The CO-H_2 Conversion Factor in Galaxies

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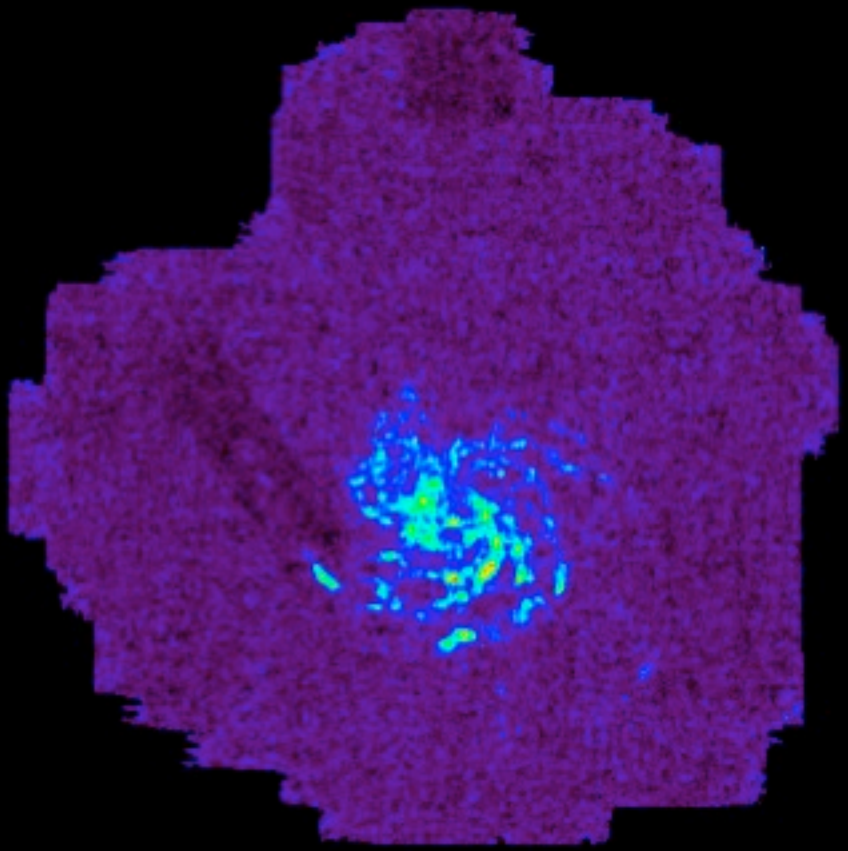
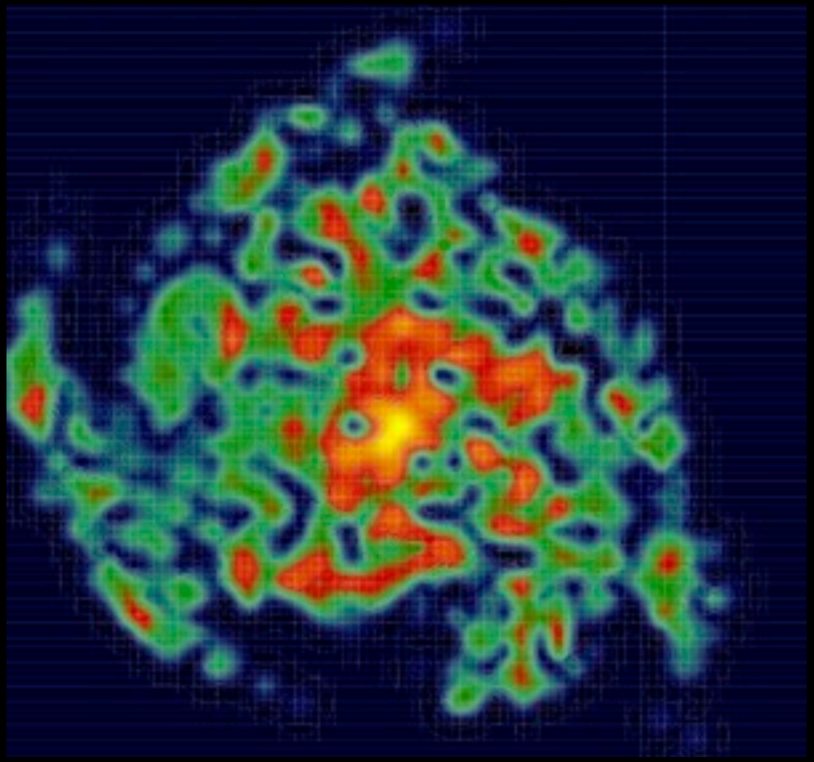
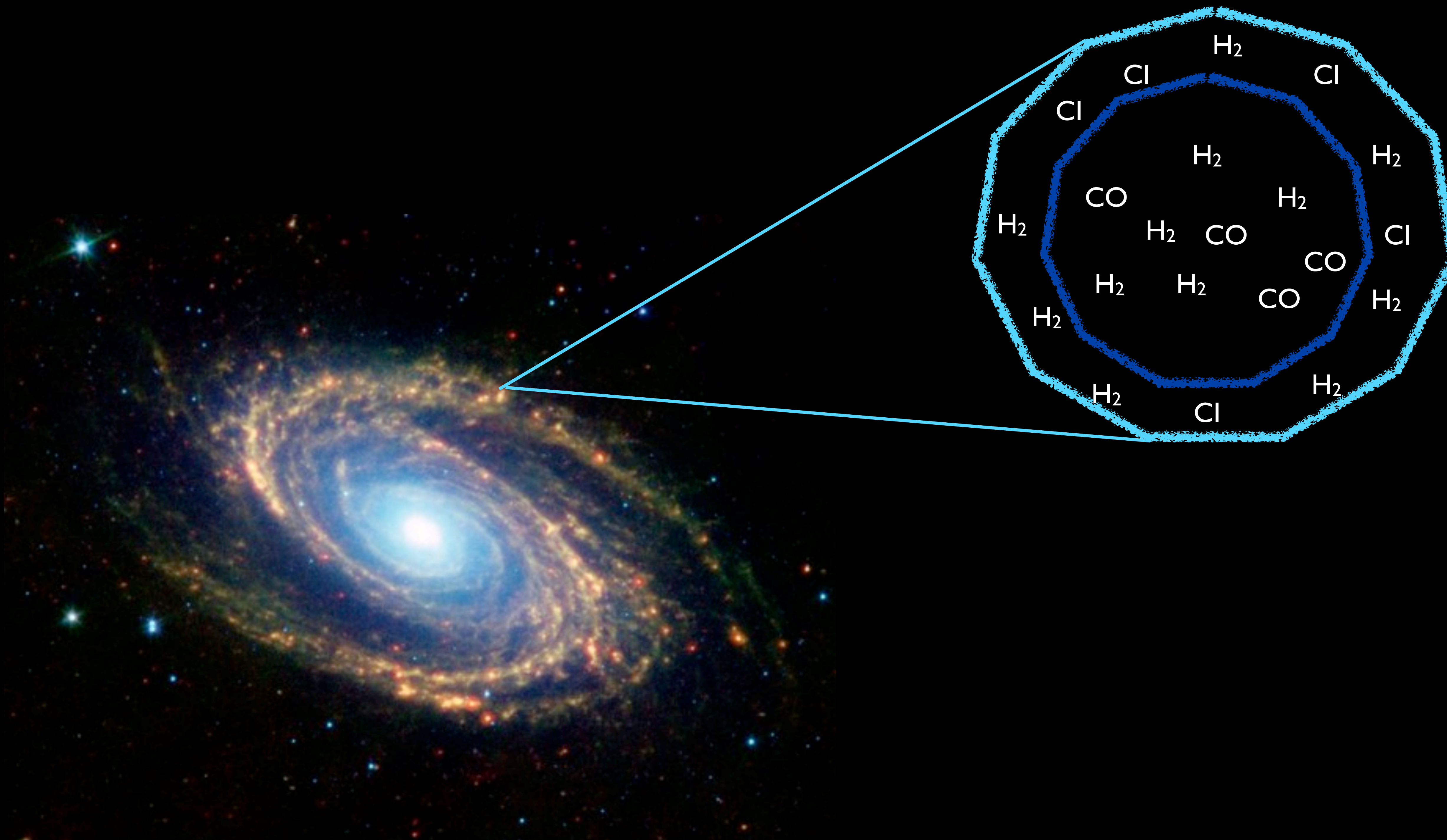
(With: Mark Krumholz, Eve Ostriker, Lars Hernquist)



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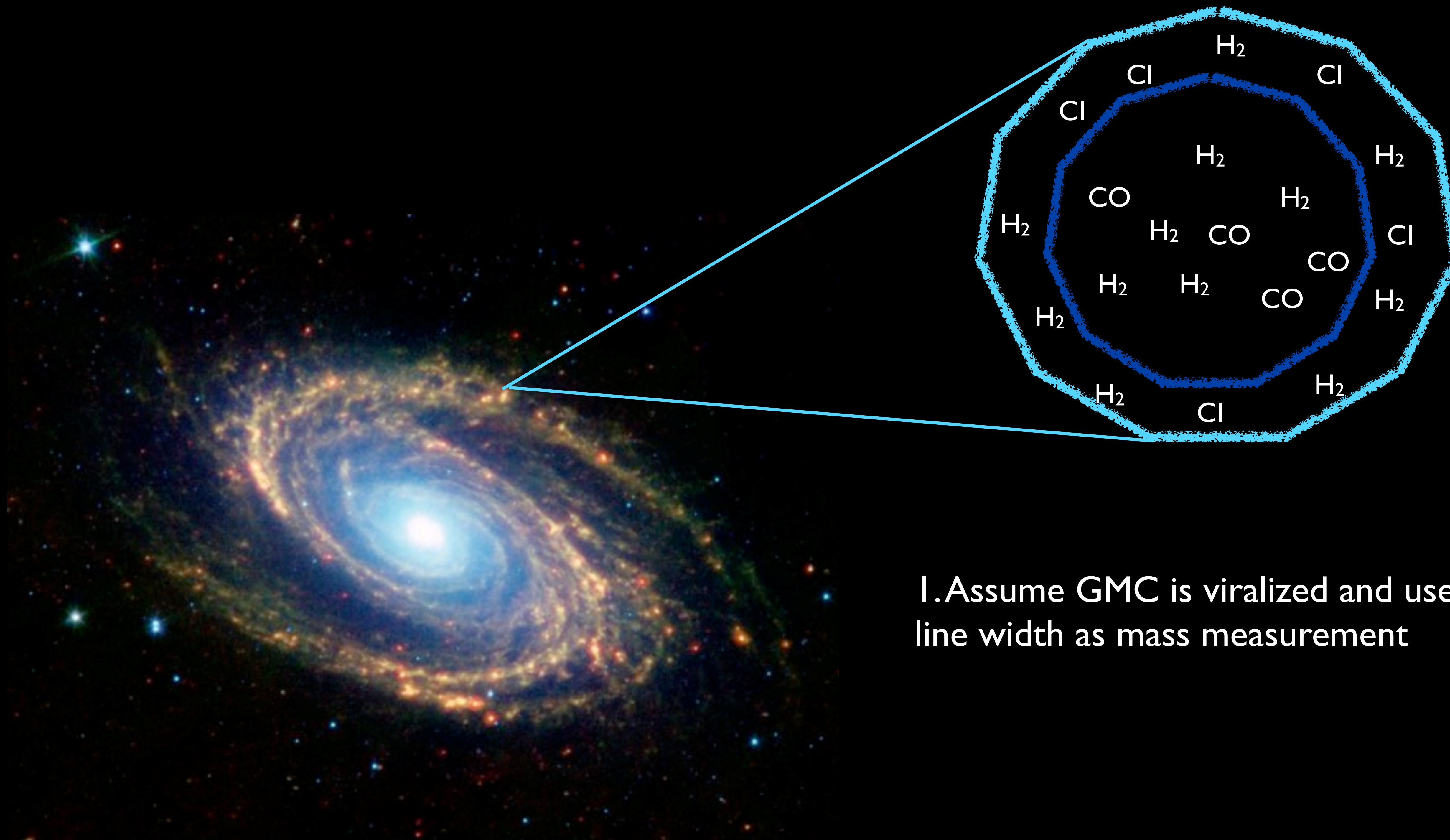
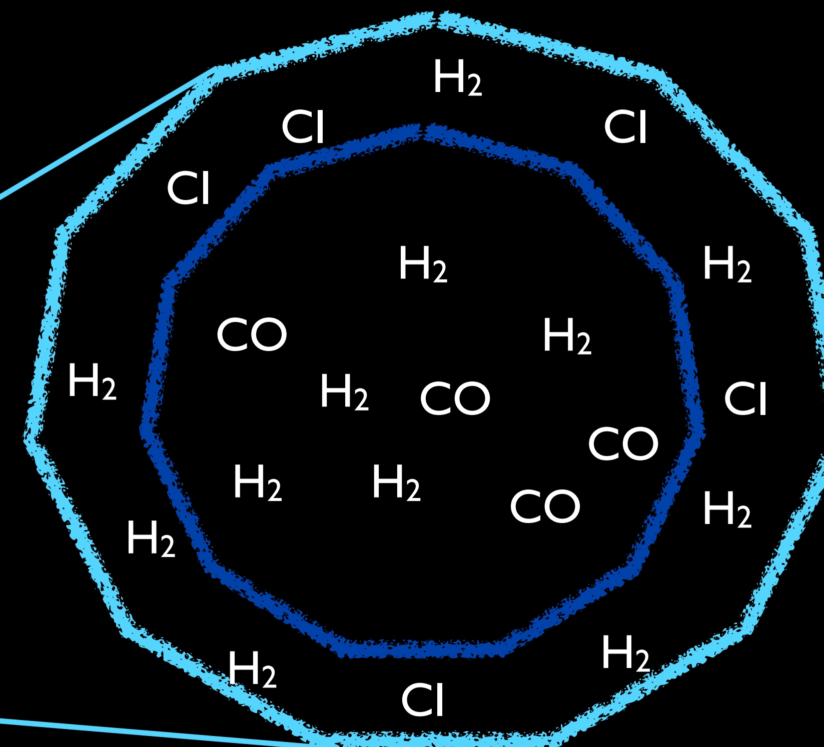
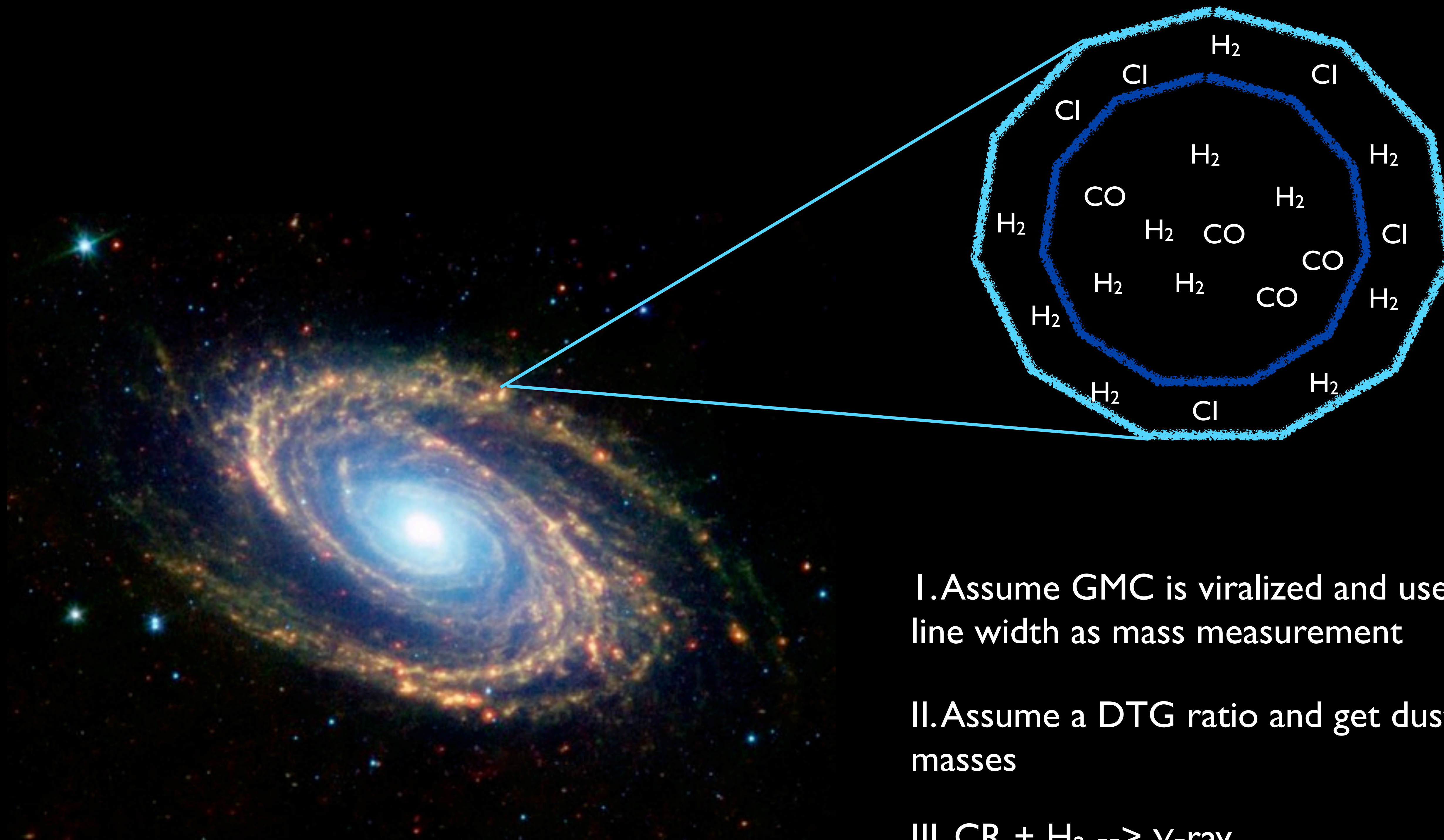


