

Variation of the 9.7 μm Silicate Absorption Feature with Extinction in the Dense Interstellar Medium

a.k.a. Dust in Space

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with Dr. Jean E. Chiar, SETI Institute



Senior Honor Presentation



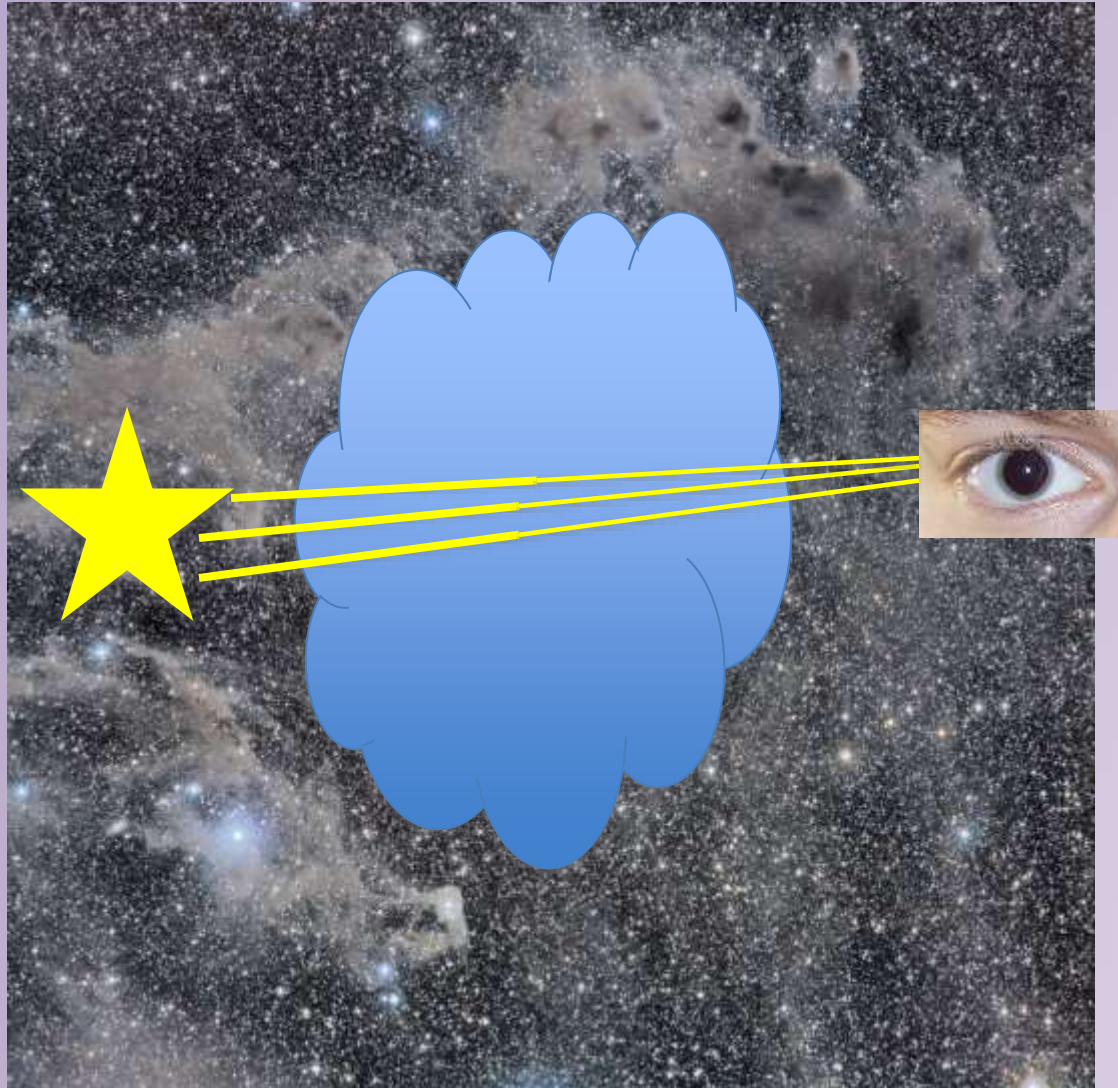
Dust in the Interstellar Medium



- Between stars, there is the interstellar medium (ISM), made up of gas and dust.
- Dust in the ISM blocks the light from distant bright objects.

Extinction is the amount of light absorbed at a given wavelength.

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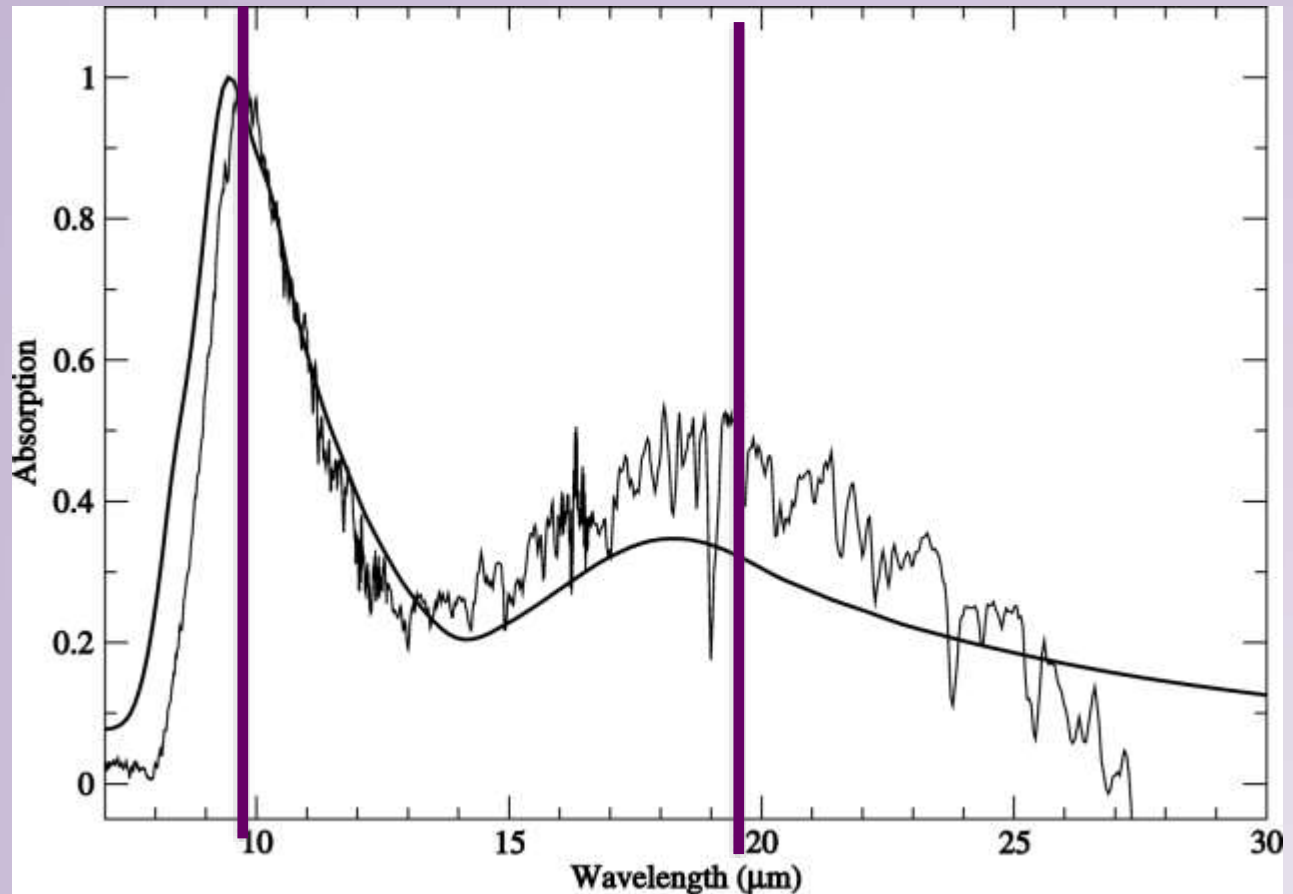
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Silicates

- Along with hydrocarbons, silicates are one of the main components of interstellar dust.
- Silicates produce infrared absorption features at 9.7 and 20 μm .



