The Department of Physical Sciences presents

MacEwan

INTERSTELLAR DUST AND OTHER STUFF

WHAT'S IT MADE OF?

HAVE YOU EVER WONDERED HOW YOU CAME TO BE?

This talk will discuss the details of one small piece of the puzzle: knowing the current composition of the galaxy around us.

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Deptartment of Physical Sciences,
MacEwan University

MONDAY, MARCH 19
3–4 p.m.
5-142 (CN Theatre)

A long time ago in a galaxy far, far away….

[er… actually the process is still happening and in many galaxies, including our own]

… interstellar gas and dust were created.

Interstellar Dust and Other Stuff: What's it made of?

Research done in collaboration with:

- Geoffrey C. Clayton (Louisiana State University)
- James T. Lauroesch (University of Louisville)
- David M. Meyer (Northwestern University)
- U.J. Sofia (American University)



Image Credit: Digitized Sky Survey (NASA/ESA/AURA/Caltech)

Who Cares?:

We want to know how to build stars and planets, even galaxies: ie. how we got here.

- Big Bang Nucleosynthesis (making of elements) tells us what ingredients we have to start. **[PHYS 320]**
- Galactic Chemical Evolution models require we know the current conditions.
  - Stellar nucleosynthetic products **[PHYS 320]**
  - Mixing within galaxies
- Using observed gas-phase interstellar abundances and dust composition models, we can figure out a reliable cosmic abundance standard for right now.

Different stellar standards:

- Look at the Sun
  - 4.5 Gyr old
- Look at young F+G stars
  - < 2 Gyr old
- Look at B stars
  - < 0.1 Gyr old

Result: No simple interpretation.

Element	Sun	F+G	B
C/H * 10^6	391	358	190
O/H * 10^6	545	445	350

=> Measure abundances in ISM directly

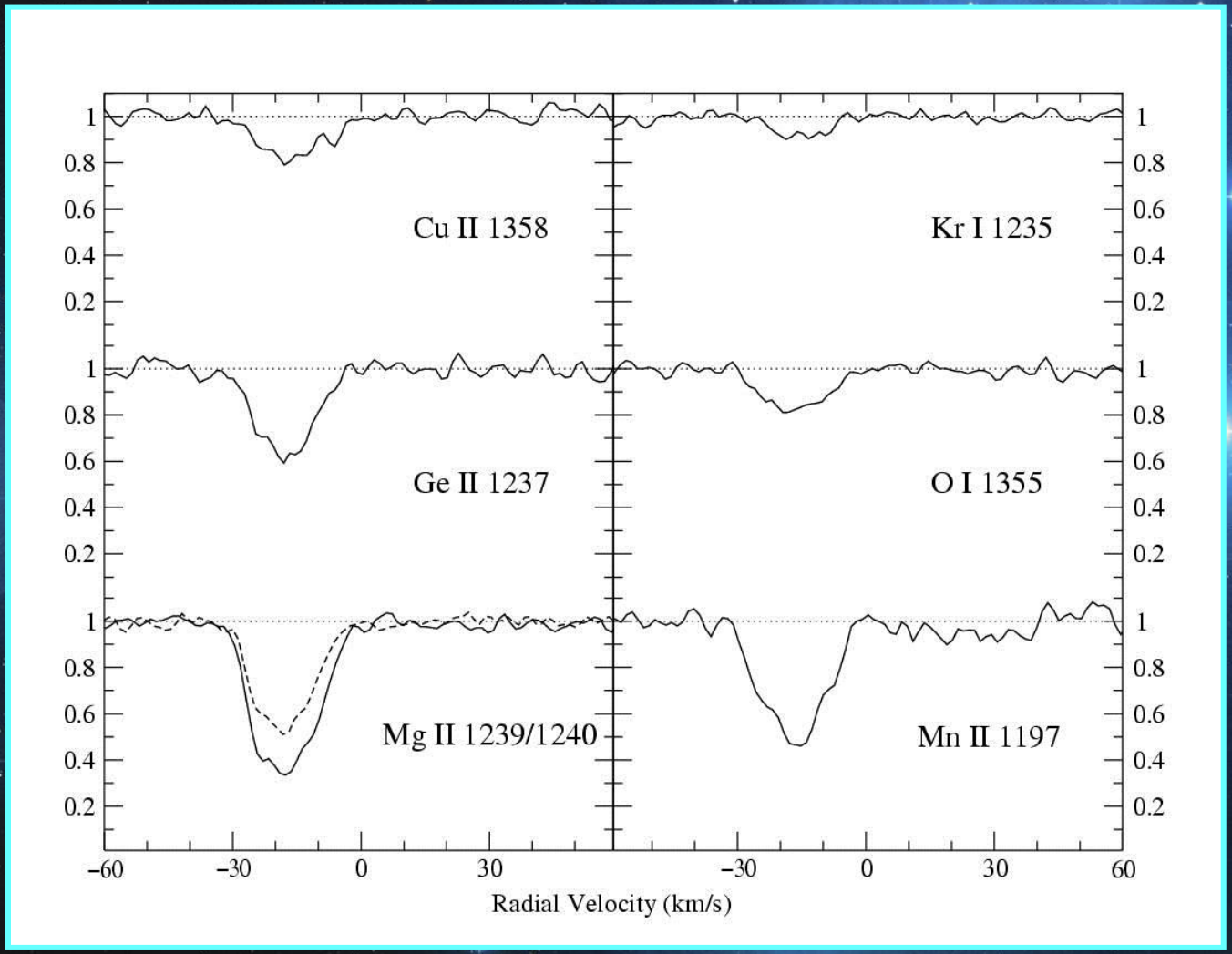
The ISM is complicated:

- Multiple environments coexist.
- Each environment contains both gas *and* dust, but the balance varies.
- Dust elemental abundances are not easy to assess, we are left with gas-phase probes only.
- We are forced to determine reliable gas-phase abundances and extrapolate the cosmic reference level.

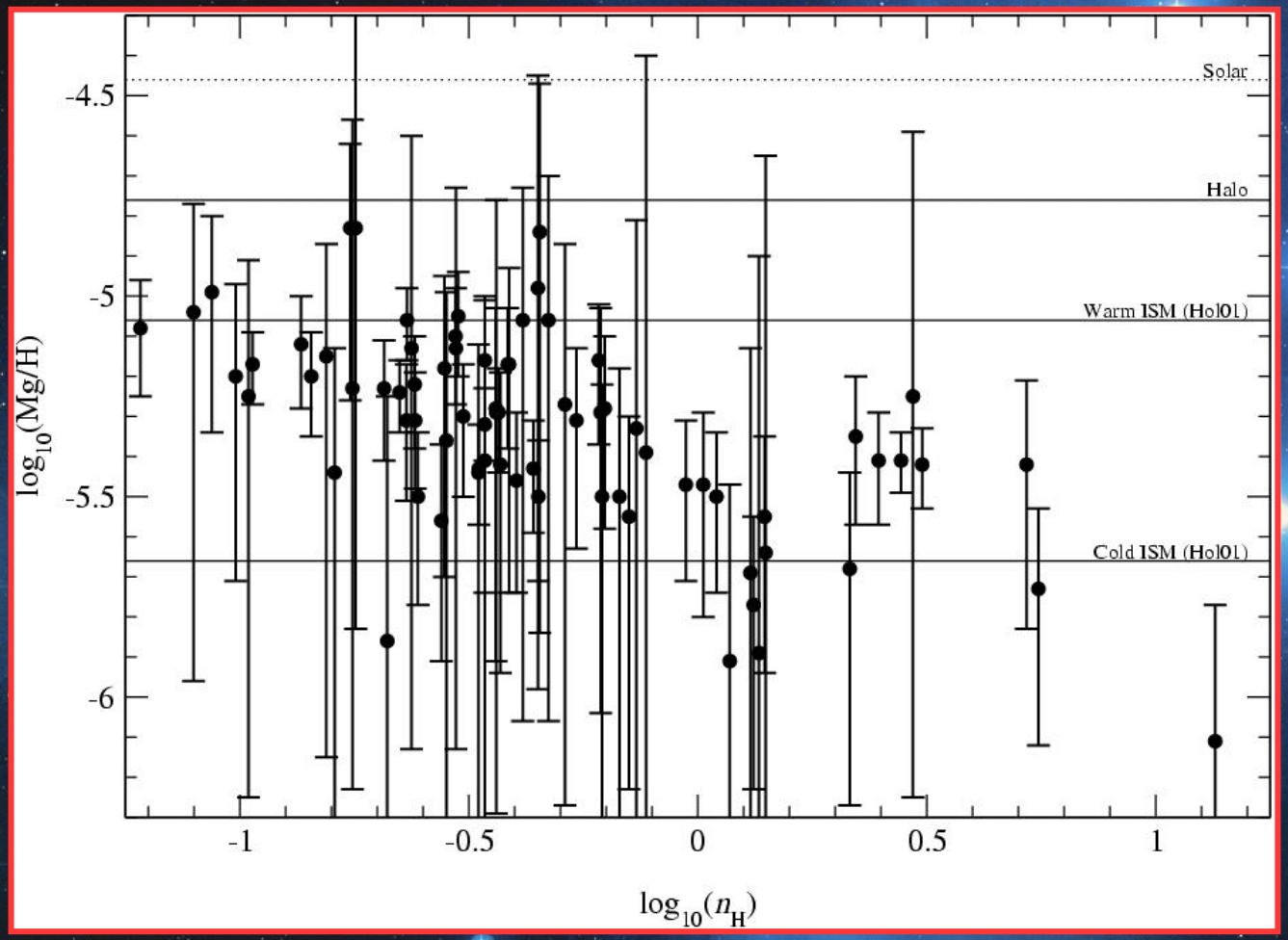
Schematic for Probing the ISM :



