Dased and ~~not~~ confused

Absorption of the Cosmic Microwave Background by methanol

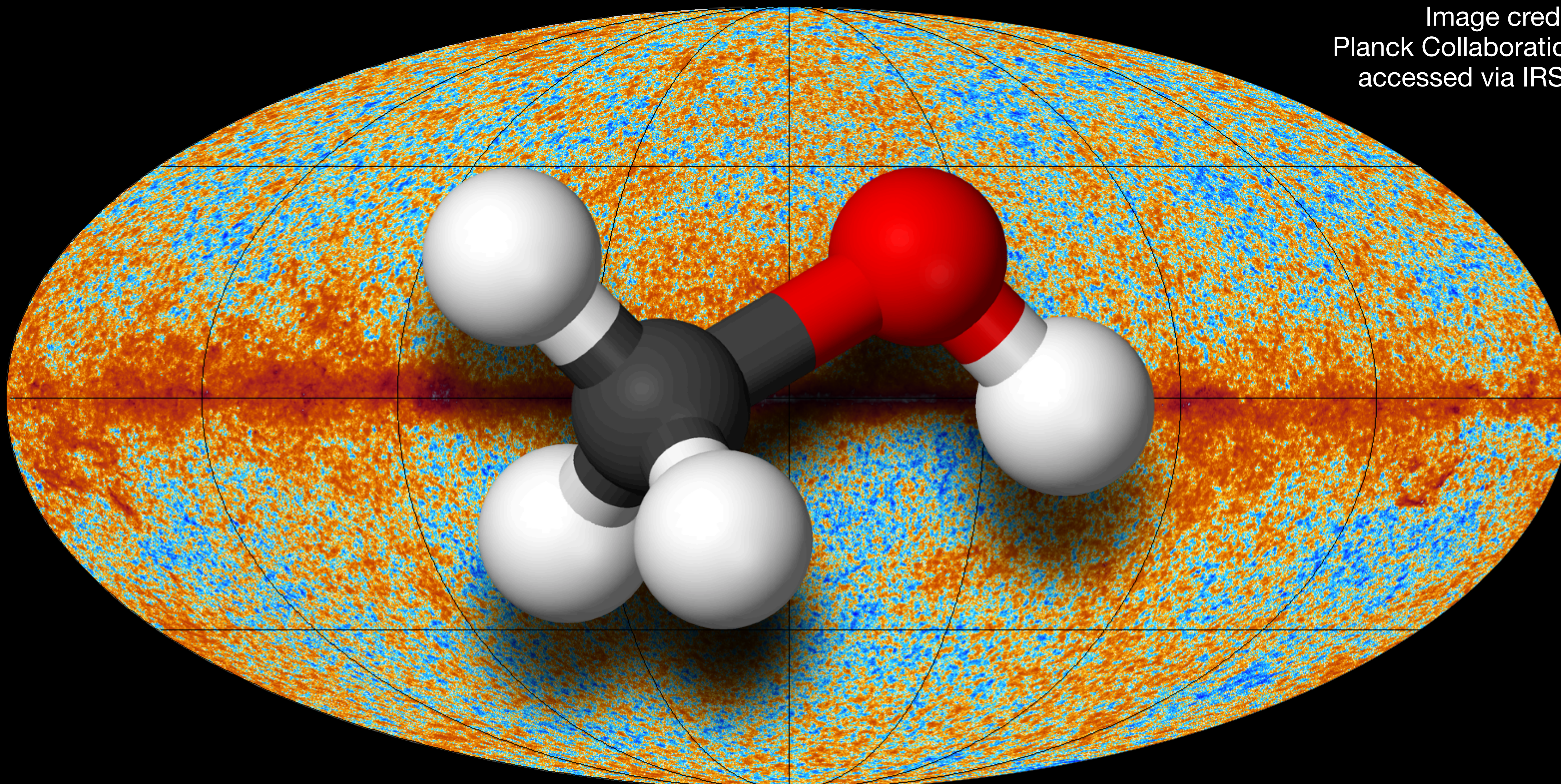

Image credit:
Planck Collaboration
accessed via IRSA

Alyssa Bulatek (she/her)
Advisor: Adam Ginsburg

October 14, 2022
Graduate Symposium

Brightness temperature

It's what we observe

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$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{\exp\left(\frac{h\nu}{k_B T}\right) - 1}$$

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    - Spectral radiance $B_\nu(T)$ is directly proportional to temperature

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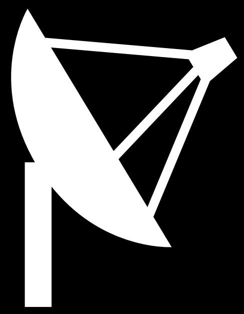