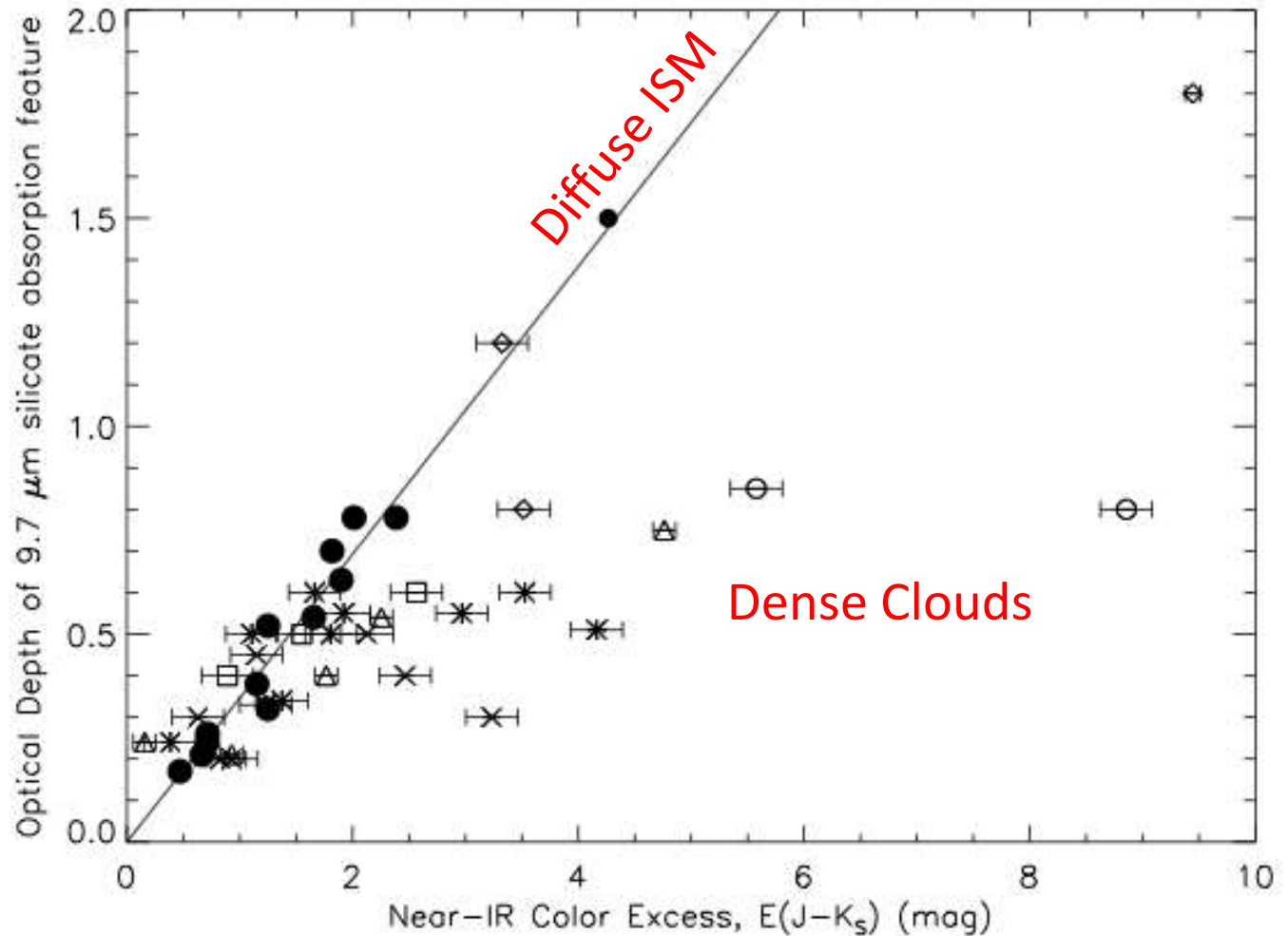
Some Earth silicates



Diffuse versus Dense ISM

The maximum absorption at $9.7\ \mu\text{m}$ gives the strength of the silicate feature.

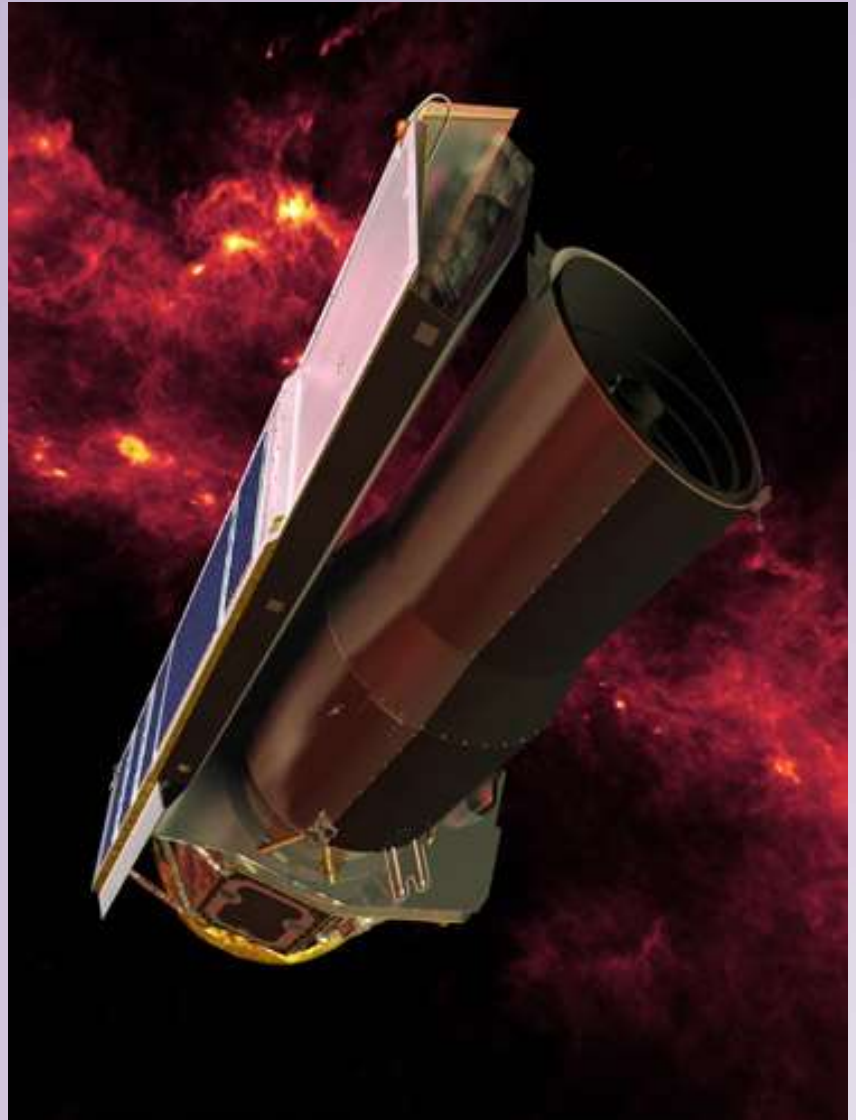
In the diffuse ISM, the dust is well-mixed, but in the dense ISM, grains may be coagulating.



