Stirring the Galactic Pot

Warm H_2 in Cold Clouds

Jim Ingalls (SSC)

Collaborators:

T. Bania (IAR/Boston U.)

F. Boulanger (IAS/U. Paris-Sud)

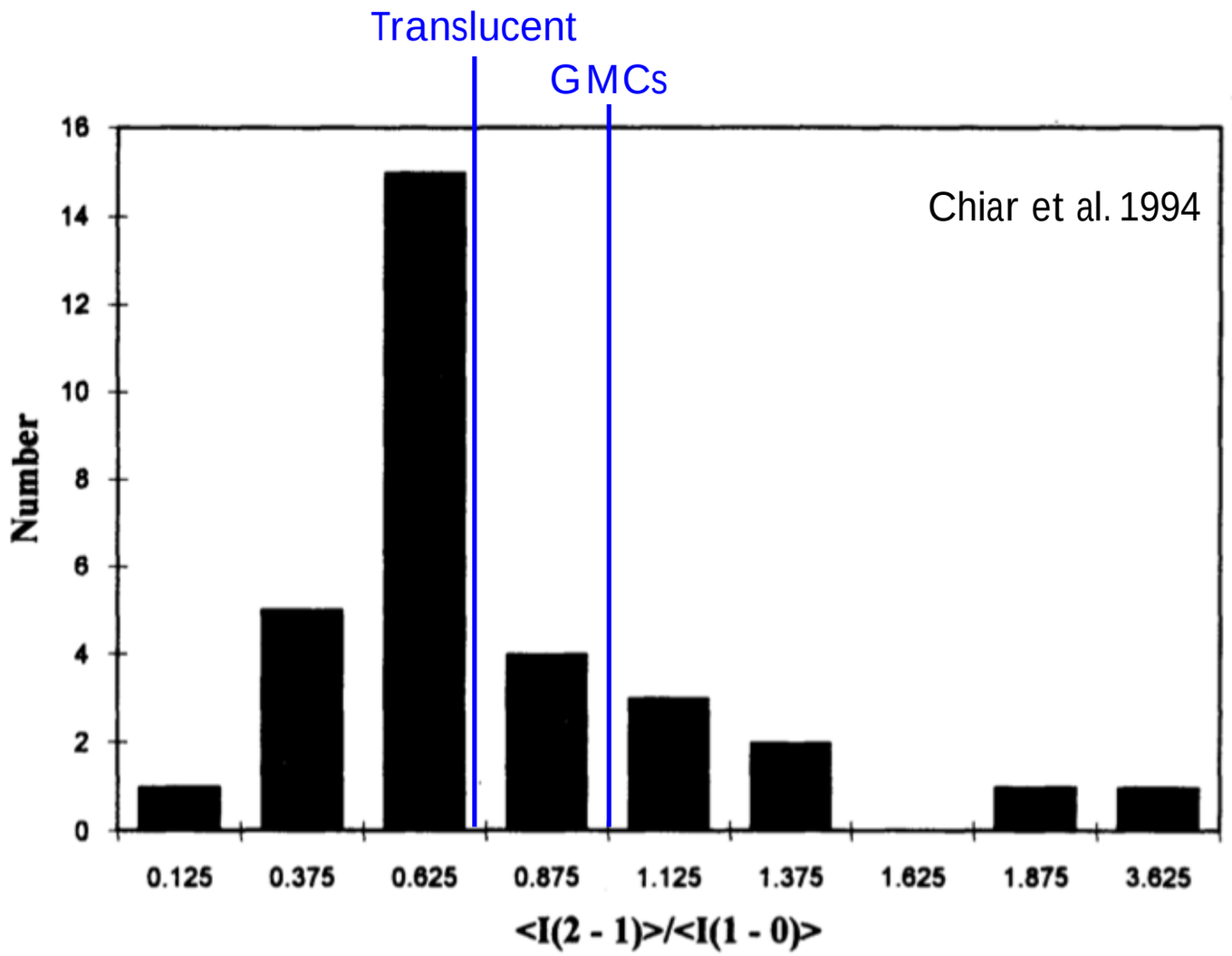
B. Draine (DAS/Princeton U.)

E. Falgarone (CNRS-ENS, Obs. Paris)

P. Hily-Blant (Obs. Grenoble)

The results discussed above show that there is a significant contribution to the large-scale ^{12}CO emission from molecular gas which has a considerably higher value of I_{12}/I_{13} than do the centers of GMCs. We now consider a simple two-

Polk et al. 1988

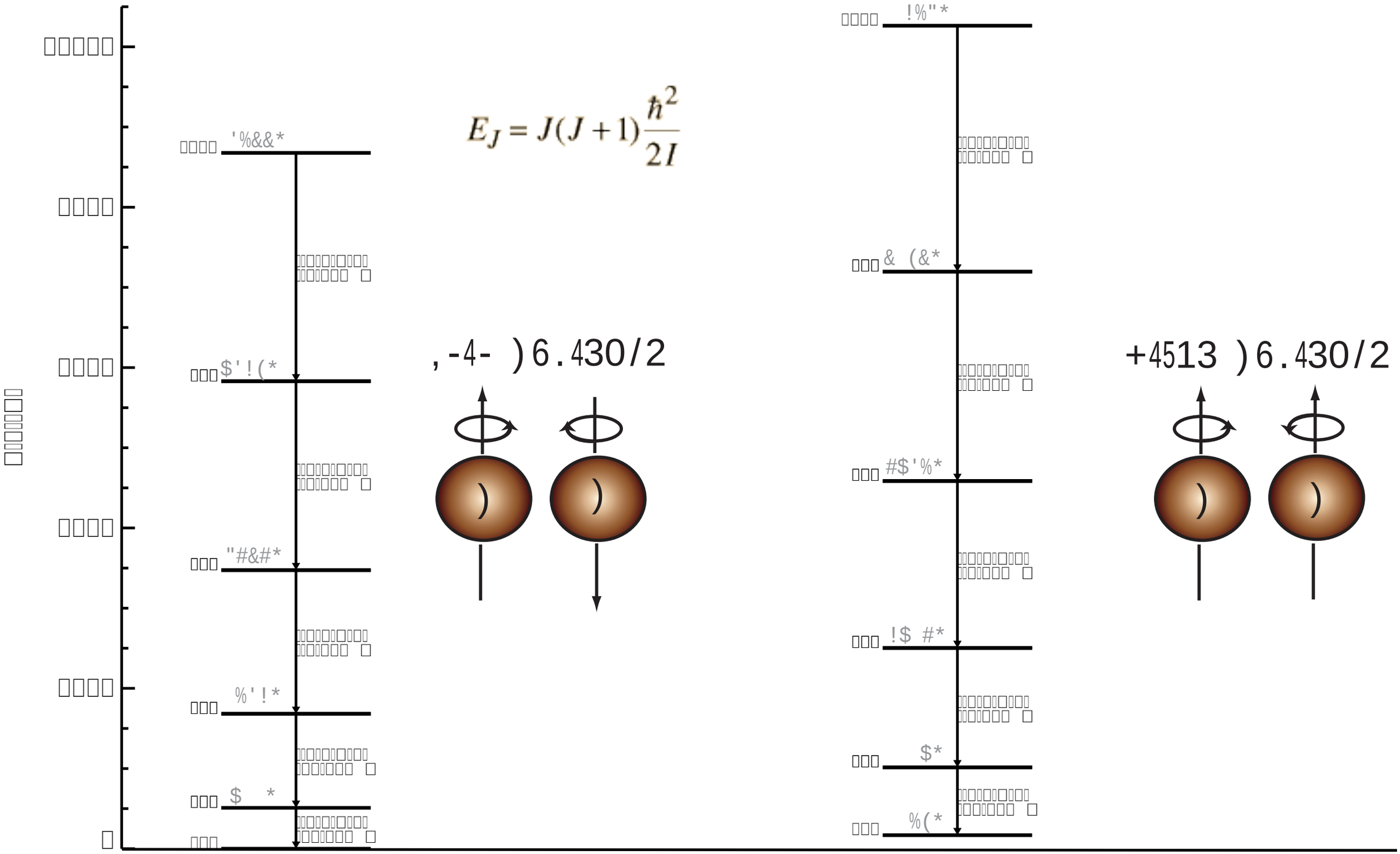


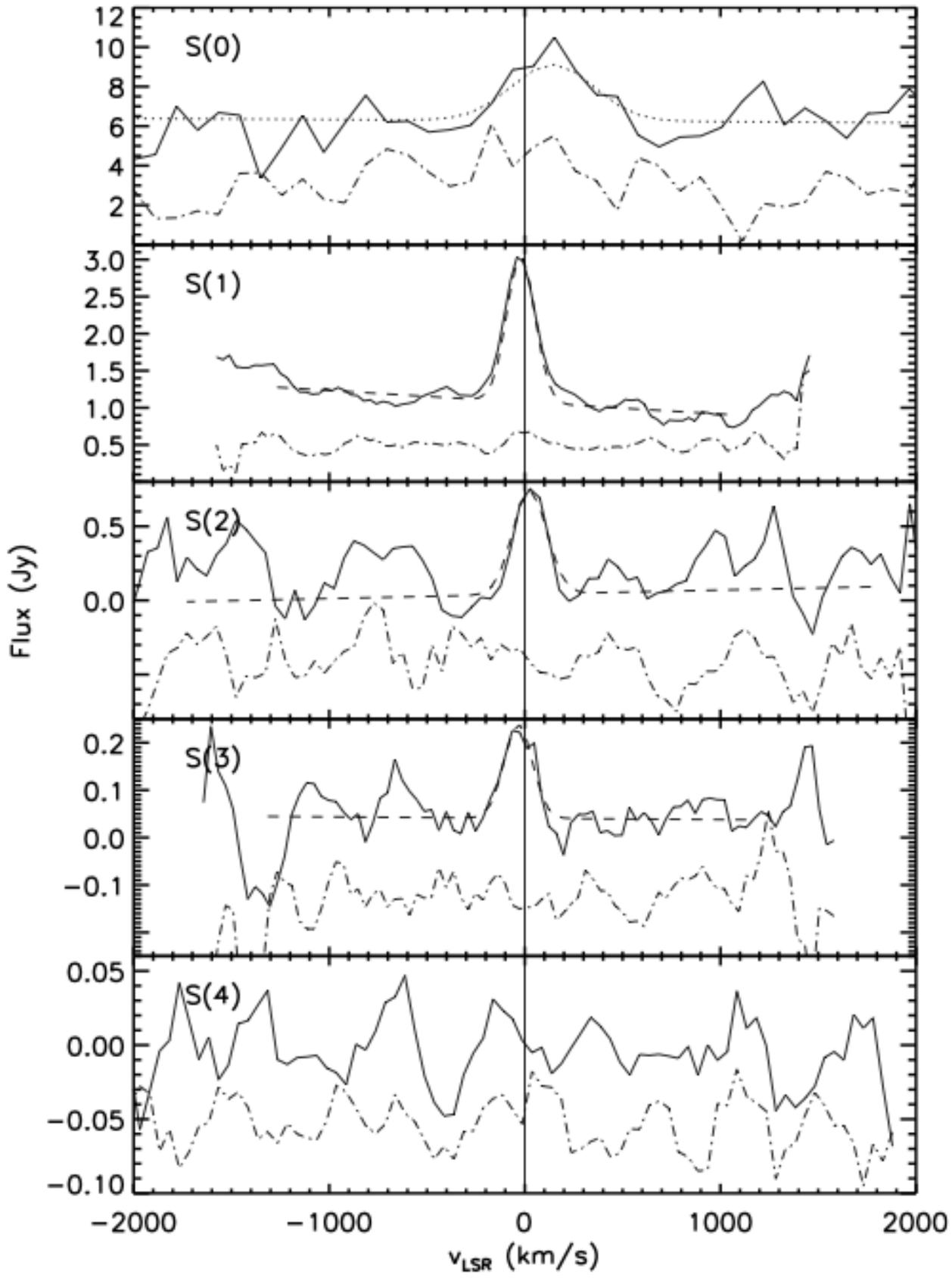
Chiar et al. 1994

FIG. 12.—Histogram of $I(2 \rightarrow 1)/I(1 \rightarrow 0)$ for the molecular clouds in the Scutum Arm with detections in both CO ($J = 2 \rightarrow 1$) and CO ($J = 1 \rightarrow 0$) transitions. The unbinned data are listed in col. (11) of Table 1. Note that the last bin is not evenly spaced.