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- Solve for temperature
  - We talk about a "temperature" even when the system is not a blackbody

$$T_b(\nu) \equiv \frac{I_\nu c^2}{2k\nu^2}$$

Excitation temperature

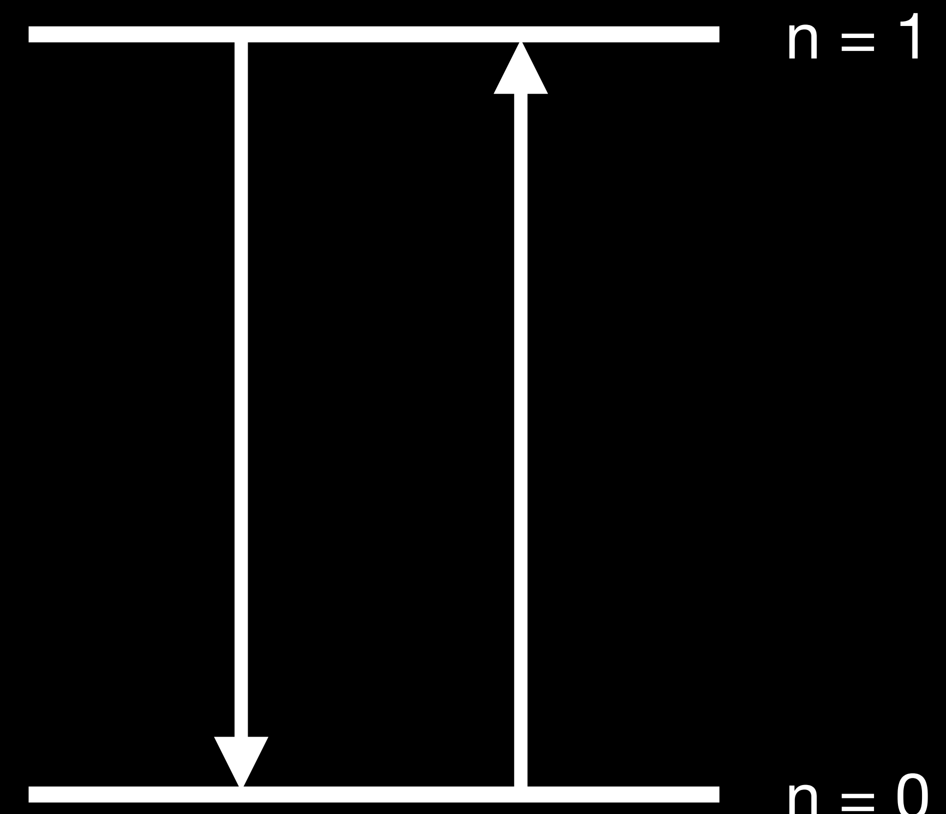
It is a fake temperature

- T_{ex} gives the ratio of number of molecules in one state versus another

$$\frac{N_u g_l}{N_l g_u} = \exp\left(\frac{-\Delta E}{k_B T_{ex}}\right)$$

- LTE: $T_{ex} = T_K$

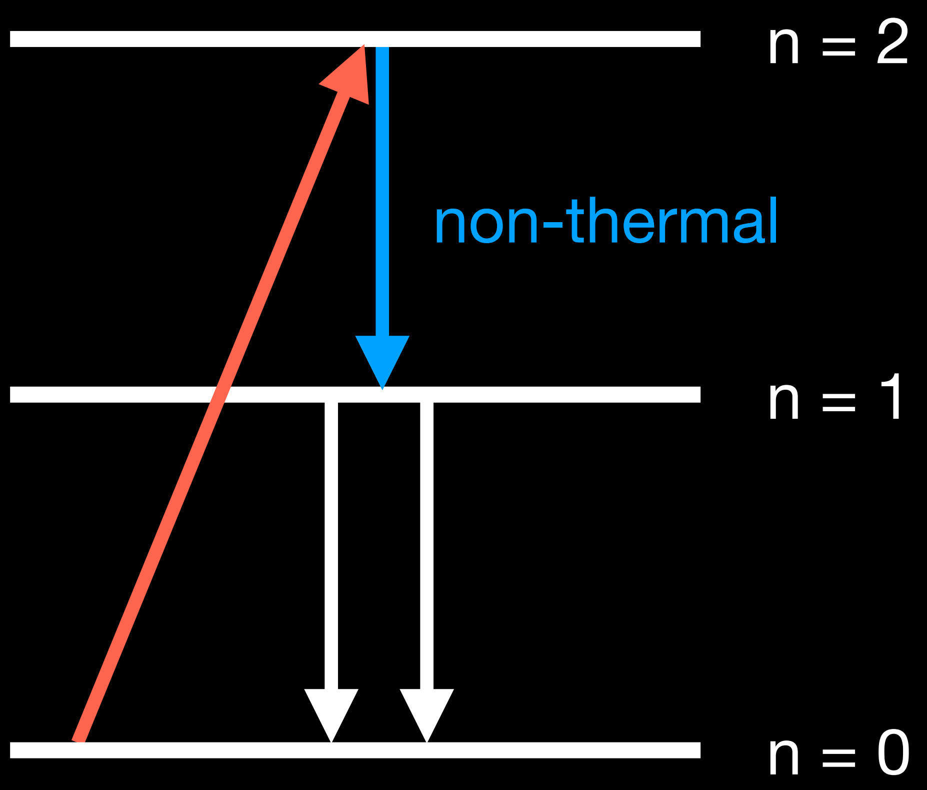
- 2.73 K is lowest possible kinetic temperature in ISM