Near-infrared color excess traces the carbonaceous dust.

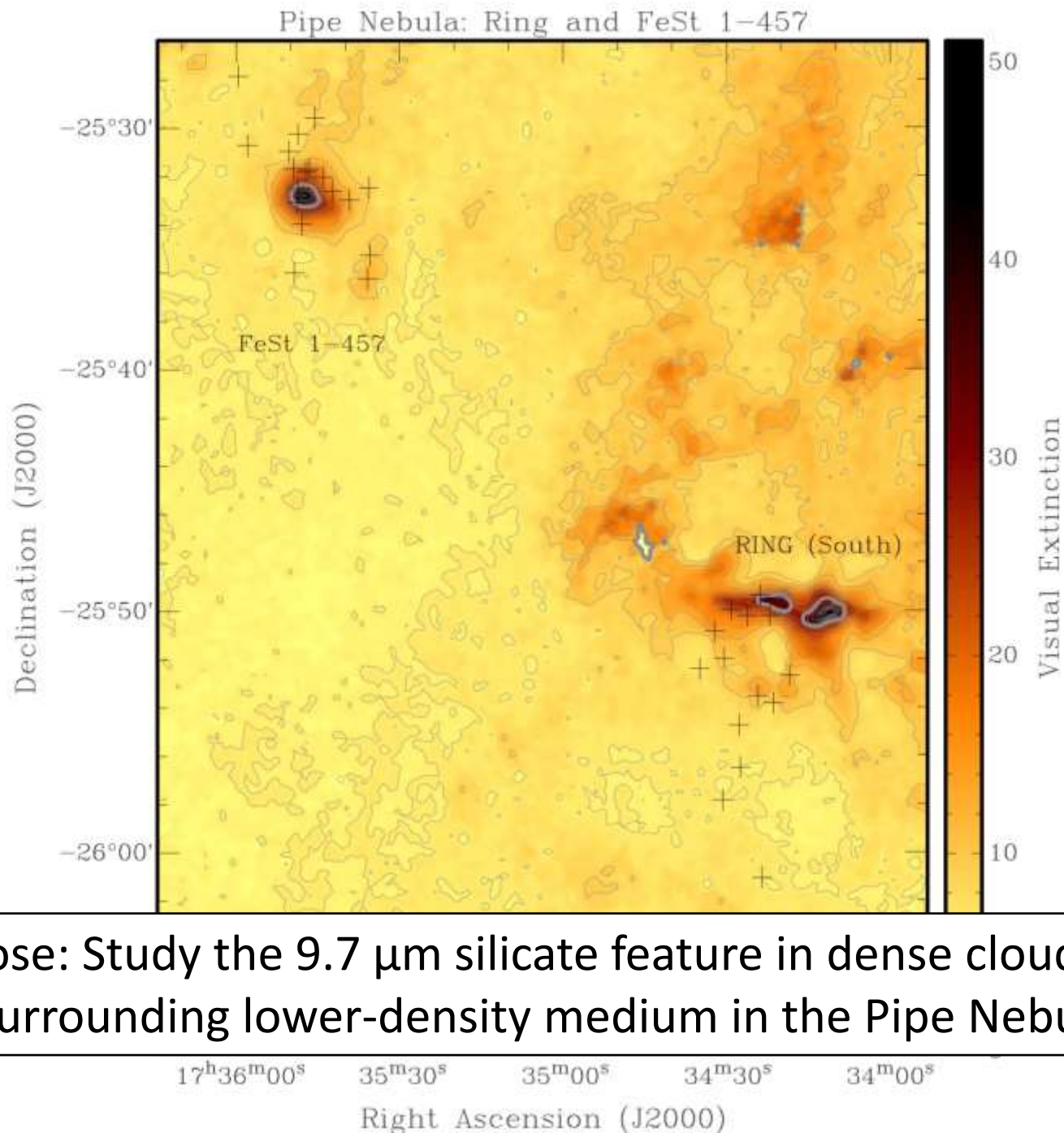
The *Spitzer* Space Telescope

- Infrared observations from the ground are limited by atmospheric absorption.
- *Spitzer's* unprecedented sensitivity allows us to observe stars behind very dense clouds.
- The Infrared Spectrograph (IRS) captures spectra from 5.2 - 38 μm .



