# Understanding the Atmospheres of Hot Earths…

Progress in the lab!

Denny Bosch

with Nolan Ingersoll, Curtis Israel, Tyler Noyes, and Cory Honer

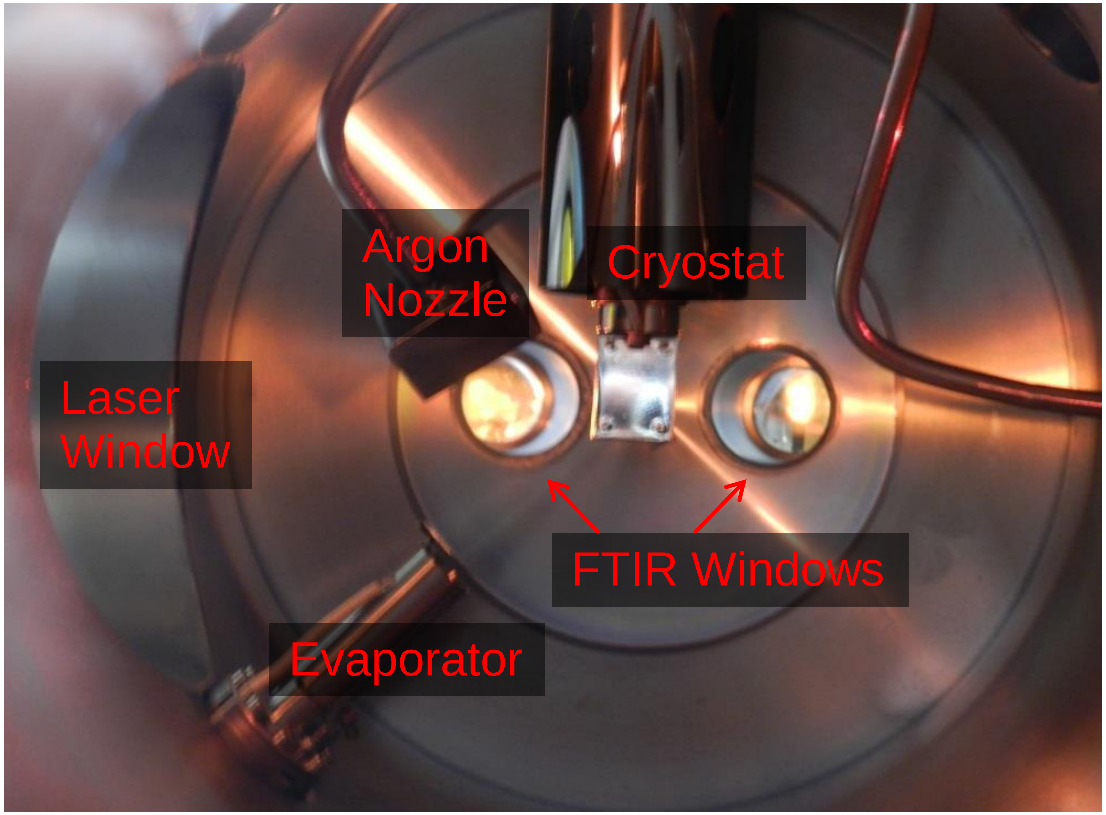
Advisor: Dr. David Cornelison

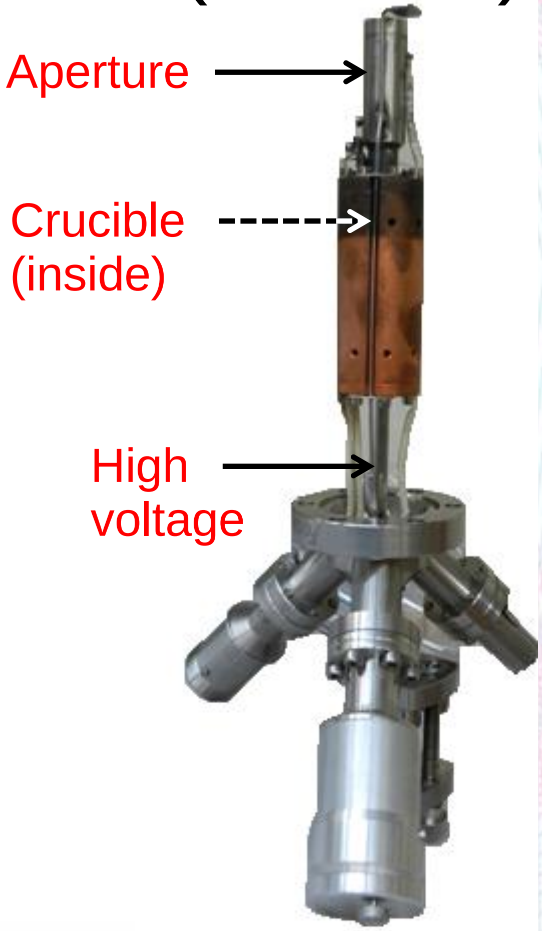
# Recap of what we've been doing:

- Matrix isolation of samples using argon ice
- Fourier transform infrared spectroscopy
- Samples (komatiite):
  - $SiO_2$
  - $MgO$
  - $CaO$
  - $Al_2O_3$
  - $FeO$

# Our (old) system

- Focus GmbH EFM 4 UHV Evaporator (e-beam)



