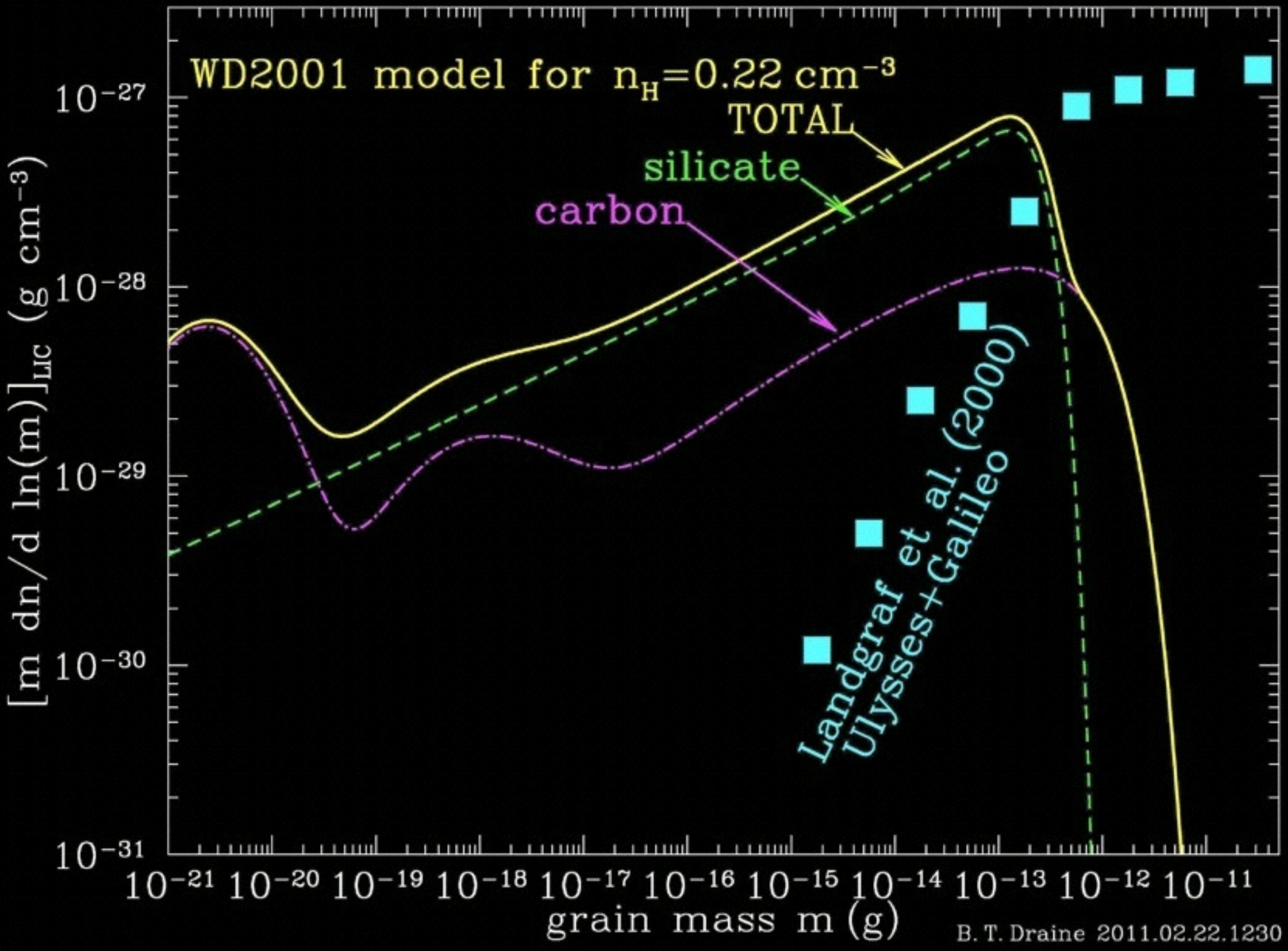
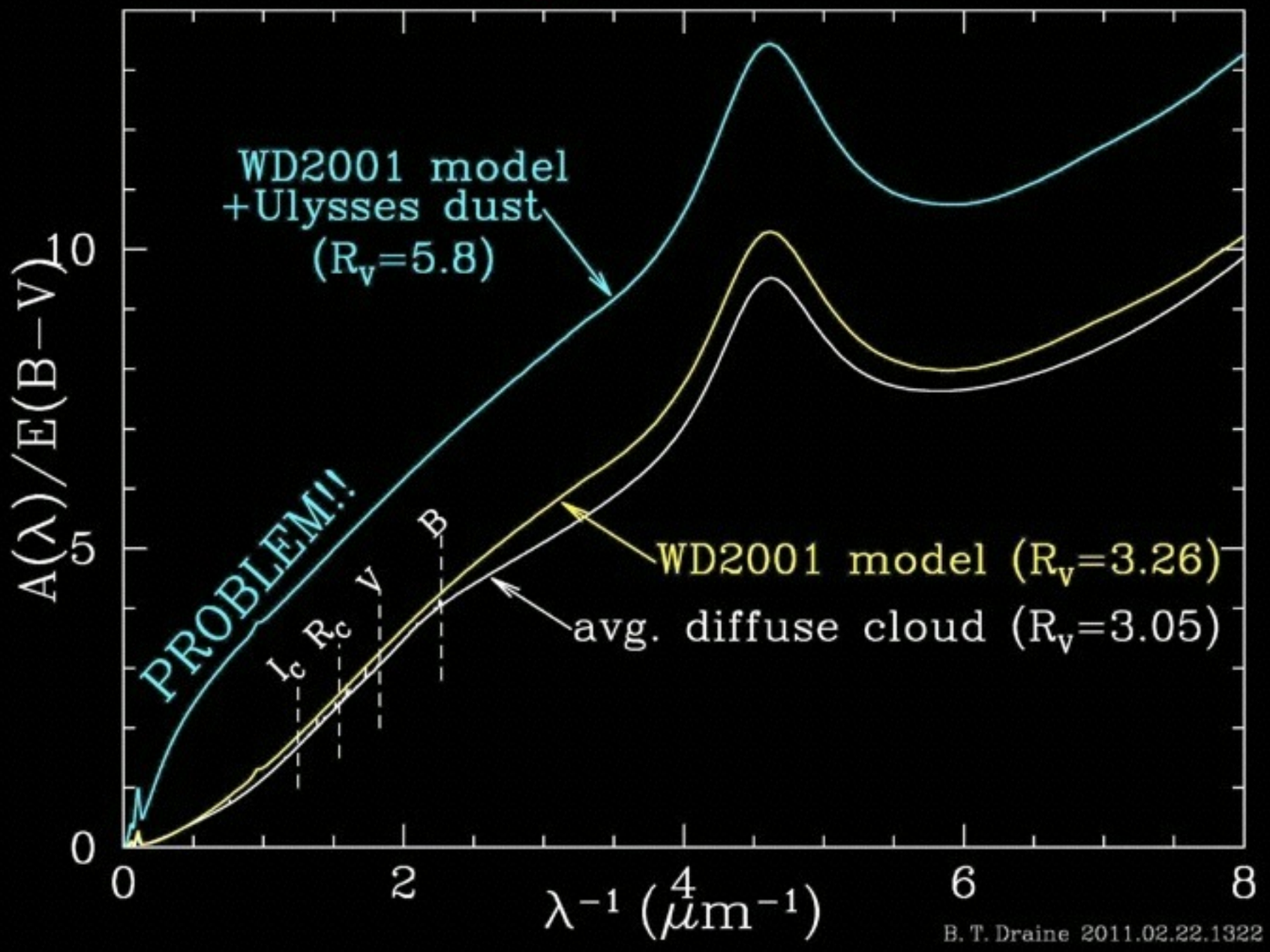
Solid H_2 : Interstellar Dust

