On the Origin of HI in Galaxies

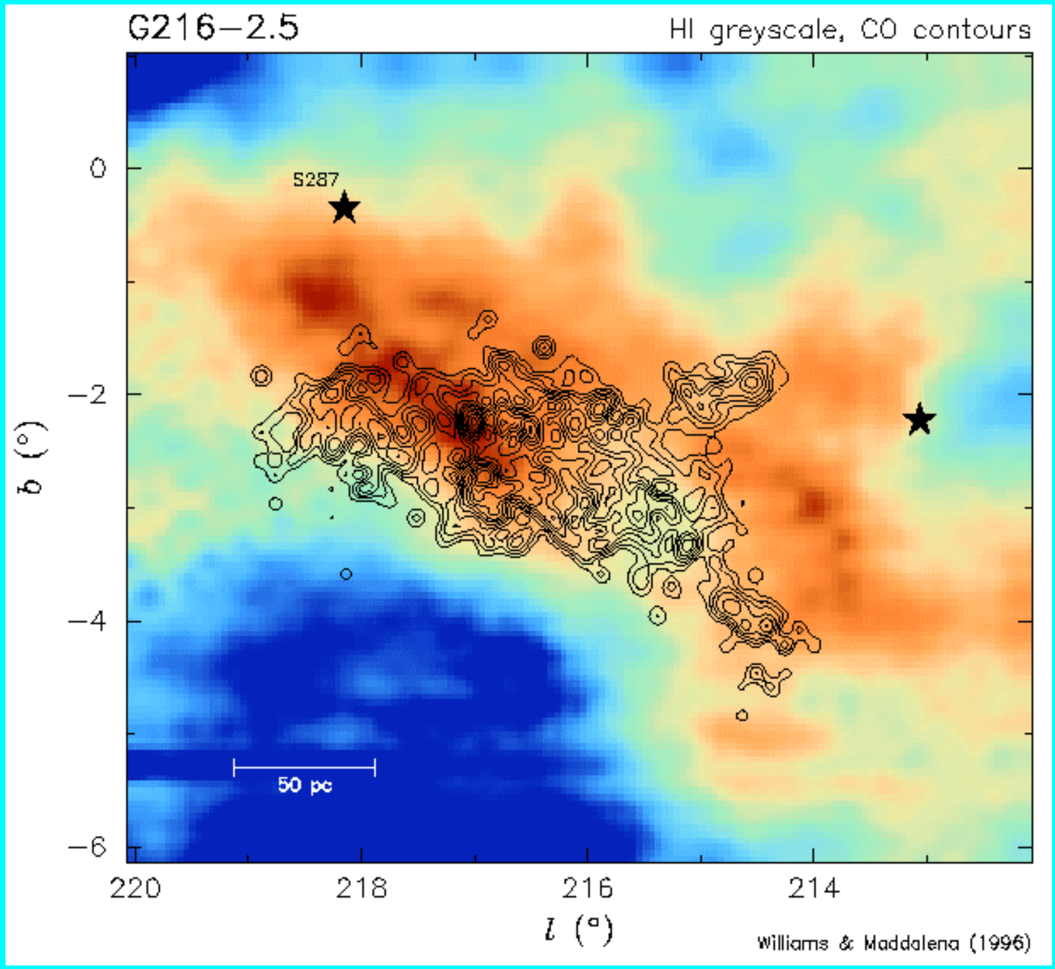
Photodissociation and the

“Schmidt Law”

for global star formation

A large PDR in the Galaxy …

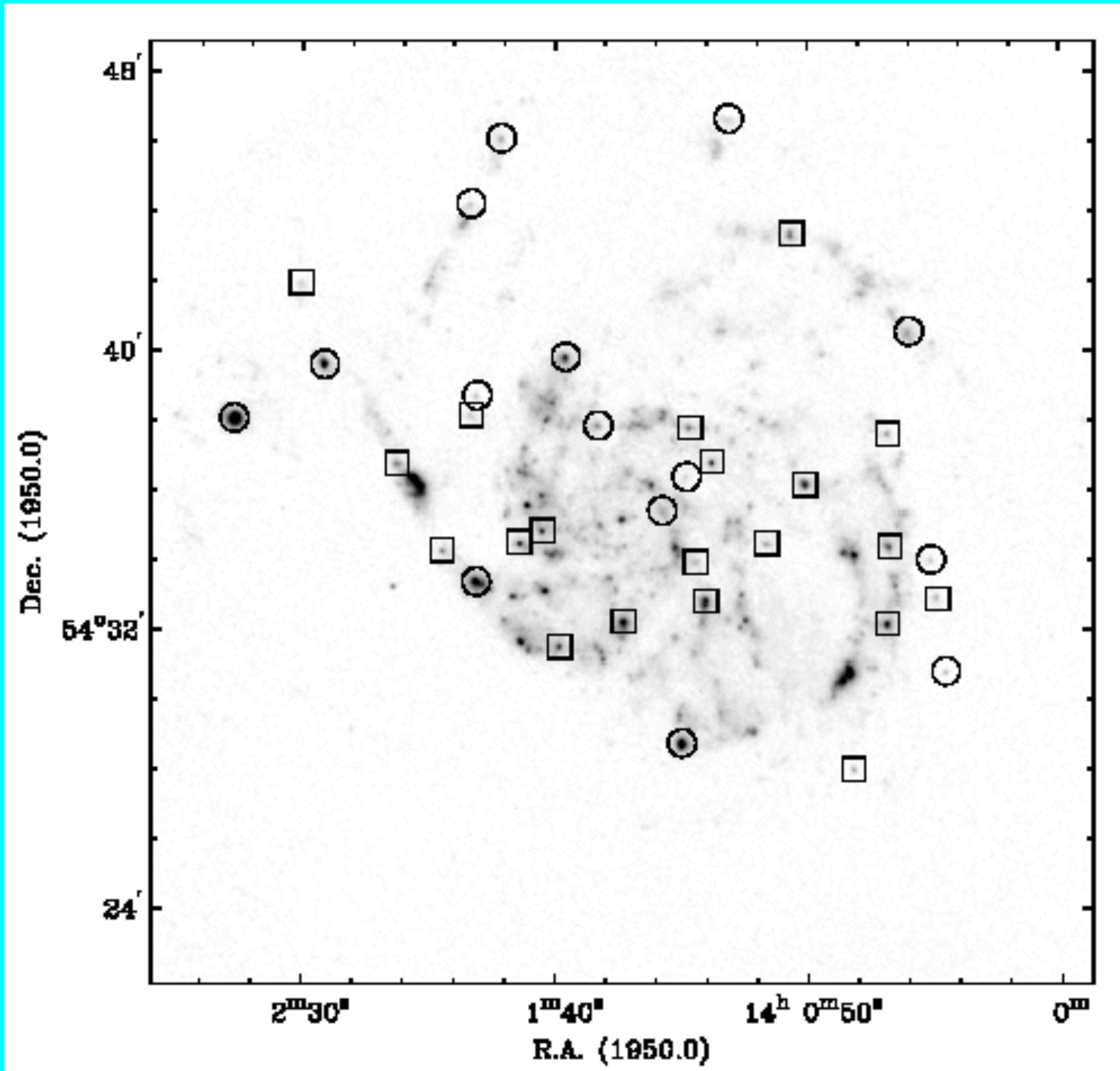
- Identified as a large PDR by WM96
  - Galactic confusion problem solved by isolating the feature in velocity in the HI and CO(1-0) data cubes according to the distances of the exciting stars
- Model fit using combined HI & CO(1-0) (AHK04)
  - n ~ 200 cm^{-3}
  - G_0 ~ 0.8
- HI thickness ~ 1 pc



