



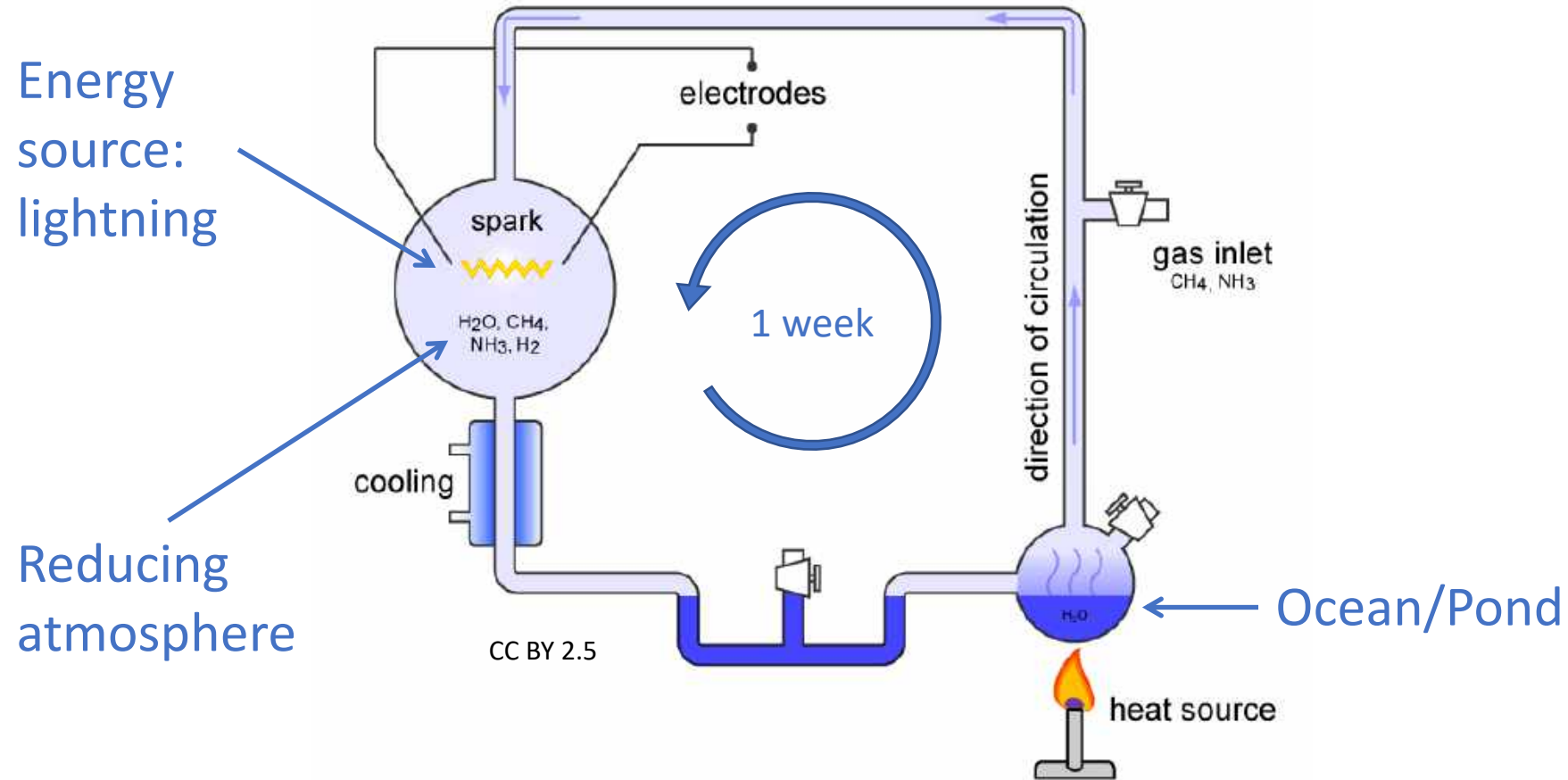
University of
St Andrews

Quantifying lightning as source of prebiotic molecules

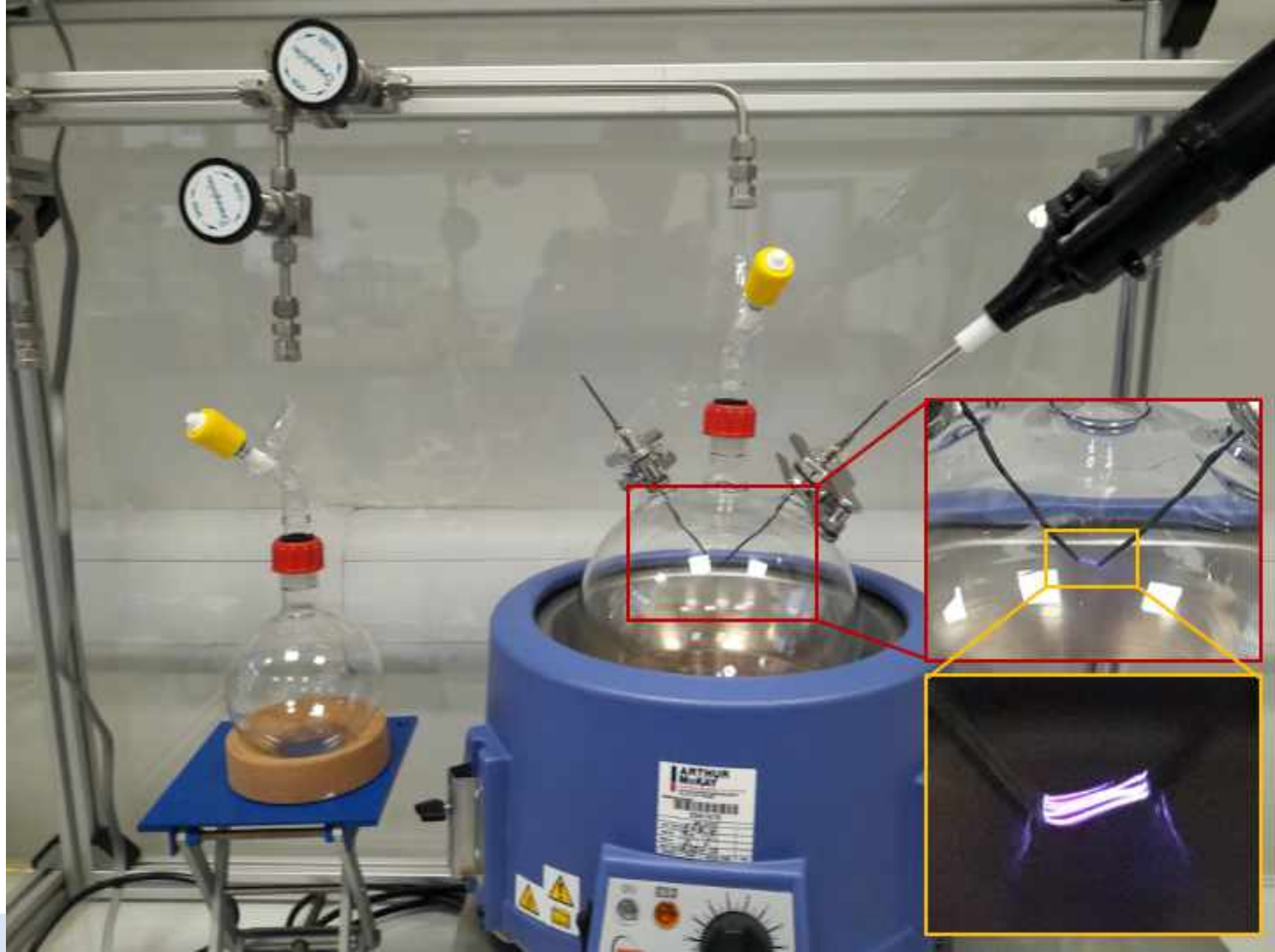
Patrick Barth (He/Him)
School of Physics and Astronomy
School of Earth and Environmental Sciences
Supervisor: Christiane Helling & Eva Stüeken

Novo Nordisk Meeting
24th July 2020

Miller-Urey experiment (1952)

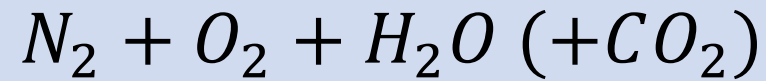


➔ More than 20 different amino acids produced

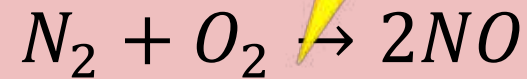


Nitrogen Fixation:

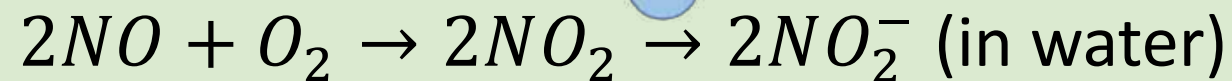
Start with:



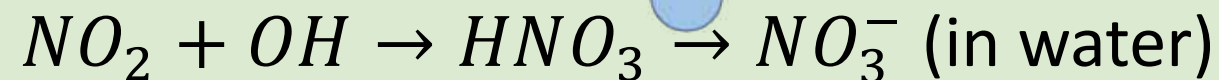
Nitric oxide:



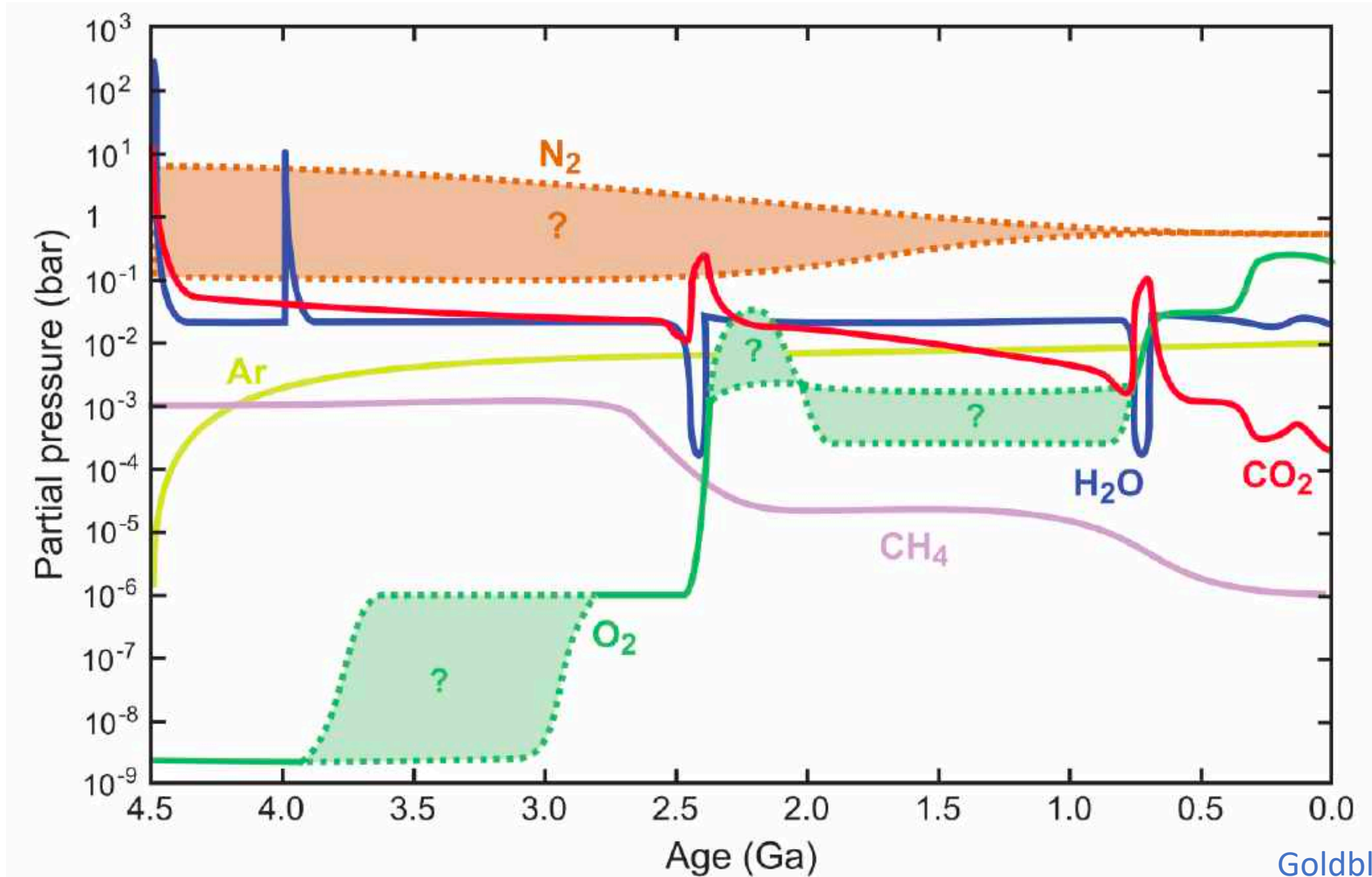
Nitrite:



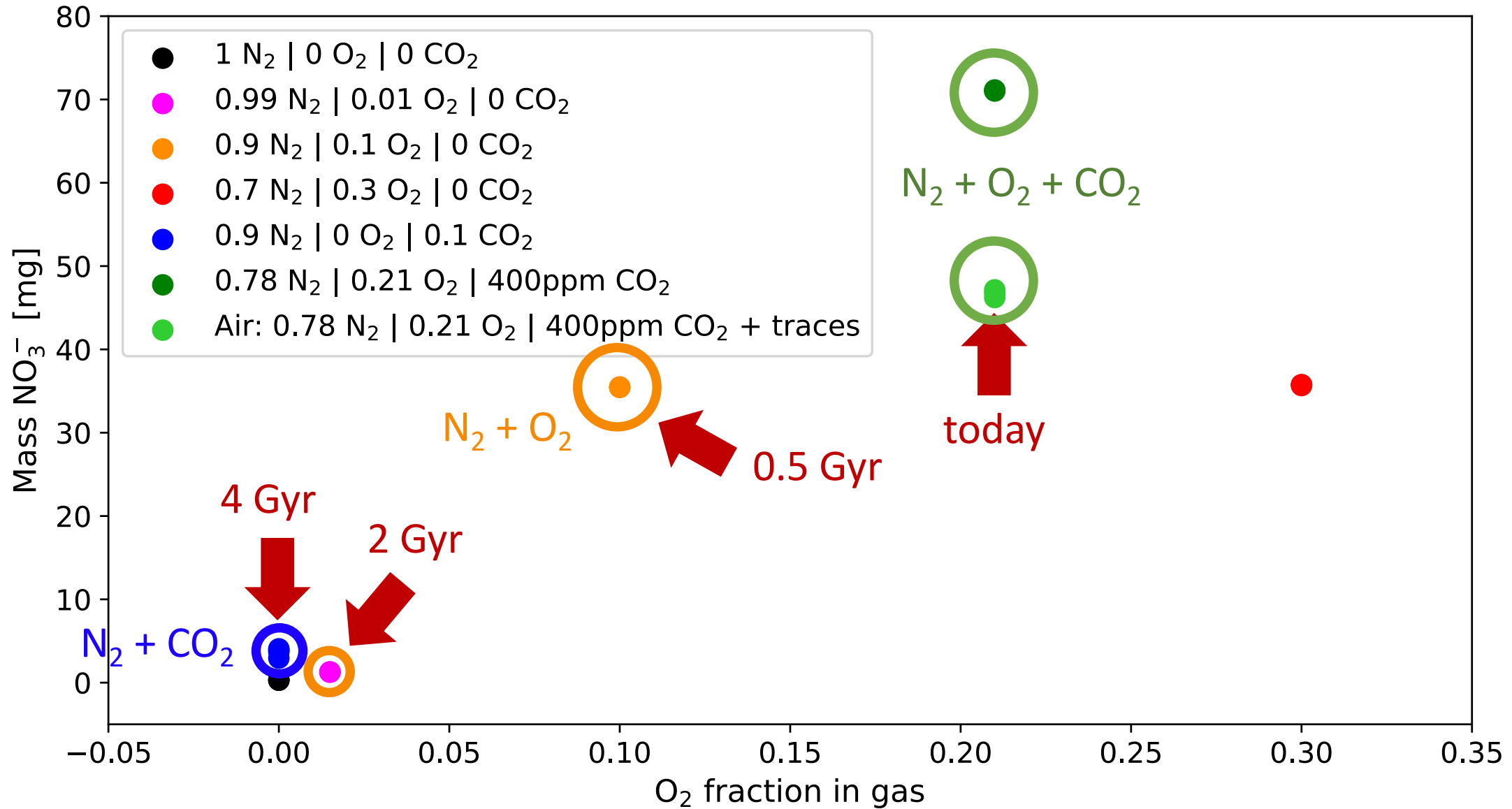
Nitrate:



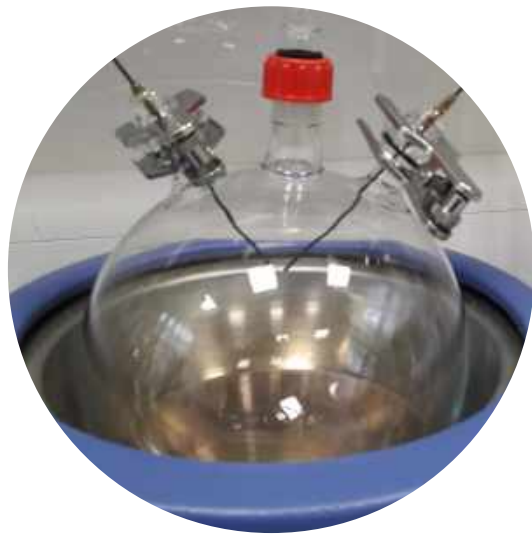
History of Earth's atmosphere



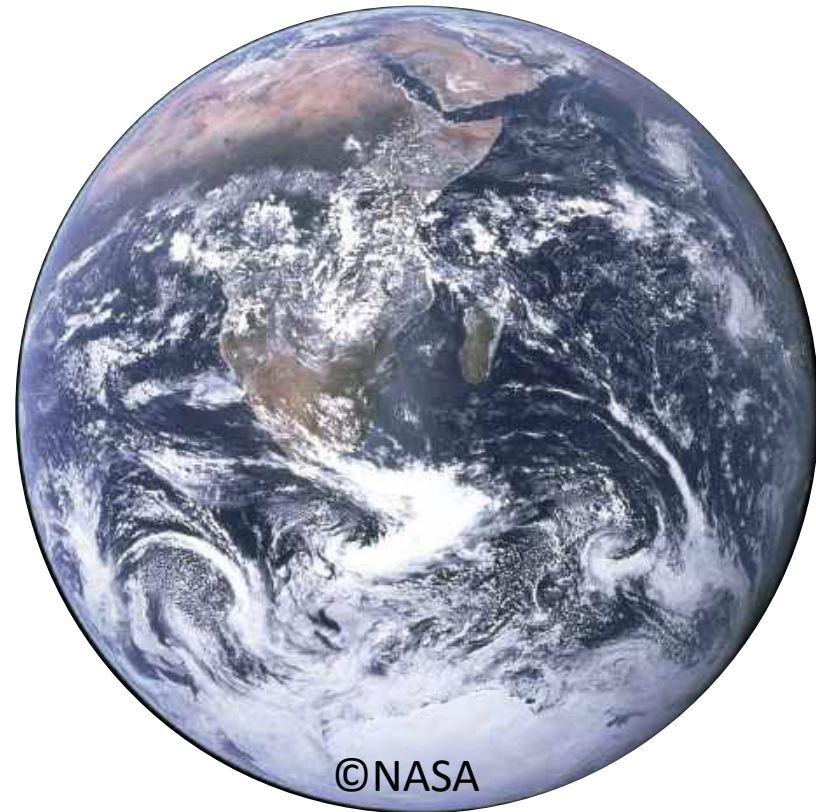
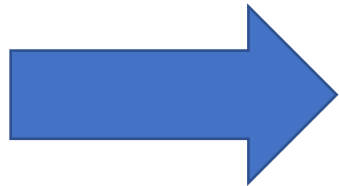
Nitrate production during history of Earth's atmosphere