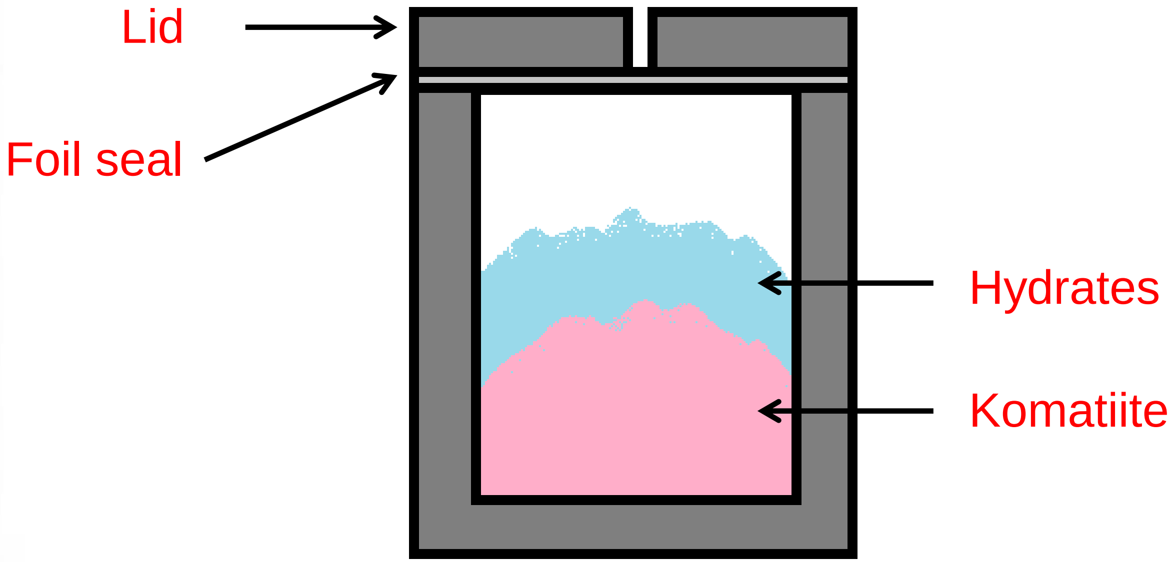
# Adding $H_2O$

- Any water added to the crucible will evaporate preferentially long before the oxide rock sample even melts.
- Waters of hydration: evaporating water from a hydrate rock (efflorescence) with increasing temperature
- $(SiO_2)_{10}\cdot 14H_2O \rightarrow SiO_2 + 14\ H_2O$

  (Water evaporates at only ~200 C)

# Sealed Crucible

- Idea: waters of hydration are confined to the crucible until the appropriate temperature.

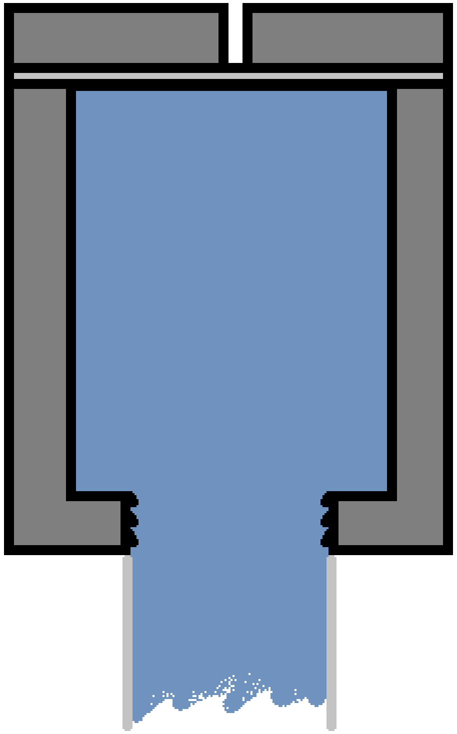



- Pressure inside crucible causes foil seal to burst at a specific temperature.

- Seal between foil, crucible, and lid is made with a press.

# Sealed Crucible

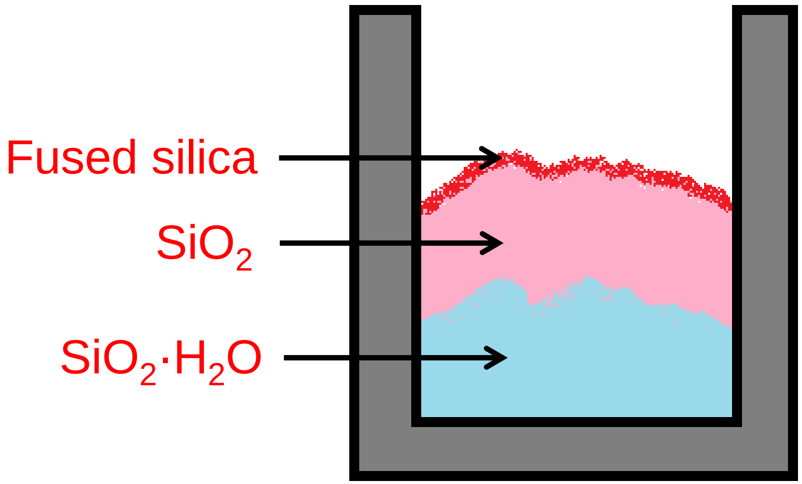
- Foil must be same material as crucible so it doesn’t pop from thermal expansion
- Tested using a crucible with gas pressure added through the bottom.
- Problem: unable to make an airtight seal using refractory metal foils (ideas?)



# Komatiite Diffusion Barrier

- Idea: creating a barrier of fused sample that will not permit diffusion of waters of hydration until the sample fully melts.

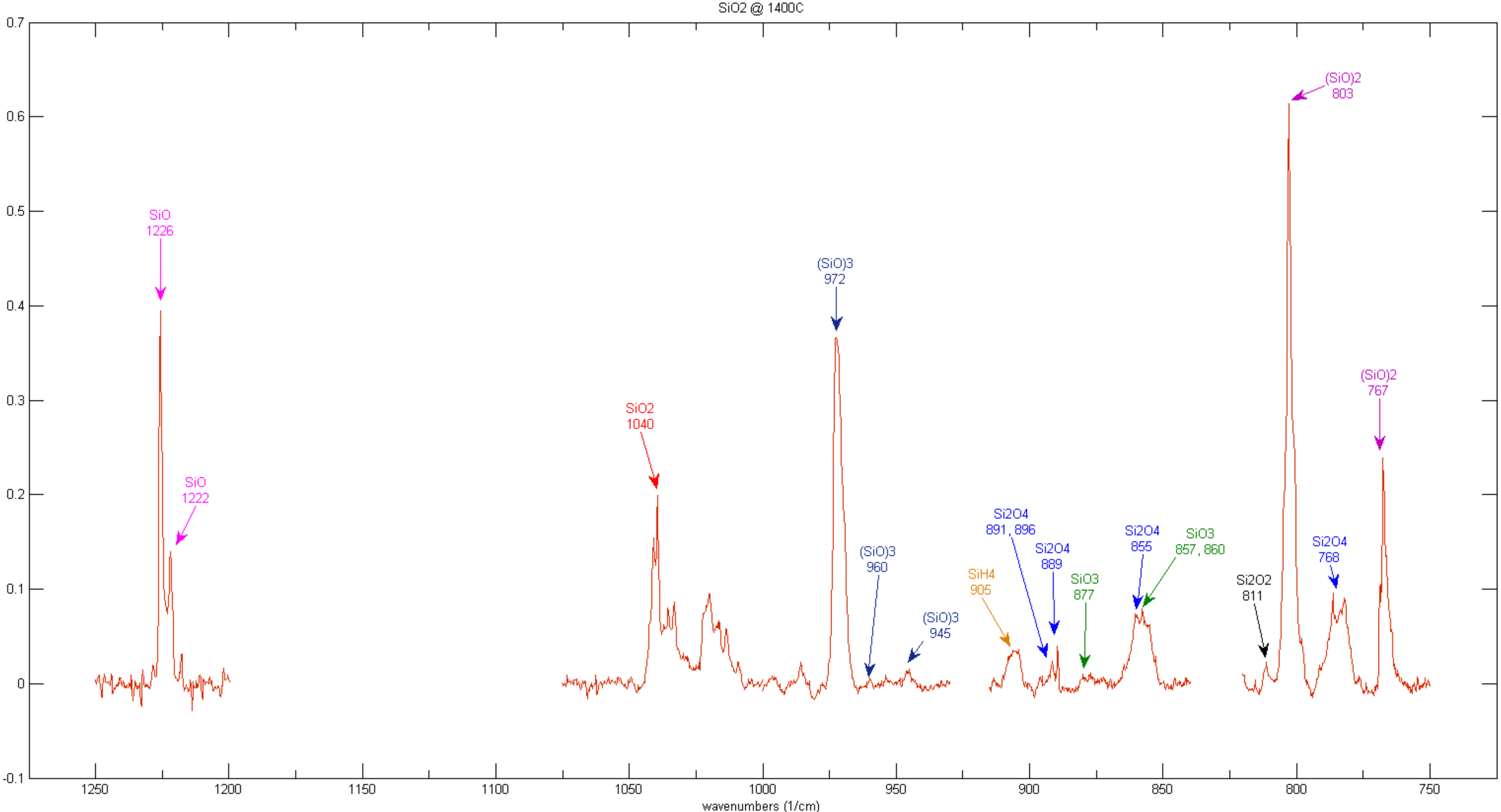
- This can be achieved by flashing the filled crucible at a temperature high enough to melt the surface grains in an inert atmosphere (argon).




