Dust-gas chemistry in AGB outflows

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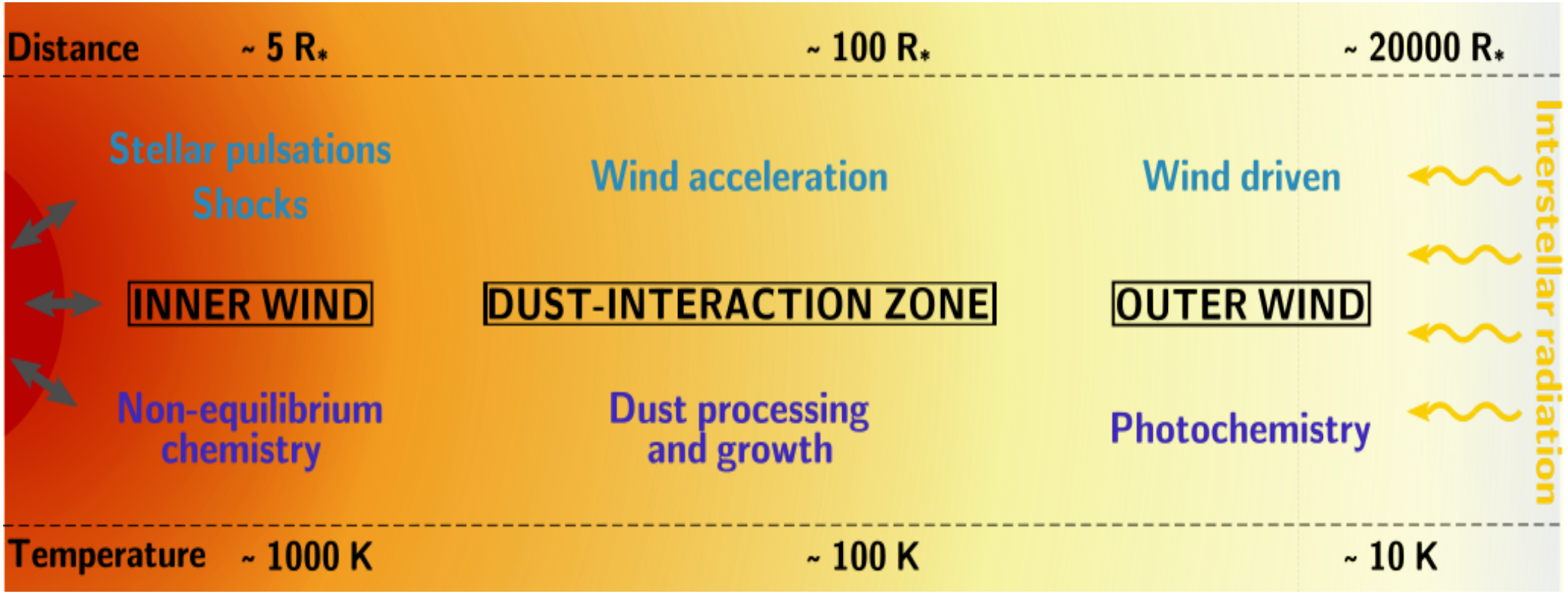
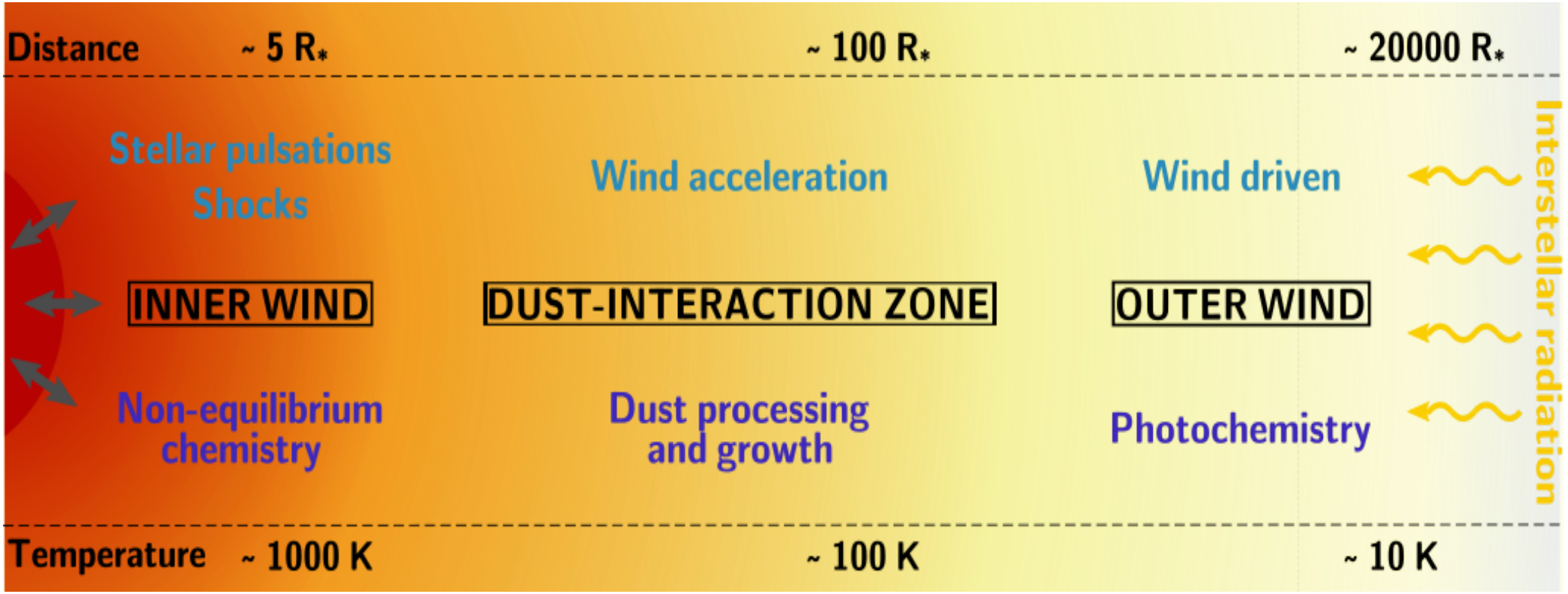
fwo Research Foundation Flanders
Opening new horizons