Pure-Rotational Transitions of H_2

$$E_J = J(J+1)\frac{\hbar^2}{2I}$$





l=26.46, b=0.09
Av ~ 30

Falgarone et al. (2005)

The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.

The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.

More information can be found at:
http://sings.stsci.edu/

Ellipticals

Strong Bulge

Unbarred Spirals

Weak Bulge

Intermediate Spirals

Strong Bulge

Irregulars

Weak Bulge

Barred Spirals

Poster and composite images created from SINGS observations by Karl D. Gordon (Oct 2007)
Blue=IRAC 3.6μm (stars)
Green=IRAC 8μm
(aromatic features from dust grains/molecules)
Red=MIPS 24μm (warm dust)

SINGS Team

Robert Kennicutt, Jr. (Principle Investigator), Daniela Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Bot, Brent Buckalew, John Cannon, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Aigen Li, Sangeeta Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Regan, George Rieke, Marcia Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thornley, Fabian Walter & George Helou

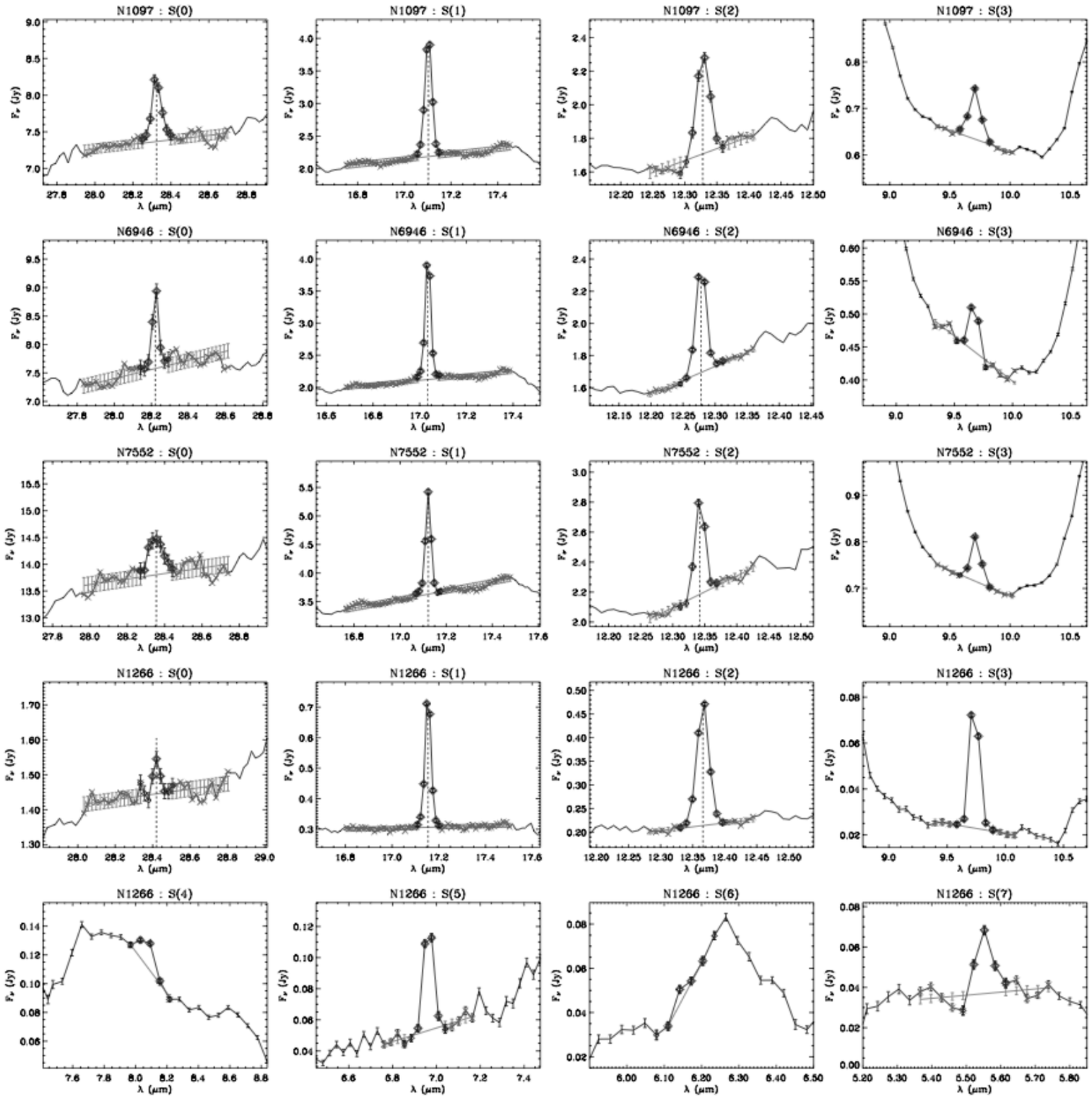


FIG. 2.—Examples of H_2 line spectra: the circumnuclear starbursts NGC 1097, NGC 6946, and NGC 7552, and the three galaxies for which we could estimate the fluxes of higher transitions than $S(3)$, NGC 1266, NGC 4569, and NGC 4579. The straight line indicates the fitted pseudocontinuum, and the diamonds show the wavelength range over which the line flux was integrated.