Spectral Profiles (HD208440)



Copernicus-based ISM Abundances



Hubble instruments do much better!

Items to remember:

1. $\langle n_H \rangle$ = (total hydrogen abundance)/(distance to star)

   This quantity is the basis for distinguishing sight line environments; basically it is the average density along the sight line.

2. A reliable set of cosmic abundances requires that the abundance variation be small for each element.

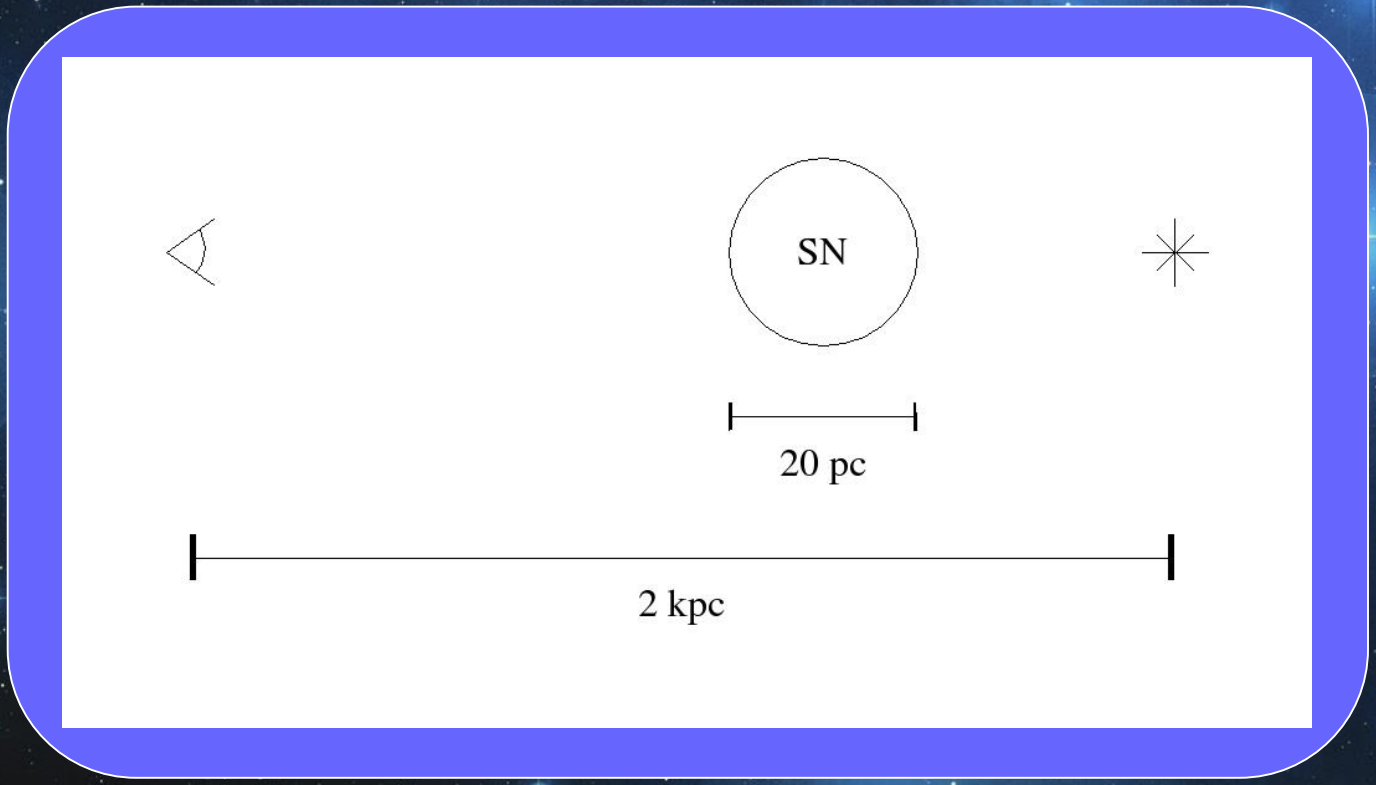
Additional motivation:

Is the ISM uniform enough to detect the affects on elemental abundances of various interstellar processes?

- Enrichment by stellar evolution
- Enrichment by supernovae

Enrichment by Supernovae

Assumptions: dust, isotropic gas dispersal, $N(H) = 10^{21}$ cm^{-2}



Abundance Changes due to SNe

Element	Total Dust Disruption		SN Ia Effect		SN Ib Effect		SN II Effect	
C	1.9%	0.008	0.0%	0.000	53.1%	0.185	4.7%	0.020
N	0.0%	0.000	0.0%	0.000	0.0%	0.000	7.2%	0.030
O	0.7%	0.003	0.9%	0.004	21.6%	0.085	52.1%	0.182
Mg	31.2%	0.118	1.2%	0.005	2.8%	0.012	32.1%	0.121
Si	18.9%	0.075	9.4%	0.039	10.4%	0.043	38.4%	0.141
S	0.0%	0.000	8.4%	0.035	9.9%	0.041	25.0%	0.097
Mn	27.1%	0.104	22.5%	0.088	0.0%	0.000	16.1%	0.065
Fe	185.1%	0.455	28.2%	0.108	9.4%	0.039	30.0%	0.114
Ni	548.6%	0.812	18.3%	0.073	0.0%	0.000	35.8%	0.133

Additional motivation:

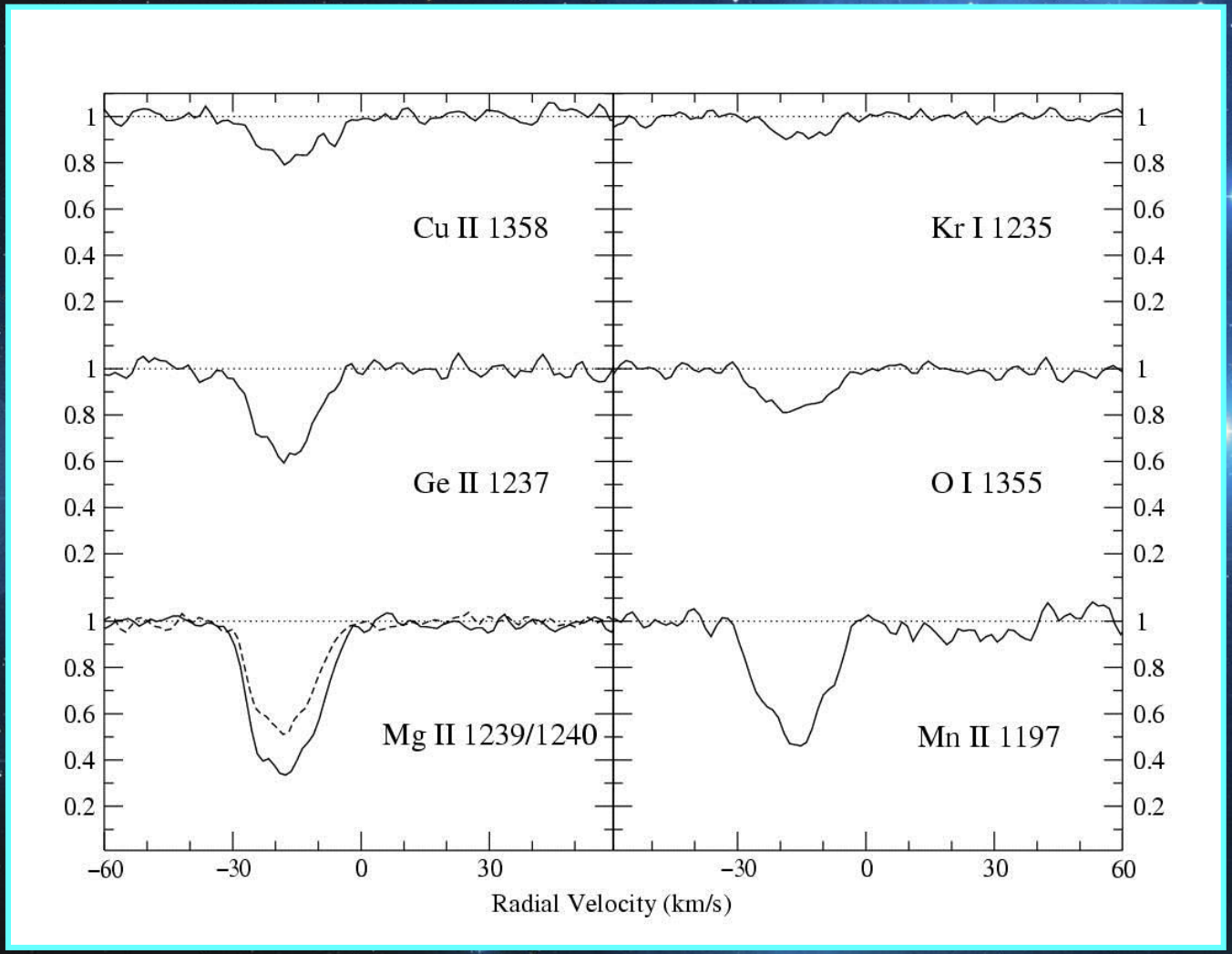
Is the ISM uniform enough to detect the affects on elemental abundances of various interstellar processes?

- Enrichment by stellar evolution
- Enrichment by supernovae
- Infall onto the Galactic disk

How do we determine a functional dependence for ISM gas-phase abundances?

- Acquire very high resolution UV spectra of bright stars whose sight lines are diverse in character.

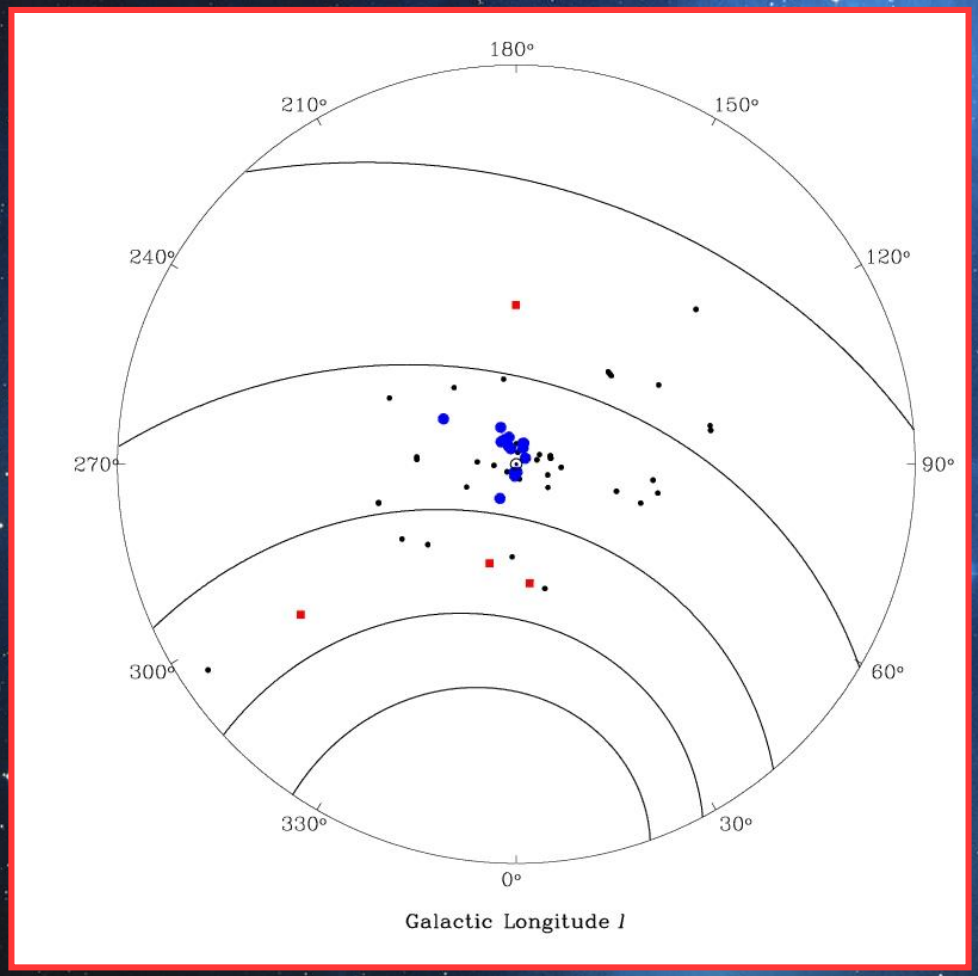
Spectral Profiles (HD208440)



The Sight Line Sample

- SNAPSHOT Survey I – (GO8241; PI Lauroesch)
  - Designed to survey paths with diverse characteristics in 360s, 720s, and 1440s.
  - 30 sight lines
- SNAPSHOT Survey II – (GO8662; PI Lauroesch)
  - Designed to survey hot gas along Galactic paths in 360s, 720s, and 1440s.
  - 11 sight lines
- Translucent ISM Study – (GO8273; PI Meyer)
  - Designed to study oxygen depletion along translucent ISM sight lines.
  - 6 sight lines
- Additional Paths – (e.g., GO9855; PI Cartledge)
  - Designed to investigate krypton abundance fluctuations on kpc scales.
  - 4 sight lines

Layout in the Galaxy



How do we determine a functional dependence for ISM gas-phase abundances?

- Acquire very high resolution UV spectra of bright stars whose sight lines are diverse in character.
- Measure column densities for each element detected toward each star.
  - Apparent Optical Depth
  - Profile-fitting

Apparent Optical Depth Method

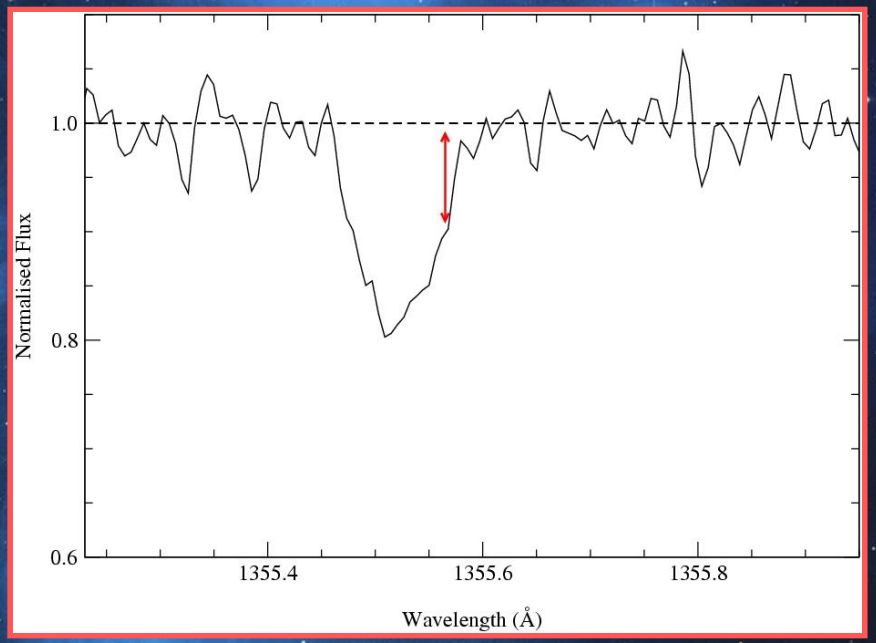
Optical Depth:

$$I(\lambda) = I_0(\lambda)\, e^{[-\tau(\lambda)]}$$

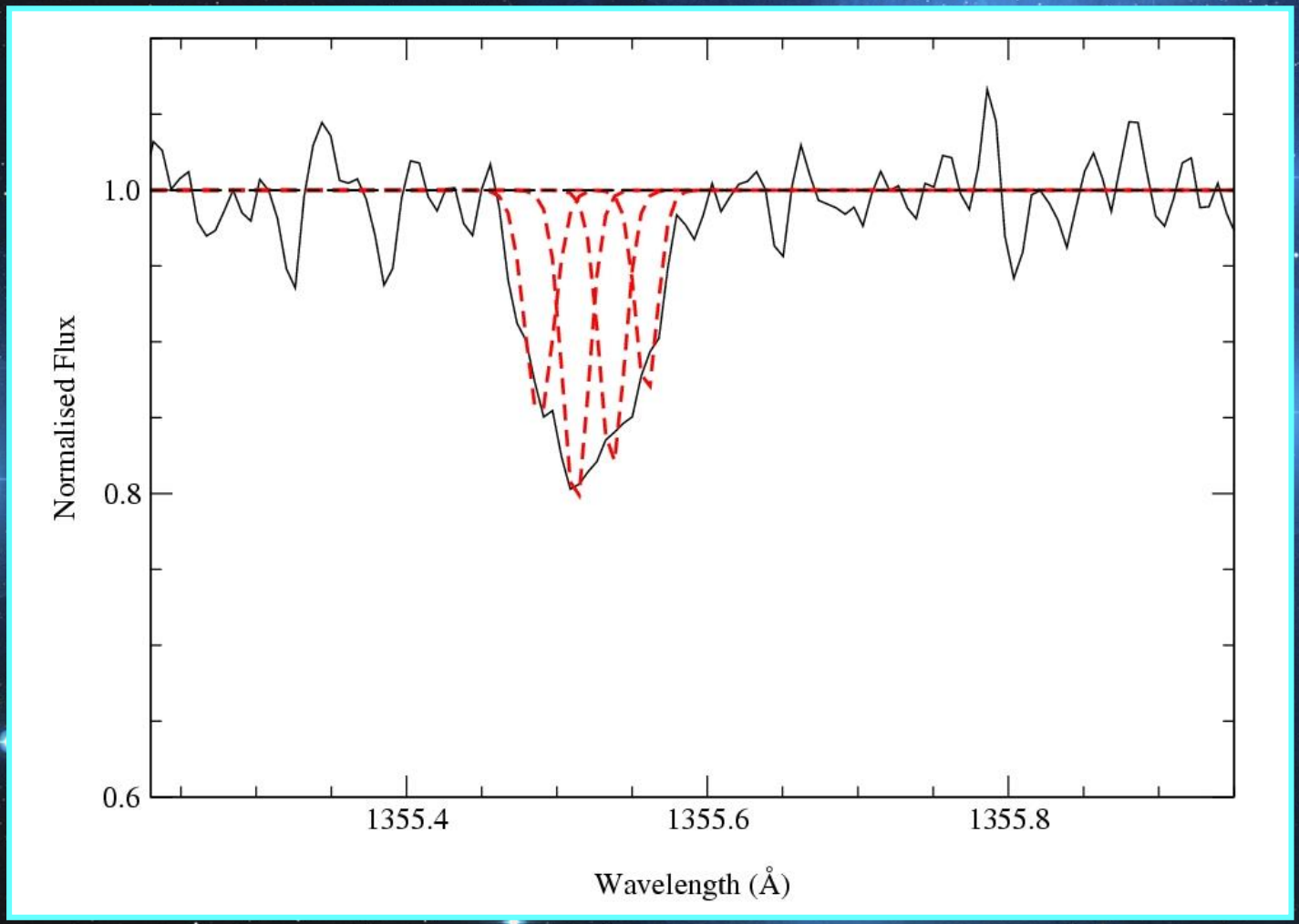
$$\tau(v) = (\pi e^2/m_e c)\, N(v) f \lambda$$

$$= 2.654 \times 10^{-15}\, N(v) f \lambda$$

$$N = \int N(v)\, dv$$



Profile Fit to HD208440 O Profile

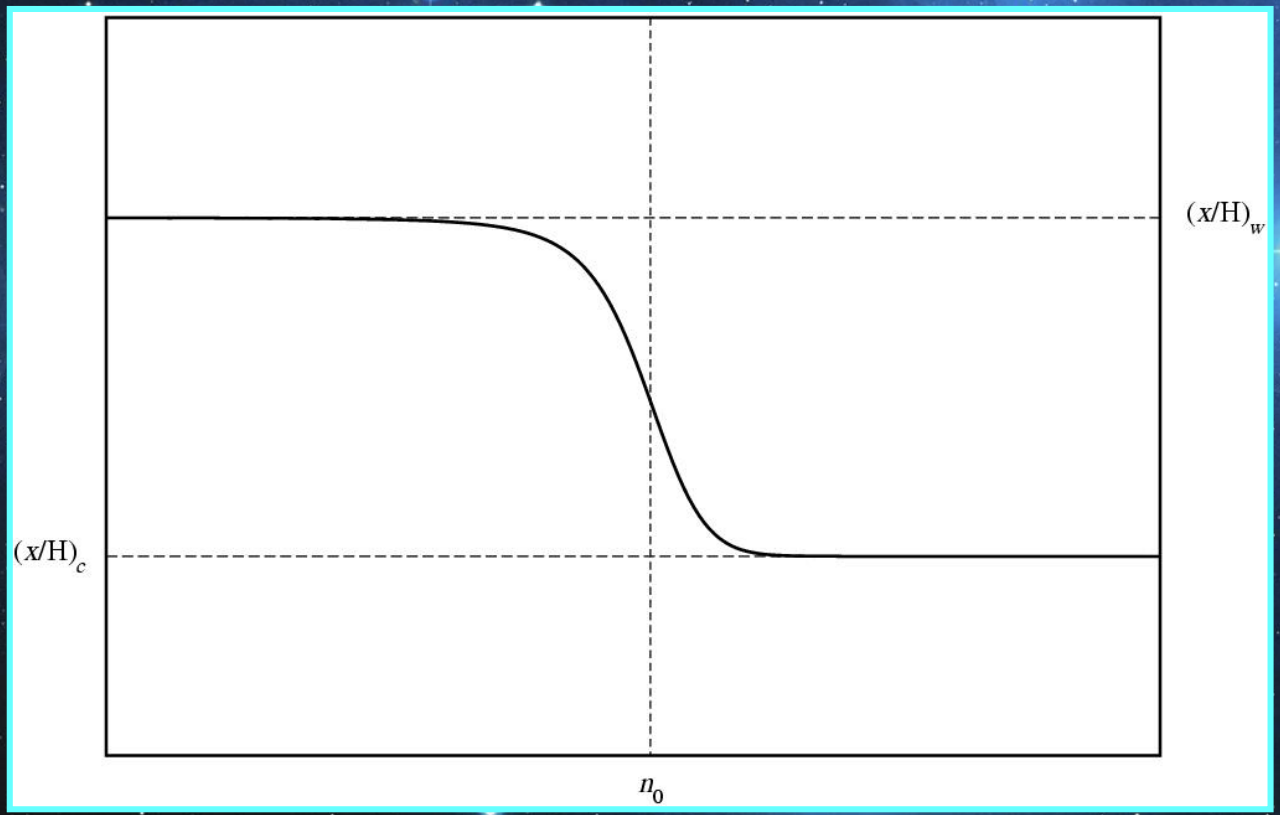


How do we determine a functional dependence for ISM gas-phase abundances?