KU LEUVEN

Circumstellar envelope



Circumstellar envelope

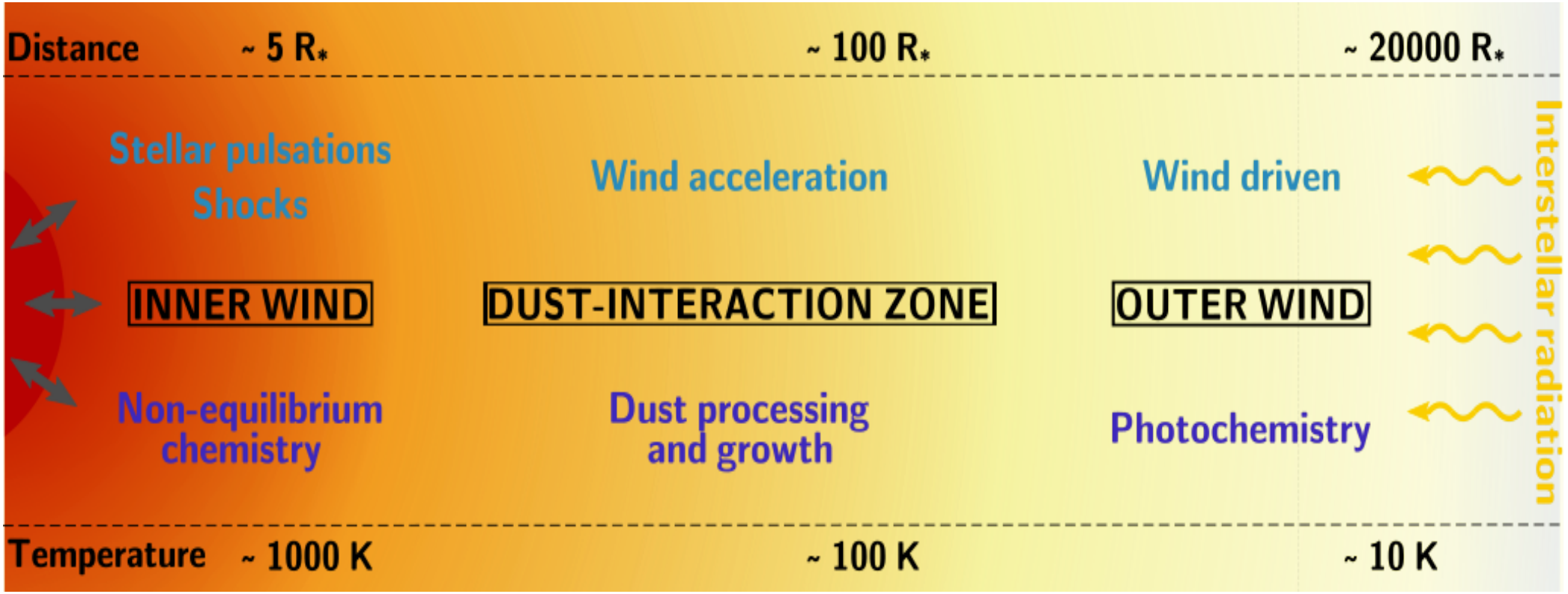


Non-TE chemistry
(e.g., Cherchneff 2006, Gobrecht et al. 2016)

Hydro + chemistry
(e.g., Boulangier+ 2019)

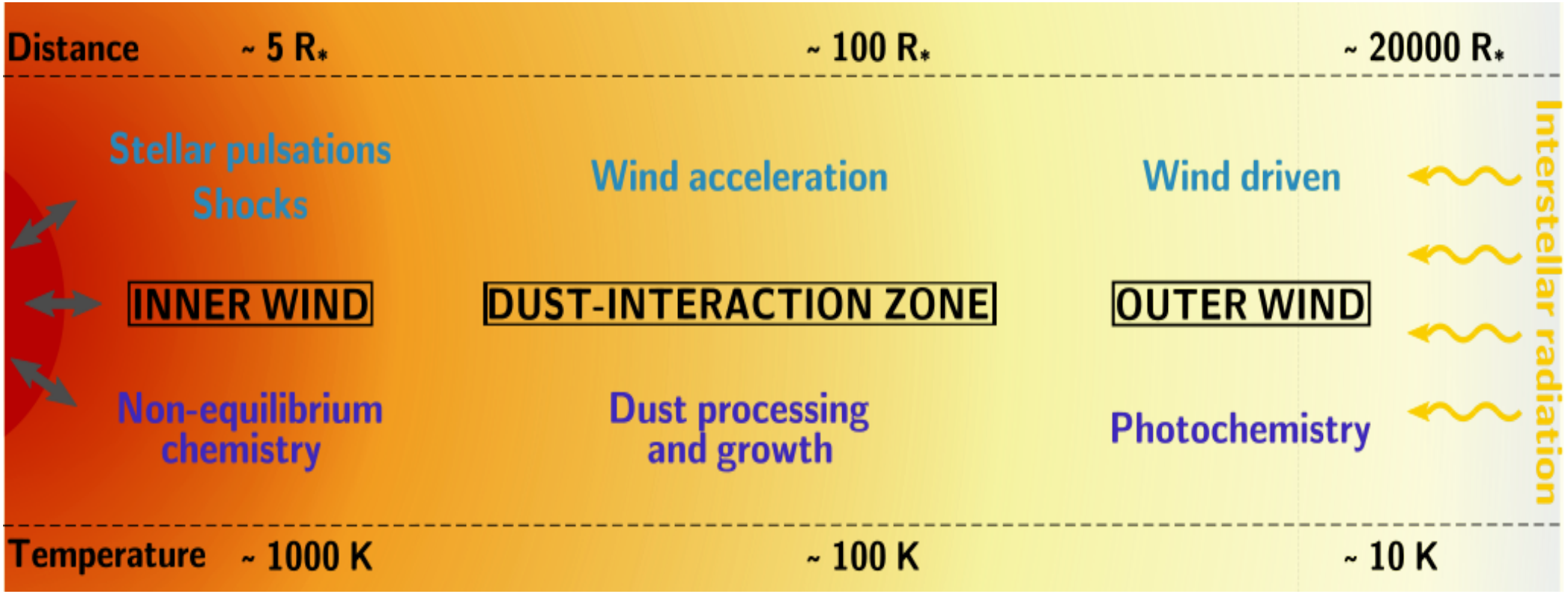
Photon-driven chemistry
(e.g., Millar et al. 2000, Li et al. 2016)

Circumstellar envelope



Decin et al. (2010)
Gonzalez-Delgado et al. (2003)
Massalkhi et al. (2019)
Sylvester et al. (1999)

Circumstellar envelope



Dust-gas interactions + surface chemistry

Van de Sande et al. (subm.)

Dust-gas chemistry

- Following recipes used in other astrochemical labs (Cuppen et al. 2017)

- **Dust-gas interactions**
  - Accretion
  - Thermal desorption
  - Photodesorption
  - Sputtering

H_2, He, CO, N_2
(Tielens et al. 1994)

- **Grain surface chemistry**
  - Langmuir-Hinshelwood
  - Eley-Rideal

    - Hydrogenation
    - Atom addition
    - Radical recombination

Description of the dust

- **Dust-grain size distribution** (Mathis et al. 1977)

$$\frac{\mathrm{d}n}{\mathrm{d}a} \sim a^{-3.5}$$

- **Temperature profile**
  - Radiative transfer modelling (MCMax)
  - Single composition of the dust
    - O-rich: melilite, silicate without Fe, silicate with Fe
    - C-rich: amorphous carbon (DHS, CDE), SiC