Mark Walker
(Manly Astrophysics)

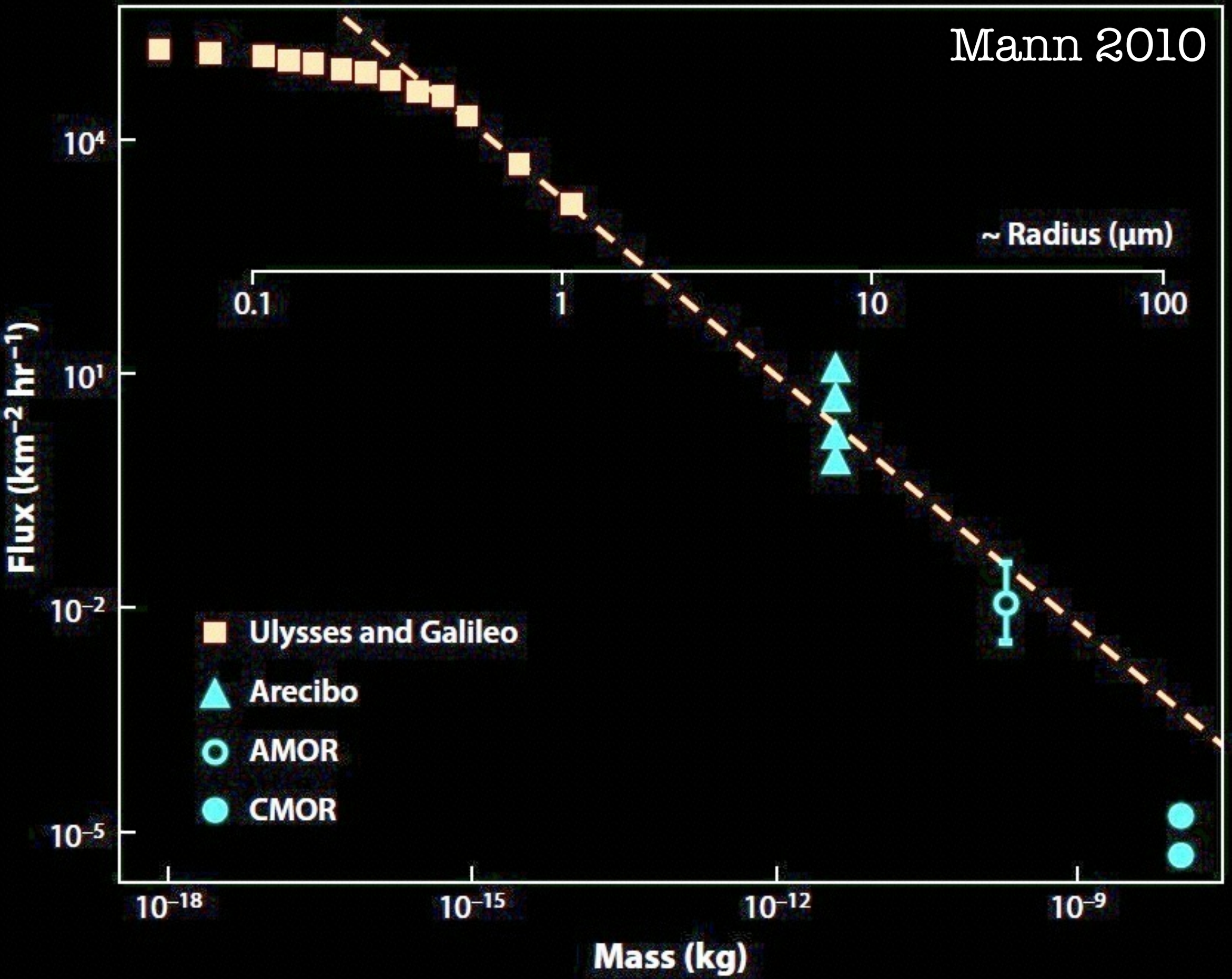

WD2001 model for n_H=0.22 cm^{-3}
TOTAL
silicate
carbon
Landgraf et al. (2000)
Ulysses+Galileo
10^{-27}
10^{-28}
10^{-29}
10^{-30}
10^{-31}
[m dn/d ln(m)]$_{LIC}$ (g cm^{-3})
10^{-21} 10^{-20} 10^{-19} 10^{-18} 10^{-17} 10^{-16} 10^{-15} 10^{-14} 10^{-13} 10^{-12} 10^{-11}
grain mass m (g)
B. T. Draine 2011.02.22.1230

Extinction Law for "Ulysses" Grain Size Distribution



