Collision-Induced Absorption of CH4-CO2 and H2-CO2 Complexes and Their Effect on the Ancient Martian Atmosphere

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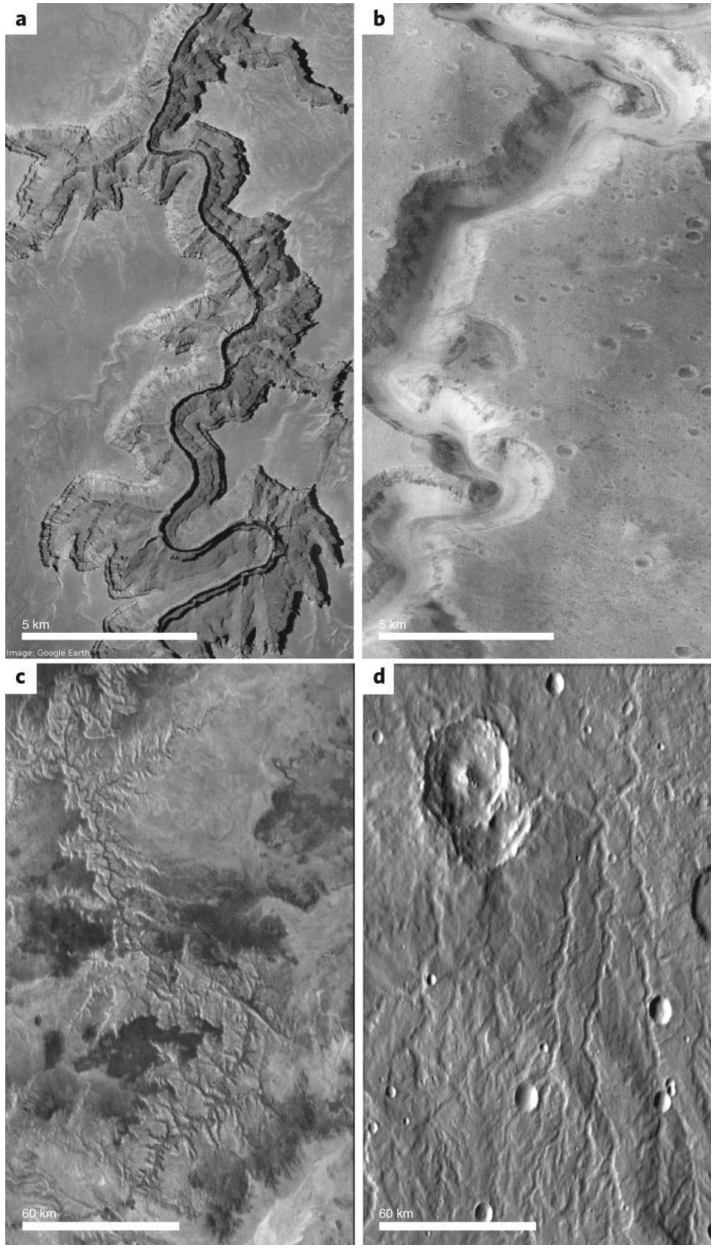
CMOS 54

Water on Mars: An Interdisciplinary Effort

- Geology:
  - Valley Networks
  - Crater lakes
  - Ocean shorelines
  - Glaciation
- Chemistry:
  - Phyllosilicates (warm+wet)
  - Lack of carbonates (warm)
- Atmospheric Physics:
  - Faint young sun
  - Low atmospheric pressure
  - Lack of greenhouse gases