- **Drift velocity** between dust and gas

Dust-gas chemistry

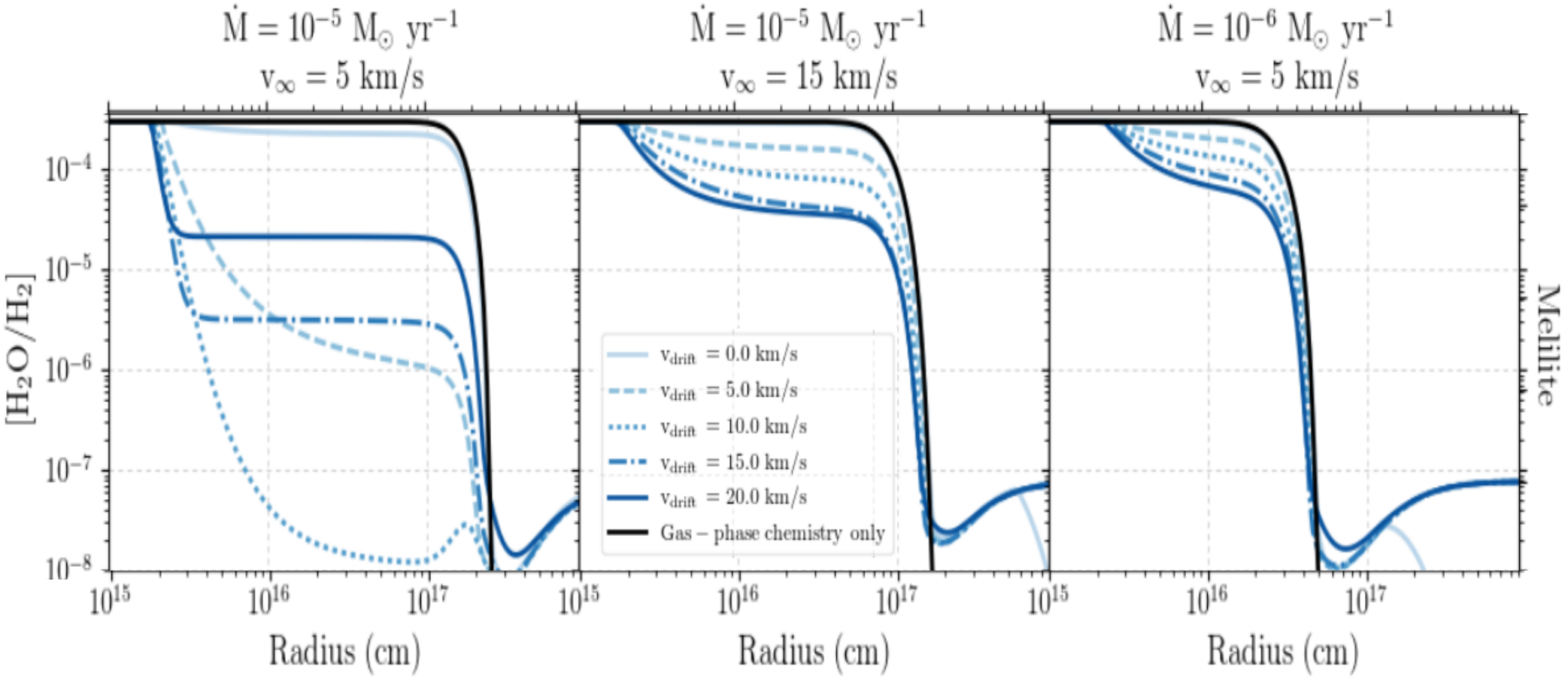
1) Outflow density

2) Dust temperature

3) Initial composition of the outflow

4) Drift velocity

Effect on gas phase: parents



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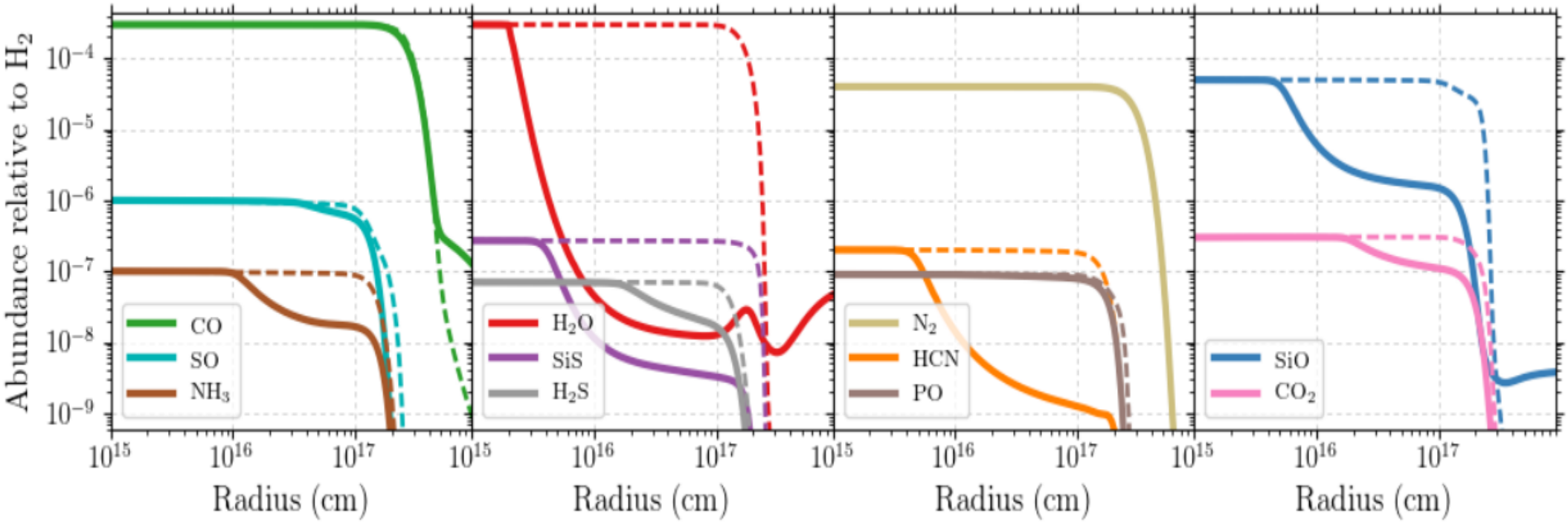
Effect on gas phase: parents



O-rich outflow

Highest outflow density

v_{drift} = 10 km/s

Coldest dust (melilite)