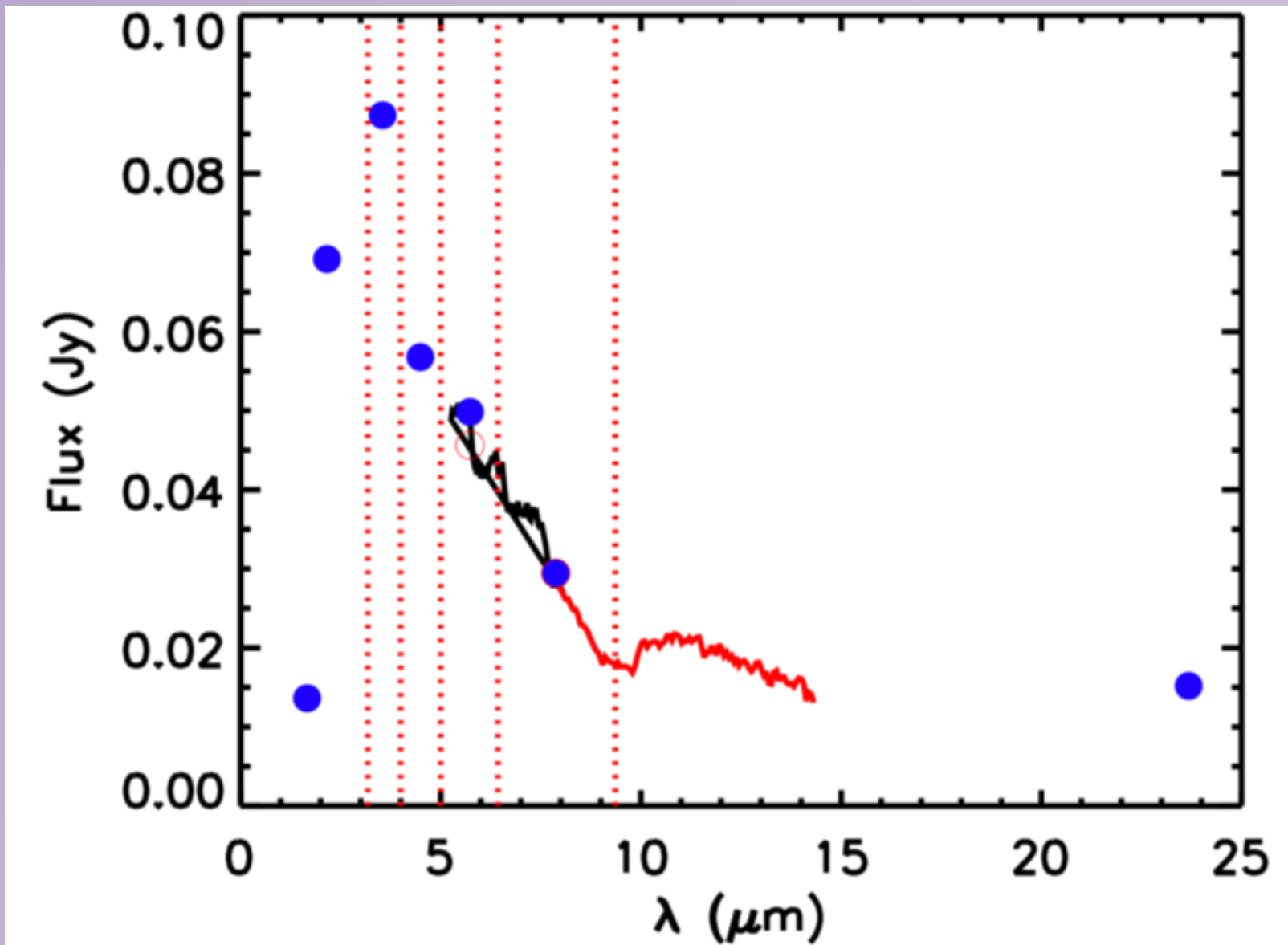
The Pipe Nebula





Purpose: Study the $9.7 \mu\text{m}$ silicate feature in dense cloud cores and surrounding lower-density medium in the Pipe Nebula.