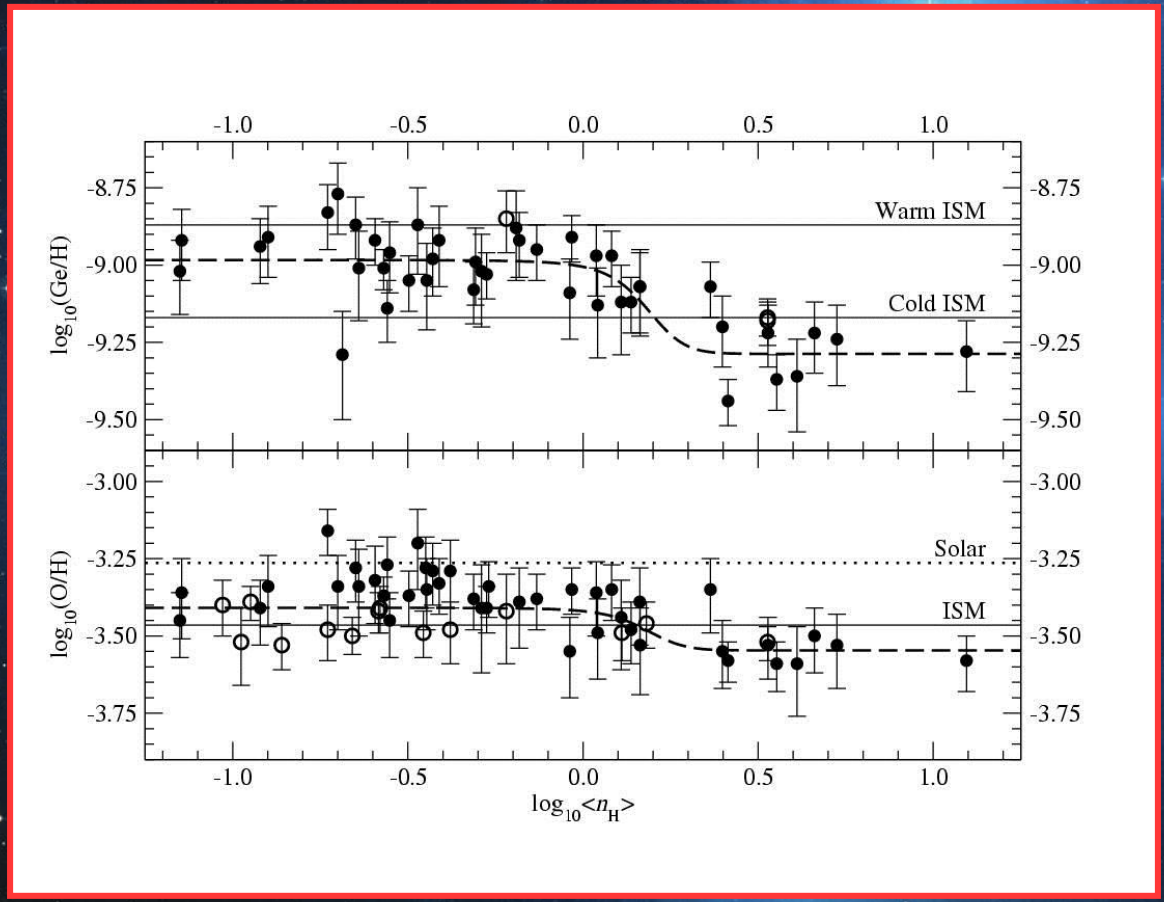
- Acquire very high resolution UV spectra of bright stars whose sight lines are diverse in character.
- Measure column densities for each element detected toward each star.
  - Apparent Optical Depth
  - Profile-fitting
- Fit the data to a functional dependence on sight line property $\langle n_H \rangle$.

Boltzmann Function

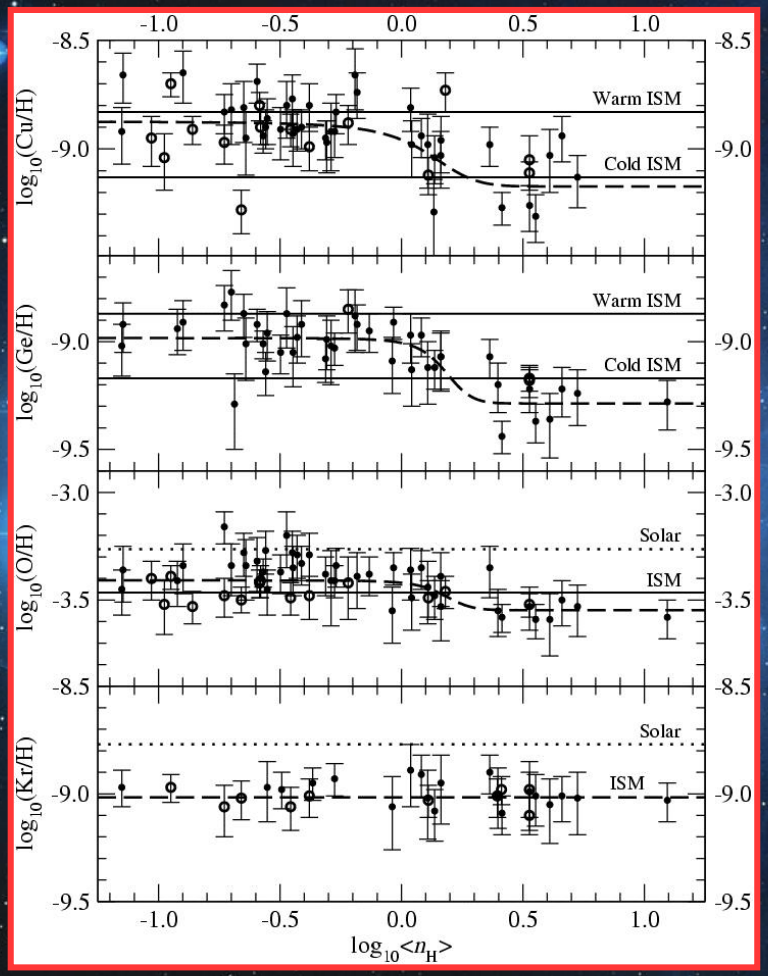
$$(x/\mathrm{H}) = (x/\mathrm{H})_c + \frac{(x/\mathrm{H})_w - (x/\mathrm{H})_c}{1 + e^{(<n_\mathrm{H}> - n_0)/m}}$$

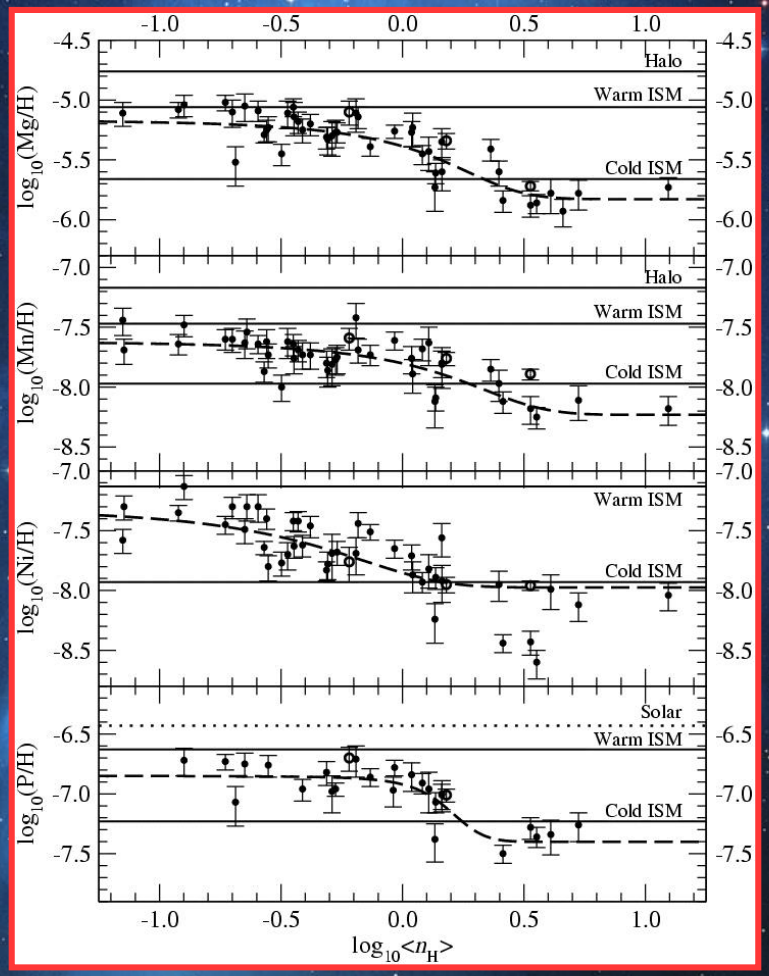


Ge and O Fits


-1.0
-0.5
0.0
0.5
1.0
-8.75
-9.00
-9.25
-9.50
Warm ISM
Cold ISM
log10(Ge/H)
-3.00
-3.25
-3.50
-3.75
Solar
ISM
log10(O/H)
log10<nH>
-1.0
-0.5
0.0
0.5
1.0