1. Assume GMC is viralized and use CO line width as mass measurement



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

II. Assume a DTG ratio and get dust masses



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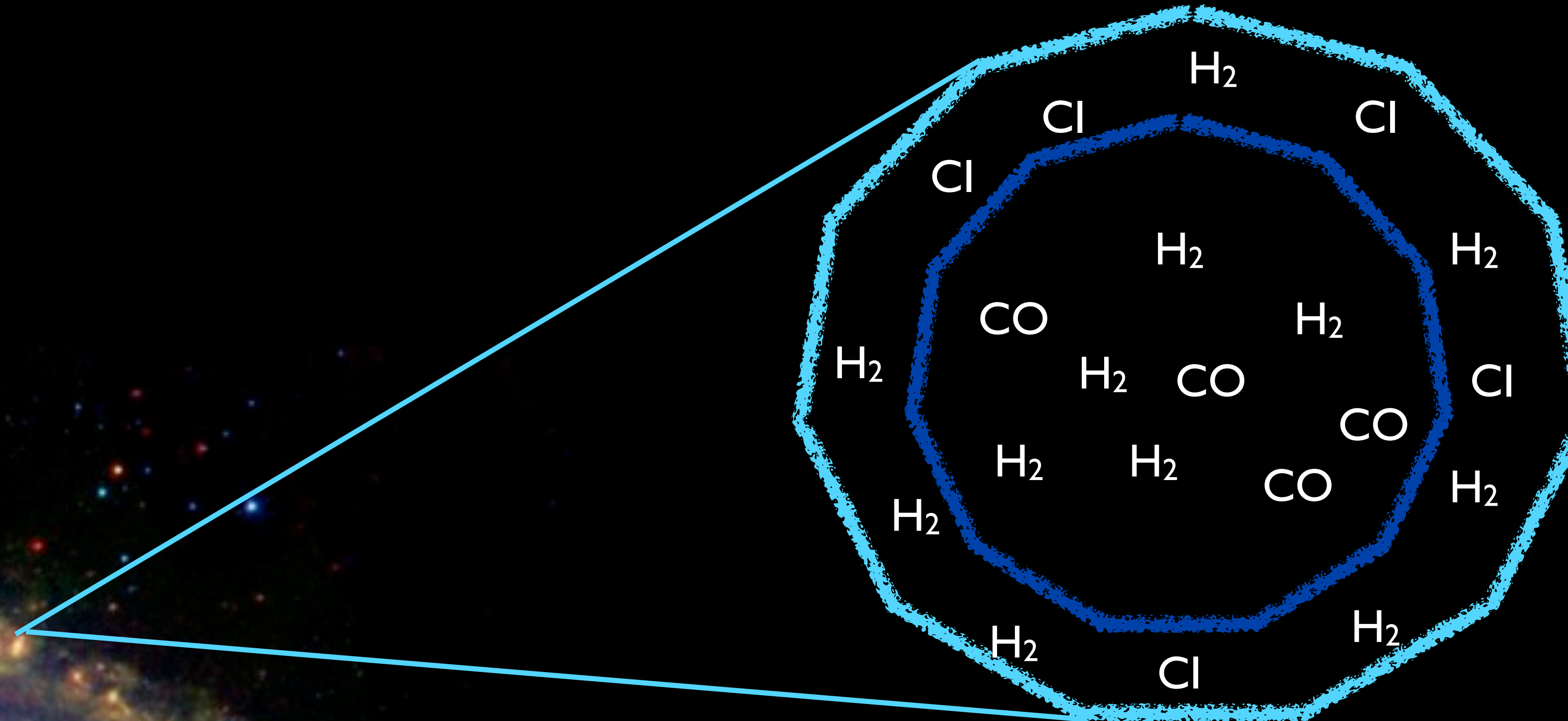
III. CR + H_2 --> γ-ray



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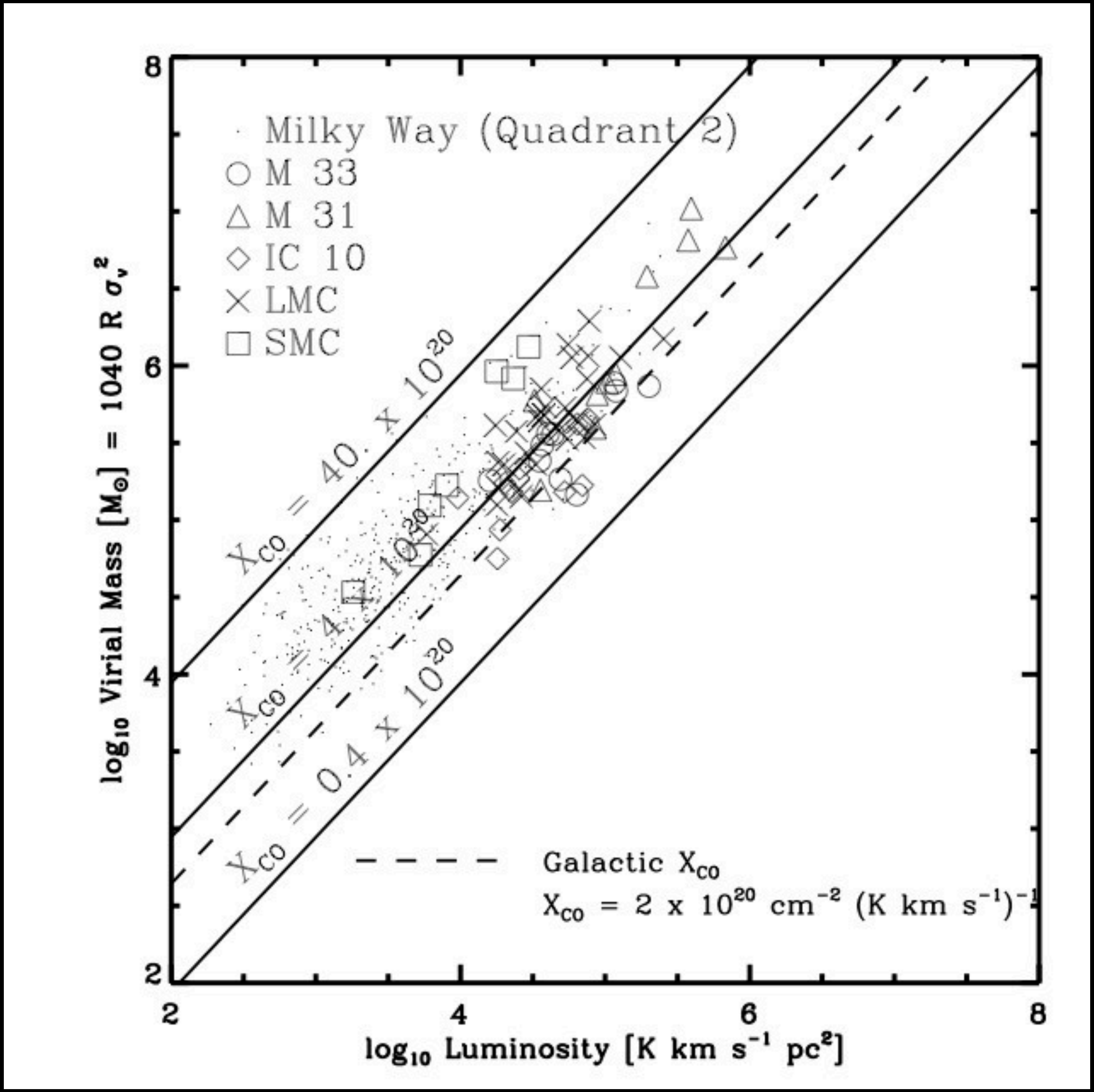
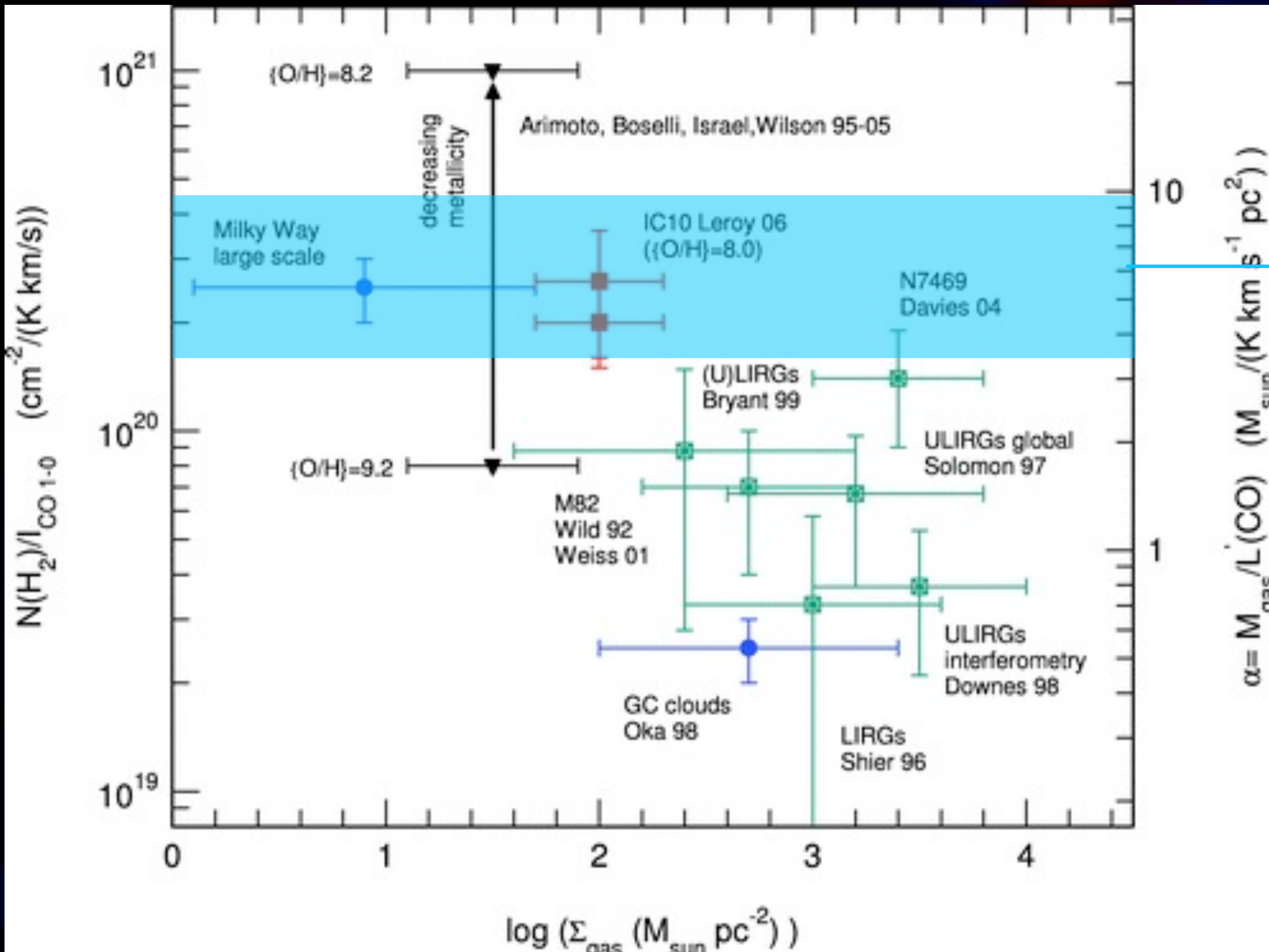
$X_{co} = N_{H2}/I_{co} = 2\text{-}4 \times 10^{20}\ \mathrm{cm}^{-2}/\mathrm{K\text{-}km\ s}^{-1}$

Xco is Similar for Local Group



Blitz et al., PPV Review Article, 2006

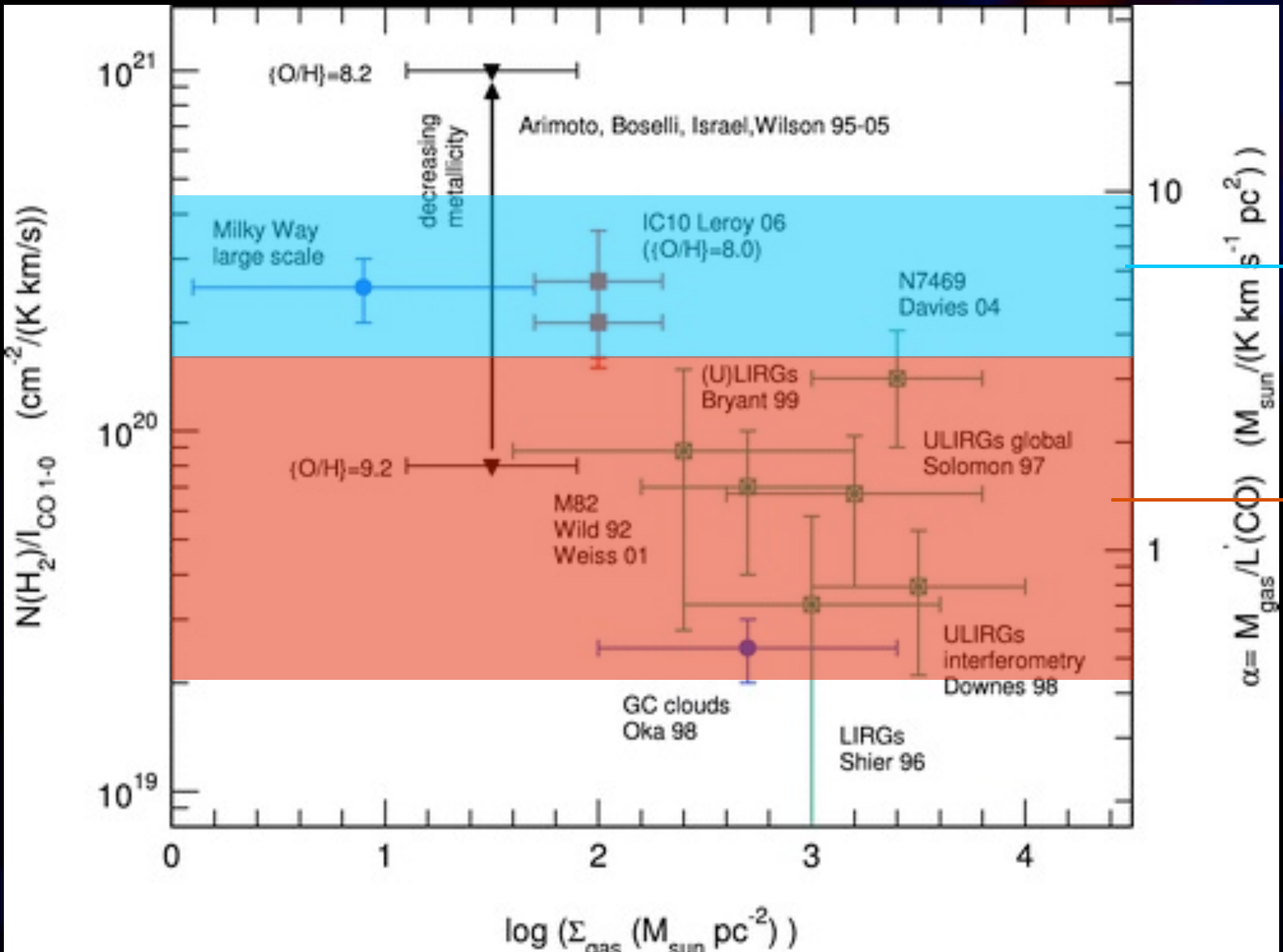
Xco = N_{H2}/I_{CO} Depends on Galactic Environment