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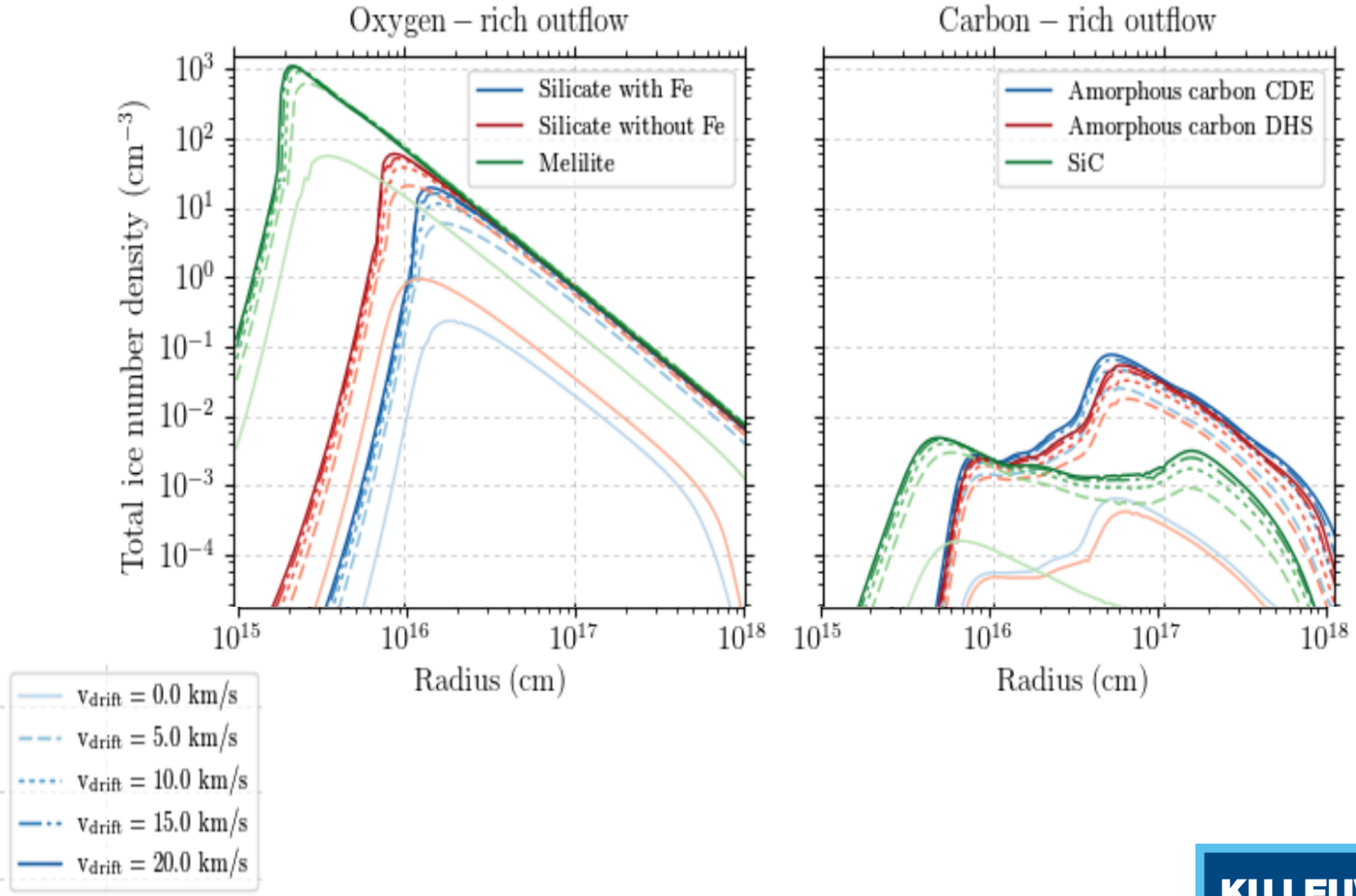
Effect on gas phase: ice mantles



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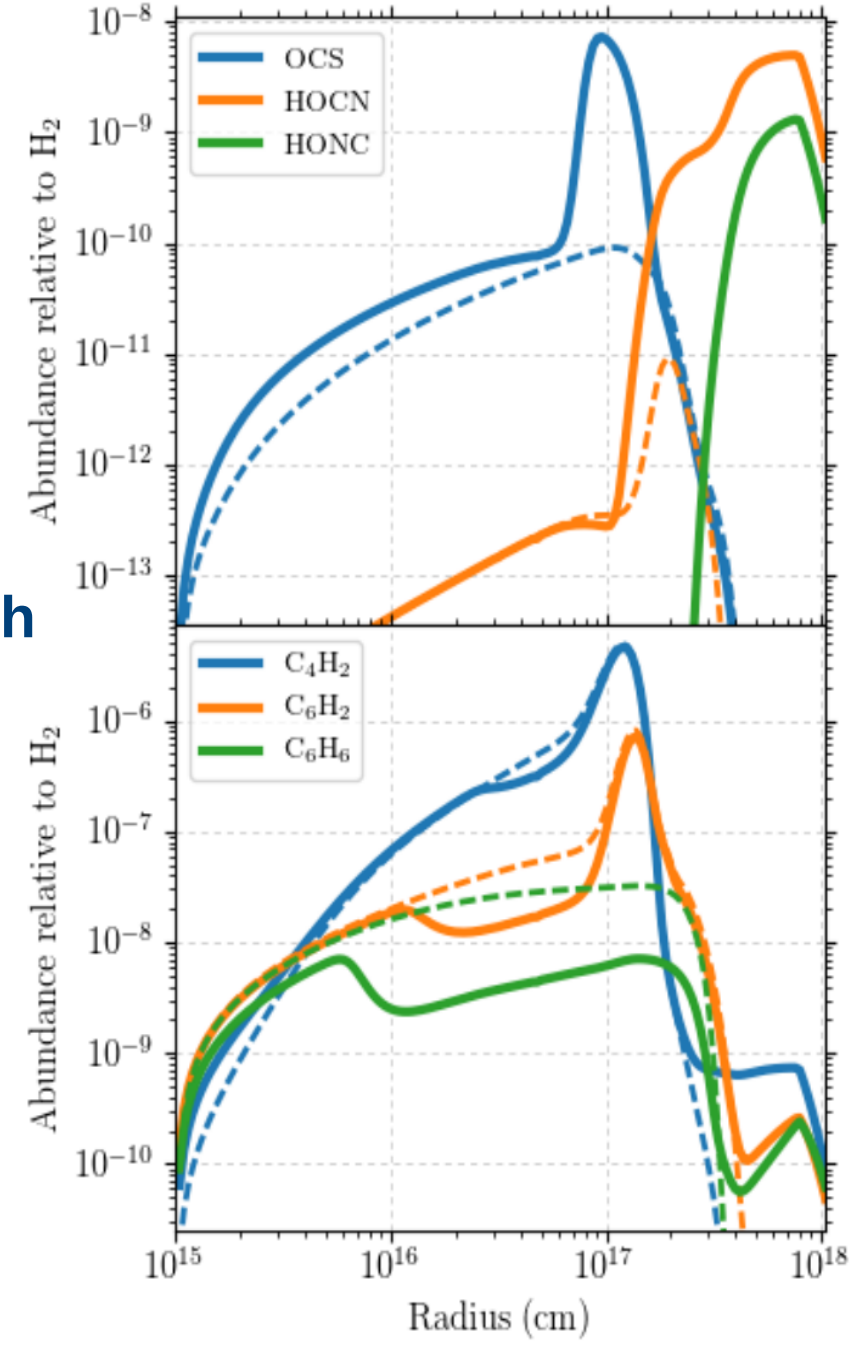
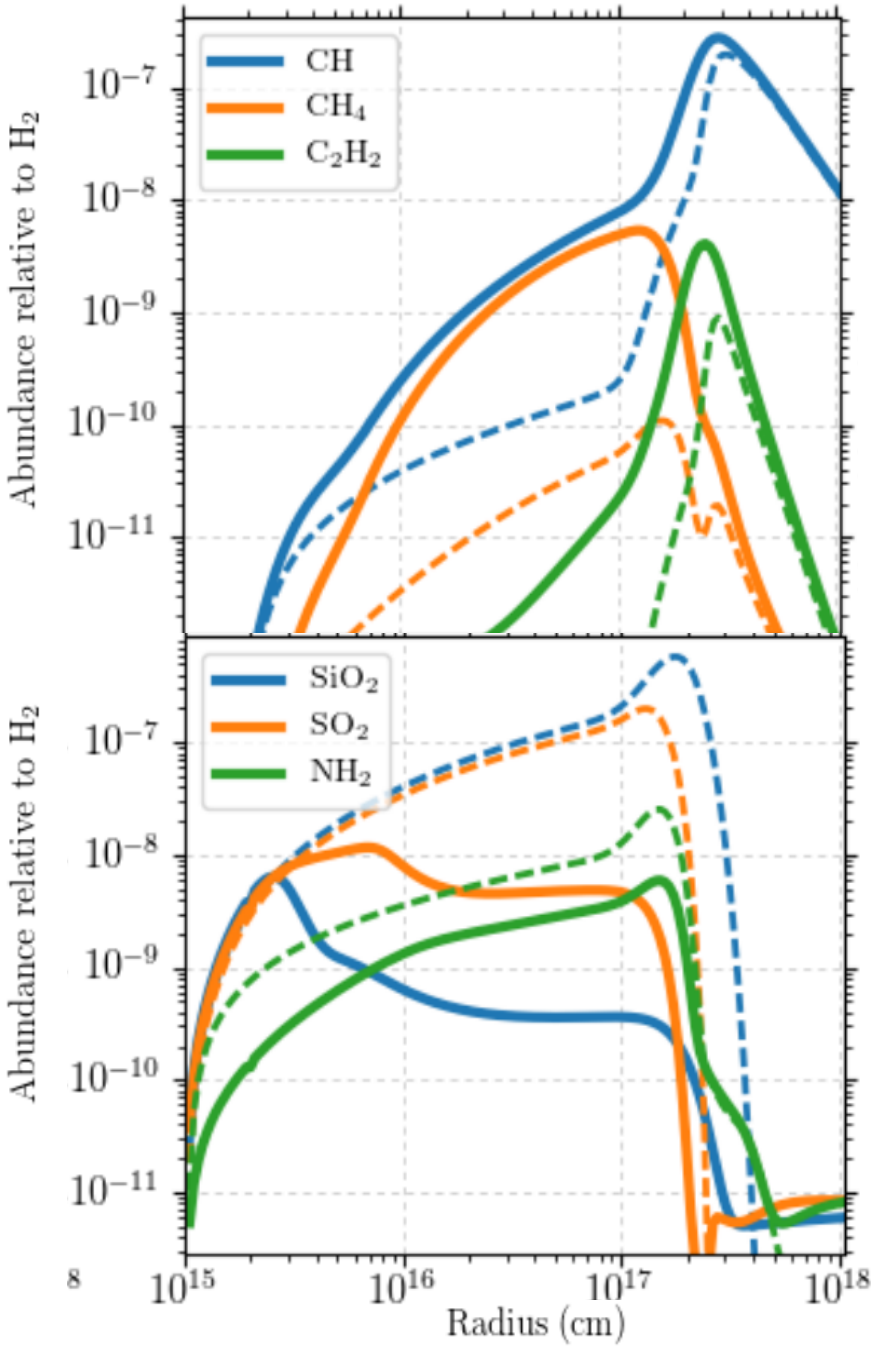
Effect on gas phase: daughters