Boltzmann Fits





Fitting results

Element	Warm ISM	$(x/\mathrm{H})_w$	Cold ISM	$(x/\mathrm{H})_c$
Magnesium	-5.06	-5.03 (0.02)	-5.66	-5.83 (0.02)
Phosphorus	-6.63	-6.85 (0.04)	-7.21	-7.40 (0.04)
Manganese	-7.47	-7.43 (0.12)	-7.97	-8.23 (0.07)
Nickel	-7.13	-7.27 (0.04)	-7.93	-7.99 (0.03)
Copper	-8.83	-8.87 (0.05)	-9.13	-9.17 (0.03)
Germanium	-8.87	-8.98 (0.01)	-9.17	-9.28 (0.02)

The fit parameters use the full leverage of the dataset.

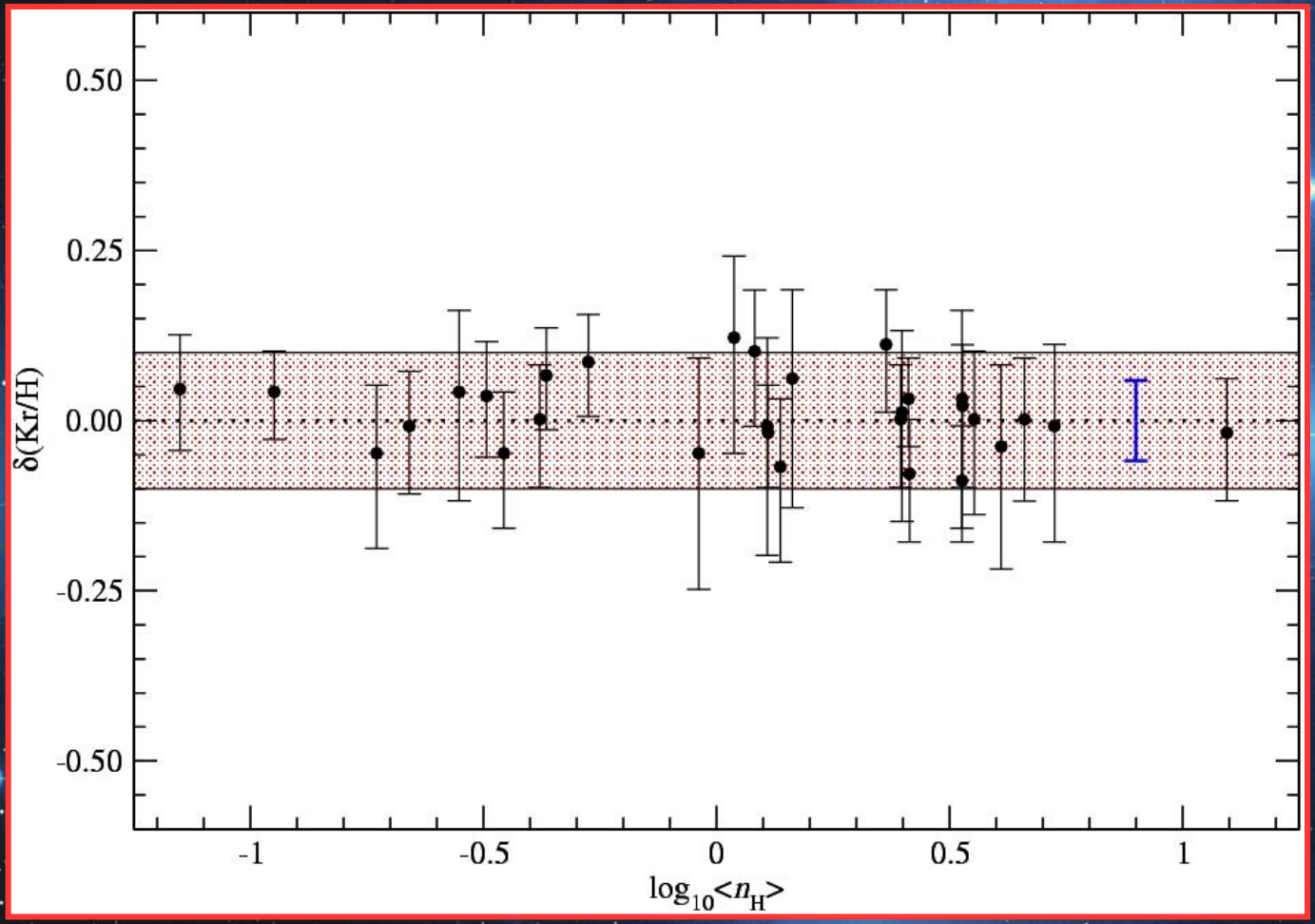
Possible Scatter Sources

- Measurement uncertainty
  - Typically about 0.09 dex (23%)
- Distance estimate
  - Perhaps 0.08 dex (20%)

Measured Scatter

- Krypton is undepleted in the ISM
  - Kr/H scatter (0.06 dex) is less than measurement uncertainty