"MW Xco"

Tacconi et al. 2008

Xco = NH2/ICO Depends on Galactic Environment: High Surface Densities

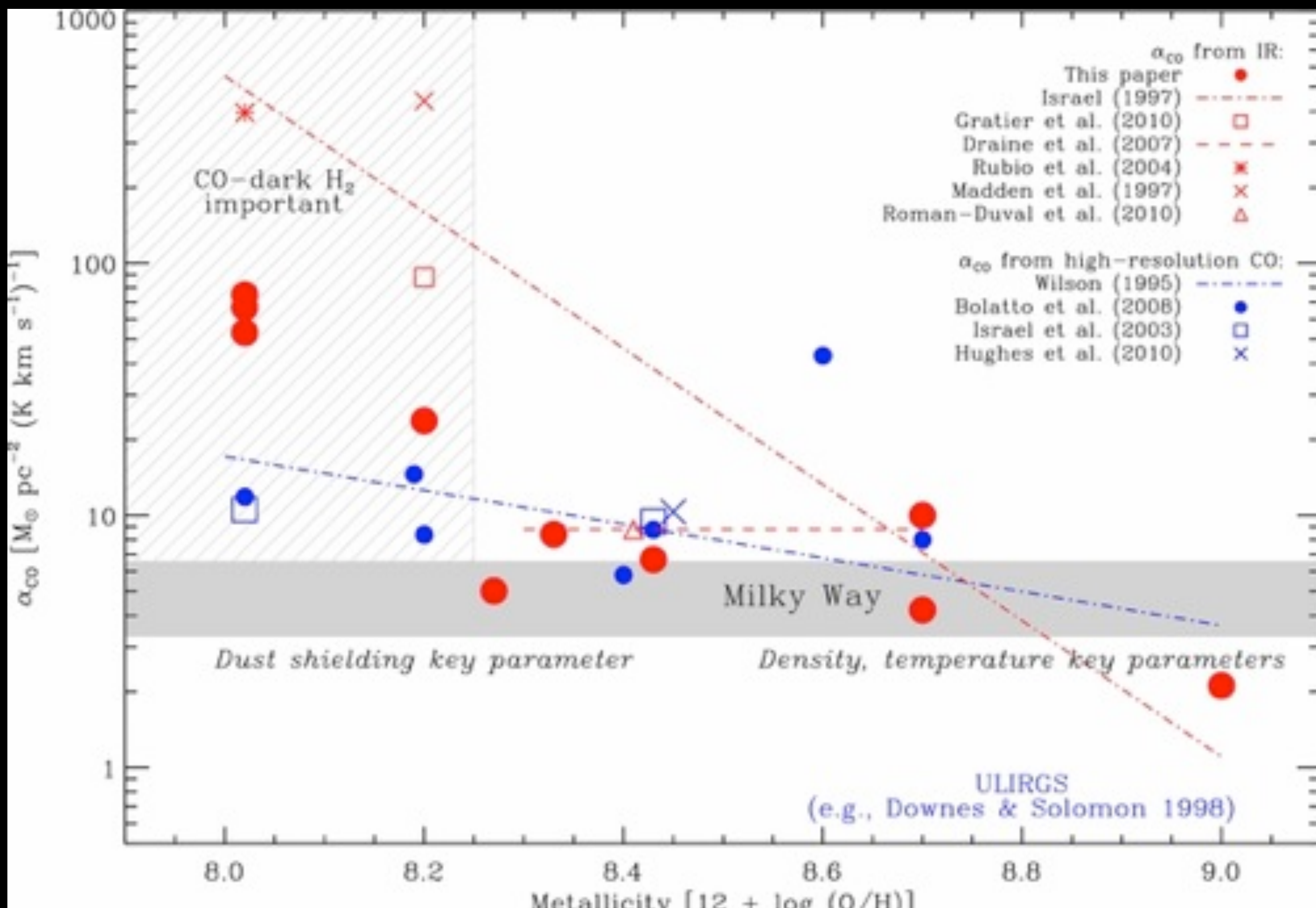


“MW Xco”

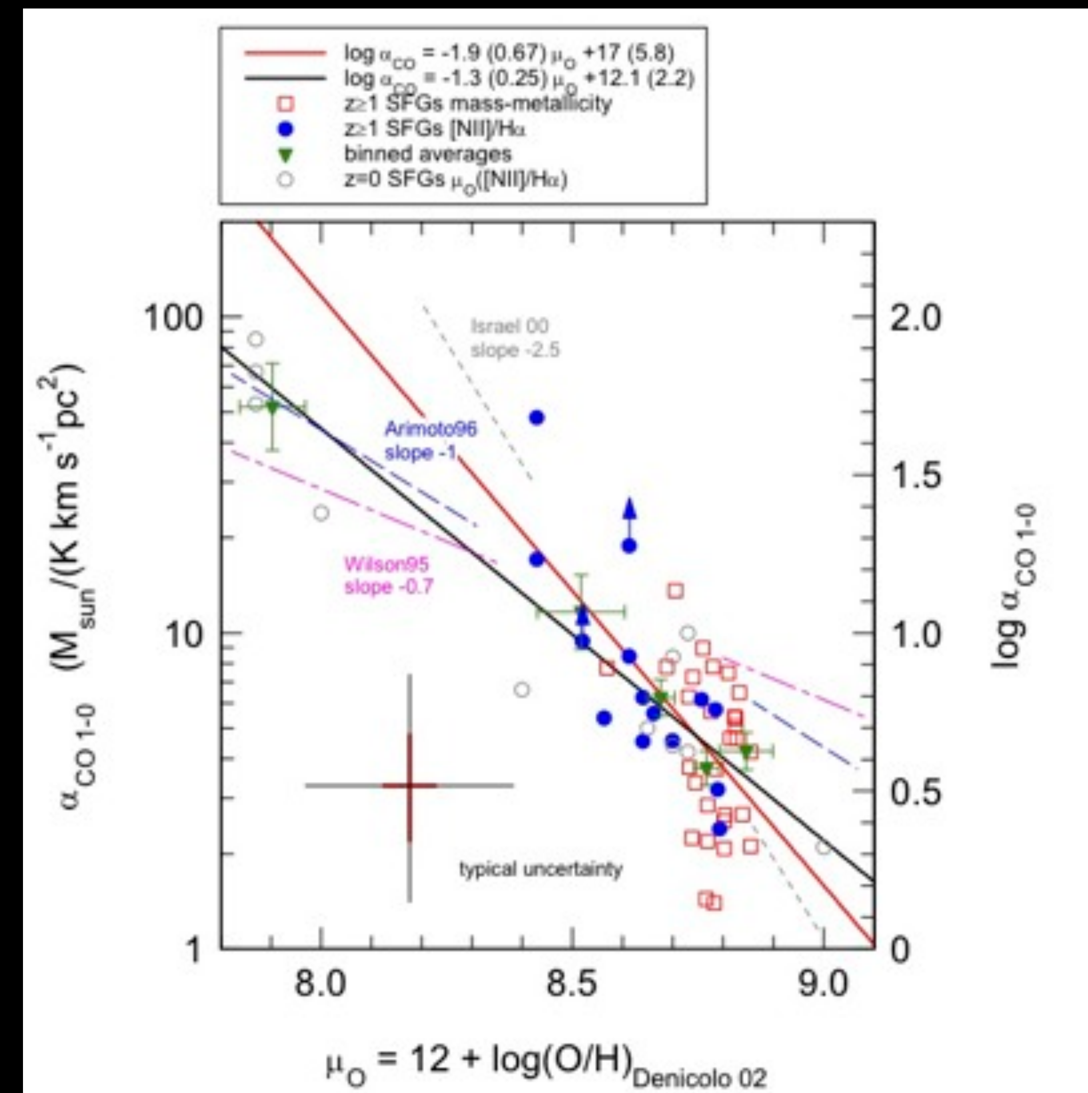
“ULIRG Xco”

Tacconi et al. 2008

Xco = NH2/ICO Depends on Galactic Environment: Low Metallicities



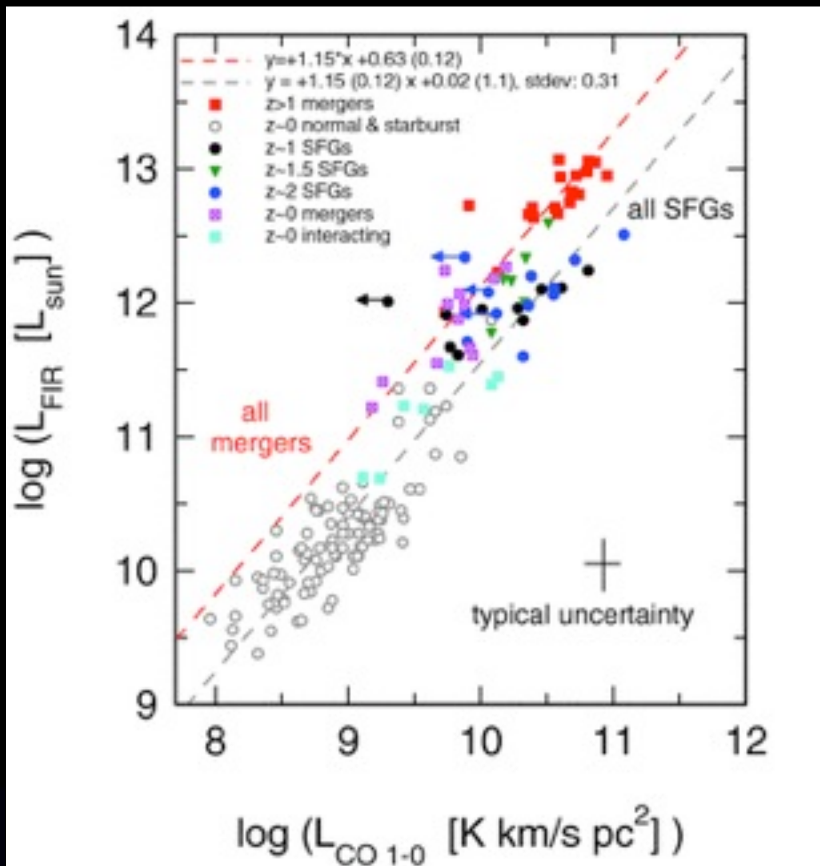
Leroy et al. 2011
(local galaxies)



Genzel et al. 2011
(z~1)