C-rich



O-rich



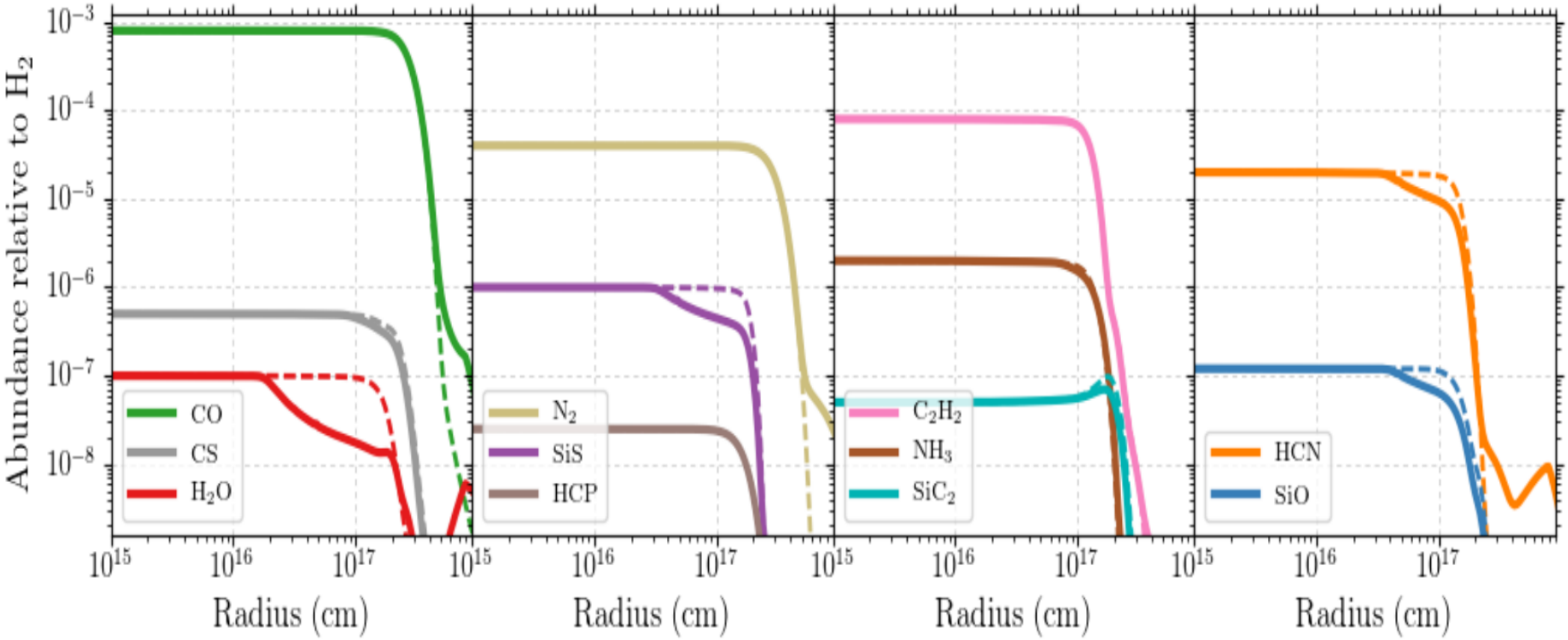
Conclusions

- **Dust-gas chemistry can impact gas phase**
  - Depletion of parent and daughter species
  - Formation of daughter species

1) Density of the outflow
2) Dust temperature
3) Initial composition
4) Drift velocity

