How Do you Determine the H_2 Content of a Dwarf? (or any galaxy)?

Desika Narayanan
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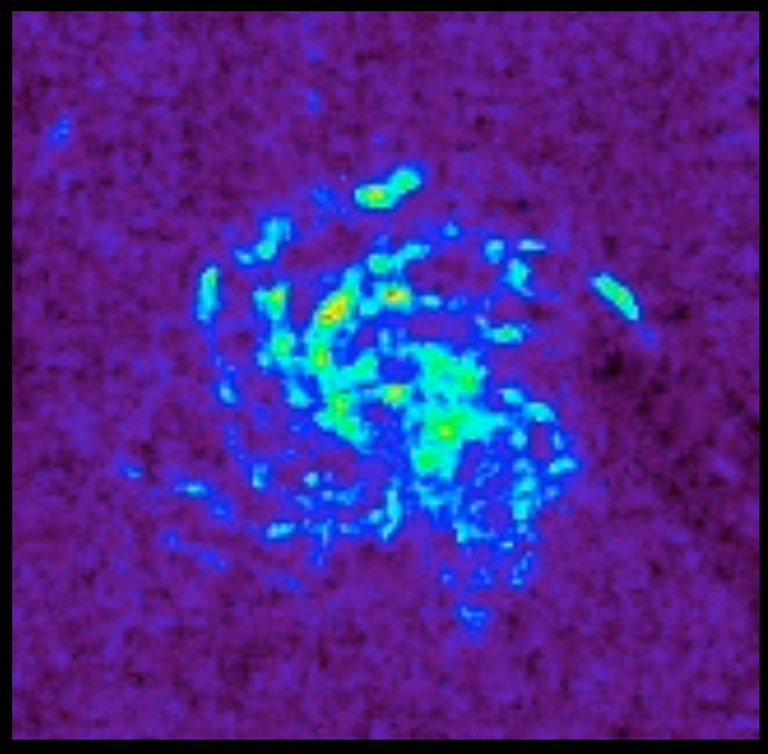
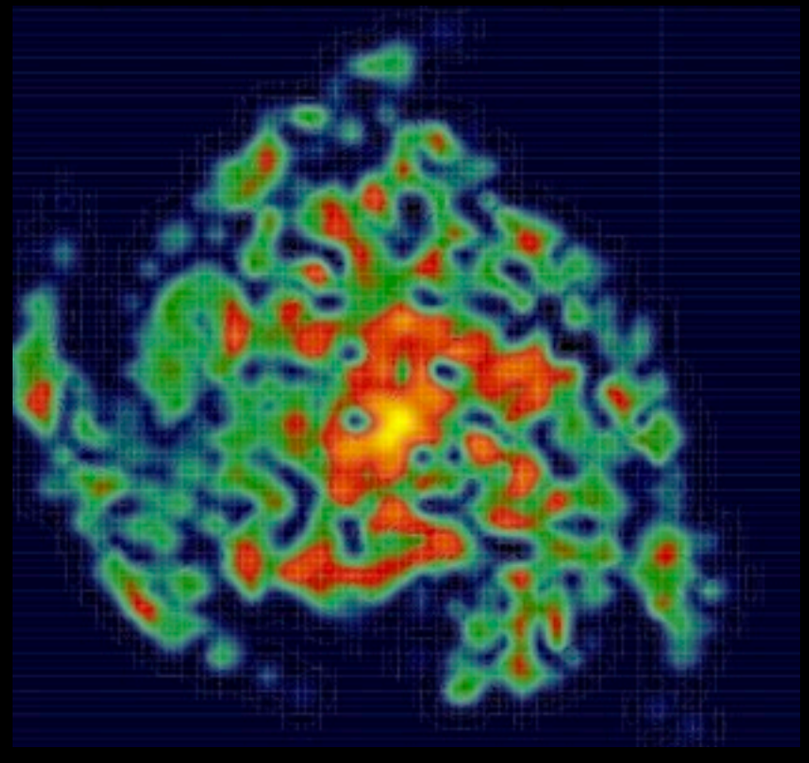
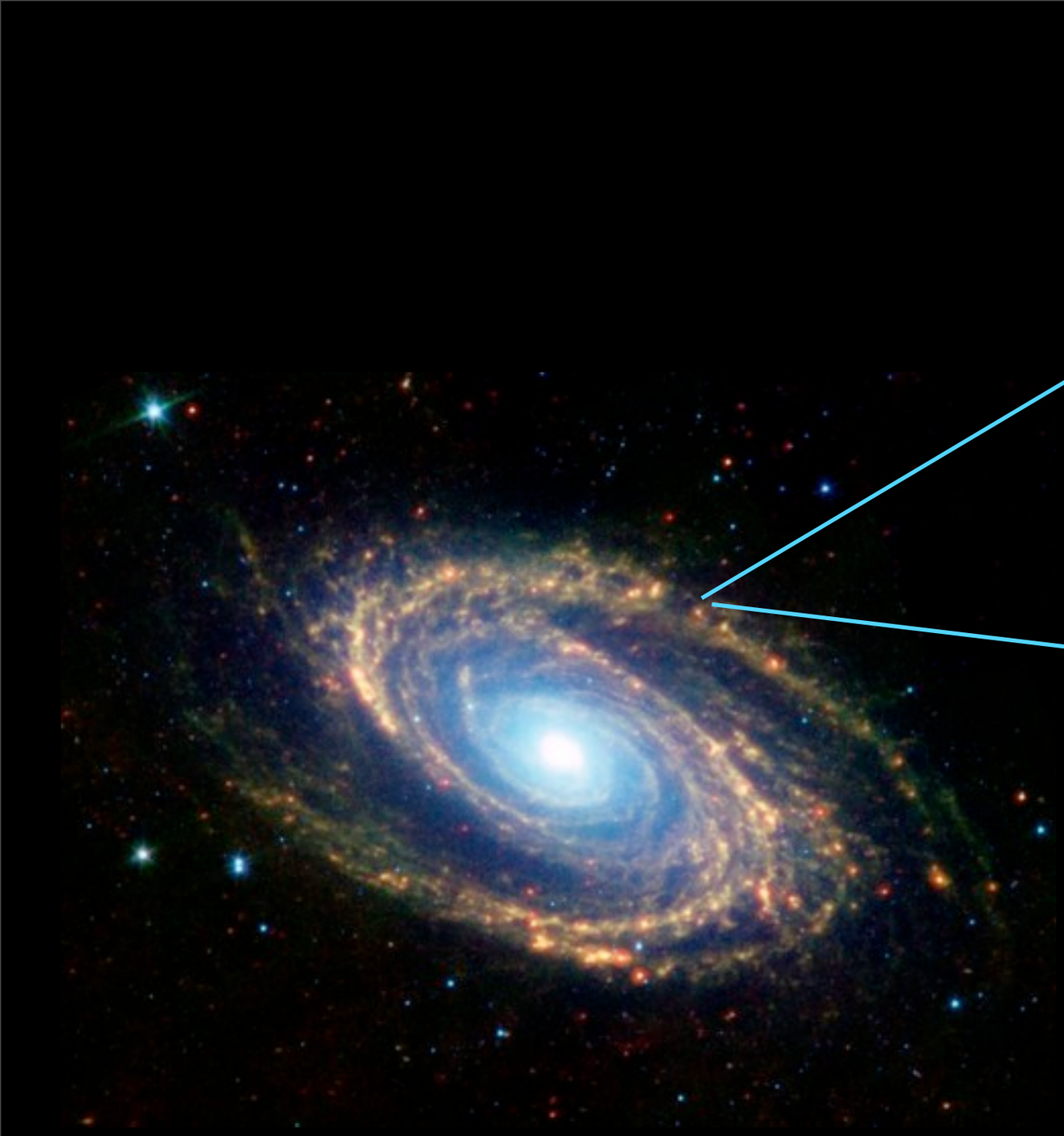
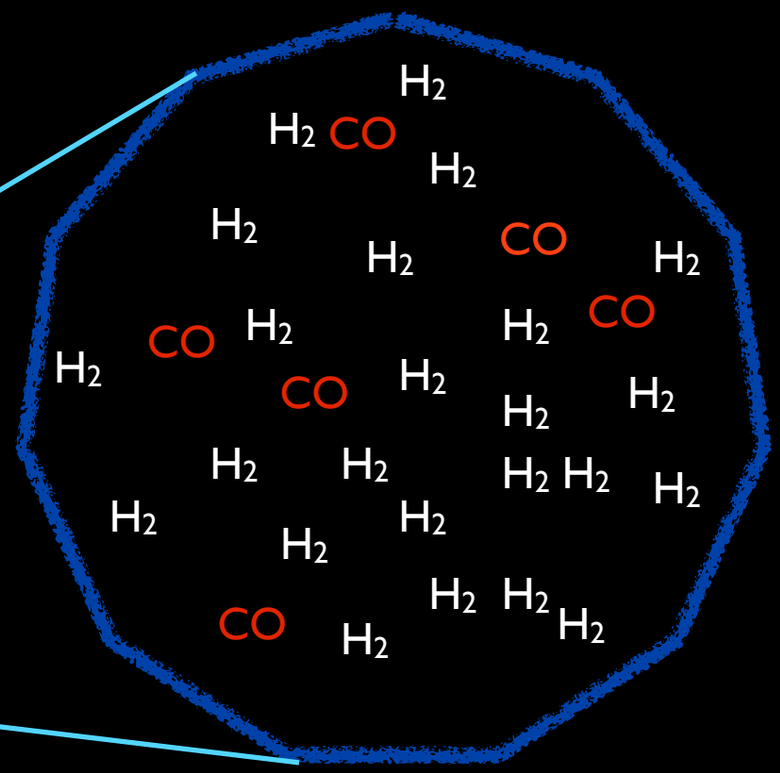