- "Ulysses" size distribution would have $R_V = A_V/E(B-V) \approx 5.8$ whereas we observe $R_V \approx 3.1$ for the (average) diffuse ISM.
- "Ulysses" size distribution *cannot* be characteristic of the diffuse ISM, based on reddening alone.

Mann 2010


~ Radius (μm)
0.1
1
10
100
10^4
10^1
10^{-2}
10^{-5}
Flux (km^{-2} hr^{-1})
Ulysses and Galileo
Arecibo
AMOR
CMOR
10^{-18}
10^{-15}
10^{-12}
10^{-9}
Mass (kg)

H_2 phase equilibrium

T_{comb}

$\propto T^{5/2} \exp(-91/T)$

P_{ism}

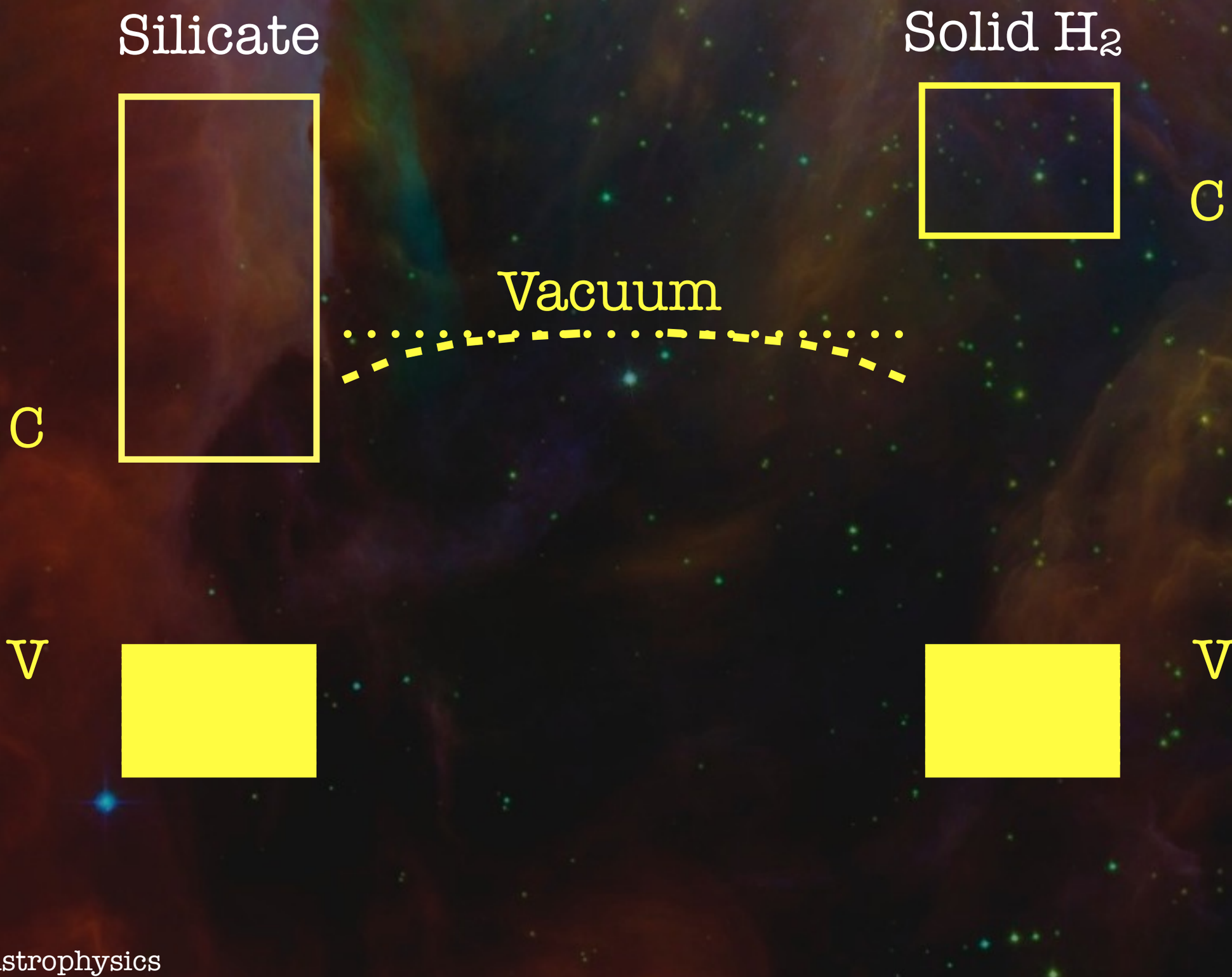
$\mathrm{Log}_{10} P\,(K\,\mathrm{cm}^{-3})$