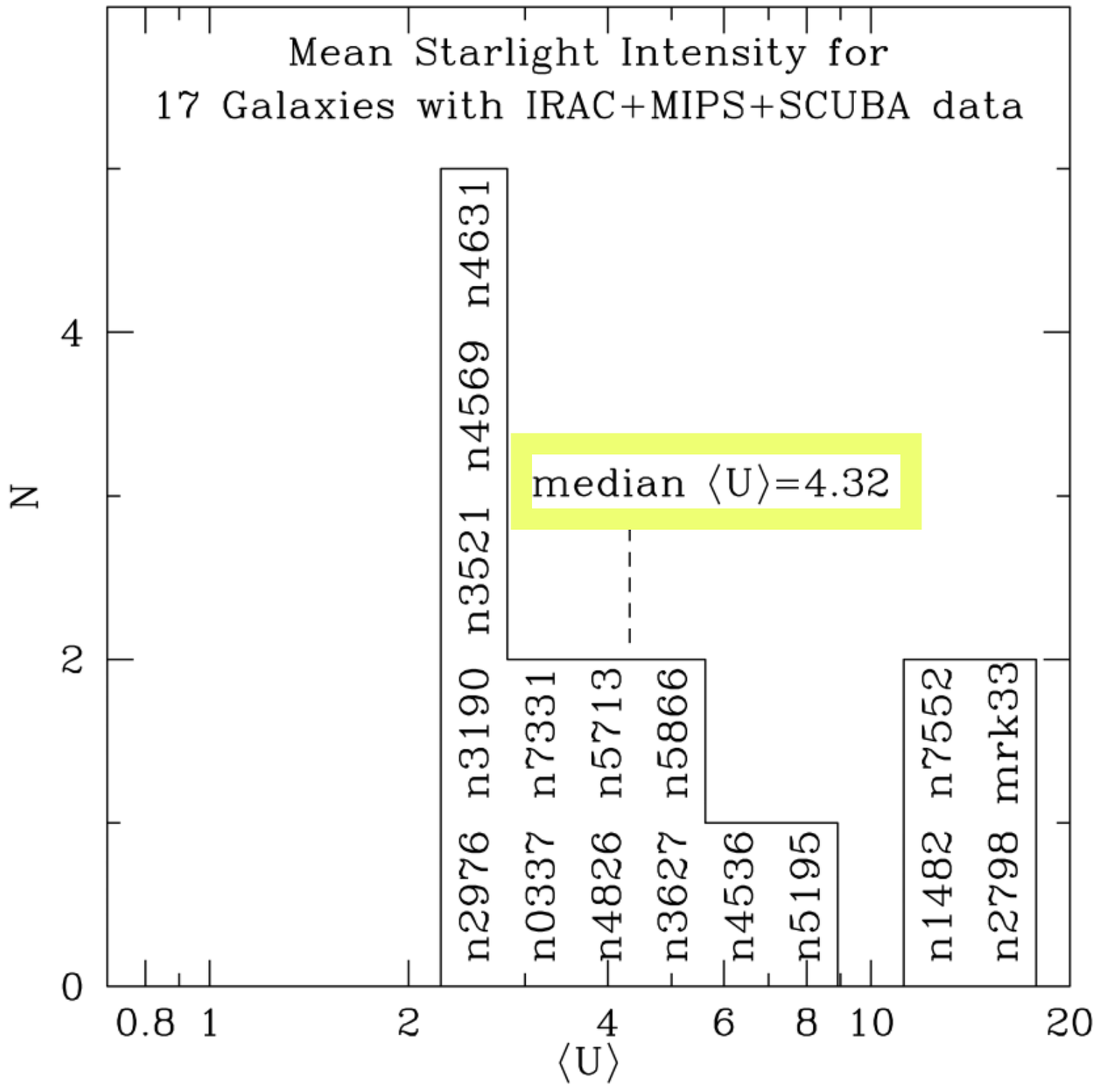
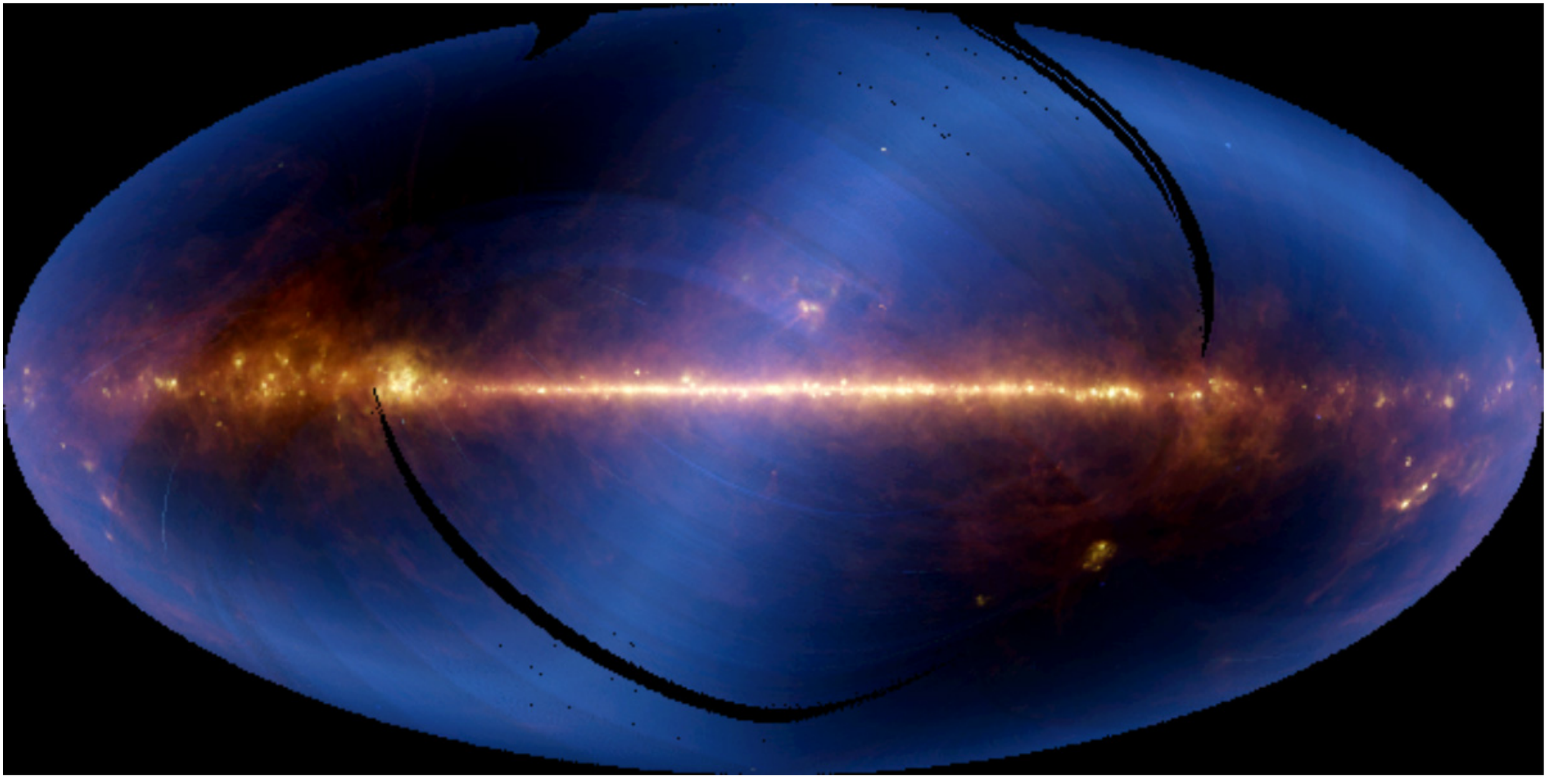
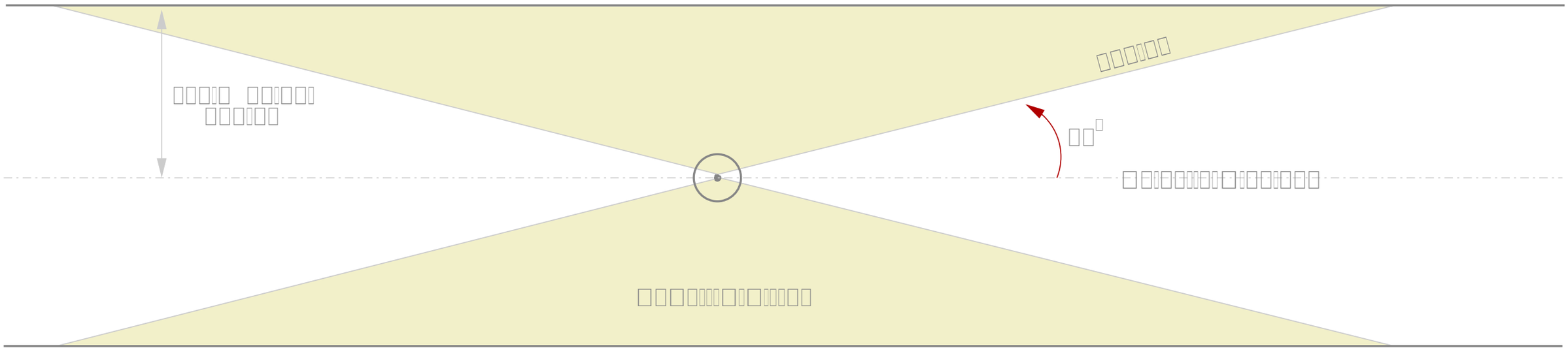
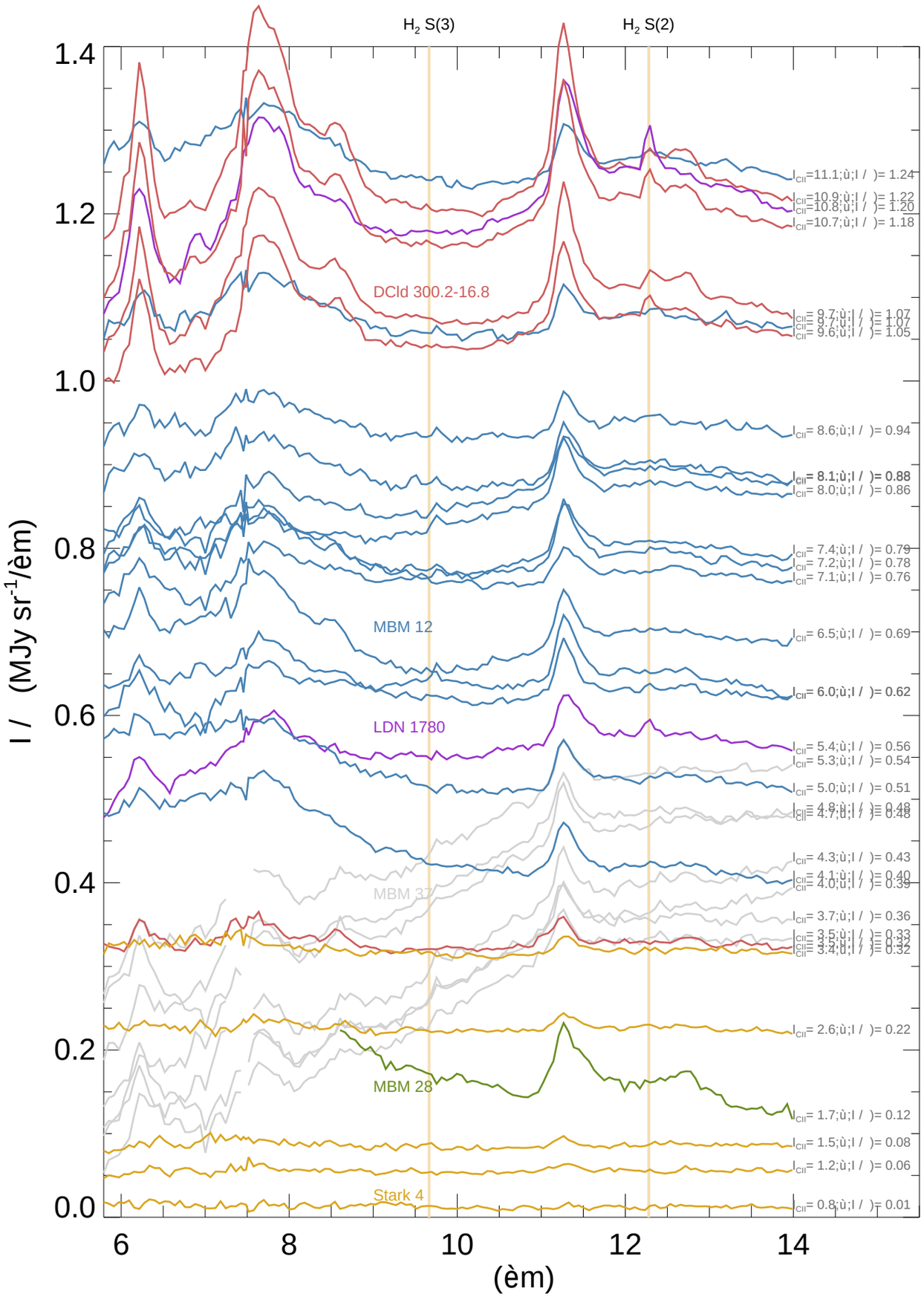


FIG. 7.—Distribution of $\langle U \rangle$ for 17 galaxies with SCUBA data (fits limited to MW dust with $U_{\rm max} = 10^6$, with adjustable γ and $U_{\rm min}$).

