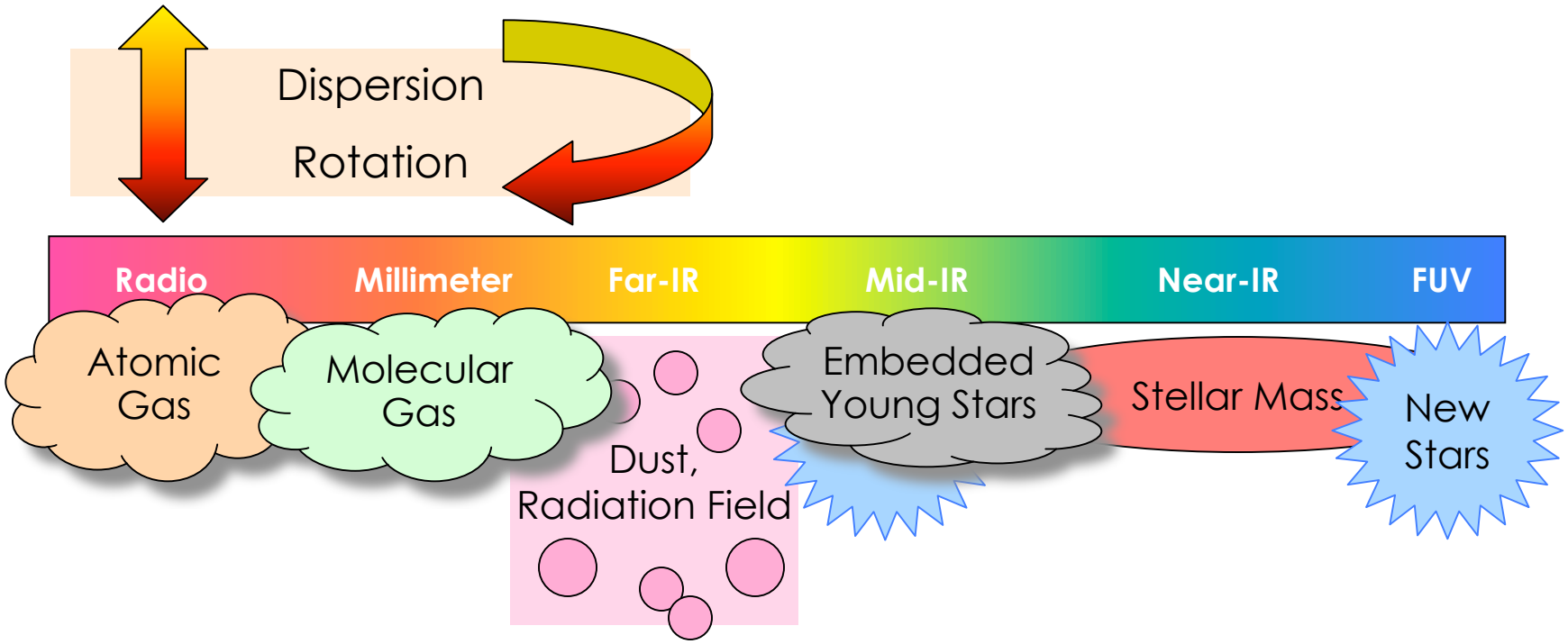
NGC 7331
FUV:
The GALEX
Nearby Galaxies
Survey

The Goal…

Compare star formation and the interstellar medium across many environments in a well-studied set of nearby galaxies.



Focusing on SFR/gas and H_2/HI to quantify the drivers of cloud formation and the conversion of stars into gas.

How We're Getting There…

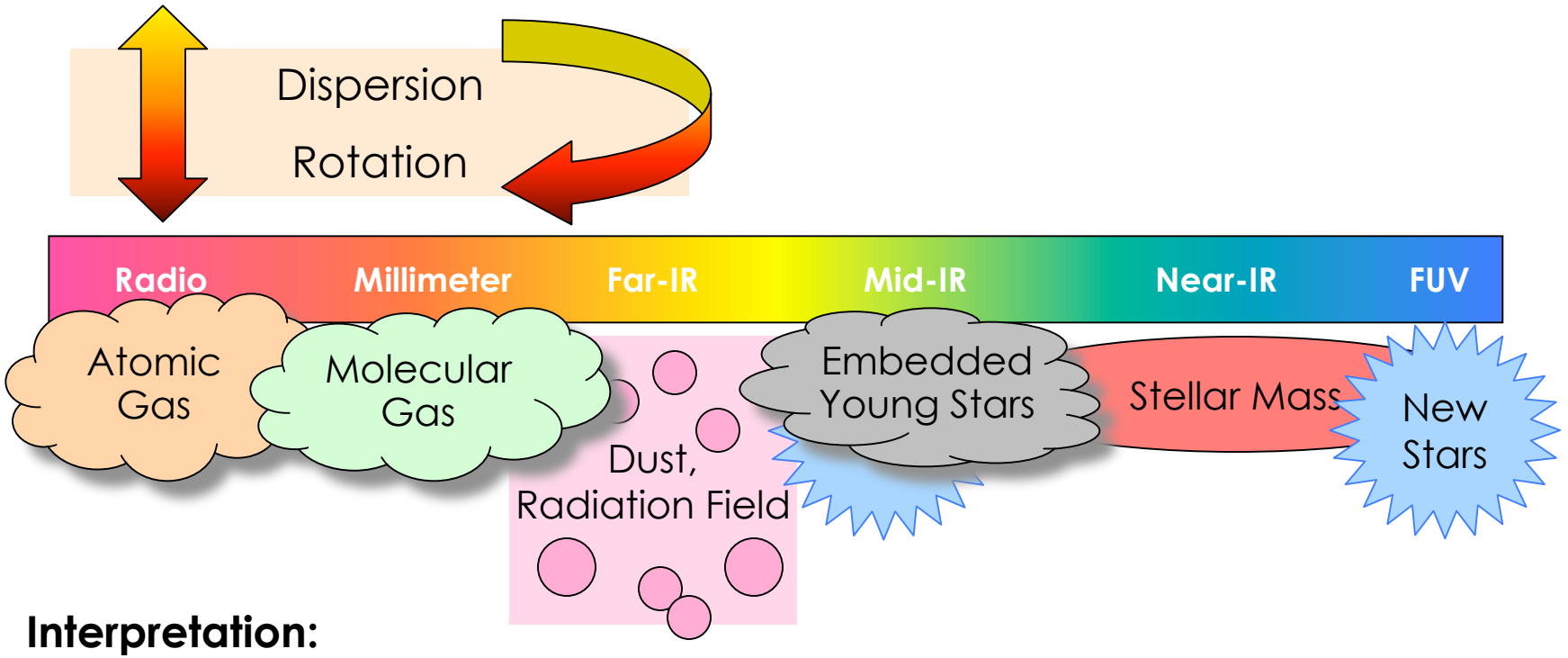
Data Sets:

THINGS
Walter+ '08

HERACLES
Leroy+ '09

SINGS
Kennicutt+ '03

GALEX NGS+
Gil de Paz+ '07



Interpretation:

de Blok+ '08
Tamburro+ '09

Draine & Li '07
Draine+ '07

Calzetti+ '07
Salim+ '07
Kennicut '98

Zibetti+ '09
Bottema '93
Kregel+ '05
Bell+ '03

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  - gravitational instability
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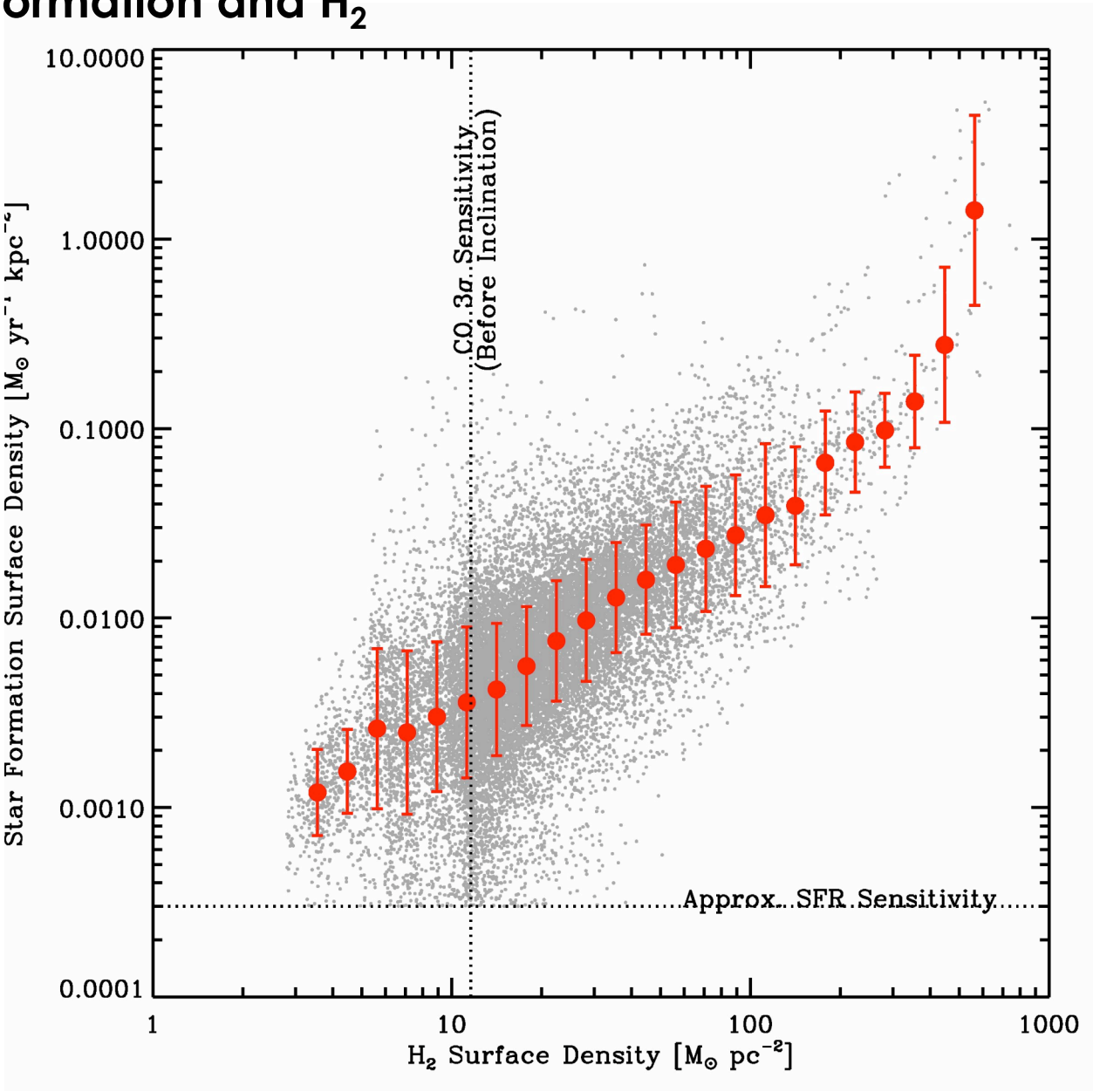
SFR vs. H_2 in HERACLES

