Star Formation on Galactic Scales: Is Life Simple?

Fermilab

THE UNIVERSITY OF CHICAGO

Co-starring

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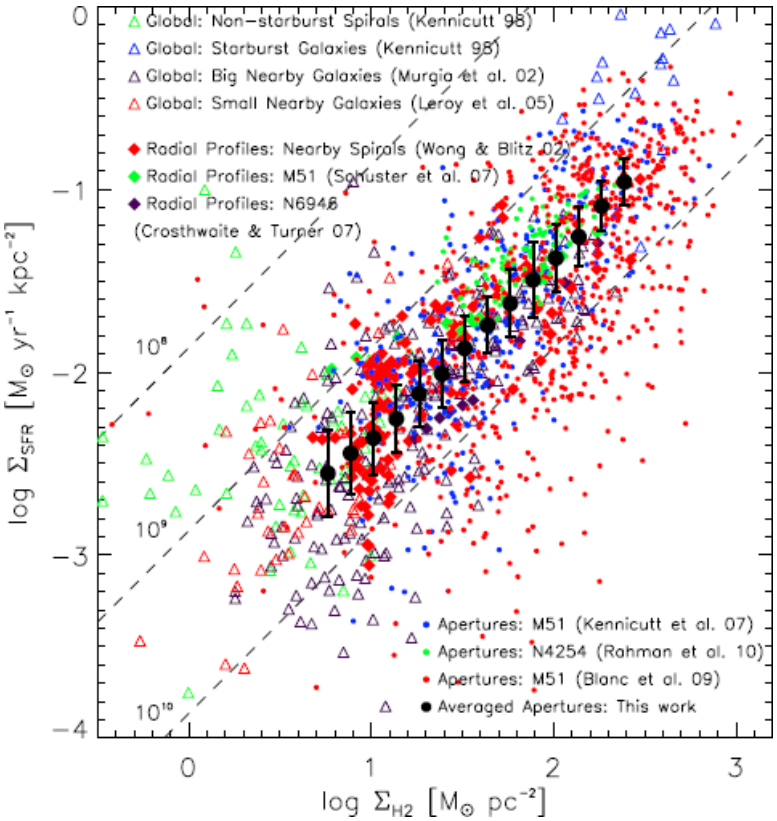
Andrey Kravtsov (Chicago)

Just One Question:

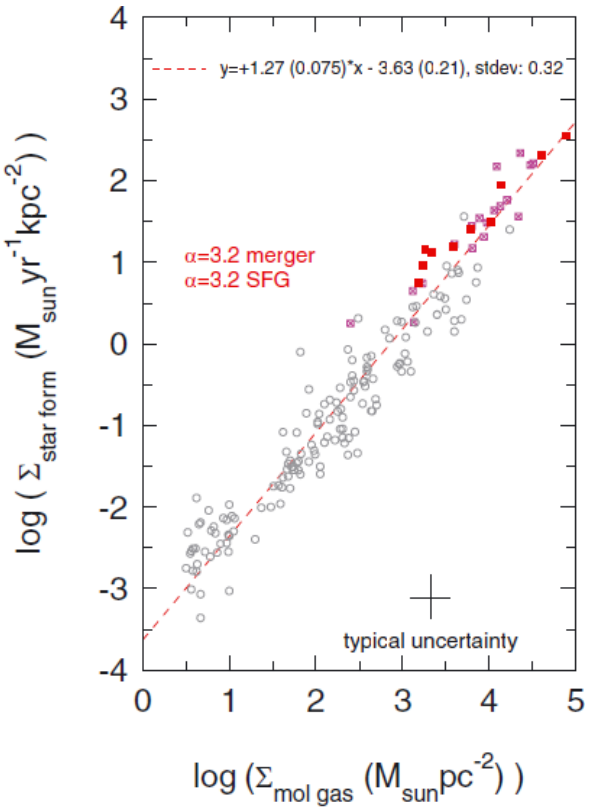
Are Gods kind to us?

What We Know About Star Formation

Star formation correlates well with molecular gas…



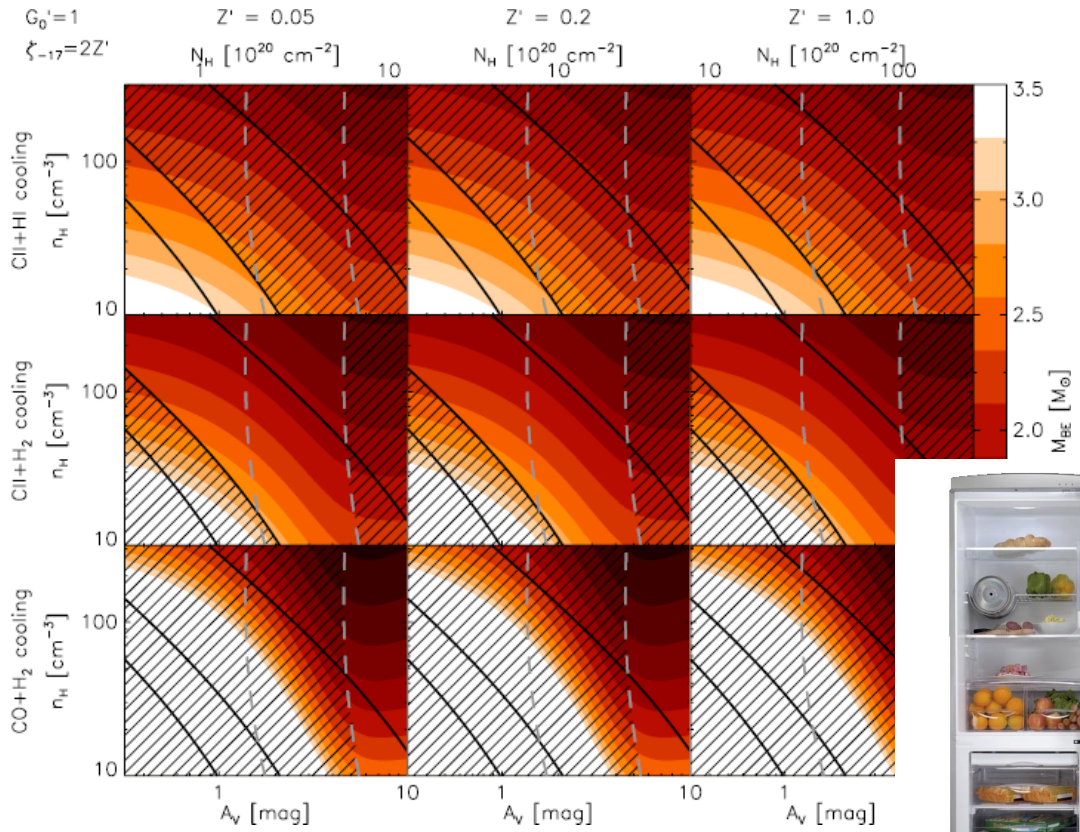
z=0 (Bigiel et al 2011)



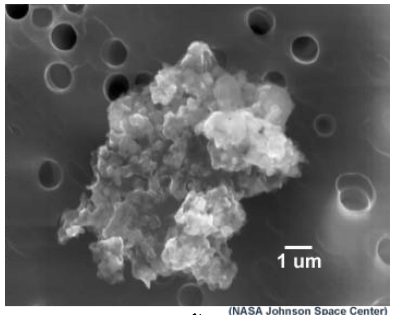
High z (Genzel et al 2010)

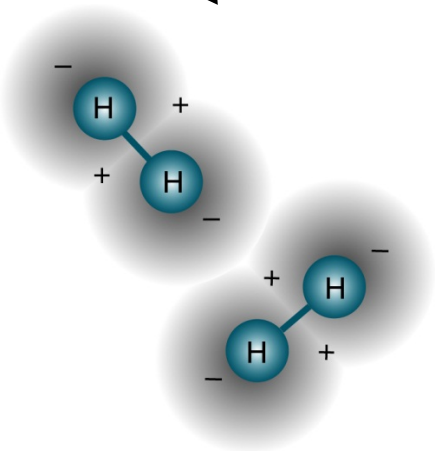
What We Know About Star Formation

… for a simple physical reason.