“ dust in the diffuse ISM dominates the IR power. ” Draine et al 2007







6 High Latitude Clouds
34 Positions
1hr integration

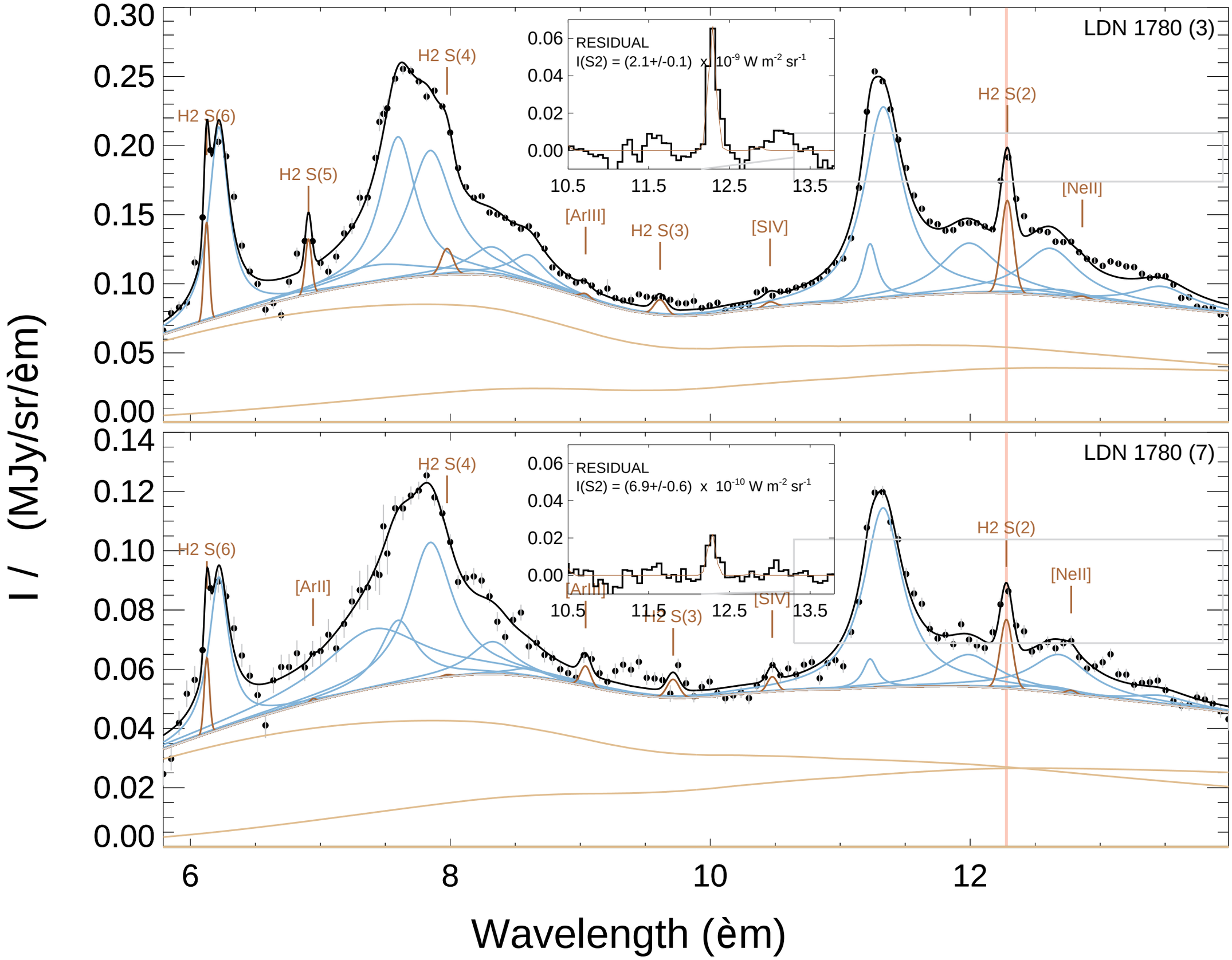
CII 峙 12 x 10^{-9} W m^{-2} sr^{-1}

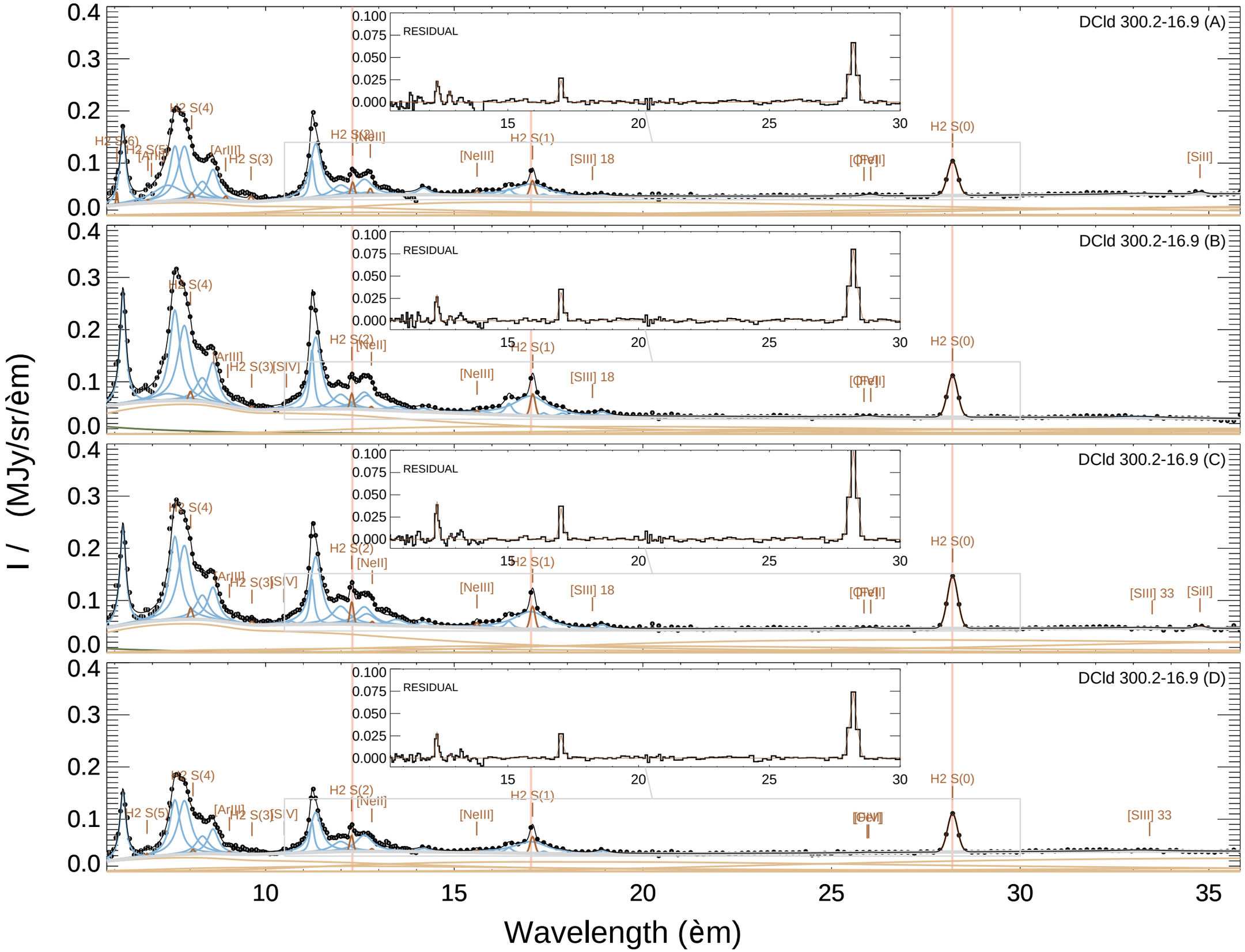
If all photons are absorbed, PE efficiency ~3%, then

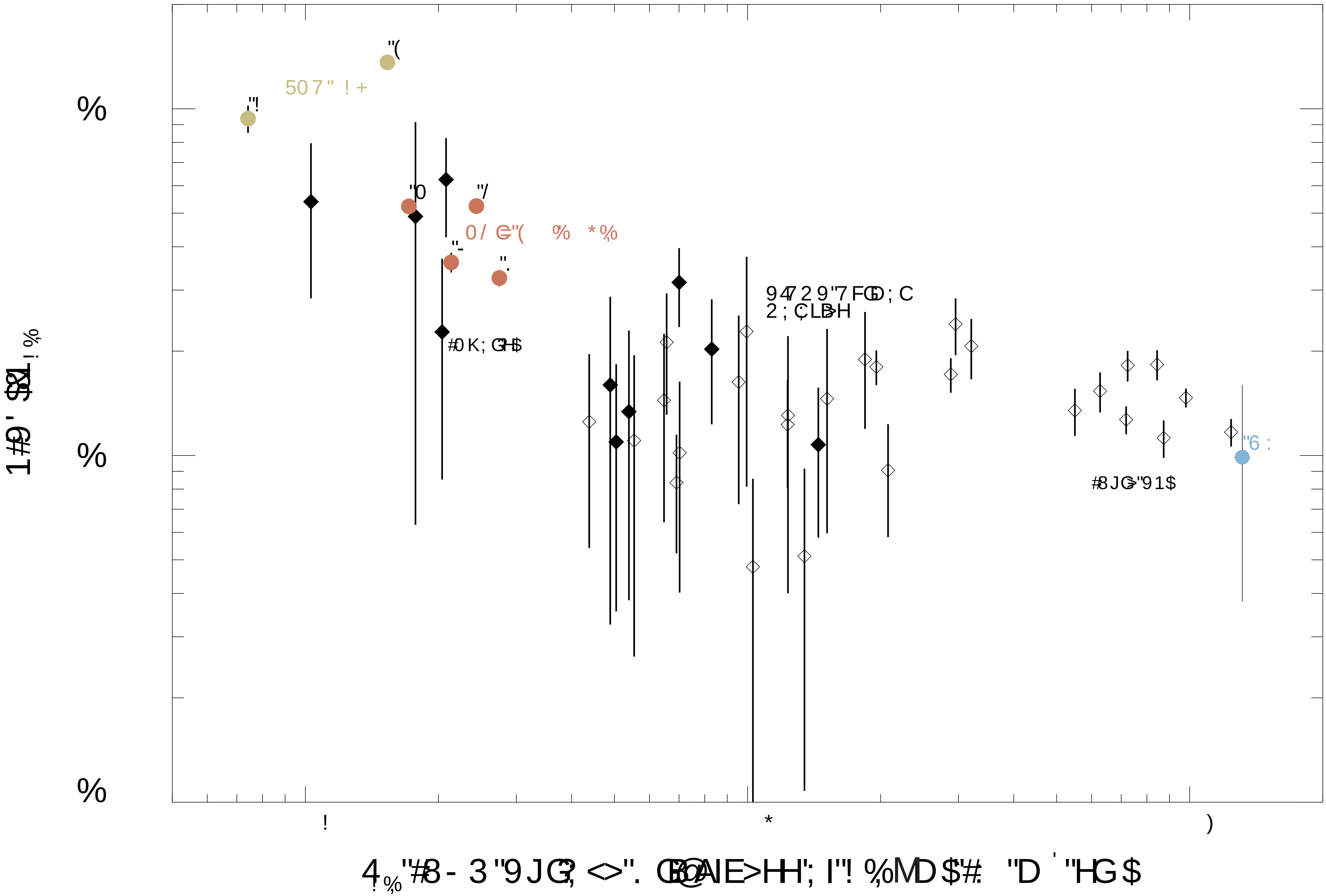
U 屹 3

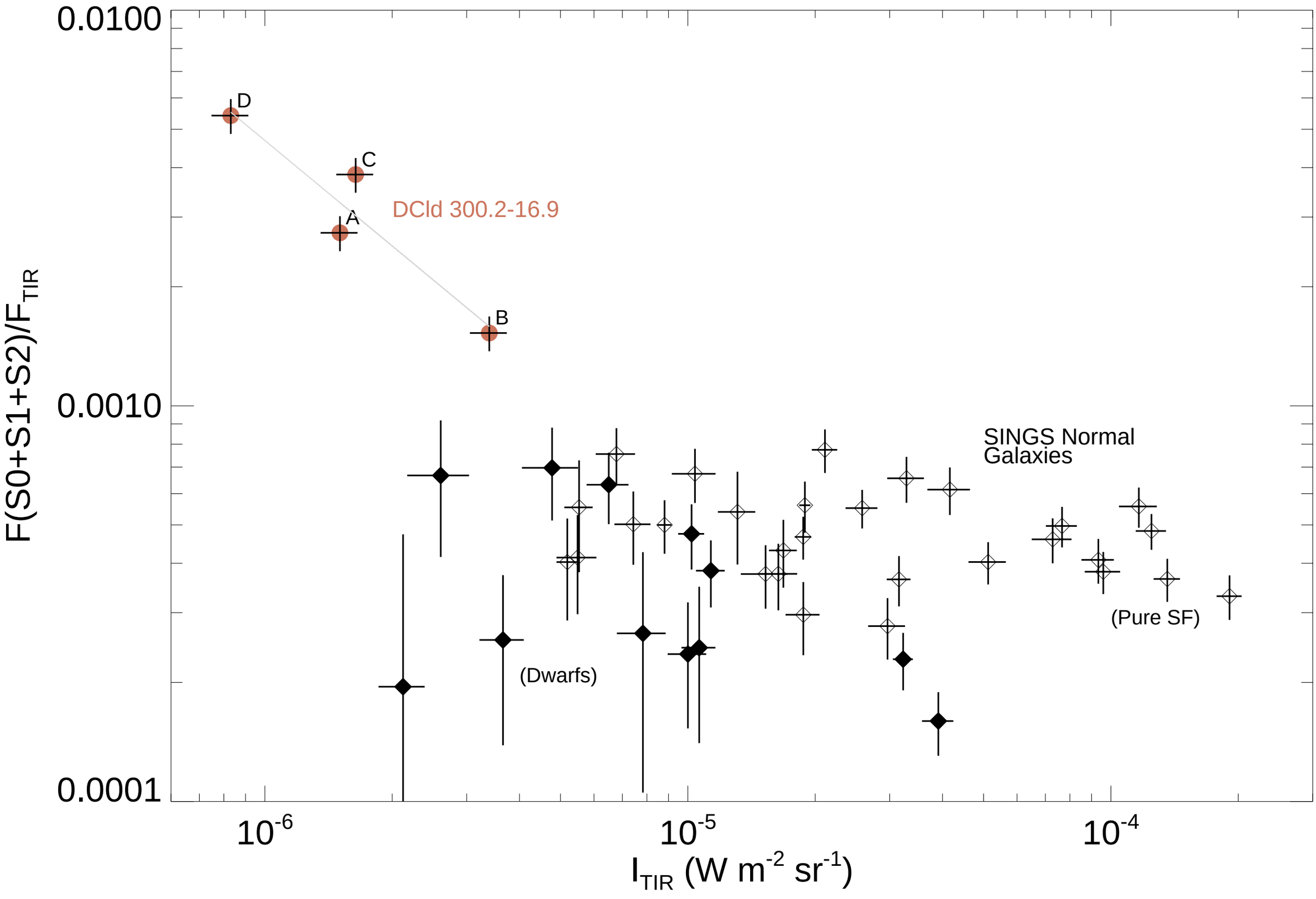
Av ~ 0.5–5

“translucent”


LDN 1780 (3)
H2 S(6)
H2 S(5)
H2 S(4)
[ArIII]
H2 S(3)
[SIV]
H2 S(2)
[NeII]
RESIDUAL
I(S2) = (2.1+/-0.1) x 10^-9 W m^-2 sr^-1
LDN 1780 (7)
H2 S(6)
[ArII]
H2 S(4)
H2 S(3)
[SIV]
H2 S(2)
[NeII]
RESIDUAL
I(S2) = (6.9+/-0.6) x 10^-10 W m^-2 sr^-1
I / (MJy/sr/èm)
Wavelength (èm)


DCld 300.2-16.9 (A)
DCld 300.2-16.9 (B)
DCld 300.2-16.9 (C)
DCld 300.2-16.9 (D)
RESIDUAL
H2 S(6)
H2 S(5)
H2 S(4)
H2 S(3)
H2 S(2)
H2 S(1)
H2 S(0)
[ArII]
[ArIII]
[NeII]
[NeIII]
[SIV]
[SiII]
[SIII] 18
[SIII] 33
I / (MJy/sr/èm)
Wavelength (èm)