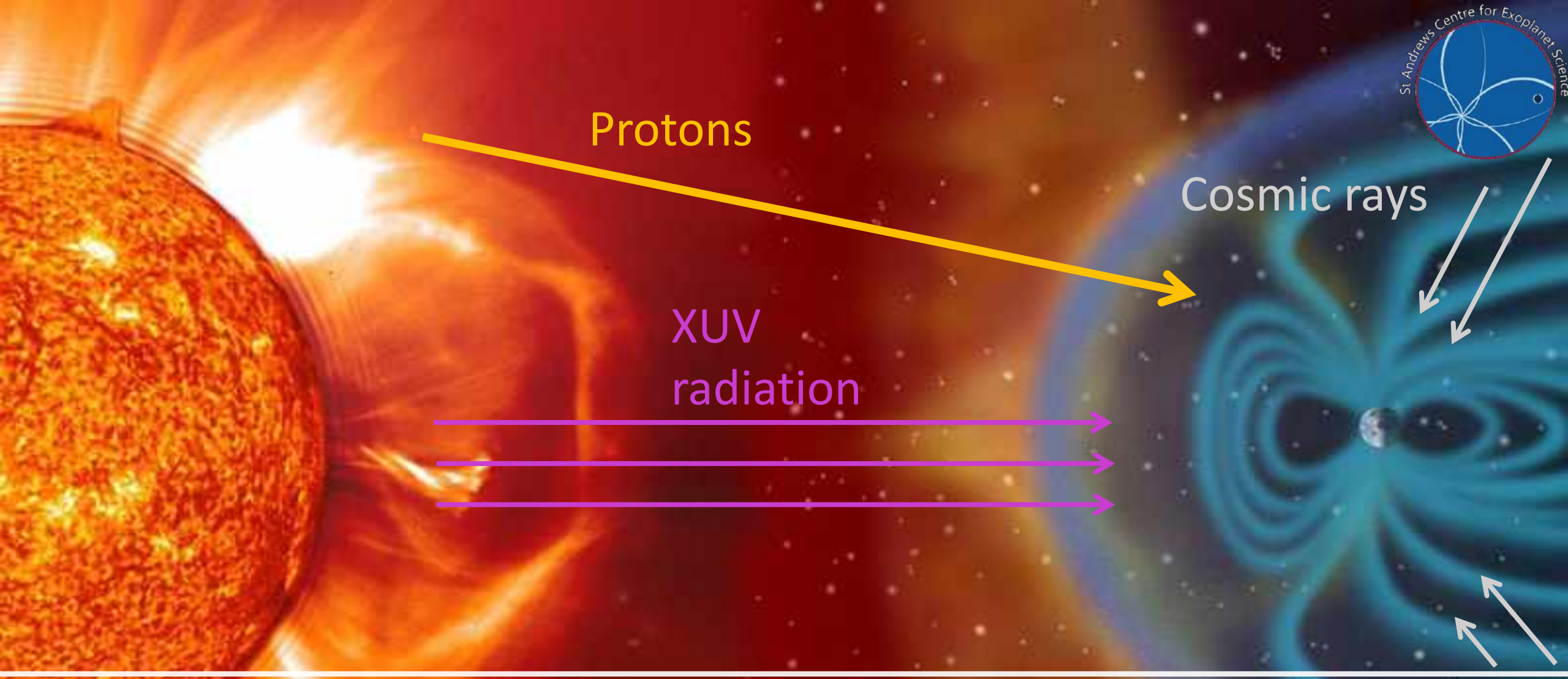
Problem: Scale



~ 20 cm



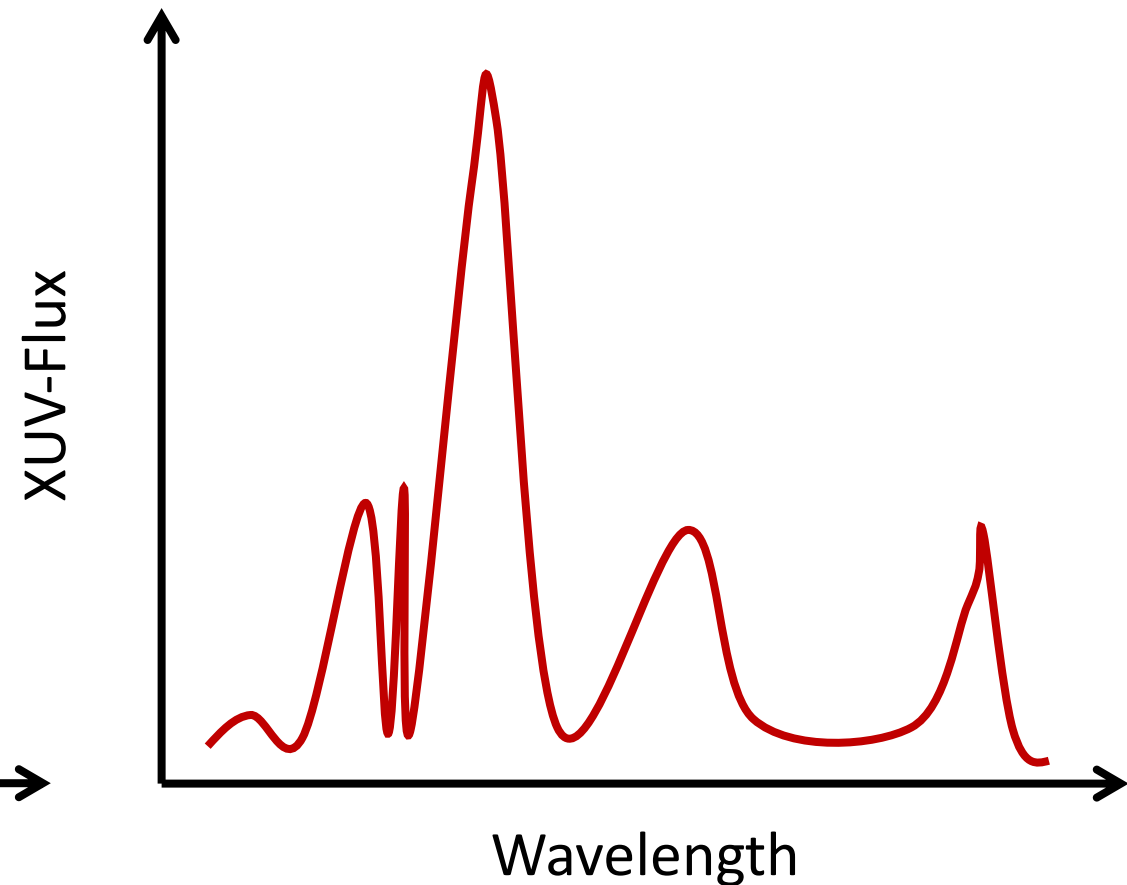
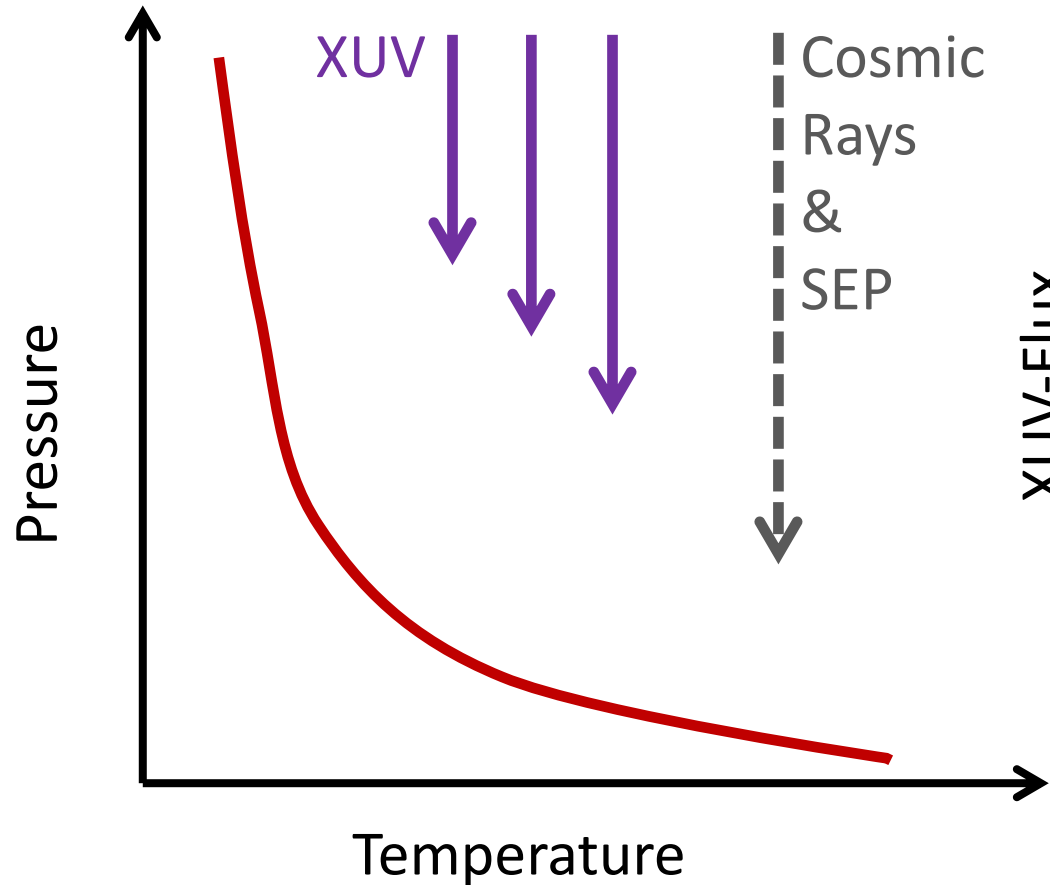
~ 12,000 km