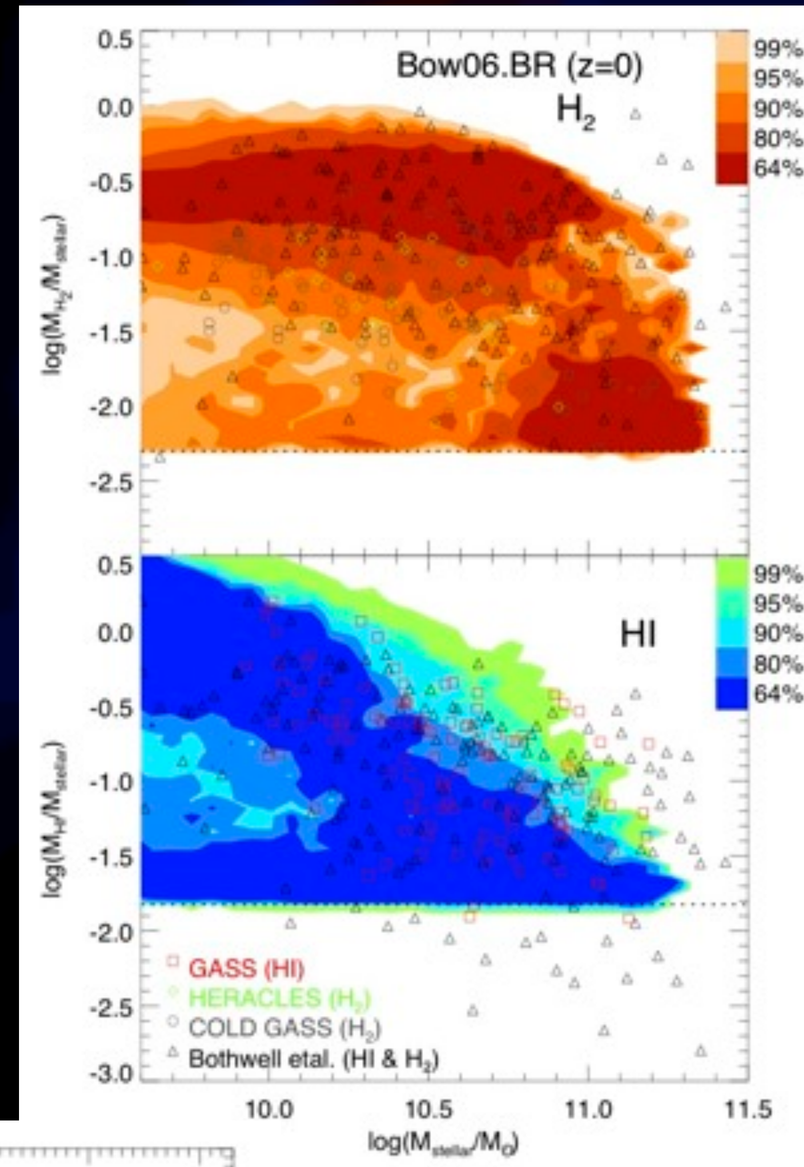
What's at Stake

KS Relations and Star Formation Efficiencies



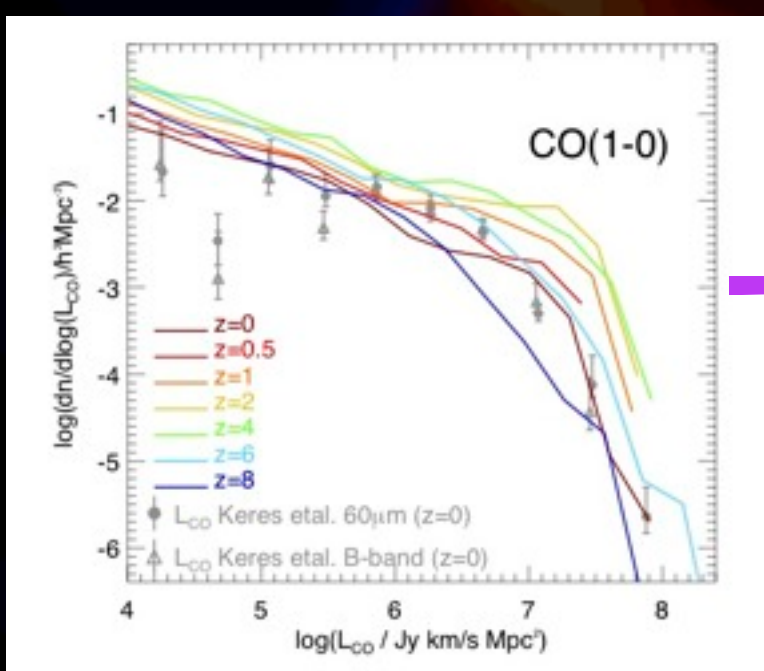
Genzel et al. 2010
Daddi et al. 2010

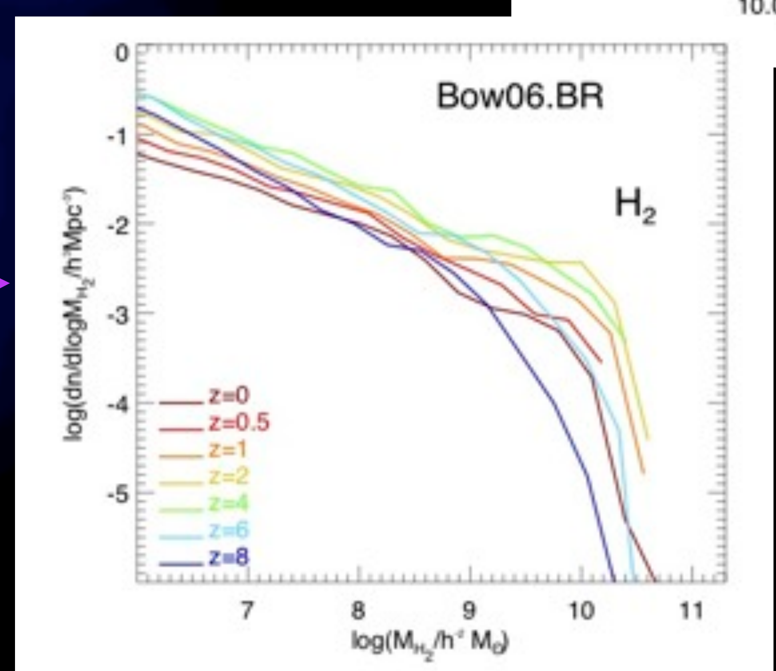
Molecular to Atomic Gas Mass Ratios



Leroy et al. 2009
Saintonge et al. 2011
Lagos et al. 2011

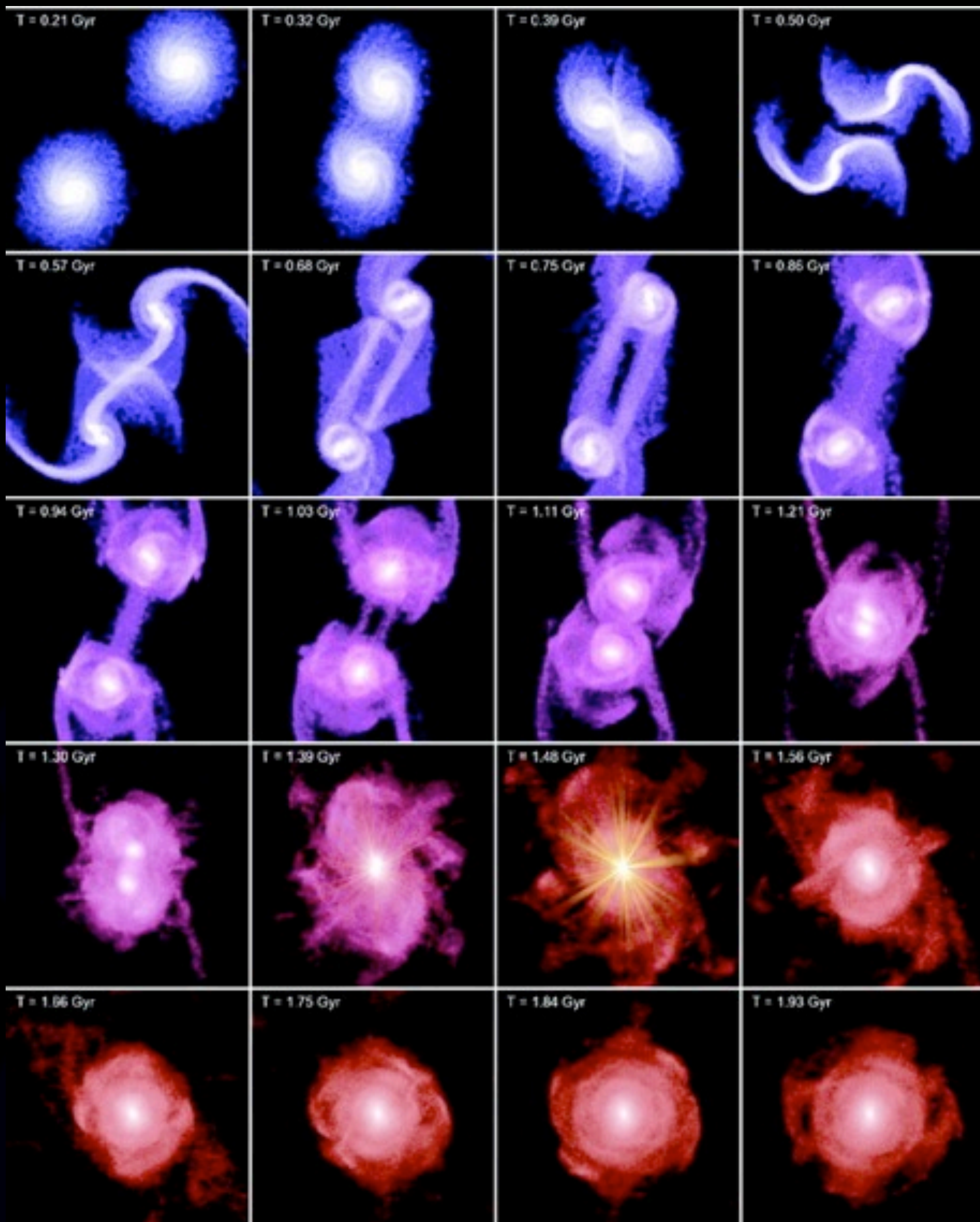
CO Luminosity Functions and $\Omega_{H2}(z)$





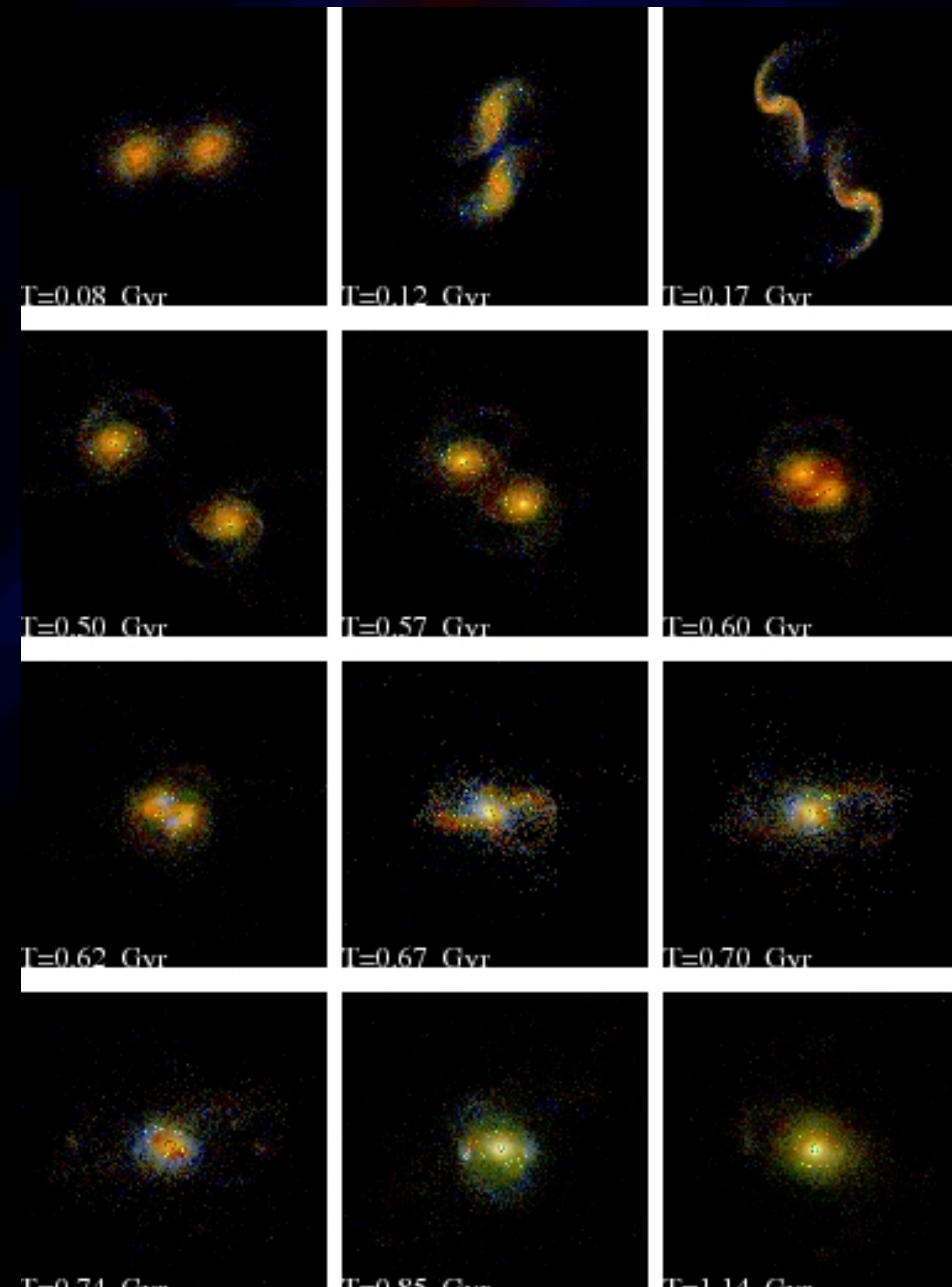
Lagos et al. 2011
Obreschkow & Rawlings 2009
Keres, Yun & Young 2003

Gadget: to get model discs and mergers at z=0,2



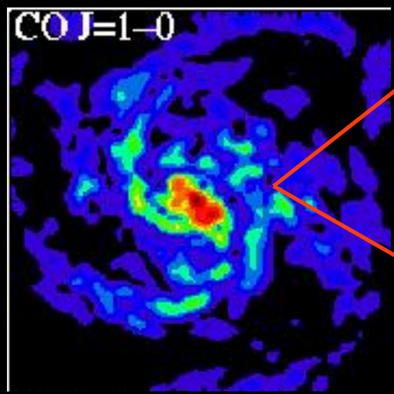
Springel et al. 2003-2005

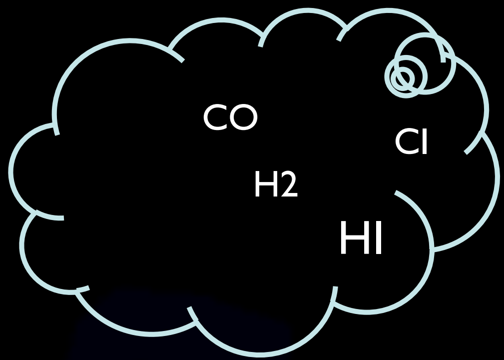
Sunrise: to get dust temperatures



Jonsson et al. 2006, 2009
Jonsson & Primack 2010

What do the molecules look like?





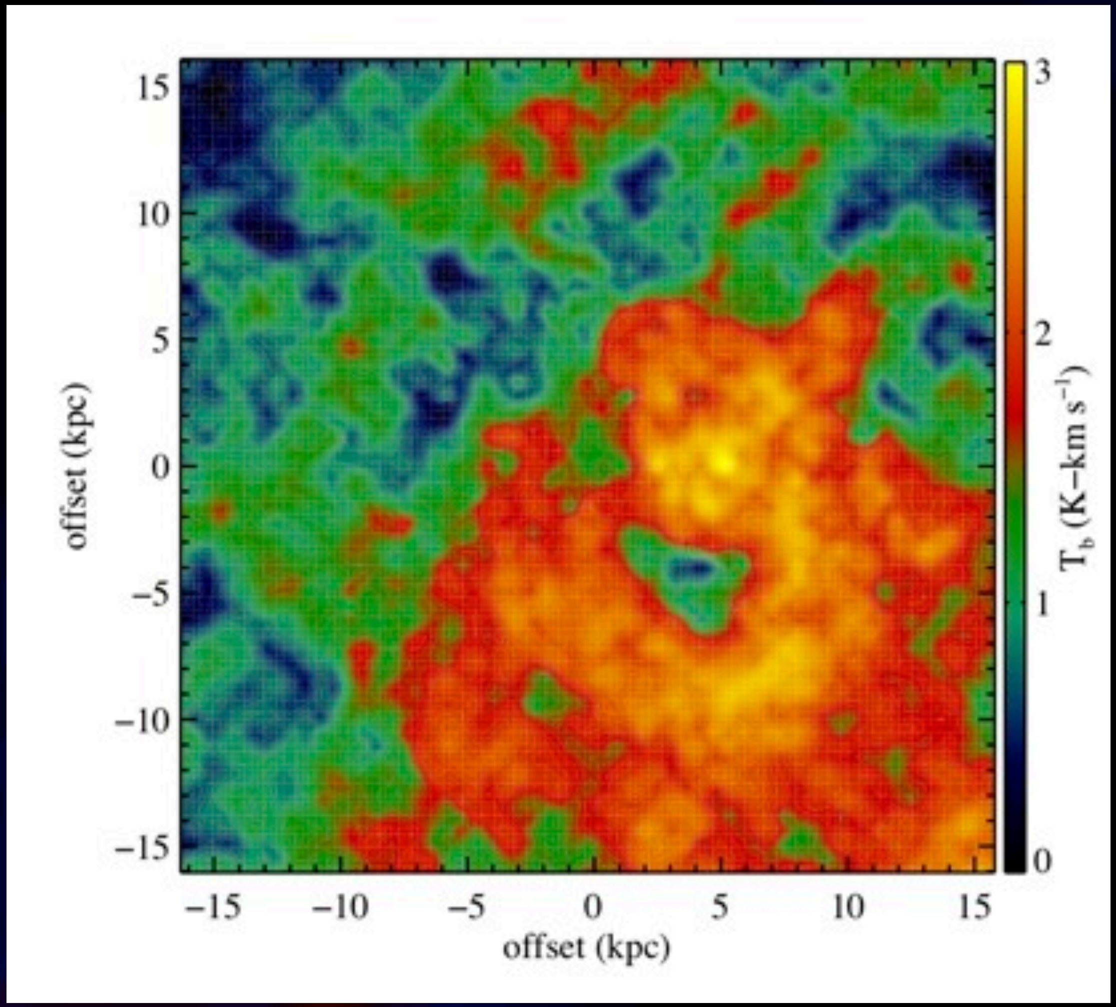
-H2-HI balance calculated by balancing growth of H2 on grains with LW band photodissociation (Krumholz, McKee, Tumlinson 2010)