20
15
10
5

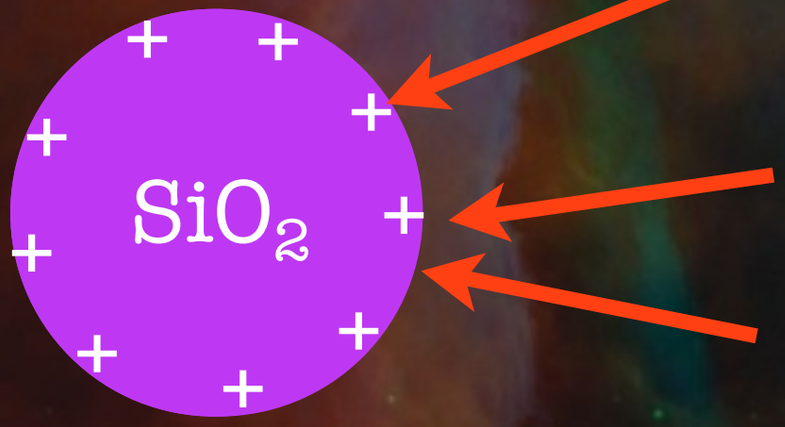
2 4 6 8 10 12 14

T (K)

Electronic band structure



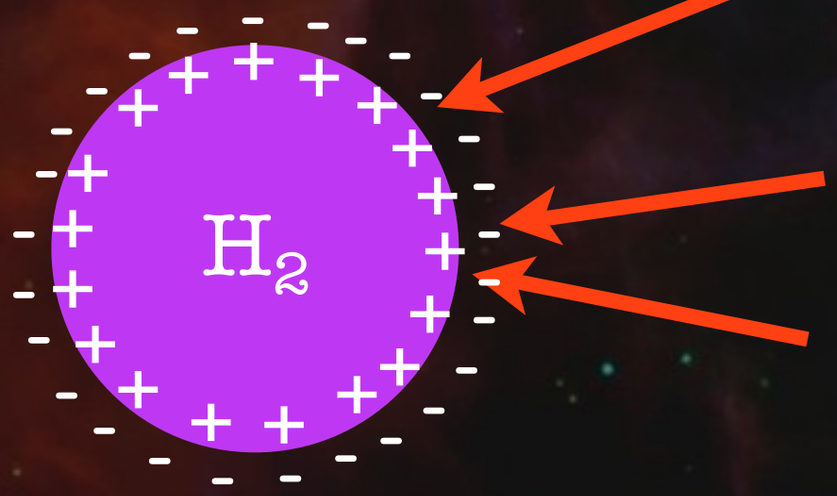
Charging of dust grains



γ : Photoelectric

e^-

p^+ Collisional



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