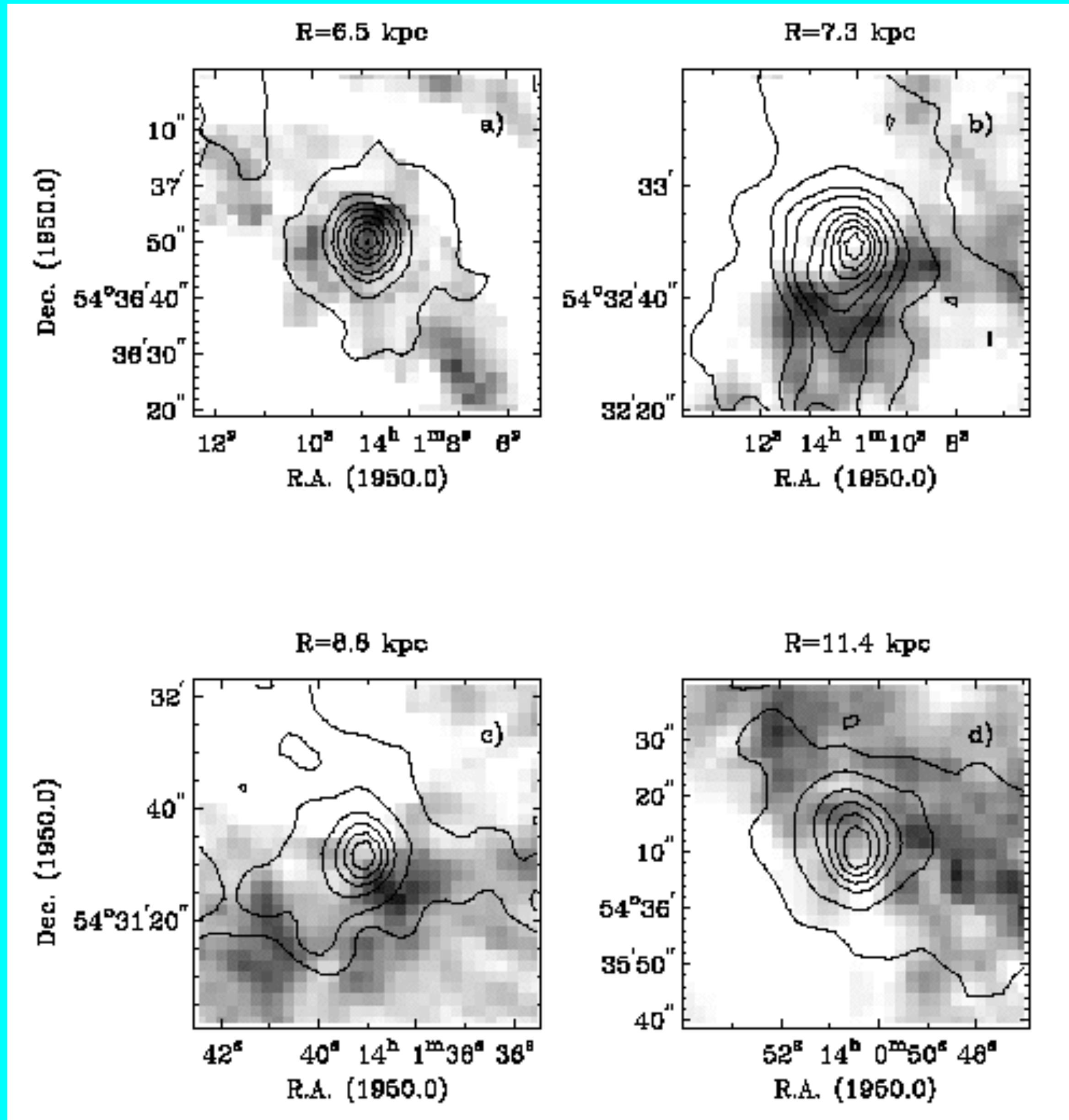
$$N(\mathrm{H\,I}) = \frac{7.8 \times 10^{20}}{(\delta/\delta_0)} \ln\left[\frac{106 G_0}{n}\left(\frac{\delta}{\delta_0}\right)^{-1/2} + 1\right] \mathrm{cm}^{-2}$$

Allen, Heaton, & Kaufman (2004)

- General features of this equation:
  - N_1 = N(HI) depends on the *ratio* of FUV flux / total volume density;
  - At a given n, N(HI) increases first linearly with FUV flux, then only logarithmically …
    - *values much larger than a few x 10^{21} ≈ few x 10 M_S /pc^2 will be rare.*
  - At a given FUV flux, N(HI) *decreases* with increasing n;
  - N(HI) *increases* with *decreasing* dust/gas ratio δ/δ_0 .

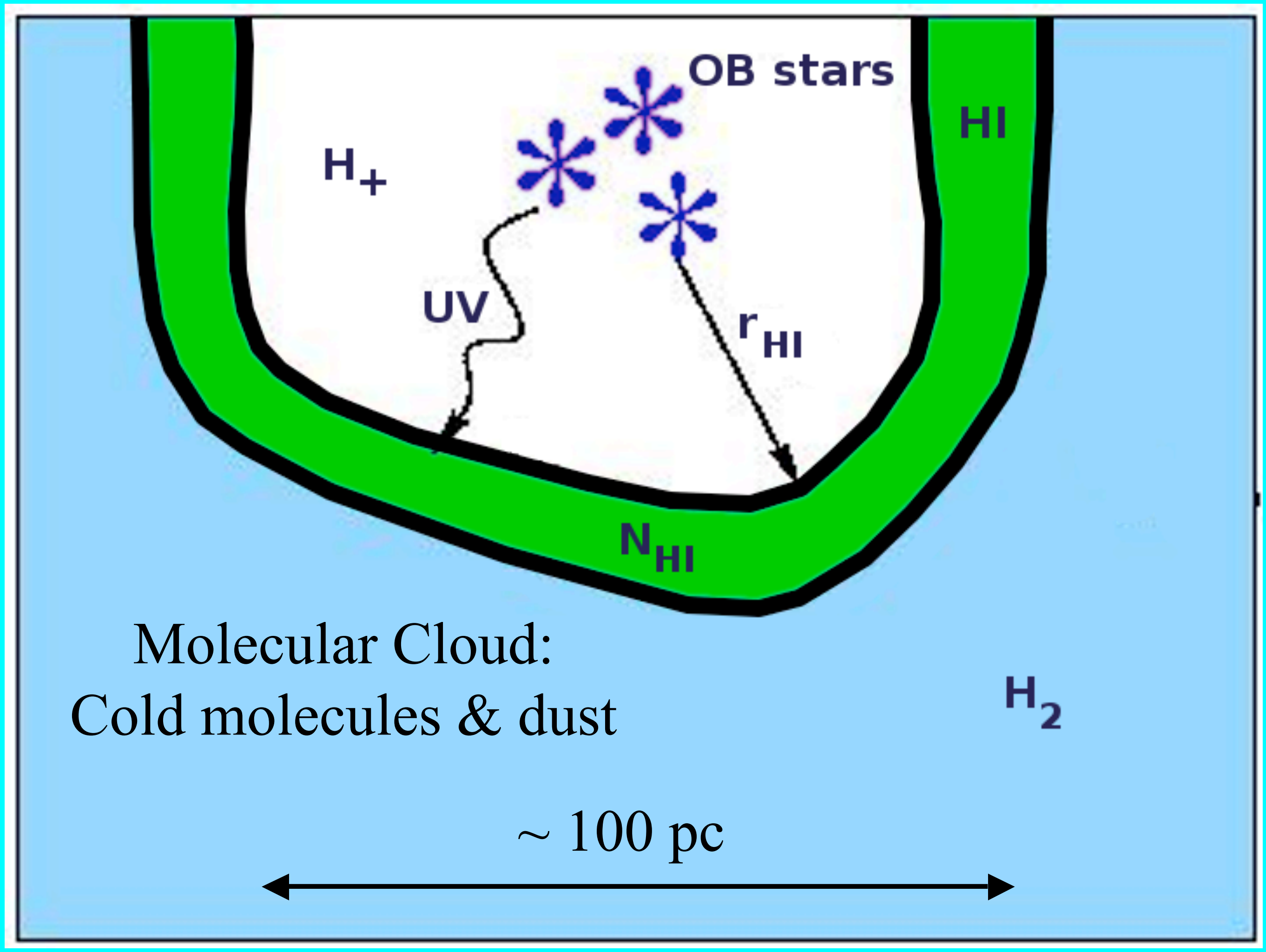


Smith et.al. (2000)



Smith et.al. (2000)