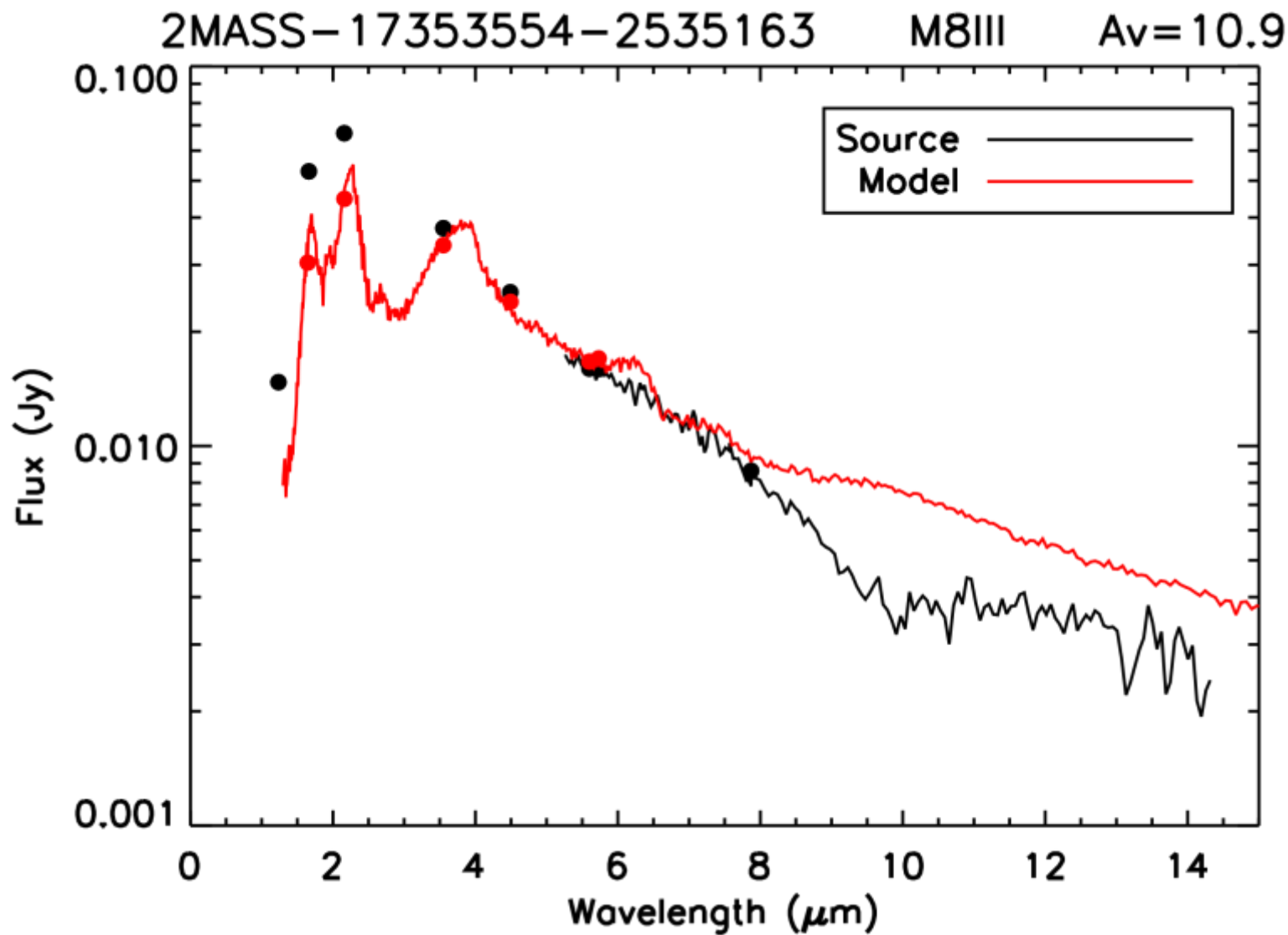
Reduced Spectra: What I Started With



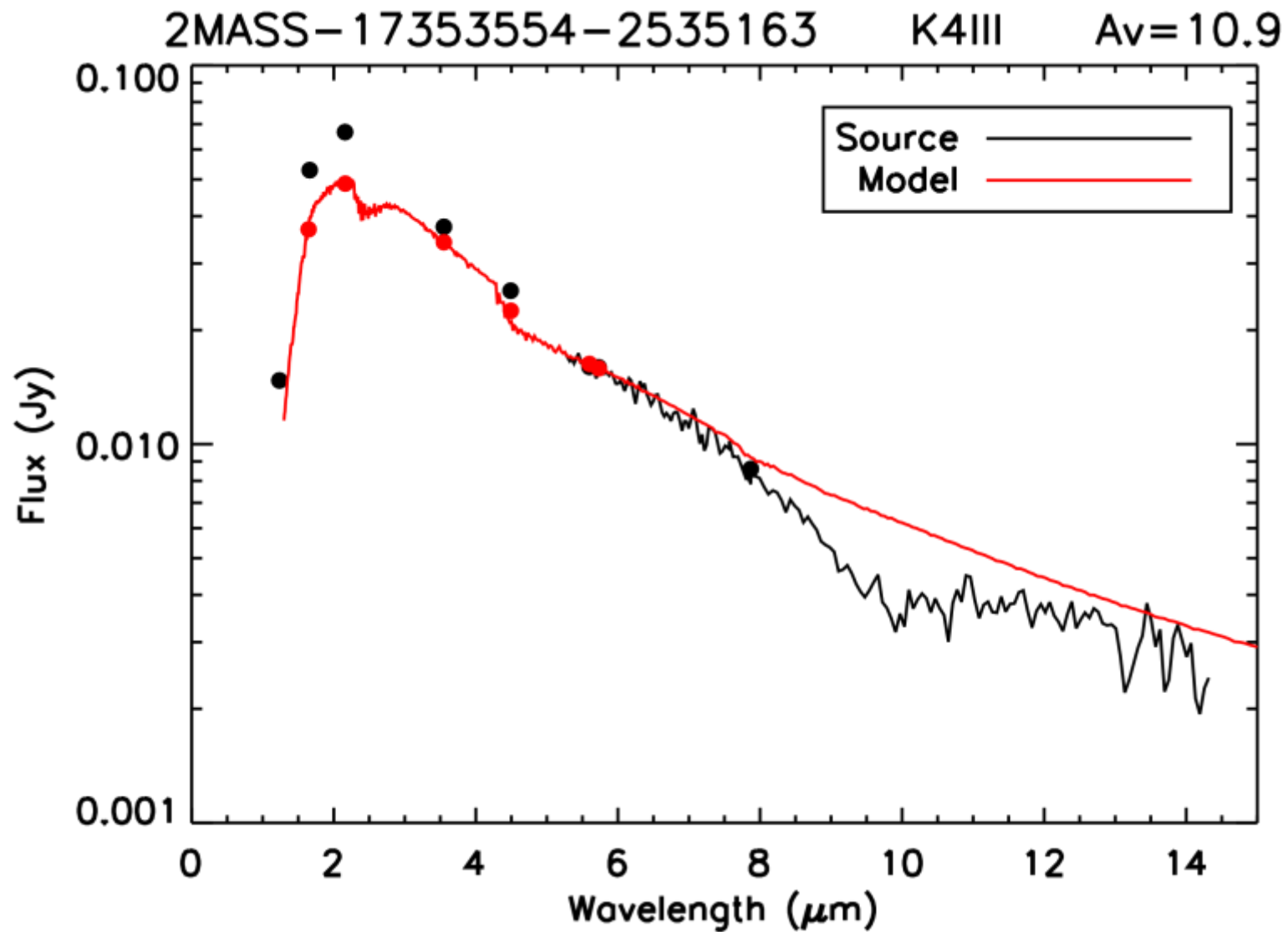
Fitting Stellar Photosphere Models

- Why fit models of starlight?
 - To remove the characteristics of the background source from the spectrum we study.
- Parameters to fit:
 - Spectral type
 - A_V (visual extinction)
 - Extinction law (converts A_V into extinction at infrared wavelengths).

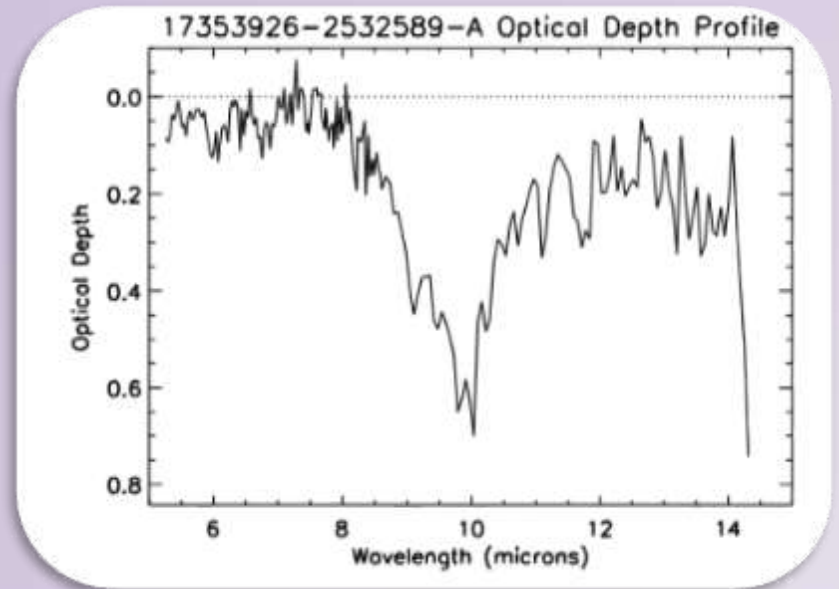
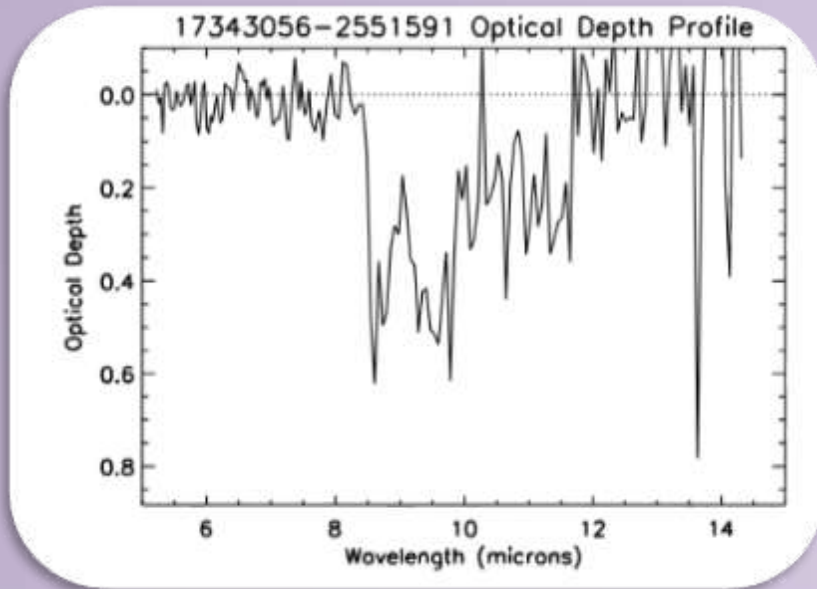
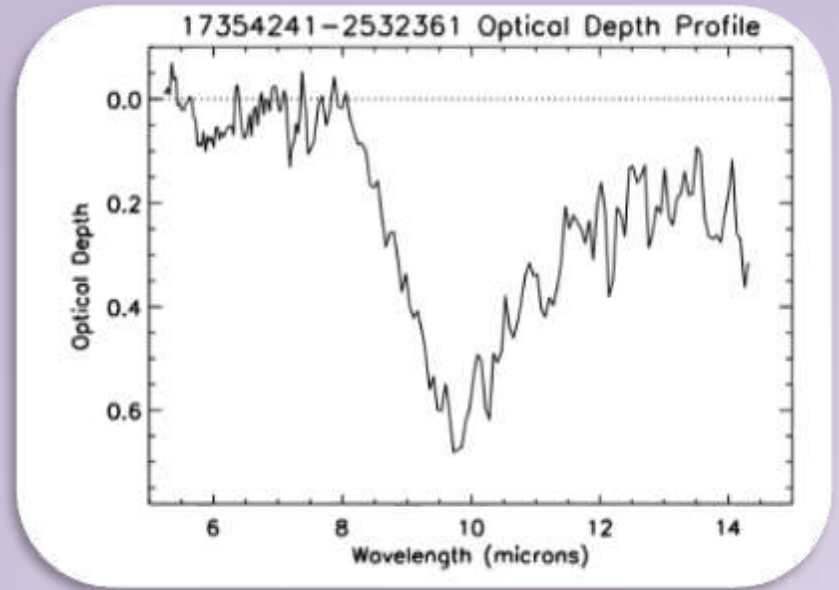
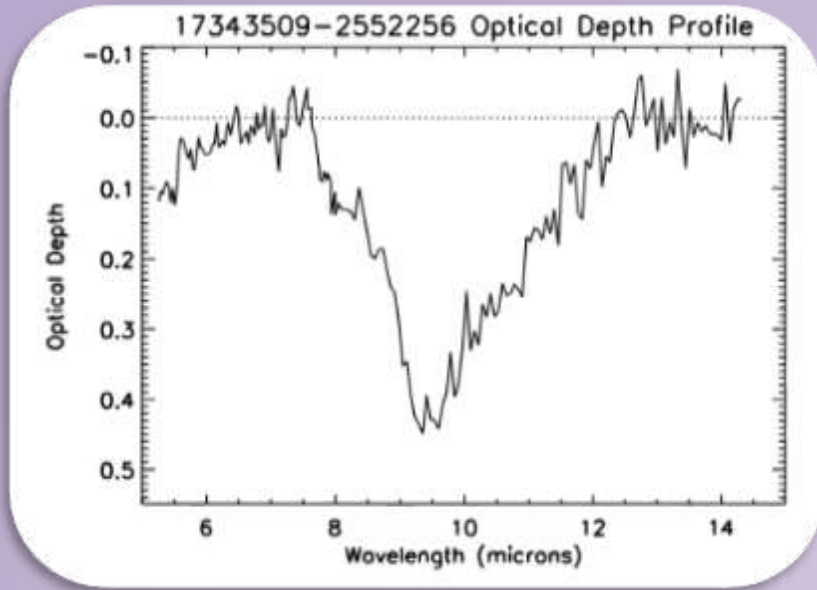
Fitting Stellar Photosphere Models