Star Formation and H_2



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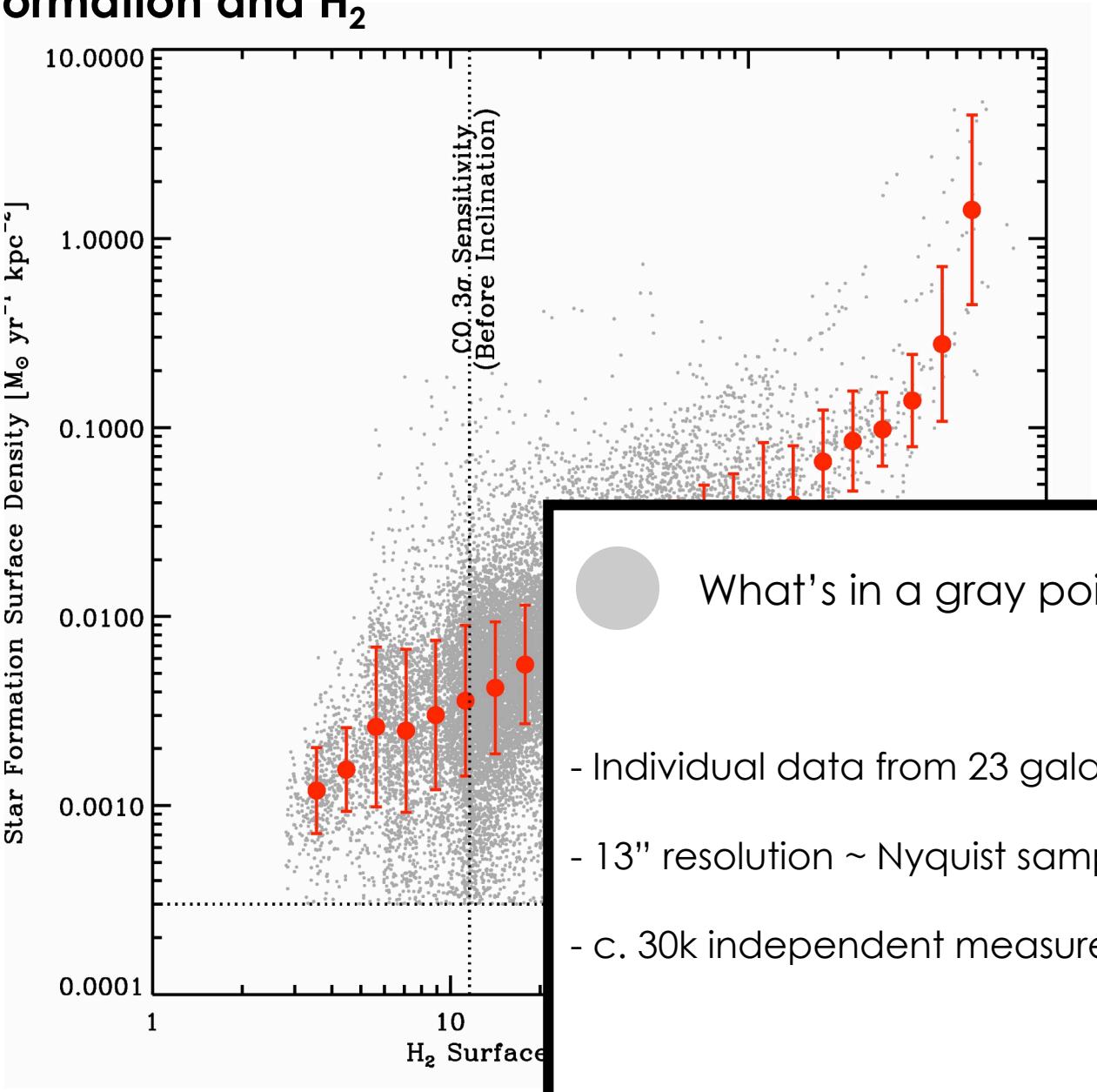

What's in a gray point?

- Individual data from 23 galaxies.
- 13" resolution ~ Nyquist sampled.
- c. 30k independent measurements.

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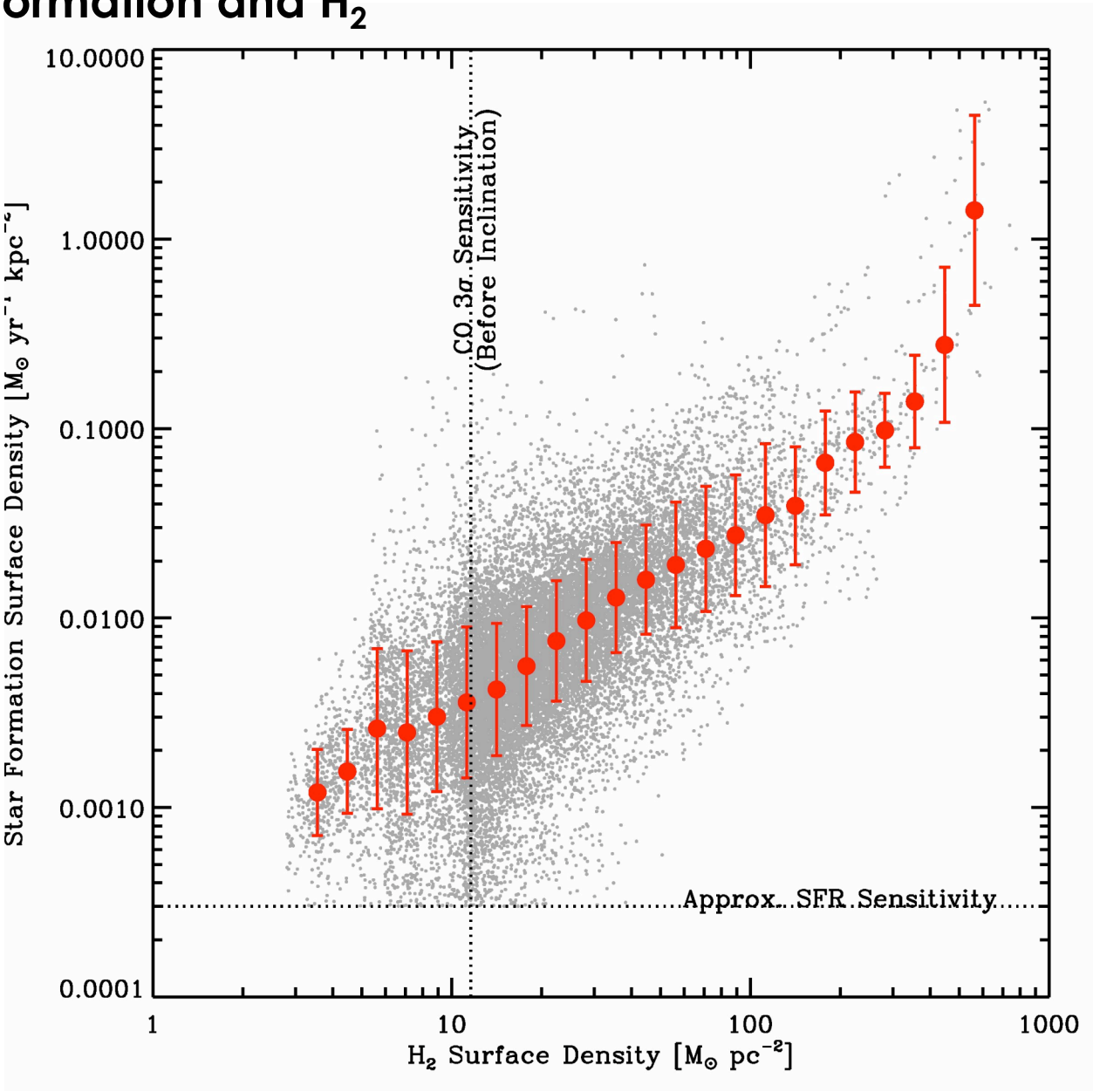