High-energy radiation

STAND2019 & ARGO

Rimmer & Helling 2016

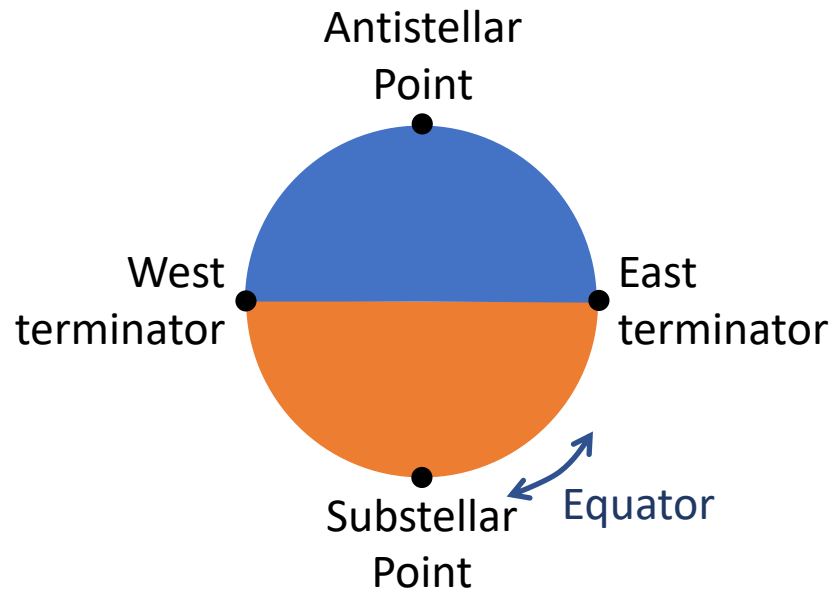


Atmospheric C/H/N/O chemistry
Complete up to 2C, 6H, 2N, 3O

XUV = X-Ray + UV radiation
SEP = Stellar Energetic Particles

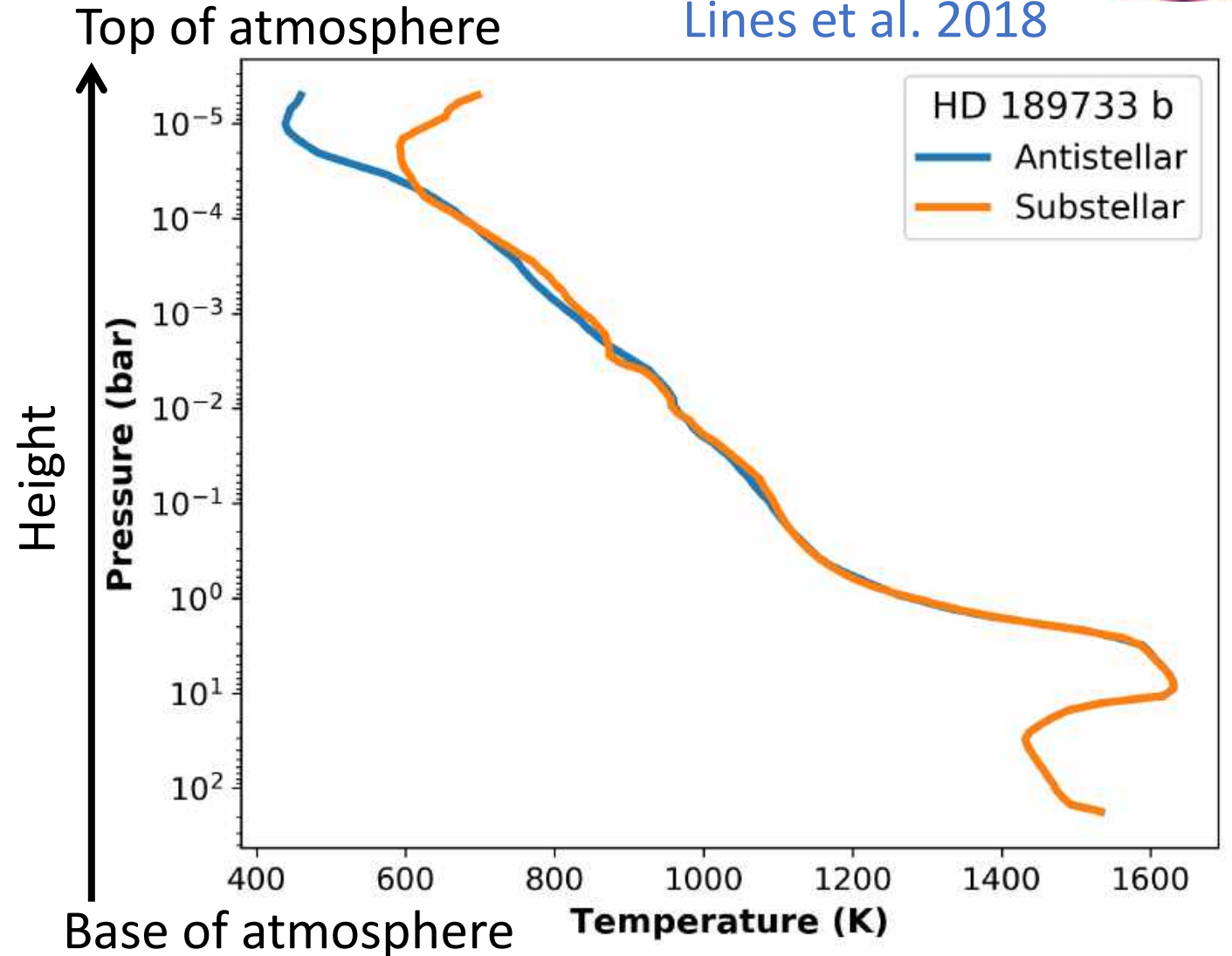
The Planet: HD 189733 b

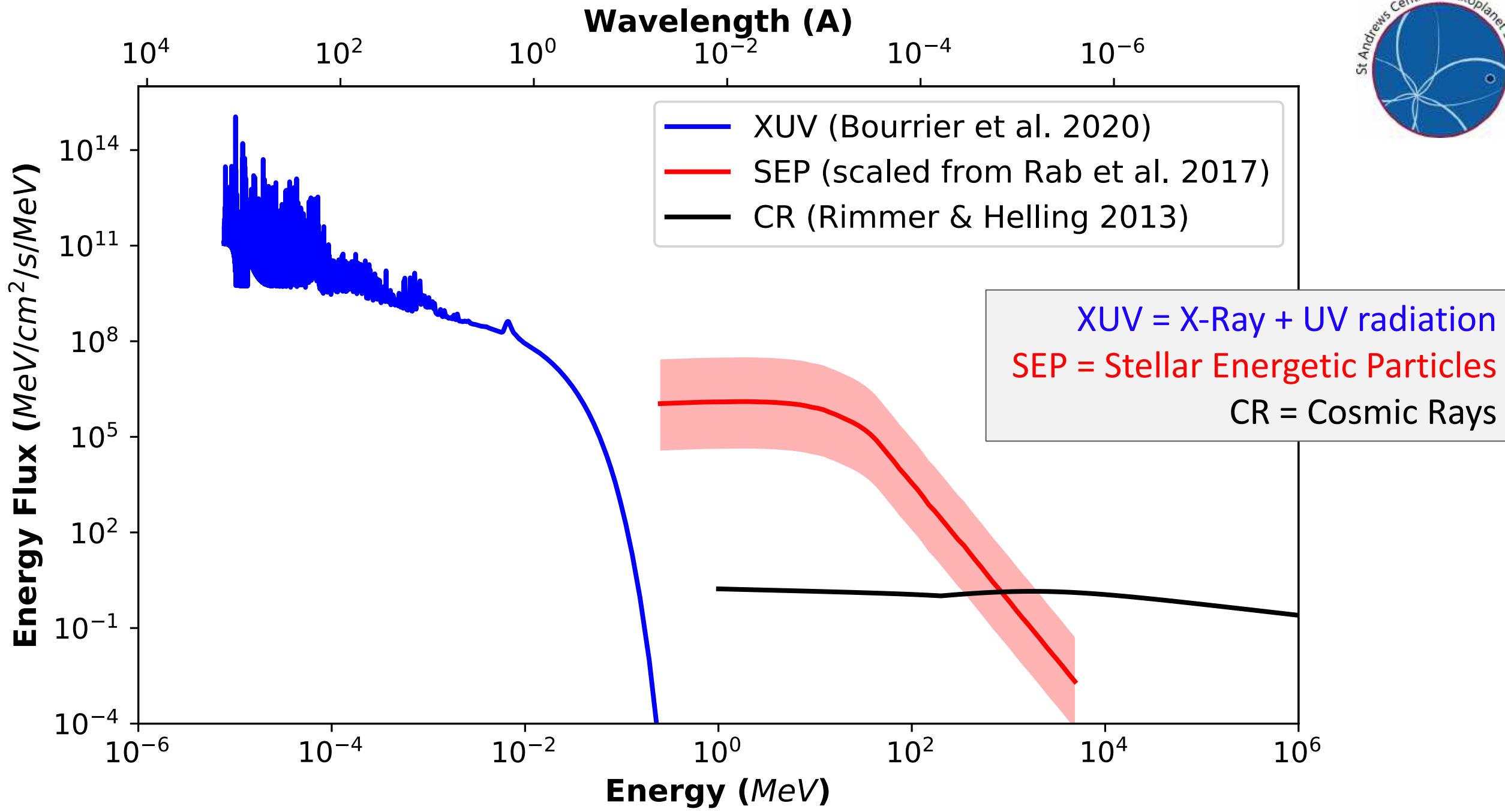
Atmospheric profiles from
3D Met Office Unified Model