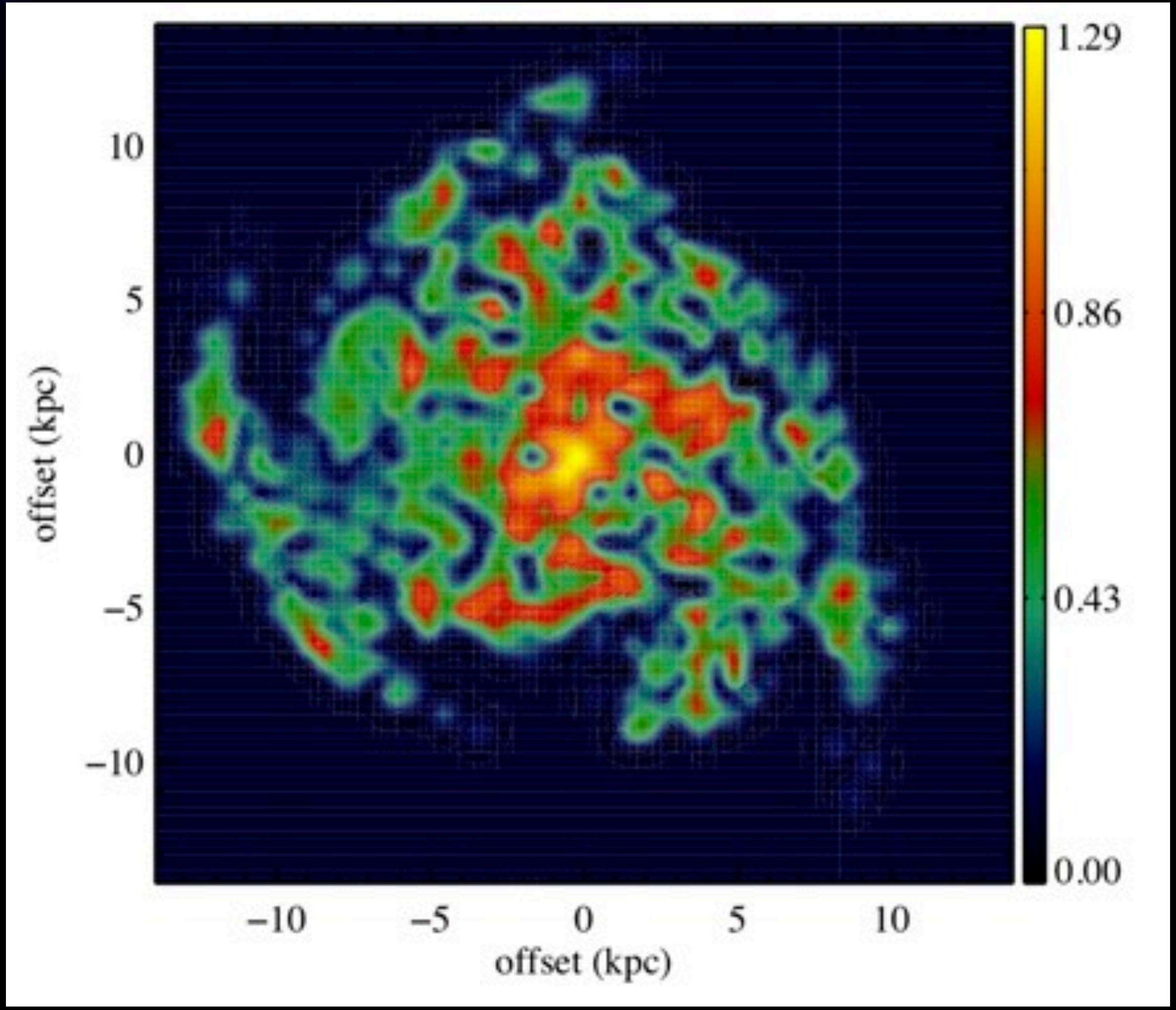
-CO-CI balance function of ISRF, Z (Wolfire et al. 2010)

-Temp calculated by balancing PE, CR heating, line cooling and thermal exchange with dust (Krumholz, Leroy, McKee 2011; Juvela 2011)

-GMCs isothermal, constant density spheres with floor surface density of ~10^{22} cm^{-3}

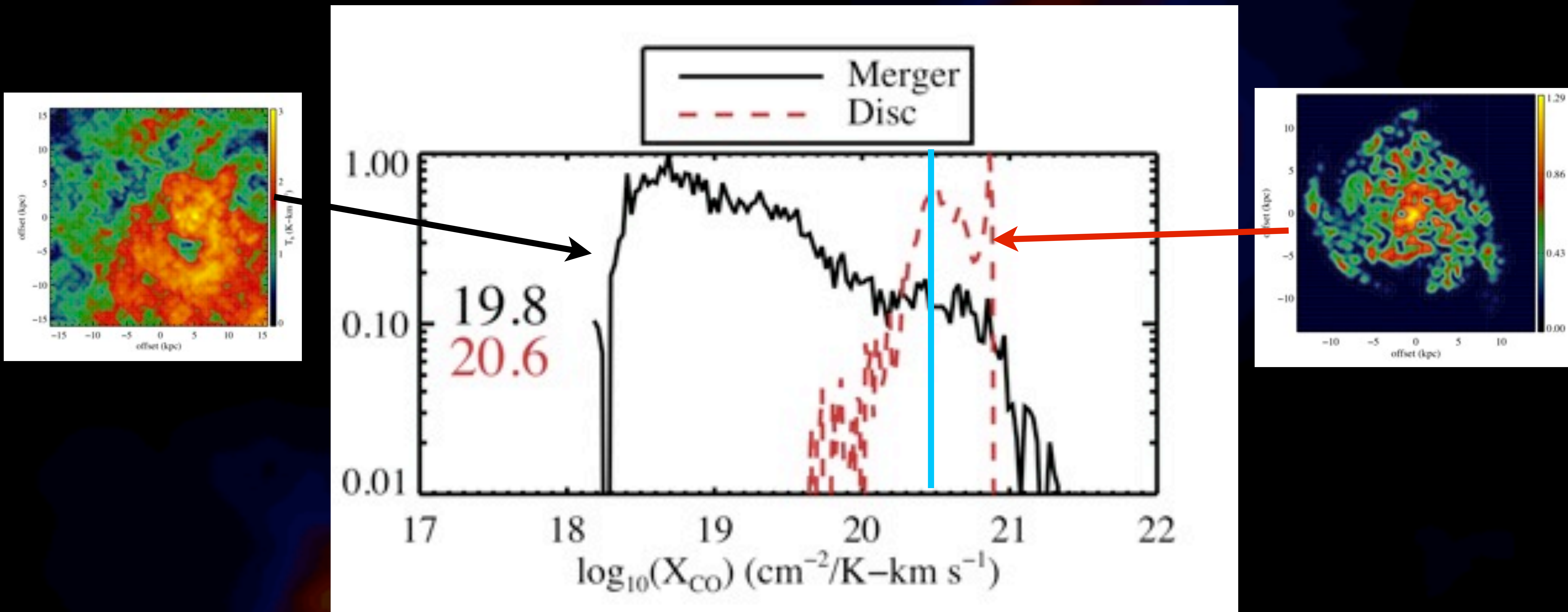
-Monte Carlo code: Calculates full statistical equilibrium of level populations in a 3D velocity, temp, density field within GMCs and galaxies (DN+2008, Krumholz & Thompson 2007, DN+2011)





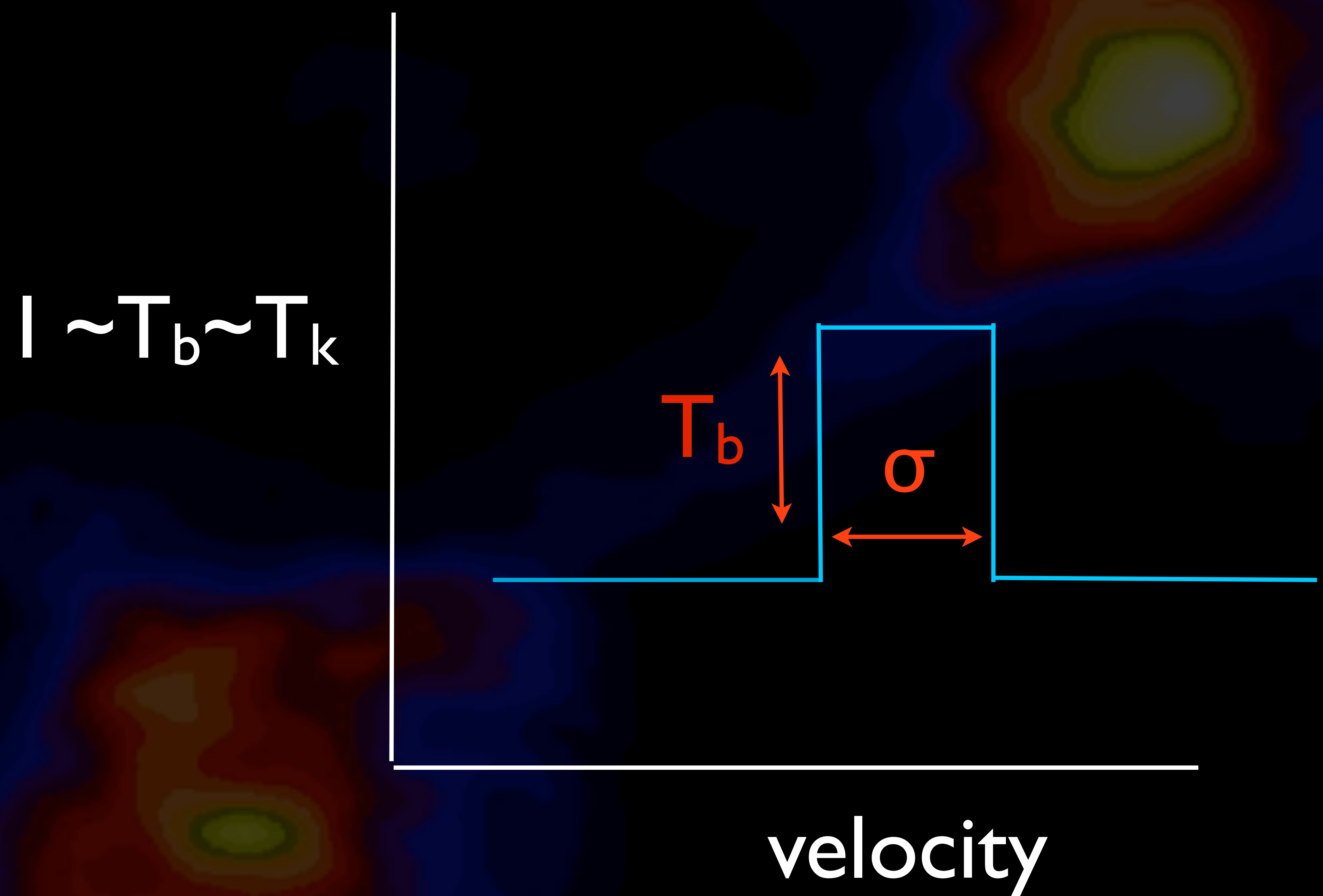
Desika Narayanan

Xco in Discs and Mergers



Narayanan, Krumholz, Ostriker & Hernquist 2011

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



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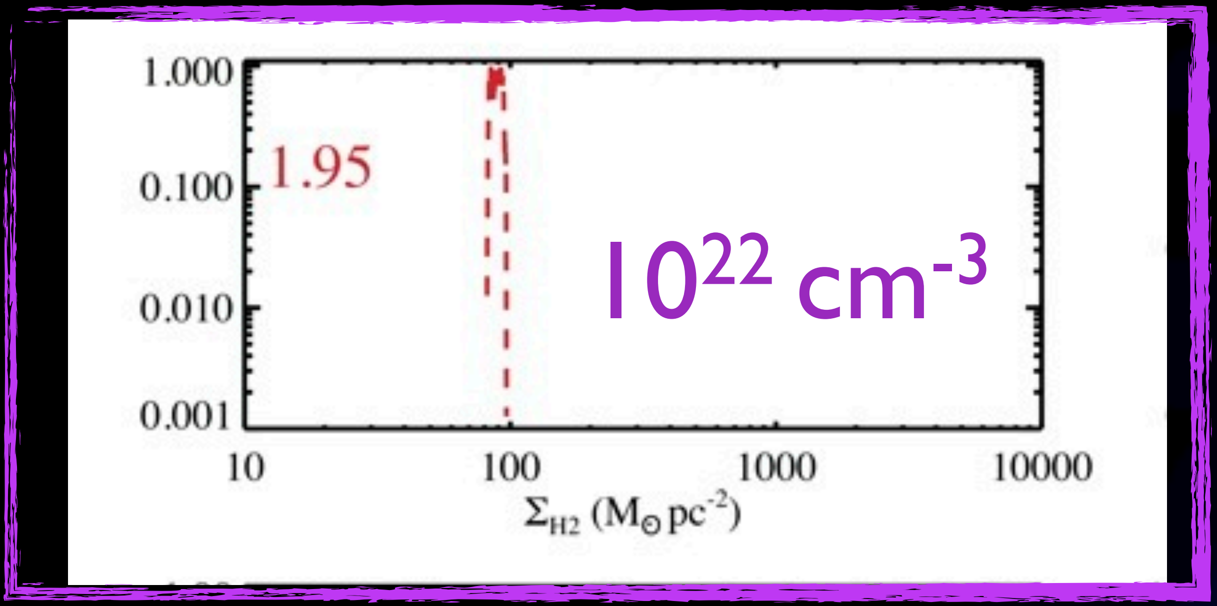

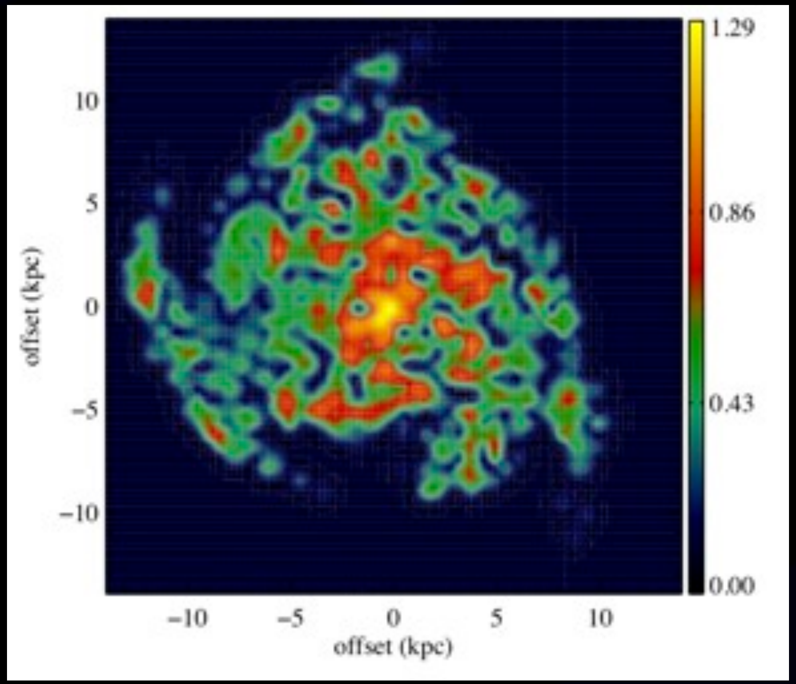

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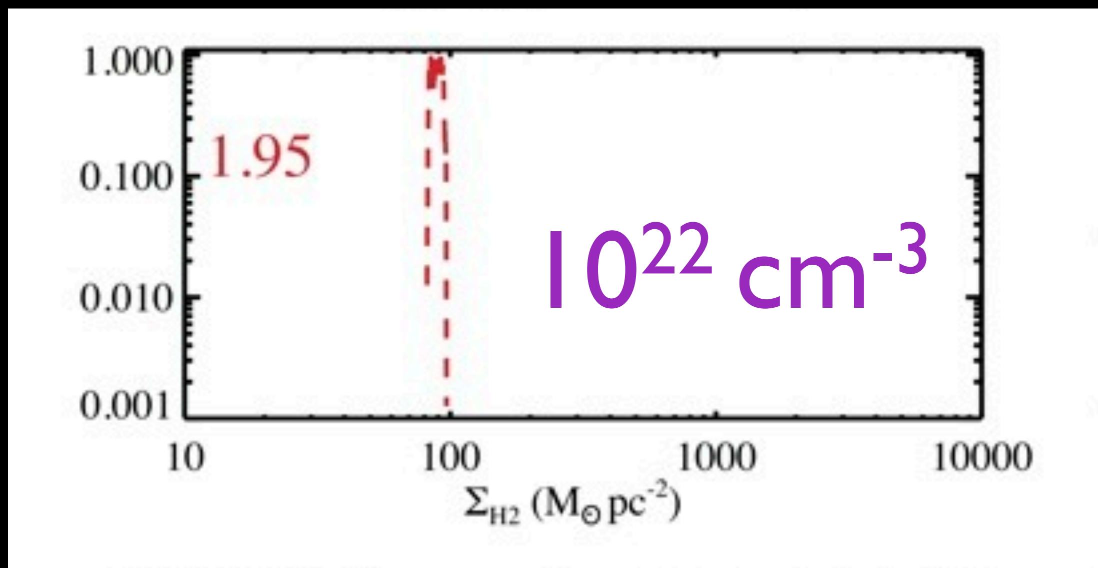