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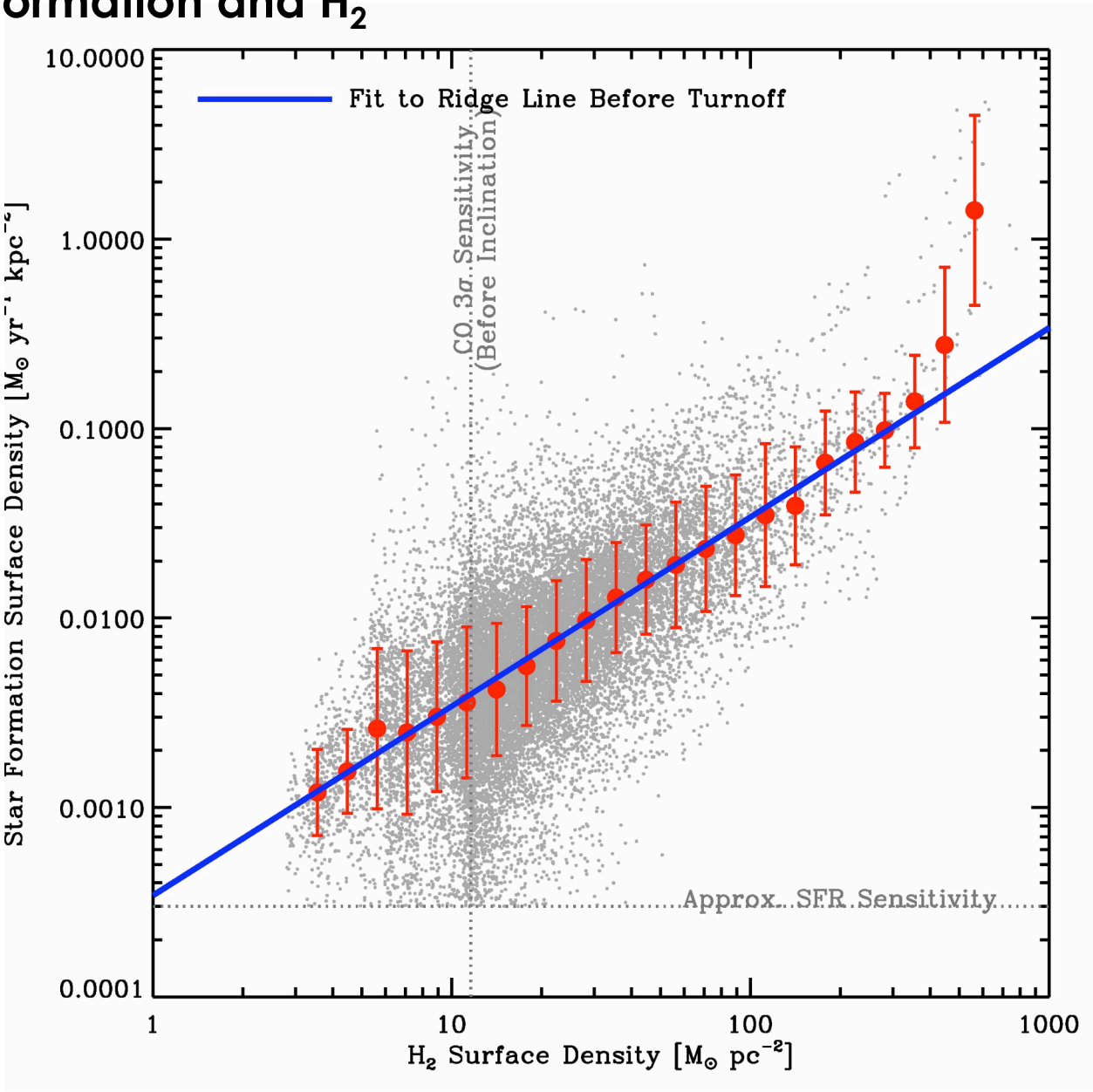
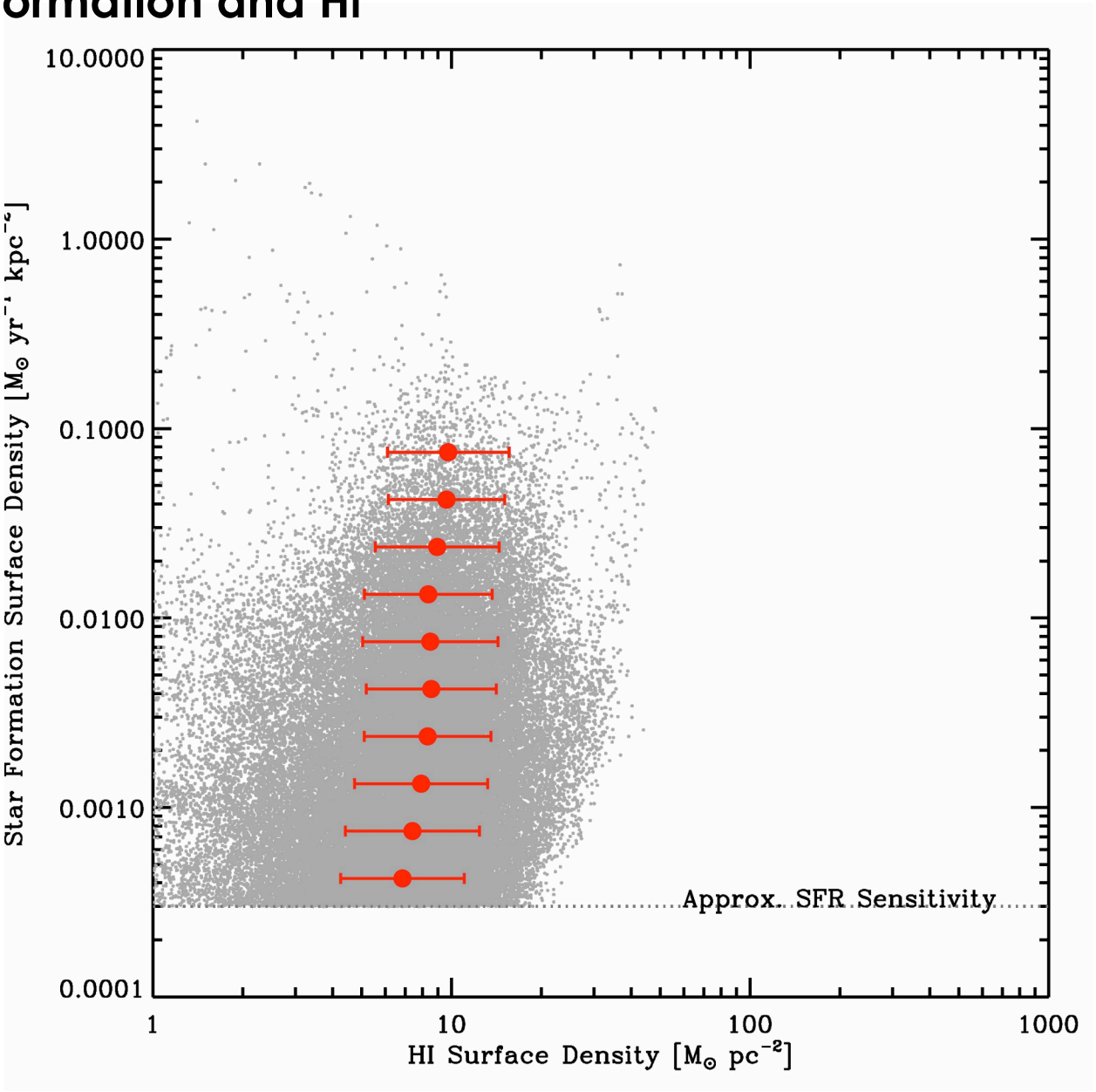