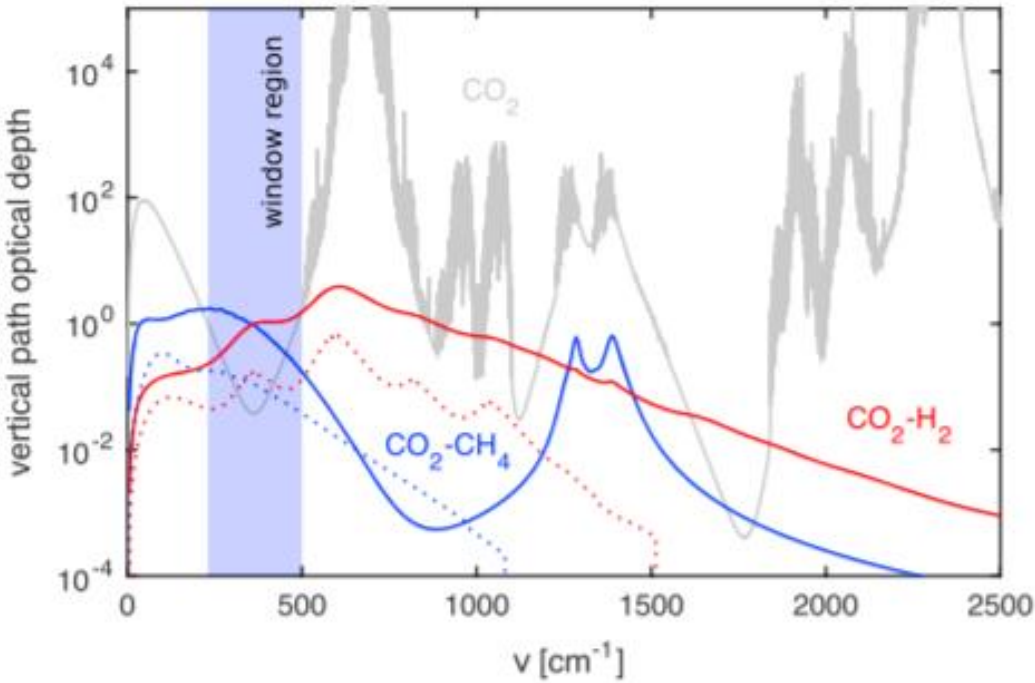


A possible solution: CIA

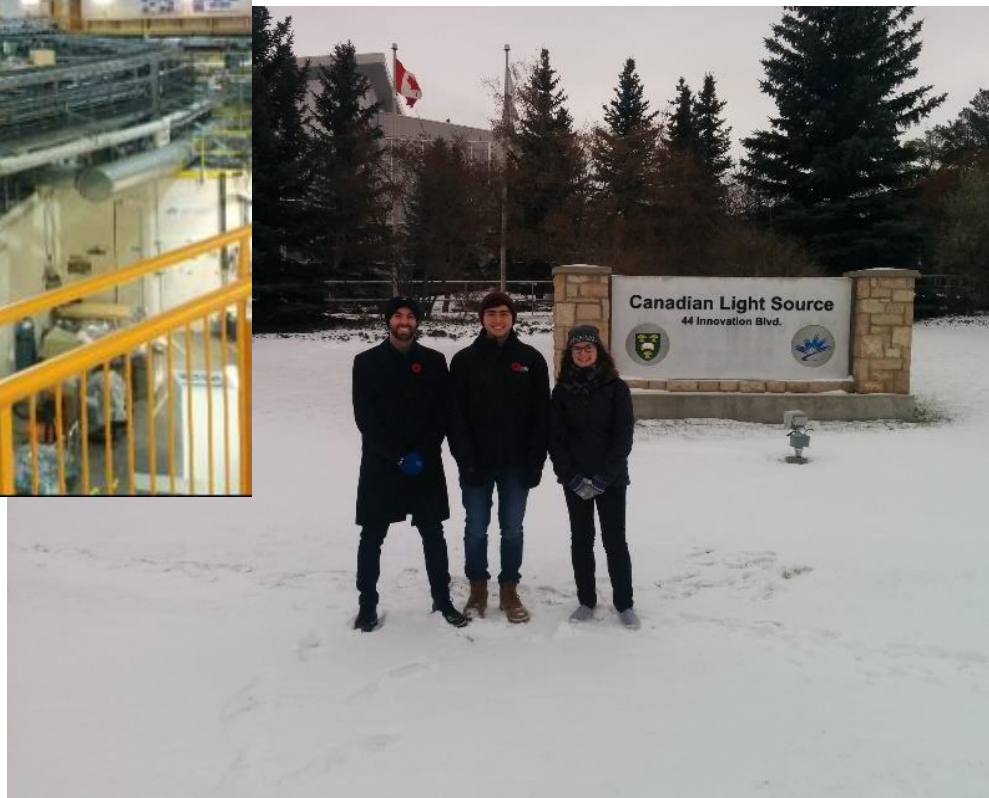
- Collisions produce temporary multi-molecular complexes.
- Complexes have their own absorption profiles:

$$I = I_o e^{-L(\rho_{CO_2}\sigma_{CO_2}+\rho_x\sigma_x+\rho^2_{CO_2}\sigma_{CO_2+CO_2}+\rho^2_x\sigma_{x+x}+\rho_{CO_2}\rho_x\sigma_{CO_2+x})}$$