Obtaining G_0 and N(HI) from the data …



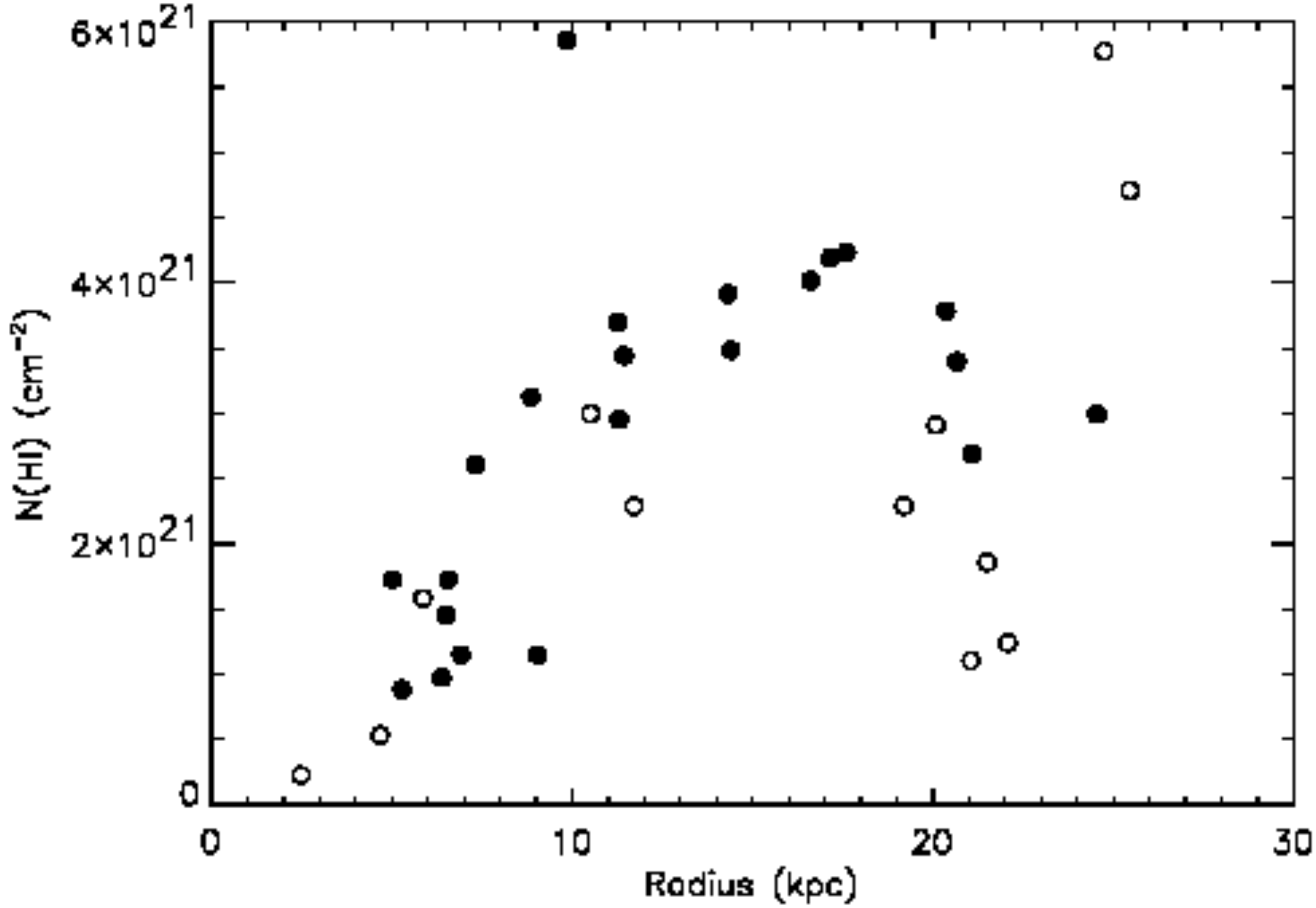


FIG. 13.—Peak column densities ($N_{\mathrm{H\,I}}$). The peak column density in the vicinity of each FUV source is measured from the H I map. Column densities generally increase as the distance from the nucleus increases, reflecting the large-scale trend seen in Fig. 2.

Smith et.al. (2000)

FUV fluxes of candidate PDRs in M101 …

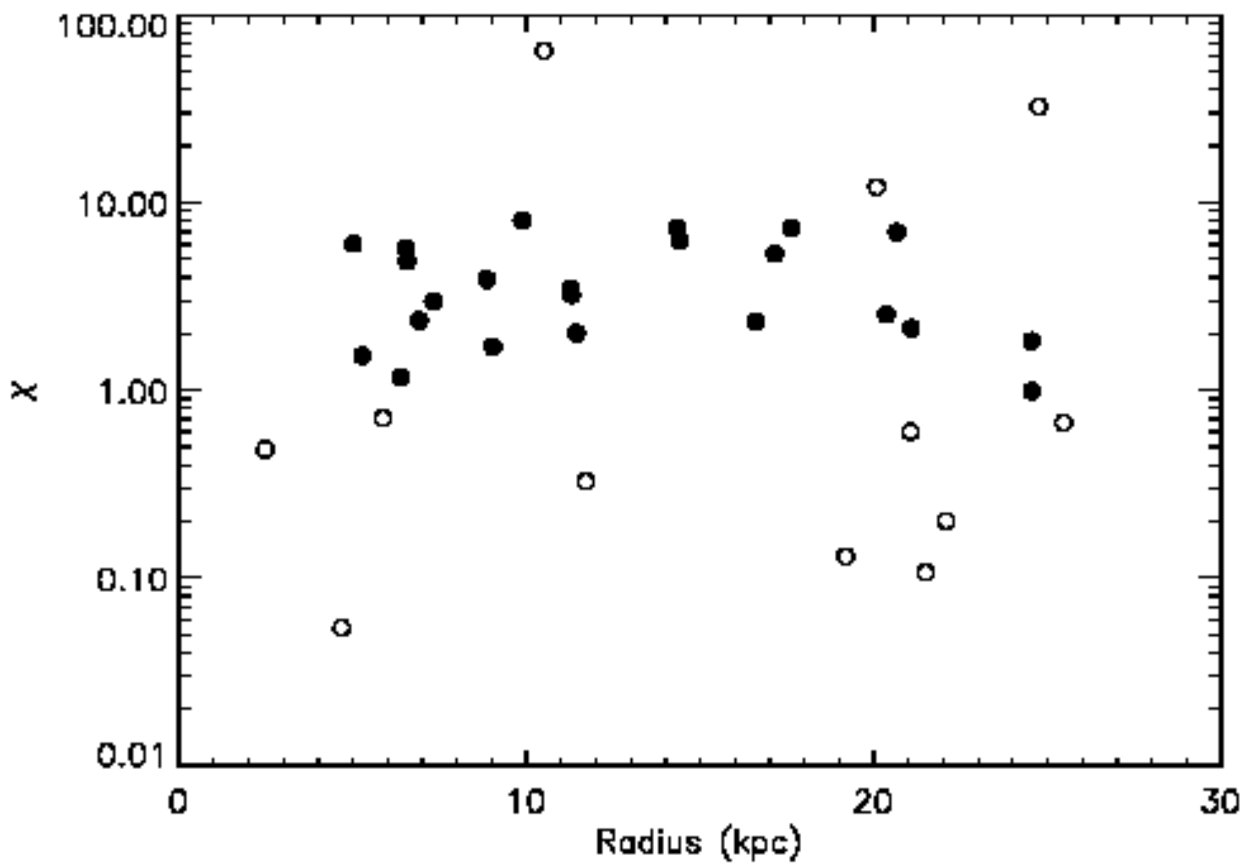


FIG. 12.—Derived χ-values. The FUV flux observed at the location of the peak H I is derived from F_{FUV} and $\rho_{\mathrm{H\,I}}$. The values of χ are independent of radius and clustered between $\chi = 0.9$ and $\chi = 10$.