- [type of laser] laser. Not yet tested.

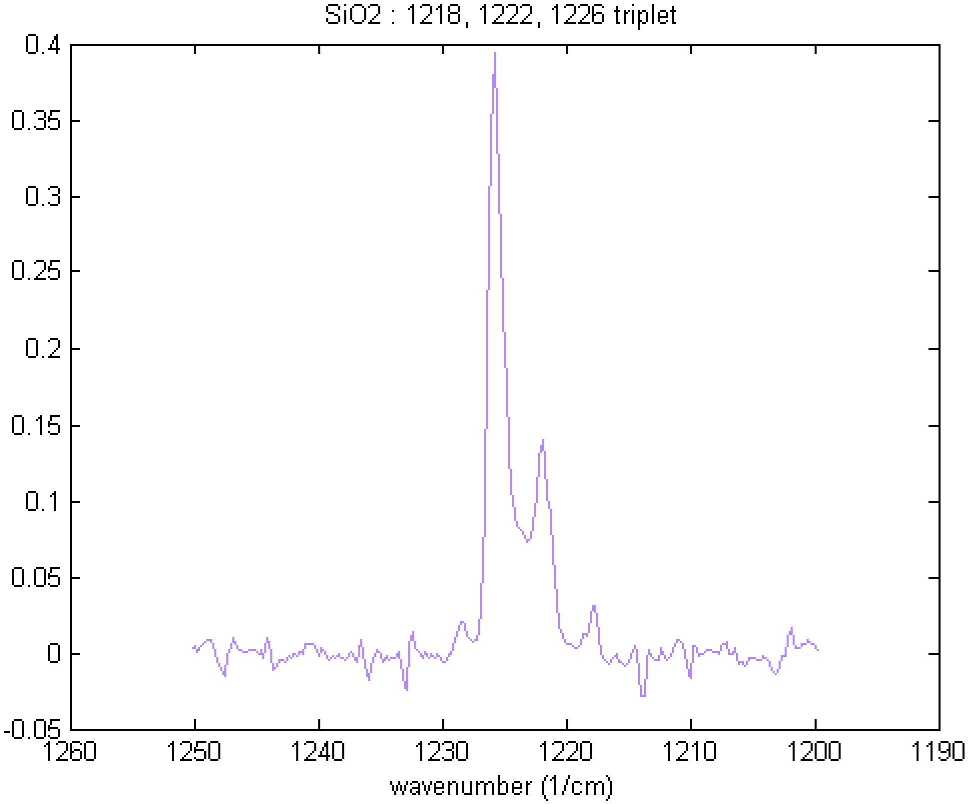
# $SiO_2$ Atmosphere IR Spectrum

$SiO_2$ was evaporated and deposited into an Ar ice.



# $SiO_2$ Atmosphere IR Spectrum

- Each peak appears as a triplet due to the presence of Si isotopes:
  - Si28 (1218 $cm^{-1}$)
  - Si29 (1222 $cm^{-1}$)
  - Si30 (1226 $cm^{-1}$)



# $SiO_2$ Atmosphere IR Spectrum

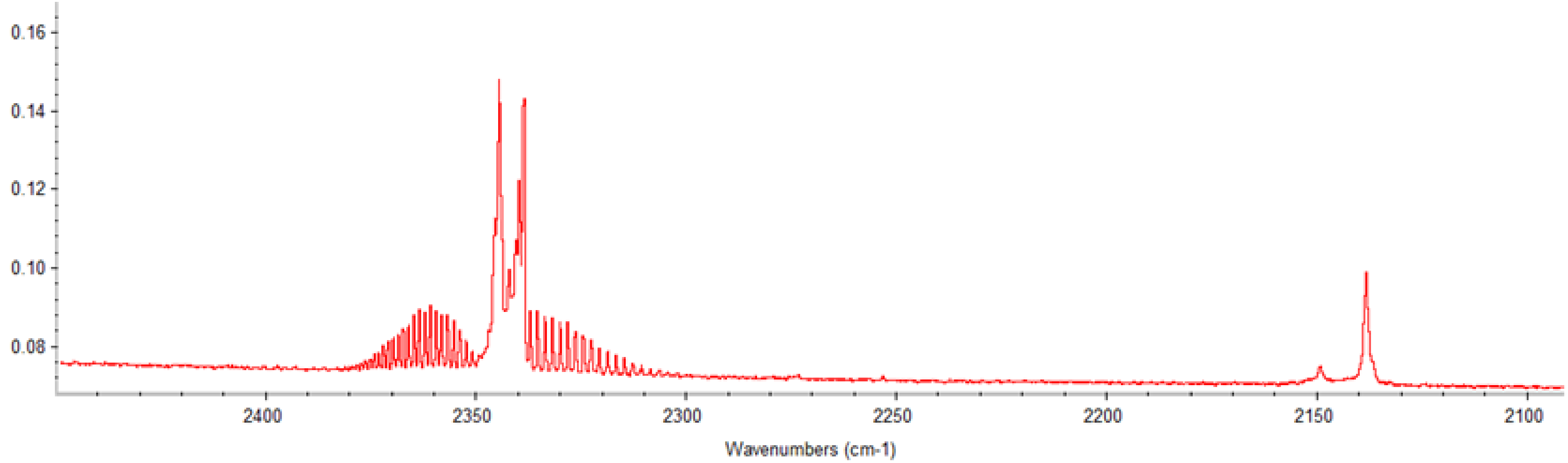
- Measured constituents of pure silica atmosphere by peak intensity:
  - SiO dimer, SiO, SiO trimer, $SiO_2$, $Si_2O_4$, $SiO_3$
  - Possible $SiH_4$ and $O_3$.
- Oxygen gas cannot be detected through IR spectroscopy but thin-film deposition and EDS/EDX measurements demonstrate a depletion of oxygen from the material in the crucible (preferential evaporation of oxygen).