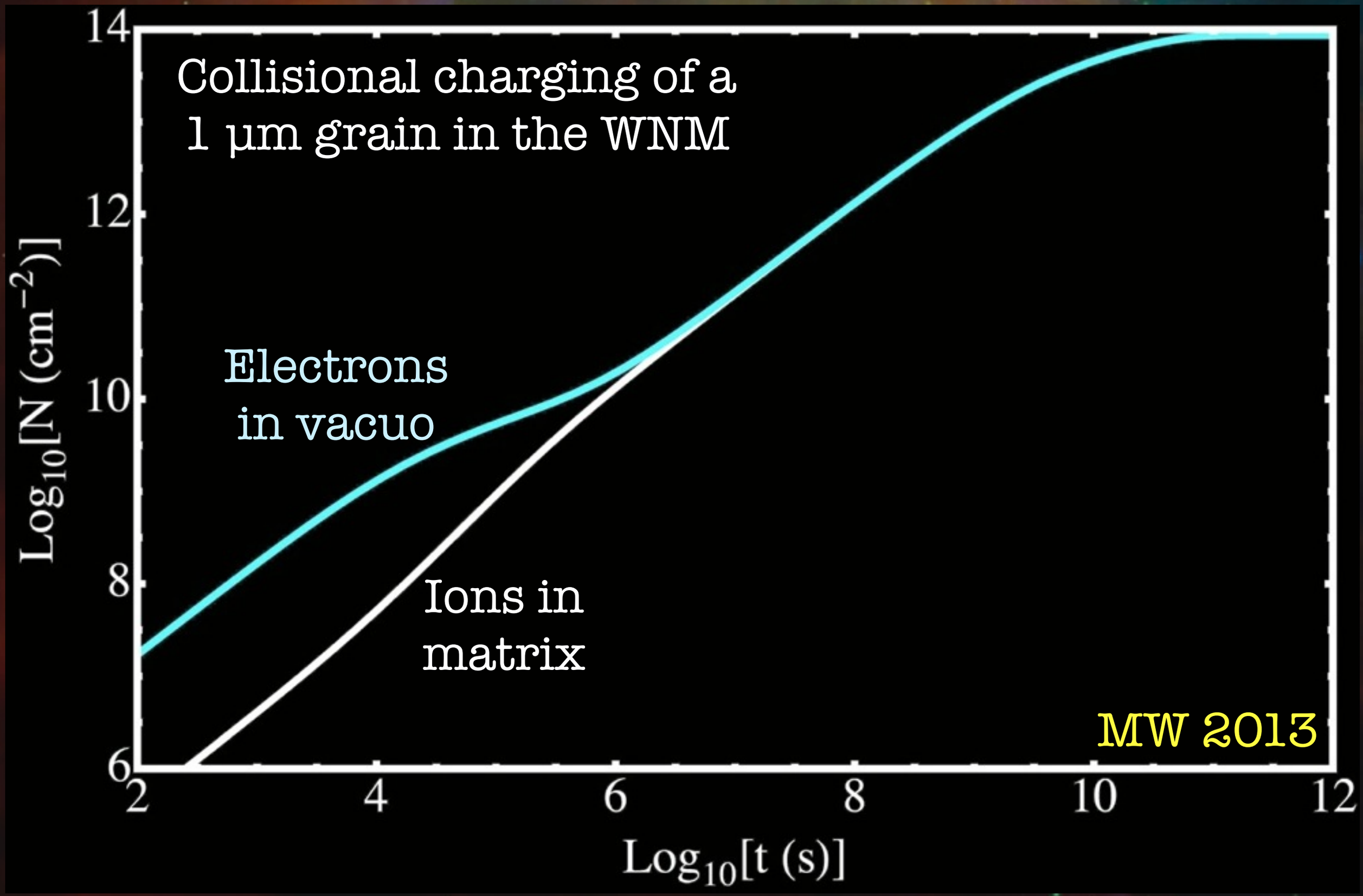
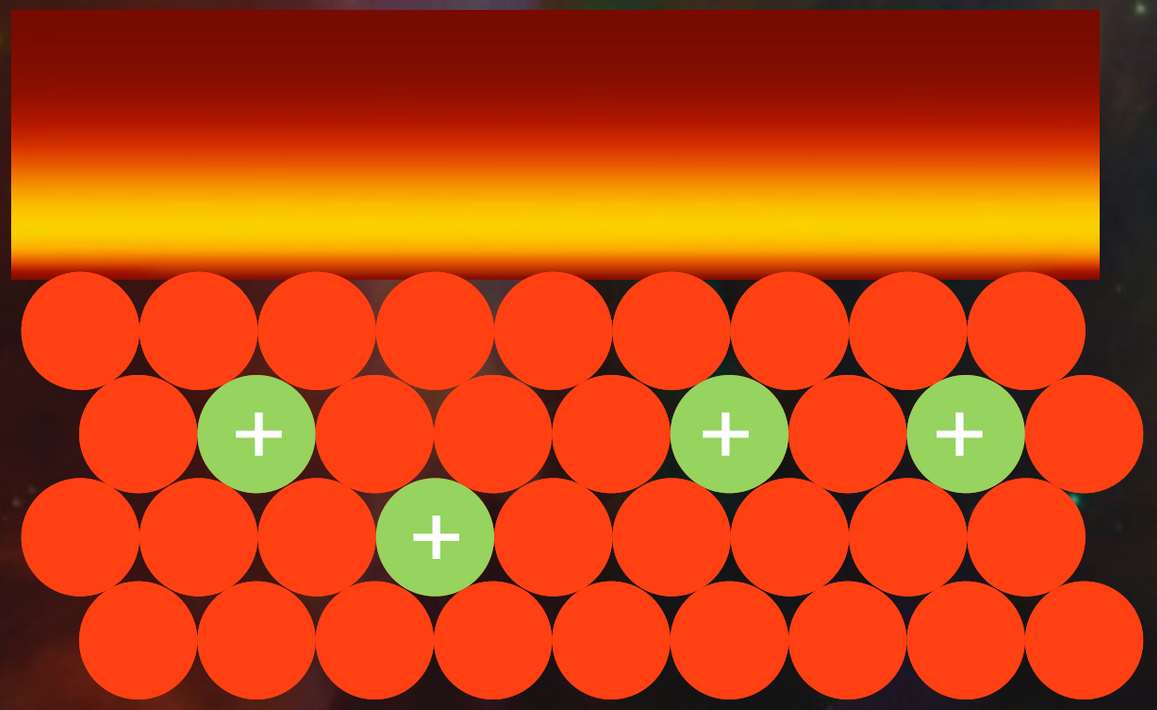

Collisional charging of a
1 μm grain in the WNM
Electrons
in vacuo
Ions in
matrix
MW 2013
$\mathrm{Log_{10}[N\ (cm^{-2})]}$
$\mathrm{Log_{10}[t\ (s)]}$
14
12
10
8
6
2
4
6
8
10
12