(Krumholz, Leroy, McKee 2011)





How We Actually Think About Star Formation

$$\dot{\rho}_* = \frac{\rho_{\mathrm{H}_2}}{\tau_{\mathrm{SF}}}$$

$$\tau_{\mathrm{SF}} = \tau_{\mathrm{SF}}\left(\rho_{\mathrm{H}_2}\right)$$

Pop quiz (10 pts): Why is this thinking wrong?

Density is only defined on a particular spatial scale.

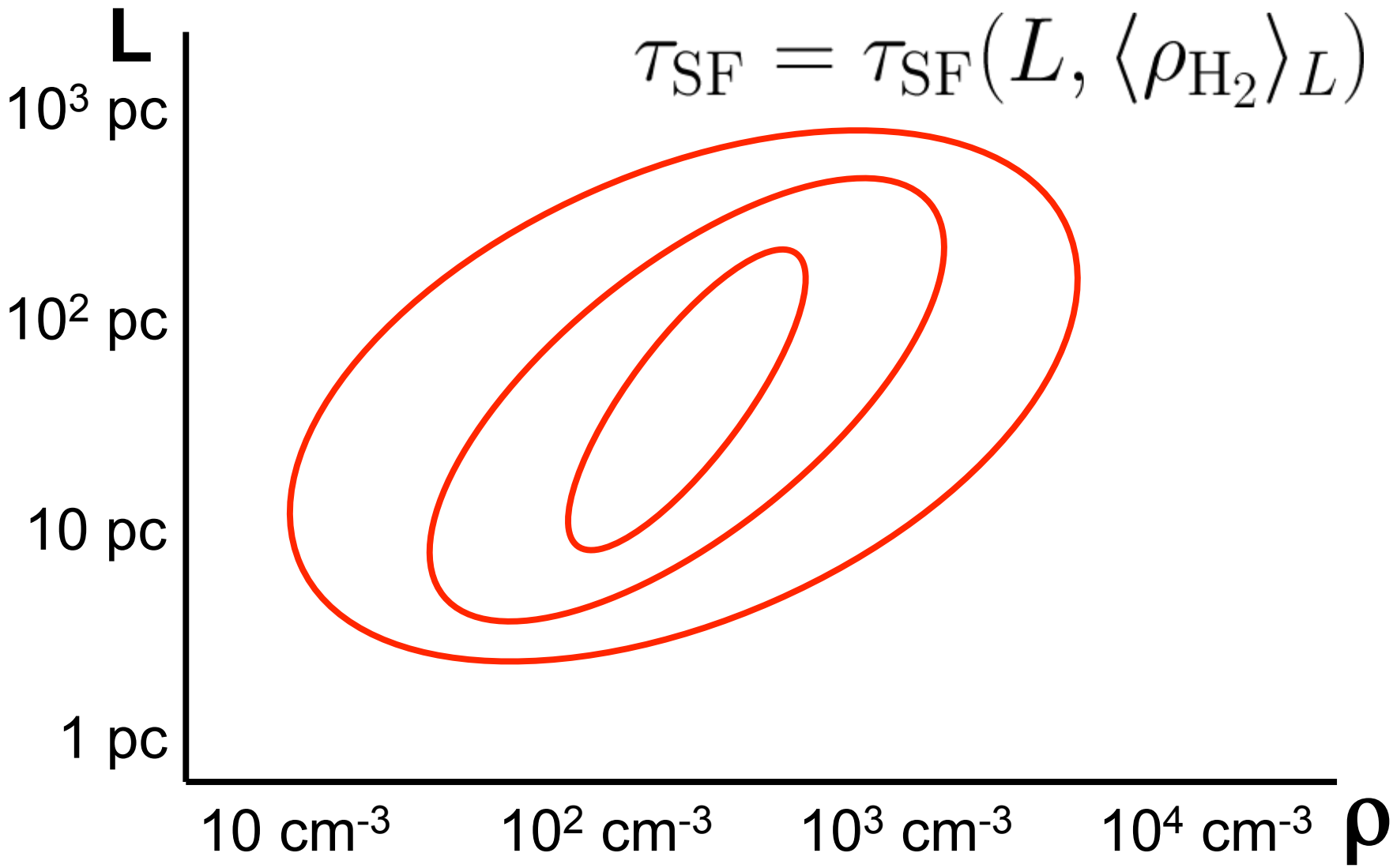
How We Should Think About Star Formation

- Take some spatial scale ***L***
- Average all densities on this scale - only those are meaningfully defined

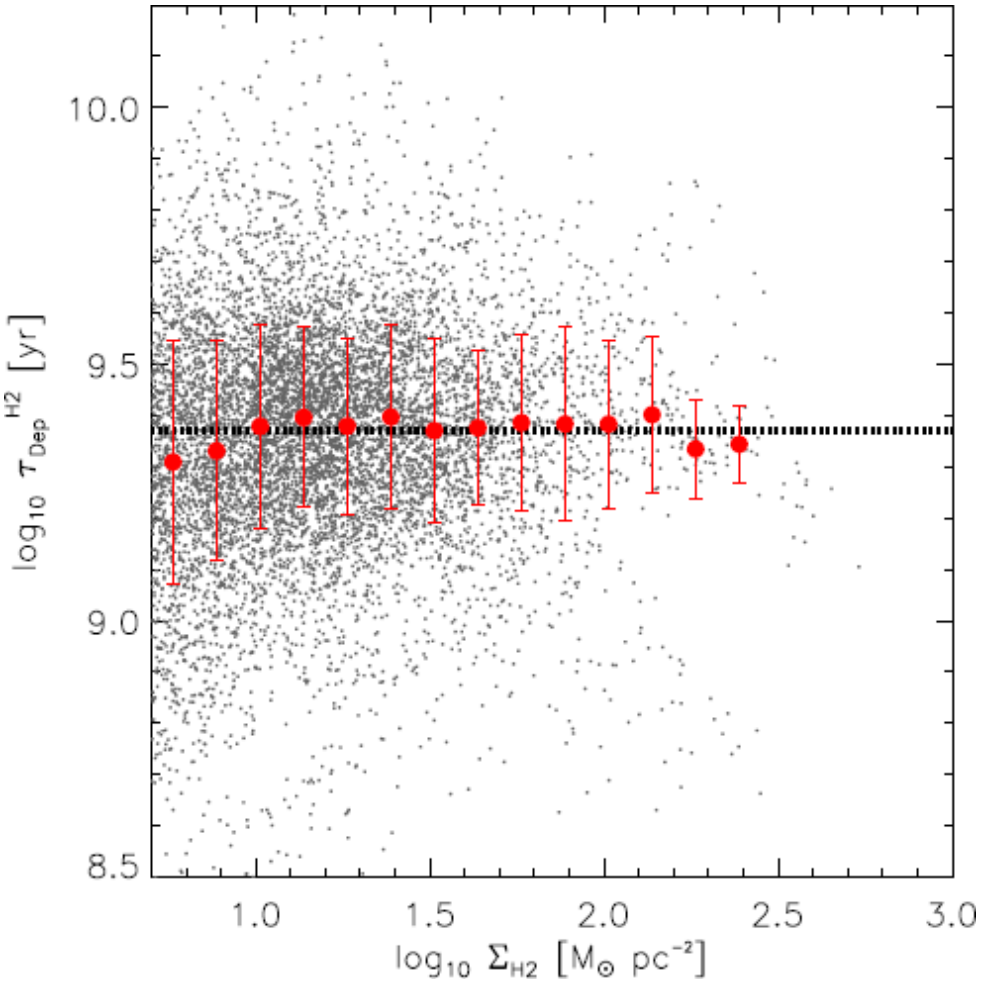
$$\left\langle \dot{\rho}_* \right\rangle_L = \frac{\left\langle \rho_{\mathrm{H}_2} \right\rangle L}{\tau_{\mathrm{SF}}}$$

$$\tau_{\mathrm{SF}} = \tau_{\mathrm{SF}}\left(L, \left\langle \rho_{\mathrm{H}_2} \right\rangle, \ldots\right)$$

Let's Think in 2D!



