

# Boron & beryllium as unlikely probes of extrasolar planets

Ben Zuckerman

UCLA Physics & Astronomy

[ben@astro.ucla.edu](mailto:ben@astro.ucla.edu)

# Techniques for discovery of planetary systems

Transits

Precision radial velocities

Direct infrared imaging

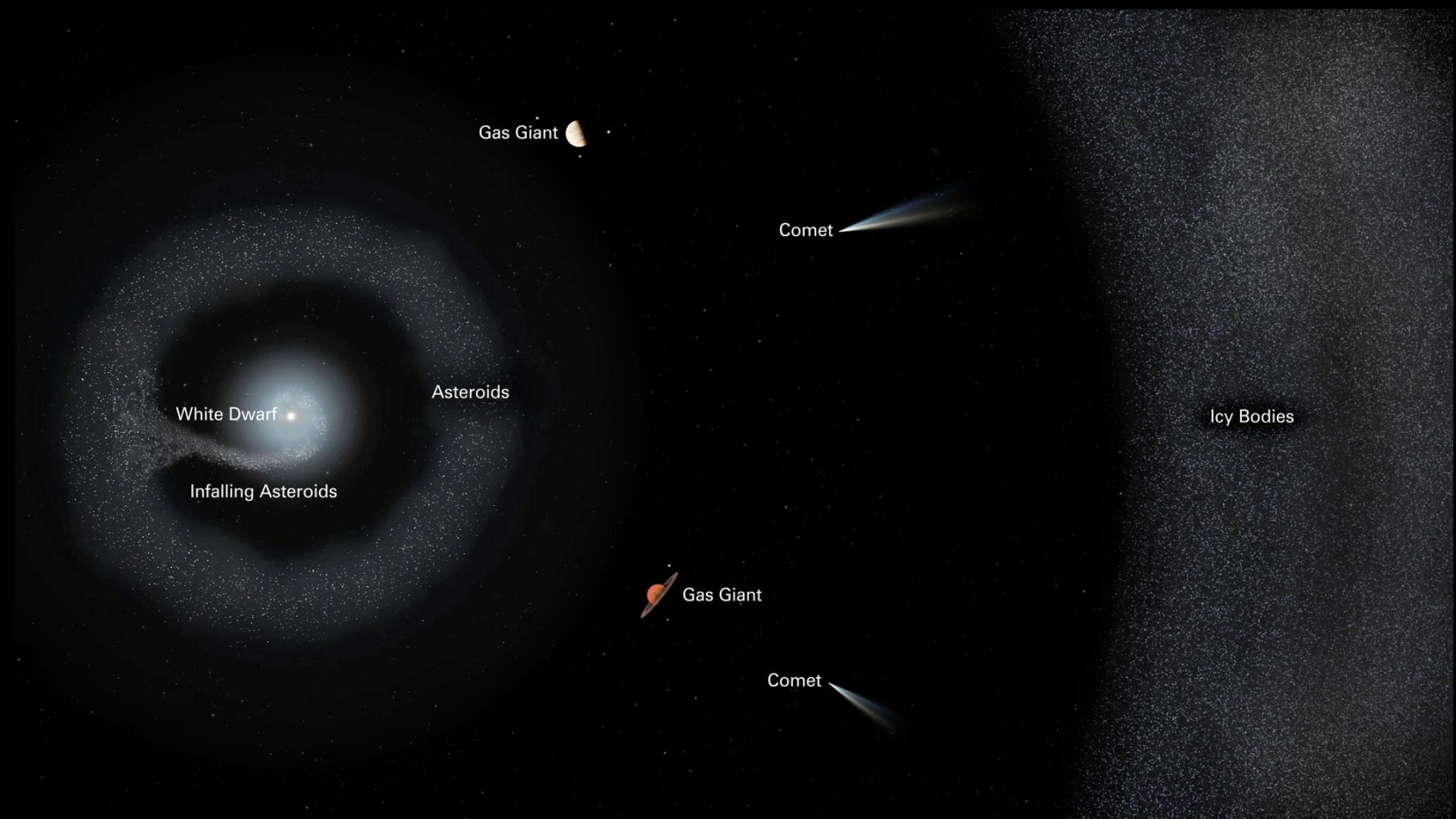
Astrometry

Microlensing

Spectroscopy of white dwarf stars

All but one of these techniques were described in the literature \*before\* they were observationally realized – even including microlensing!