(with Mark Krumholz, Eve Ostriker, Lars Hernquist)



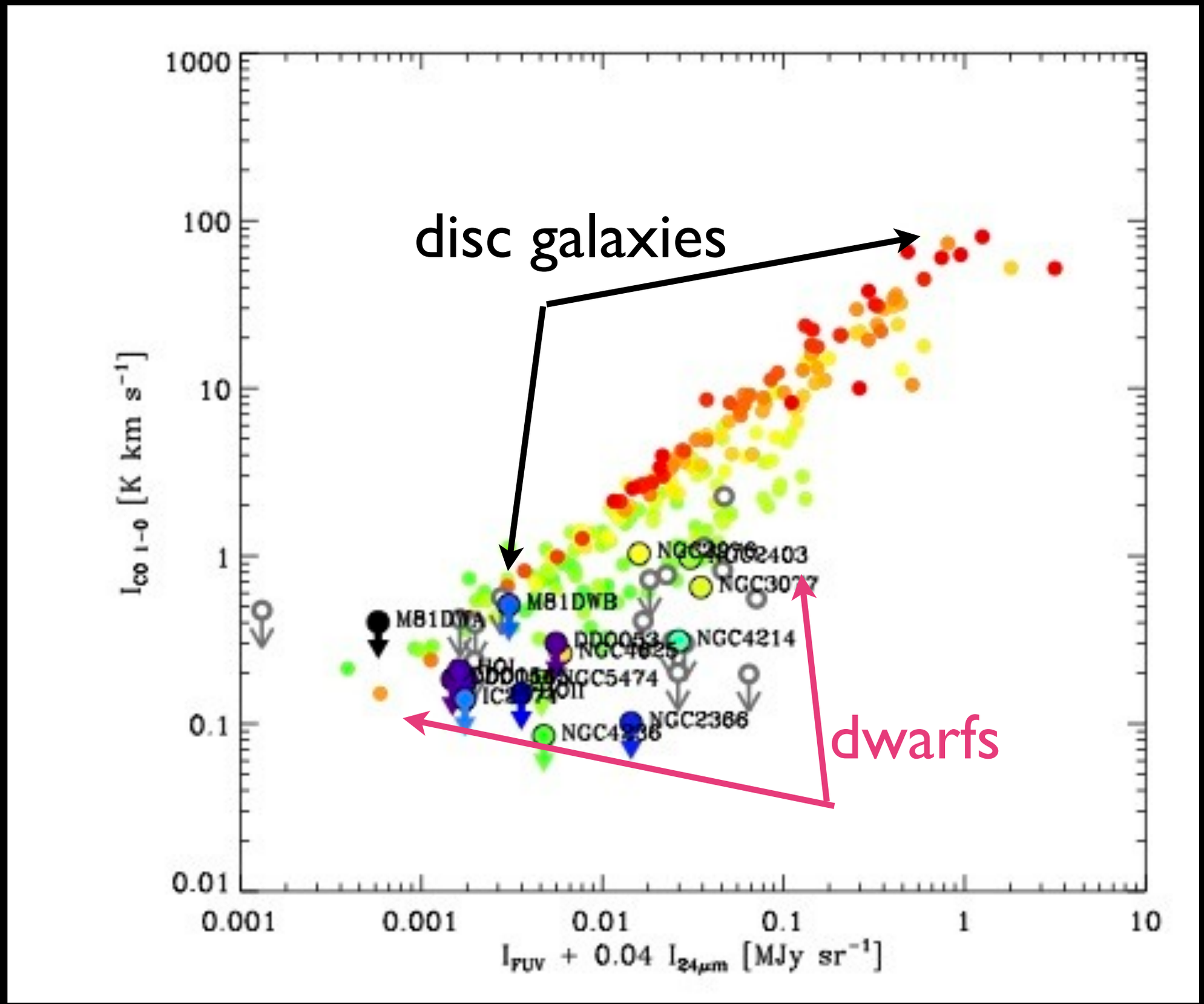


I. Assume GMC is viralized and use CO line width as mass measurement

II. Assume a DTG ratio and get dust masses

III. CR + H_2 --> γ-ray

$$X_{CO} = N_{H2}/W_{co} = 2\text{-}4 \times 10^{20}\ cm^{-2}/K\text{-}km\ s^{-1}$$