Large Scales: z=0



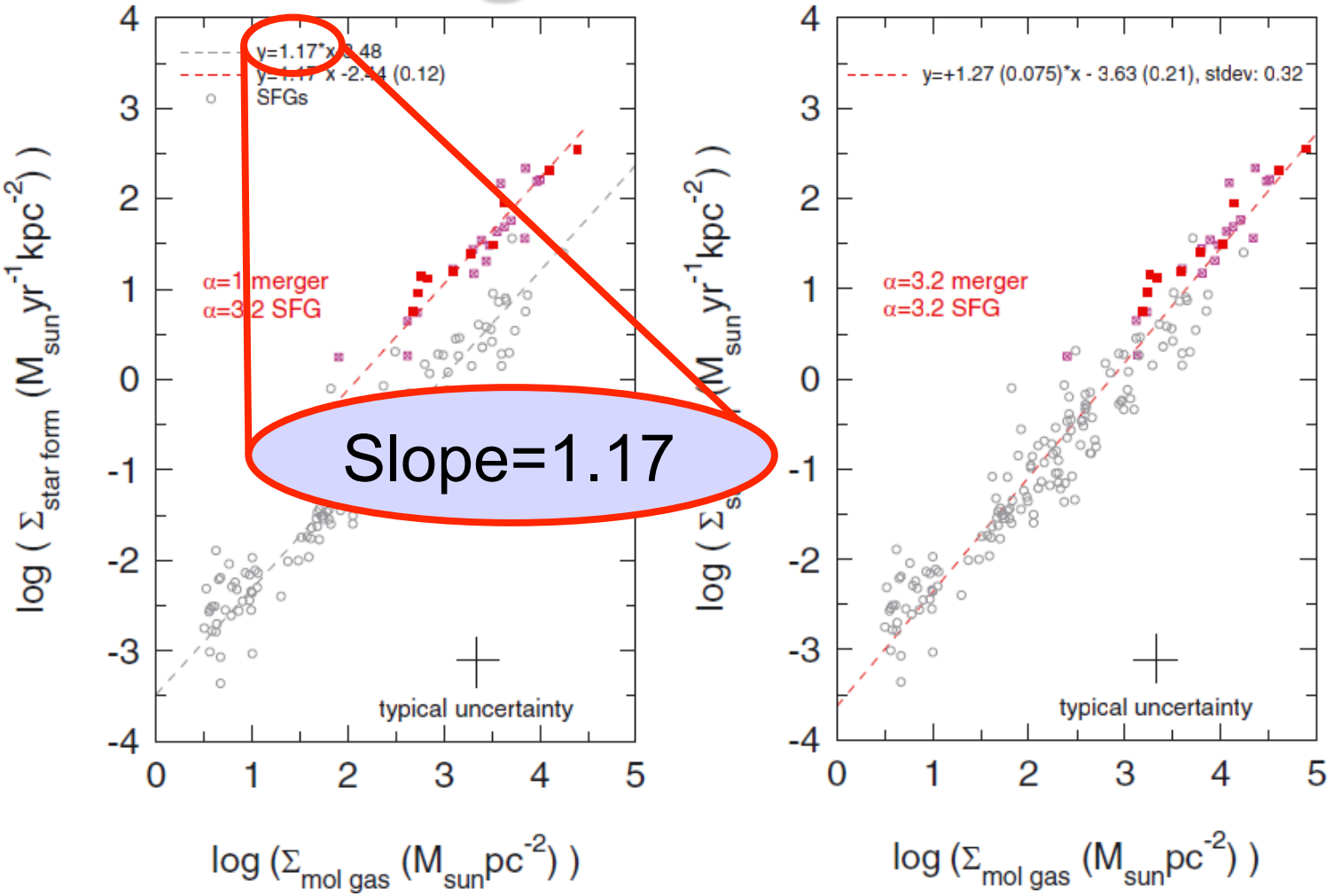
(Bigiel et al 2011)

$$L \sim 500\,\mathrm{pc}$$

$$\tau_{\mathrm{SF}} \approx 2\,\mathrm{Gyr}$$

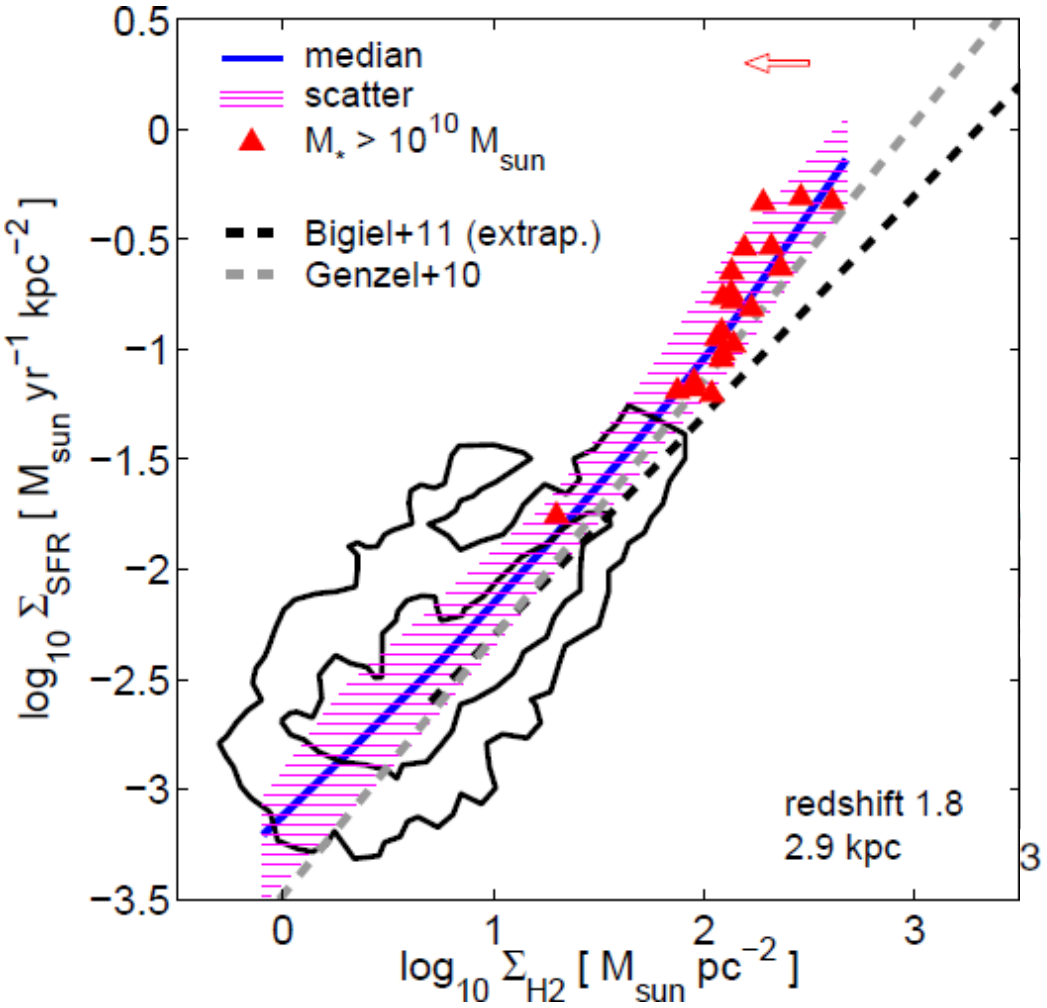
- Constant time-scale
- Linear SF recipe

Large Scales: z>1



(Genzel et al 2010)

Large Scales: z>1



(Feldmann, Gnedin, Kravtsov 2012)

- X-factor **must** increase at large surface densities (unless the metallicity is very low)
- Genzel et al data **are consistent** with the constant depletion time-scale