n = 1.0

Wong & Blitz '02, Murgia+ '02, Kennicutt+ '07, Bigiel+ '08

SFR vs. HI

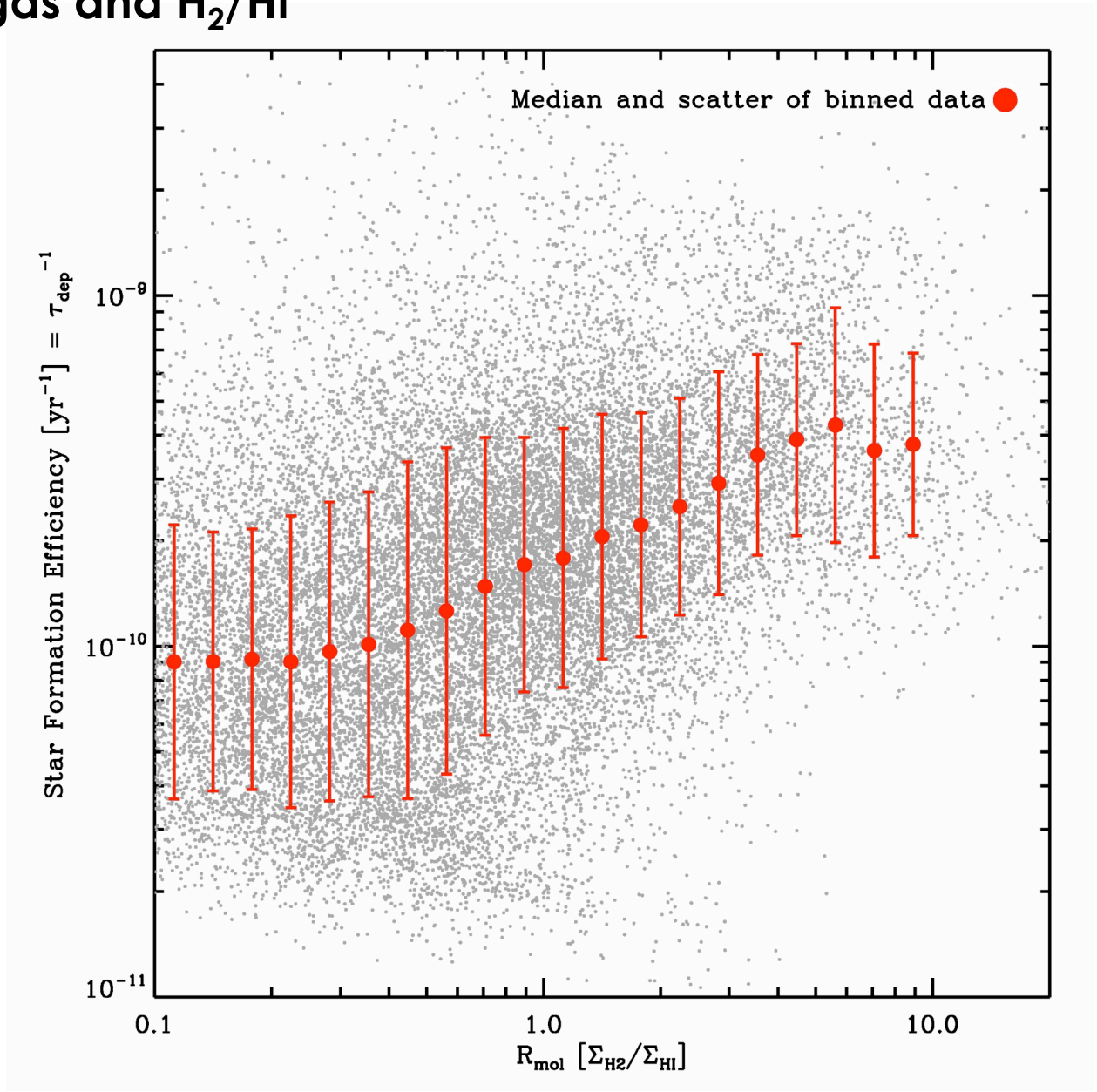
Star Formation and HI



Hunter & Elmegreen '98, Wong & Blitz '02, Kennicutt+ '07, Bigiel+ '08

Star Formation Efficiency vs. H_2/HI

SFR/gas and H_2/HI



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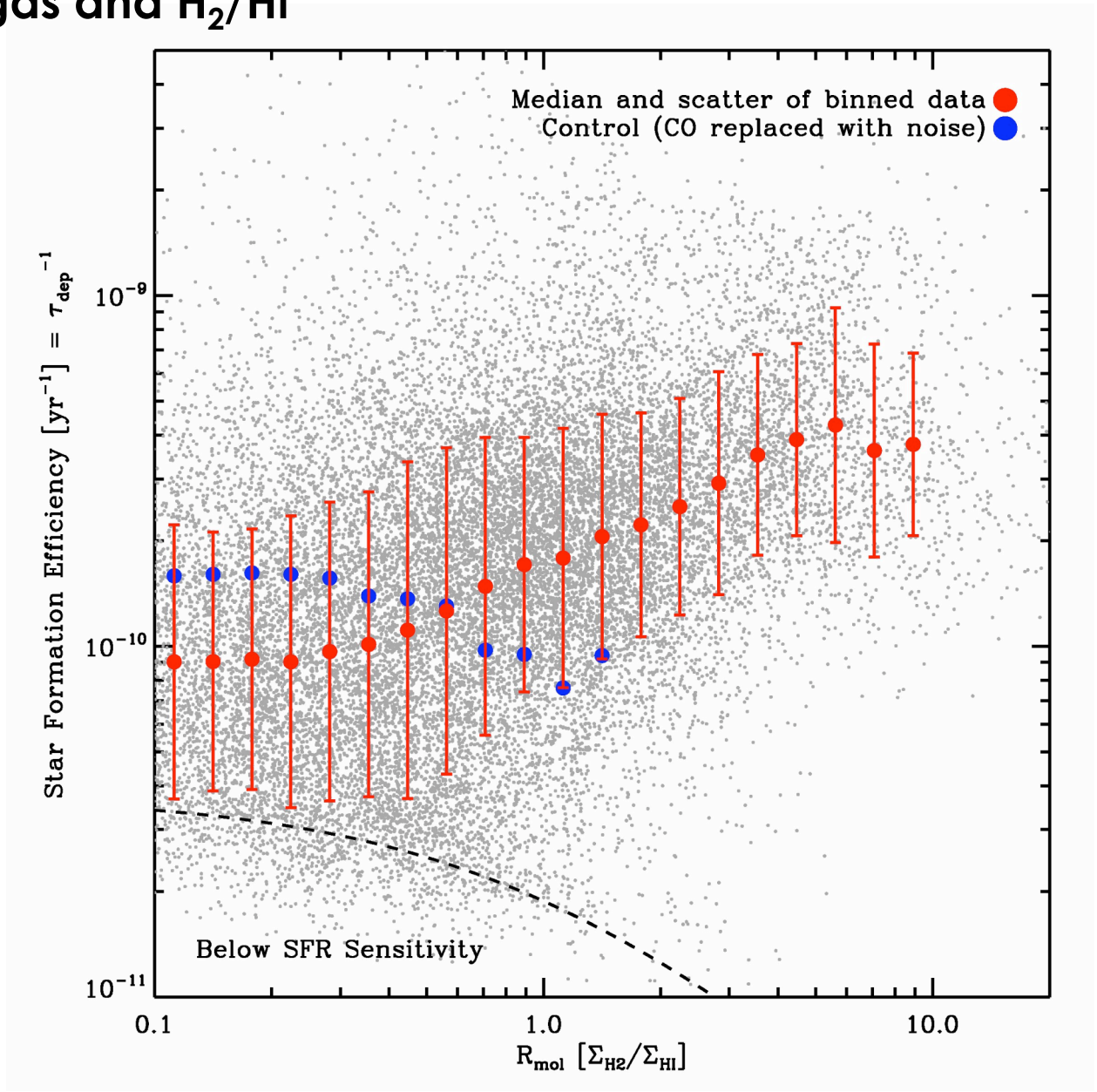

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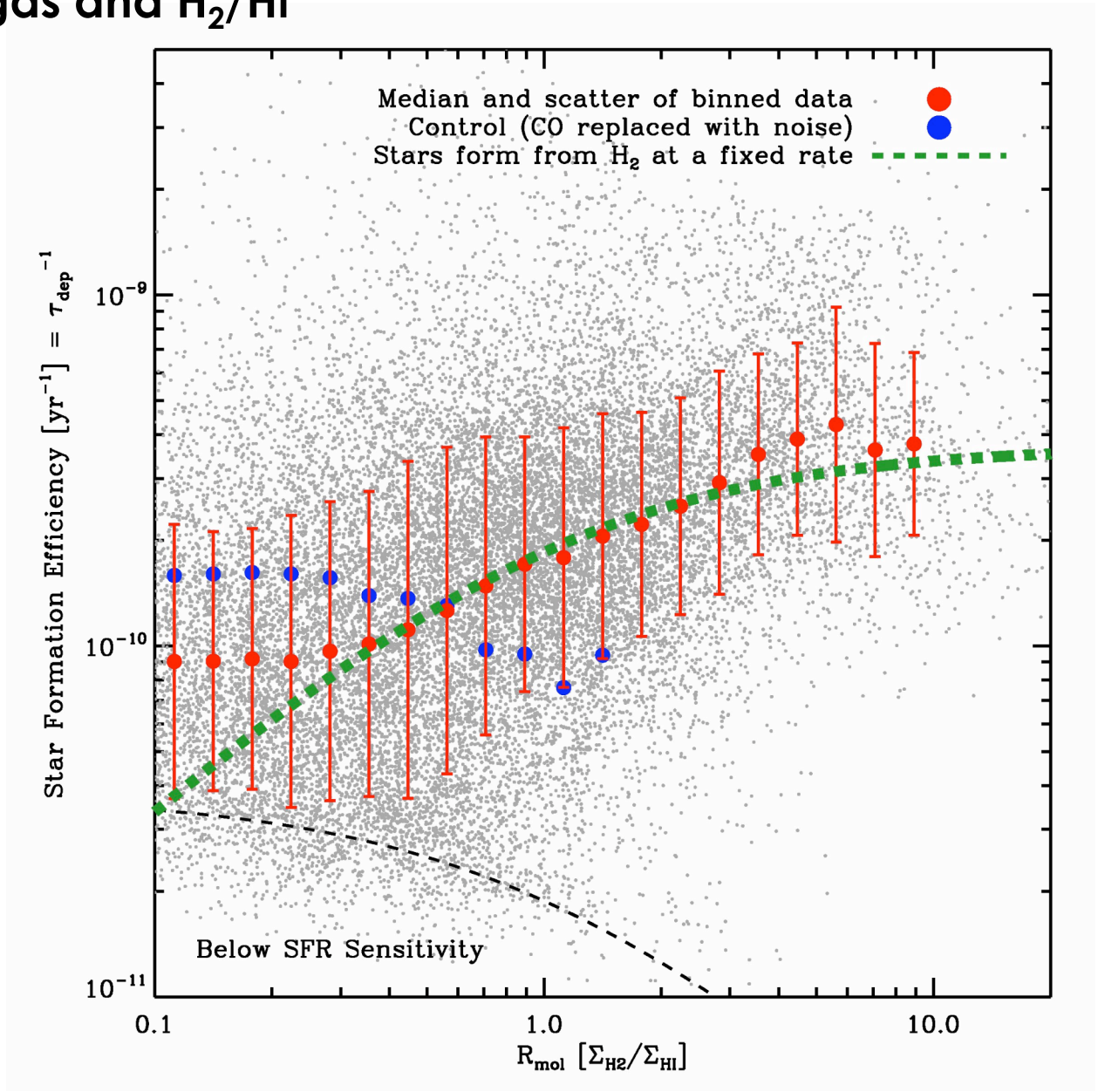
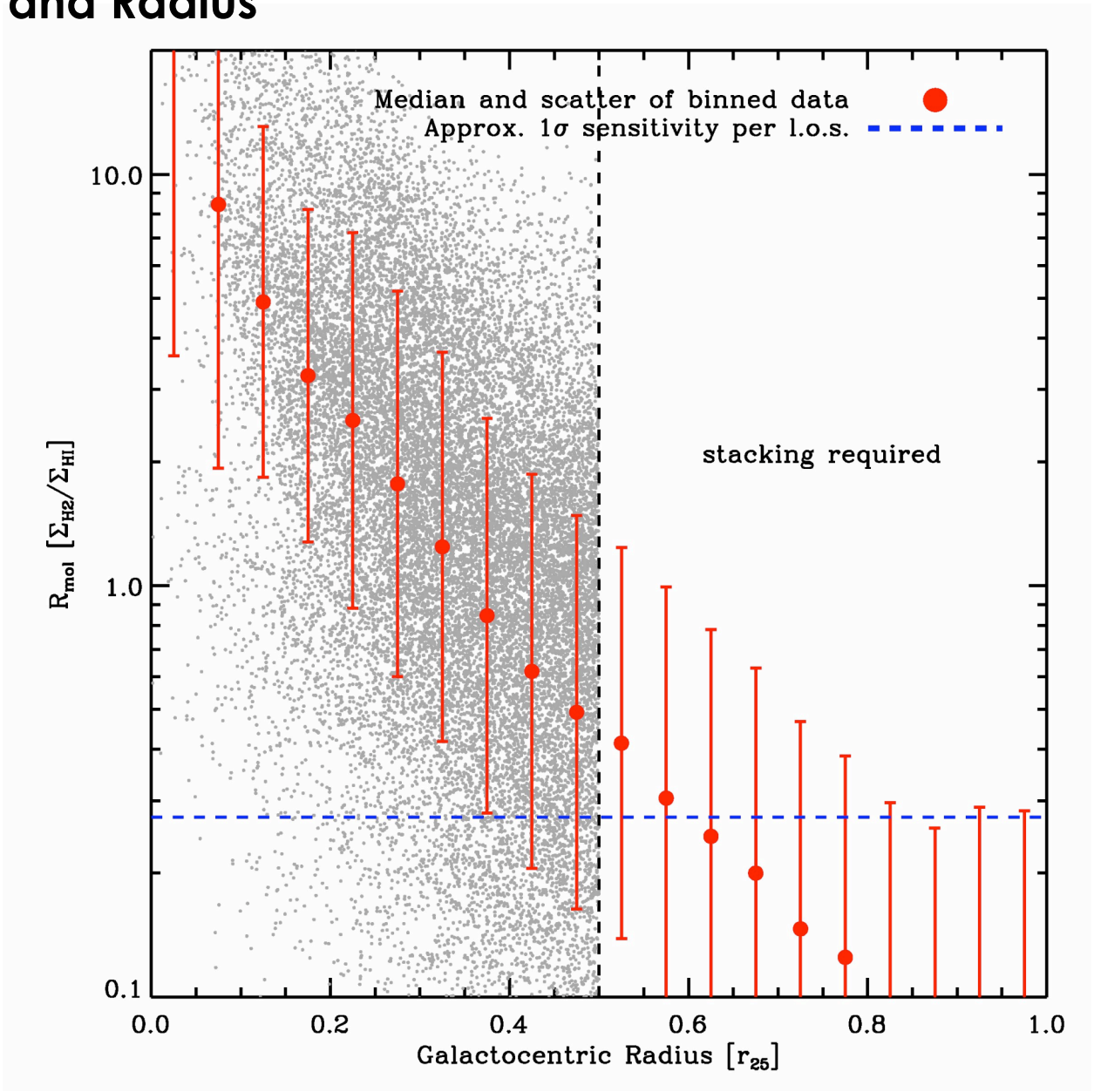