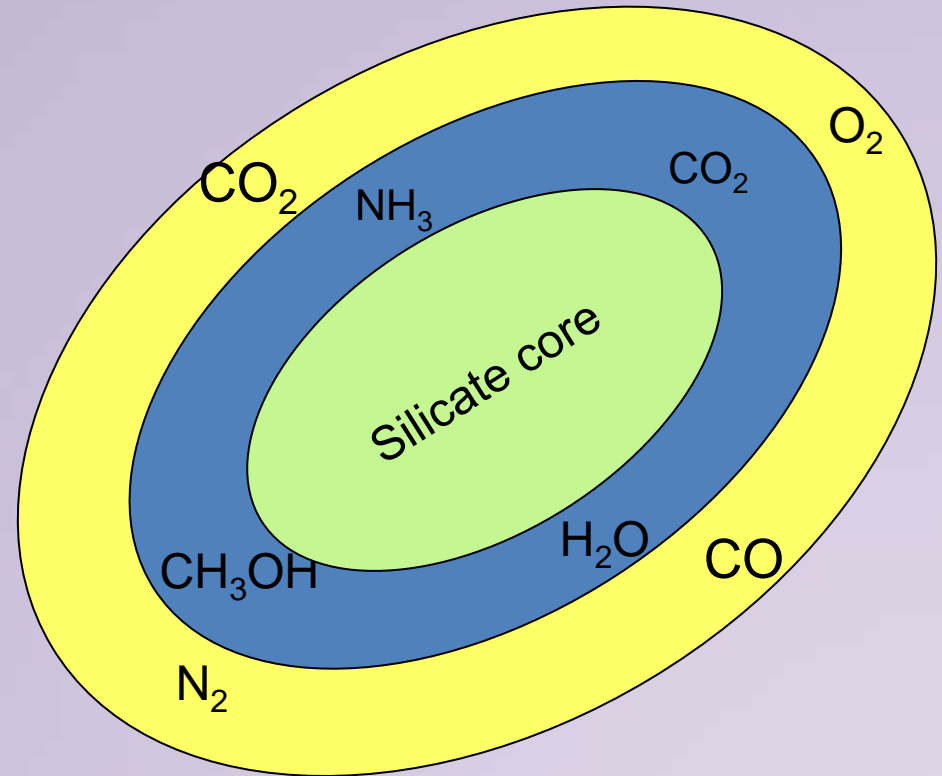
Fitting Stellar Photosphere Models



Examples of Optical Depth Profiles

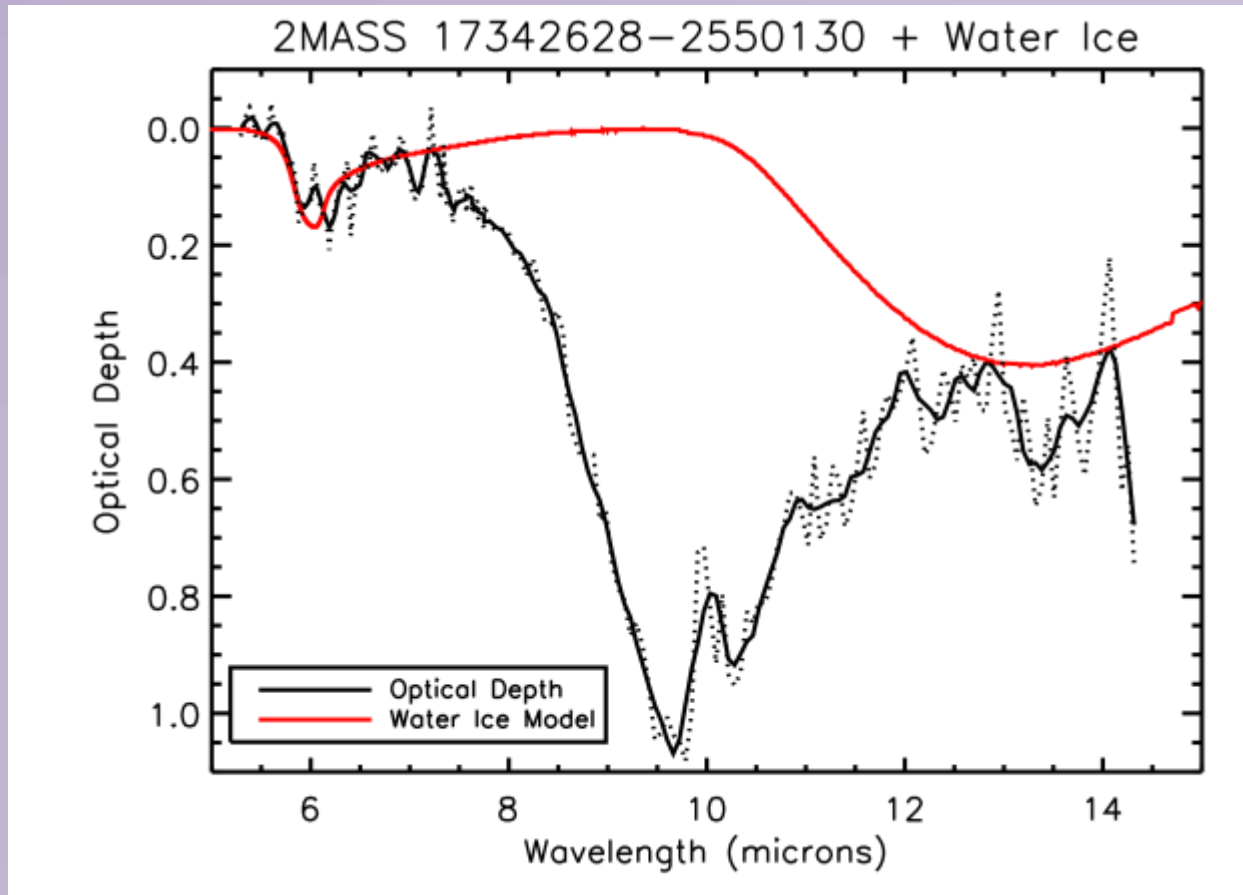


Absorption by Water Ice



- The absorption by water ice at $12\ \mu\text{m}$ can affect the long-wavelength side of the silicate feature, so the water ice contribution was subtracted.