- **Grain size distribution**
- **Ice composition**

Effect on gas phase: depletion

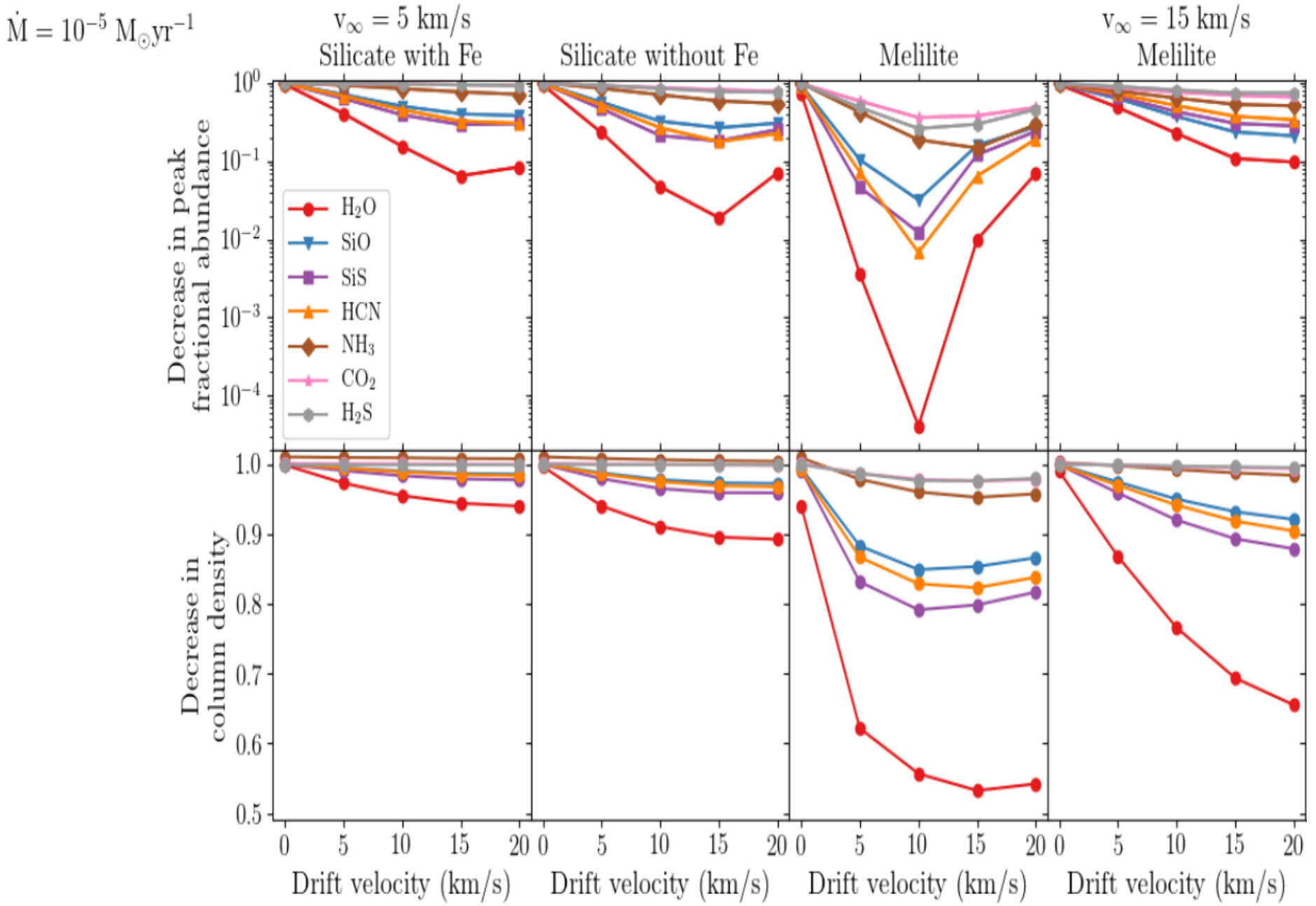


C-rich outflow

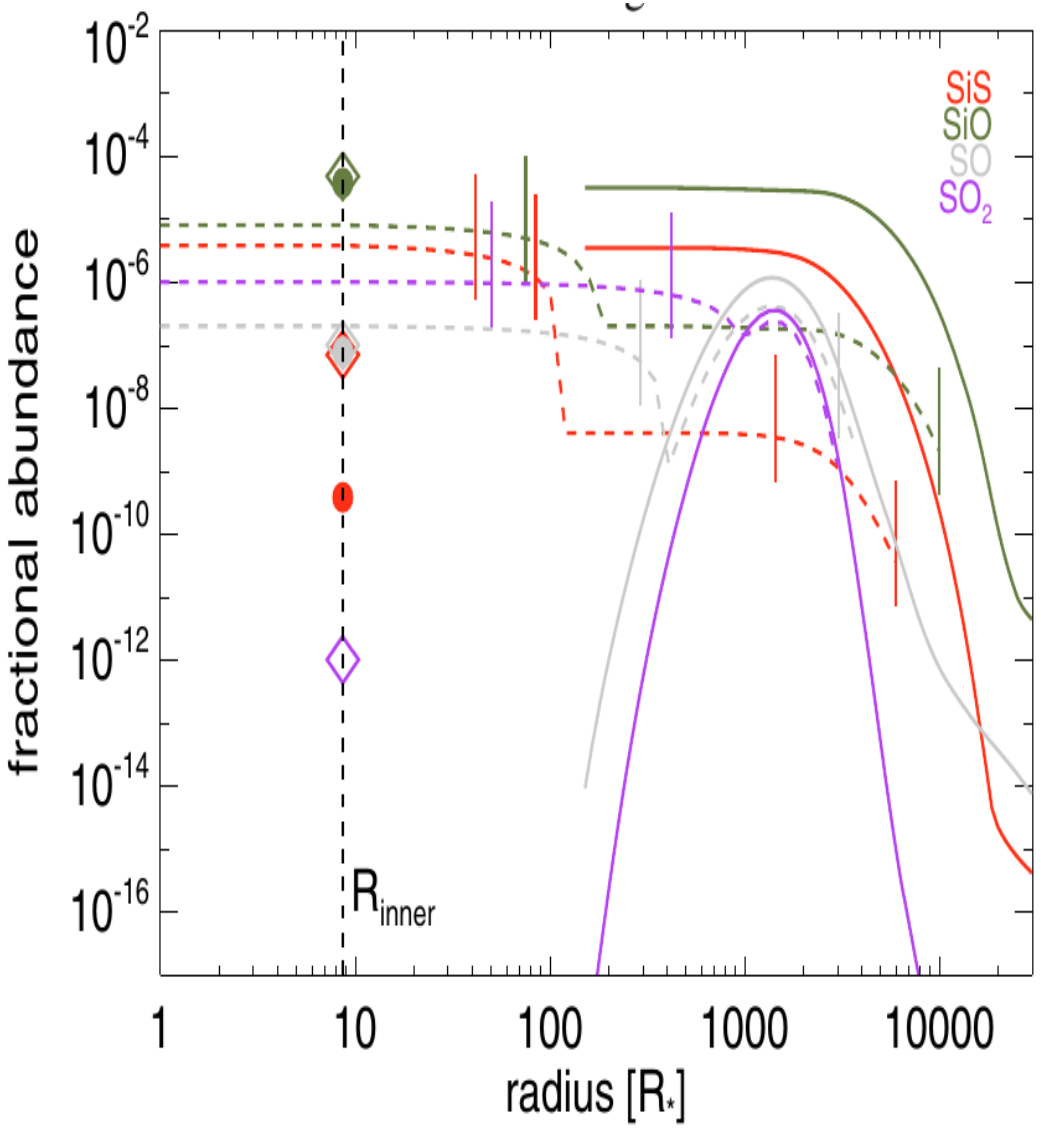
Highest outflow density, v_{drift} = 10 km/s