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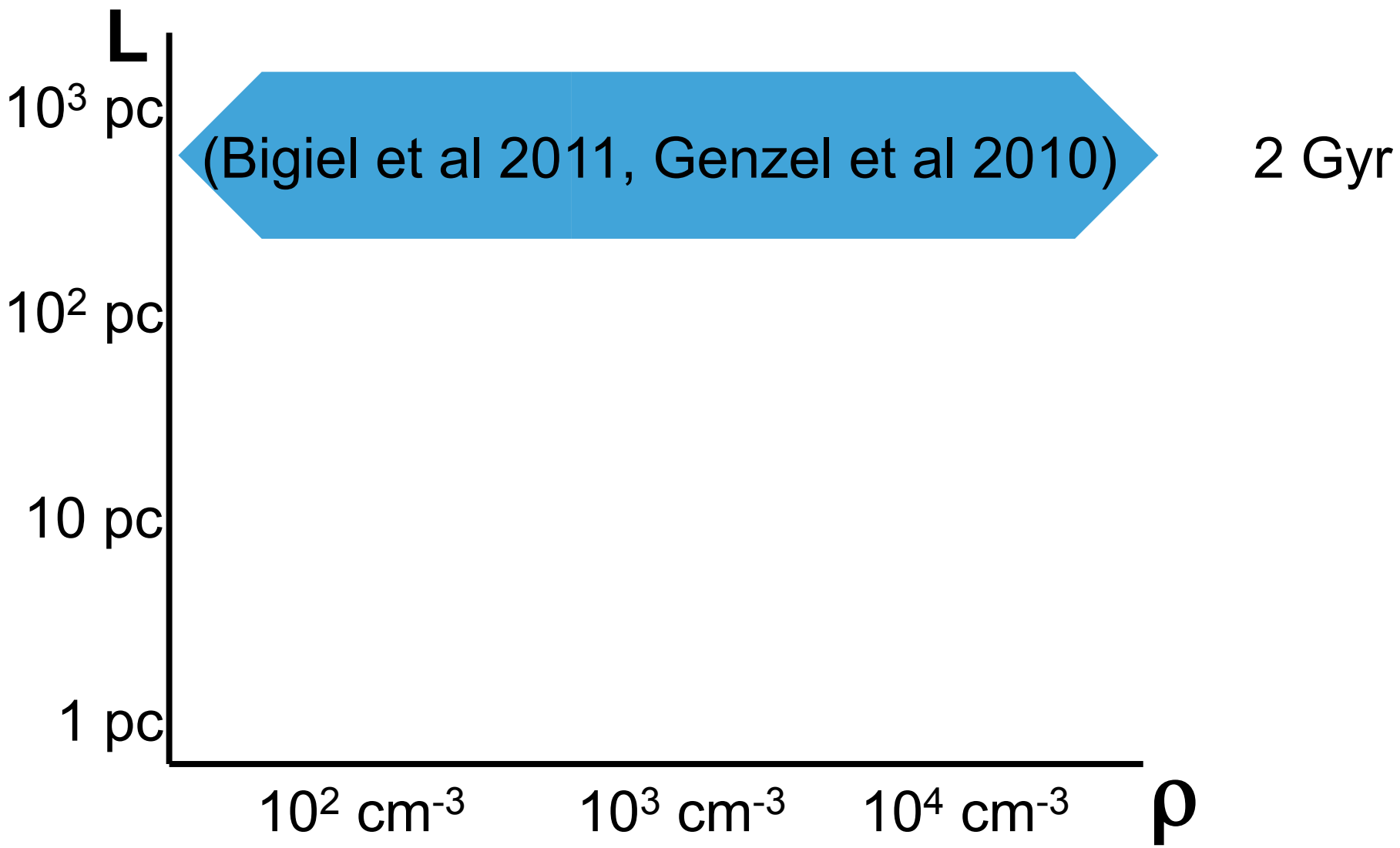

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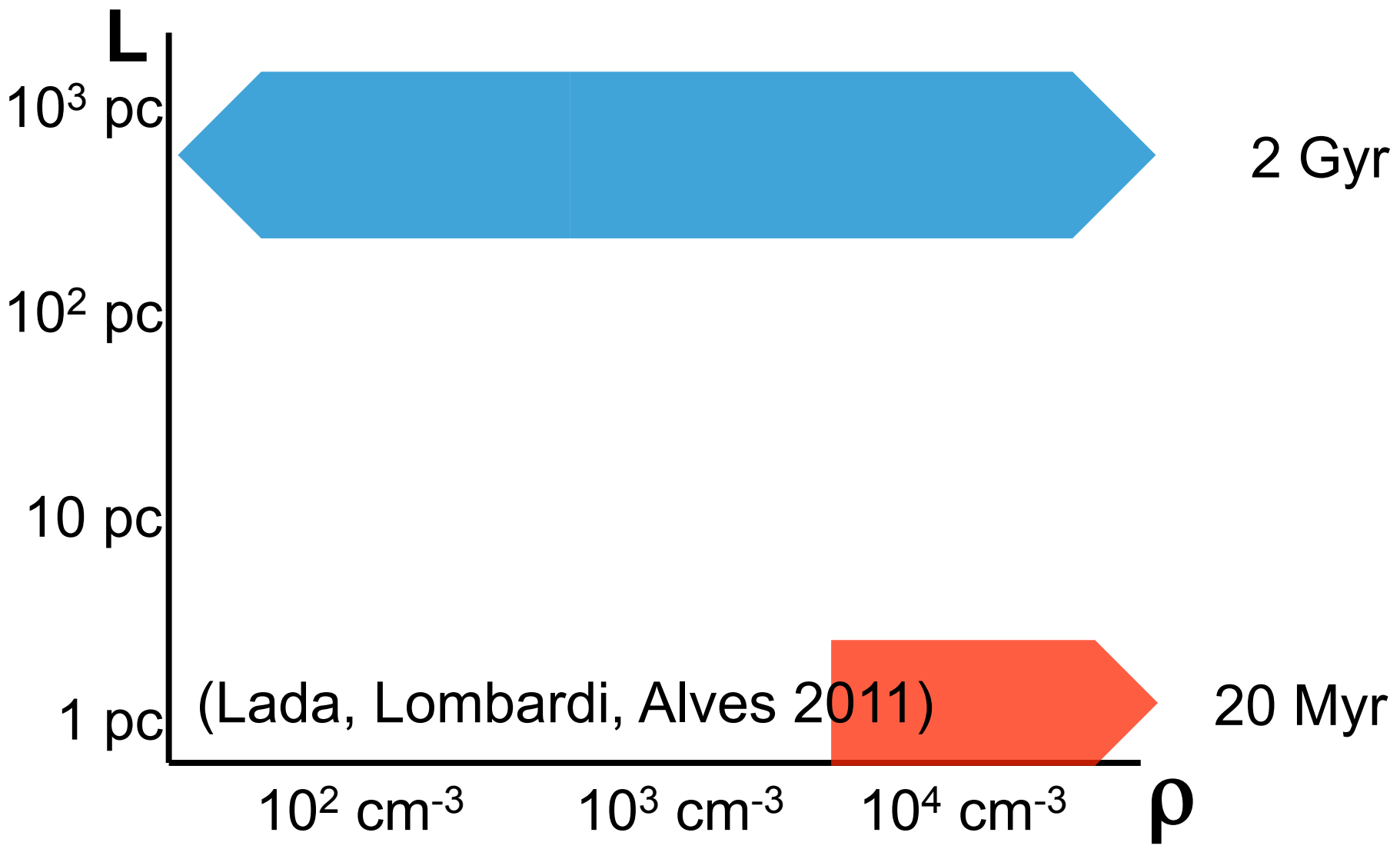
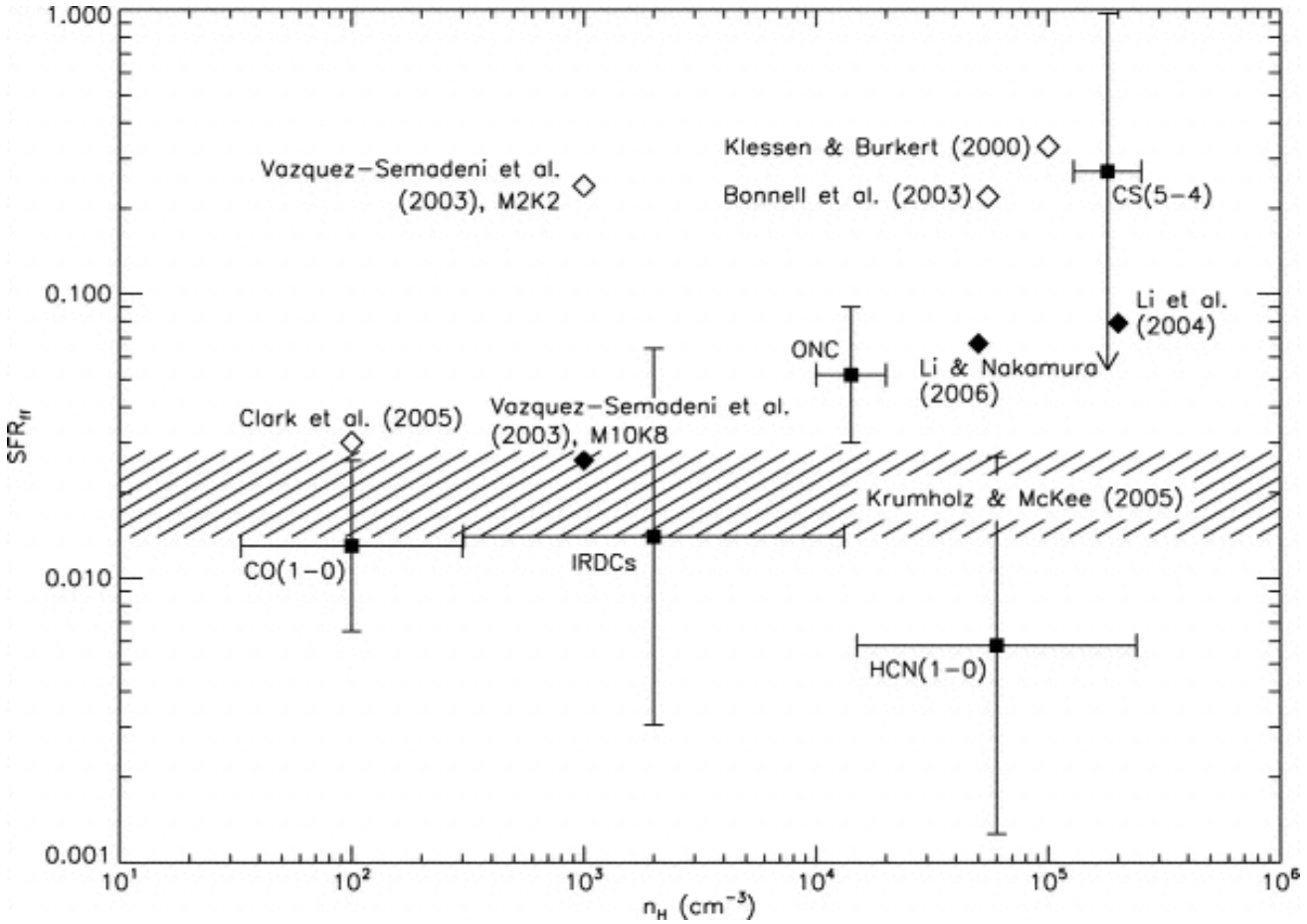