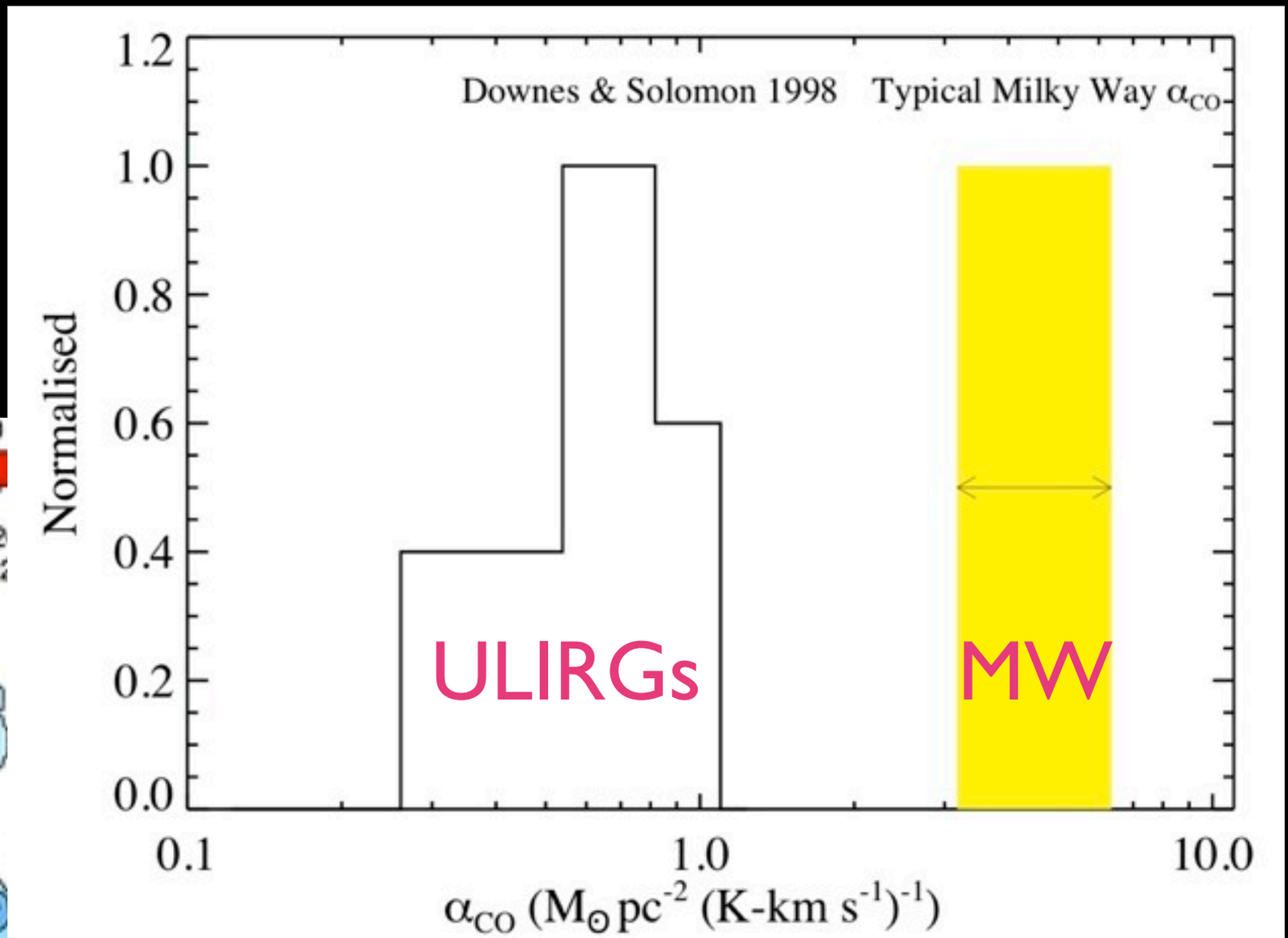


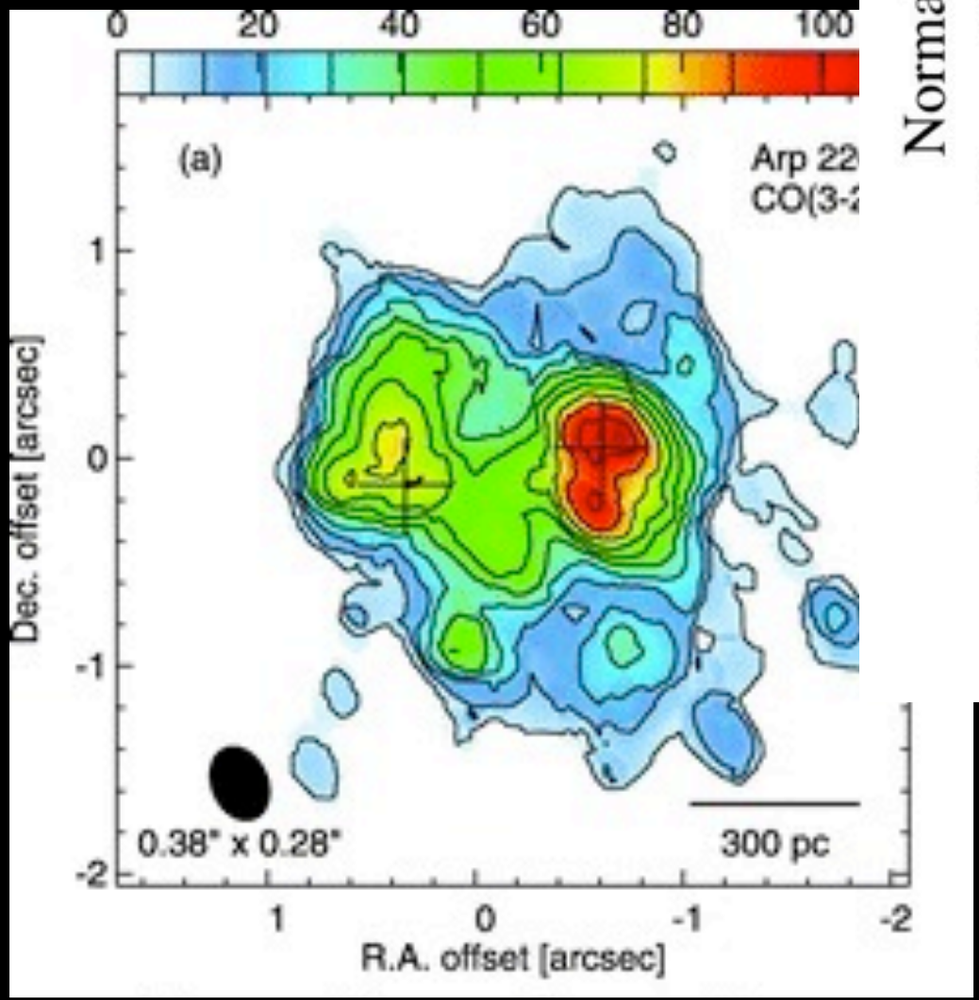
W_{CO} ⟶

SFR ⟶

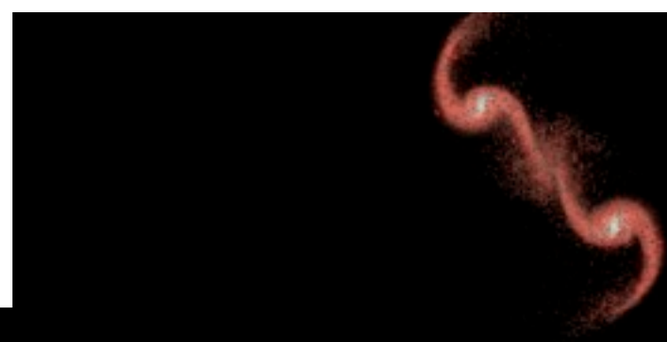
Schruba, Leroy et al. 2012
Taylor et al. 1998

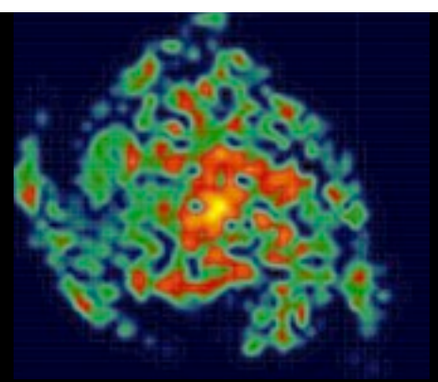
Narayanan (2011)

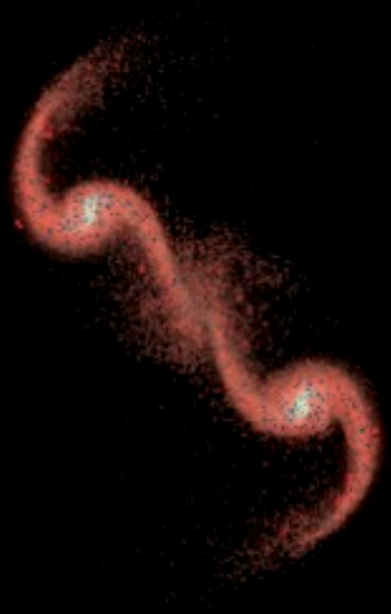


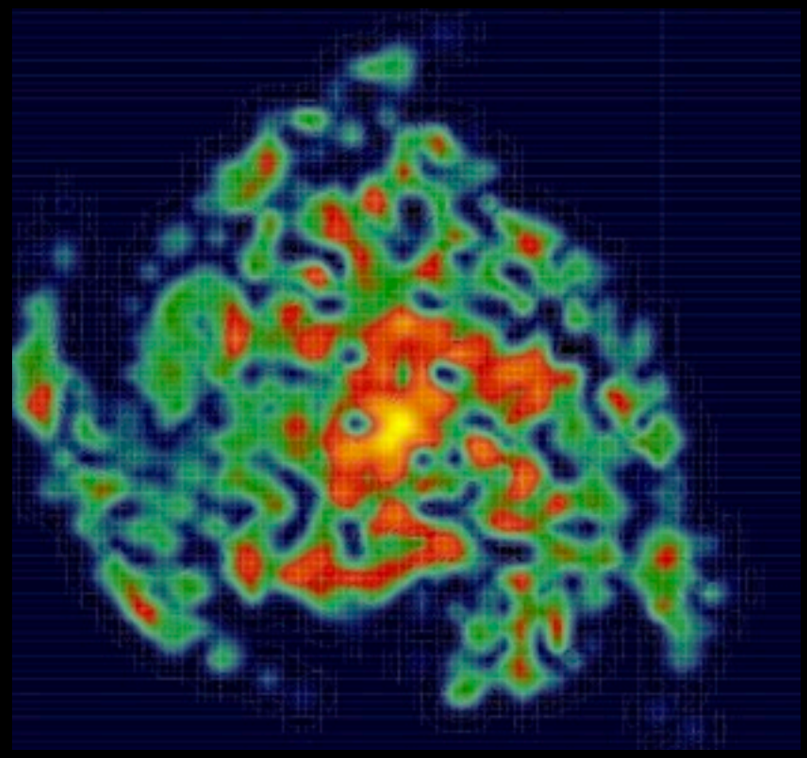


Sakamoto et al. 2008









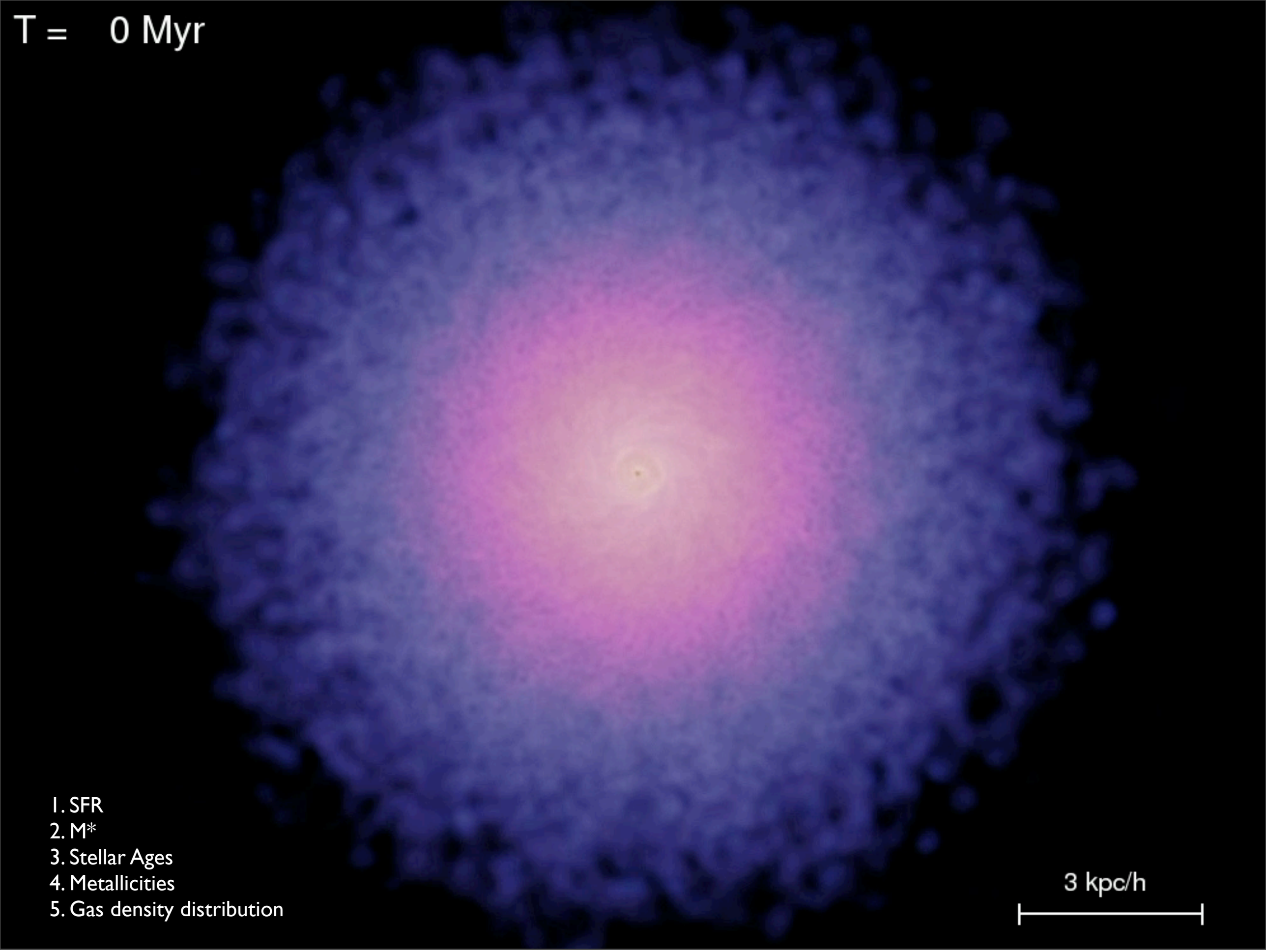
“Merger Value”