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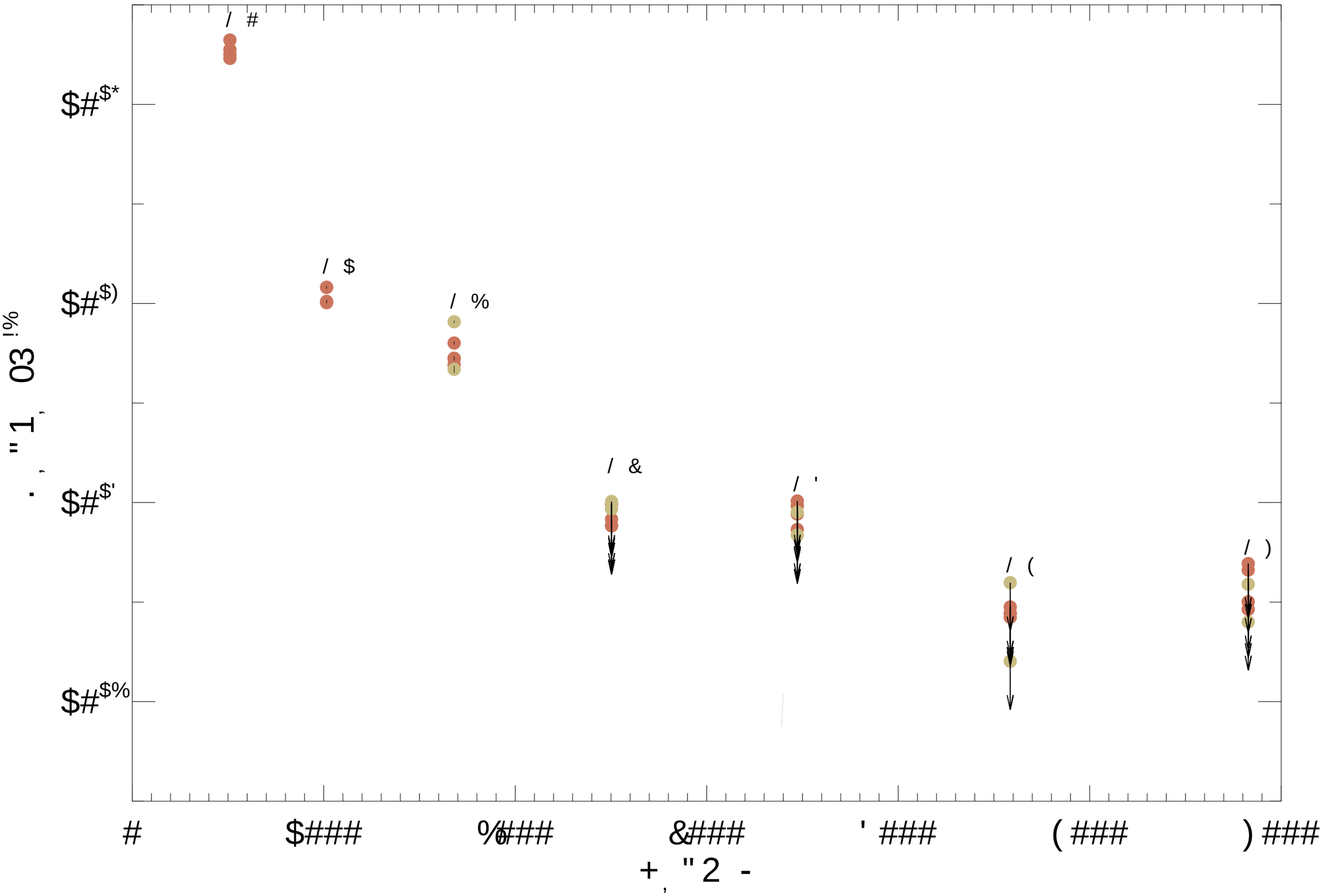
0.0010
0.0001
F(S0+S1+S2)/F_TIR
D
C
A
B
DCld 300.2-16.9
SINGS Normal Galaxies
(Pure SF)
(Dwarfs)
10^-6
10^-5
10^-4
I_TIR (W m^-2 sr^-1)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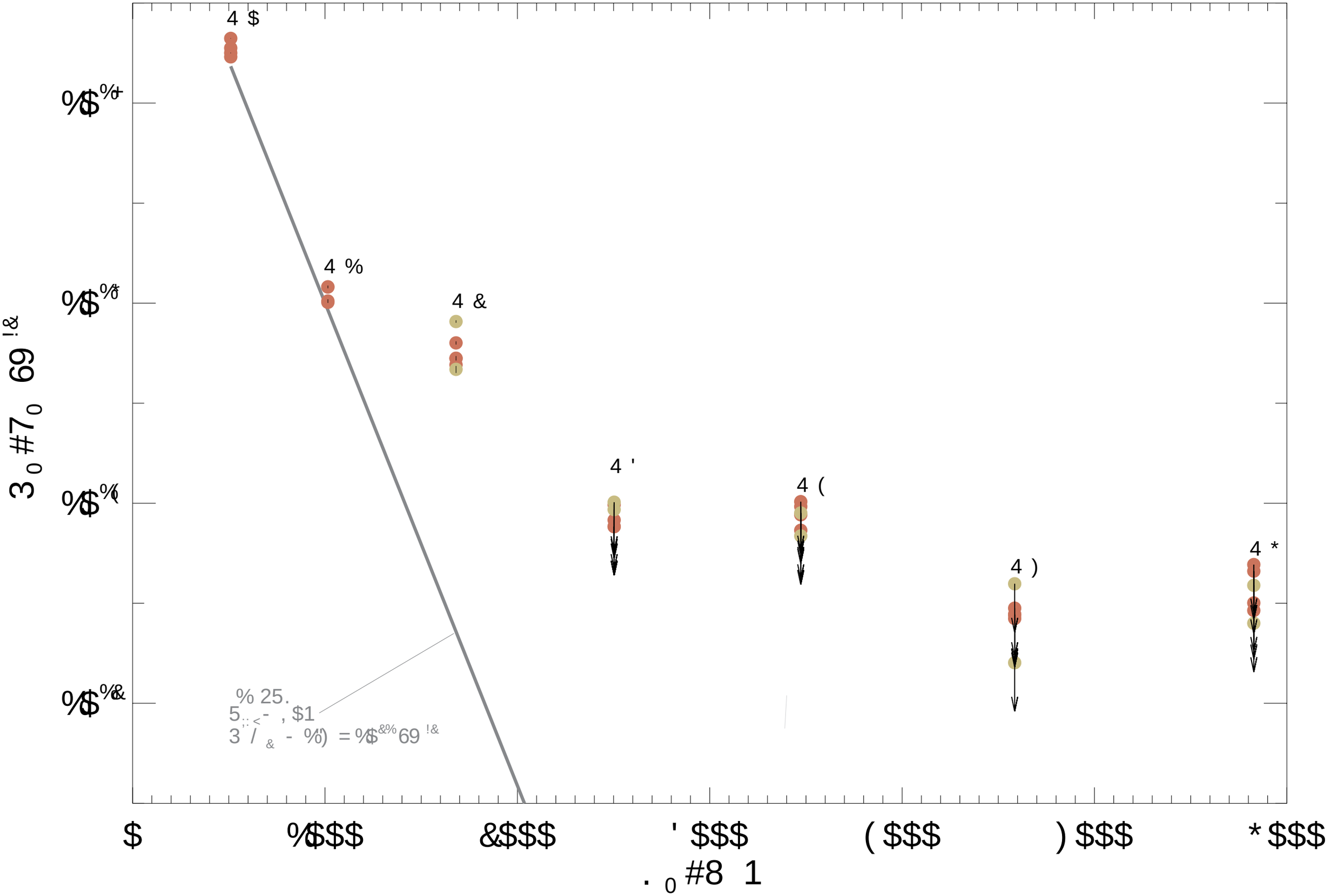
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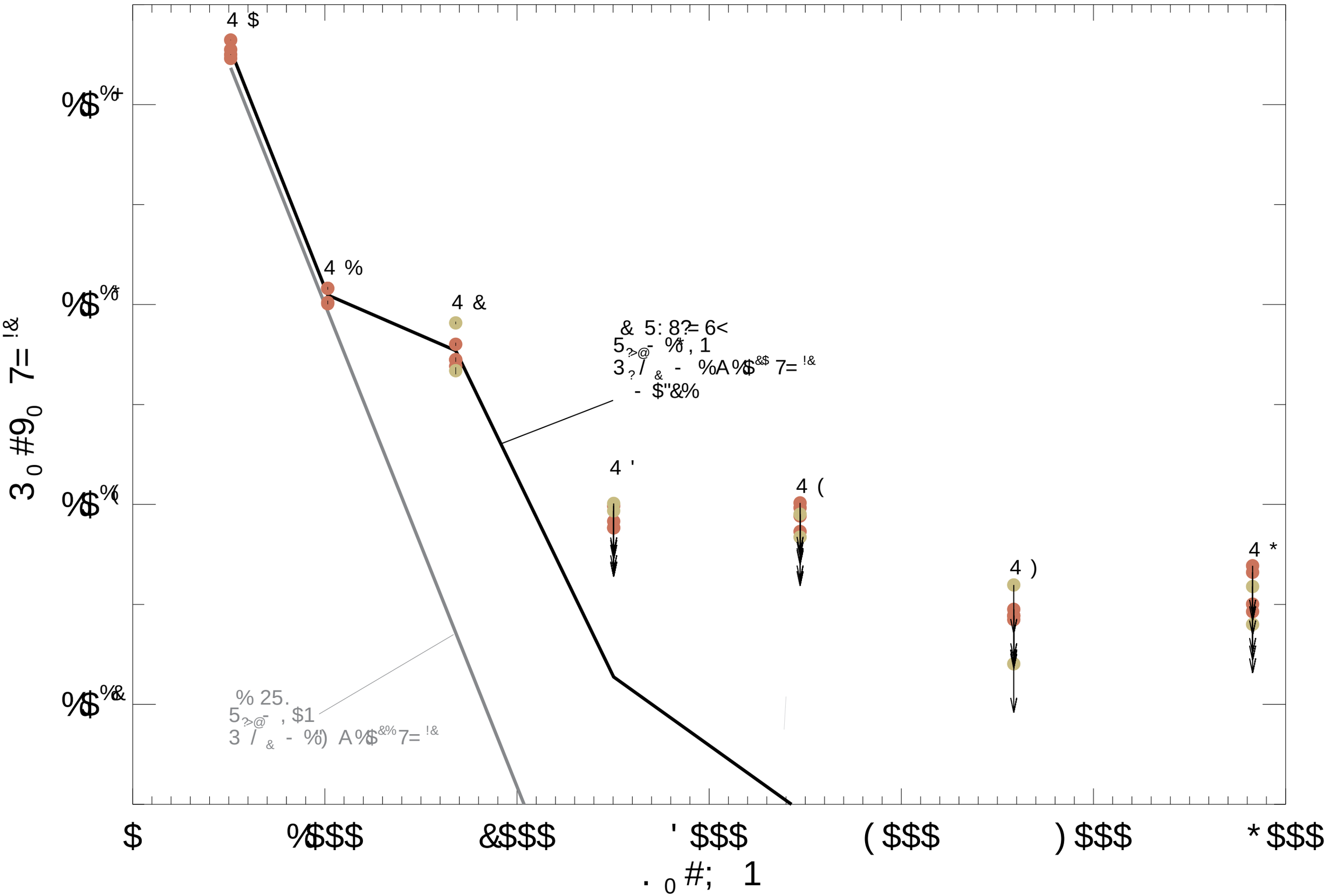
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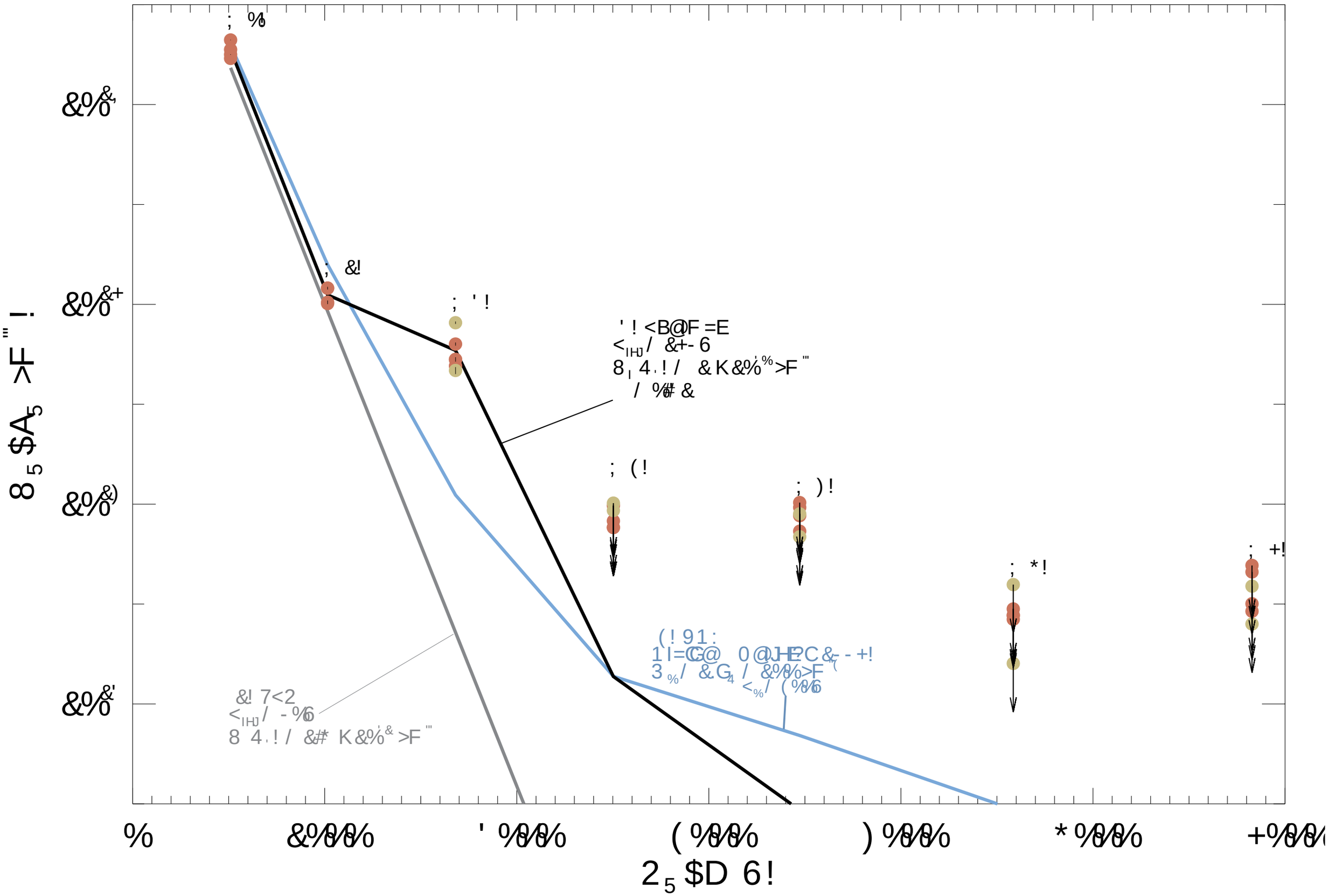
Low o/p in Nearby H2:

Goldsmith et al. 2010 (Taurus) ⟶ T=225K, o/p = 0.15

Rachford et al. 2001 (HD 110432) ⟶ T=186K, o/p = 0.36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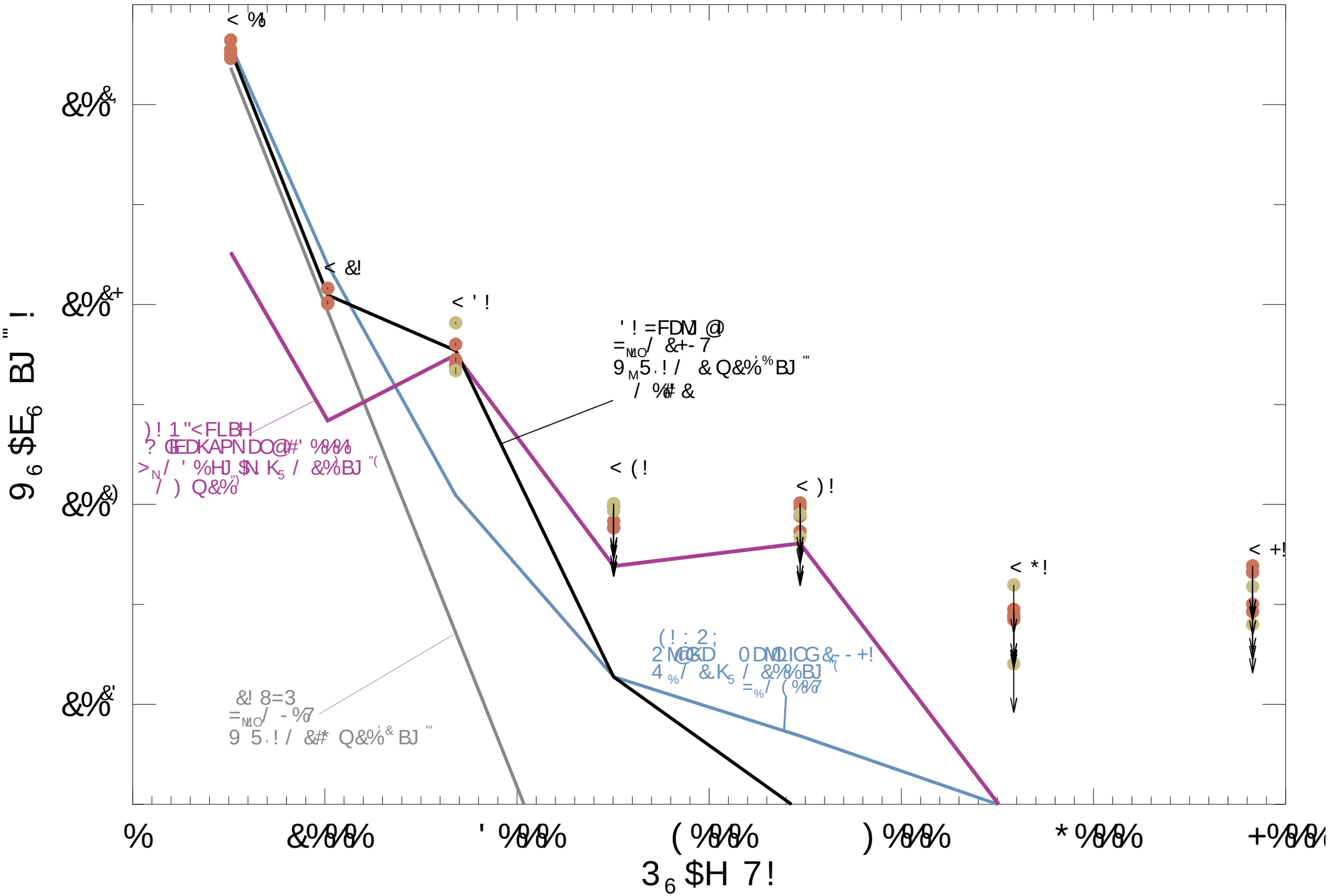
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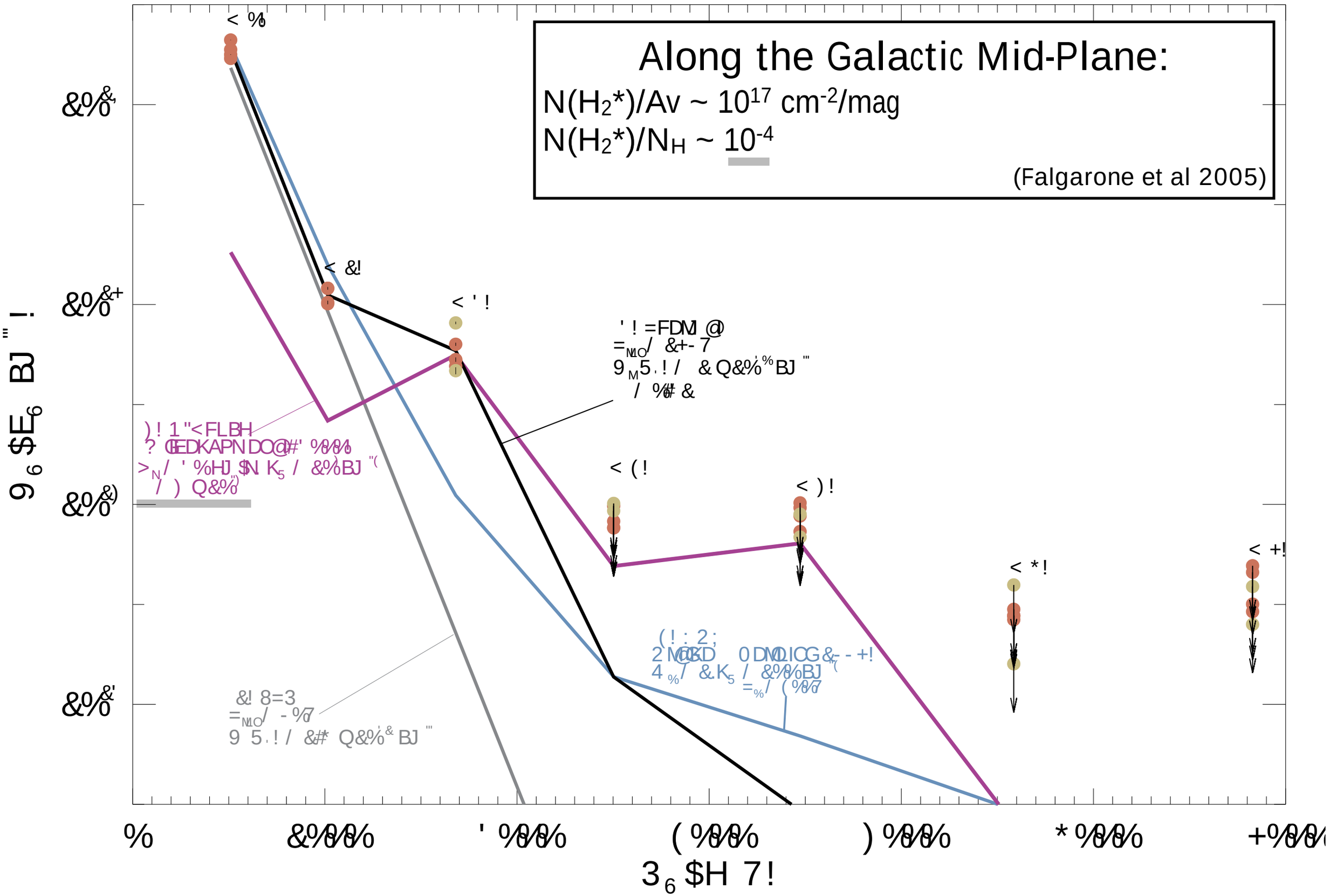
Along the Galactic Mid-Plane:
N(H2*)/Av ~ 10^17 cm^-2/mag
N(H2*)/NH ~ 10^-4
(Falgarone et al 2005)
< %
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< ' !
< (!
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< *!
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' ! =FDMJ @
=MO/ &+- 7
9M5.!/ &Q&%'%BJ '''
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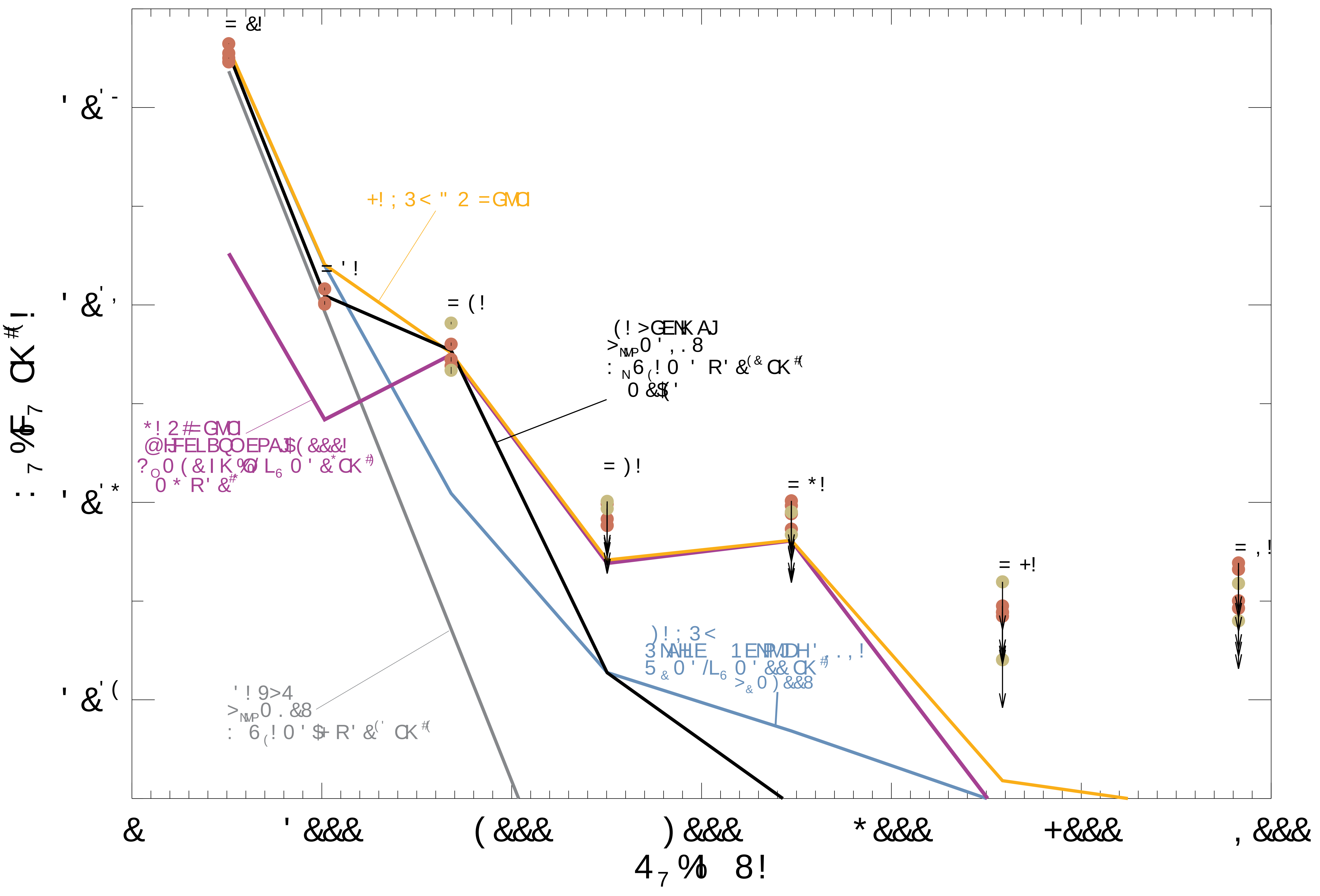