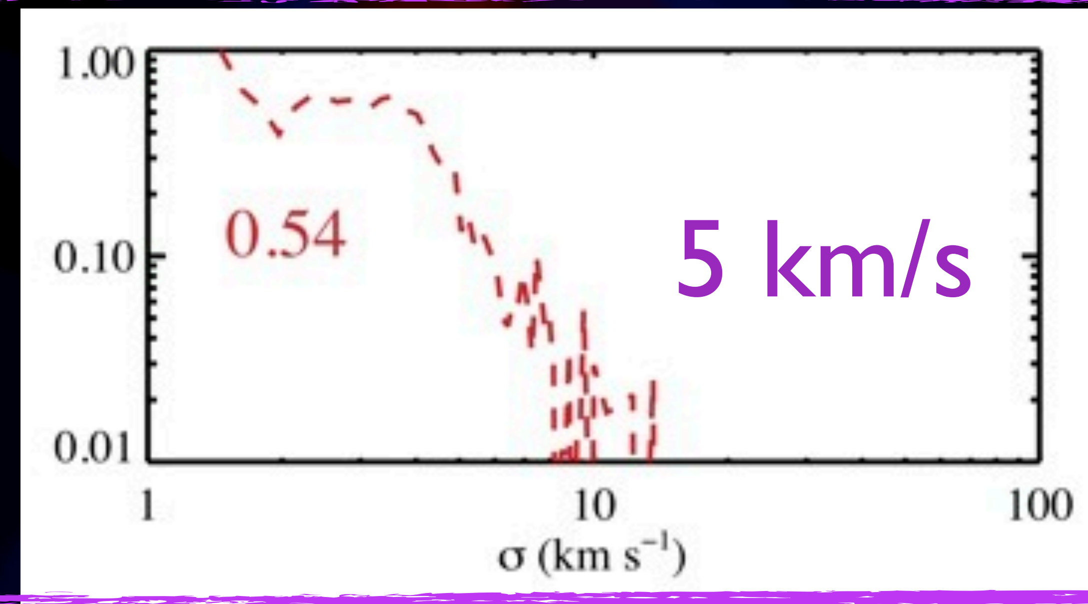

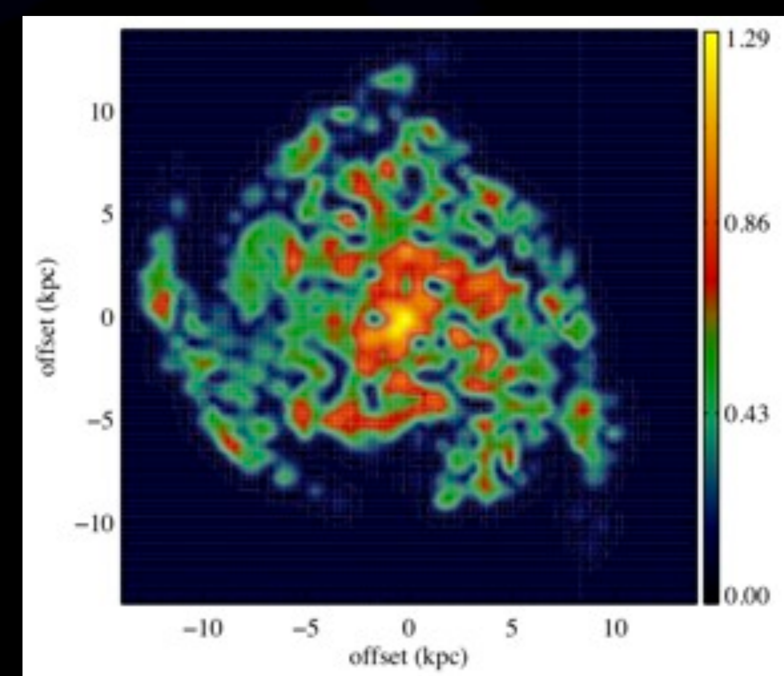

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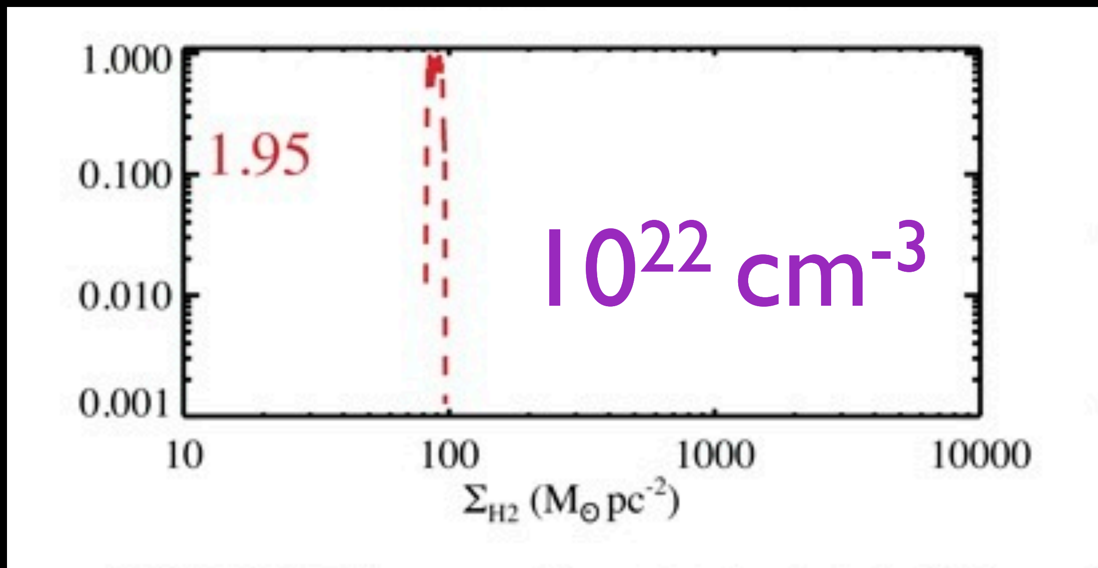

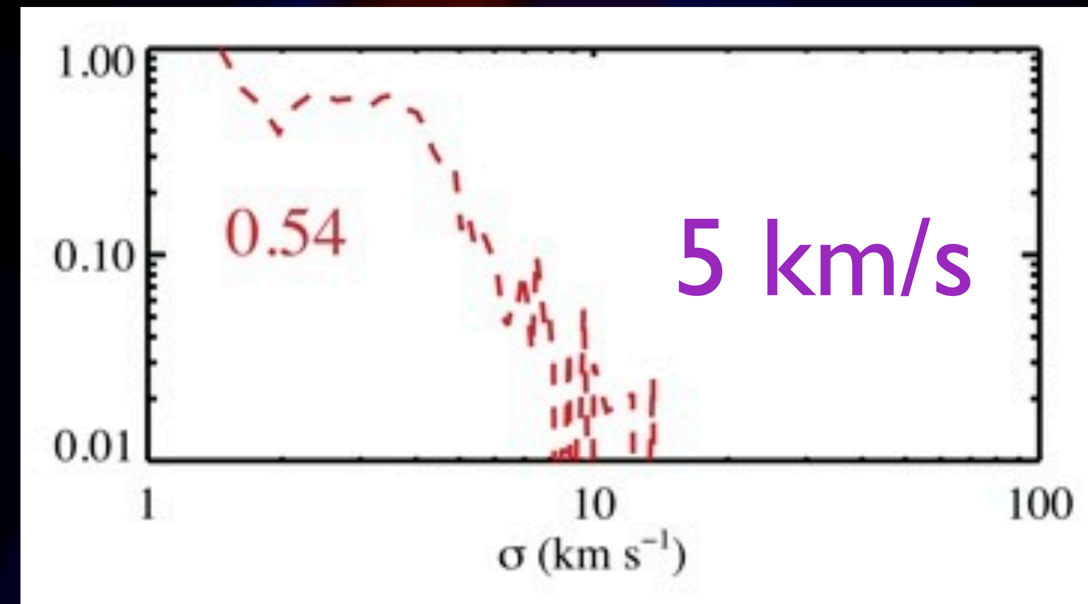

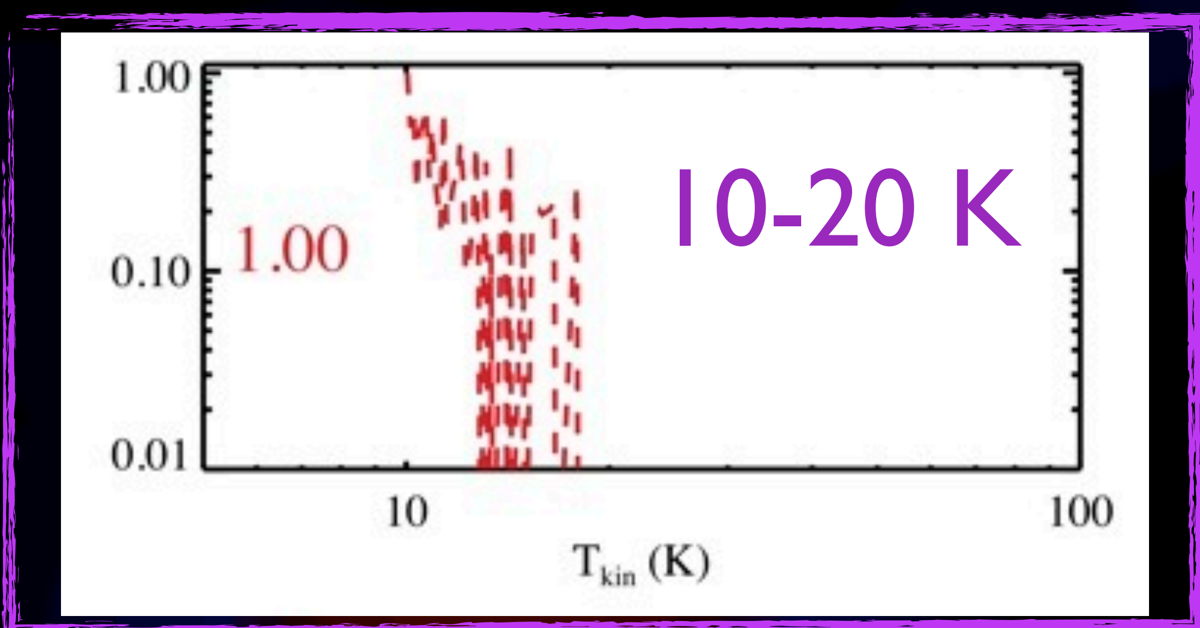

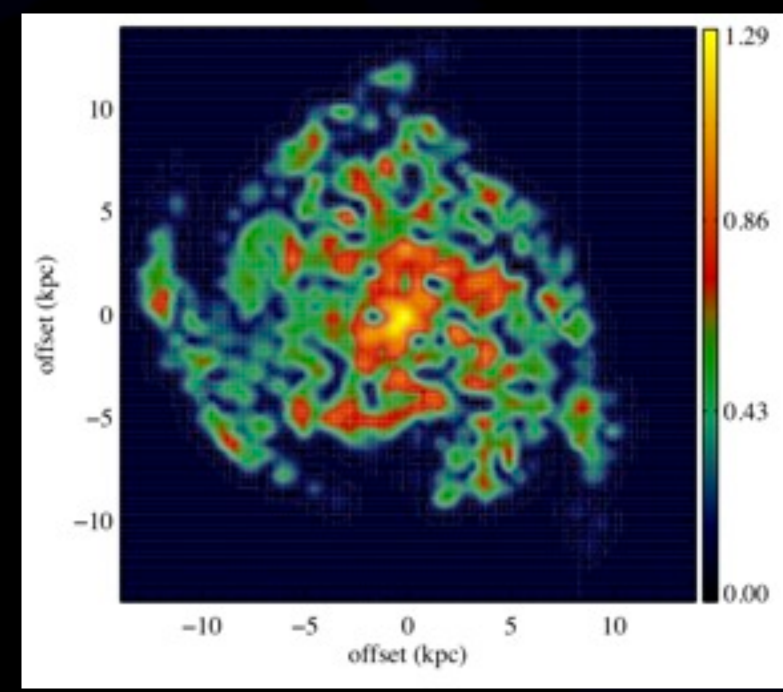

X_{CO} (MW) = few x 10^{20} cm^{-2}/K-km/s

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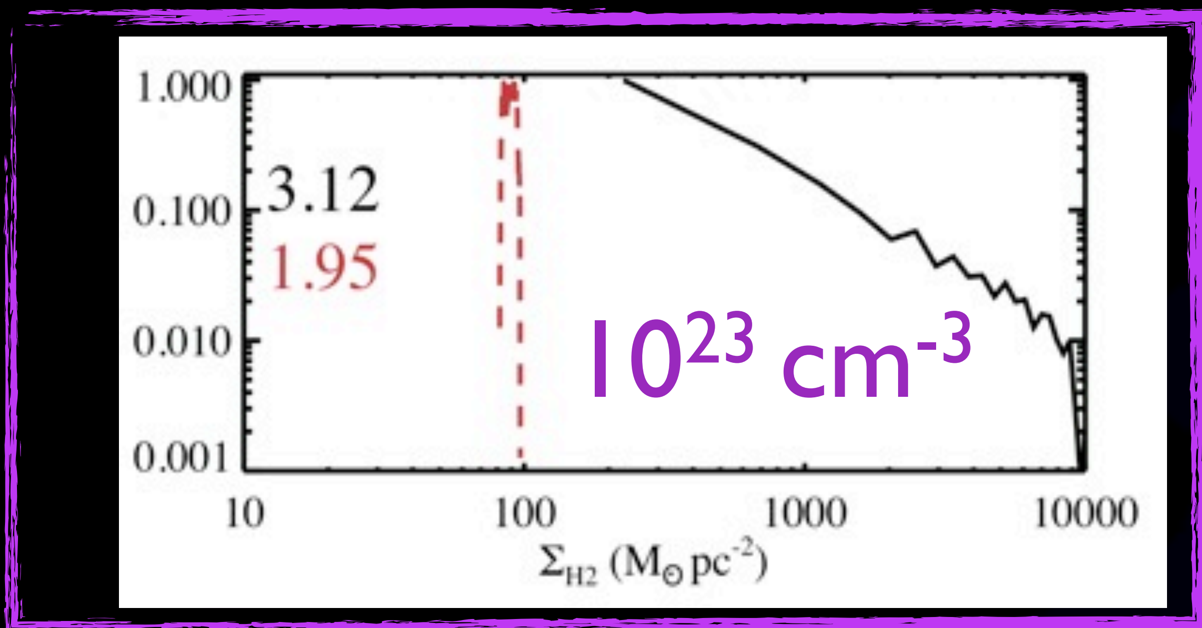

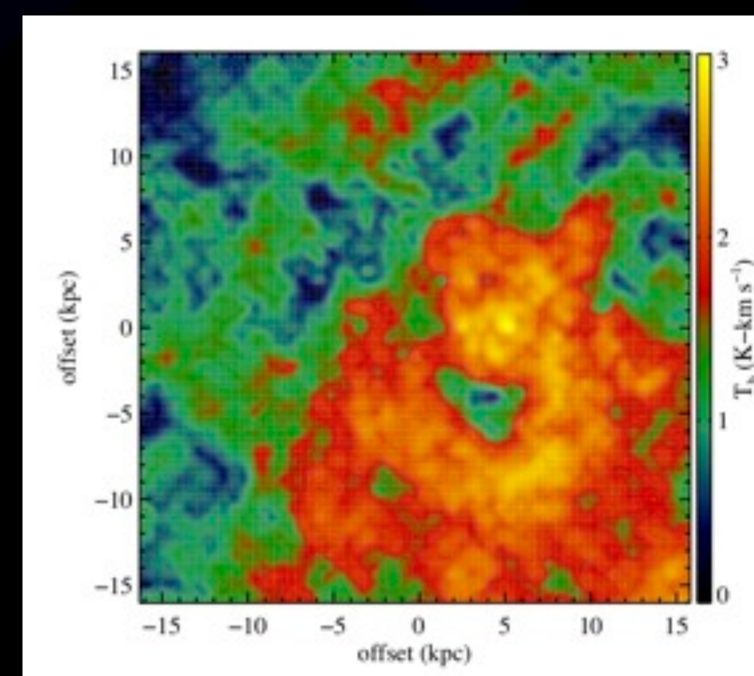

Narayanan, Krumholz, Ostriker & Hernquist 2011

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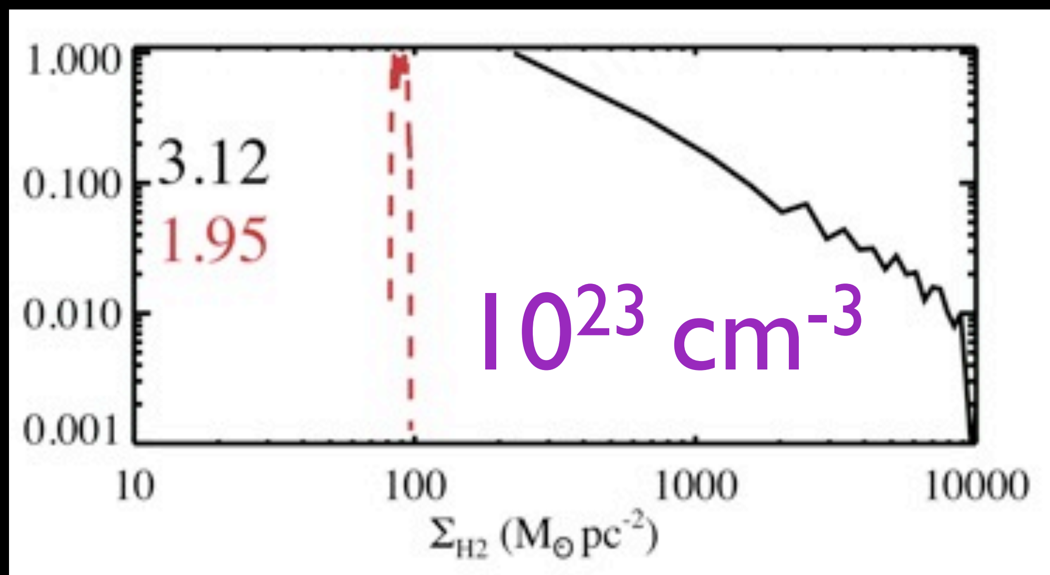