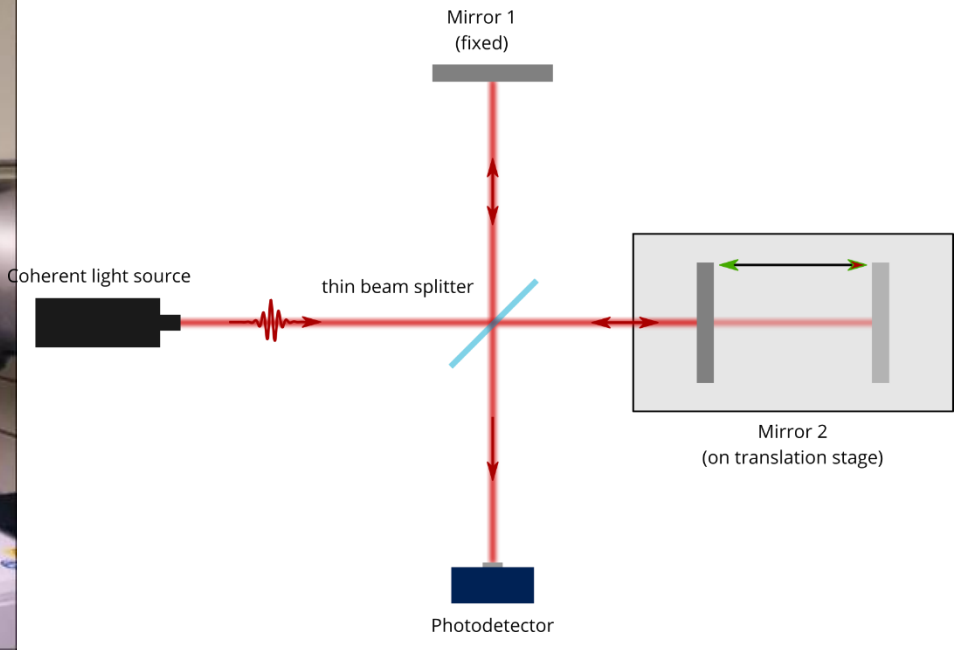
- Missing CIA may sufficiently increase greenhouse effect.
- Transient warming.

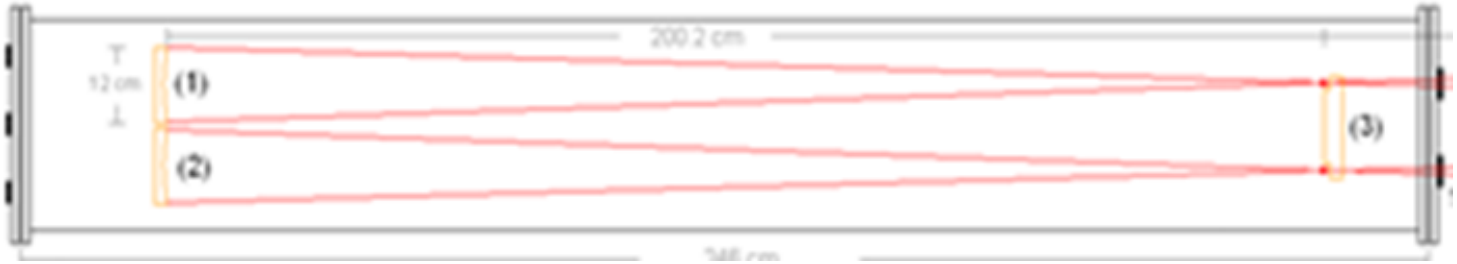


Canadian Light Source (CLS)