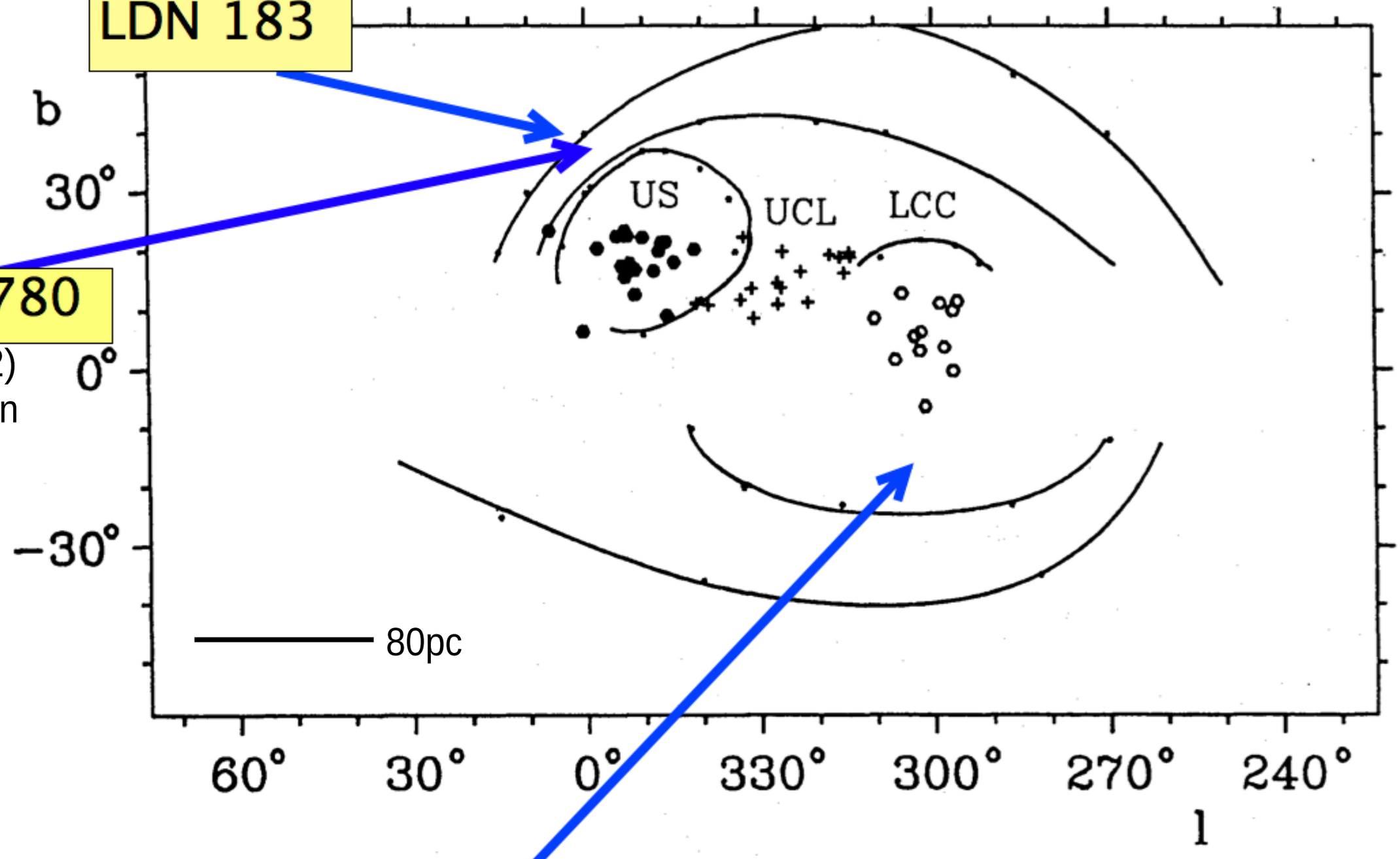
Sco-Cen OB Association

Doesn't have S(2) emission

LDN 183

LDN 1780

Has S(2) emission



DCld 300.2−16.9 Has S(2) emission

de Geus 1992

Additional Slides

“WARM”

“COLD”

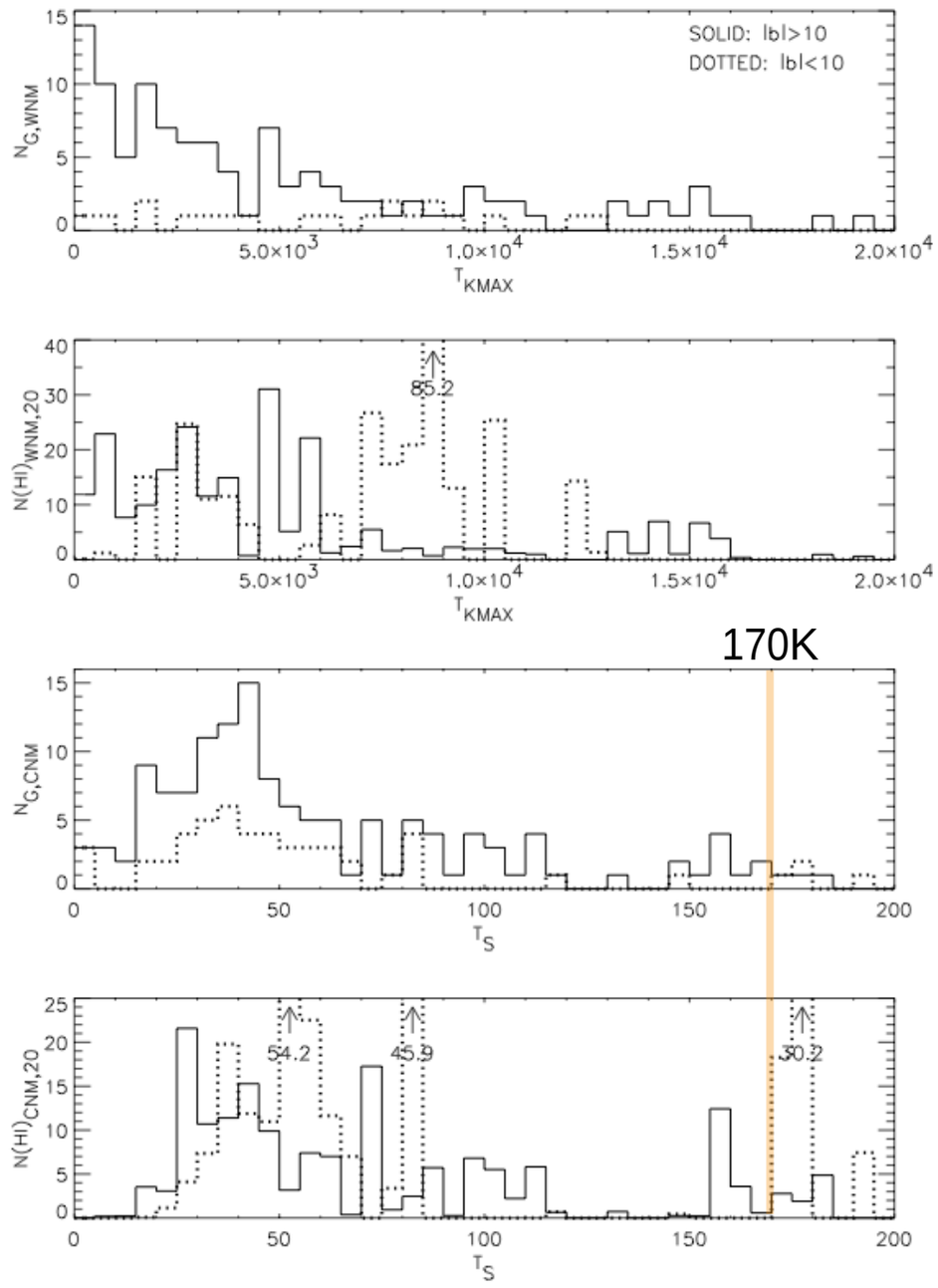
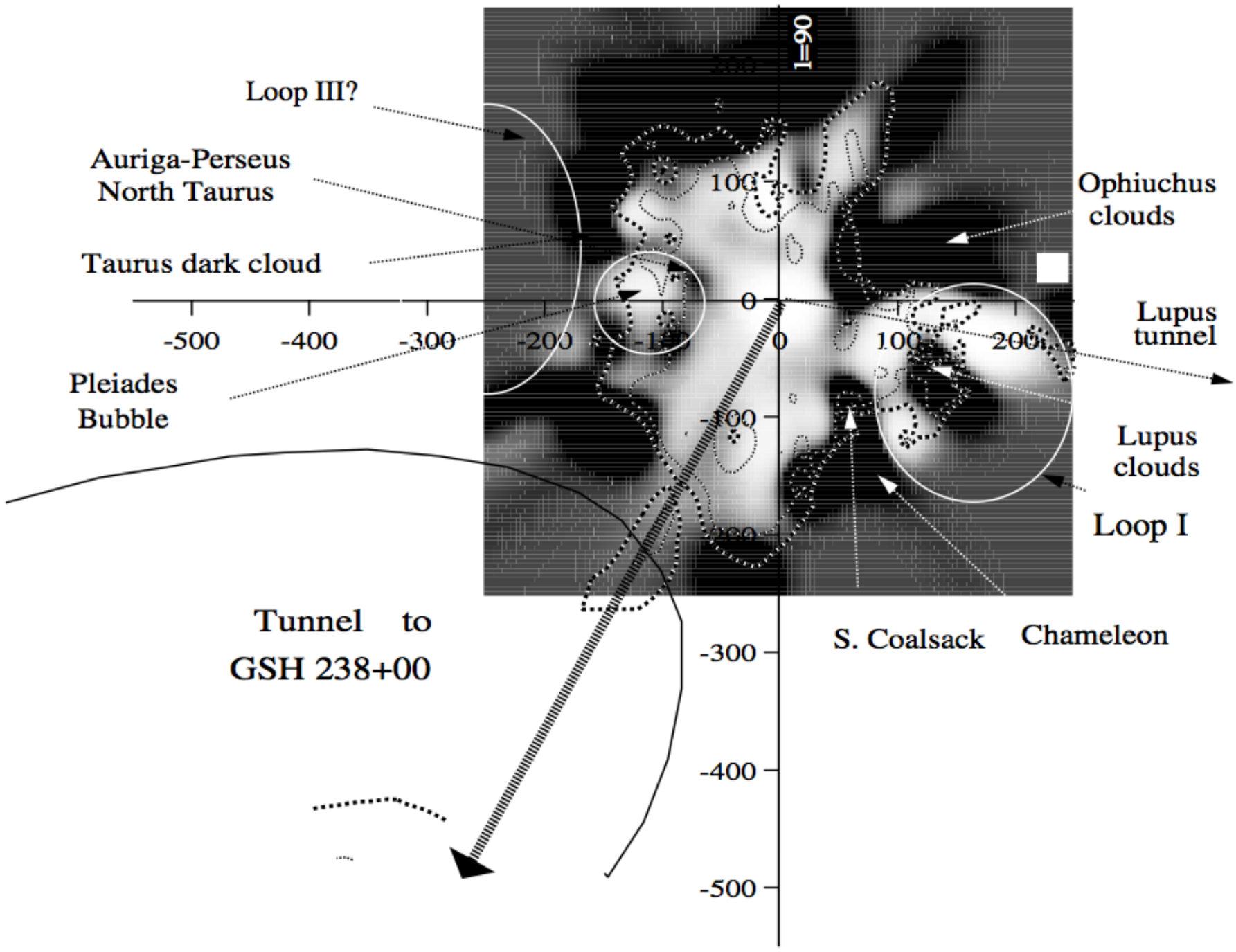