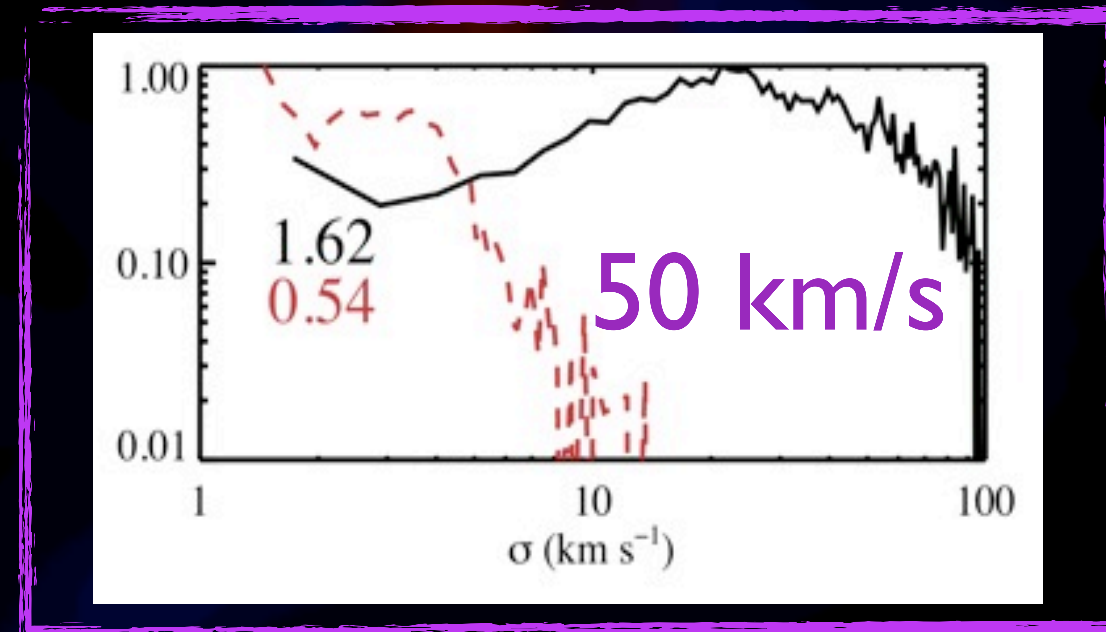

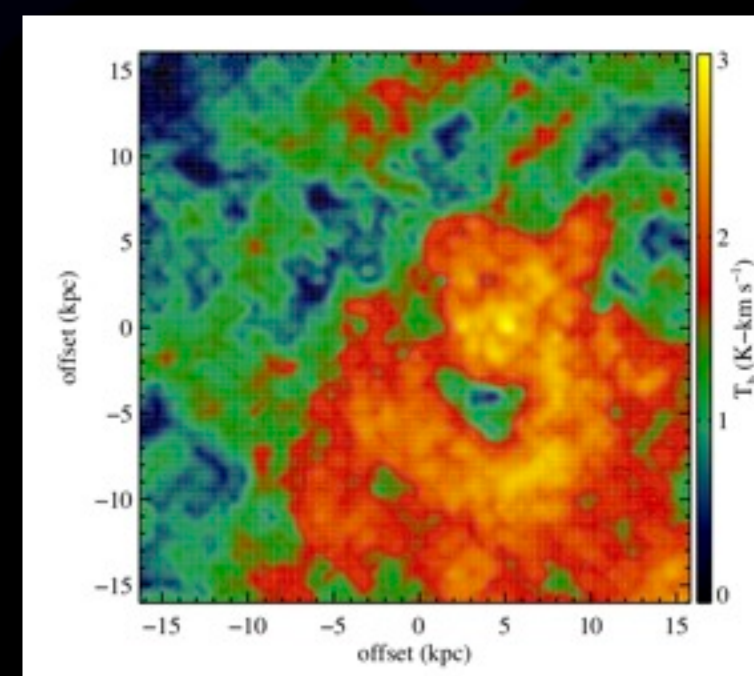

Narayanan, Krumholz, Ostriker & Hernquist 2011

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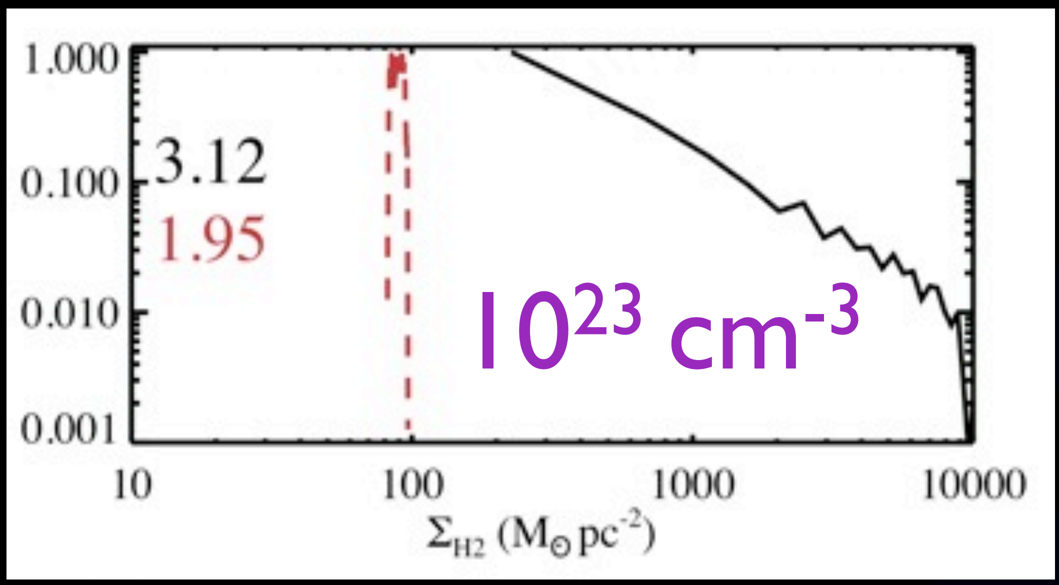
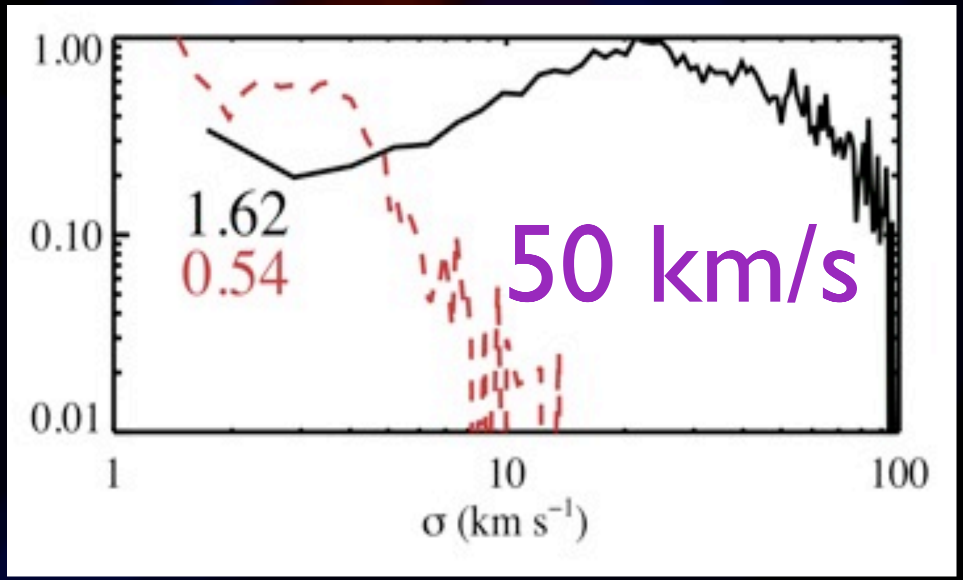
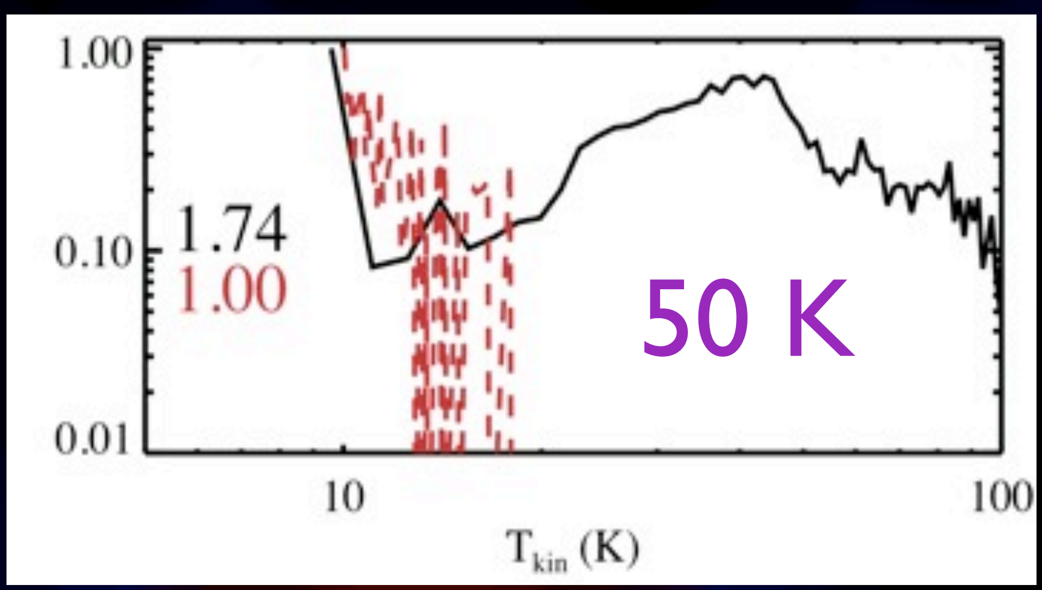
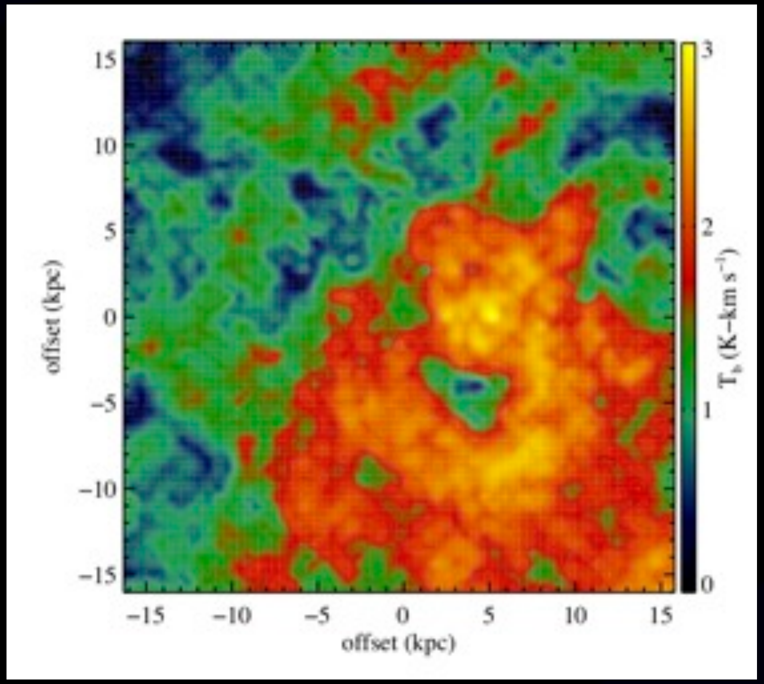