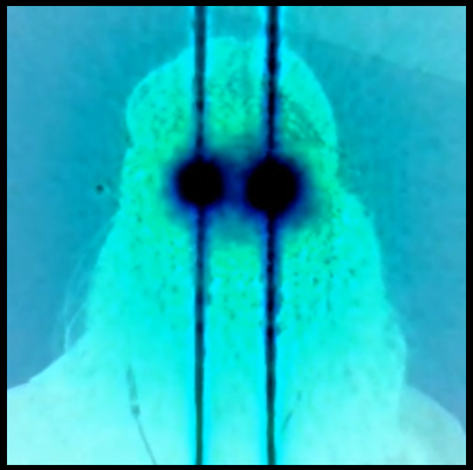
Masers

It's exactly like a laser, pretty much

- MASER = Microwave Amplification by Stimulated Emission of Radiation
- Population inversion
  - Excess population of molecules in upper energy state, that then emit 2 photons each
- Needs source of coherent amplification, like pumping in a lab laser

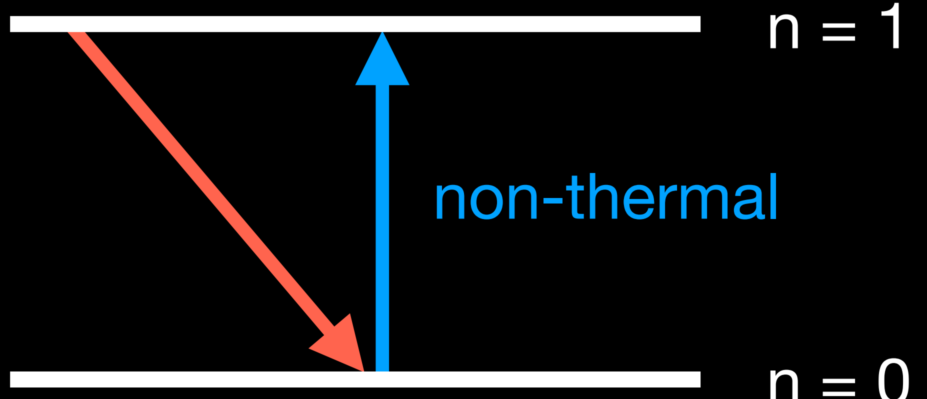


Dasars



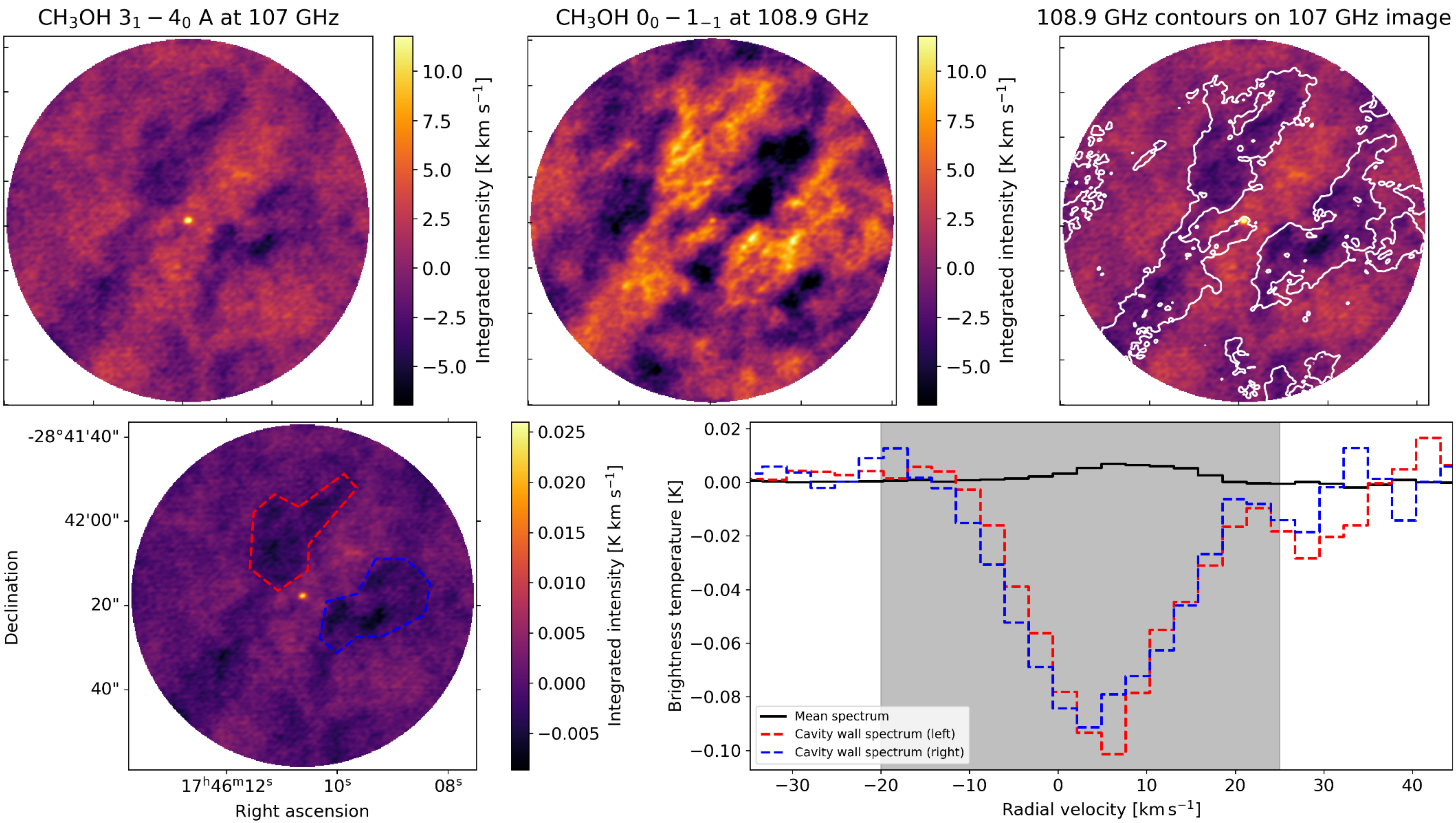
It's exactly like a maser, except totally different