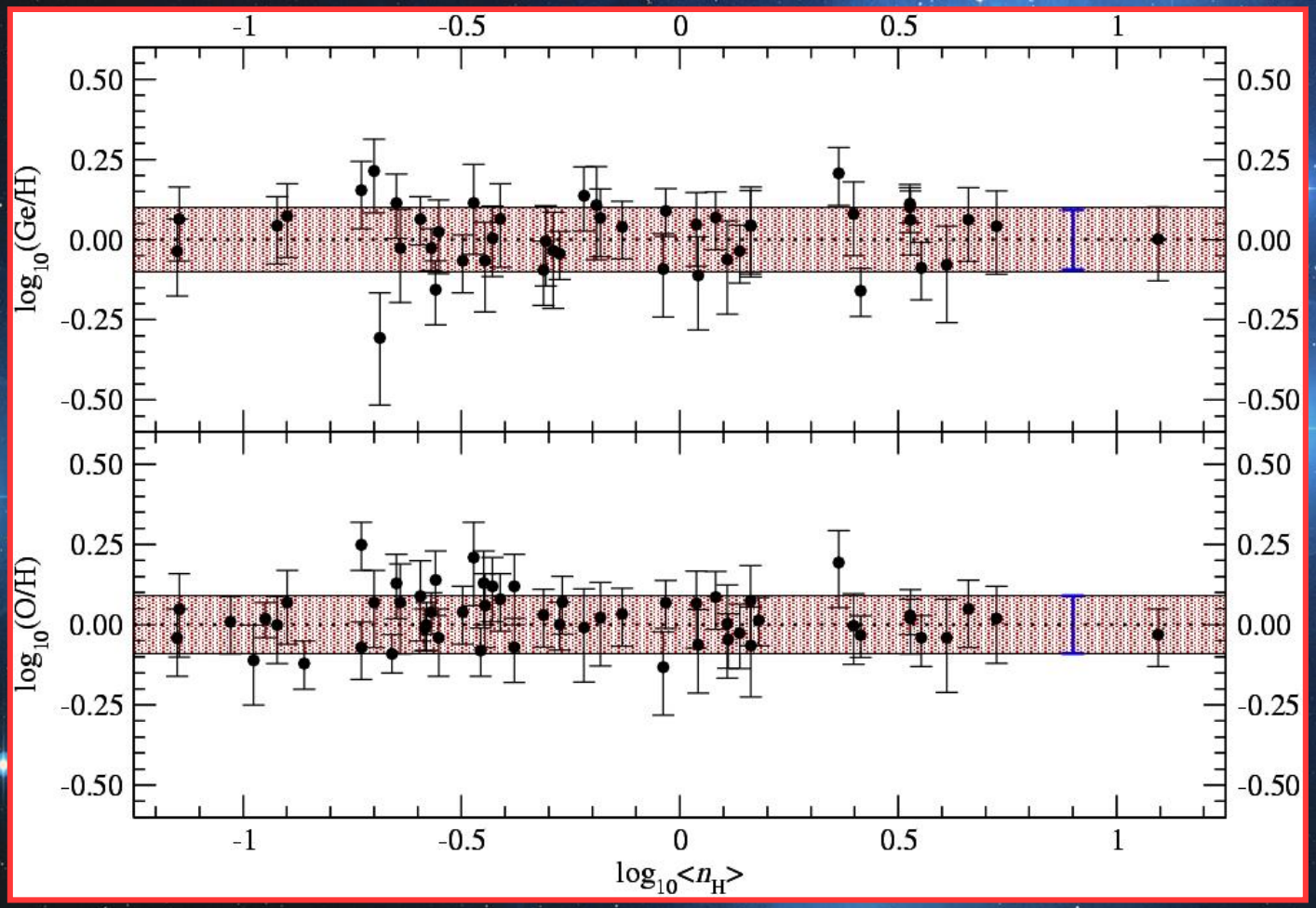
Krypton Scatter Plot



Measured Scatter

- Krypton is undepleted in the ISM
  - Kr/H scatter (0.06 dex) is less than measurement uncertainty
- Germanium and oxygen are lightly depleted
  - Ge/H,O/H scatters are slightly less than the typical uncertainty (0.10 and 0.09 dex, respectively)

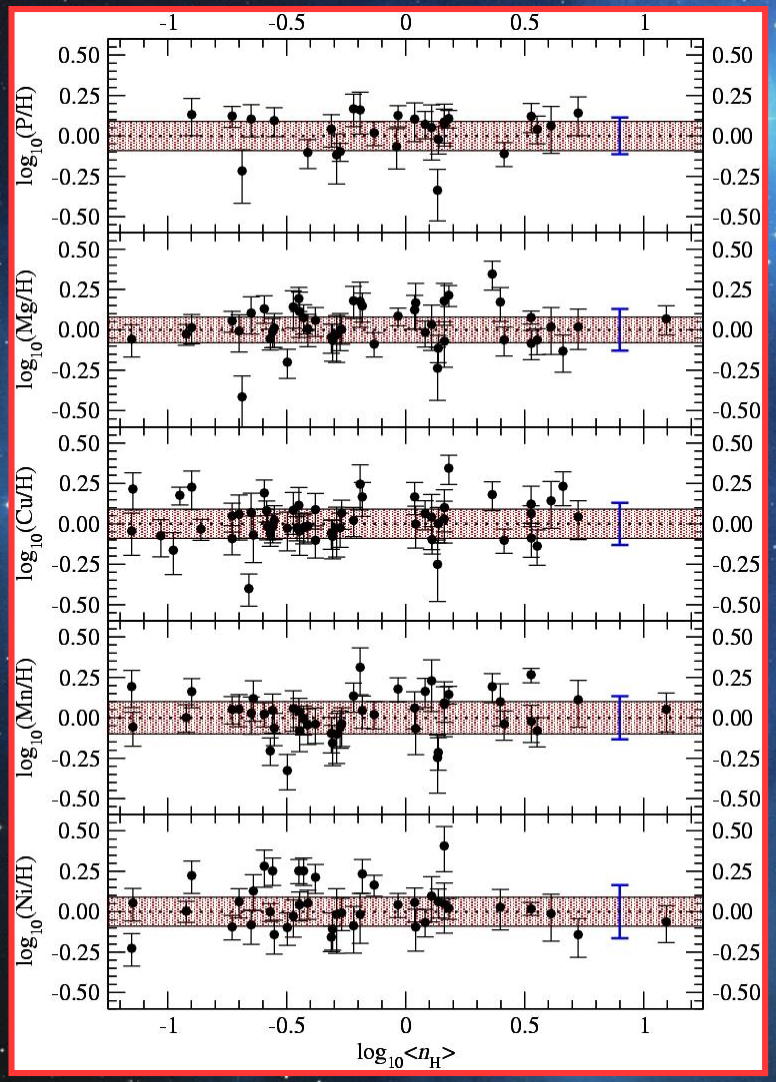
Germanium and Oxygen



Measured Scatter

- Krypton is undepleted in the ISM
  - Kr/H scatter (0.06 dex) is less than measurement uncertainty
- Germanium and oxygen are lightly depleted
  - Ge/H,O/H scatters are slightly less than the typical uncertainty (0.10 and 0.09 dex, respectively)
- The amount of scatter increases with the overall level of depletion.

More Heavily Depleted Elements



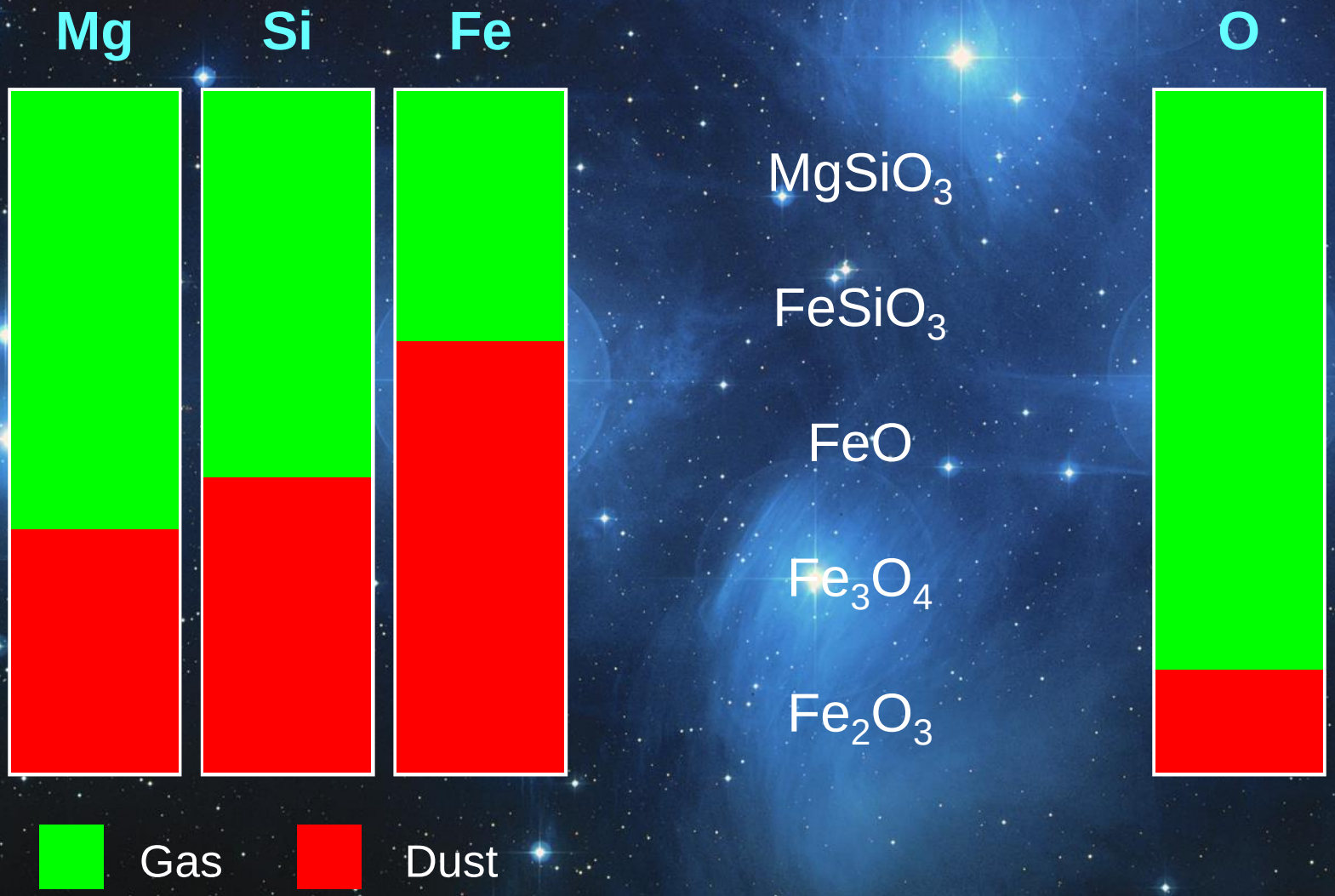
Implications

- Krypton is undepleted in the ISM
  - Kr/H scatter (0.06 dex) is less than measurement uncertainty
- Germanium and oxygen are lightly depleted
  - Ge/H,O/H scatters are slightly less than the typical uncertainty (0.10 and 0.09 dex, respectively)
- The amount of scatter increases with the overall level of depletion.