Surface layers of H_2 crystal



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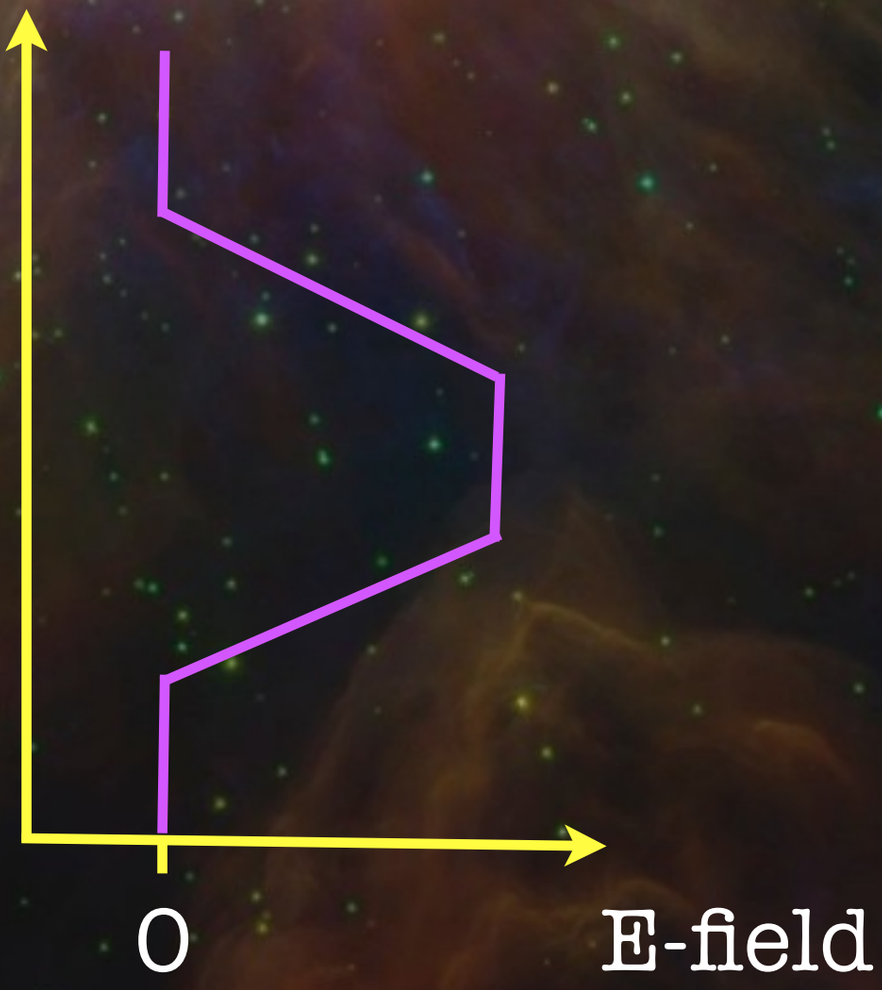

$$U_{pol} = -\alpha E^2 / 2$$
$$\simeq -980\ K$$

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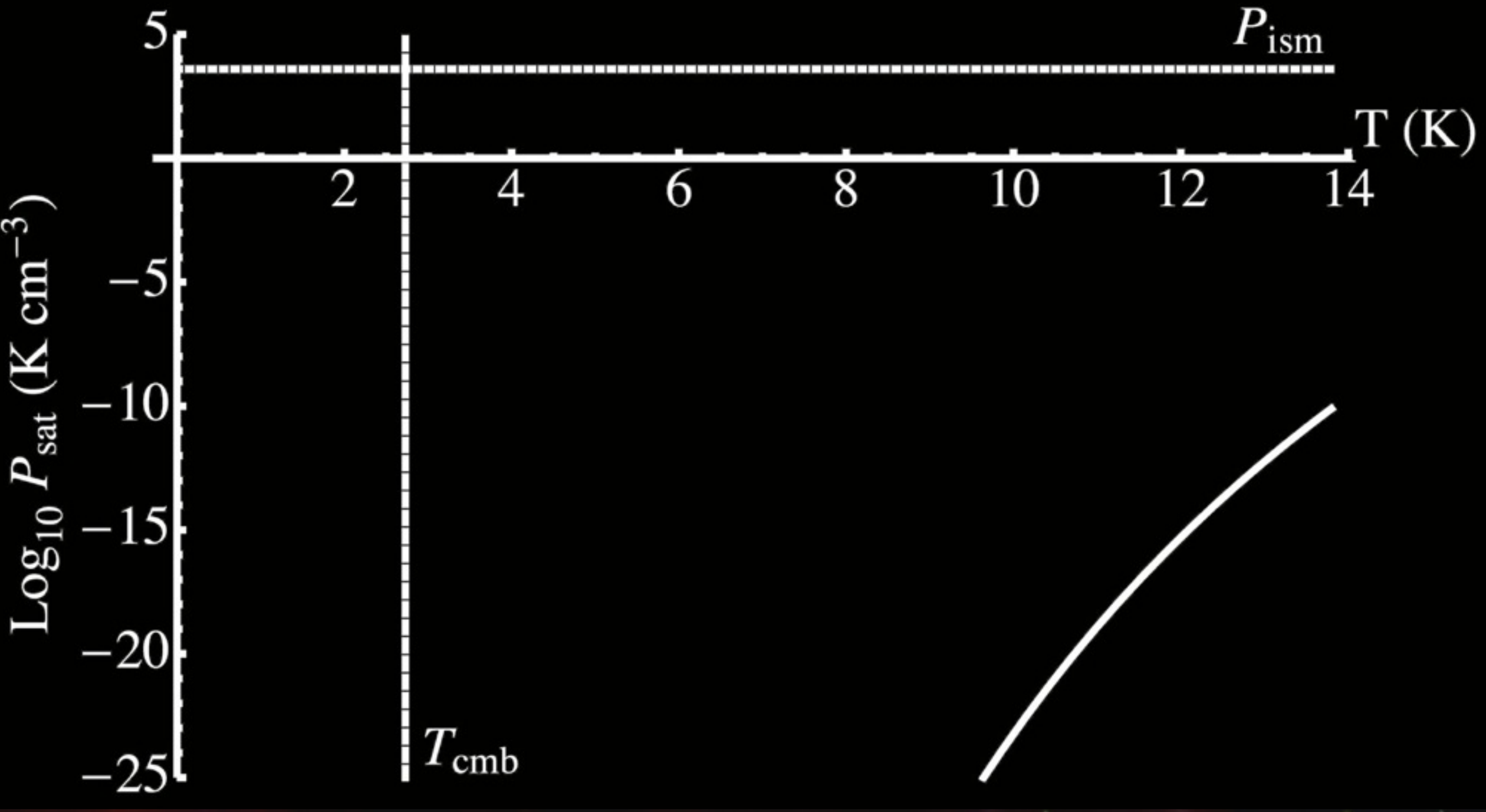
Charged - H_2 phase equilibrium