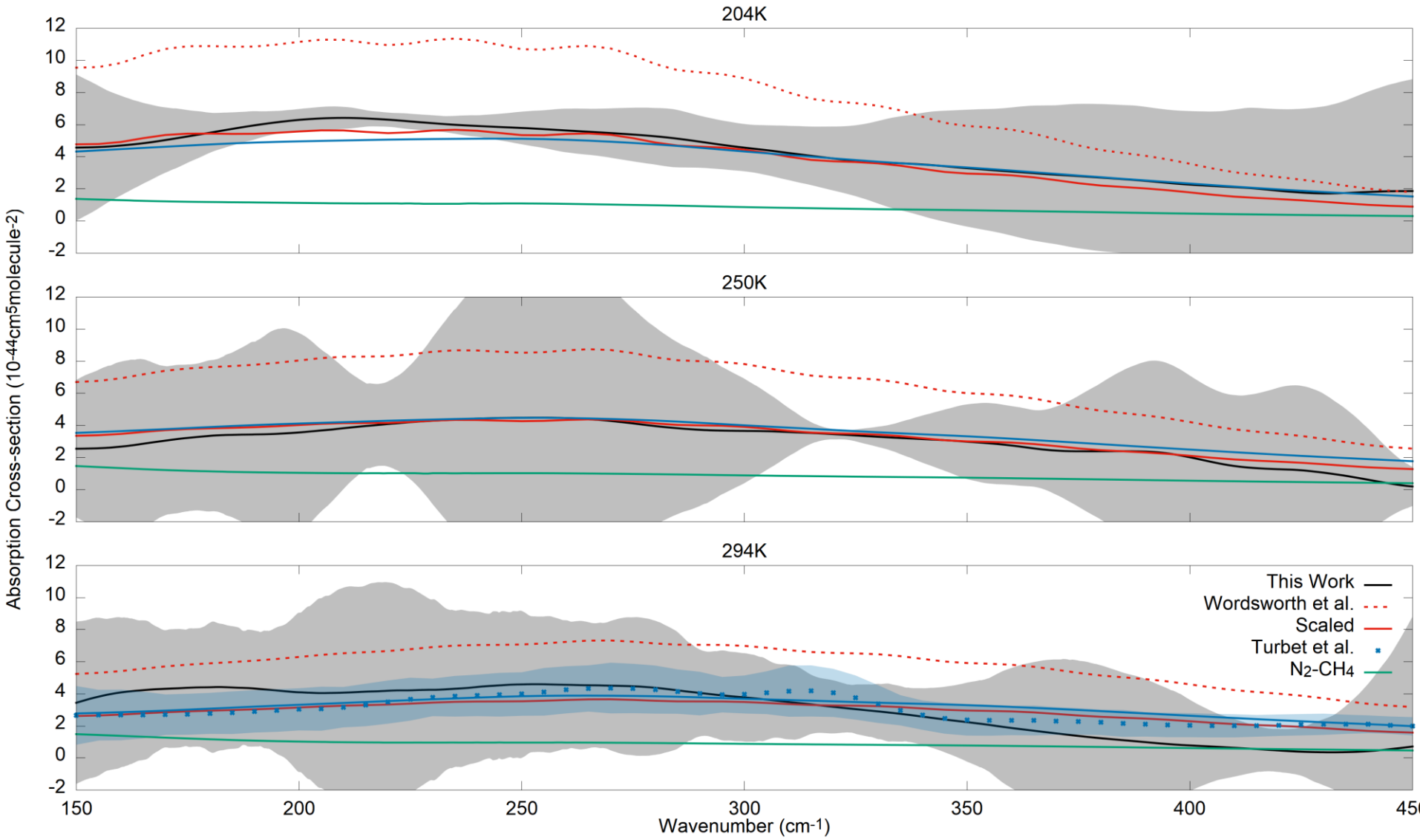


CLS Far-IR Beamline

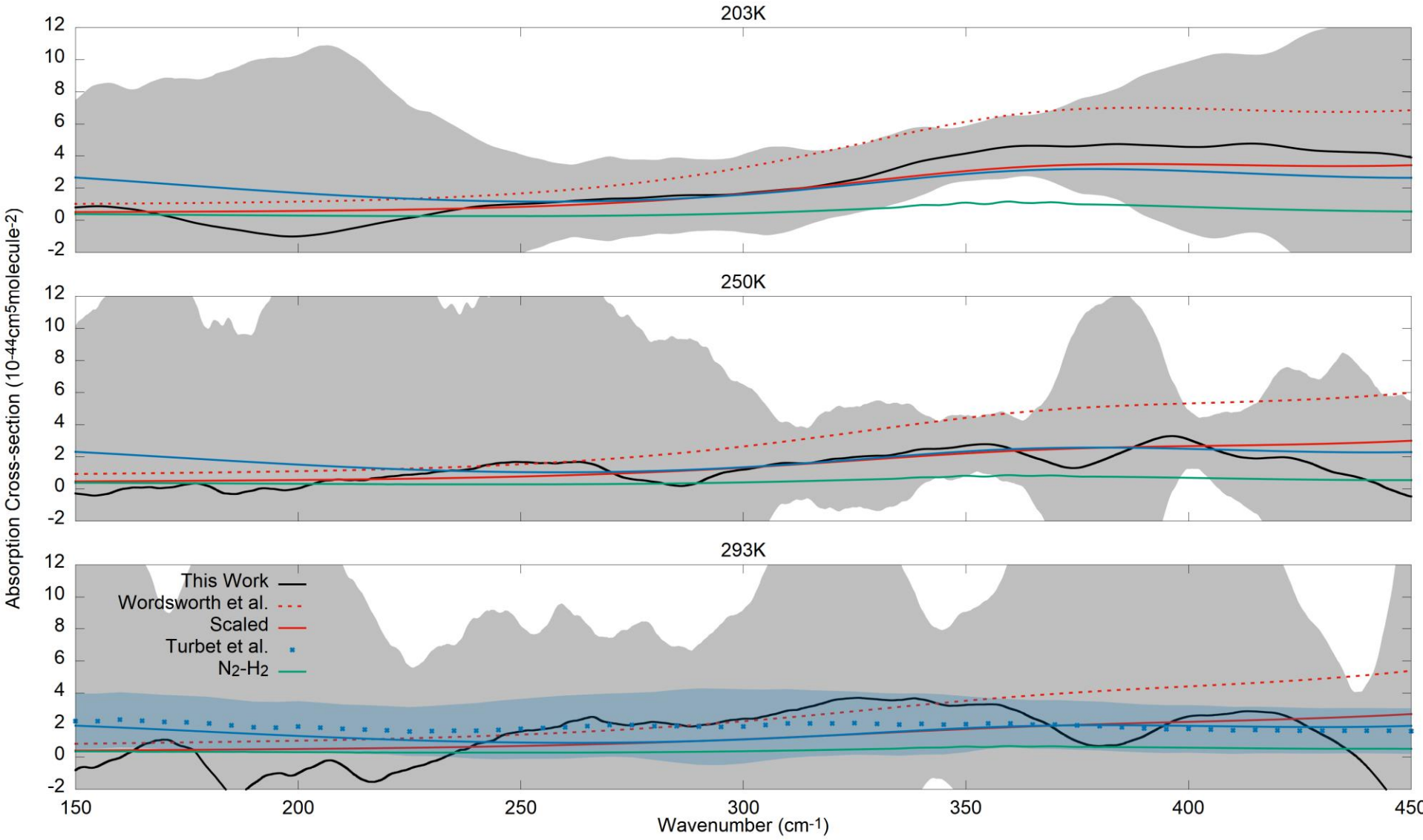




CO2-CH4 CIA

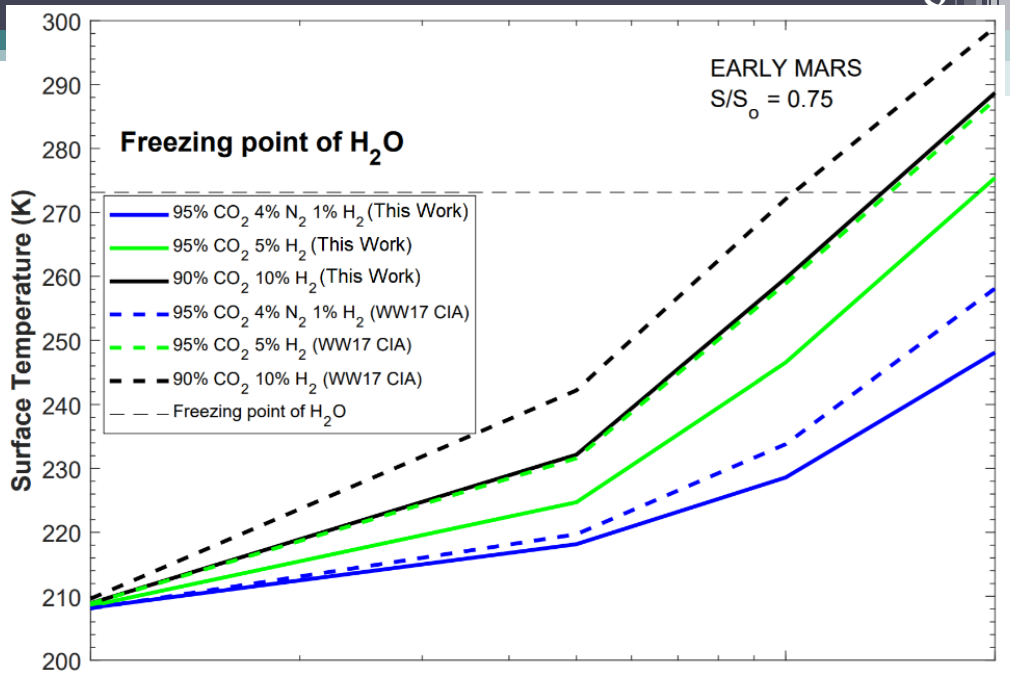

204K
250K
294K