Observed metallicity gradient …

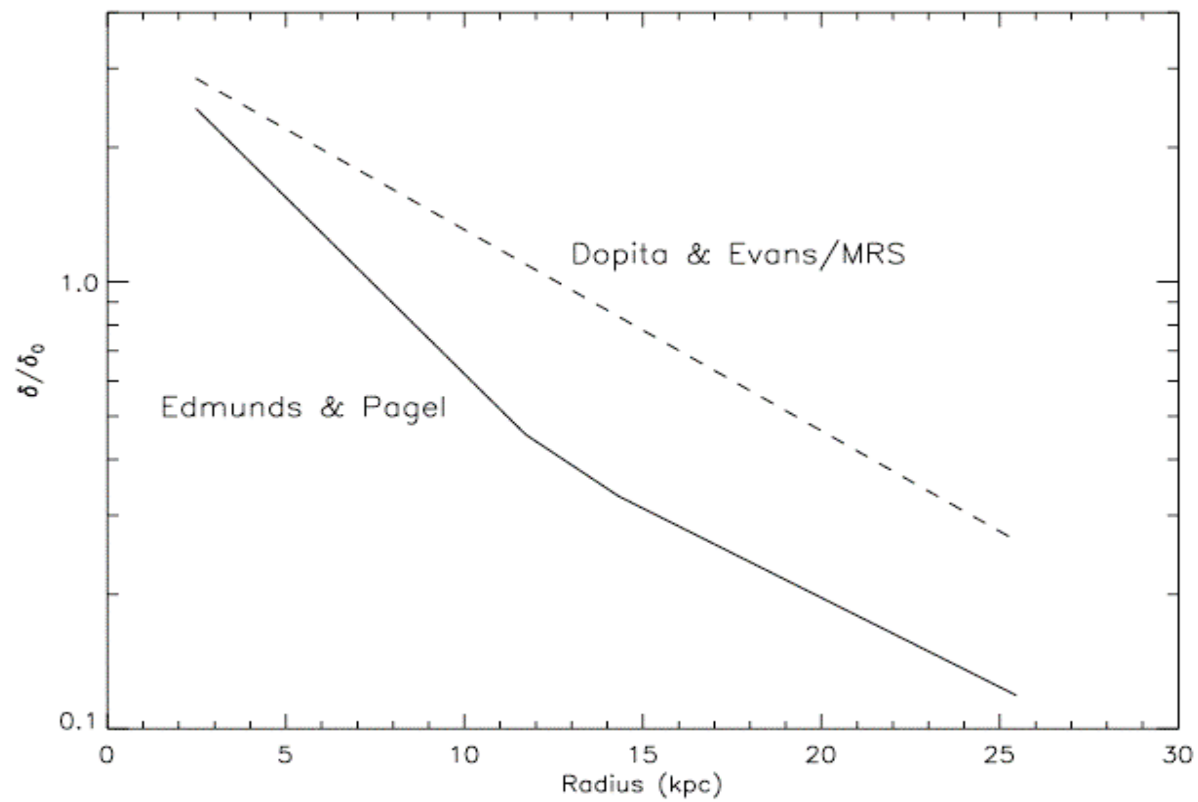


FIG. 16.—Dust-to-gas profiles obtained from the metallicity gradients given in Kennicutt & Garnett (1996). The solid line is based on the calibration of Edmunds & Pagel (1984); the dashed line reflects the average of the calibrations of Dopita & Evans (1986) and MRS.

GMC densities in M101 …

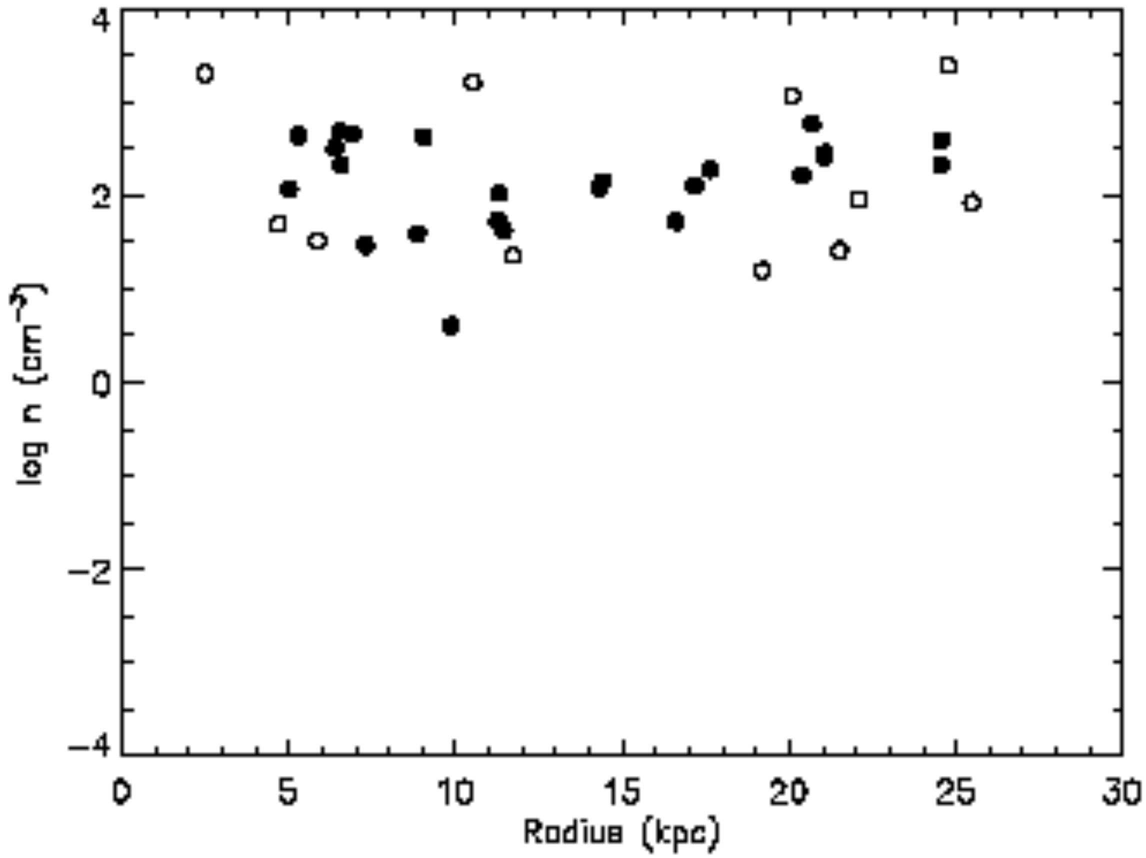


Figure 6. Total gas volume density in GMCs near a sample of 35 young star clusters in M101. This is all H_2 deep within the cloud. See Figure 19 in Smith et al.(2000) for further details.