MW 2013

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H_2 ionisation chemistry

Gas phase: $H_2^+ + H_2 \rightarrow H_3^+ + H$

Solid phase: $H_2^+ + 2\,H_2 \rightarrow H_6^+$

ESR : Miyazaki, Kumada, Kumagai, Shimizu
Theory : Kurosaki & Takayanagi

"New" molecule: H_6^+
No lab spectroscopy yet.
But have ab initio model.

Ab Initio model of H_6^+ vibrations

Leaf Lin,
Andrew Gilbert,
& MW 2011

CCSD + cc-pVTZ

Highly anharmonic :
Include cubic & quartic
Use VCI method

Can only model 5 modes

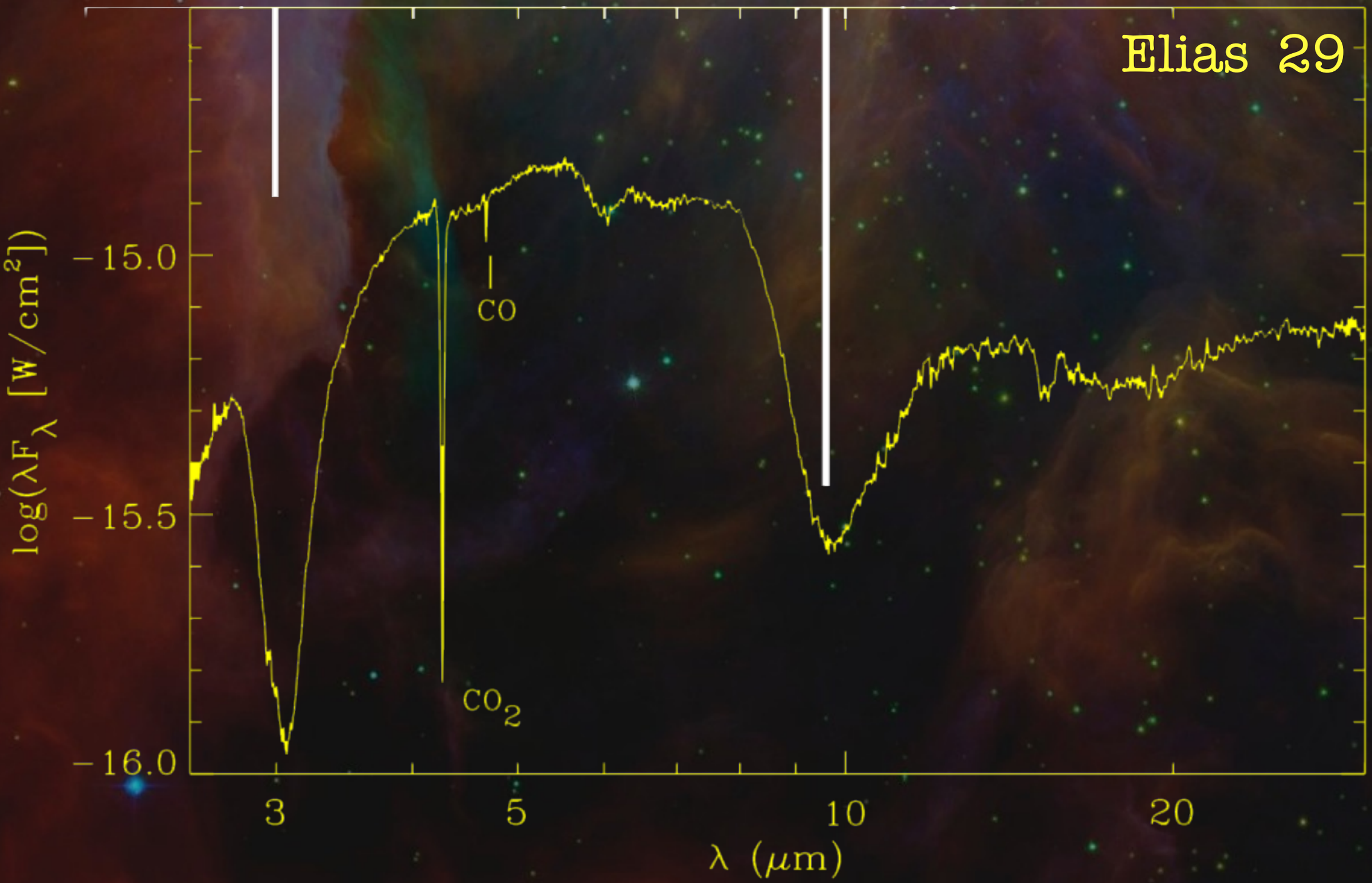
H_6^+ and $(HD)_3^+$
Isotopomers

Dust features in absorption

H_6^+

Boogert et al 2000

Elias 29