X_{CO} ~ few x10^{19} cm^{-2}/K km s^{-1}

“Disk Value”

X_{CO} ~ 2x10^{20} cm^{-2}/K km s^{-1}

In the last decade of literature, this is used bimodally


T = 0 Myr
1. SFR
2. M*
3. Stellar Ages
4. Metallicities
5. Gas density distribution
3 kpc/h

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Lyman-Werner Band Photons

HI
H_2
H_2
HI
H_2
H_2
Z'
H_2
H_2
H_2
Z'
HI
Z'
HI
H_2
H_2
H_2
H_2
H_2
H_2
H_2
HI

Krumholz, McKee & Tumlinson (2008,2009)

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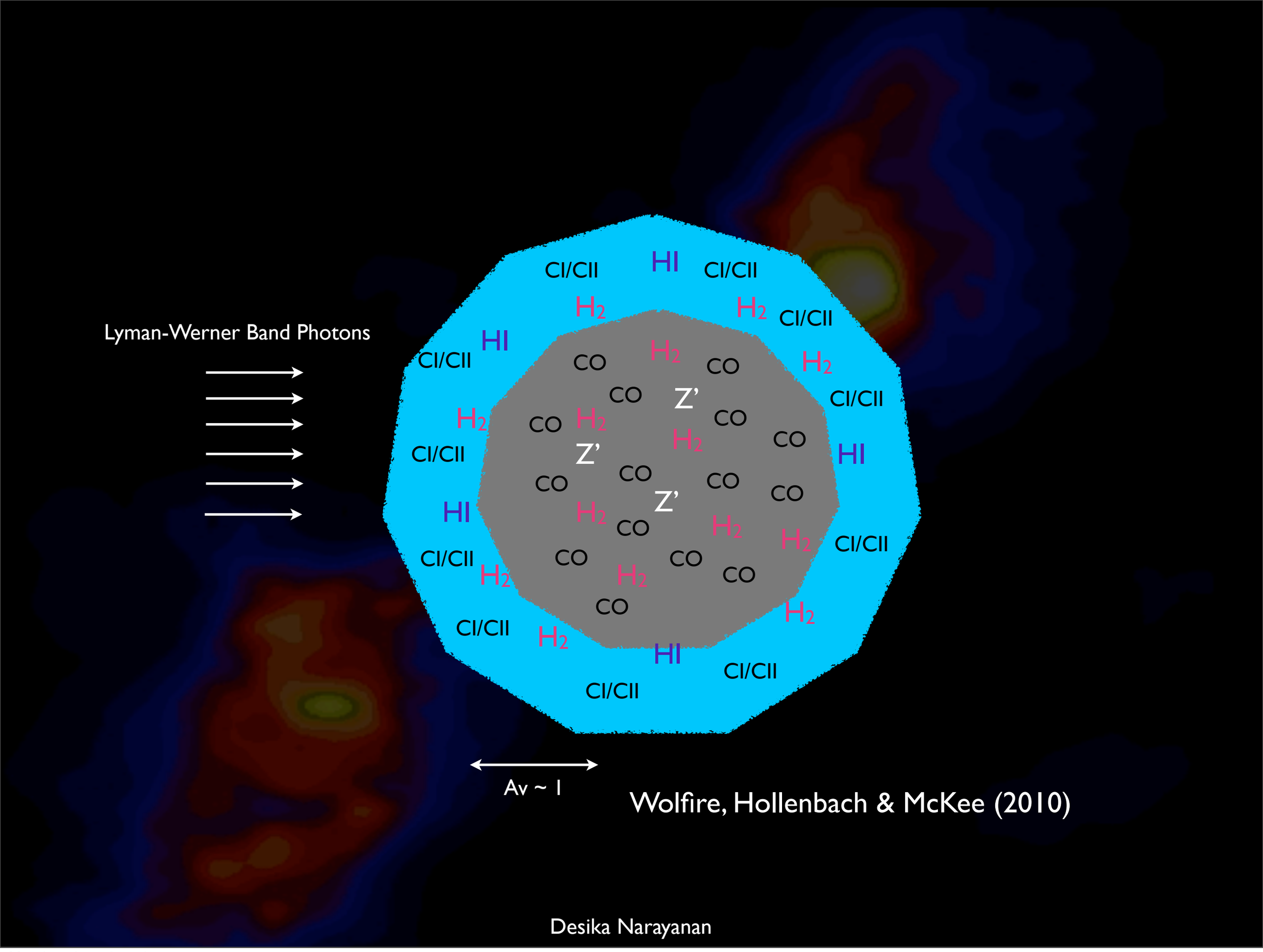
Lyman-Werner Band Photons
CI/CII
HI
CI/CII
H2
H2
CI/CII
HI
CI/CII
CO
H2
CO
CO
Z'
H2
CO
H2
CO
CI/CII
Z'
H2
CO
HI
CO
CO
CO
Z'
HI
H2
CO
H2
H2
CI/CII
CI/CII
CO
CO
CO
H2
CO
H2
H2
CI/CII
HI
CI/CII
CI/CII
Av ~ 1
Wolfire, Hollenbach & McKee (2010)
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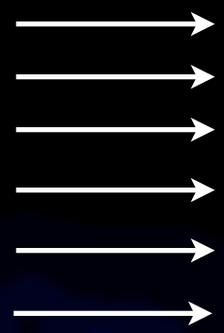
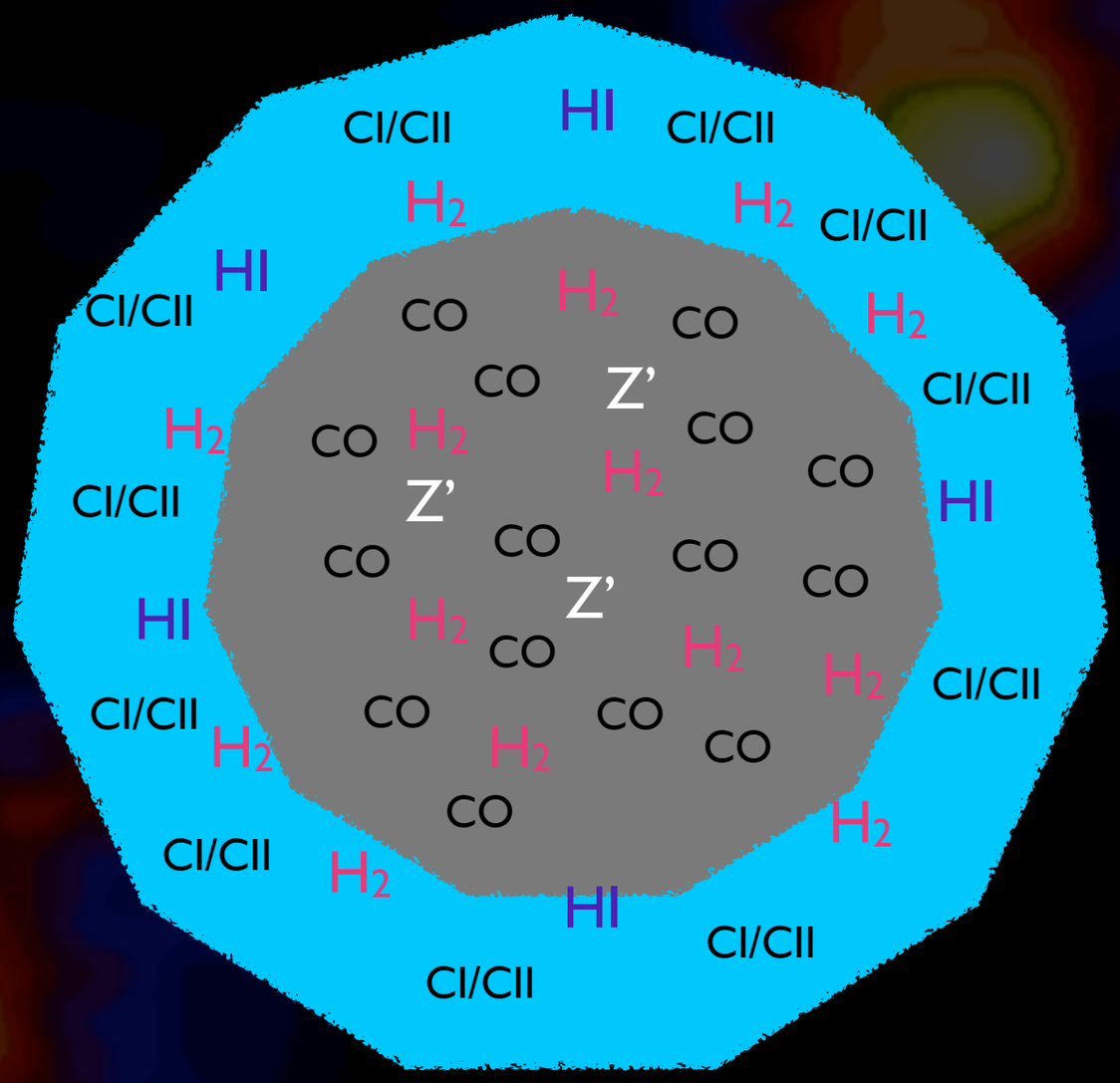
$$\Gamma_{\rm pe} + \Gamma_{\rm CR} - \Lambda_{\rm line} + \Psi_{\rm gd} = 0$$