“Don’t Be Hasty…”

Krumholz & Tan (2007): $\tau_{\rm SF} \propto \tau_{\rm ff} \propto \rho^{-1/2}$



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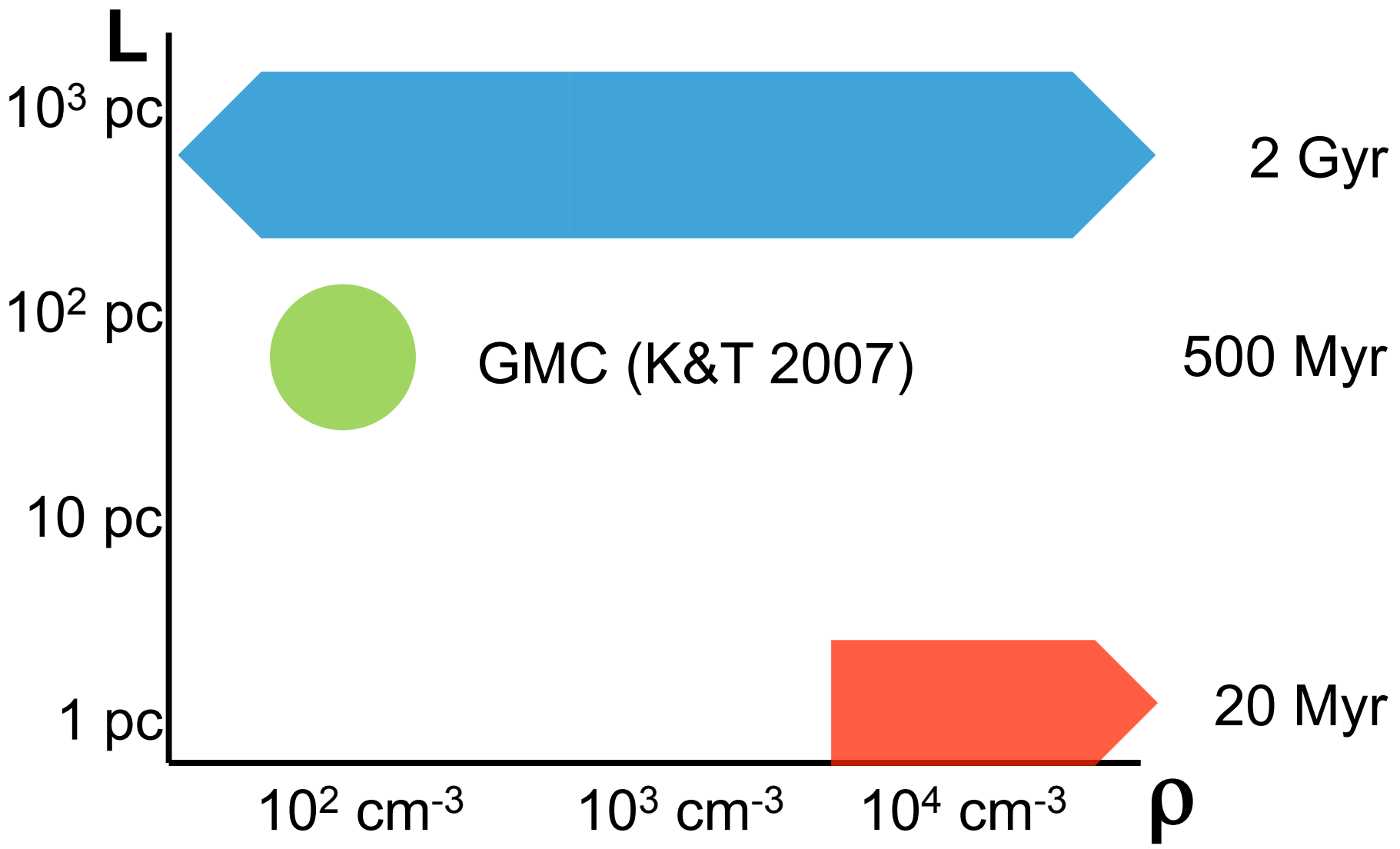