# Is this representative of an equilibrium atmosphere?

- Matrix isolation spectroscopy is claimed to work at ratios of 1000:1 argon to sample and at low temperatures
- We need to verify that no diffusion occurs in order to present matrix isolated results as equivalent to material in the crucible that is still at an equilibrium.
- Experiment: time evolution of spectra at various temperatures and pressures of argon

# Problems!

- Contamination feature began to appear:



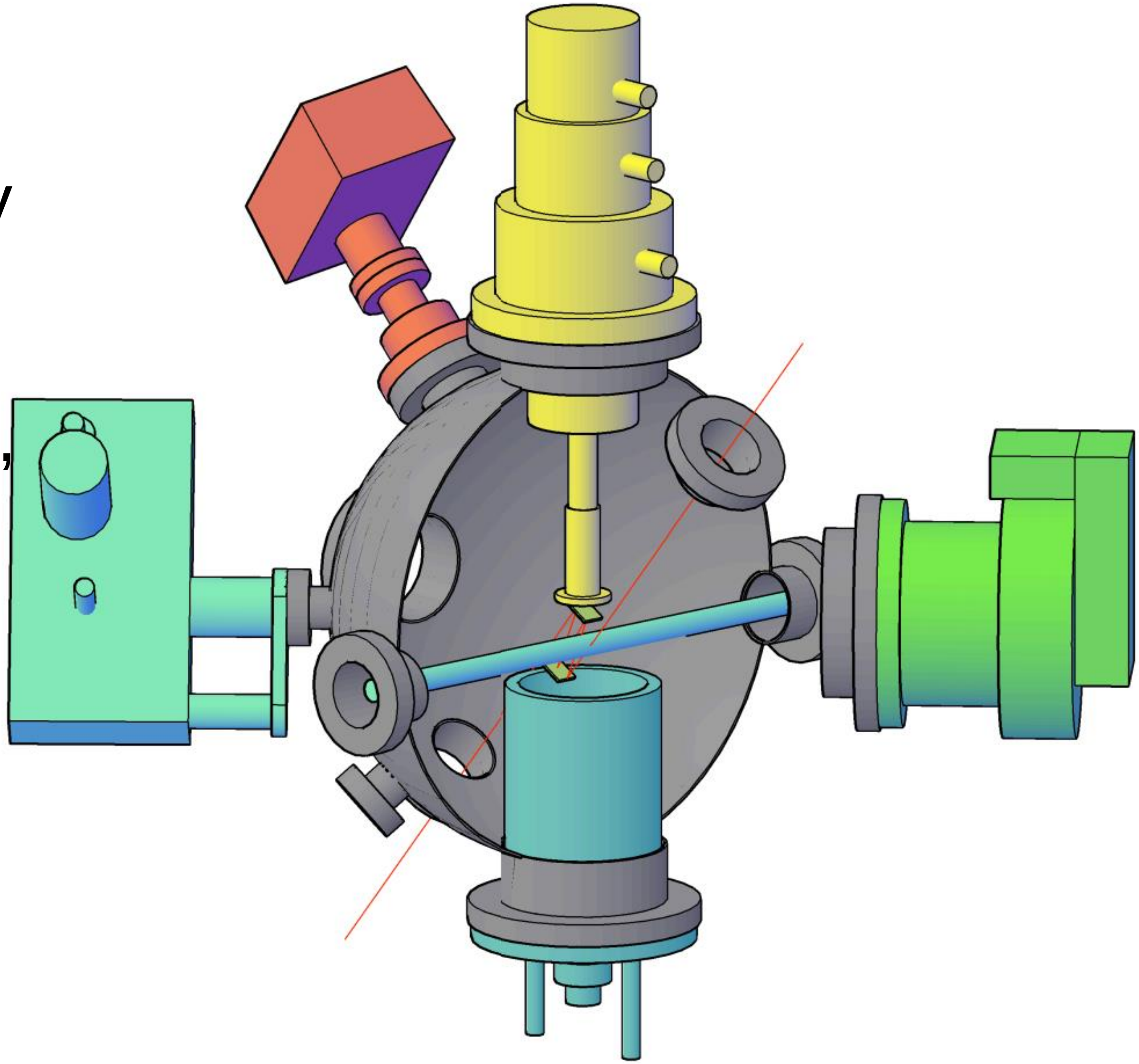

- Identified as tungsten oxide, most likely residue from thoriated tungsten filament.
- Need to develop a cleaning technique to remove contamination from evaporator.