The exception is spectroscopy of white dwarfs. The very first evidence for the existence of an extrasolar planetary system occurred more than 100 years ago when van Maanen discovered heavy elements in the spectrum of the single white dwarf closest to Earth – it took about 90 years before astronomers understood convincingly that these elements were remnants of a rocky parent body that had previously orbited the white dwarf!



Gas Giant

Comet

White Dwarf

Asteroids

Icy Bodies

Infalling Asteroids

Gas Giant

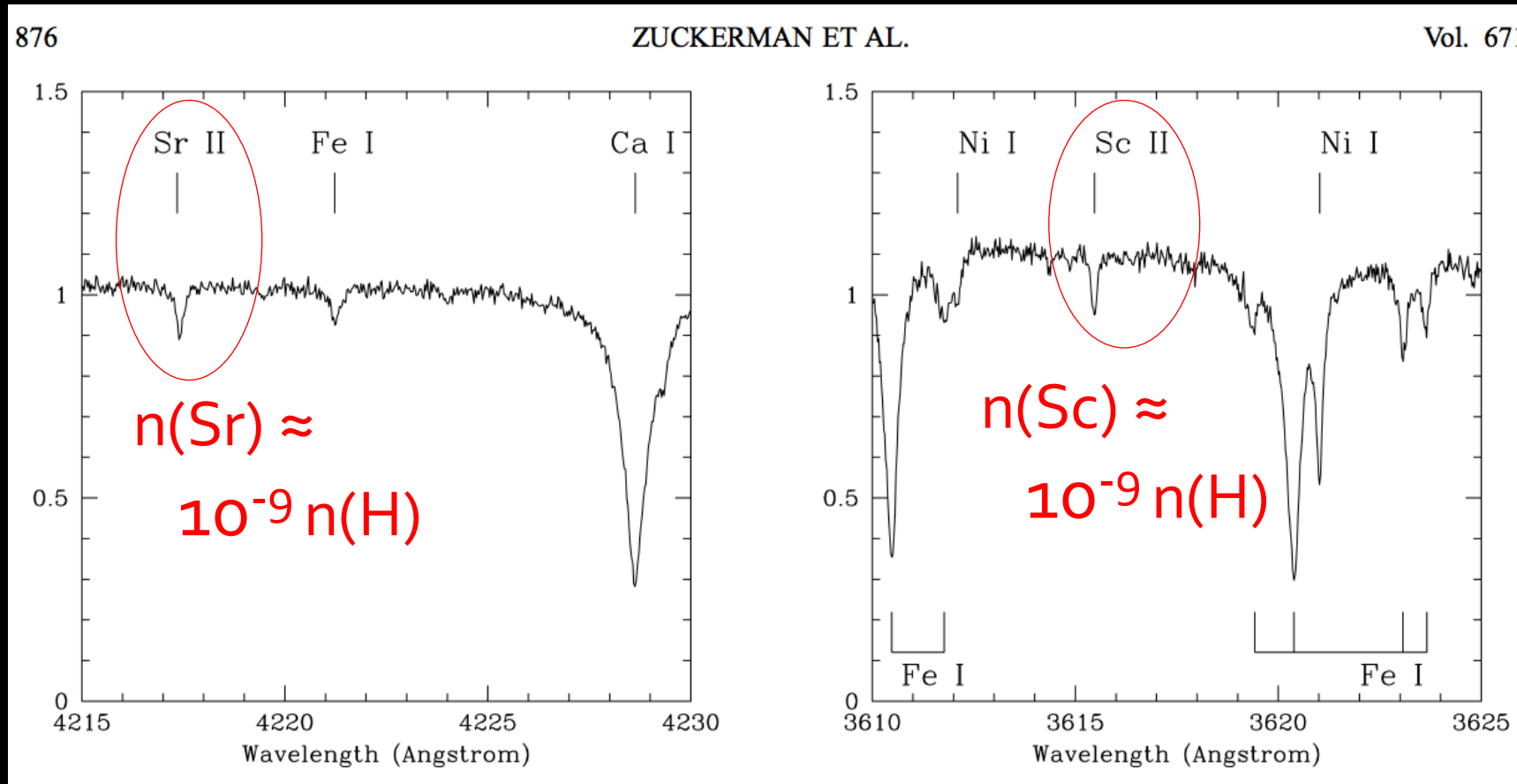
Comet



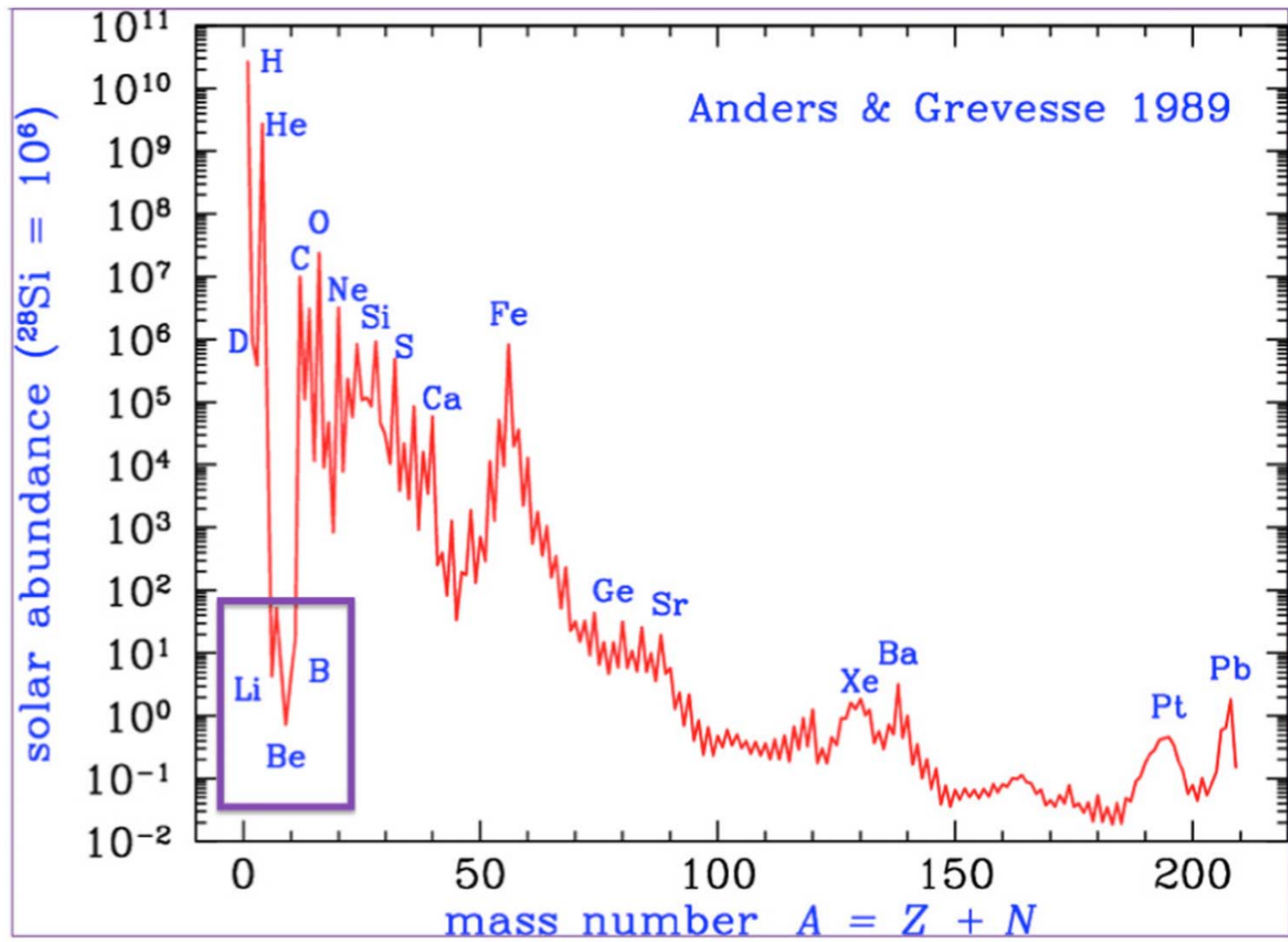
Spectroscopy of white dwarf stars enables measurement of the bulk elemental compositions of accreted objects.