R_{mol} vs. Radius

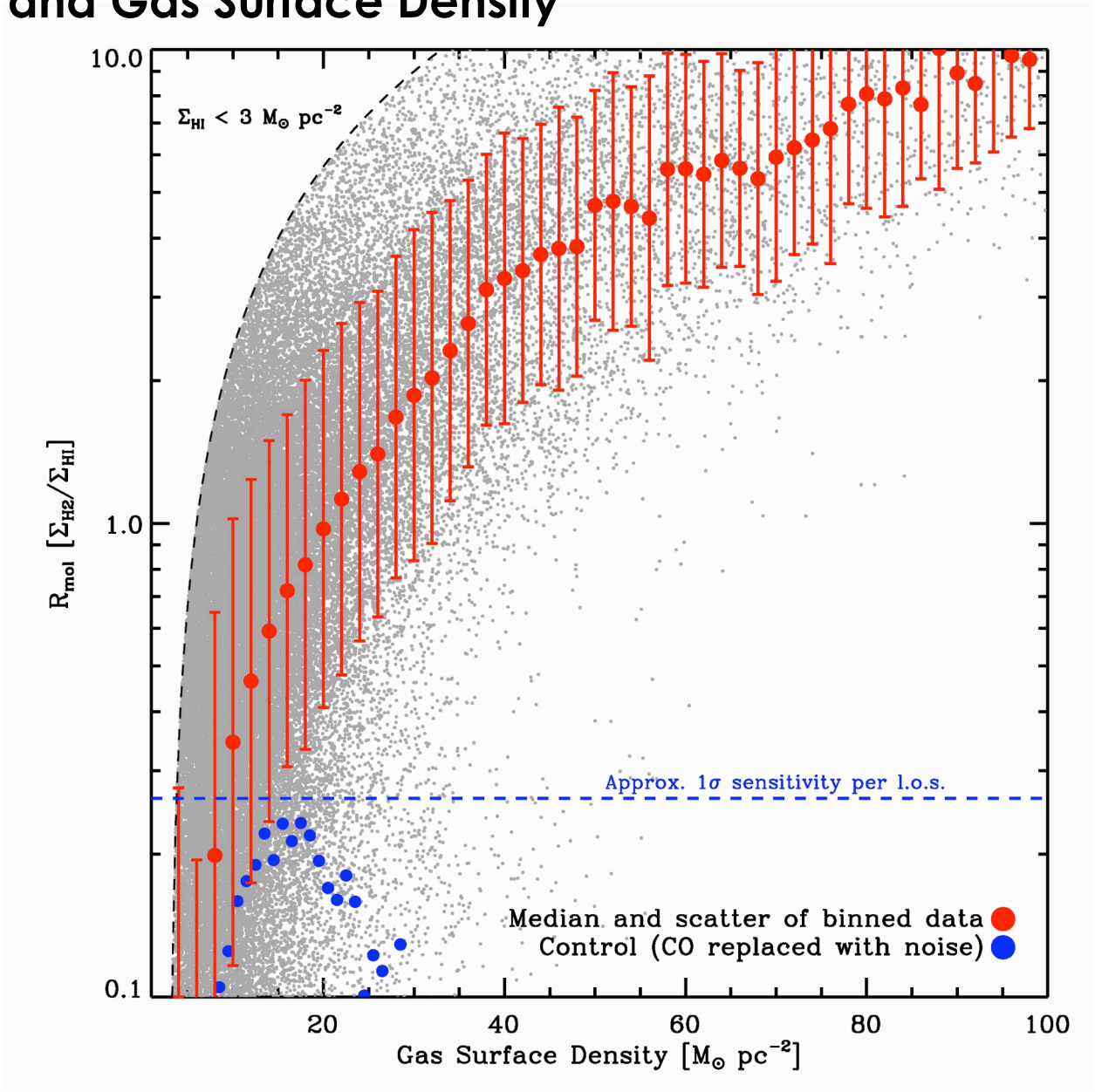
H_2/HI and Radius



Young+ '95, Wong & Blitz '02, Heyer+ '04

R_{mol} vs. Gas

H_2/HI and Gas Surface Density



Krumholz+ '09ab

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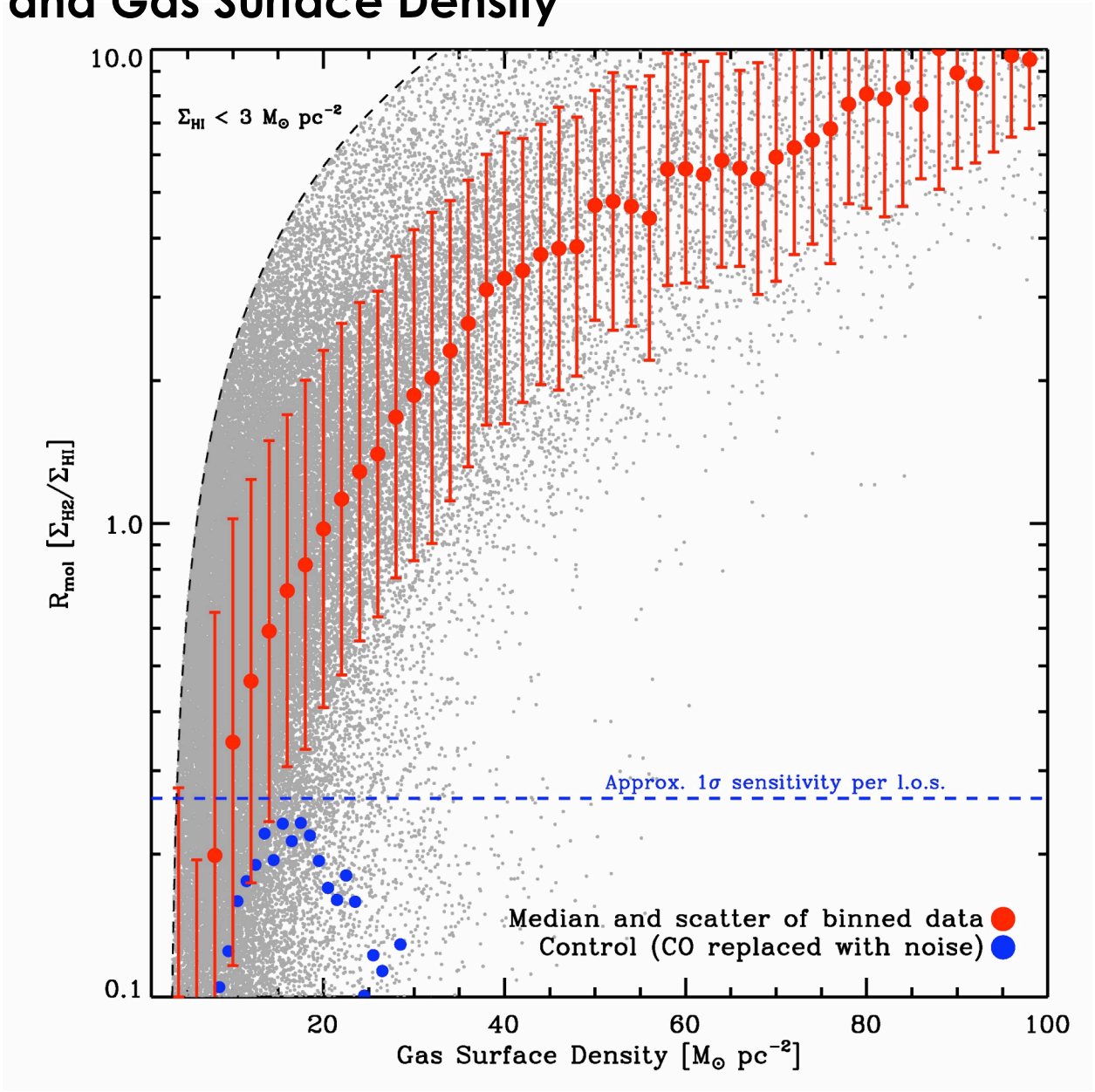
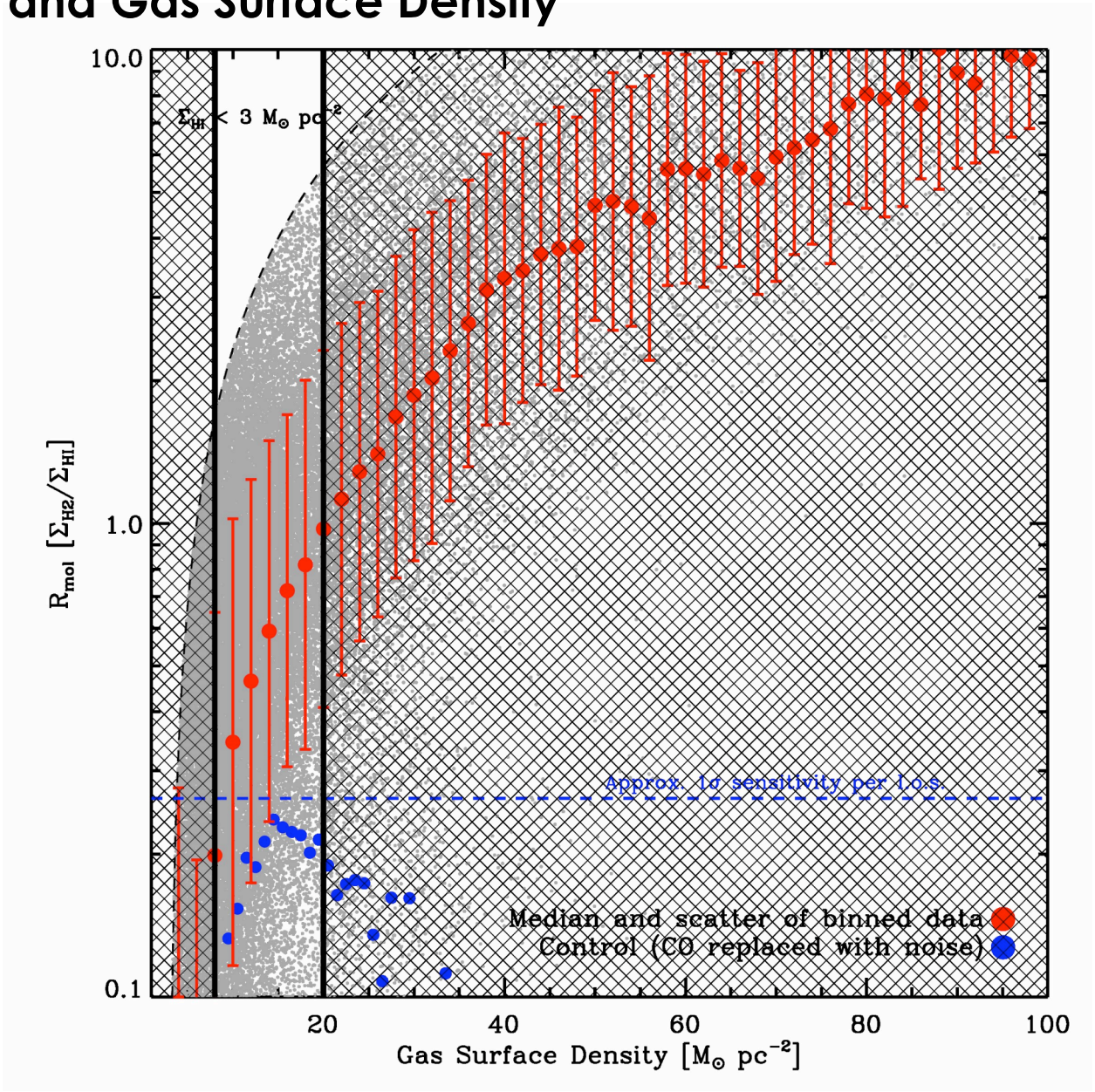
H_2/HI and Gas Surface Density