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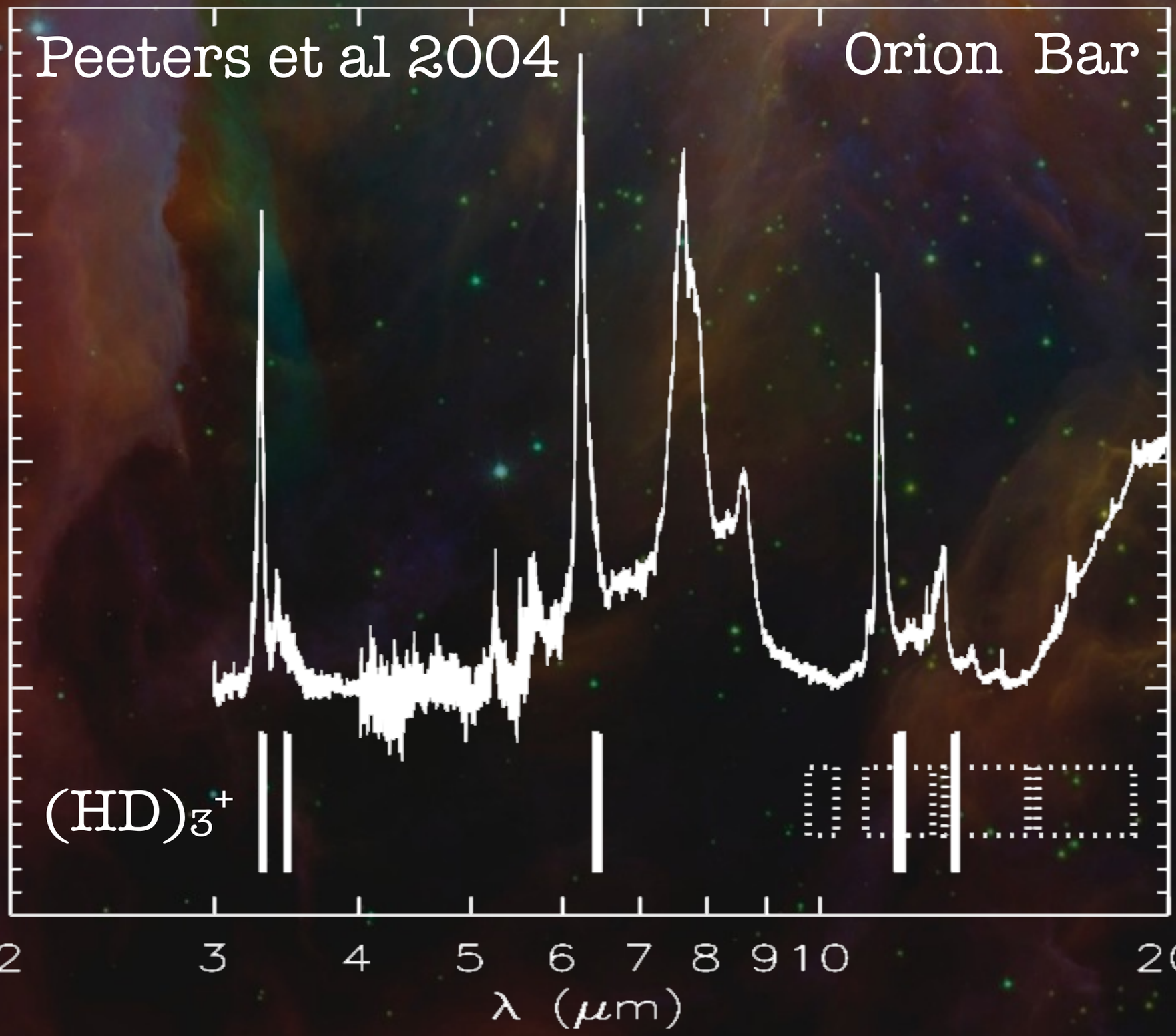
Dust features in emission



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Where does this leave us?

- Astronomy: Solid H_2 not considered since 1970
  - Might be the dominant constituent of ISD
  - Many issues need to be examined:
    extinction curve, IR emission, polarisation ...
- Direct sampling: Solid H_2 never considered ?
  - Might explain large ISD grains
    - Few ISD compositional results to date
      - No calibrations for hypervelocity H_2 particles
    - Sample return signature:
      aerogel tracks with no extant projectile
    - Useful to simulate H_2 grain impacts ?
- Direct sampling could be conclusive