Lyman-Werner Band Photons





Av ~ 1

Goldsmith (2001)

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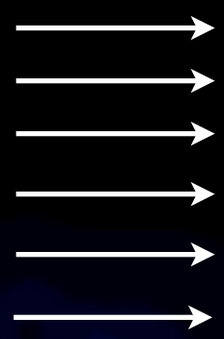
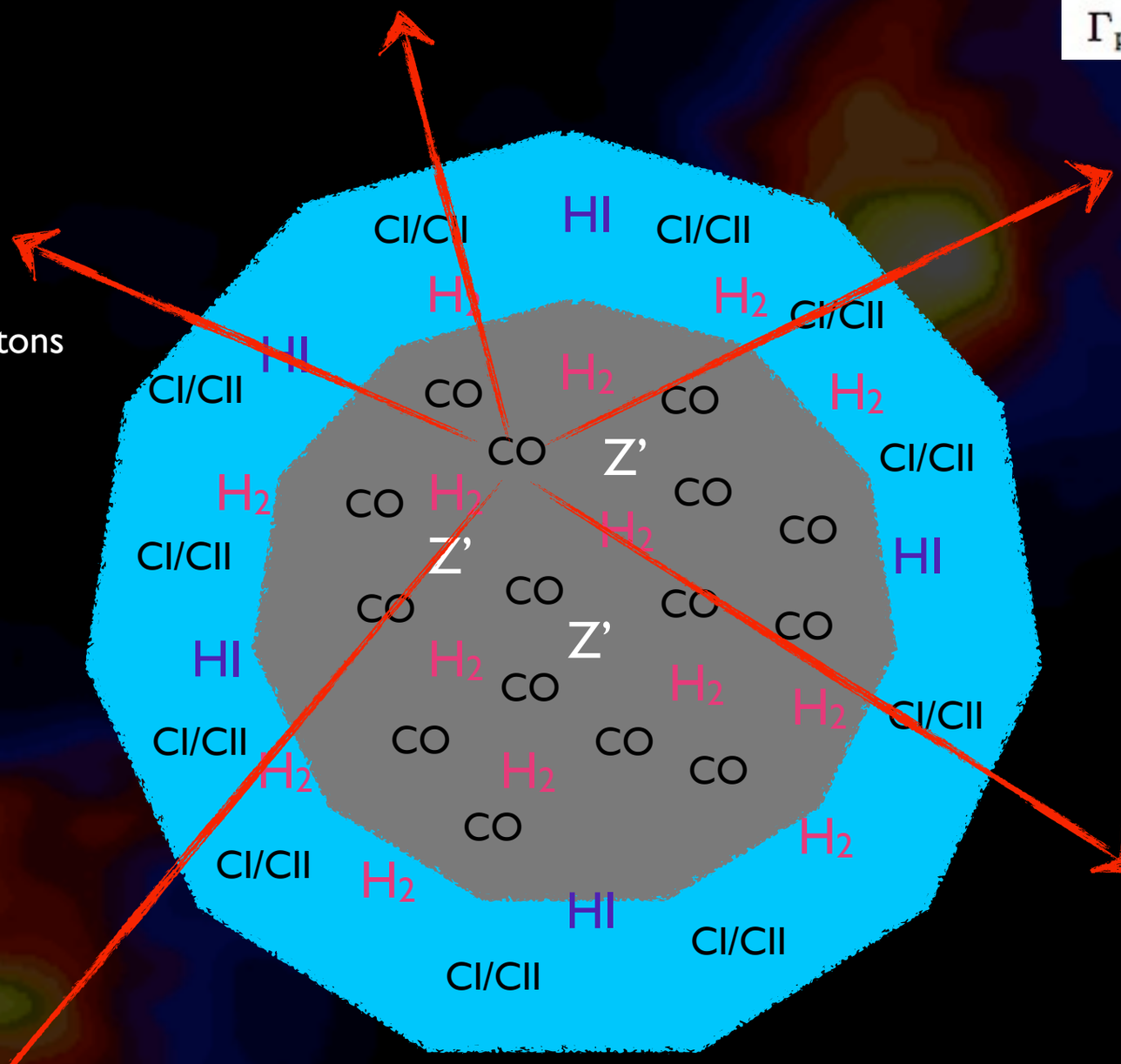
$$\Gamma_{\rm pe} + \Gamma_{\rm CR} - \Lambda_{\rm line} + \Psi_{\rm gd} = 0$$

Lyman-Werner Band Photons





Av ~ 1

Krumholz, McKee & Leroy (2011)
Narayanan et al. (2011b)

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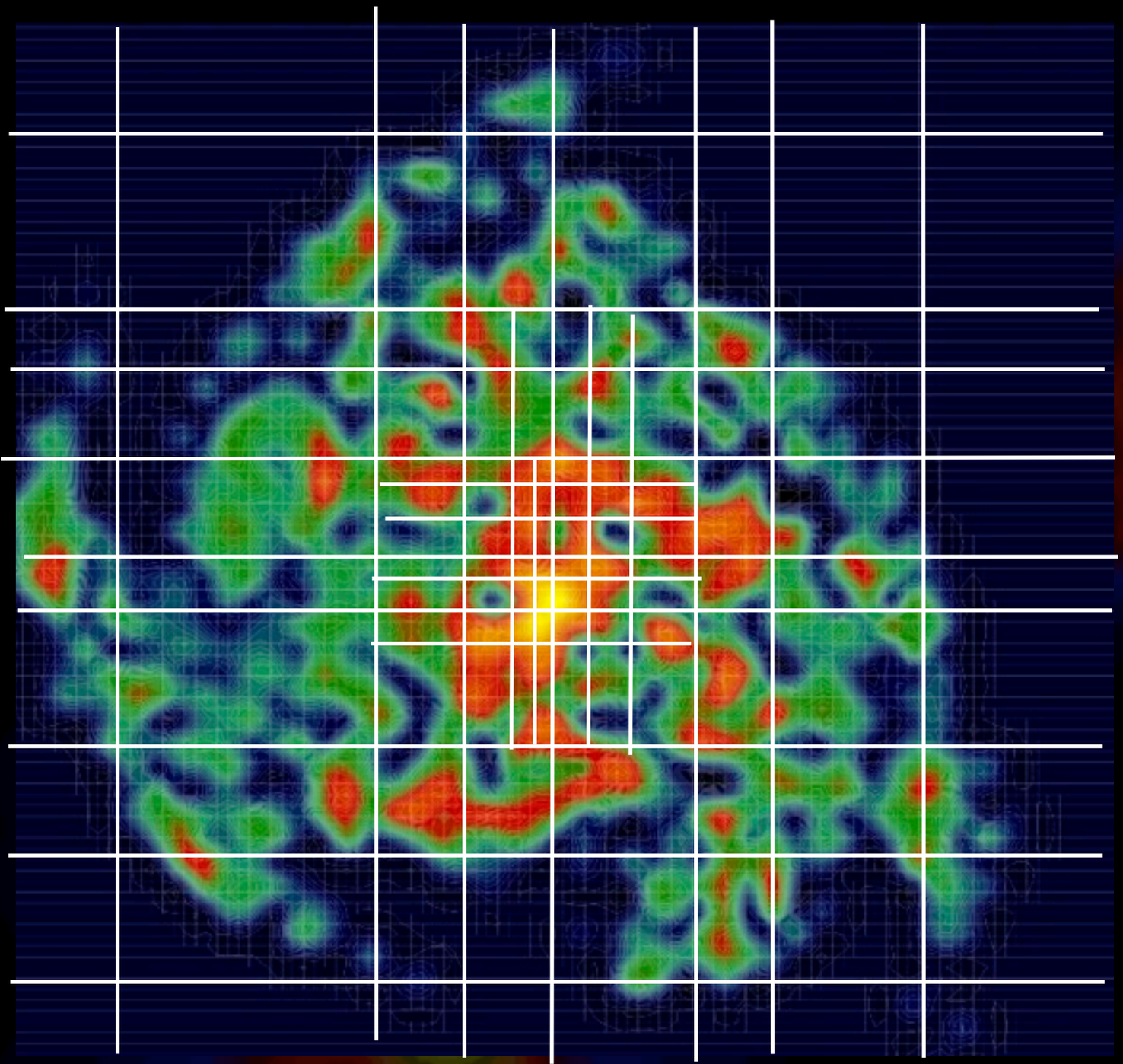