Absorption Cross-section (10-44cm5molecule-2)
Wavenumber (cm-1)
This Work
Wordsworth et al.
Scaled
Turbet et al.
N2-CH4

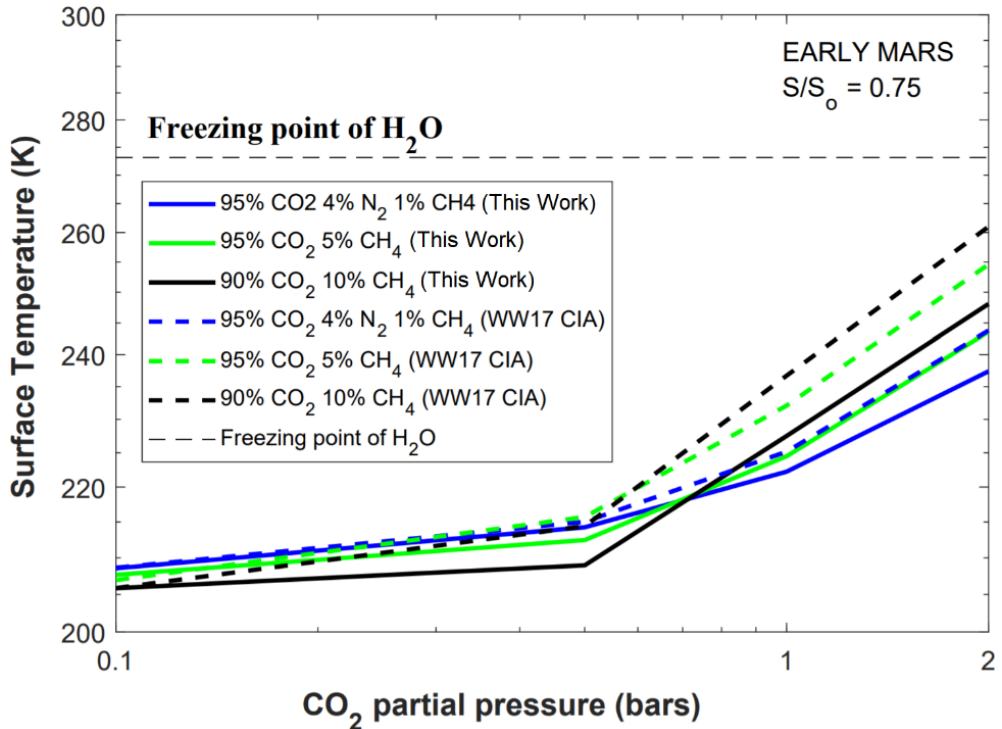
CO2-H2 CIA


203K
250K
293K
This Work
Wordsworth et al.
Scaled
Turbet et al.
N2-H2
Absorption Cross-section (10-44cm5molecule-2)
Wavenumber (cm-1)
12
10
8
6
4
2
0
-2
150
200
250
300
350
400
450