- DASAR = Dark "Amplification" by Stimulated Absorption of Radiation
    - AKA "anti-inversion," "non-thermal absorption" or "refrigeration"
- Pump drives molecules into lower energy state, that then absorb photons
    - If pump gets T_{ex} cold enough, molecule could even absorb the CMB!
- Non-amplified, non-directional
- Has extragalactic uses



Dasar in The Brick

- Where most methanol (CH_3OH) lines emit, one absorbs



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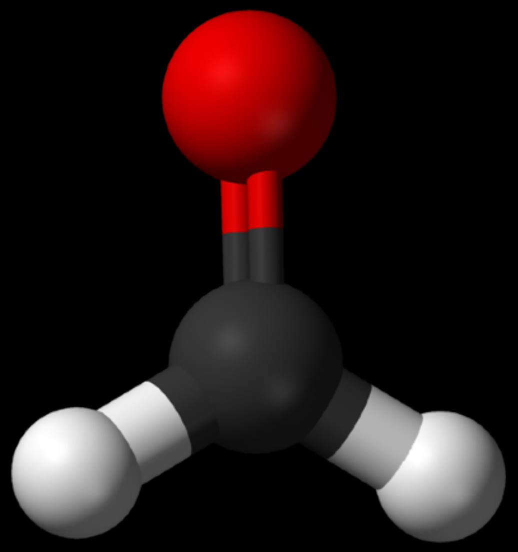

- Formaldehyde (H_2CO) (e.g. Ginsburg+2011)
  - $1_{10} - 1_{11}$, $2_{11} - 2_{12}$, $3_{12} - 3_{13}$

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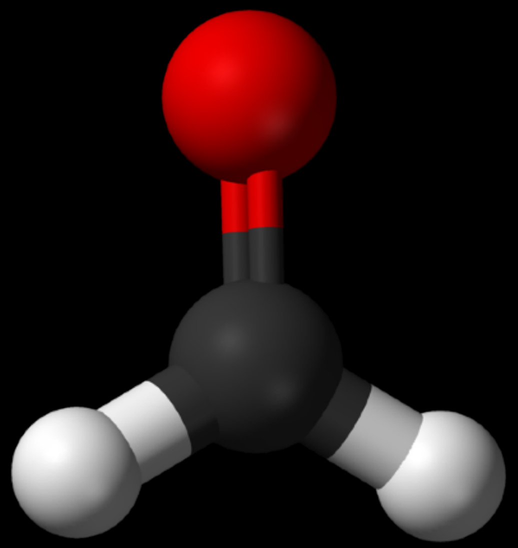

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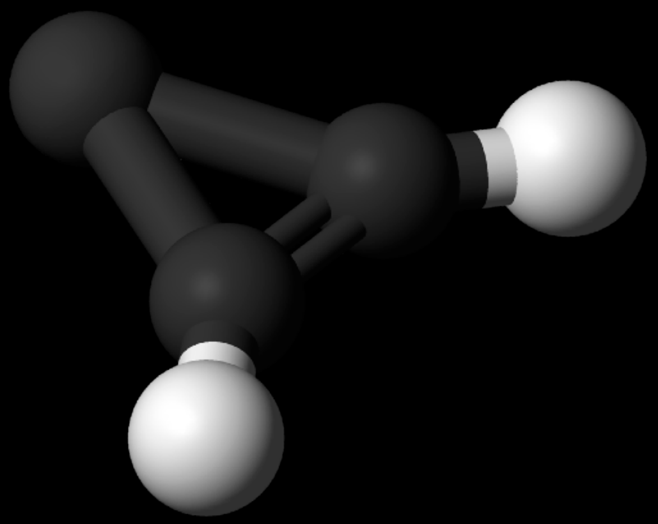
- Cyclopropenylidene ($c\text{-}C_3H_2$) (e.g. Sharma and Chandra 2022)
  - $2_{2,0} - 2_{1,1}$, $4_{4,0} - 4_{3,1}$, $3_{3,0} - 3_{2,1}$, $4_{3,2} - 5_{0,5}$