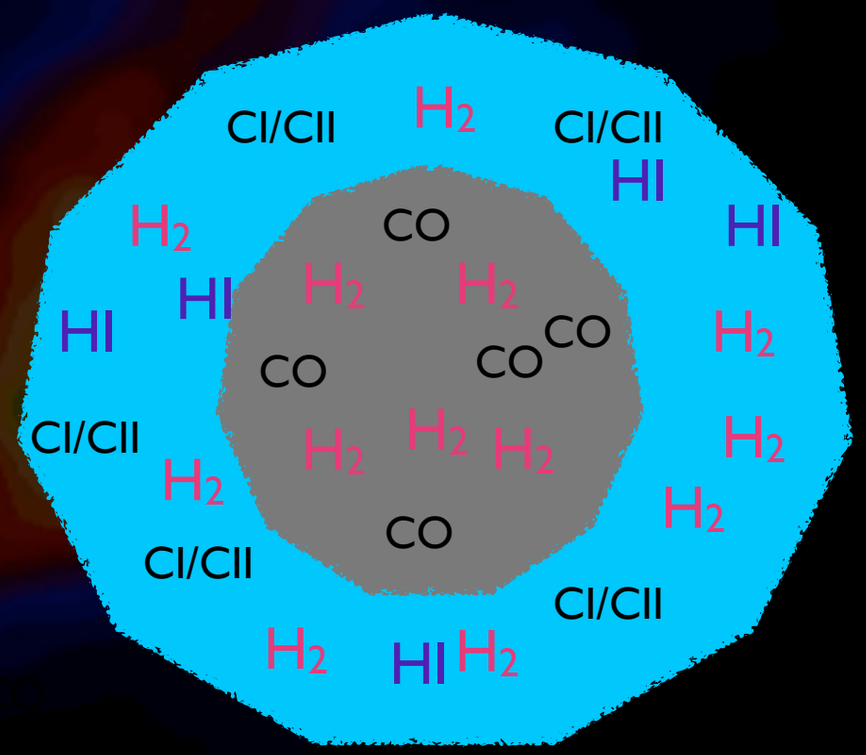

TURTLEBEACH; Narayanan et al. 2006,2008

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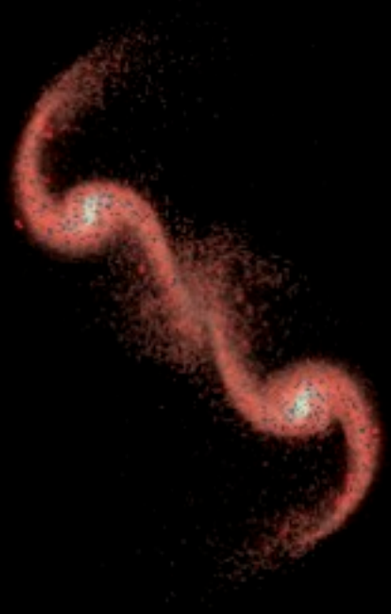

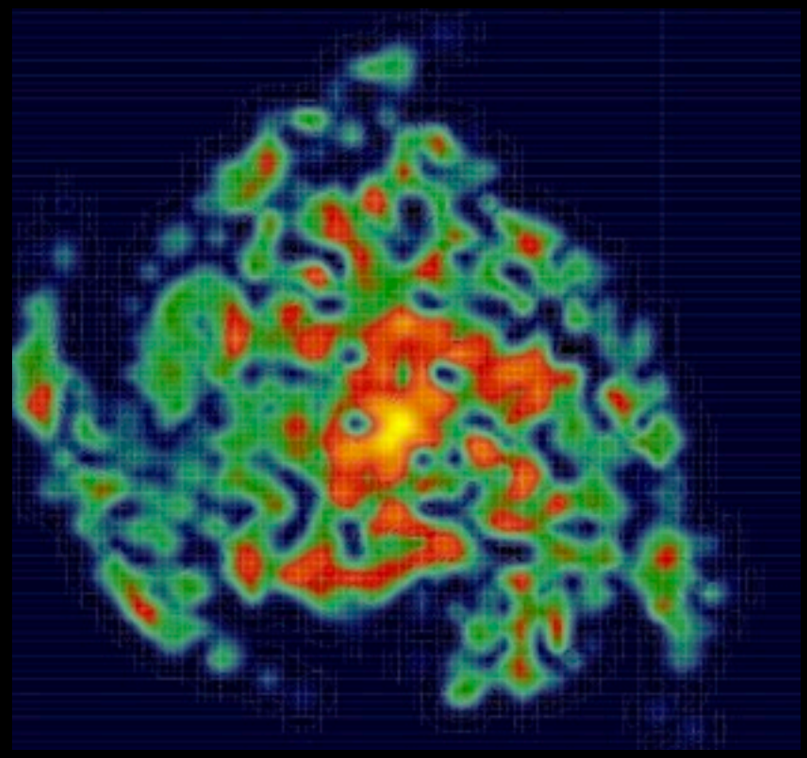

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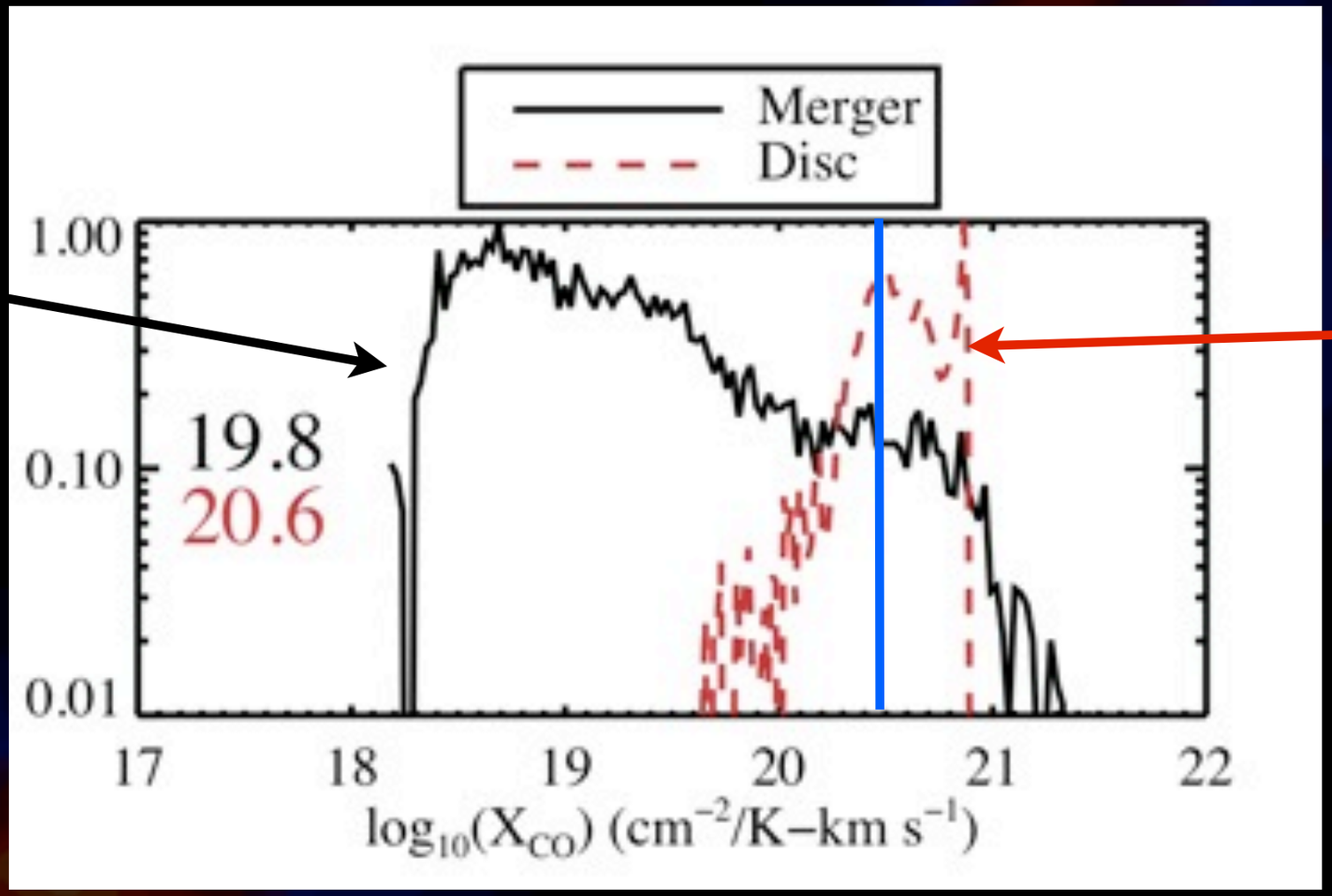
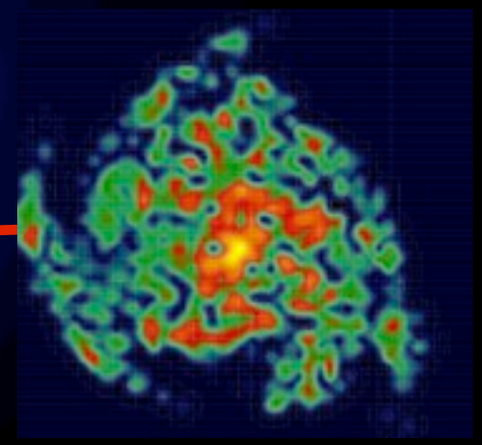
Xco in Discs and Mergers