Absorption by Water Ice

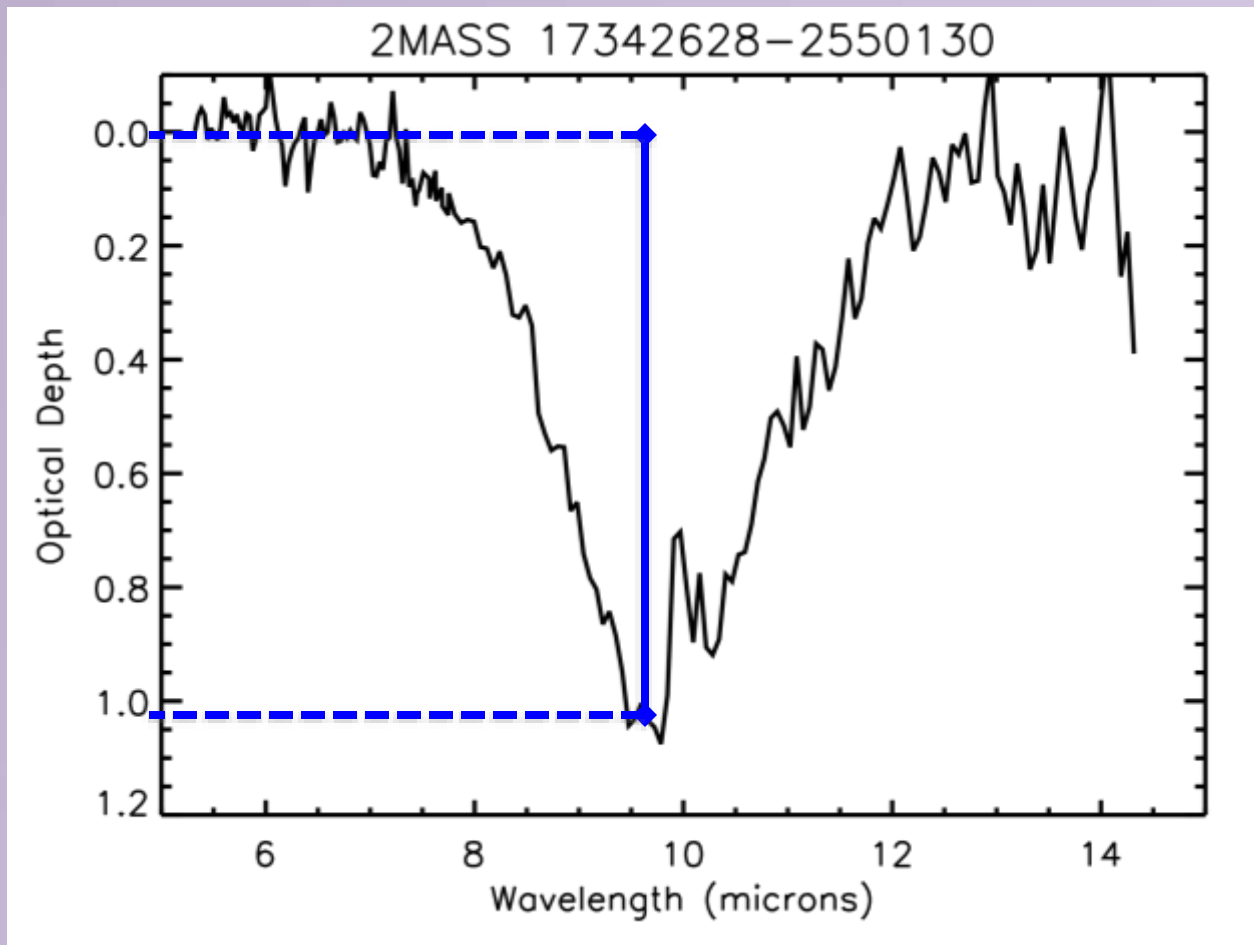


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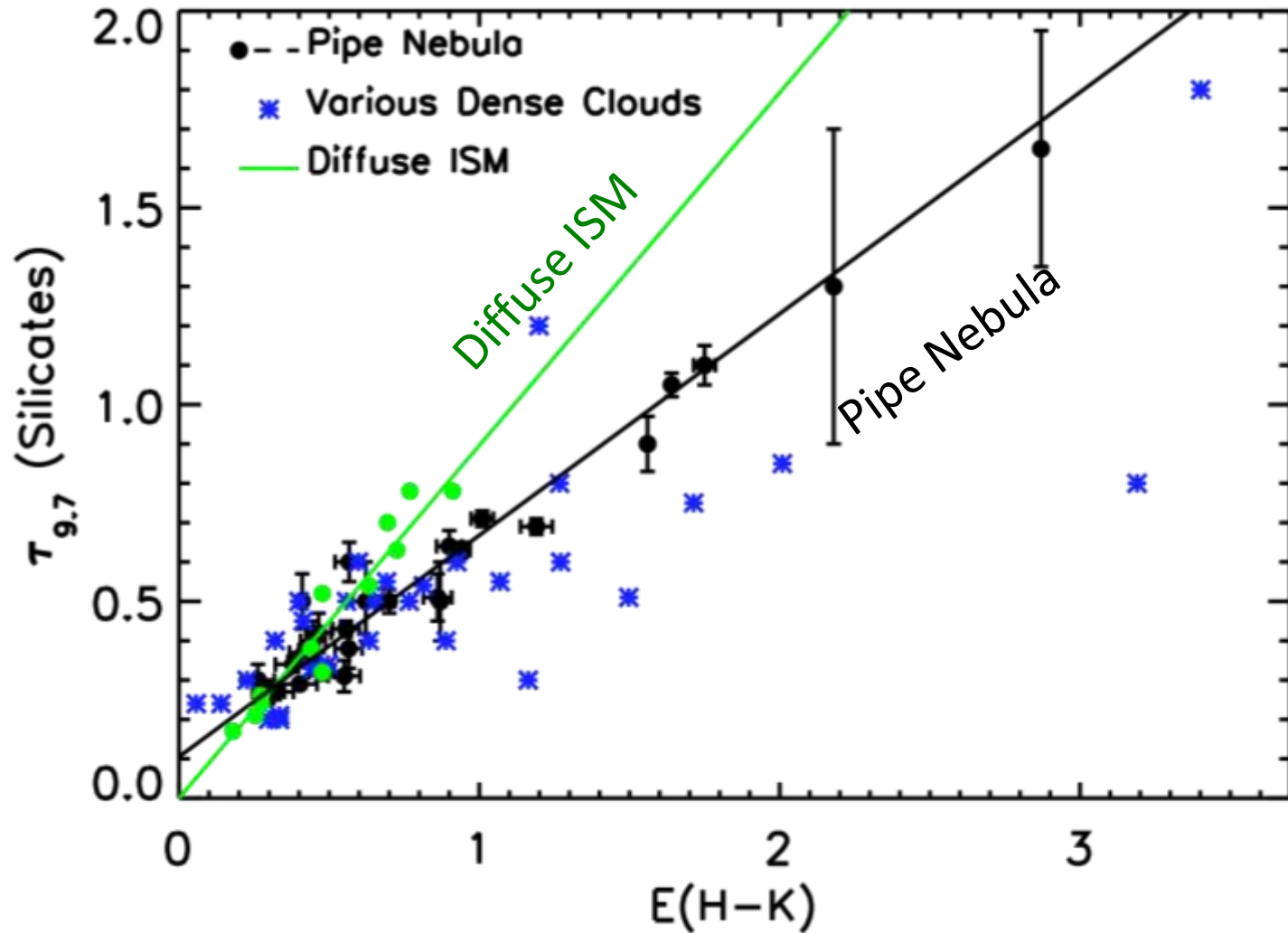
Estimating $\tau_{9.7}$