# More Problems!

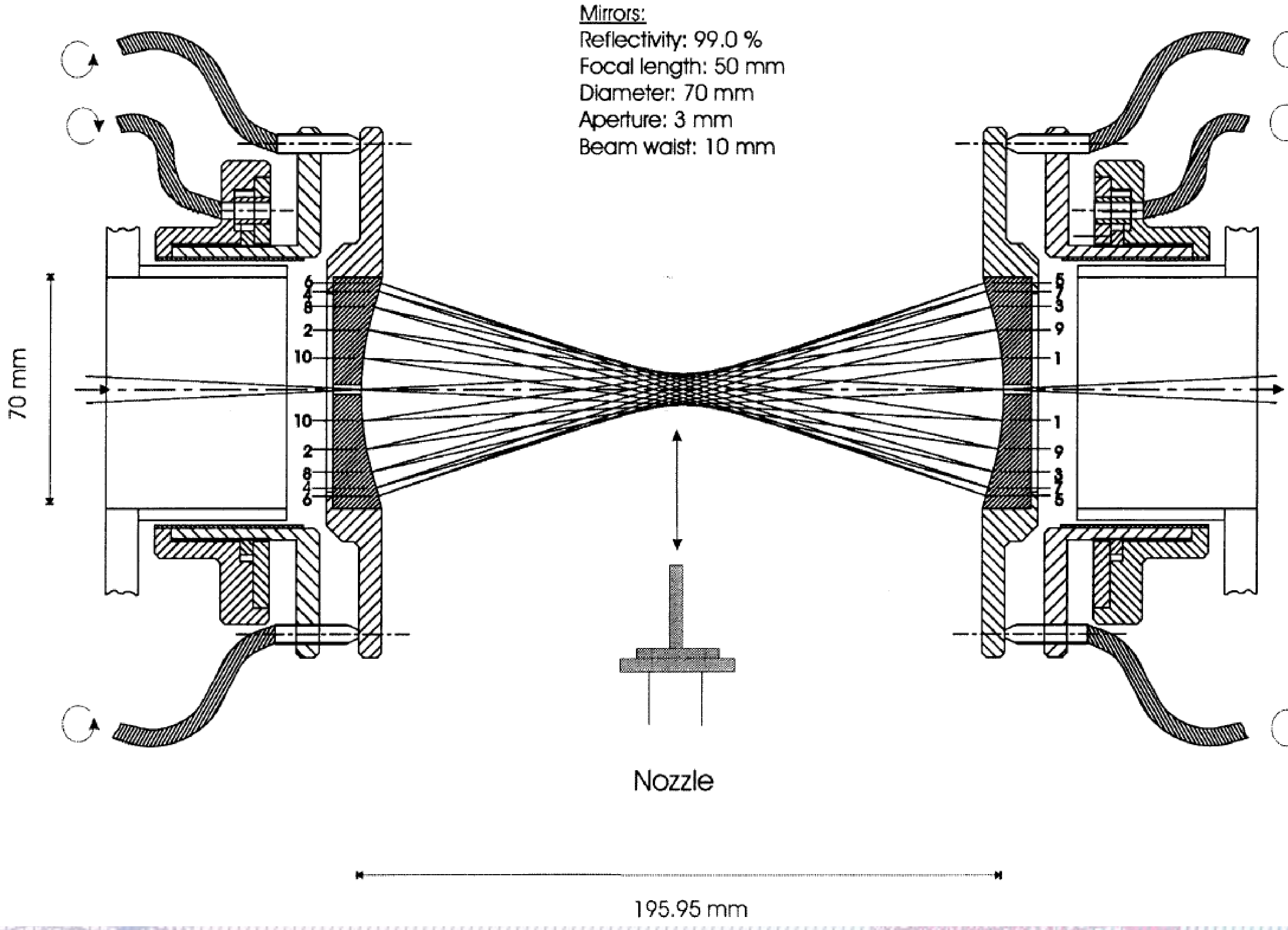
- Power supply failure: both power supplies (EVC100 and NGEFM) are unable to provide the desired current and voltage outputs to obtain high temperatures
- Solution: design our own evaporator that doesn't constantly fail and contaminate itself!
  - Thoriated tungsten electron source for e-beam evaporator doubles as a contamination source.
  - E-beam evaporator power supplies are expensive to repair and would not be able to melt some of our materials even when fixed.

# New Designs

New vacuum chamber geometry will allow for simultaneous growth of samples, measurement of sample thickness, and infrared spectroscopy.