Temp vs Pressure

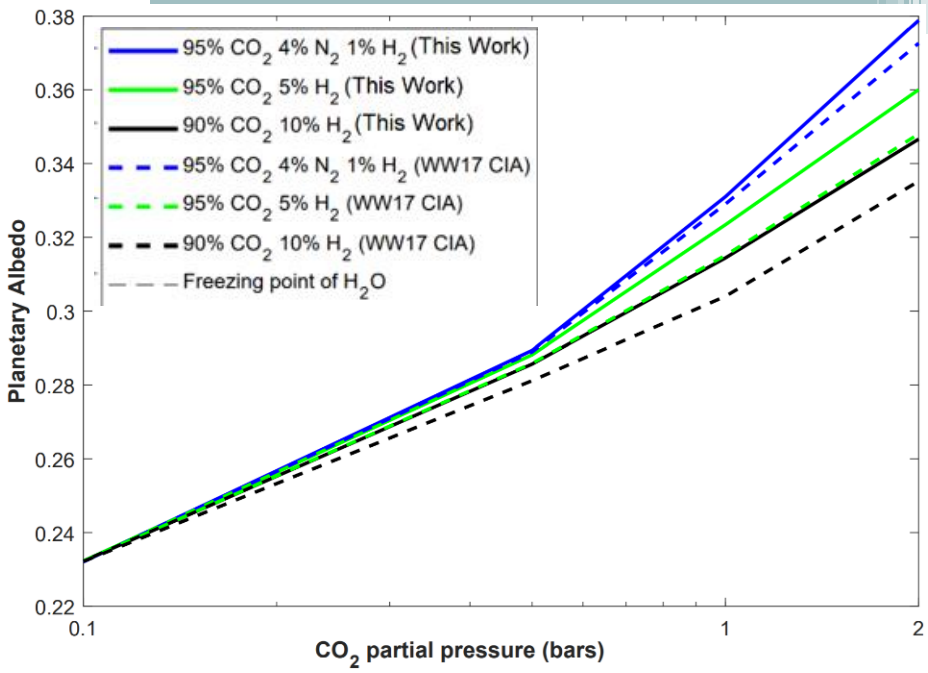
- Radiative transfer model used simulate ancient Martian atmosphere.
- Different mixing ratios of CO2/H2/CH4 investigated.