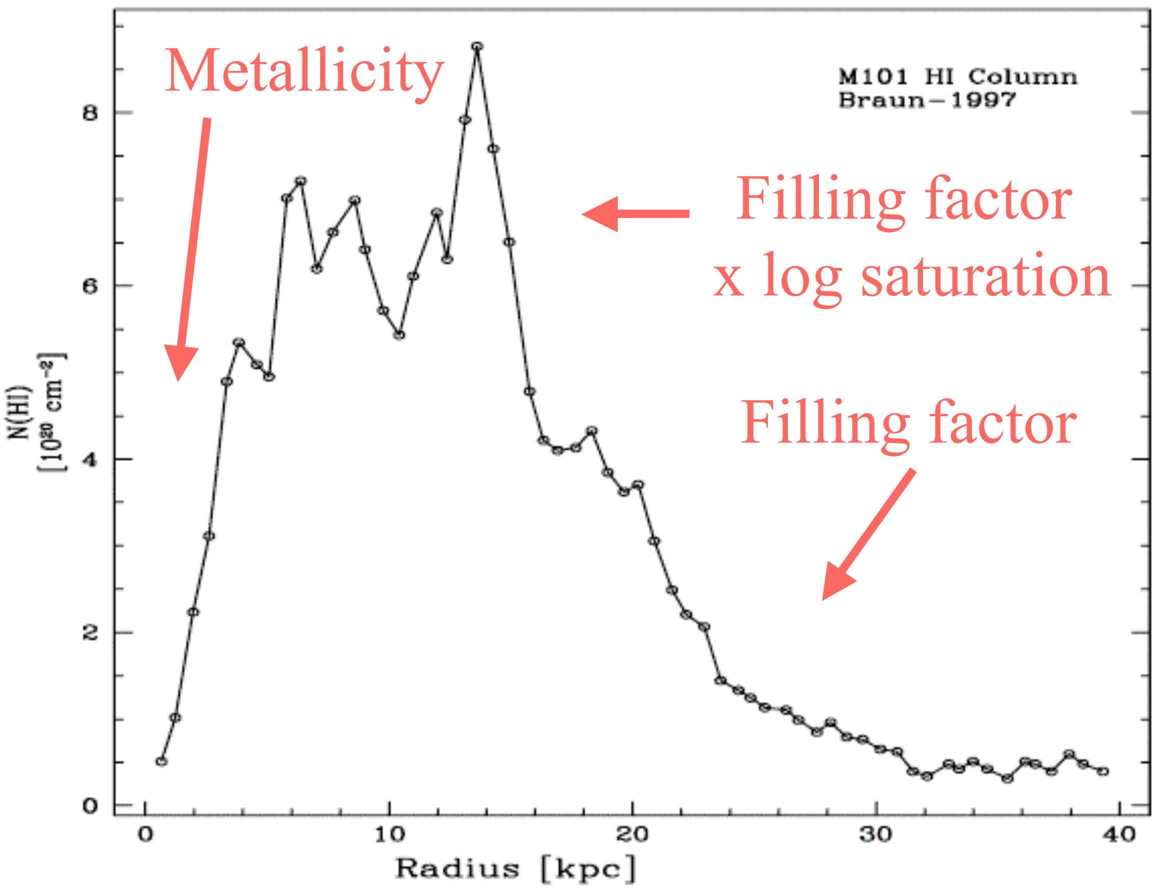


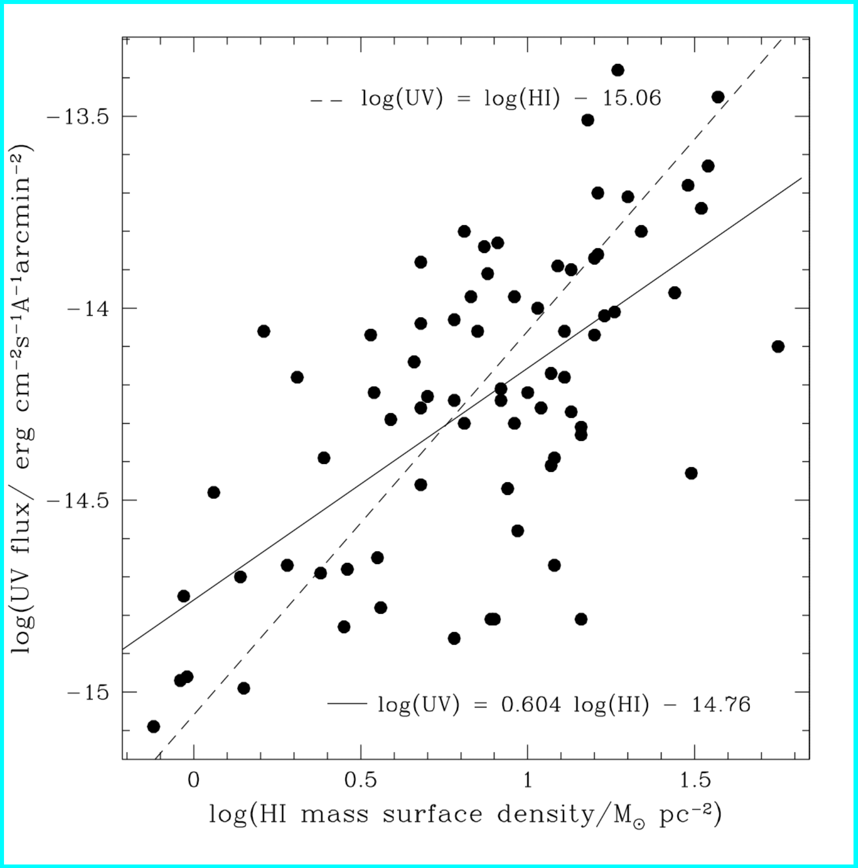
Figure 3. Radial distribution of H I surface brightness for the nearby giant Sc galaxy NGC5457 = M 101 obtained by averaging the H I data in annular elliptical rings. From Braun(1997), adjusted to an assumed distance of 5.4 Mpc. R_{25} for this galaxy is $13.5' \approx 21$ kpc.

What does this have to do with the KS law?

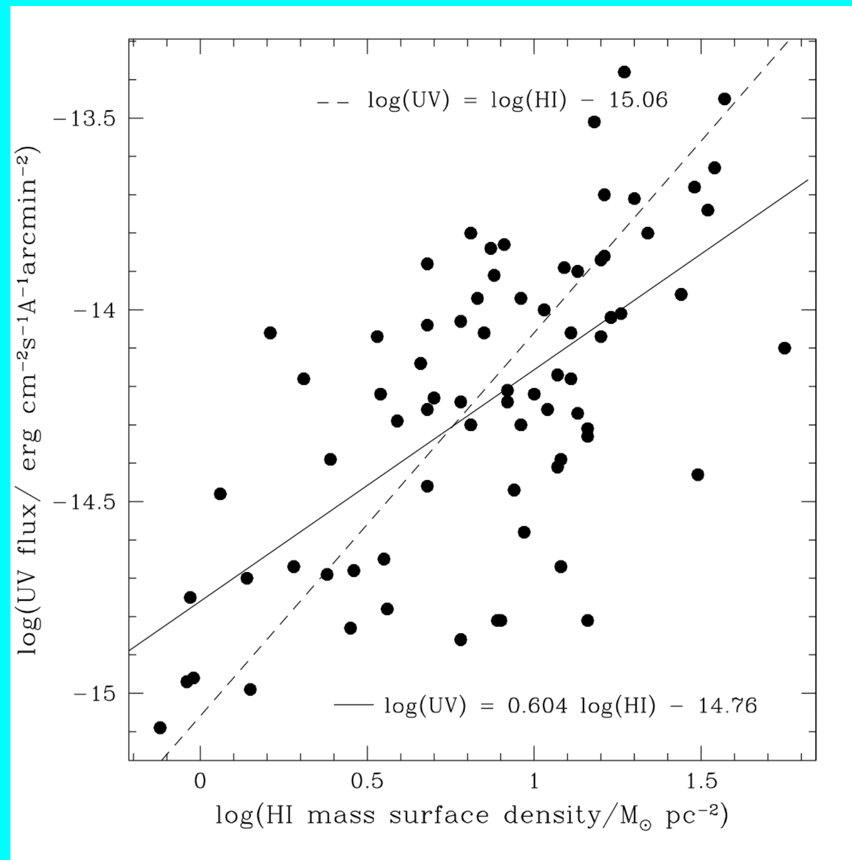
- In this picture, the HI in the disks of galaxies is viewed not as a precursor to the star formation process, but as a *product* of it.
- HI is maintained at the observed column densities in the disk by the dissociating FUV flux from massive young stars (mostly B stars).
- The relevance of any specific amount of observed HI column density to discussions of star formation by gravitational instabilities in galaxy disks is not obvious.

The “Global Schmidt Law” …

- More HI is assumed to produce more stars.
- The physics of this process is not simple.
- There are various approaches under consideration.