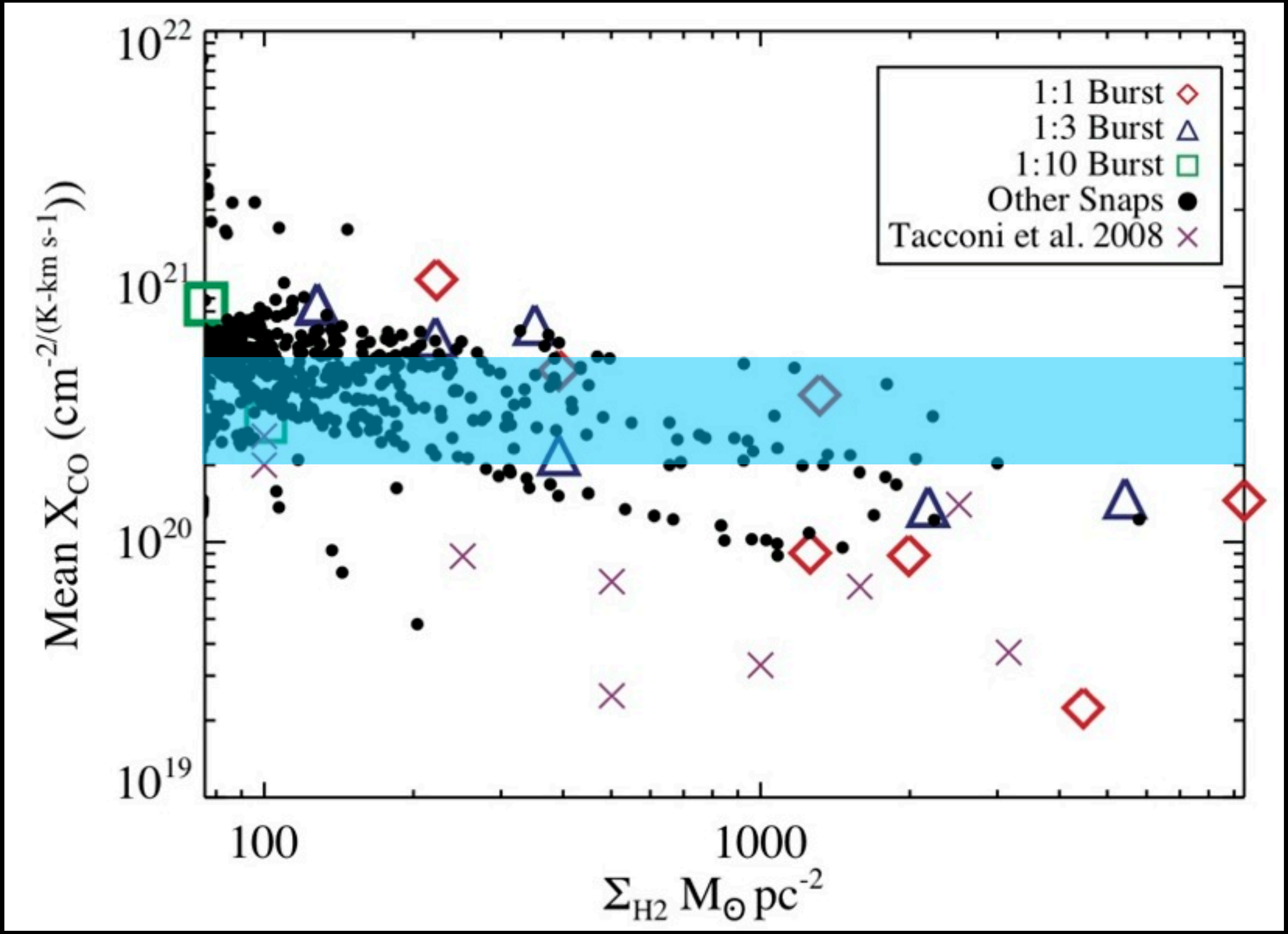




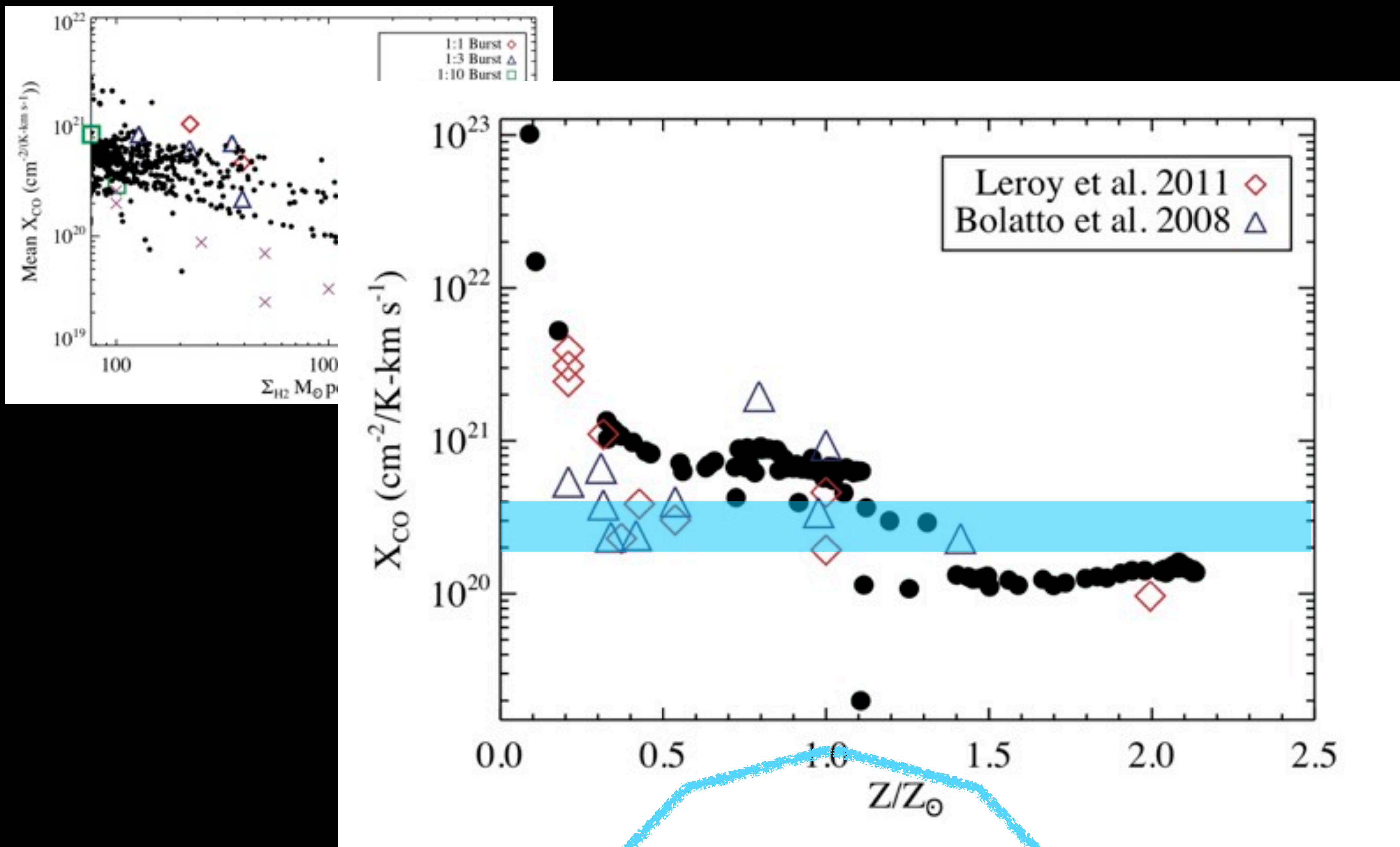
X_{CO} (MW) = few x 10^{19} cm^{-2}/K-km/s

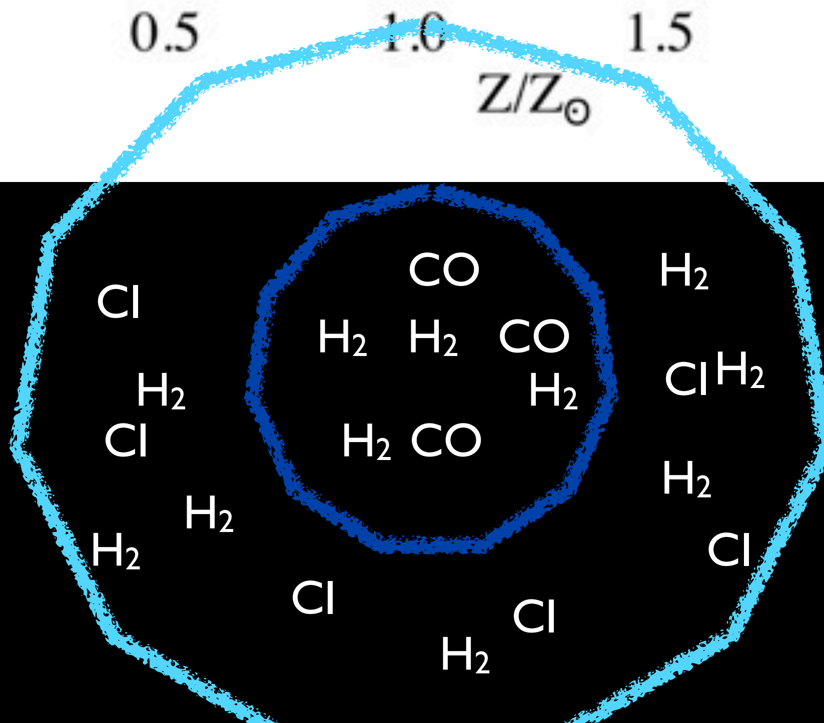
Narayanan, Krumholz, Ostriker & Hernquist 2011

Xco decreases with increasing Σ_{H2}

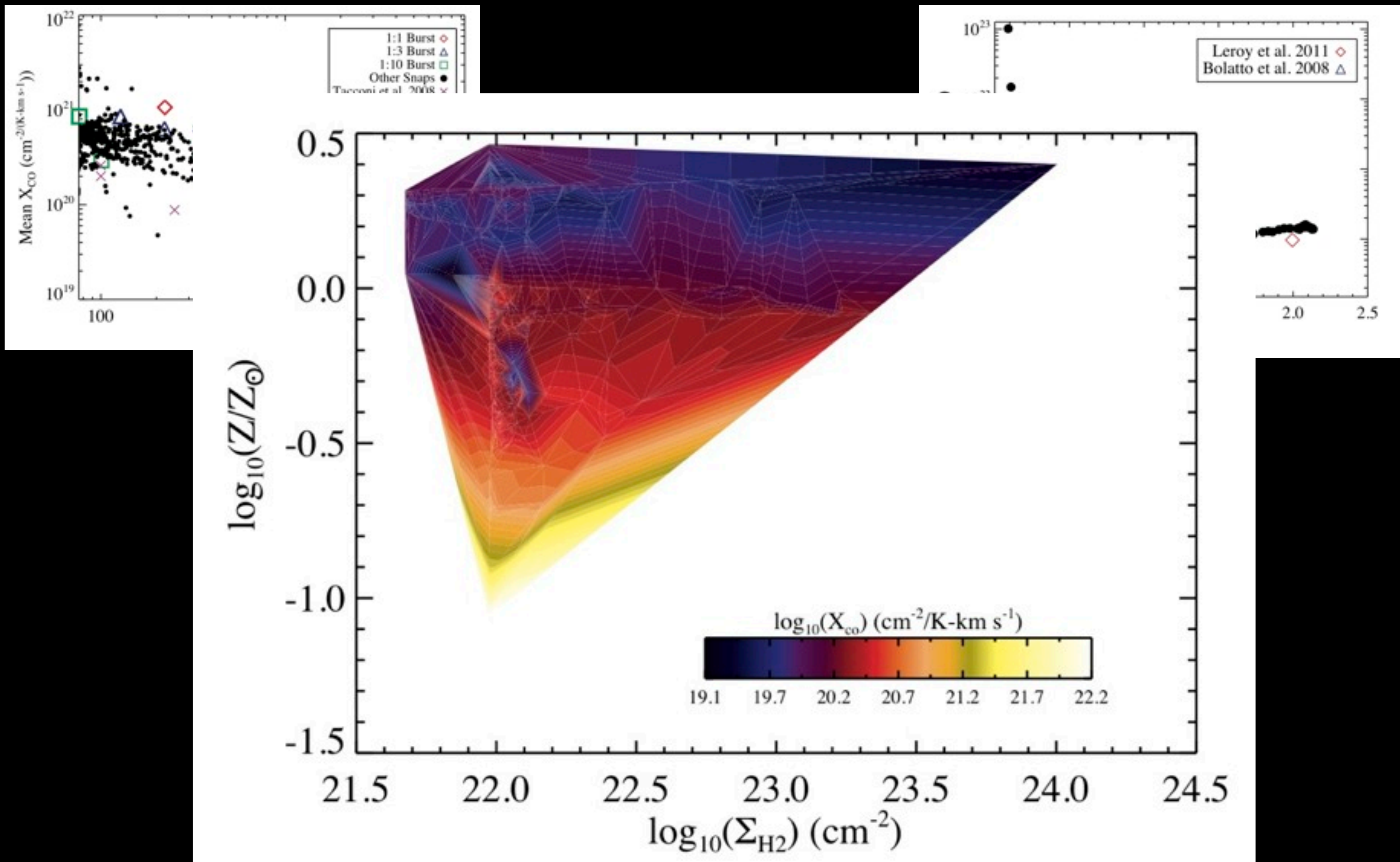


Xco increases with decreasing Z





A General Prediction for Xco



$$X_{co} \sim \Sigma_{H2}^{\;-0.2}\, e^{-Z/Z_{\odot}}$$

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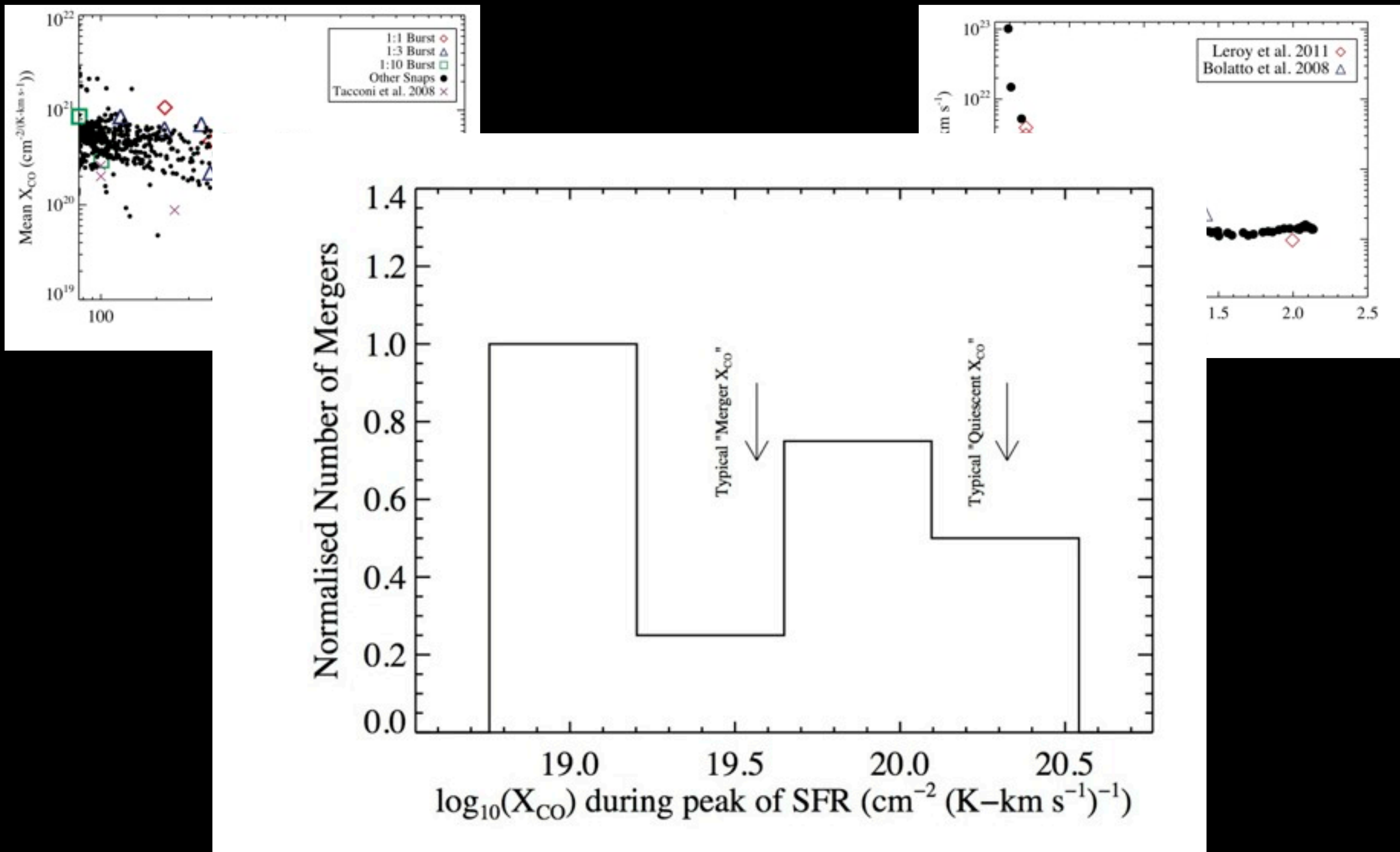
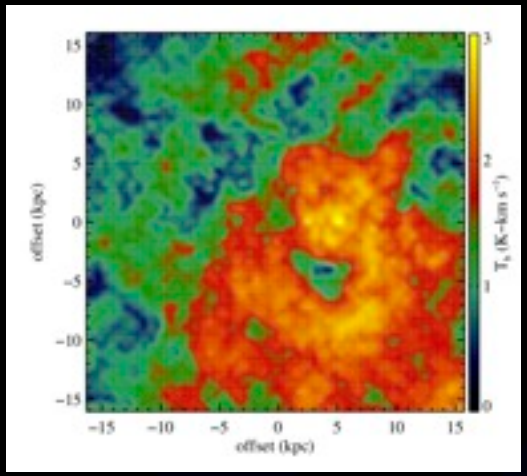
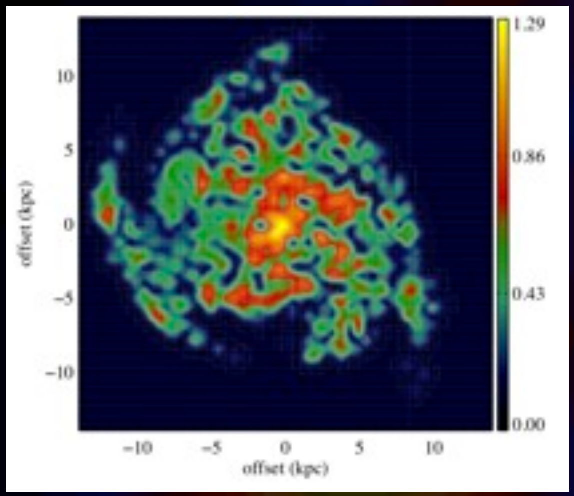


$$X_{co} \sim \Sigma_{H2}^{-0.2}\, e^{-Z/Z_{\odot}}$$

Conclusions





Xco a continuous function dependent on metallicity and thermal and dynamical state of galaxies

- In starburst galaxies hotter and high velocity dispersion gas causes Xco (on average) to be lower than Galactic mean

- In low metallicity galaxies, lack of dust shielding increases mass of CO-dark clouds, and drives Xco to larger values than Galactic mean