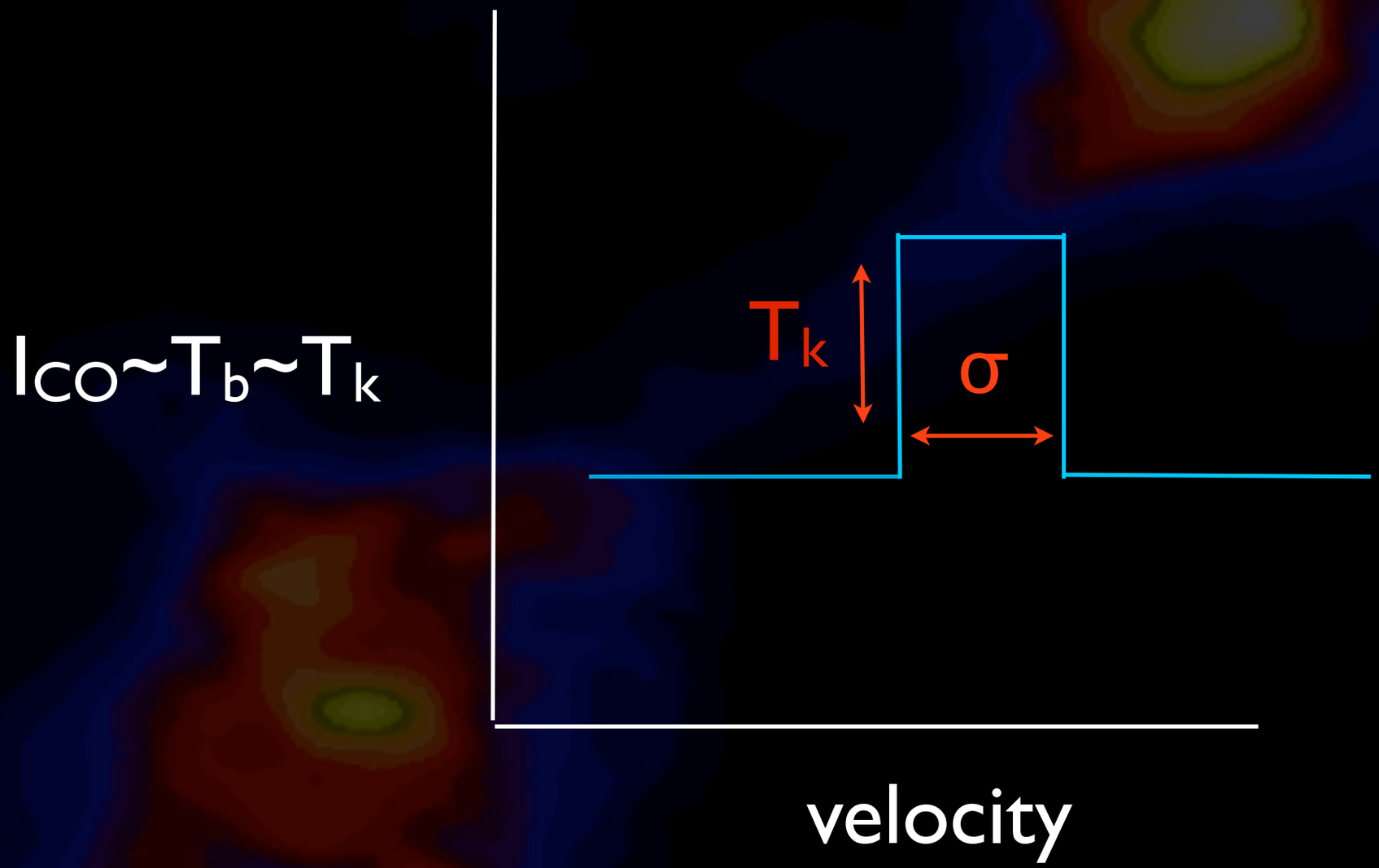




Narayanan, Krumholz, Ostriker & Hernquist 2011,2012

The Physics Controlling X_{co} I: Gas Kinematics and Thermal Structure

$$Xco = N_{H2}/W_{CO} \sim N_{H2}/(T*\sigma)$$



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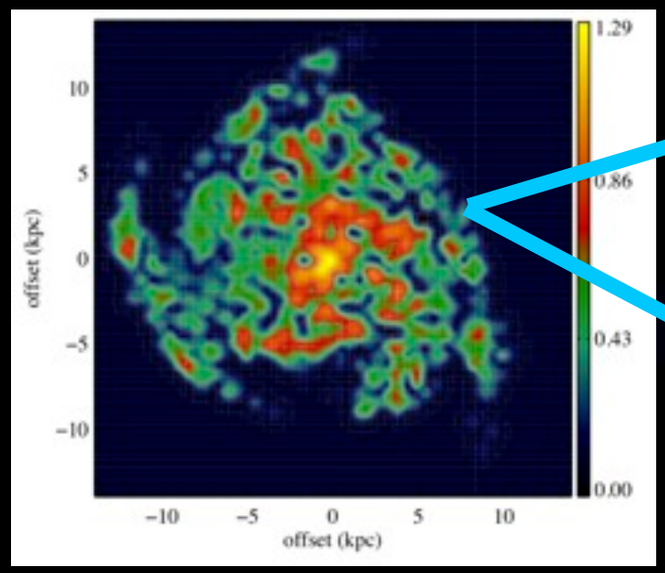
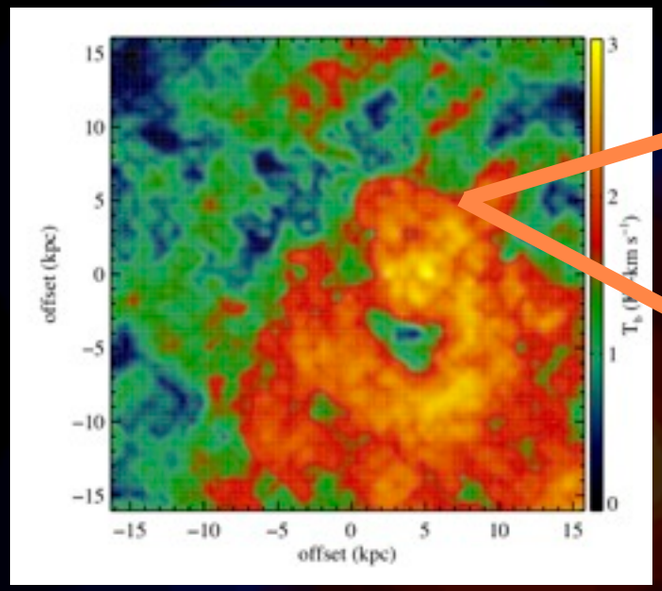
$X_{CO} = N_{H2}/W_{CO} \sim N_{H2}/(T*\sigma)$



$N_{H2} \sim 10^{22}$ cm^{-2}
T~ 10 K
σ ~ 5 km/s

Virialized GMCs unaffected by galactic environment

$X_{CO} \sim 2 \times 10^{20}$ cm^{-2}/K km s^{-1}



$N_{H2} \sim 10^{23}$ cm^{-2}
T~ 50 K
σ ~ 50 km/s

non-virialized GMCs strongly affected by galactic environment

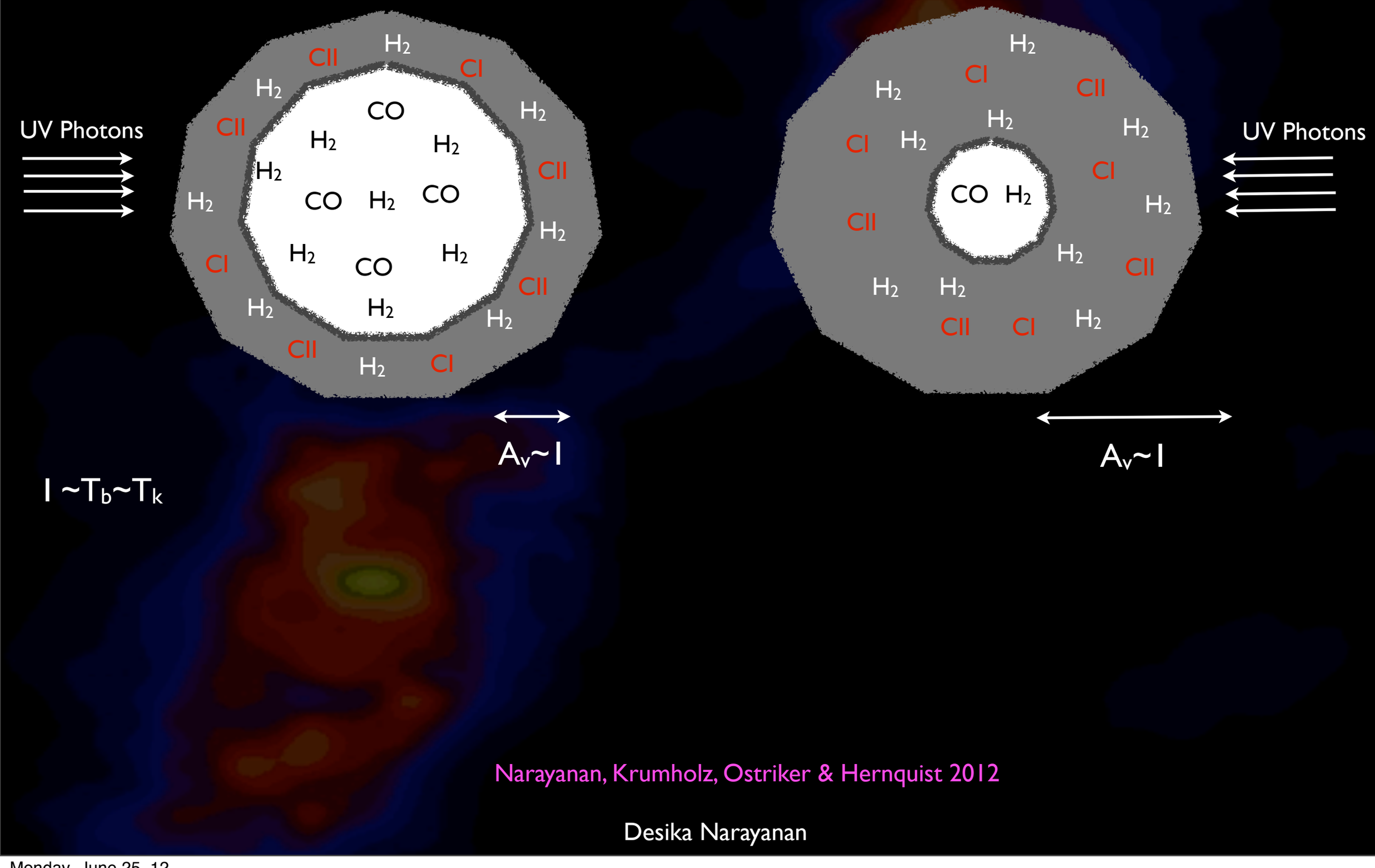
$X_{CO} \sim$ few $\times 10^{19}$ cm^{-2}/K km s^{-1}