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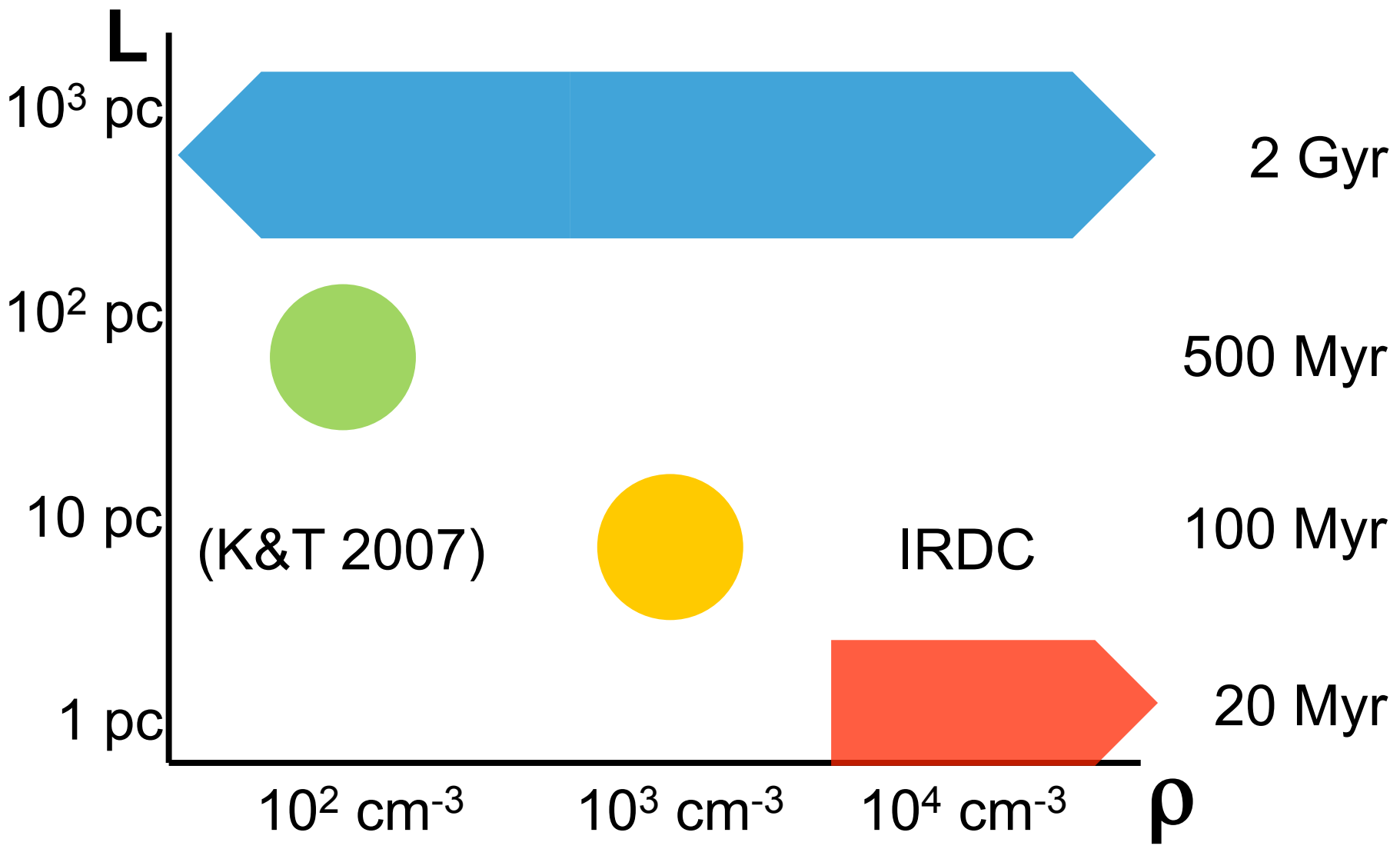

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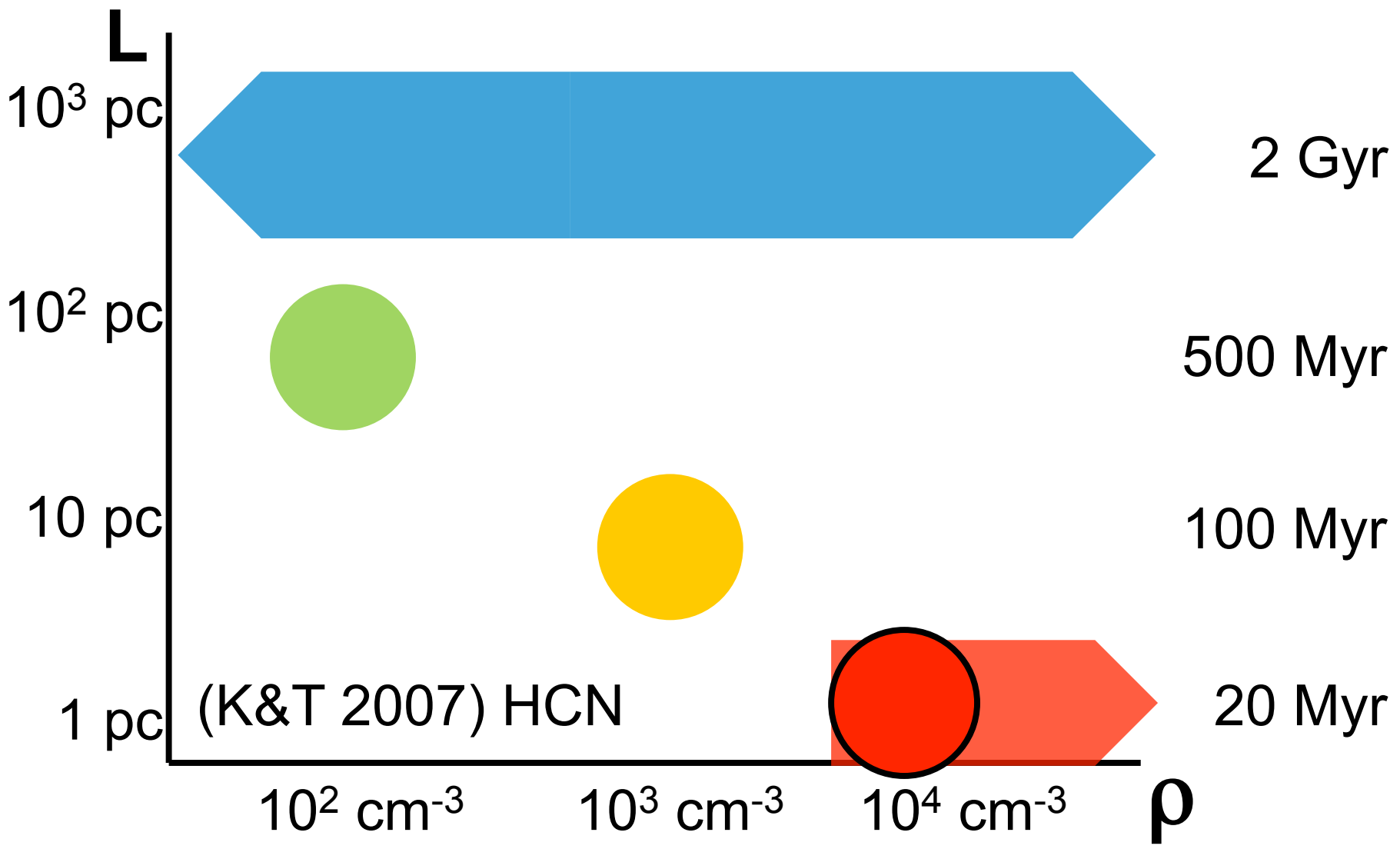