Star: HD189733

Lines et al. 2018





Substellar
point

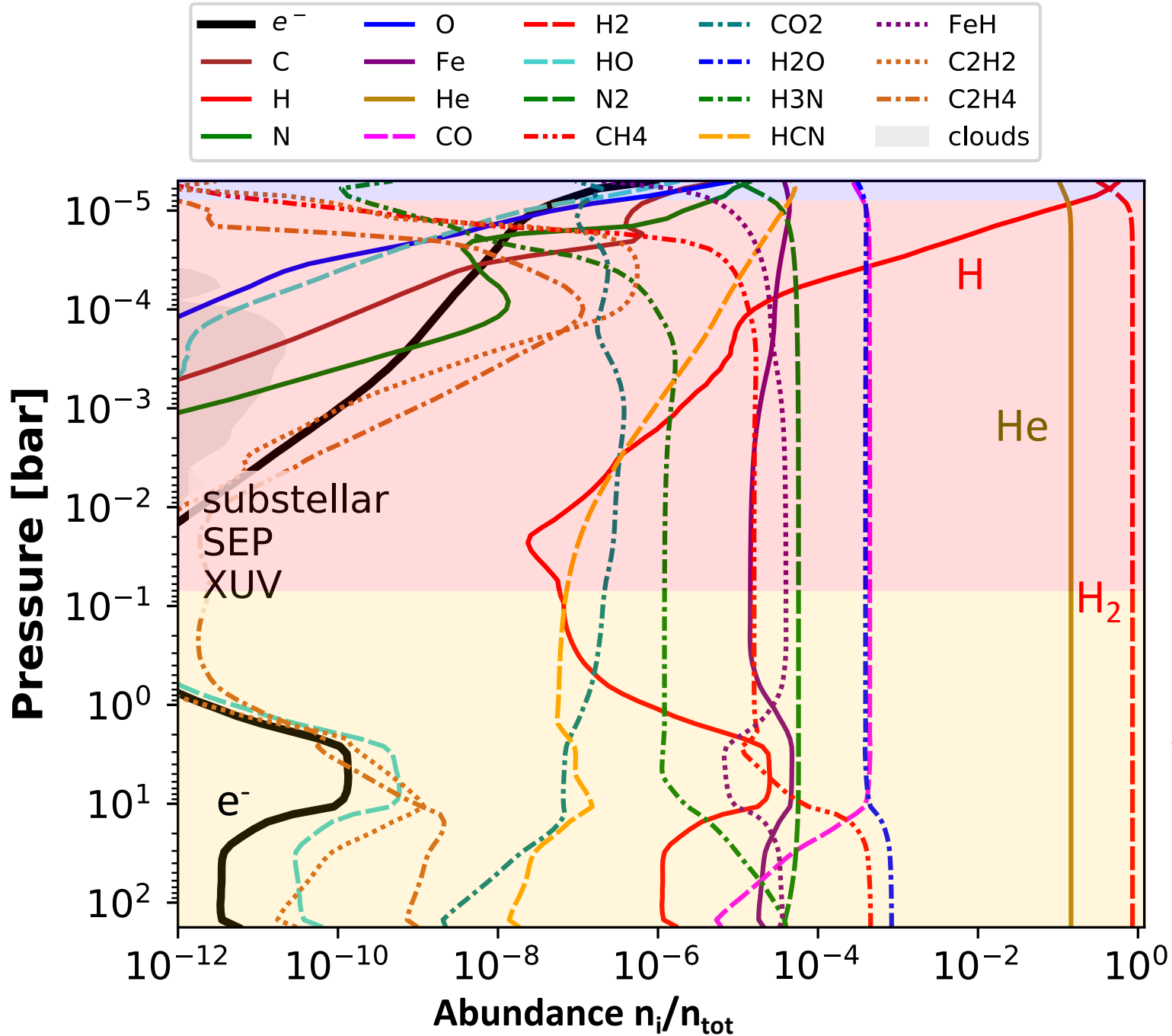
XUV



CR



SEP



XUV

SEP

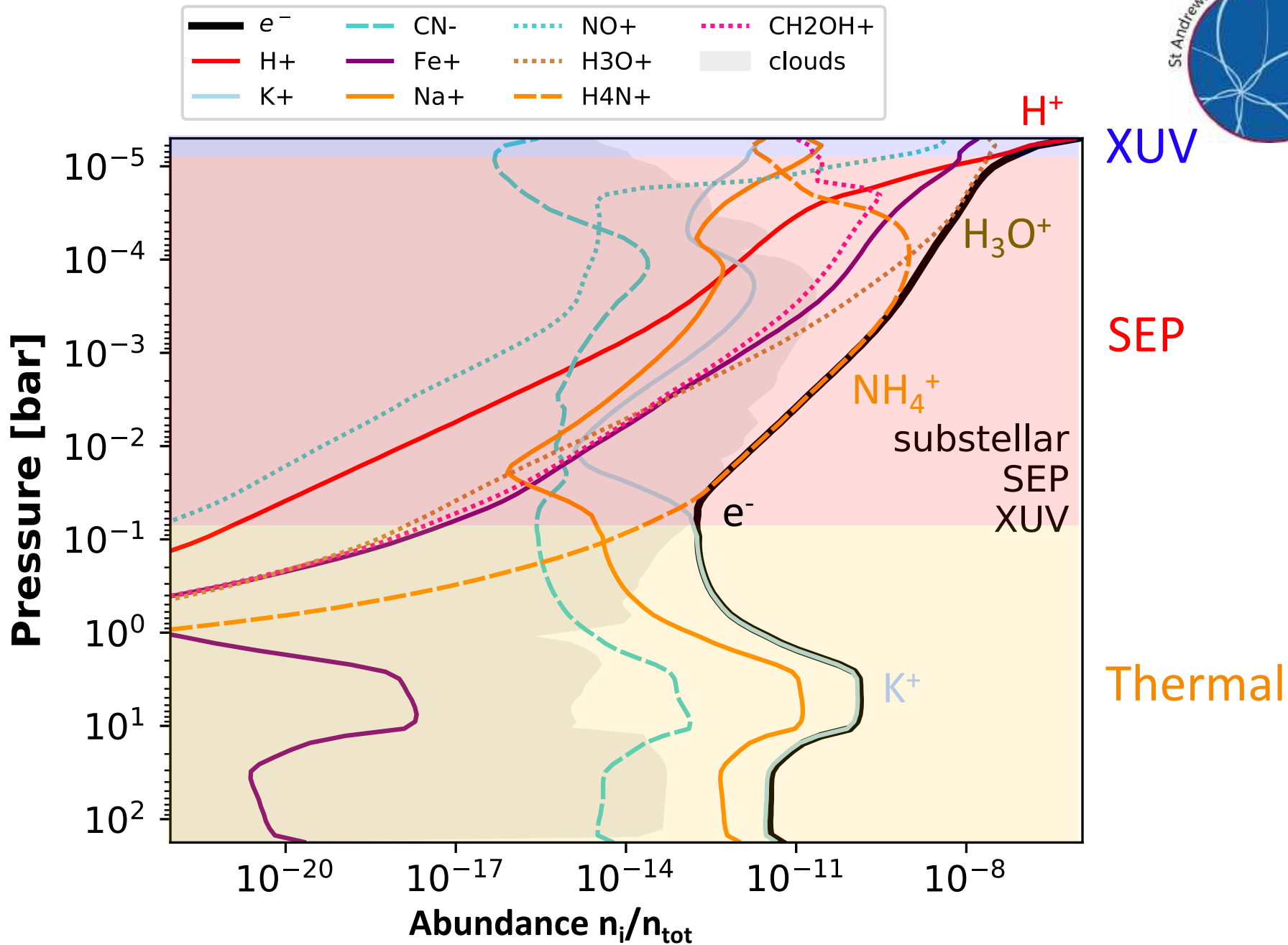
Thermal

Substellar
point

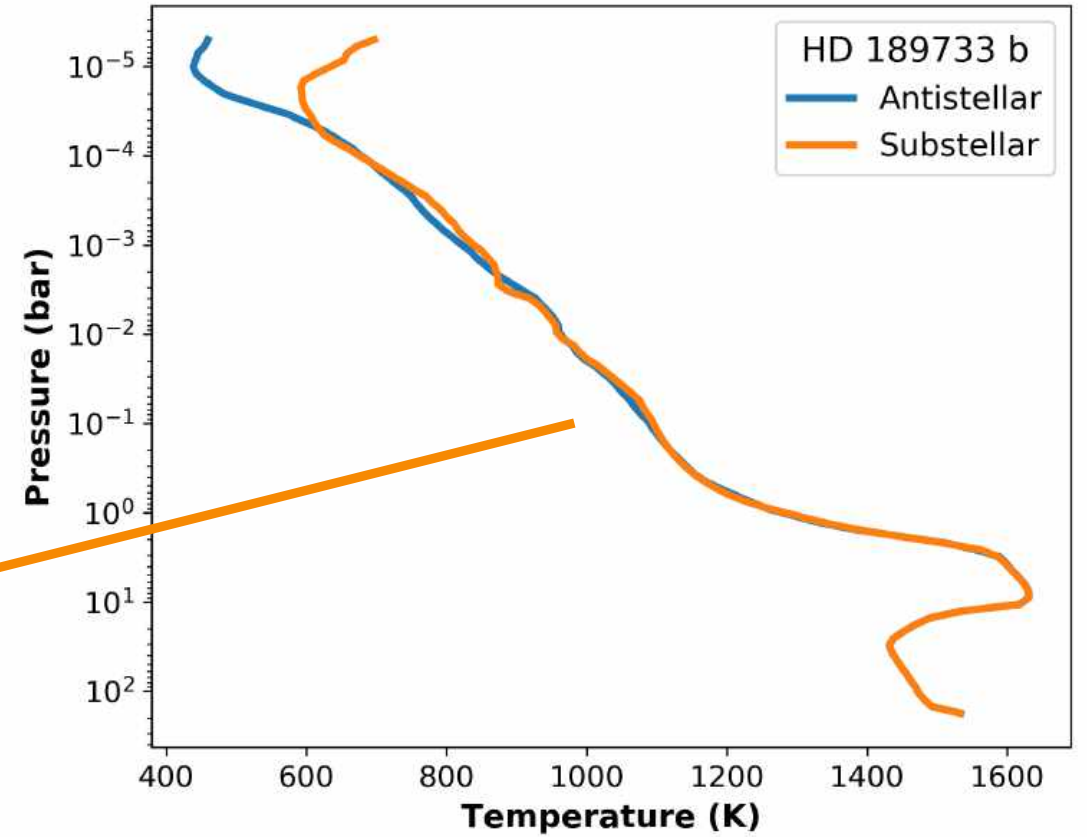
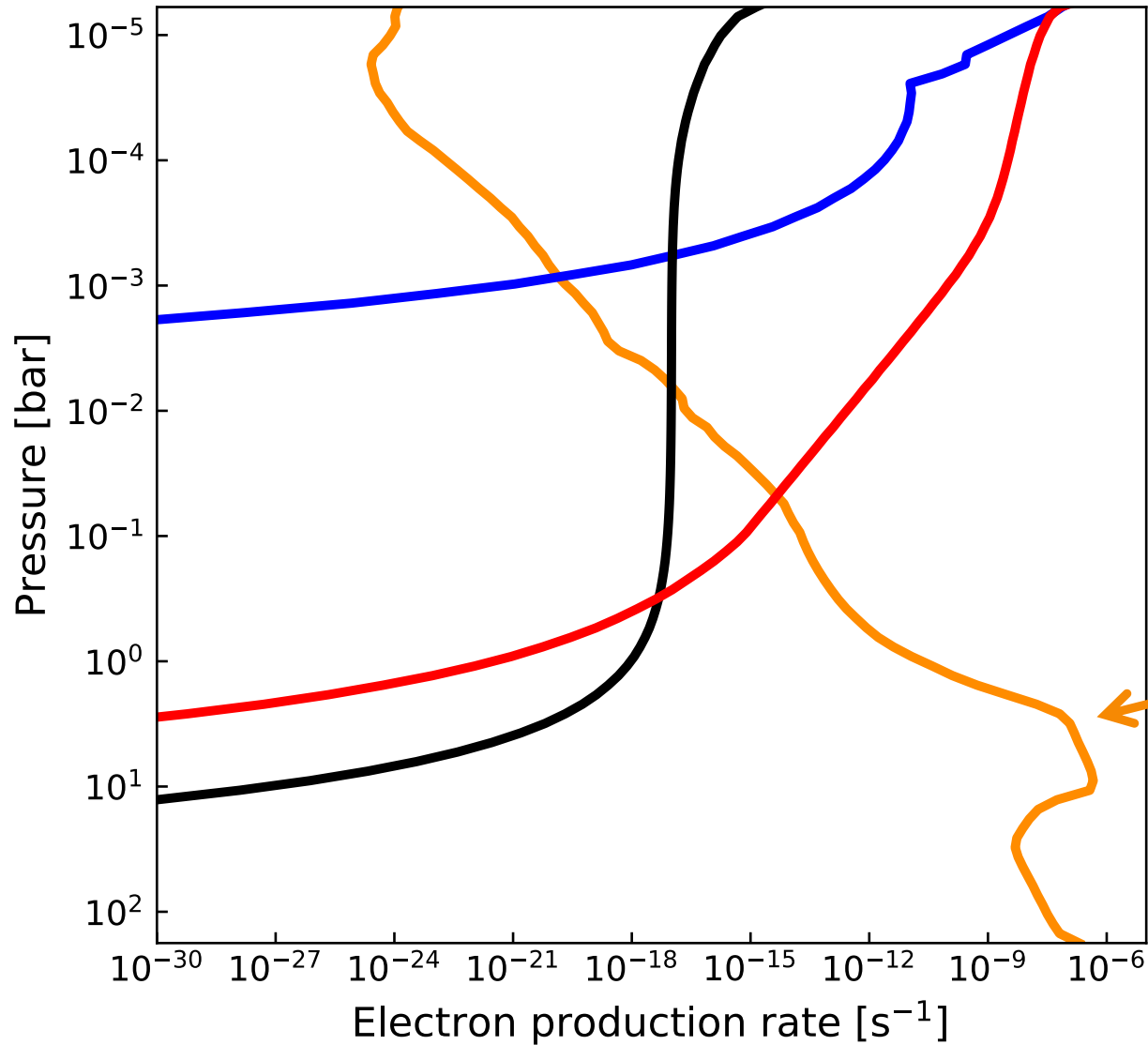
XUV ✓