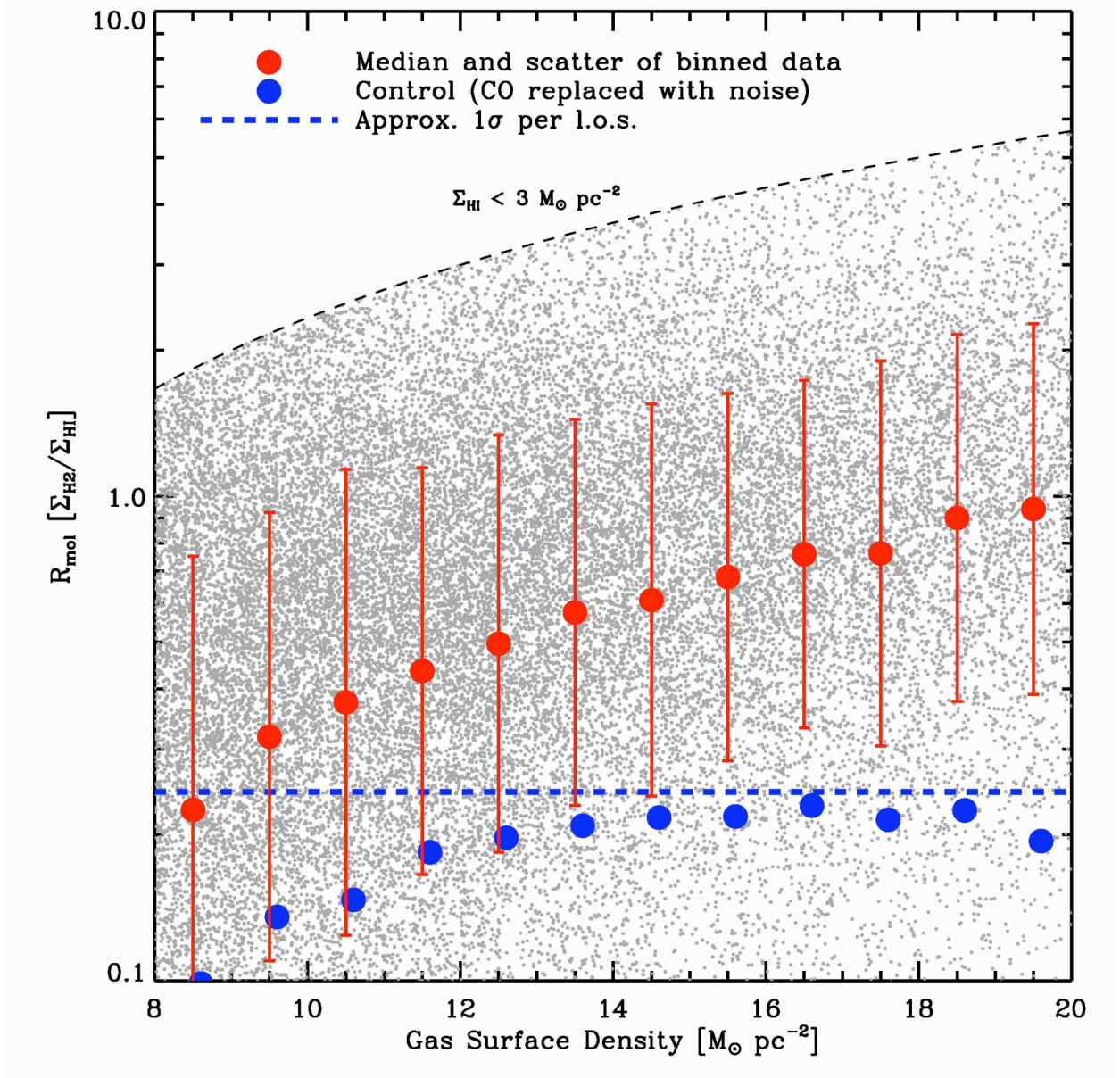
Where the Action is…

H_2/HI and Gas Surface Density



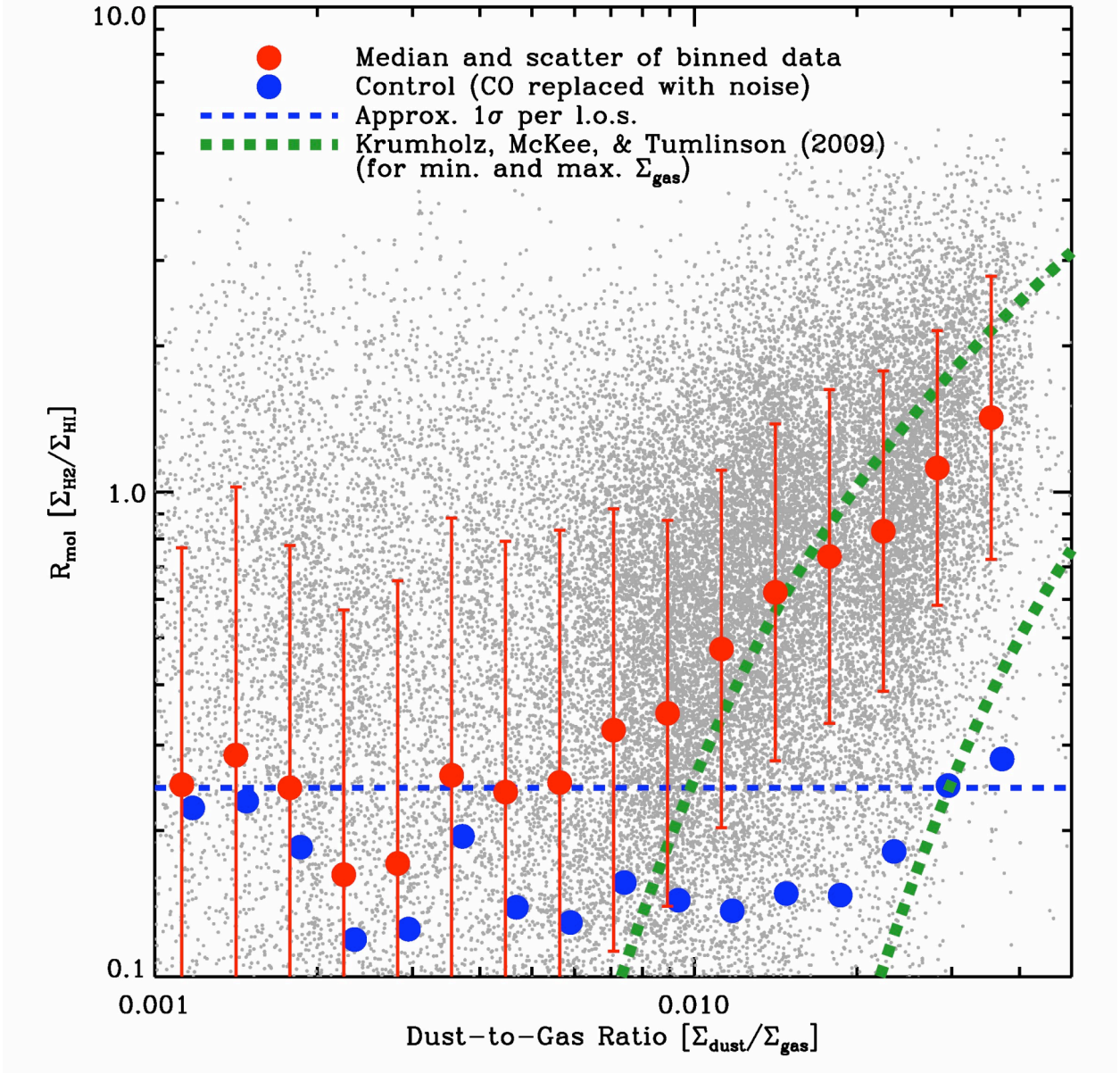
Zoomed In…

H_2/HI and Gas Surface Density (over a narrow range of Σ_{gas})