Invert the plot …



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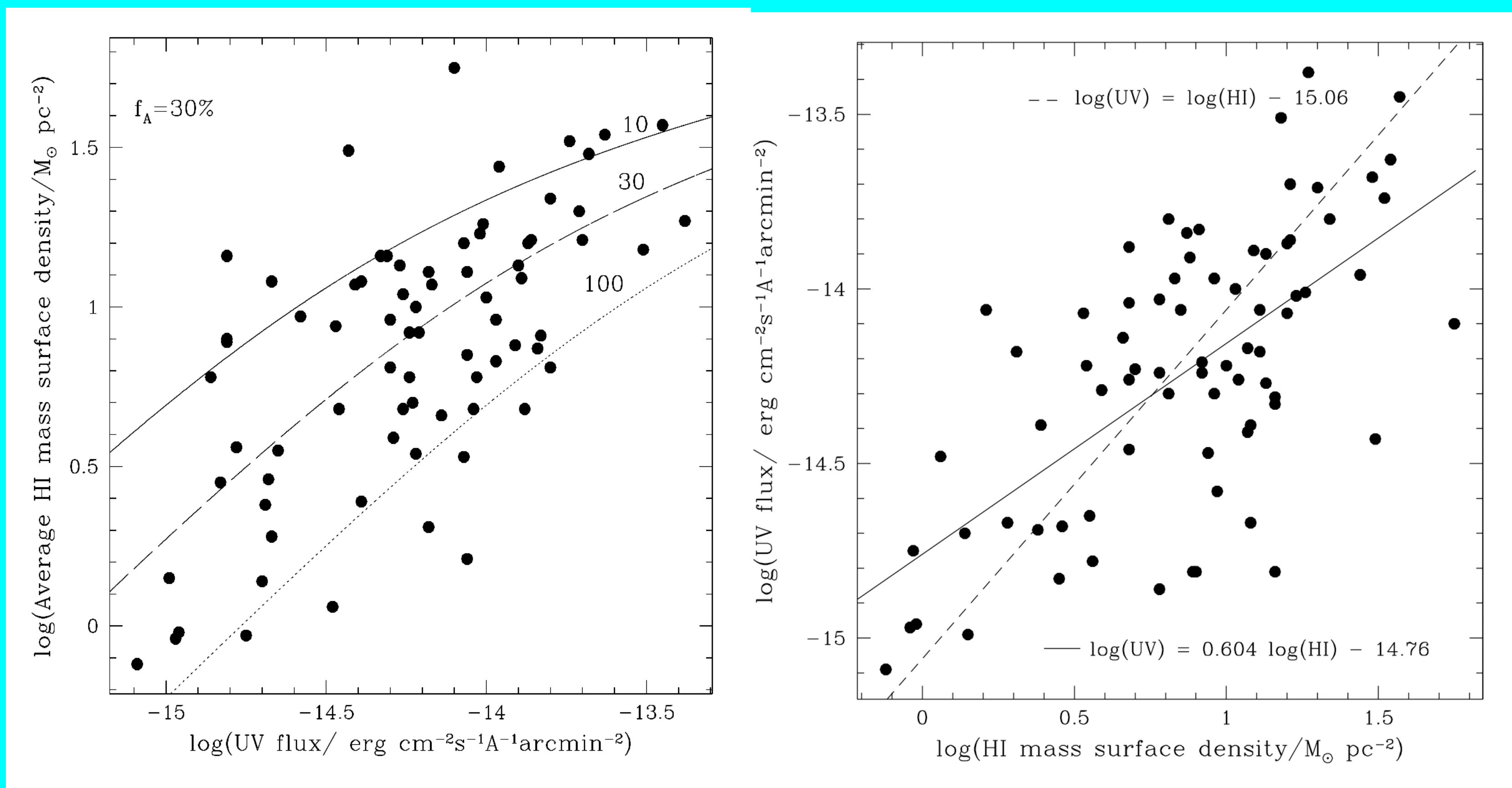
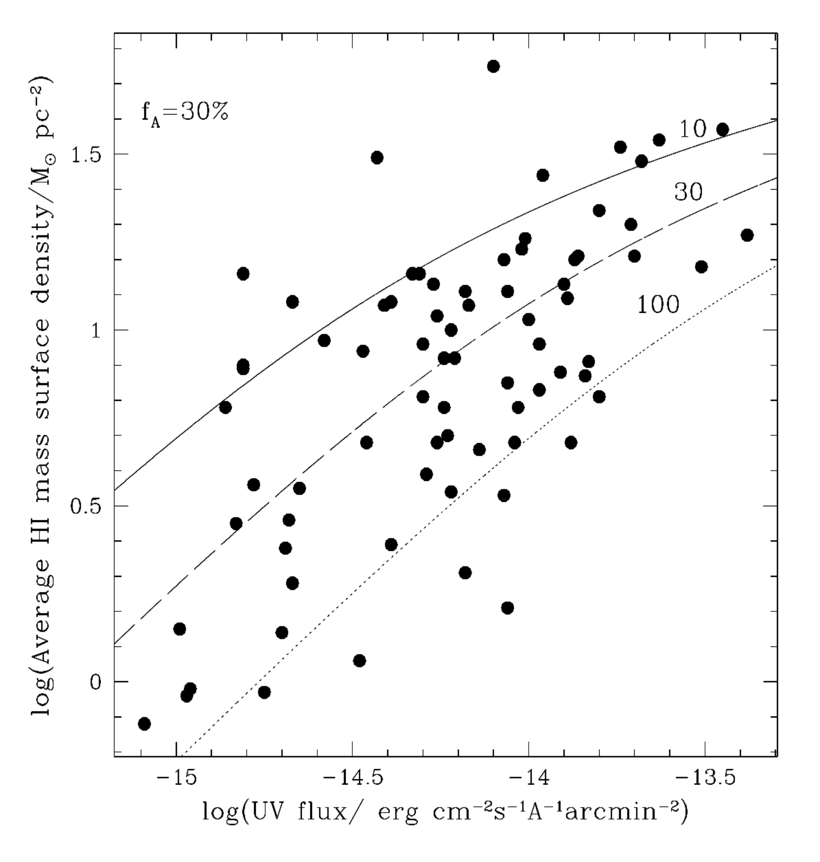
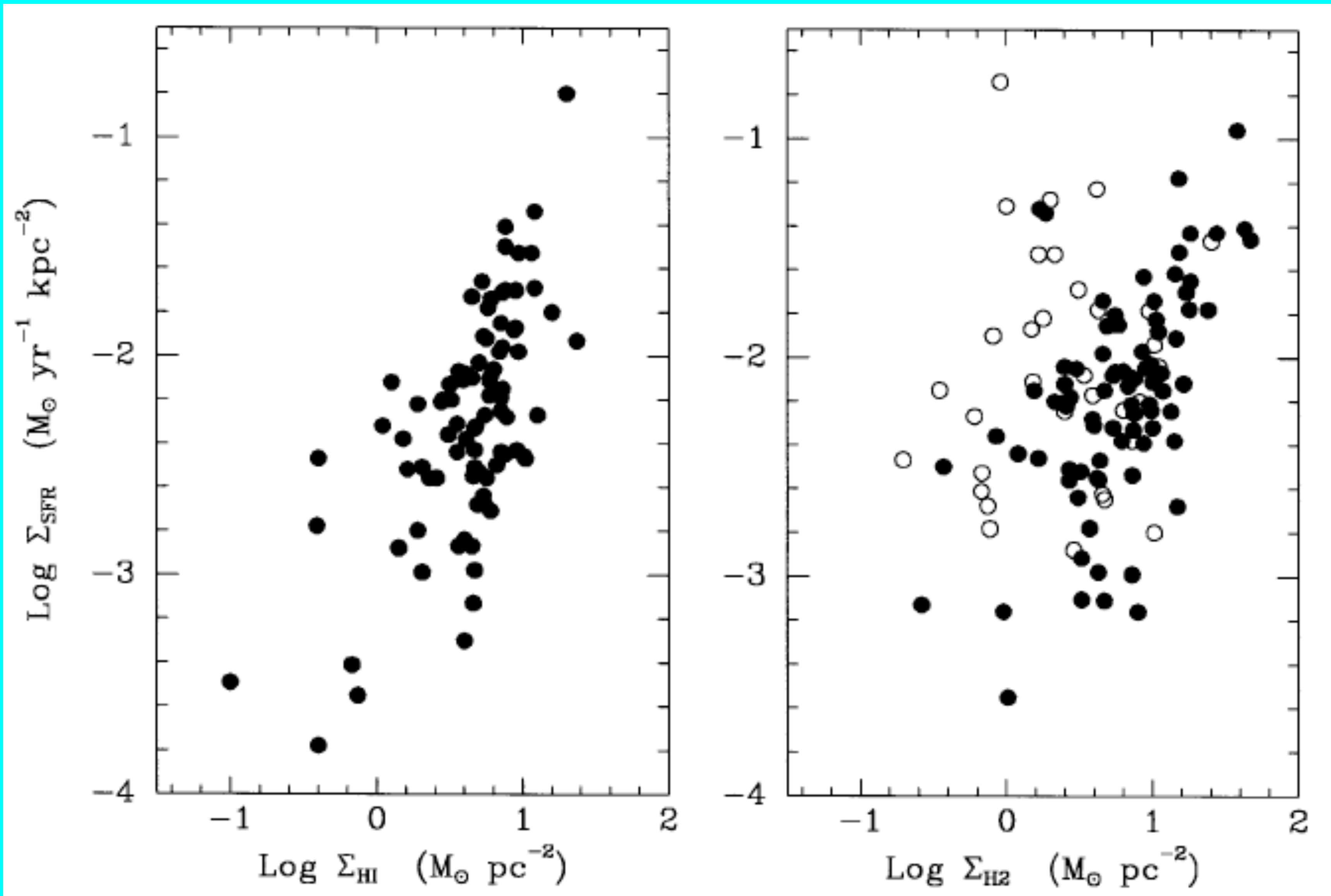