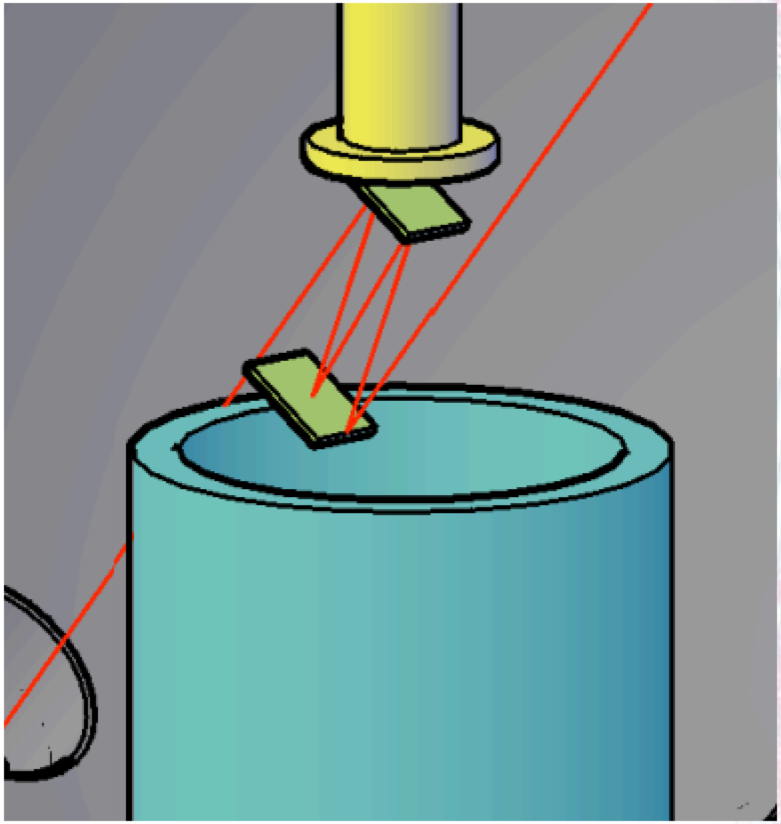
# Optical System




*R. Petry et al. / Journal of Molecular Structure 612 (2002) 369–381*

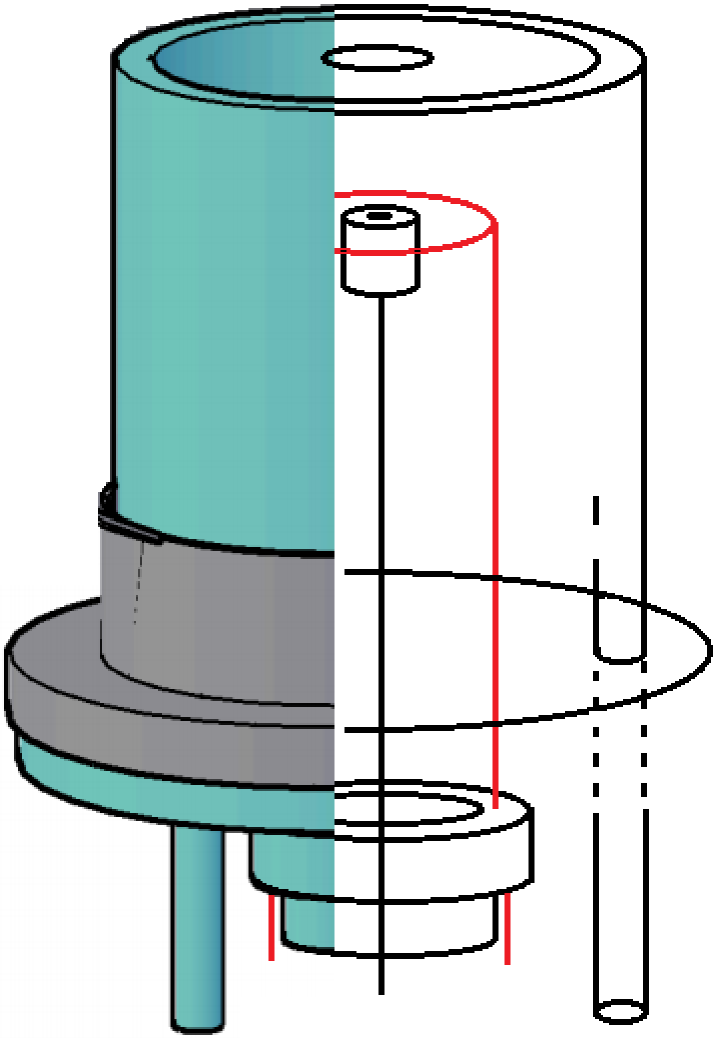
# Optical System

- Multi-pass optics to increase signal for in-beam spectroscopy.
- “Traditional” matrix isolation spectroscopy can still be done, as well.
- Still in the design phase.



# Evaporator

- Resistive heating:
  - Higher temperature range
  - More reliable
- Crucible:
  - Larger sizes possible for better volume:aperture ratio or higher flux
  - On a bottom-loading flange like previous design
- Water-cooling shroud



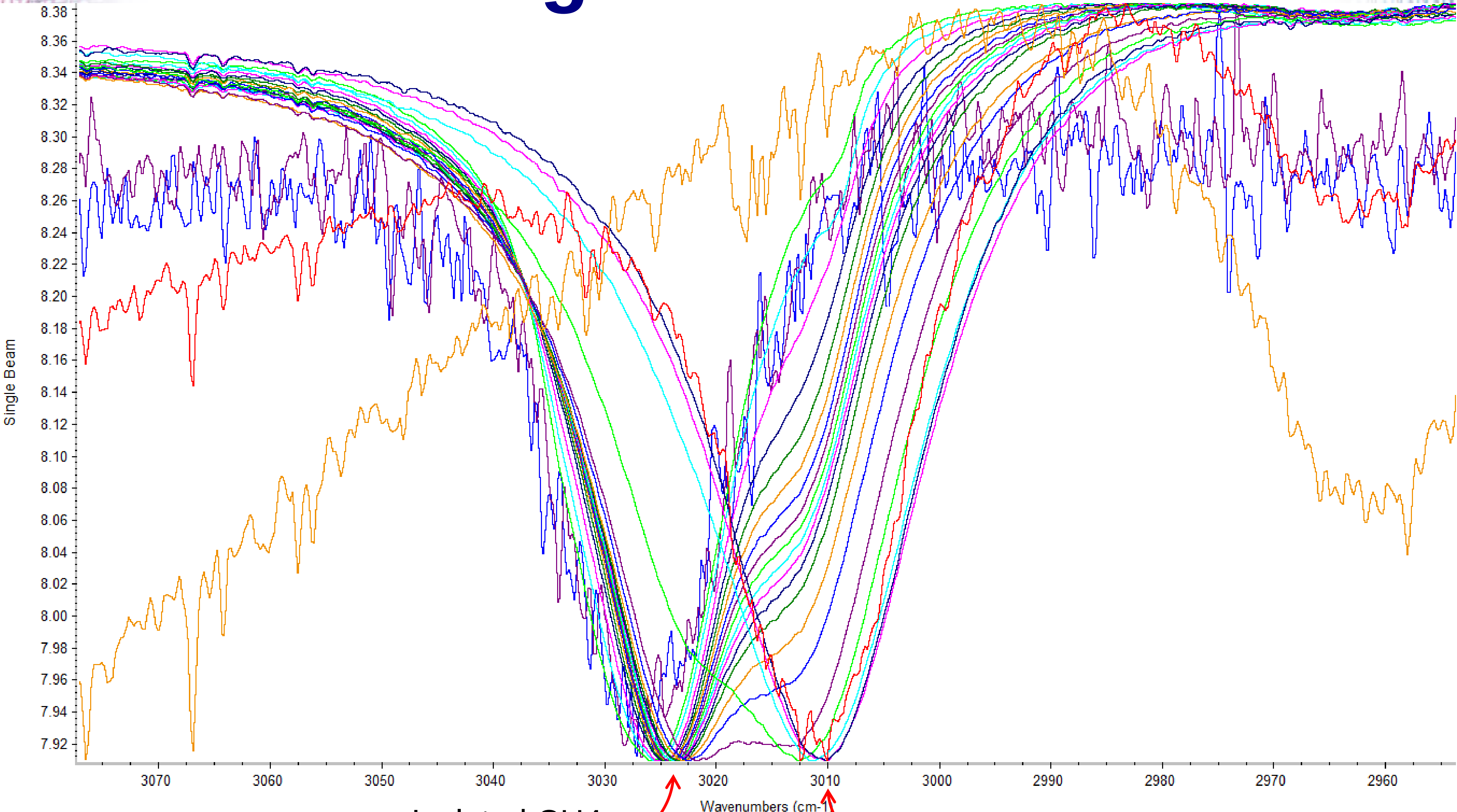
# We could use some help with...

- The problem of adding water to a rock atmosphere remains.
- Water must be same temperature as komatiite sample.
- Nate's design: inner/outer crucible... how does it work?