Elem.	O	Mg	P	Mn	Ni	Cu	Ge	Kr
σ_{intr_max}	0.00	0.08	0.05	0.07	0.14	0.07	0.00	0 dex

Allowed intrinsic scatters are for gas-phase abundances; <0.01 dex in total abundance (if solar).

Dust and Cosmic Abundances



Dust and Cosmic Abundances

	Solar Mg, Si, Fe	Solar O
Low-$\langle n_H \rangle$ O_{dust}/H (10^{-6})	72±14	86±51
High-$\langle n_H \rangle$ O_{dust}/H (10^{-6})	140±14	192±51

- Despite doubts, Solar abundances appear to be a self-consistent standard for abundant elements.

Summary

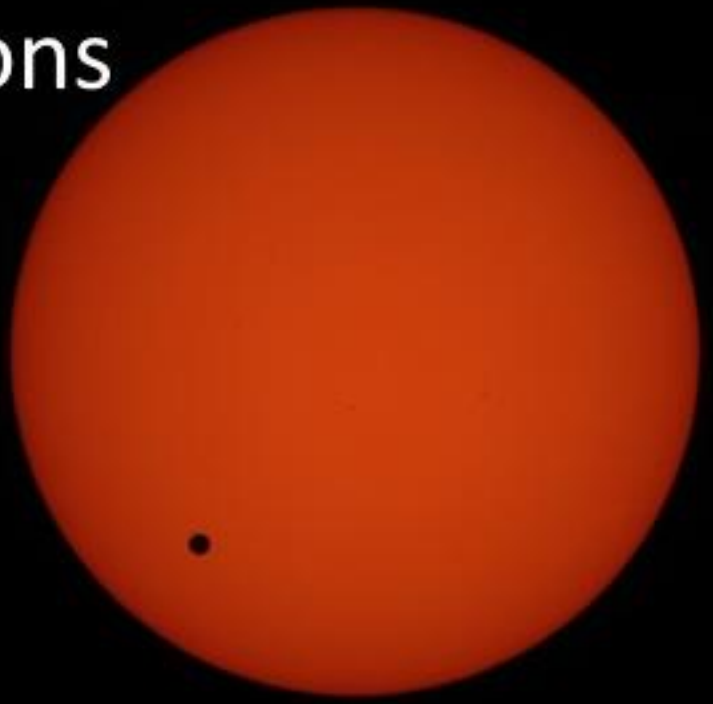
- Absence of measurable intrinsic scatter in undepleted (Kr) and lightly depleted (O, Ge) elements implies that the ISM is very well mixed on scales of a few hundred parsecs; this is also supported by the observed scatter in more heavily depleted elements.

- There is a set of reliable cosmic elemental abundances that can be derived by combining gas-phase measurements with models of dust grain composition.

Future Outlook

- Space Telescope Imaging Spectrograph (STIS; aboard *Hubble Space Telescope*) operations are currently scheduled for 3 – 4 more years.
- Space Telescope Science Institute (STScI) Archive is being scoured for additional data (e.g. rare elements; James Mazurok).
- X-ray telescopes (e.g., Chandra) offer the opportunity to simultaneously measure a myriad of physical and chemical states (C through Fe).
- We need a new UV telescope!

Transits of Venus: Triumphs and Tribulations

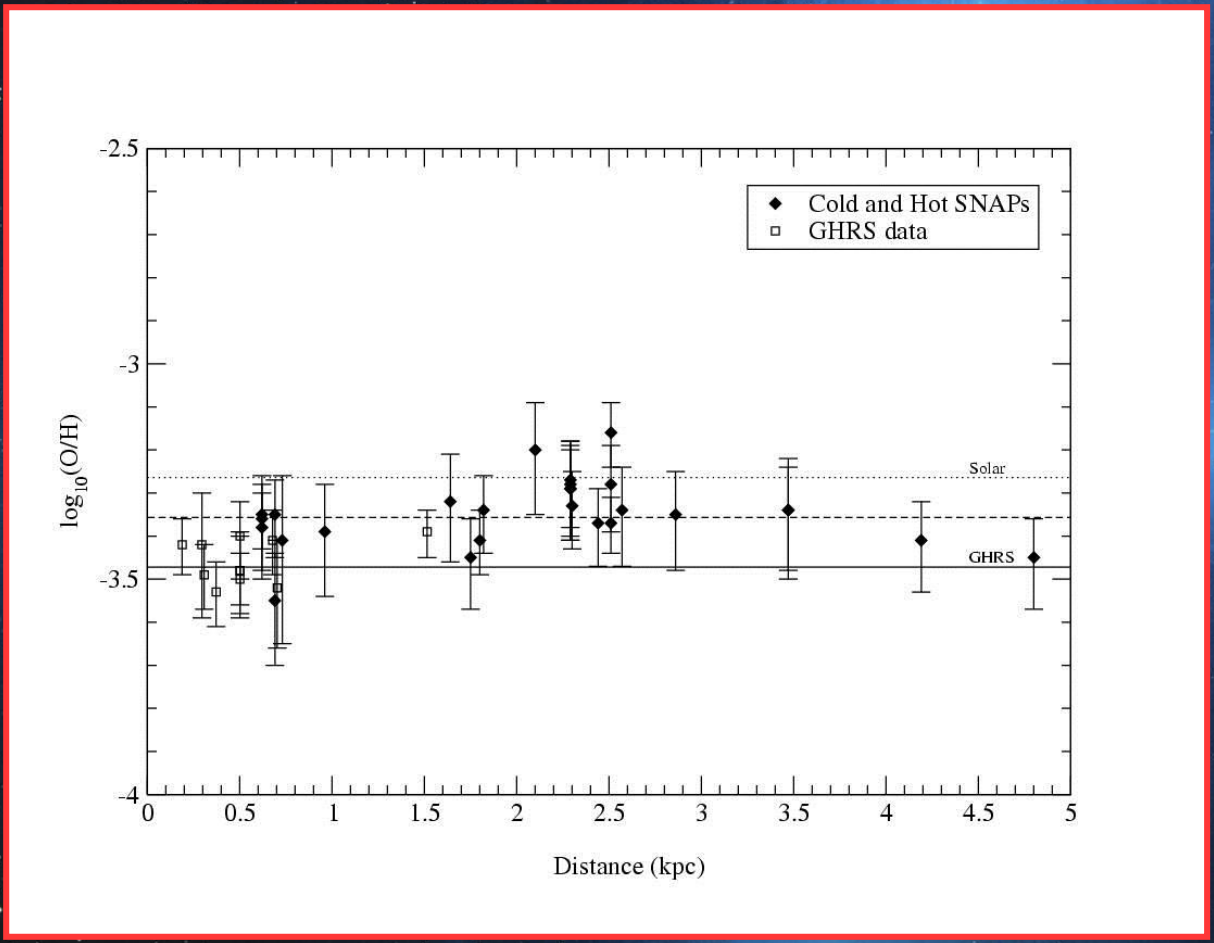


Department of Physical Sciences
Grant MacEwan University
Speaker: Dr. Douglas Hube
Date: Wednesday, April 4, 2012
Time: 4 – 5 pm
CCC 5-142 (CN Theatre)

Since the invention of the telescope four centuries ago, the planet Venus has passed across -- transited -- the face of the Sun 7 times, but only 6 of those rare events have been observed. The next transit of Venus will occur on June 5, 2012. With a little preparation you will be able to observe this once-in-a-lifetime event. In this presentation, I will describe the science and the history of the phenomenon, and explain why observations of transits of Venus constituted 'big science' in the 18th and 19th centuries. I will describe where you must go to observe the transit and what precautions must be taken to do so safely. If you miss this year's transit, you will have to wait more than a century for the next opportunity!

EVERYONE IS WELCOME TO ATTEND

Heliocentric distance trend (infall?)



Extinction Curves