CR ✗

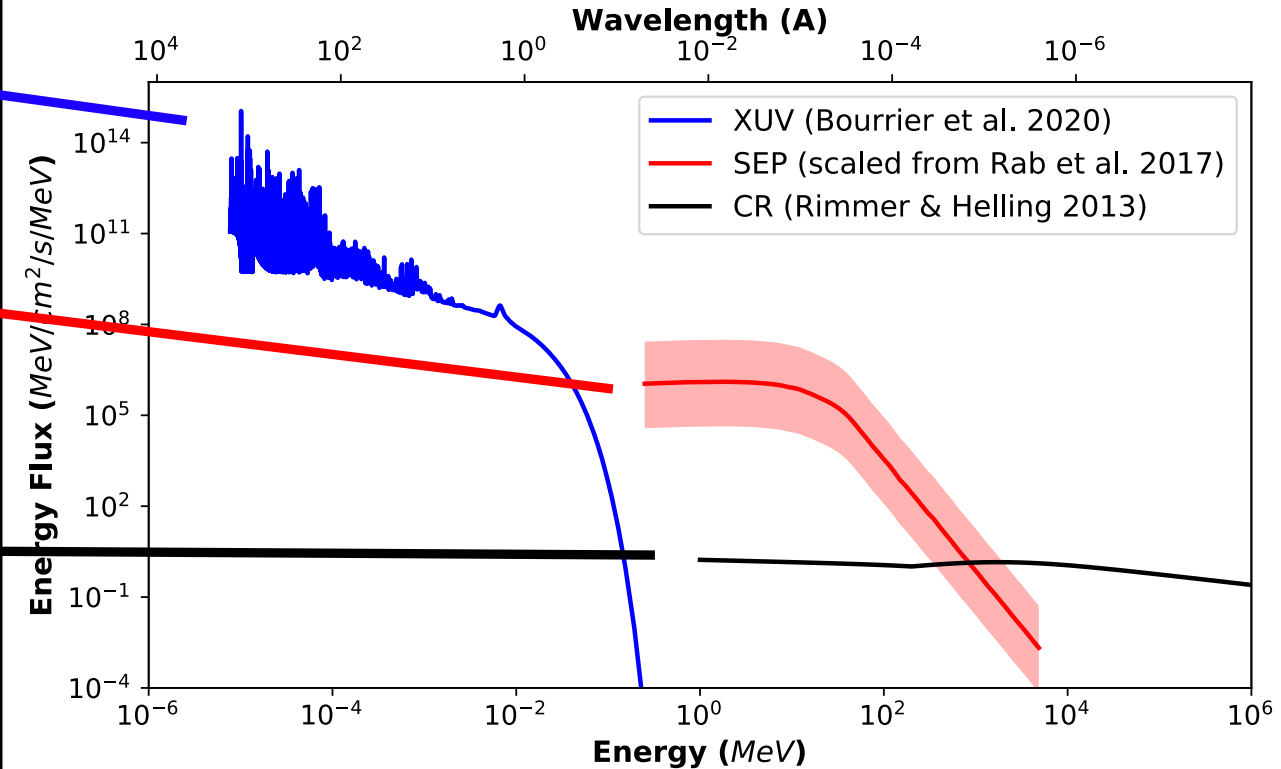
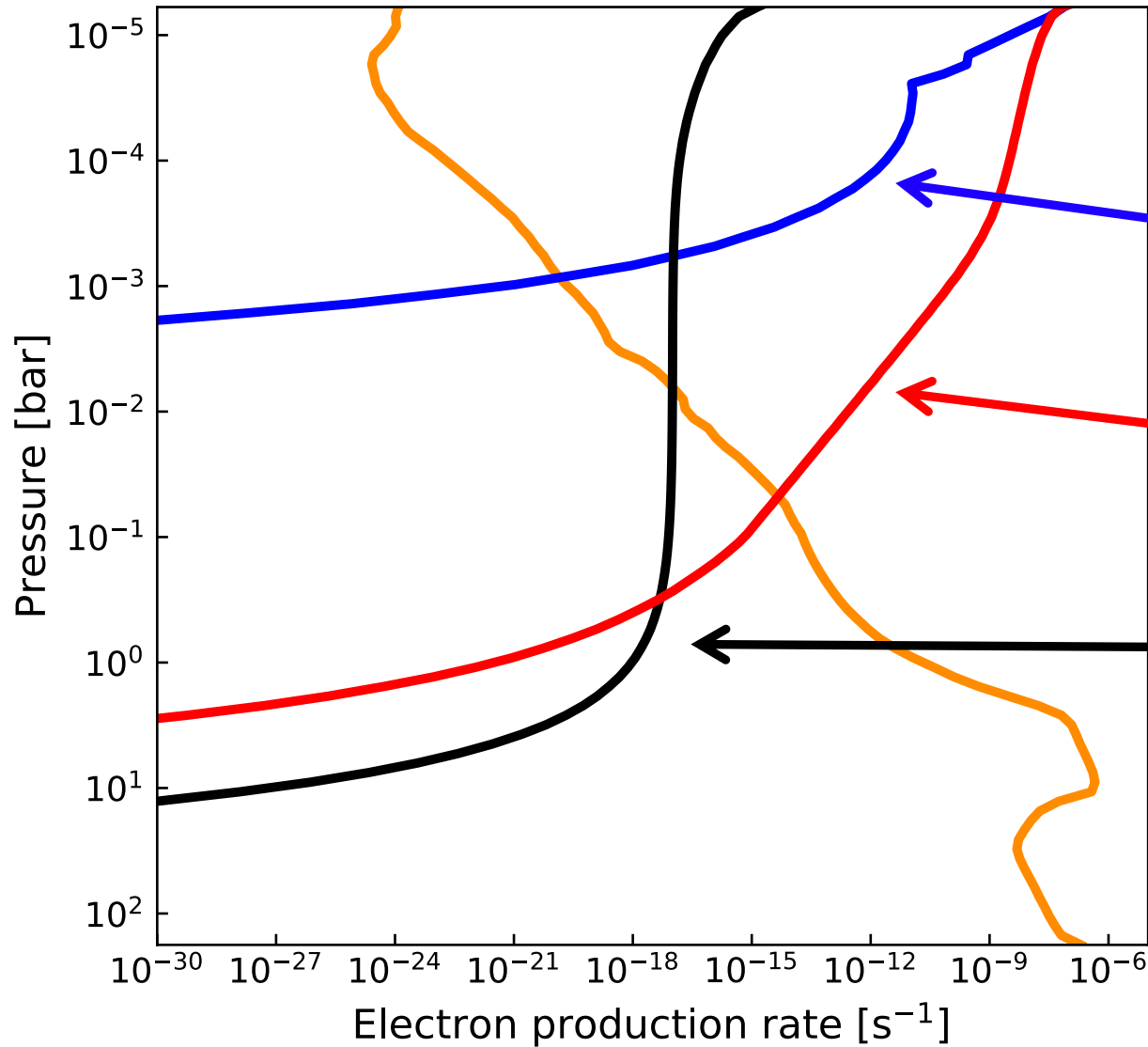
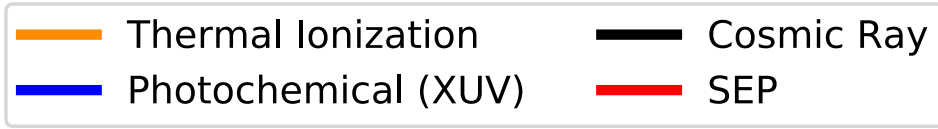
SEP ✓