# Diffusion studies in Ar matrix isolation at low temperatures

- We have demonstrated that at temperatures below 18 K, no diffusion of $CH_4$ atoms takes place within an argon matrix over a period of 20+ hours, even at ratios of less than 1000:1 Ar:$CH_4$.
- Beginning at 19 K under ultra-high vacuum pressures (approx. $10^{-9}$ torr), argon atoms begin to leave the ice matrix allowing diffusion to take place.

# Temperature-correlated diffusion in argon ice matrix

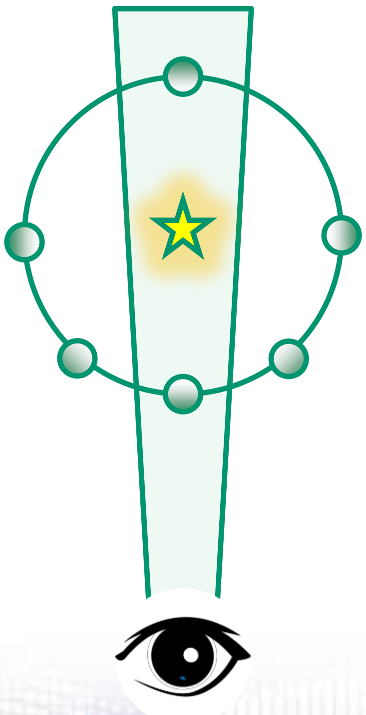


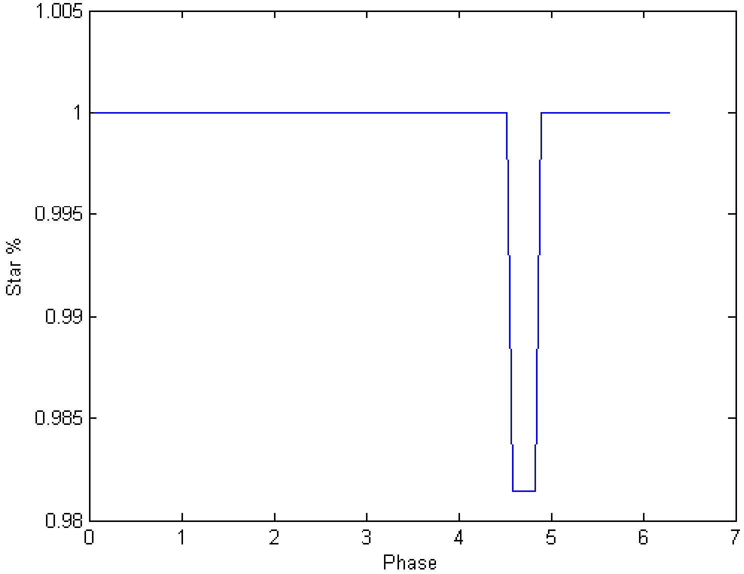

Isolated $CH_4$
T=17.75 K

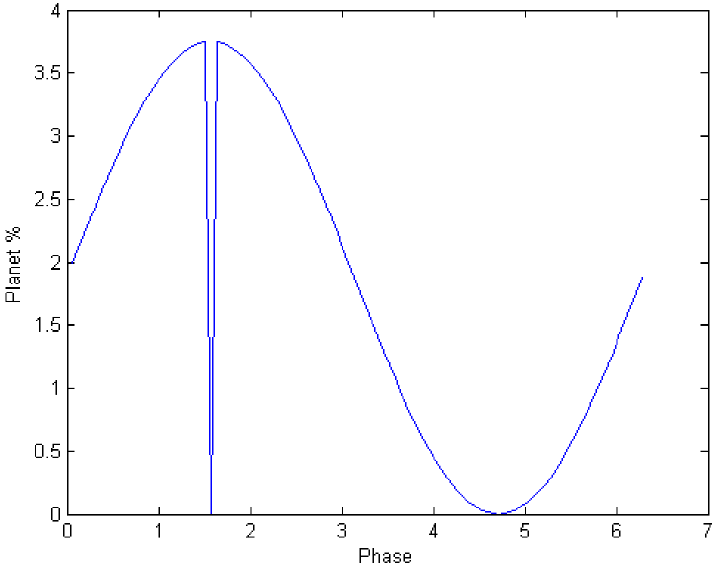
Bulk $CH_4$
T=30.5 K

# Other Work

- MATLAB code for modeling planetary atmospheres as seen by telescope CCD





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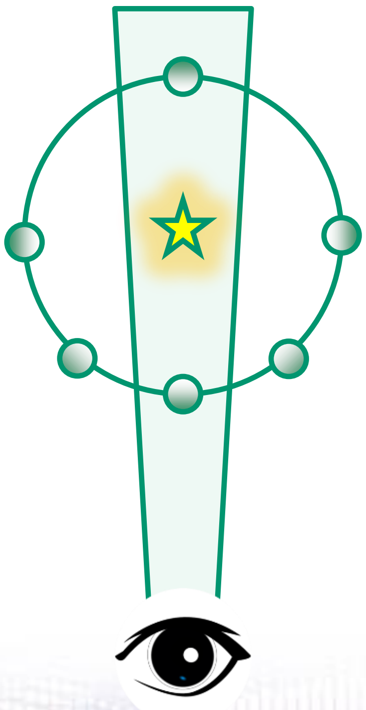