Narayanan, Krumholz, Ostriker & Hernquist 2011,2012
Narayanan & Hopkins (submission imminent)

The Physics Controlling X_{co} II: Gas Phase Metallicity (N_{H2}/W_{CO})

$Z/Z_\odot \sim 1$

$Z/Z_\odot << 1$



$I \sim T_b \sim T_k$

Narayanan, Krumholz, Ostriker & Hernquist 2012

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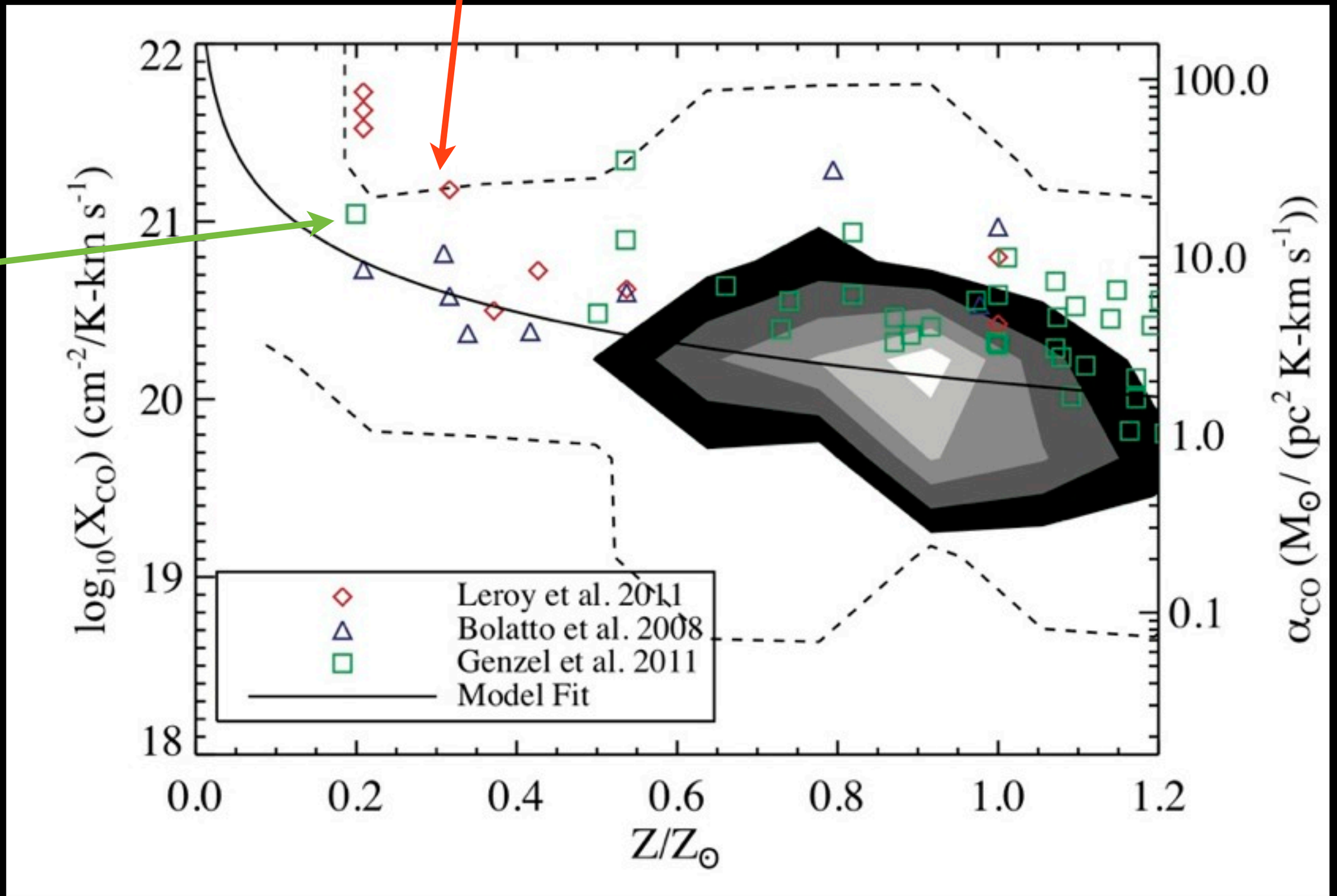
SMC

Hi-z



Narayanan, Krumholz, Ostriker & Hernquist 2012

This results in a relation between $X_{\rm CO}$, Z', and $\langle W_{\rm CO} \rangle$:

$$X_{\rm CO} = \frac{6.75 \times 10^{20} \langle W_{\rm CO} \rangle^{-0.32}}{Z'^{0.65}}$$

→ Surface Brightness (K-km/s)

→ (units of $Z_\odot$)

constant (or bimodal)
X_{CO}

Narayanan, Krumholz, Ostriker, Hernquist 2012

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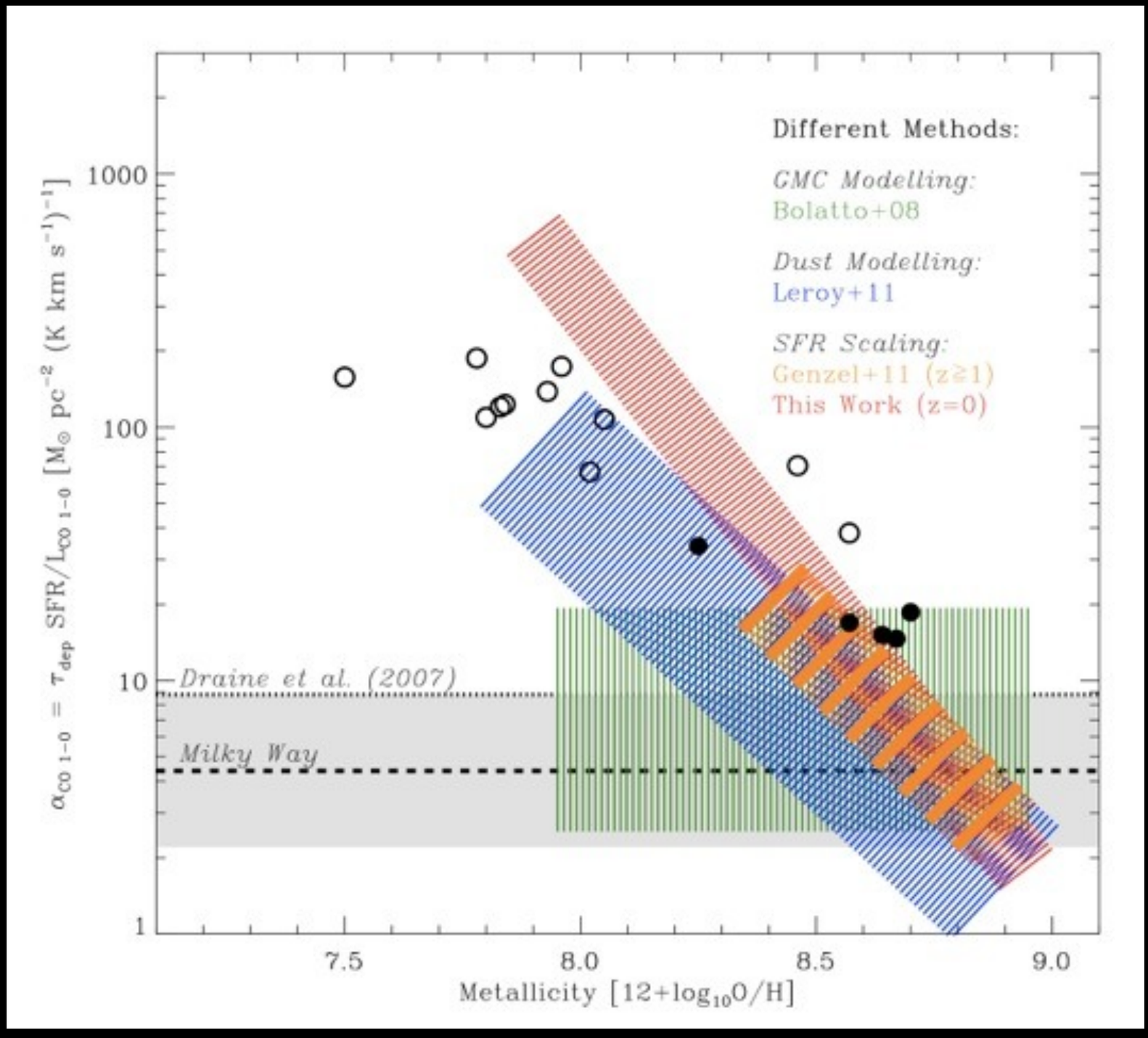
Schruba et al. 2012



Narayanan, Krumholz, Ostriker, Hernquist 2012

Summary

Xco depends on galactic environment:

I. In high surface-density environments, X_{CO} is lower than the MW "constant" value due to high T and σ

II. In low metallicity gas, CO cannot easily survive and X_{CO} rises rapidly - can have X_{CO} a factor of 100 larger than MW

This results in a relation between $X_{\rm CO}$, Z', and $\langle W_{\rm CO}\rangle$:

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