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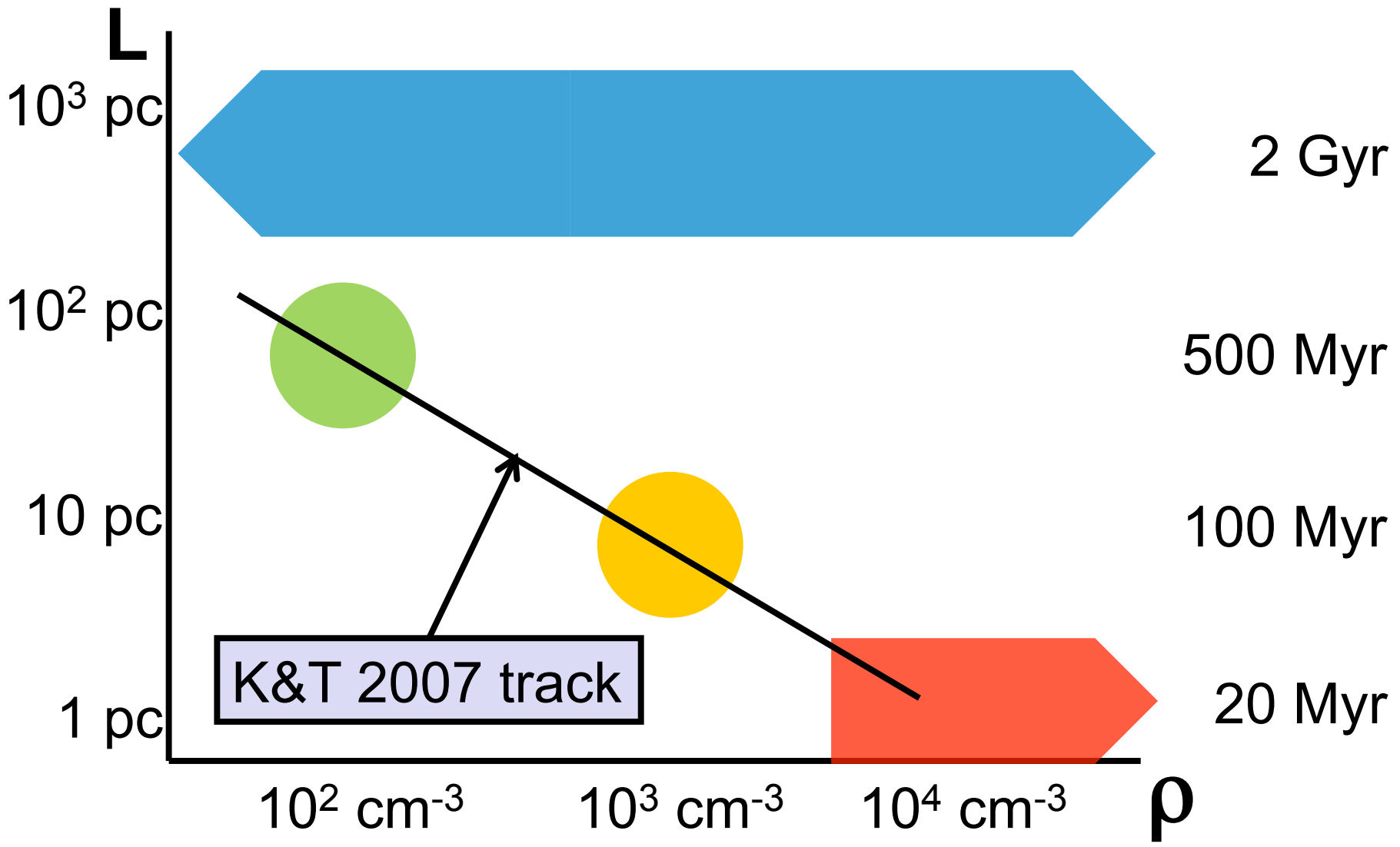
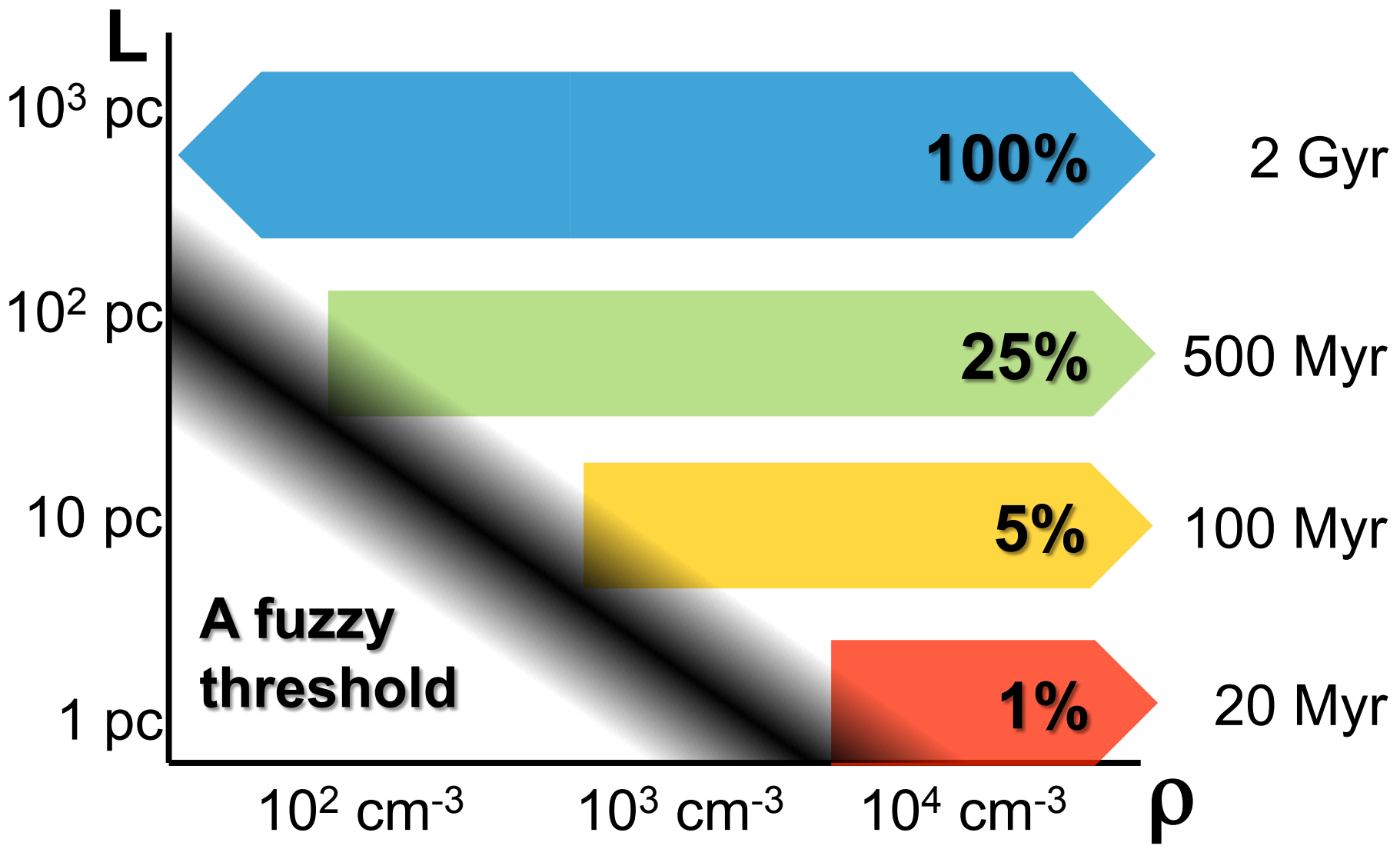
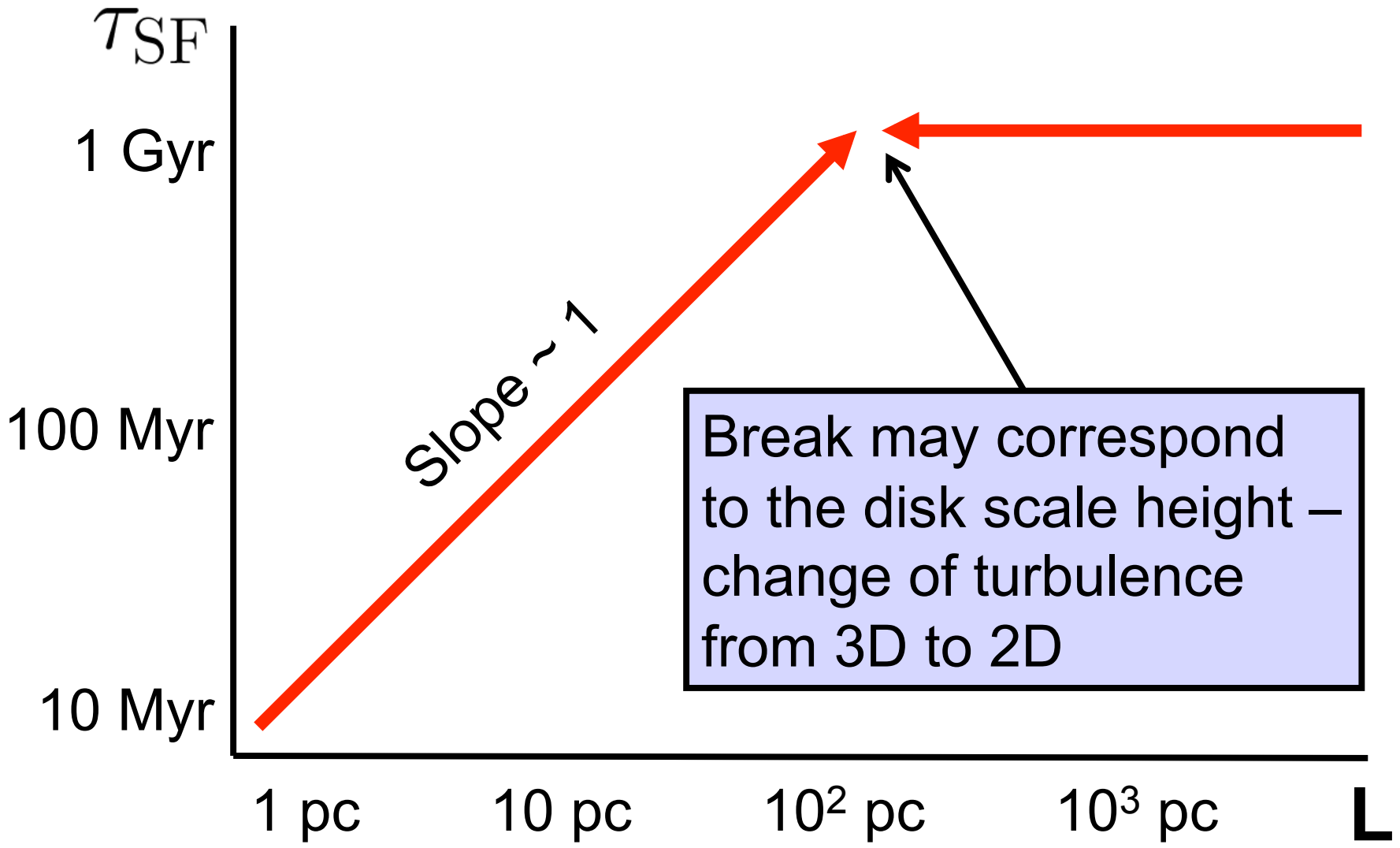