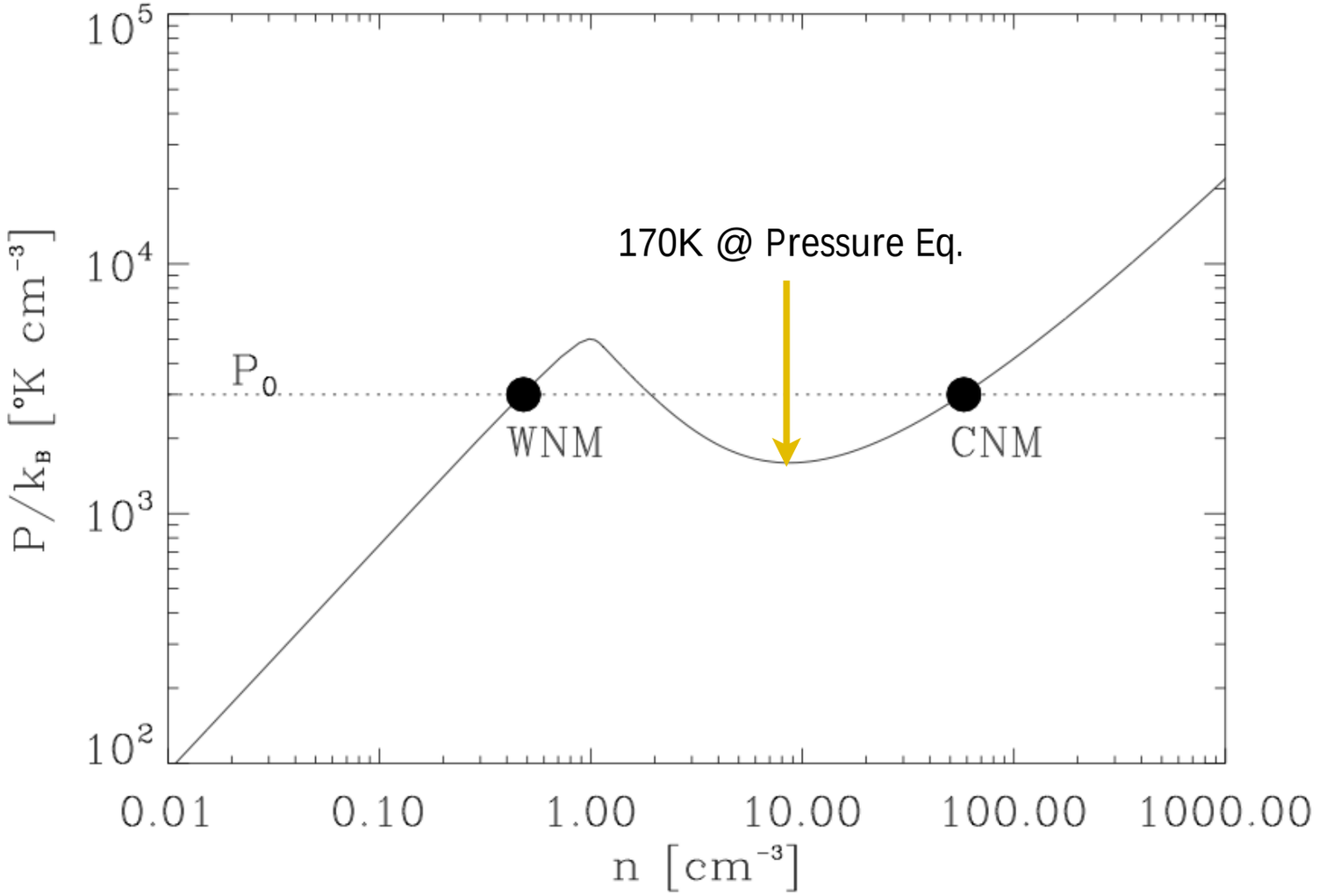
FIG. 2.—Histograms of $T_{k,\max}$ for the WNM (*top two panels*) and of T_s for the CNM (*bottom two panels*). The solid lines are for $|b| > 10°$ and the dotted ones for $|b| < 10°$. N_G is the number of Gaussian components; $N(\mathrm{H\,I})_{20}$ is column density in units of 10^{20} cm^{-2}.

	Median T_s (K)	Mean T_s (K)
CNM, $\|b\| > 10°$, by $N(\mathrm{H\,I})$	70	108

Heiles & Troland 2003



Lallement et al. 2003



"...**shocks** traversing the warm neutral gas leave it in an **unstable** regime, from which it cools down to CNM conditions in roughly one cooling time, which may amount to up to a few Myr, depending on the strength of the shock... . These processes populate the **entire range of values of density and temperature** between those of the classical cold and warm phases, creating a **continuous distribution.**"

Vasquez-Semadeni 2009

“Three Components Regulated by Supernova Explosions”

Produce H_2 S(2) Emission?

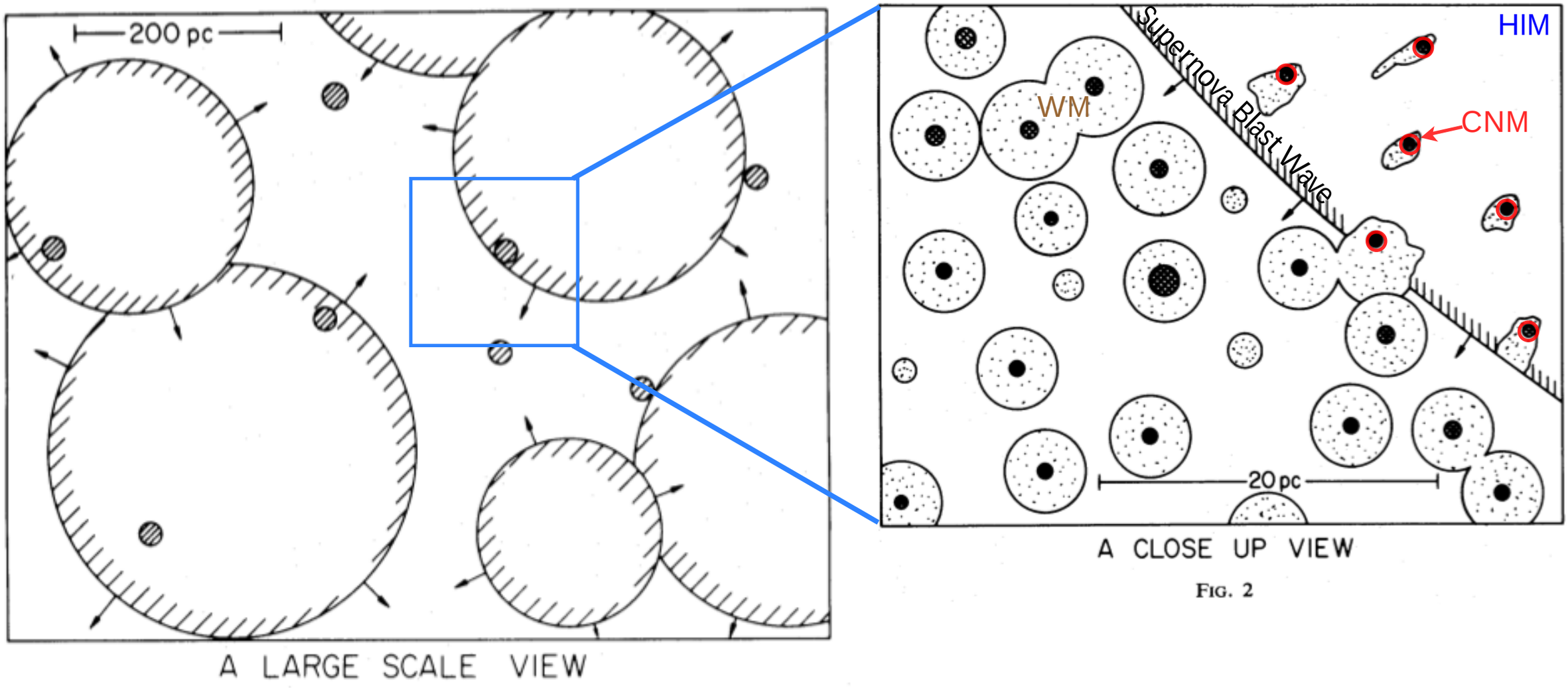


FIG. 2

McKee & Ostriker 1977