H_2/HI vs. **DGR** over 8 - 20 M_{sun} pc^{-2}

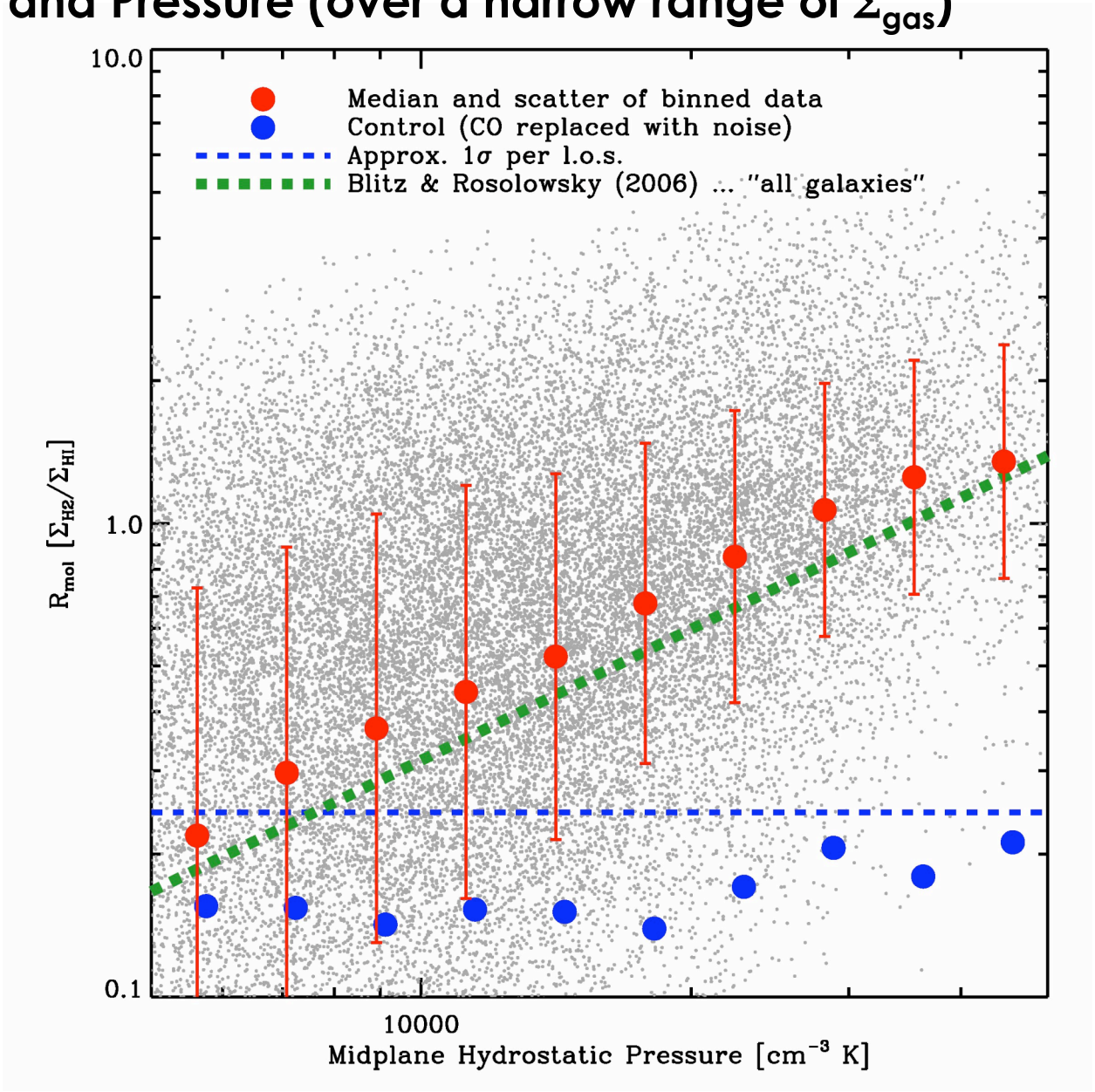
H_2/HI and Dust-to-Gas Ratio (over a narrow range of Σ_{gas})



Draine & Li '07, Robertson & Kravtsov '08; Krumholz+ '09ab; Gnedin+ '09

H_2/HI vs. **Pressure** over 8 - 20 M_{sun} pc^{-2}

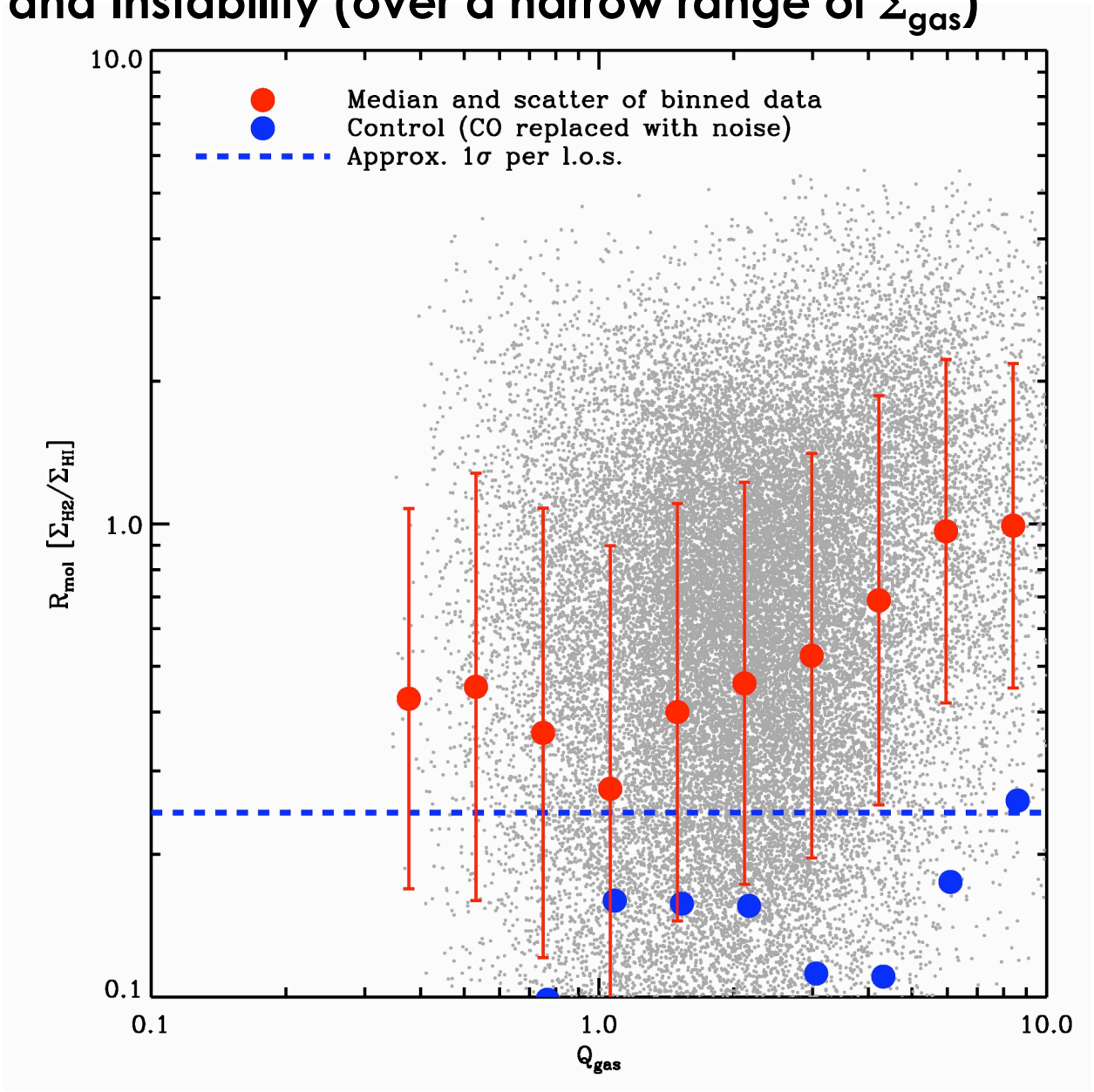
H_2/HI and Pressure (over a narrow range of Σ_{gas})



Elmegreen & Parravano '94, Wong & Blitz '02, Blitz & Rosolowsky '04, '06

H_2/HI and Instability (over a narrow range of Σ_{gas})

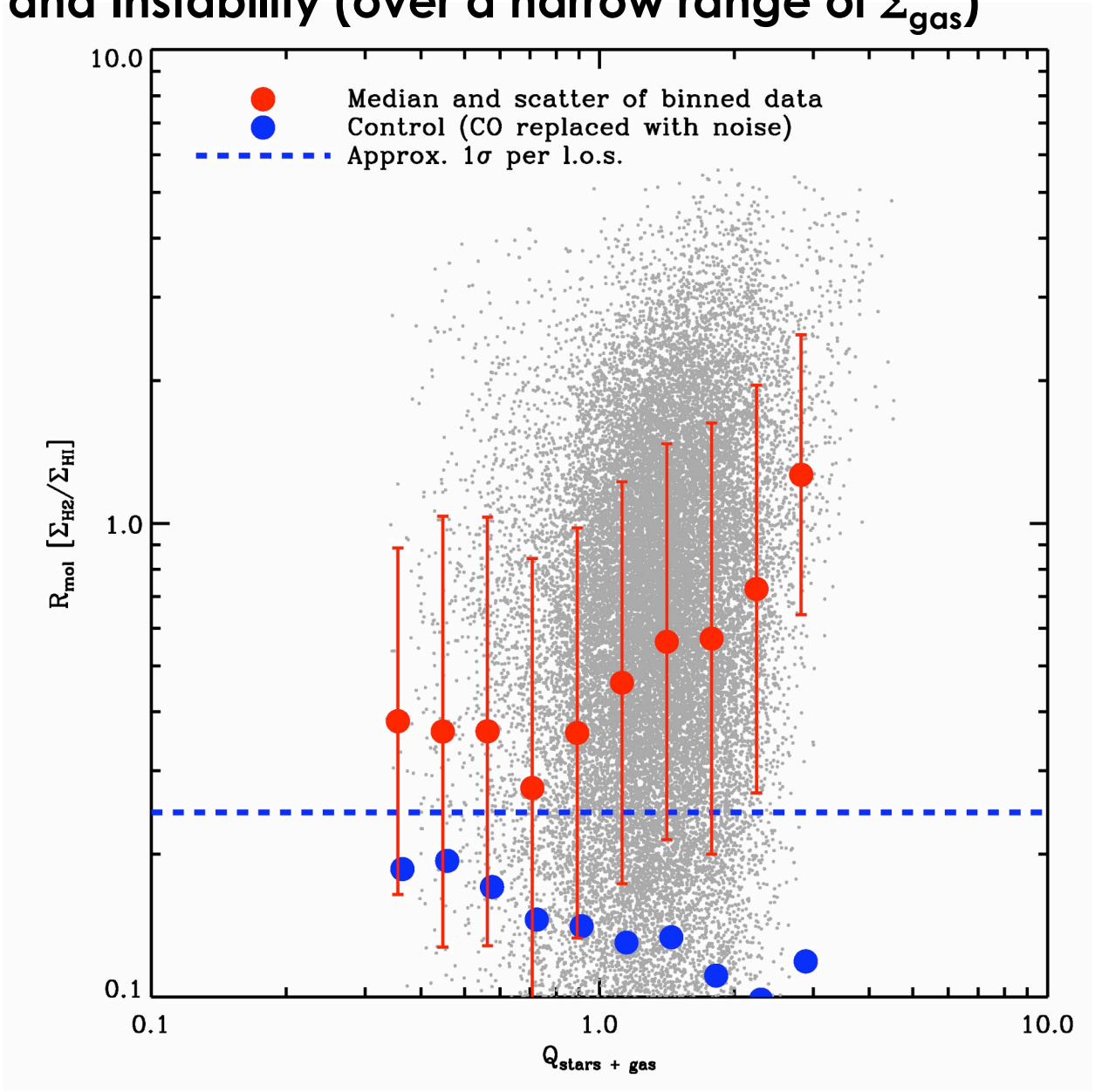
H_2/HI vs. Q_{gas} over 8 - 20 M_{sun} pc^{-2}