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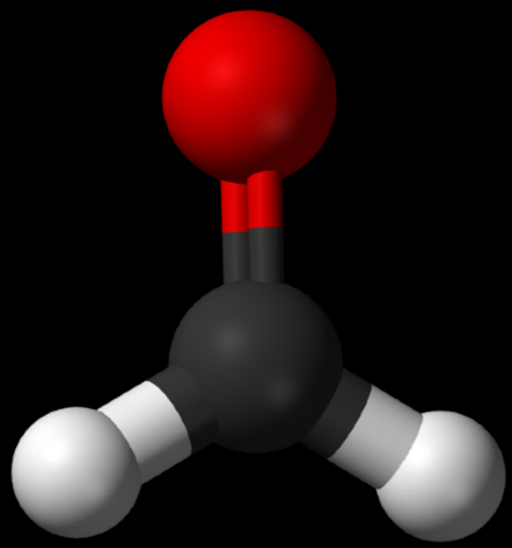

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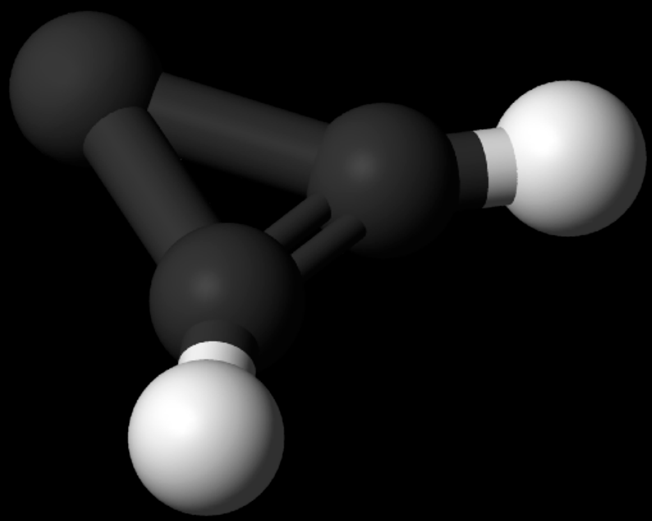
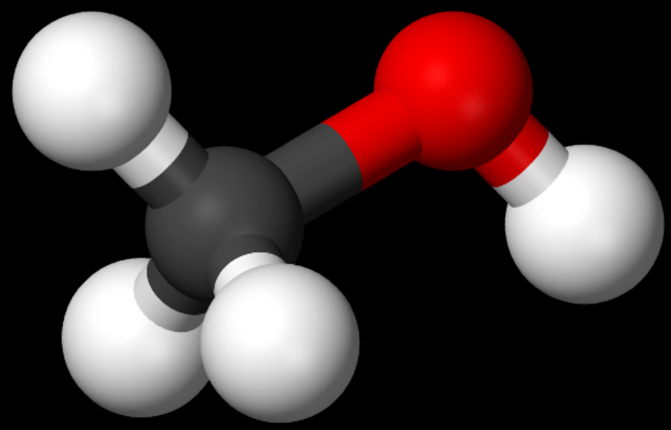


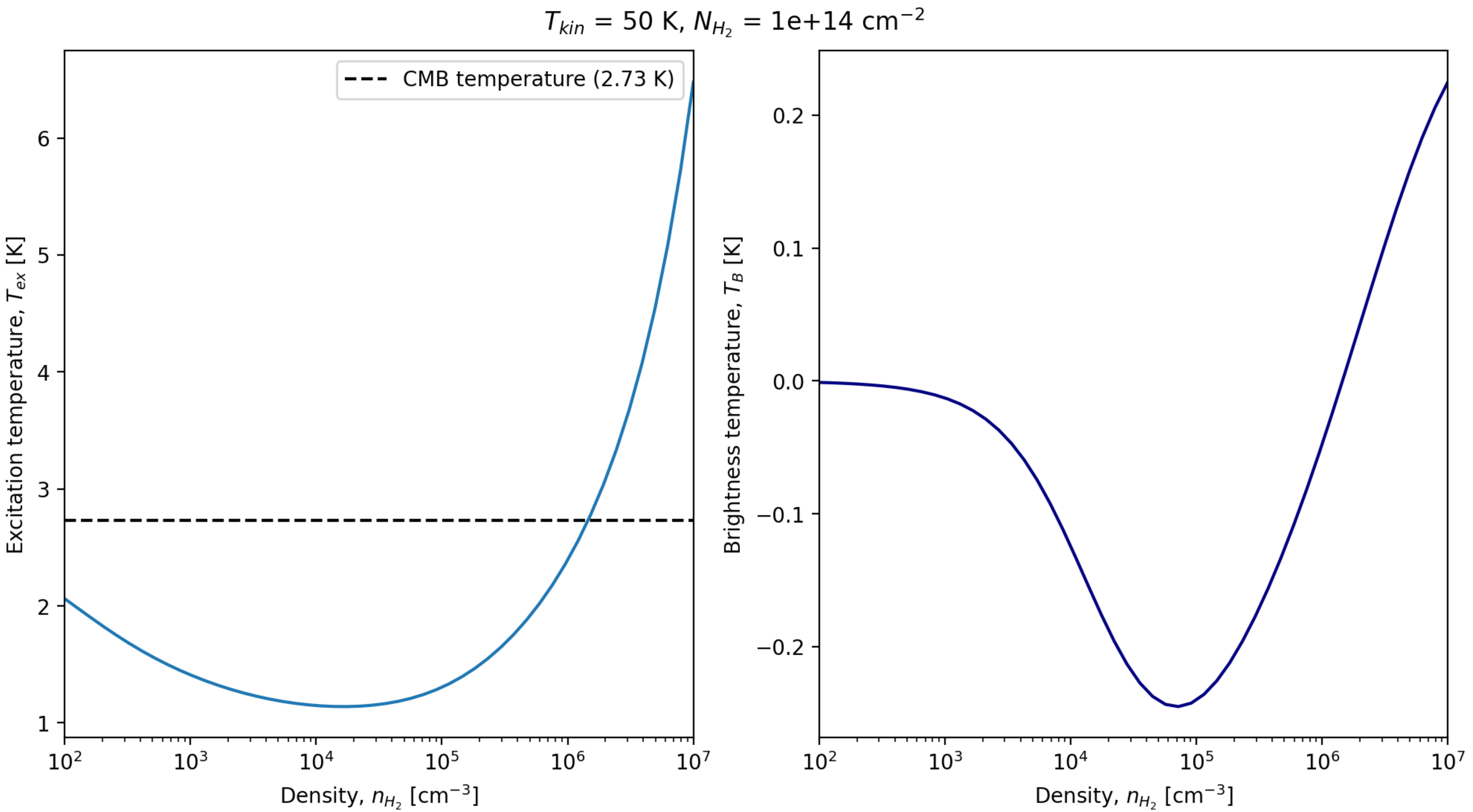
- Methanol (CH_3OH) (e.g. Bulatek+202X in prep.)
  - 107 GHz line reported in absorption, but people have assumed it's against a continuum source
  - Now have clear evidence it's dasing; there is no continuum source behind The Brick