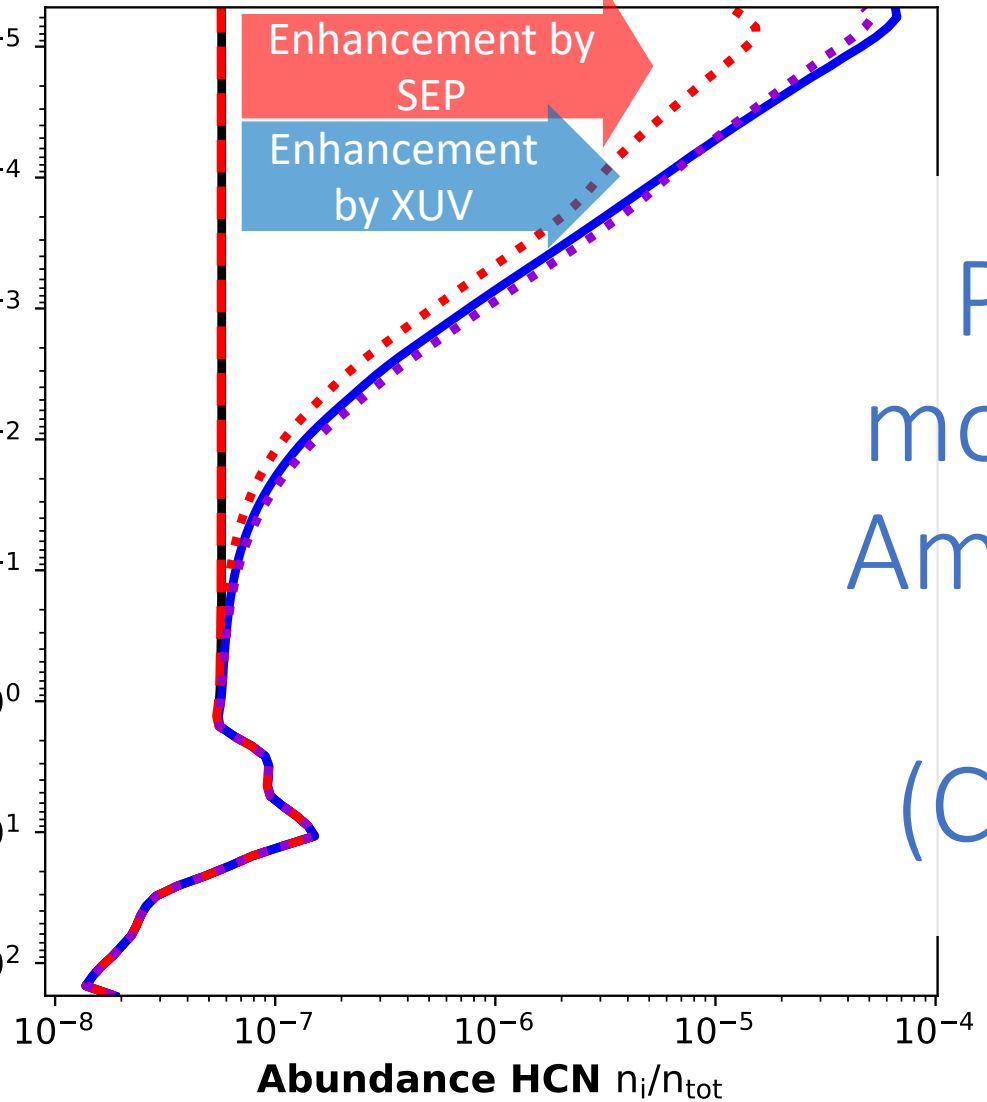
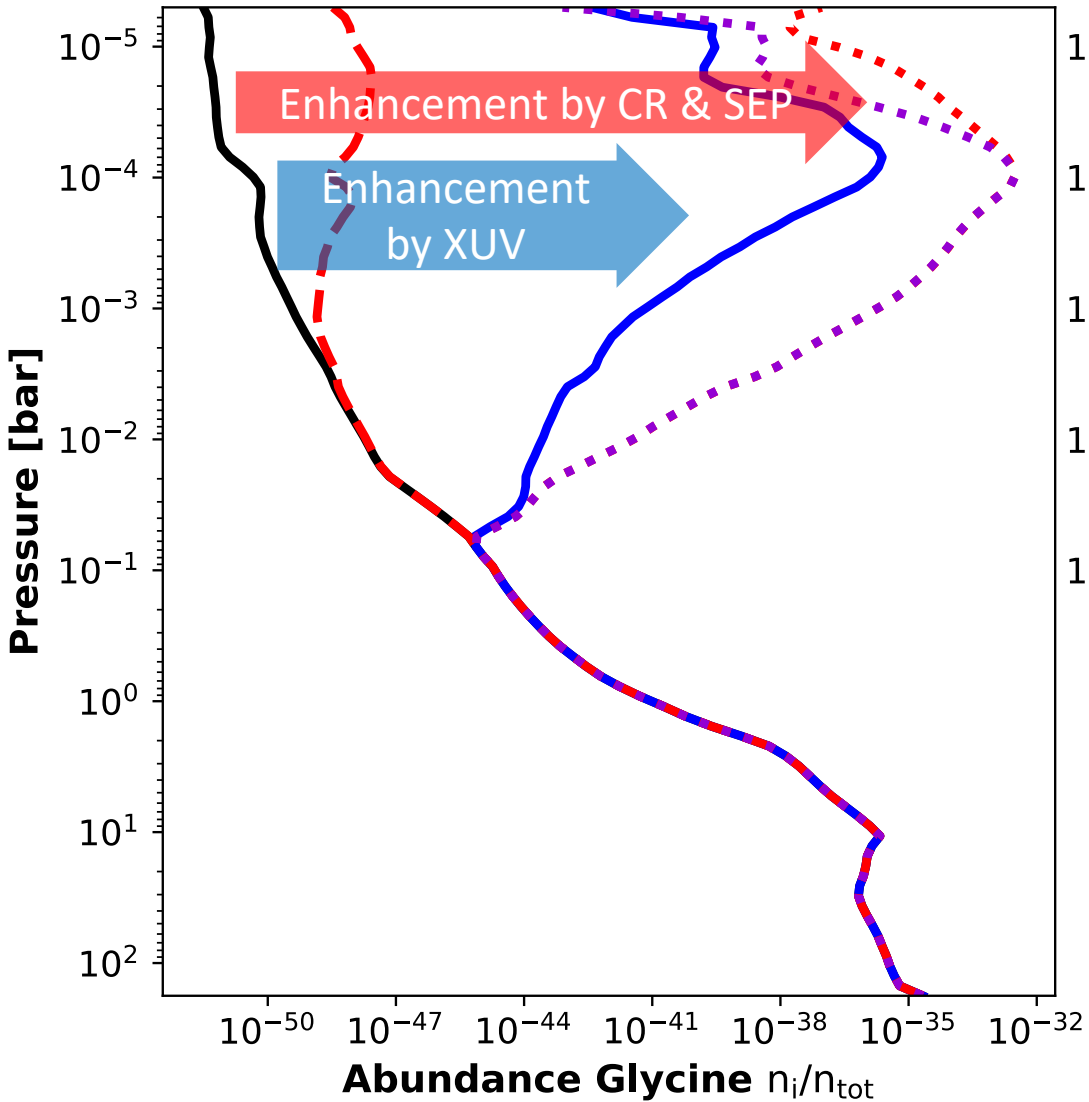
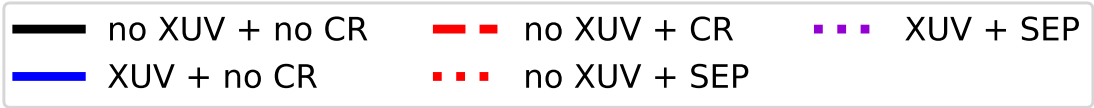


Ionization rates for different processes



Ionization rates for different processes





Prebiotic molecules:
 Amino acid
 Glycine
 ($C_2H_5NO_2$)

Conclusion

- Nitrate production increase with oxygen abundance
- CO₂ possible oxygen source for nitrate in early Archean
- Energy input needed for prebiotic molecules
- XUV/SEP/CR: important energy source for prebiotic chemistry
- Tracer for SEP/CR ionisation: NH₄⁺, HCN

Outlook

- Reproduce nitrate production experiments
- Measure nitrogen isotope fraction
- Include lightning in model
- Add aqueous chemistry