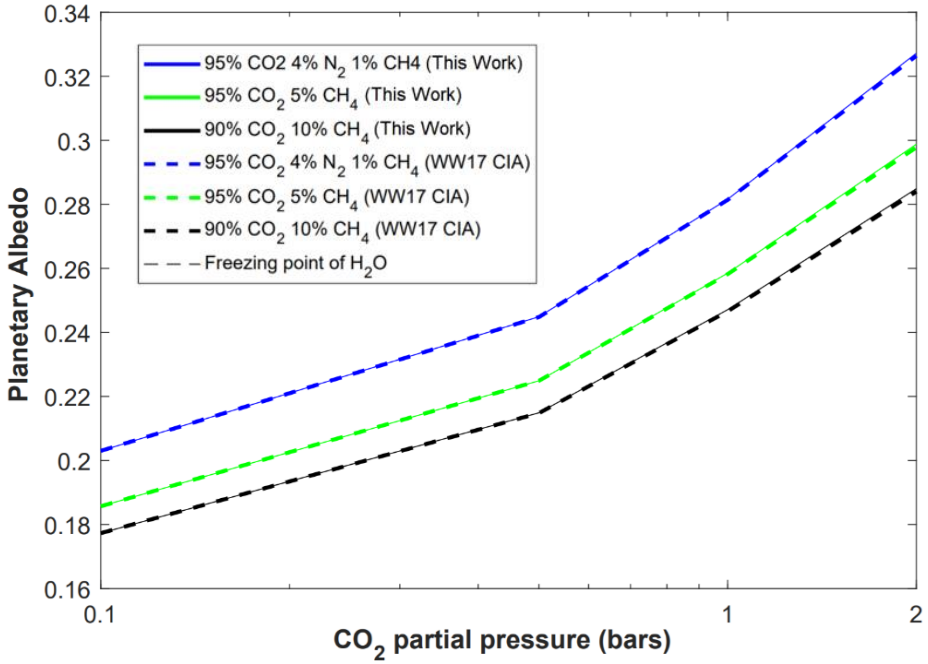




Planetary Albedo

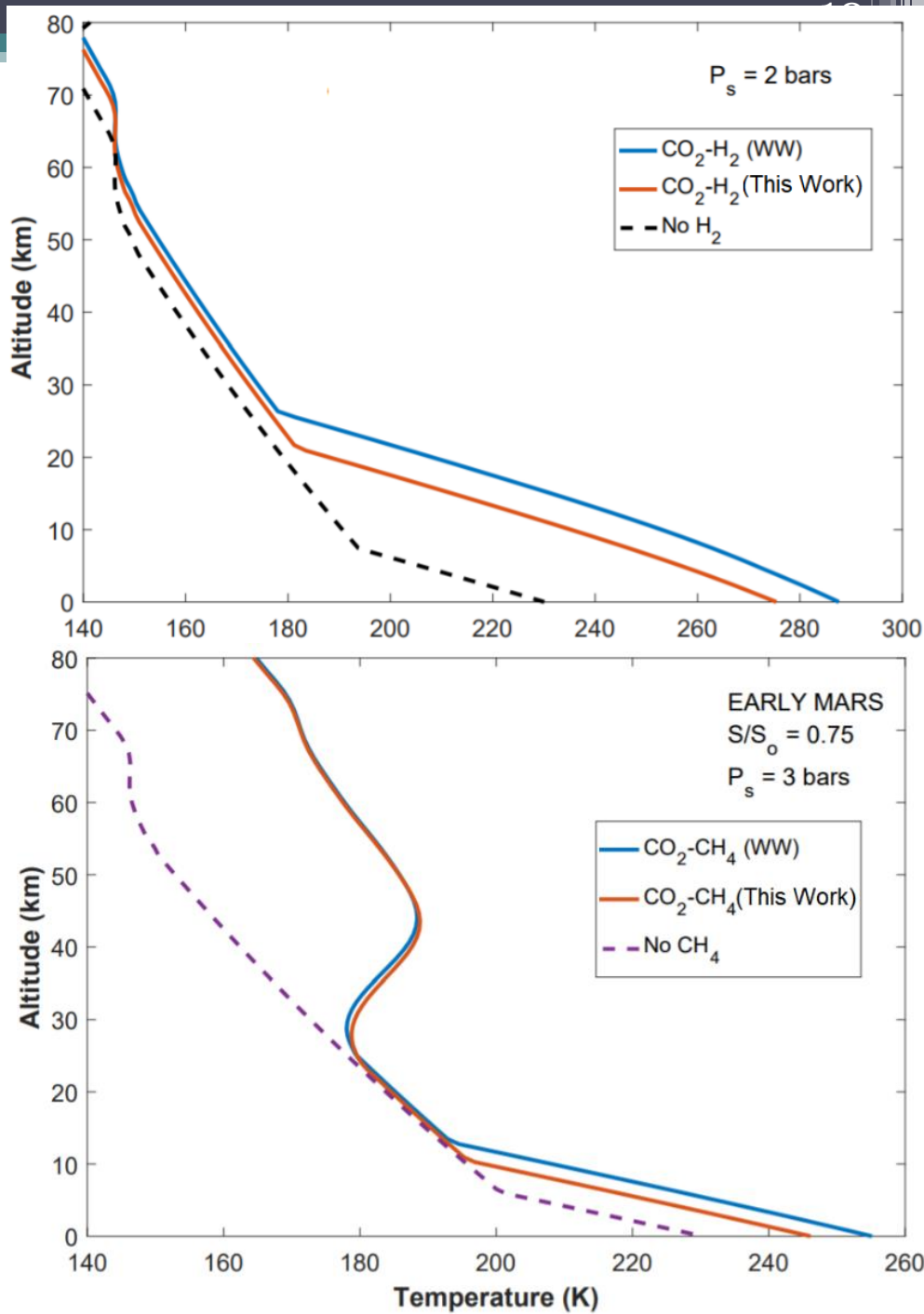
- Increasing CH4/H2 concentrations increase scattering, lowering albedos.
- Greater difference in H2 albedos with updated CIA values.
- Higher temperatures increase water vapour concentrations.





Temperature Profiles

- Temperature profiles for “best case” scenarios.
- Significant changes at the surface with updated CIA values.



Conclusions

- First temperature-dependent experimental measurements of CO2-H2 and CO2-CH4 CIA.
- Radiative transfer calculations of the early Mars atmosphere were performed and showed that CO2-CH4 CIA is not as promising as initially argued.
- CO2-H2, however, liquid water is possible with 5% hydrogen and less than 2 bar of surface pressure.