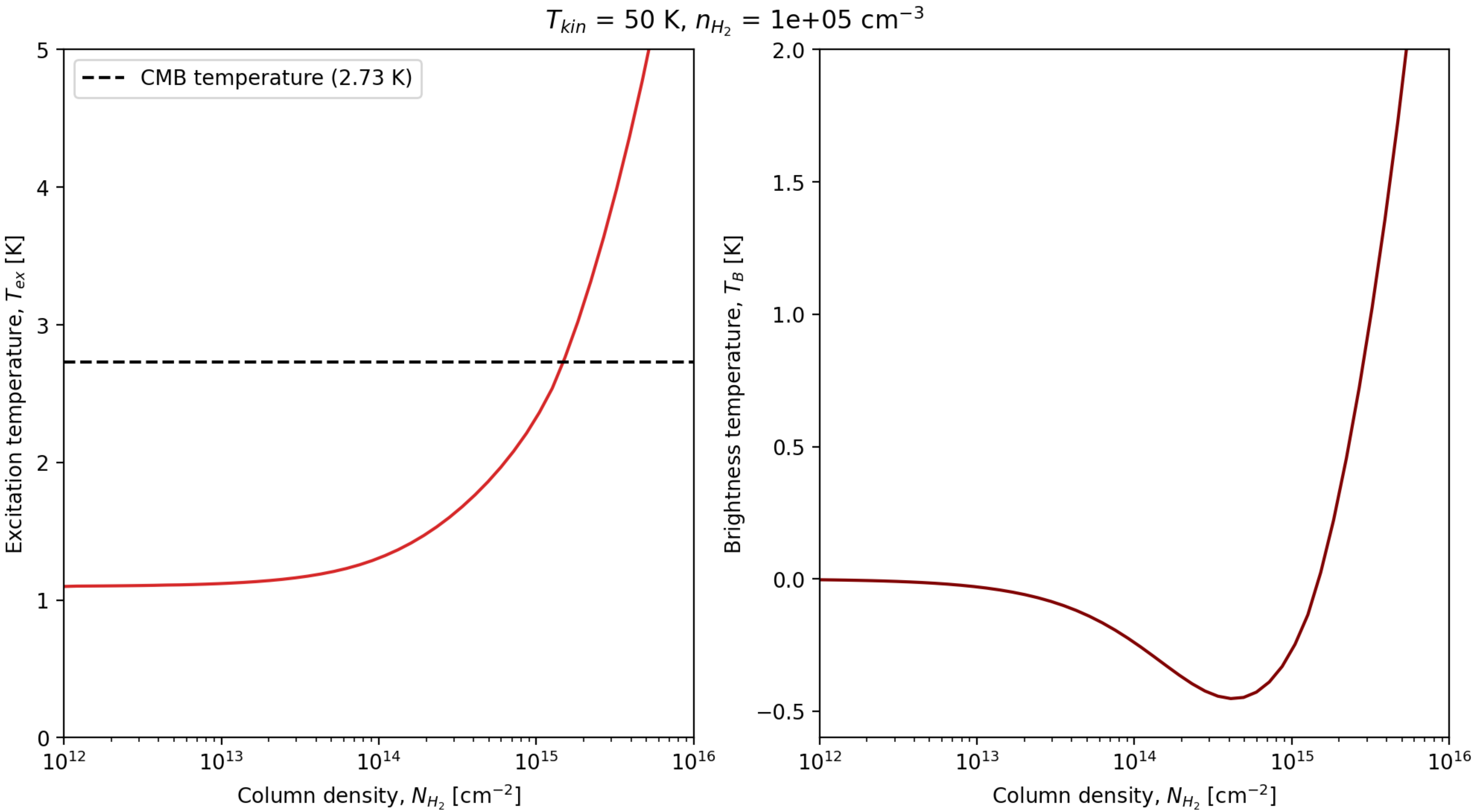
What can we learn from the presence of a dasar?