Martin & Kennicutt '01, Wong & Blitz '02, Kim & Ostriker '01, '07, Boissier+ '03

H_2/HI vs. $Q_{stars+gas}$ over 8 - 20 M_{sun} pc^{-2}

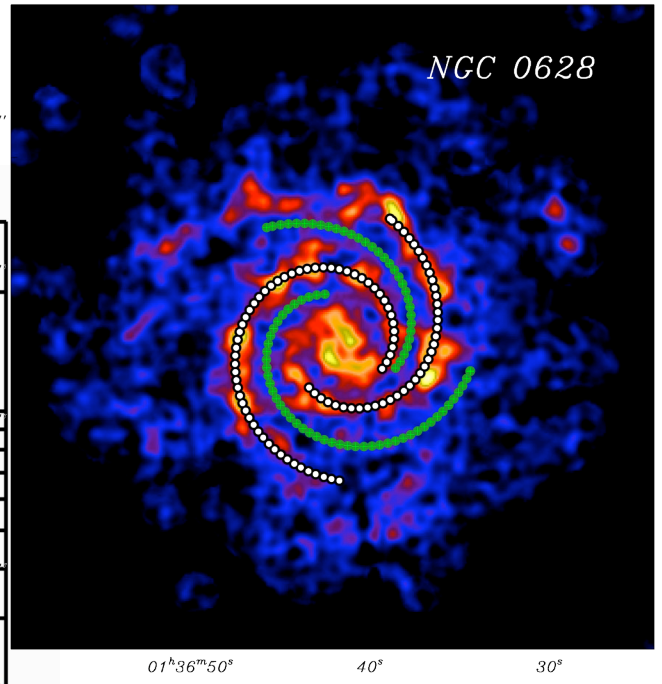
H_2/HI and Instability (over a narrow range of Σ_{gas})

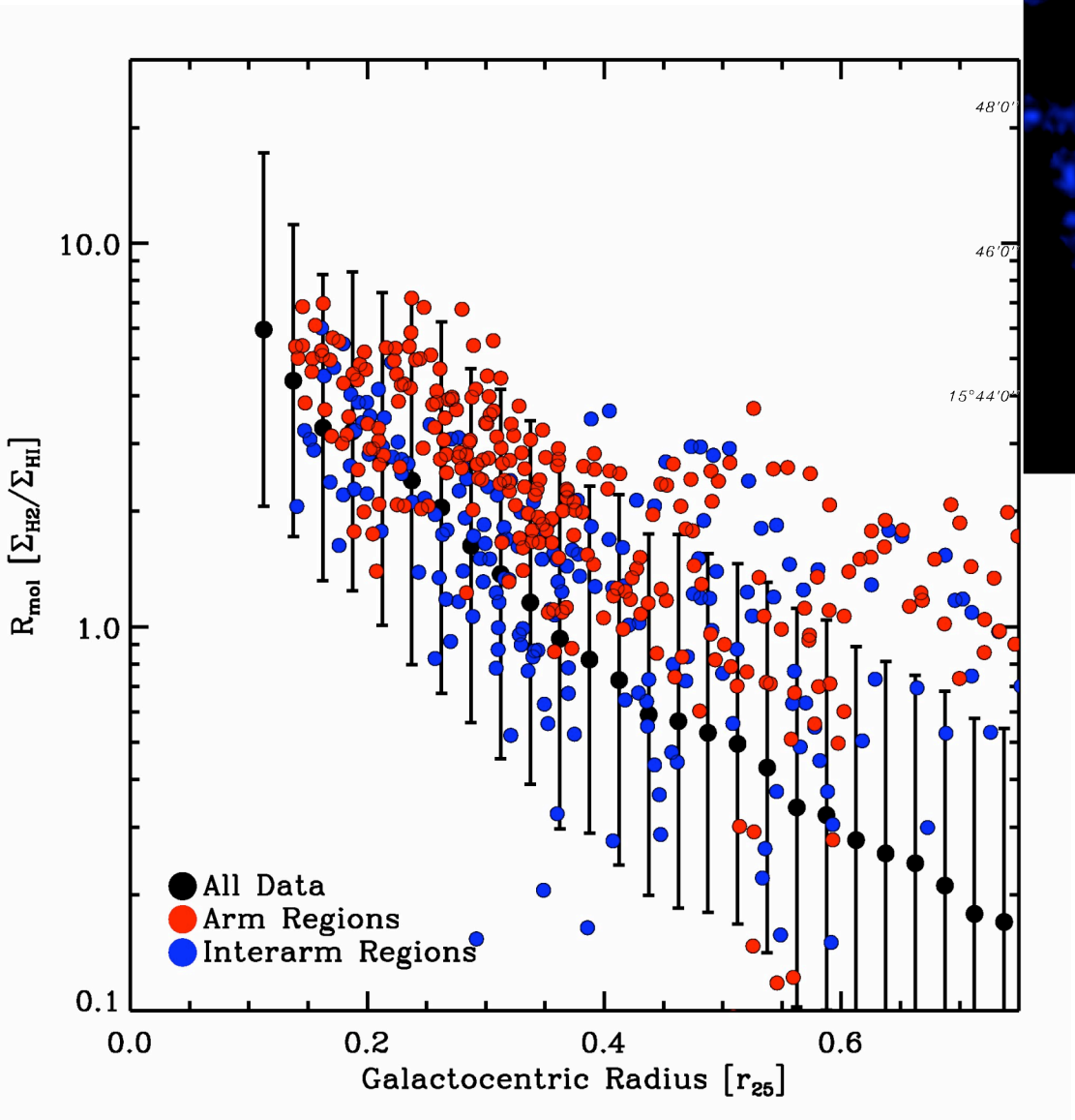


Wang & Silk '94, Rafikov '01, Boissier+ '03, Li+ '05,'06, Yang+ '07

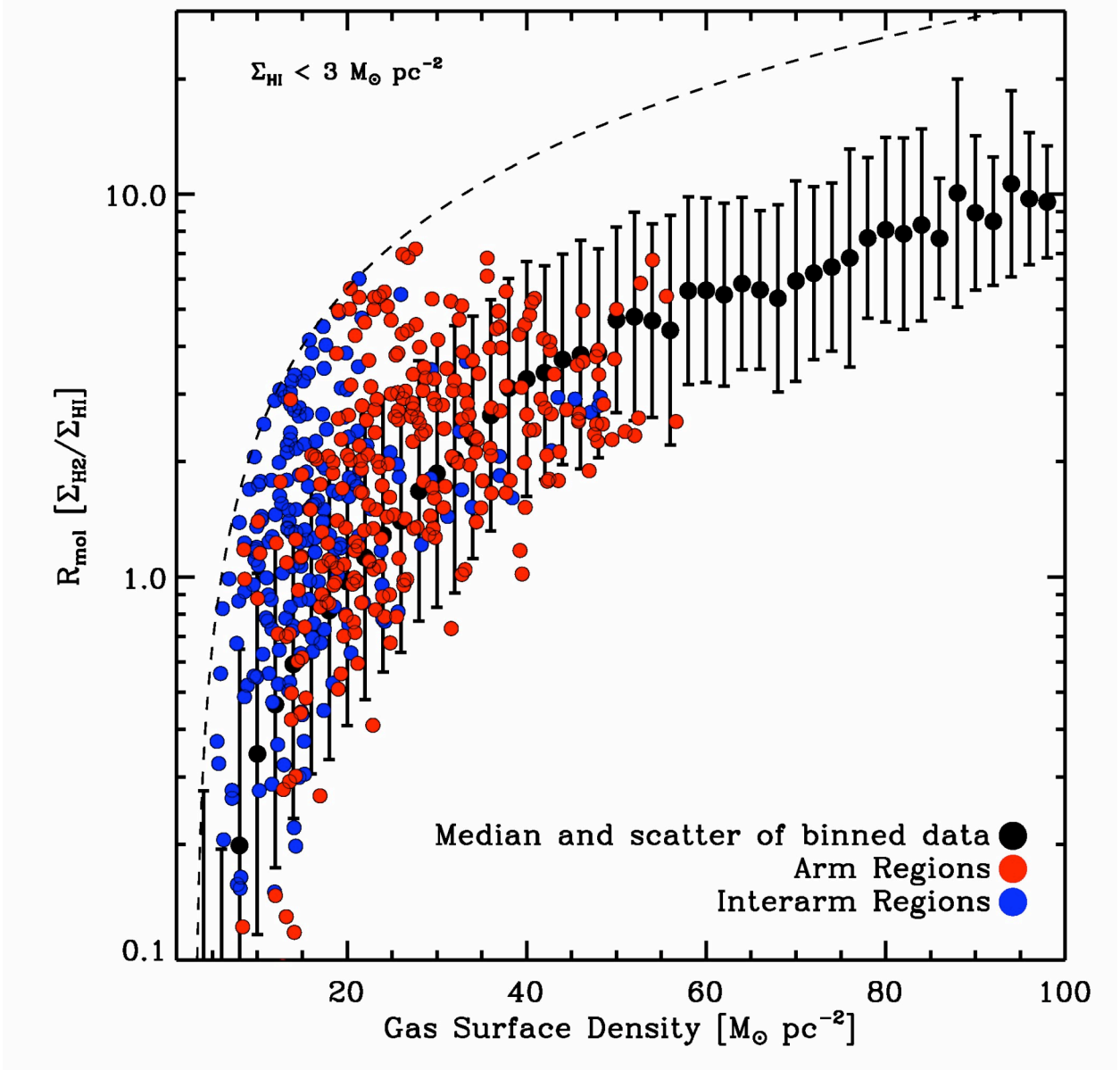
H_2/HI and Radius (for Arm and Interarm Regions)

Spiral Shocks?





H_2/HI and Gas Surface Density (for Arm and Interarm Regions)



Spiral Shocks?

Where is the ISM Good At Forming Stars?

- The ISM is good at forming stars where gas is **molecular**.
- Gas is molecular …
  - where the total gas surface density is high.
  - in the inner parts of galaxies.
- For gas surface densities near $R_{mol} = H_2/HI \sim 1$ …
  - dust-to-gas ratio and pressure correlate with R_{mol}.
  - disks marginally stable, Q shows weak/anti correlation with R_{mol}.
  - spiral arms: enhanced R_{mol} just a result of higher Σ_{gas} .
- H_2 formation driven by ISM physics not large-scale processes?
- **HERACLES**, THINGS, SINGS, GALEX ++ :
  large, growing database to test theories of the ISM and star formation.

Leroy, Walter, Brinks, Bigiel, de Blok, Madore, & Thornley, 2008, AJ, 136, 278 (+ new stuff)

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