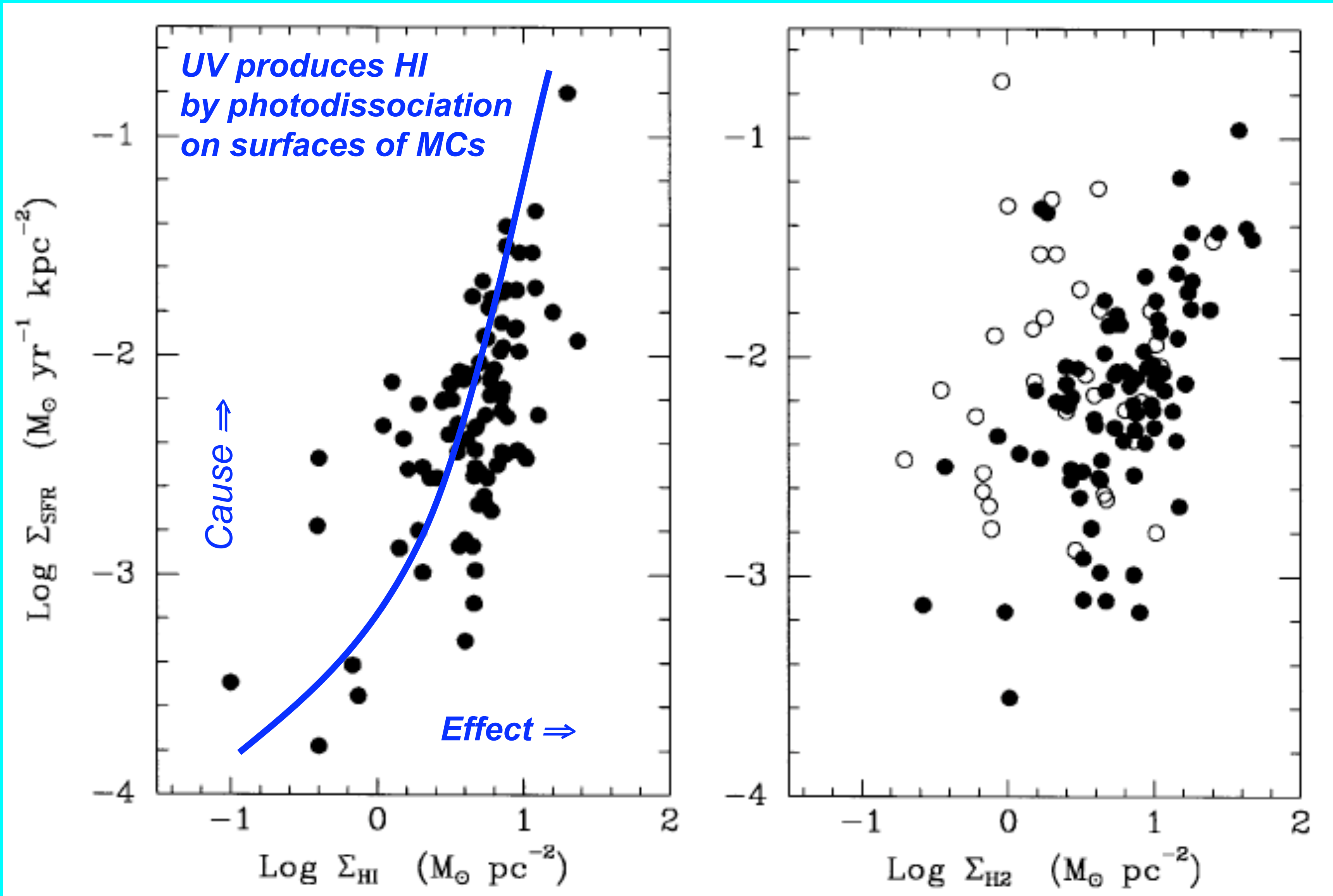
Photodissociation …



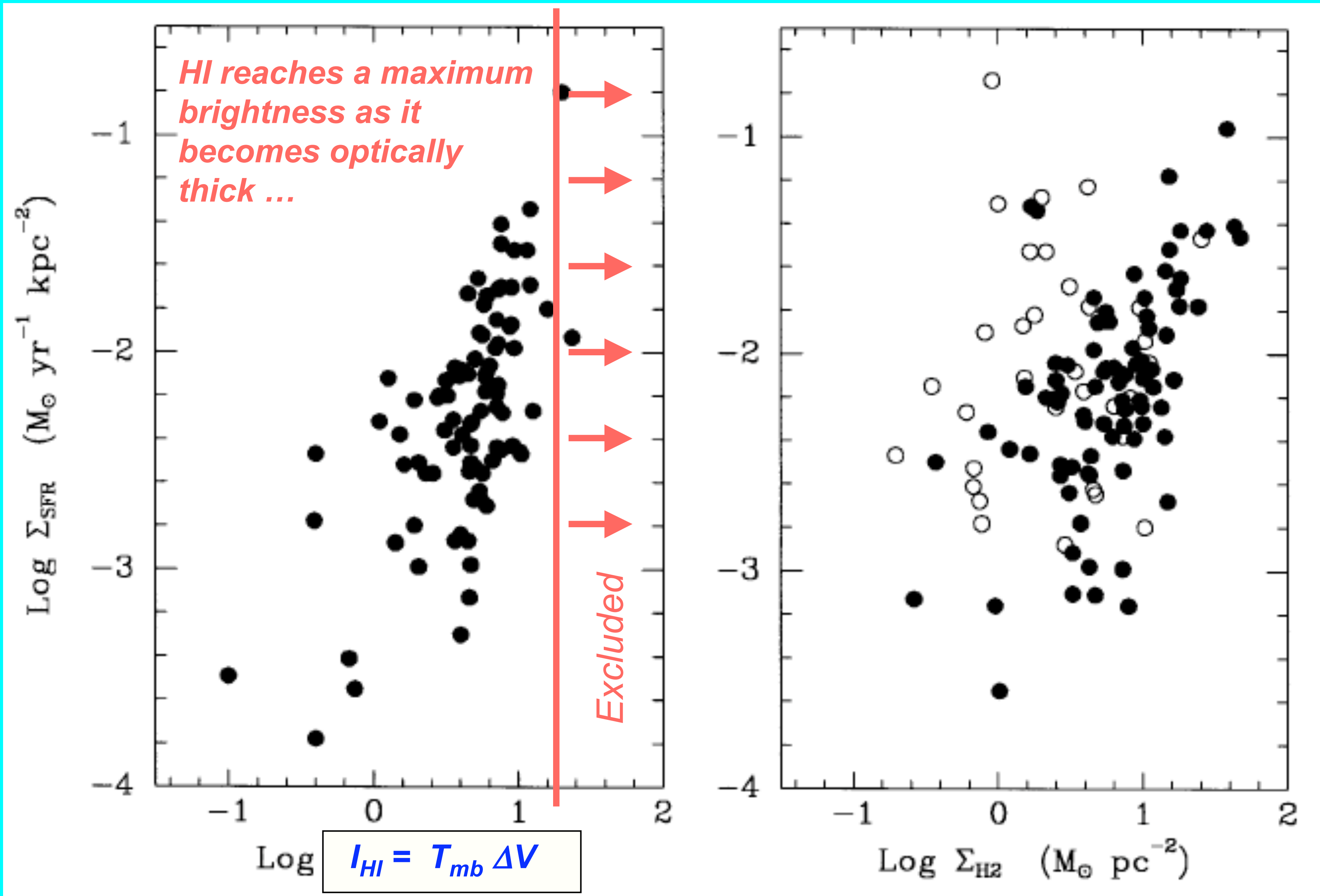
- N(HI) ~ log{1 + kG_0/n}
- Treats the UV brightness as the *cause* and N(HI) as the *effect.*
- *Physics is quite simple.*



Kennicutt (1998)



Kennicutt (1998)



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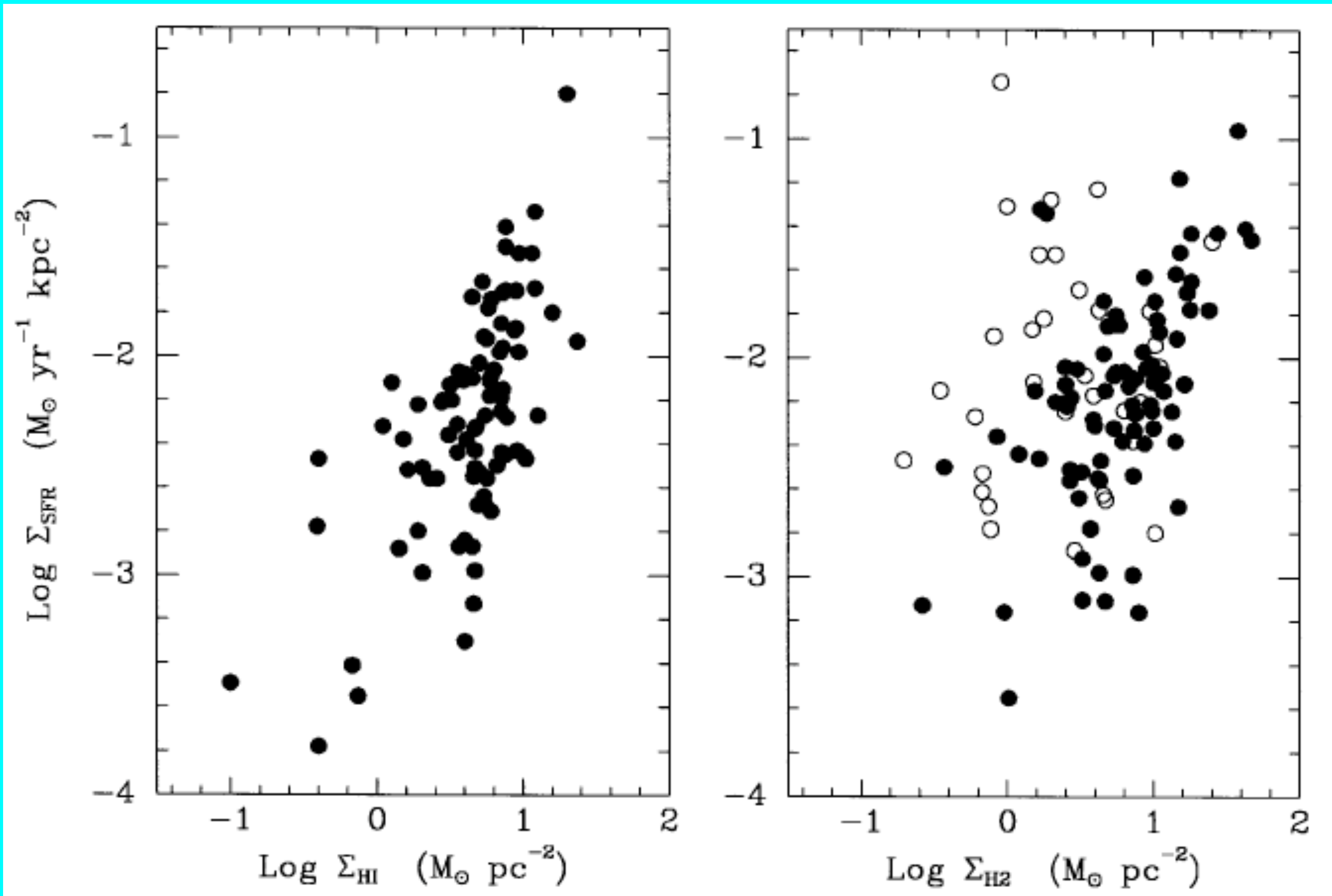