Physical parameters

Where it is dense enough to dase

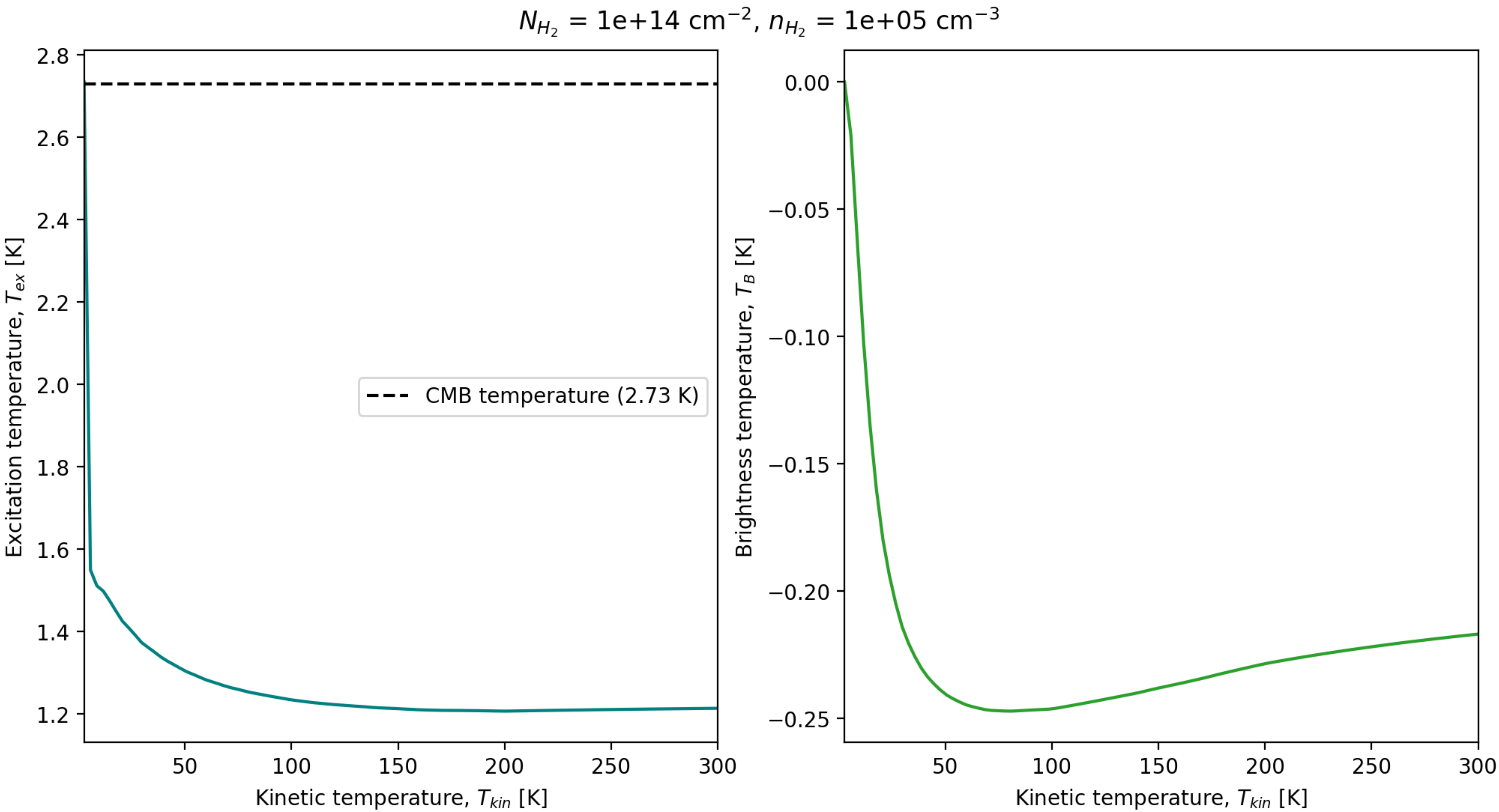


Wow, this looks very similar to
the last slide but now it's column density



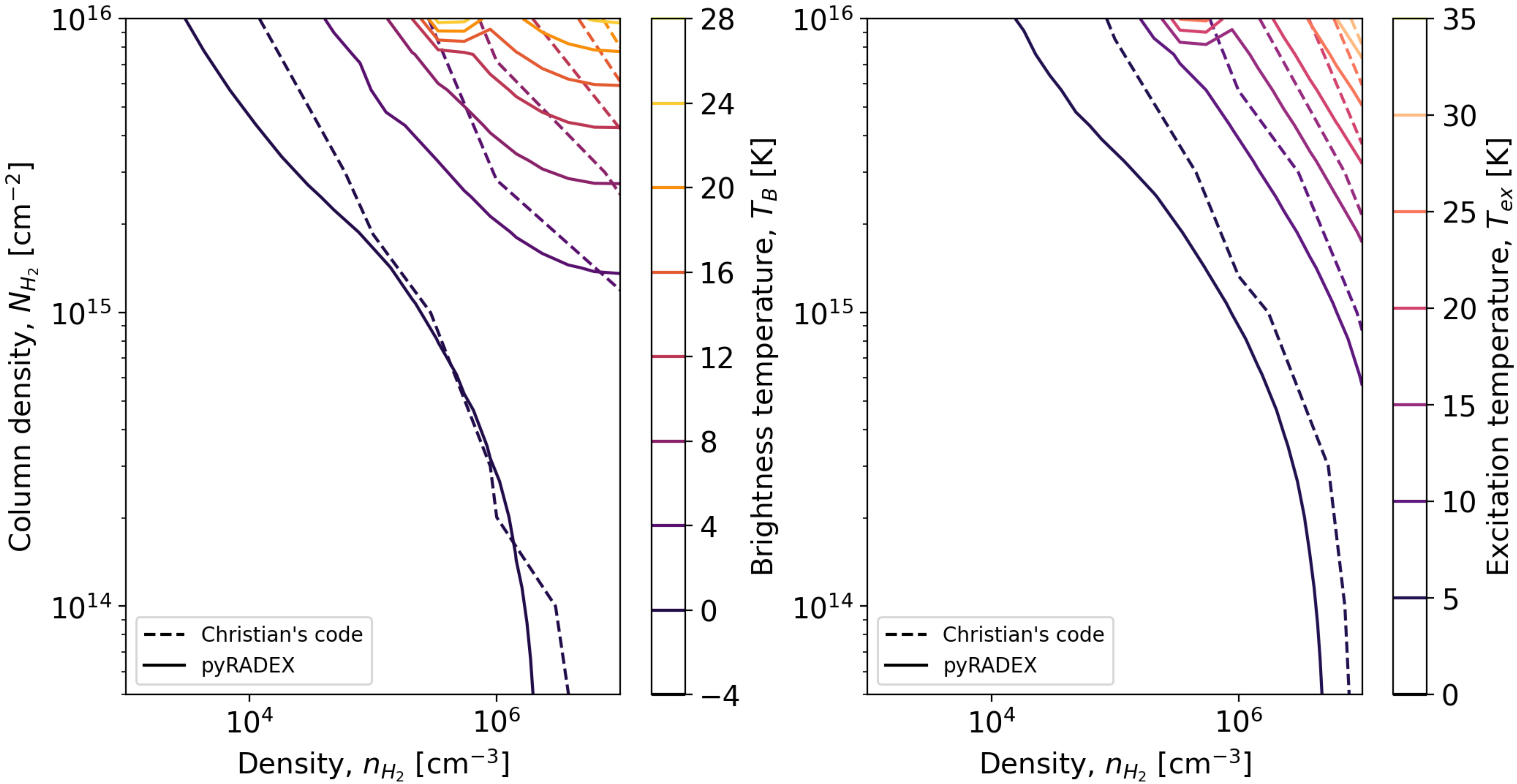
Dasing at ALL kinetic temperatures

including absolute zero



Dasing parameter space in 2D

- Compared our code (pyRADEX, a RADEX wrapper in Python) to a collaborator's code using the same conditions



Thank you!

References