CDE amorphous carbon

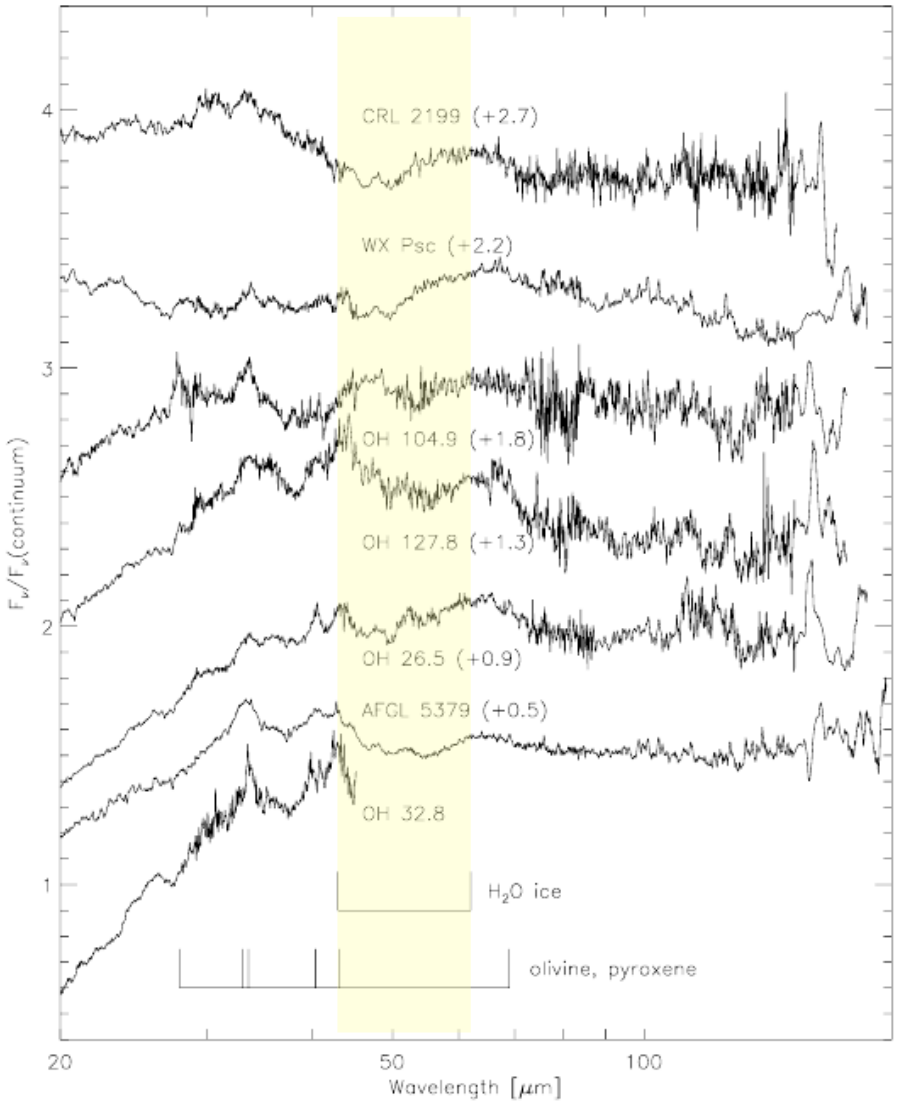
Effect on gas phase: depletion



Observations: depletion

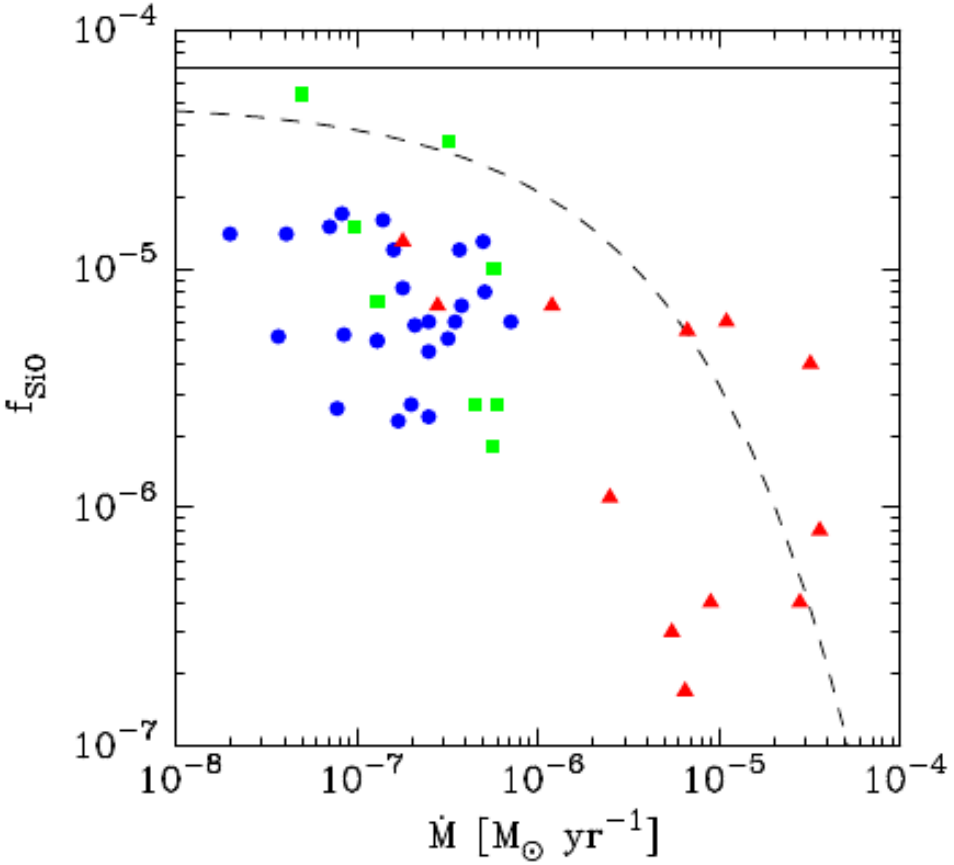


SiO and **SiS** in IK Tau
(Decin et al. 2010)