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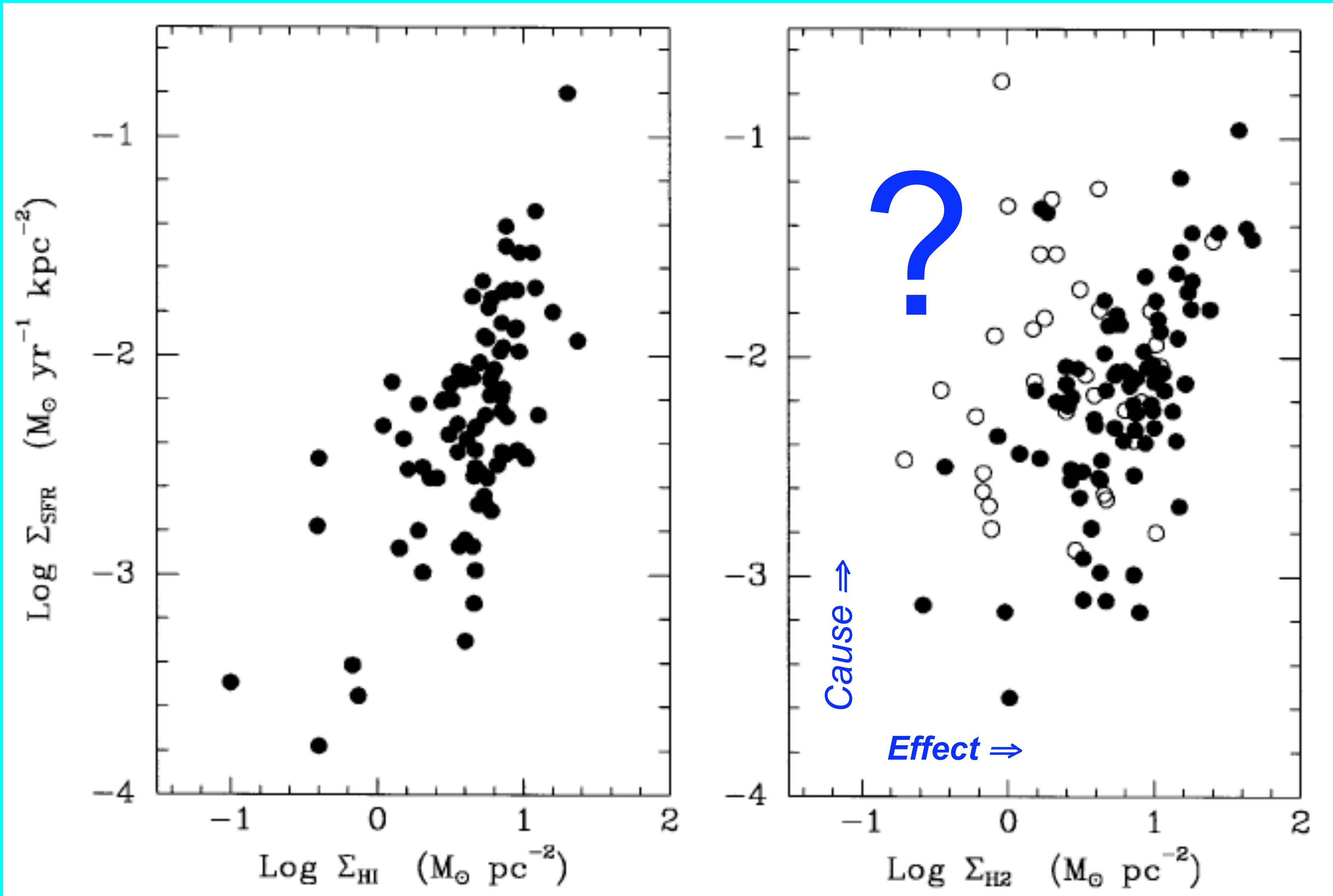
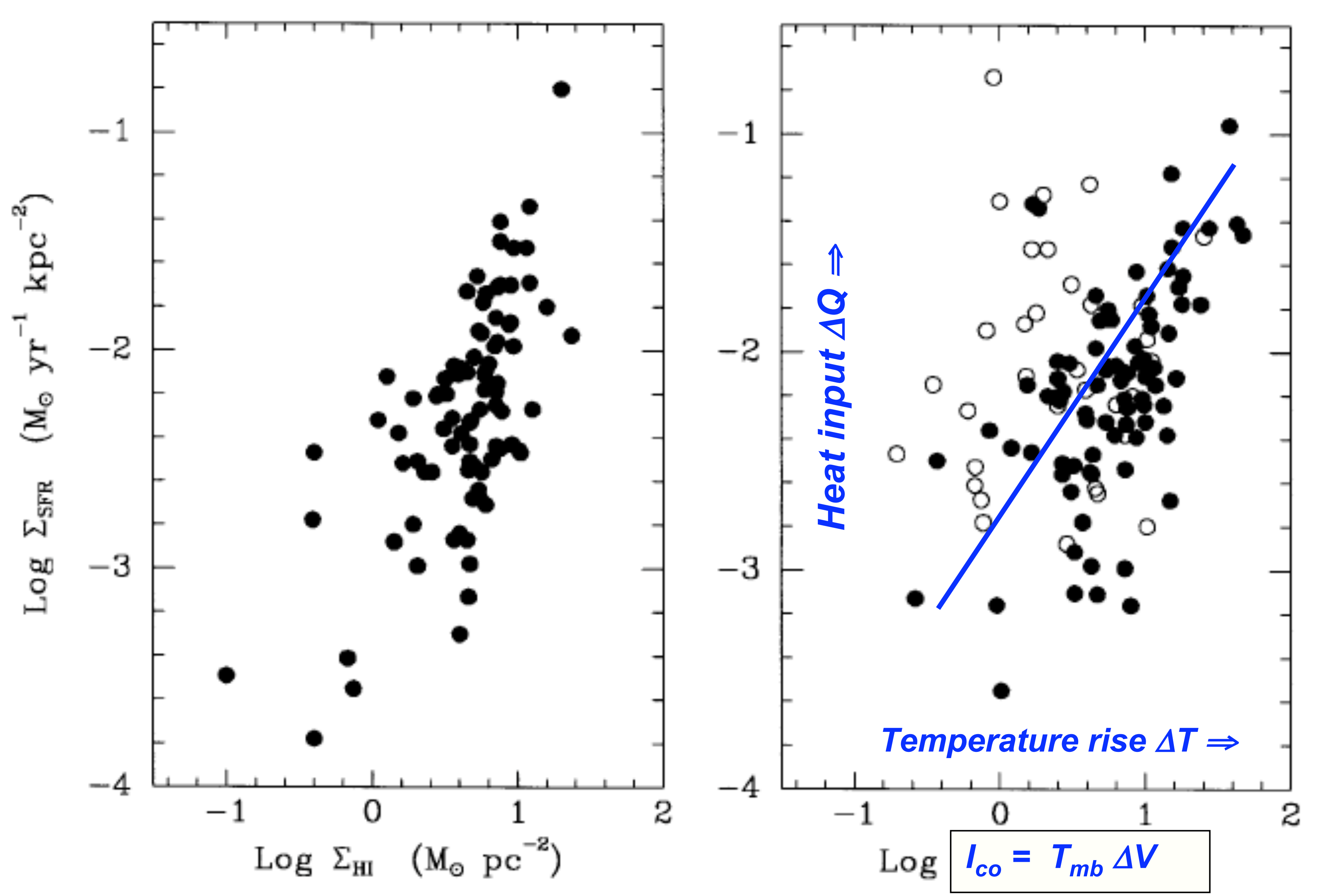


Kennicutt (1998)



Kennicutt (1998)

“It ain’t what you don’t know that gets you into trouble.

It’s what you know for sure …

… that just ain’t so.”

Mark Twain (1835-1910)