- Condon, J. J., and Ransom, S. M. 2016, Essential Radio Astronomy (Princeton University Press)

- Ginsburg, A., Darling, J., Battersby, C., et al. 2011, *ApJ*, 736, 149. doi:10.1088/0004-637X/736/2/149

- Sharma, M. K. and Chandra, S. 2022, *MNRAS*, 514, 2116. doi:10.1093/mnras/stac1360

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References

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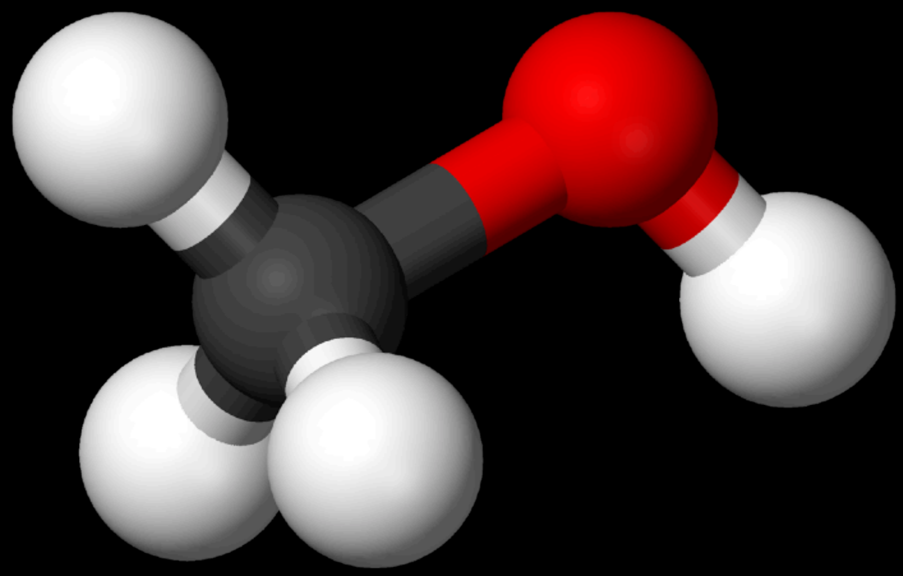

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