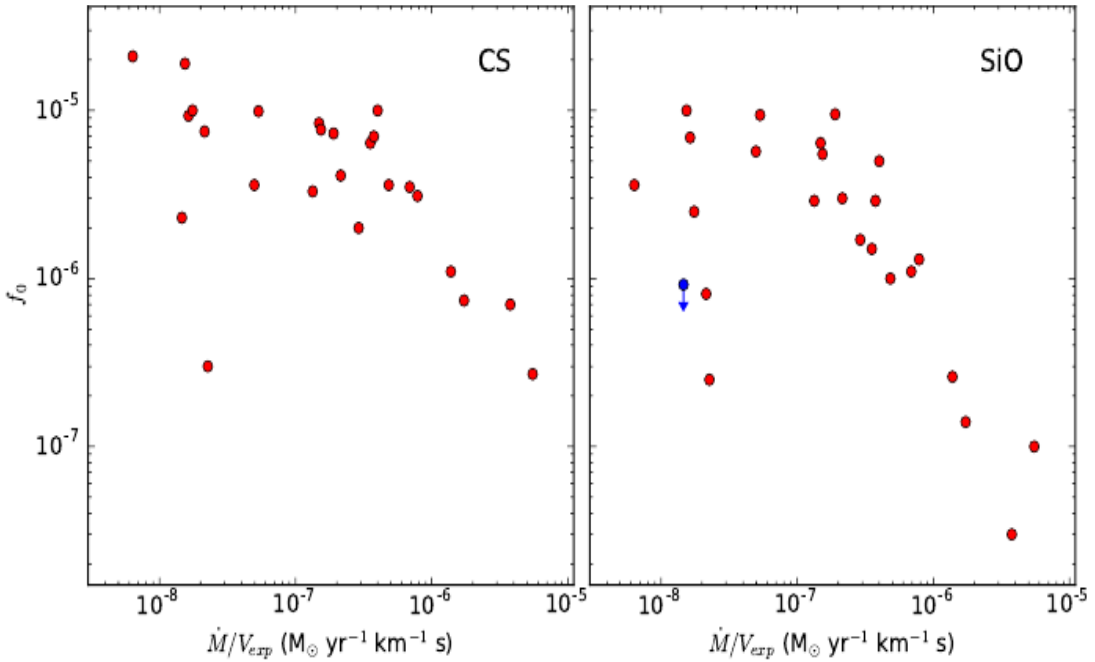


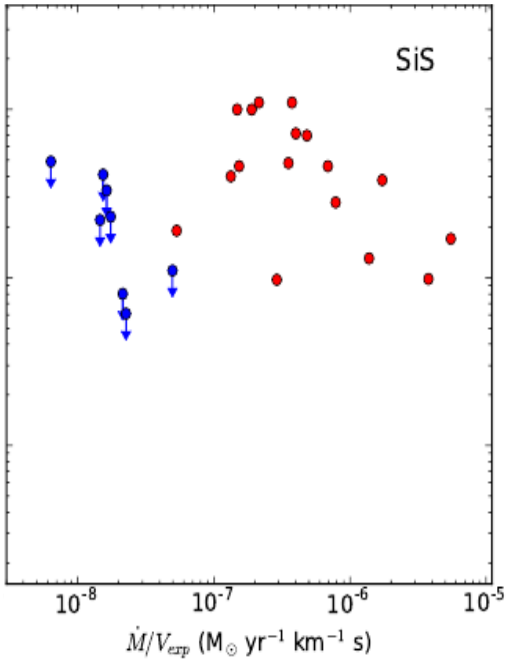
H_2O depletion in OH/IR stars
(Sylvester et al. 1999)

Observational trends with outflow density



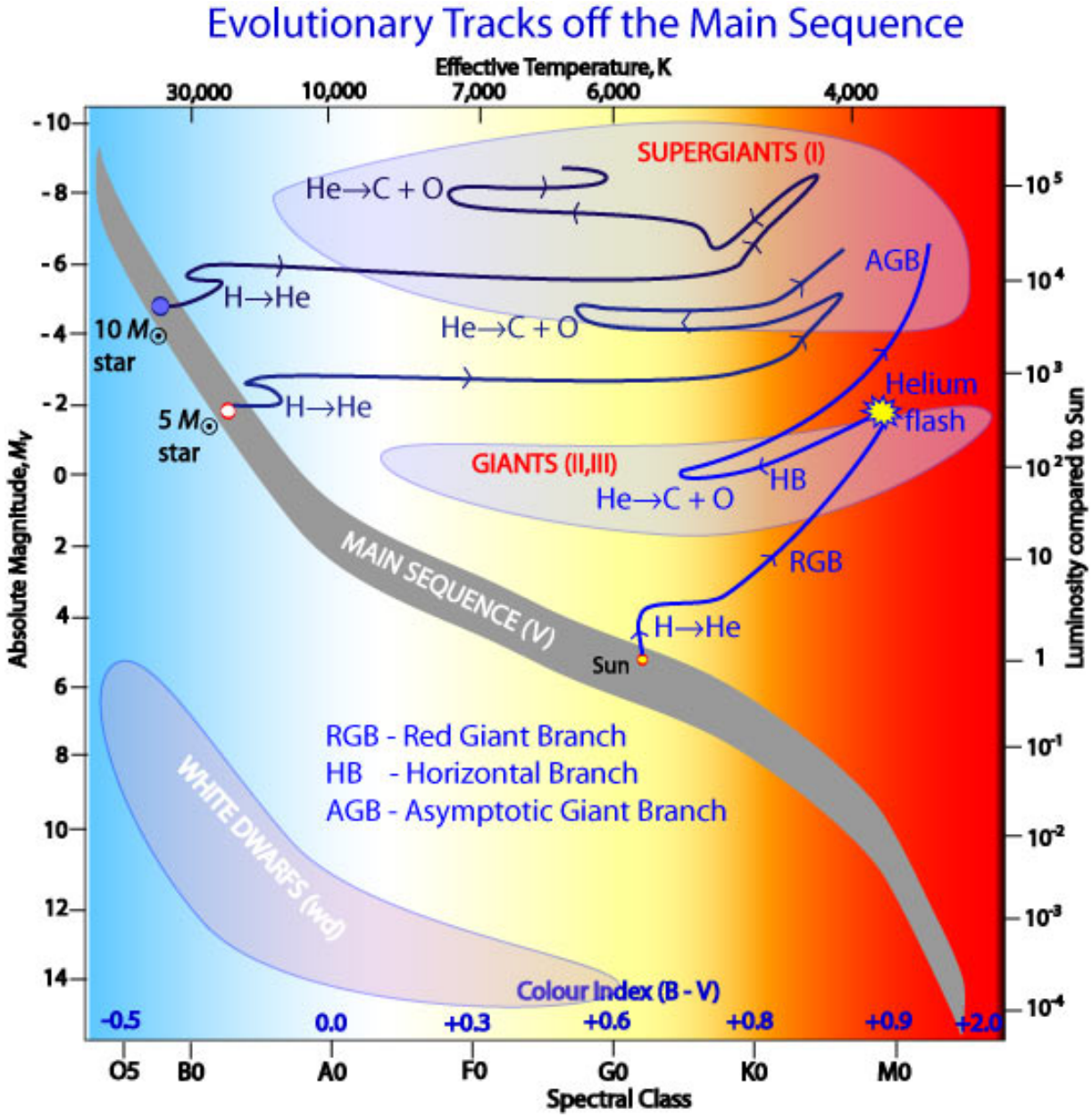
SiO depletion in O-rich stars
Gonzalez-Delgado et al. (2003)





CS, SiO, SiS depletion
in C-rich stars
Massalkhi et al. (2019)

Asymptotic Giant Branch stars



From https://www.cpp.edu/~pbsiegel/phy303/ch13.html