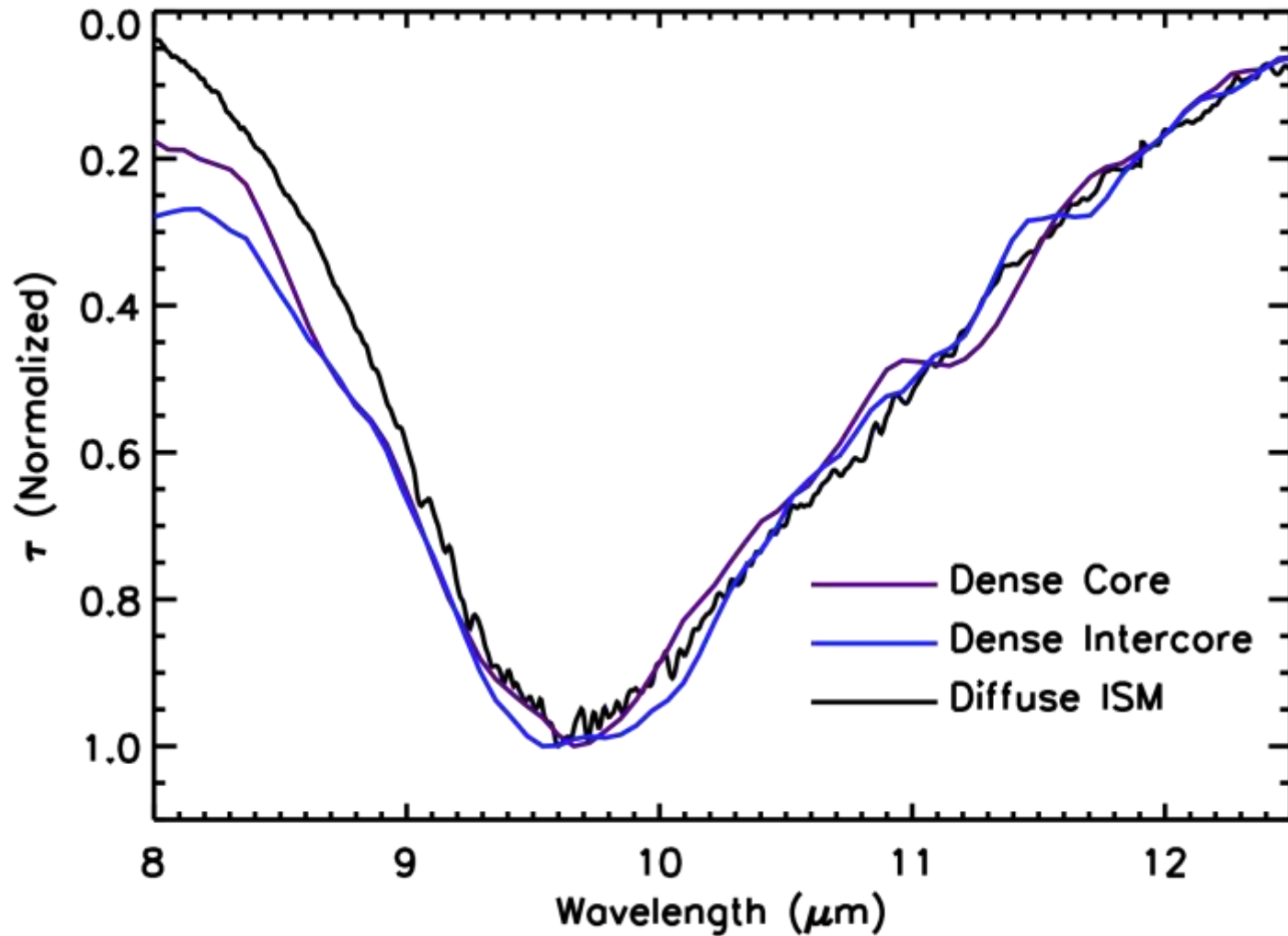
$$\tau = -\ln(\text{observed flux} / \text{model continuum flux})$$

- $\tau_{9.7}$ is the maximum optical depth of the silicate feature.



Optical Depth versus Extinction

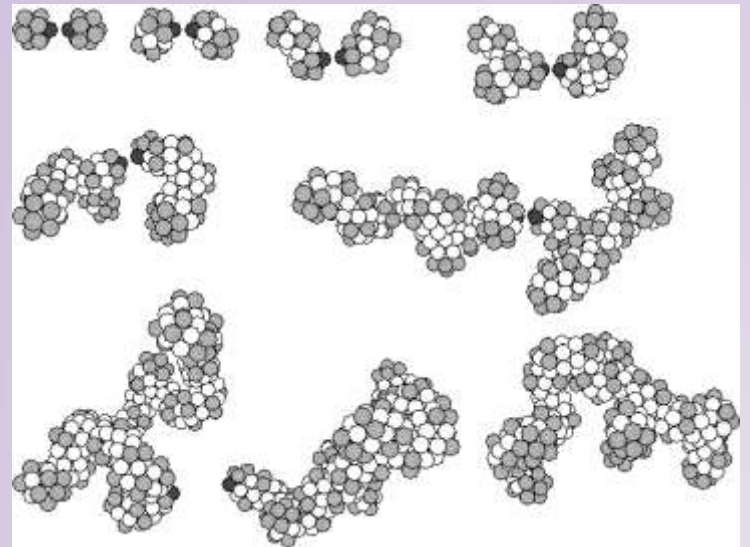




Changes in the Silicate Absorption Profile

Conclusions

- Thus far, we see what is expected: the tight relationship between $\tau_{9.7}$ and extinction that is seen in the diffuse ISM breaks down at higher values of extinction in dense clouds.
- We also see changes in the shape of the silicate absorption profile in dense clouds.
- These indicate changes in dust properties, particularly due to grain coagulation.



Future Work

- We will be getting observations of 1-5 μm spectra on the Very Large Telescope in Chile.



Image Credits

Slide 1: Gleason, John, & Mandel, Steve. "Rho Ophiuchi and the Pipe Nebula."
<http://www.celestialimage.com/page2.html>

Slide 2: Kuznetov, Andrey. "The Chameleon's Dark Nebulae." Astronomy Picture of the Day, 15 July 2009. <http://apod.nasa.gov/apod/ap090715.html>

Slide 4: Weller, R. "Olivine Photos." Cochise College, 2008.
<http://skywalker.cochise.edu/wellerr/mineral/olivine/olivineL.htm>
Mattox, Steve. "Common Minerals in Volcanic Rocks."
<http://volcano.oregonstate.edu/vwdocs/vwlessons/rocks2.html>

Slide 6: NASA/JPL. "Infrared View of Spitzer."
http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=SIRTF_ir_

Slide 7: Betelsky, Yuri. "The Pipe Nebula."
<http://www.astronomy.com/asy/default.aspx?c=pod&id=186&aid=8424>

Slide 10: "Red Giants." <http://cse.ssl.berkeley.edu/bmendez/ay10/2000/cycle/redgiant.html>

Slide 16: <http://carol.gimp.org/writing/images/cherries.php>

Slide 21: Wright, E. L. "Fractal Dust Grains." 10 May 1999. <http://www.astro.ucla.edu/~wright/dust/>

Slide 22: "The VLT Platform at Paranal." 21 Jan 2009.
<http://www.eso.org/gallery/v/ESOPIA/Paranal/phot-33k-01-normal.jpg.html>

References

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Questions?