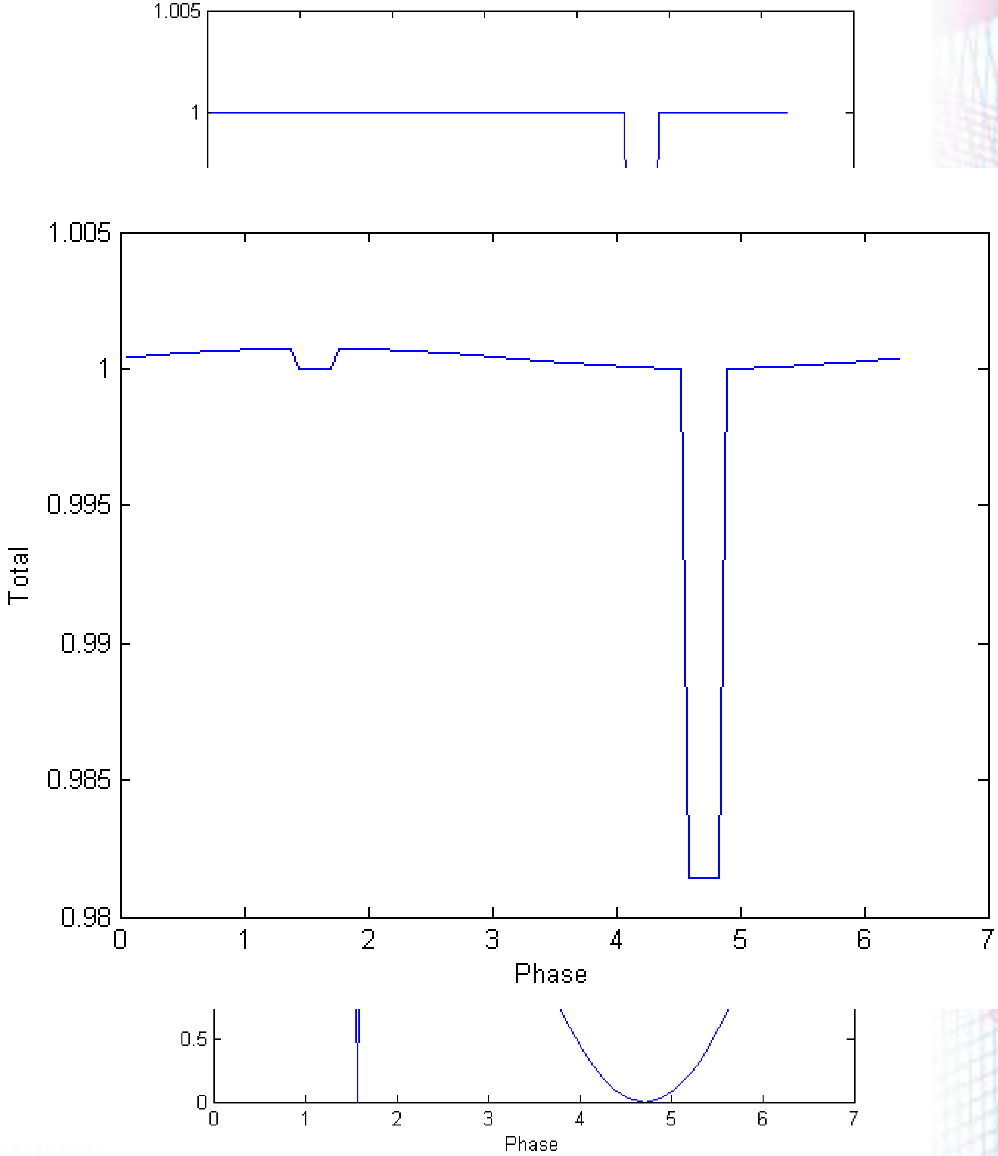

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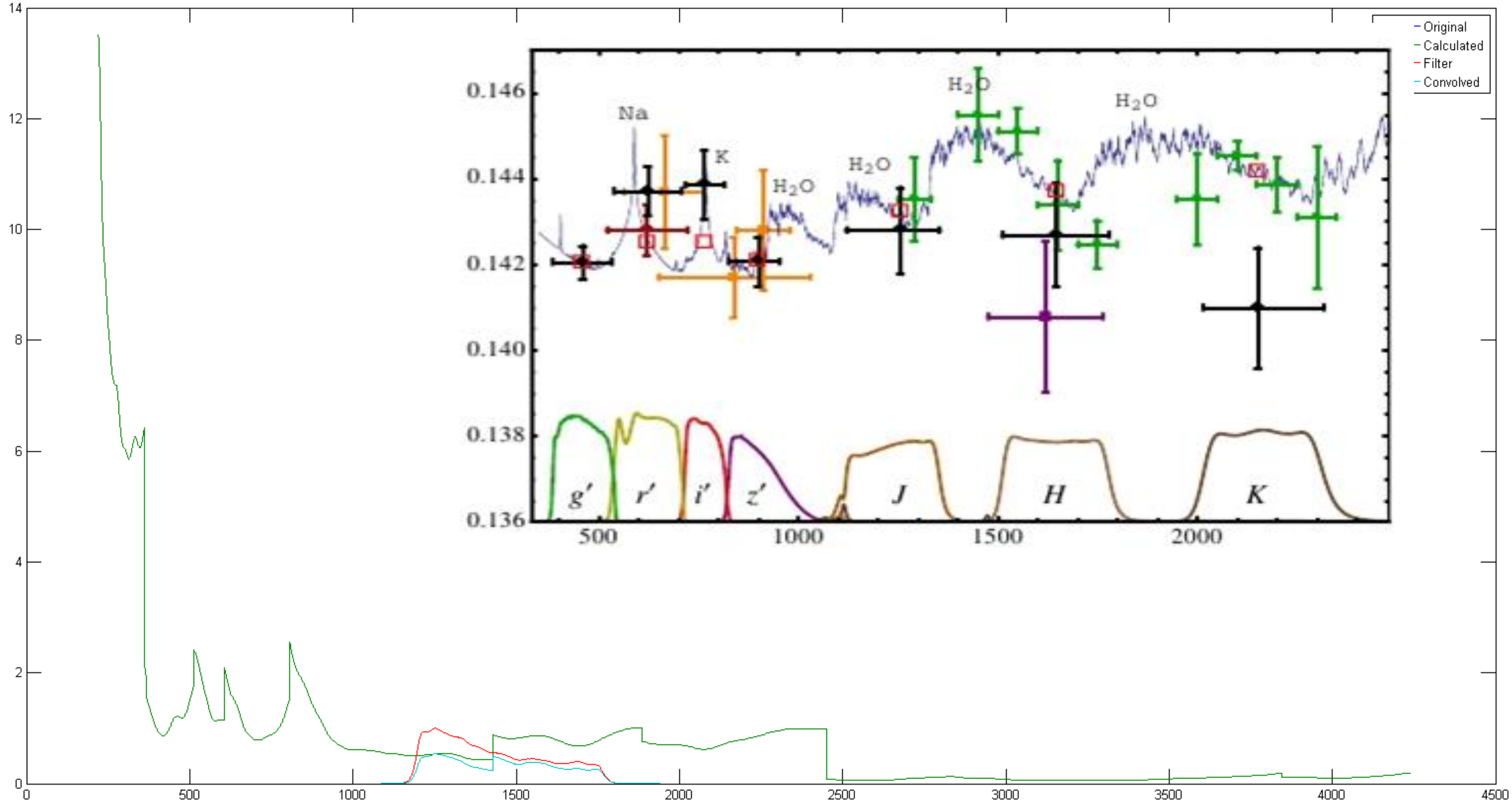


- Filters/bins modeled