Simple Life Idea



Simple Life Idea



Simple Life Idea

$$\tau_{\rm SF}(L) \approx 2\,{\rm Gyr} \times \min\left(1, \frac{L}{100\,{\rm pc}}\right)$$

May be

$$\rho_{\rm min}(L) \approx 10/{\rm cc} \times \min\left(1, \frac{L}{100\,{\rm pc}}\right)^{-1}$$

Does It Work?

PRELIMINARY!!!

NO PHOTOGRAPHY!

Conclusions

- Star formation recipe depends on both ***scale*** and ***density***:

$$\left\langle \dot{\rho}_* \right\rangle_L = \frac{\left\langle \rho_{\mathrm{H}_2} \right\rangle_L}{\tau_{\mathrm{SF}}}$$

- Existing data are consistent with the ***linear*** (in density) ***average*** star formation hypothesis (there must be scatter/hidden parameters, Gods are never ***that*** kind):

$$\tau_{\mathrm{SF}} = \tau_{\mathrm{SF}}\left(L, \left\langle \rho_{\mathrm{H}_2} \right\rangle_L\right)$$

× *scatter*
× *threshold*

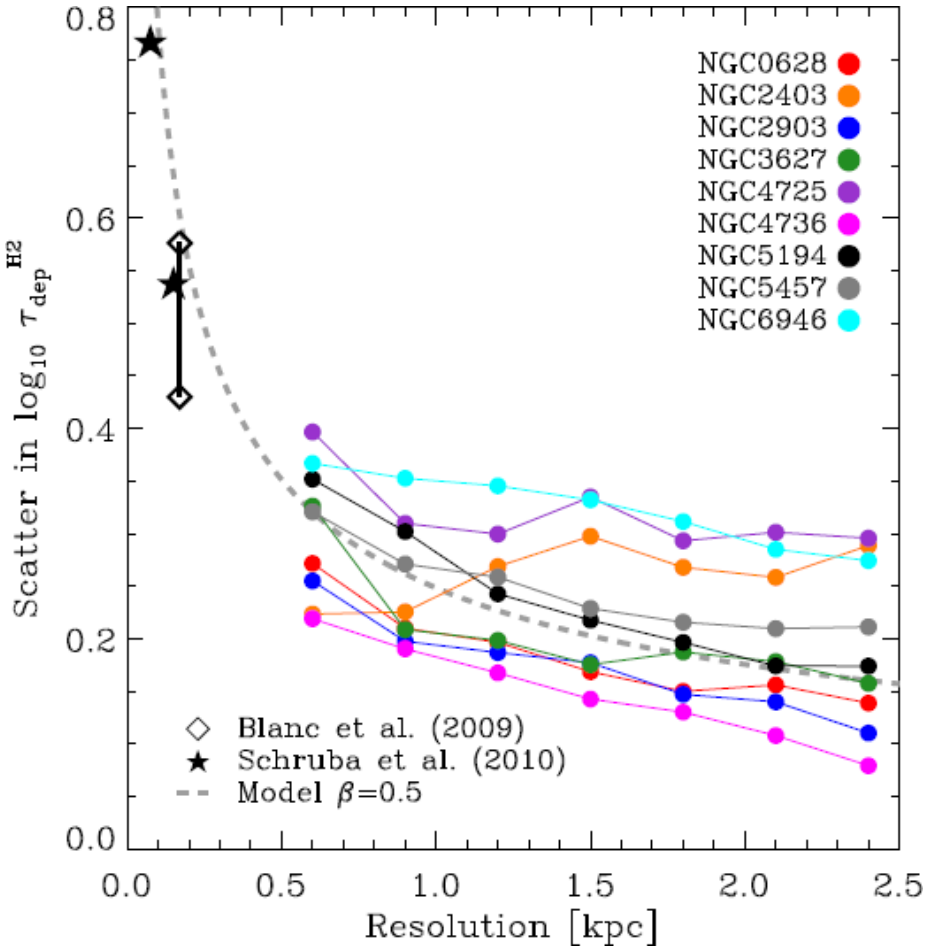
Conclusions

- If that hypothesis is true, life becomes easier for simulators:
  - In simulations with $\approx$ constant resolution, the SF rate is a linear function of (molecular) gas density;
  - Long consumption time-scale eliminates the need for early feedback a-la Stinson et al 2012 (gas remains as gas until z~3, plenty of time to blow it out);
  - With linear SF recipe simulations numerically converge.

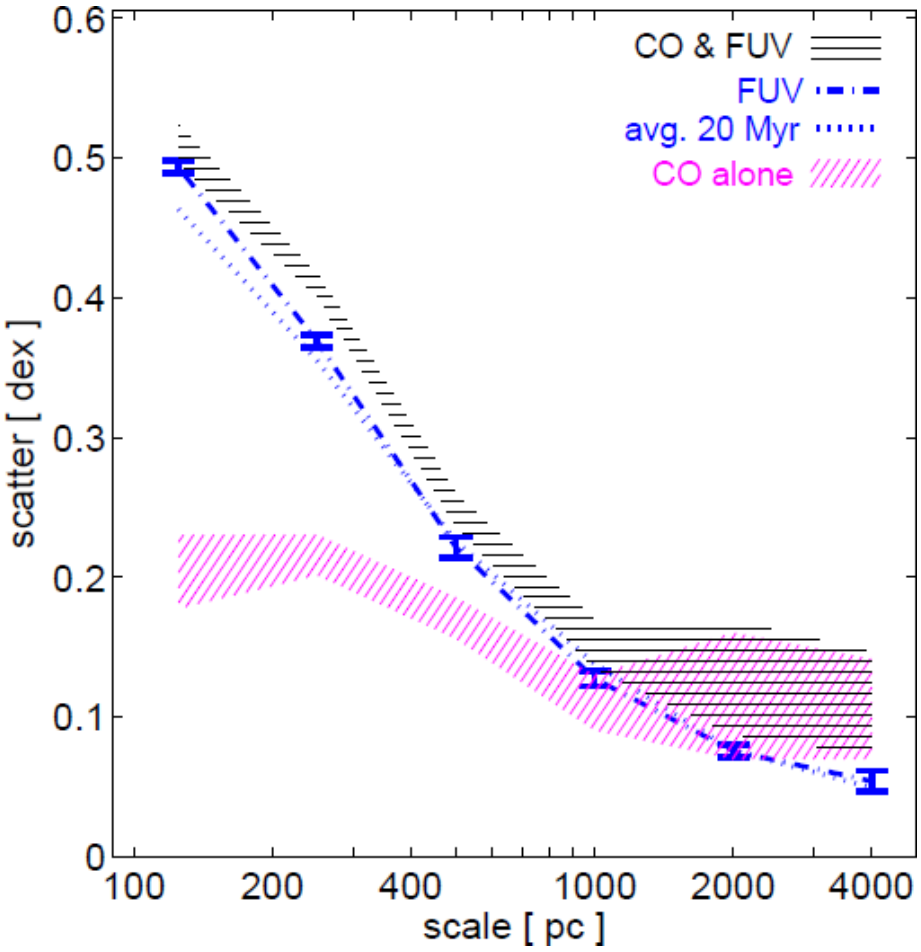
GO
LINEAR

The End

No Scatter?



(Leroy et al 2012)



(Feldmann et al 2012)