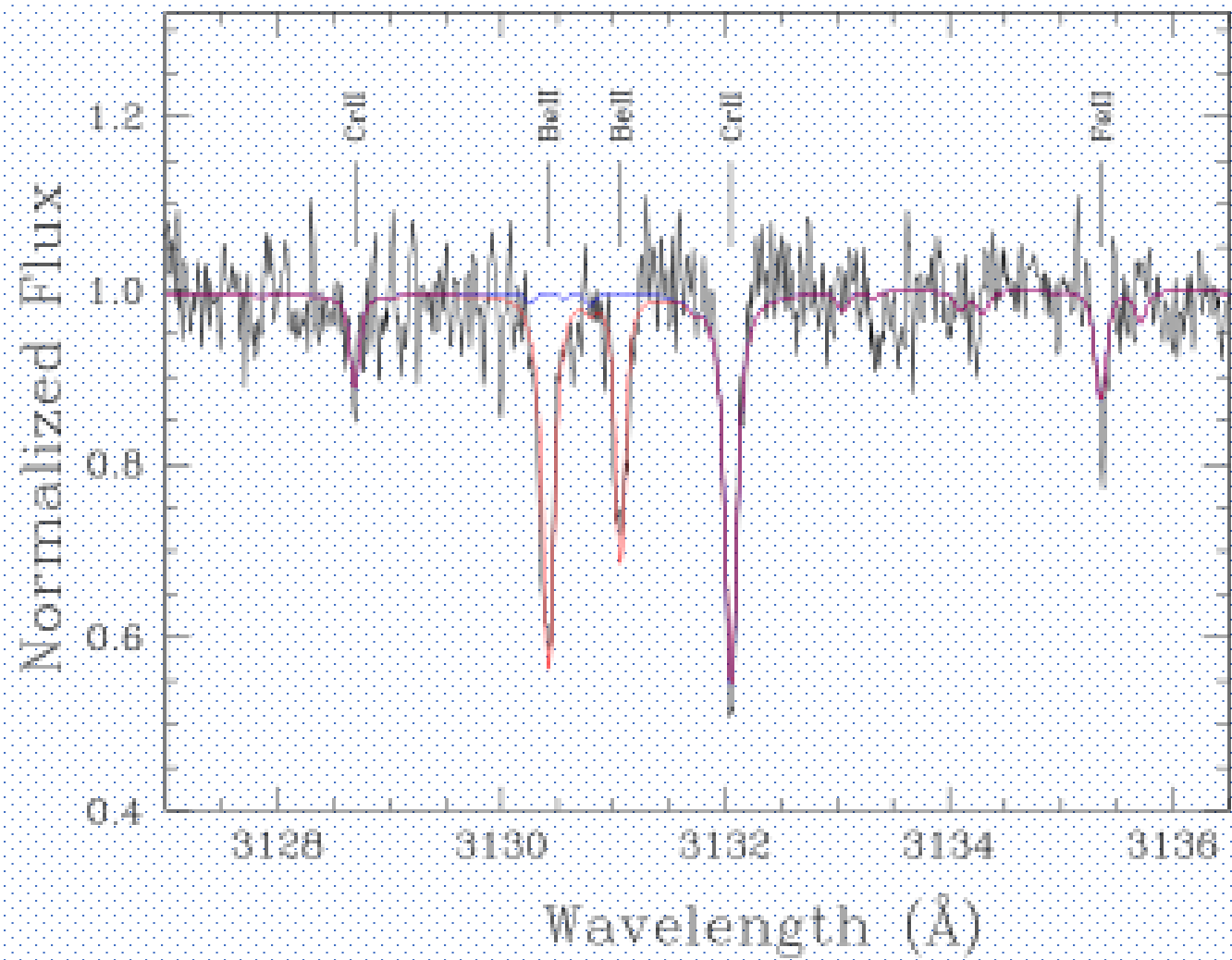
Bulk compositions cannot be measured with any other technique used to study exoplanets. This is also the situation for the planets, moons, asteroids, etc. of our own solar system – indeed even for our own Earth!

High resolution spectroscopy: exquisitely sensitive to even trace amounts of material.



Dramatic Example - GD 362

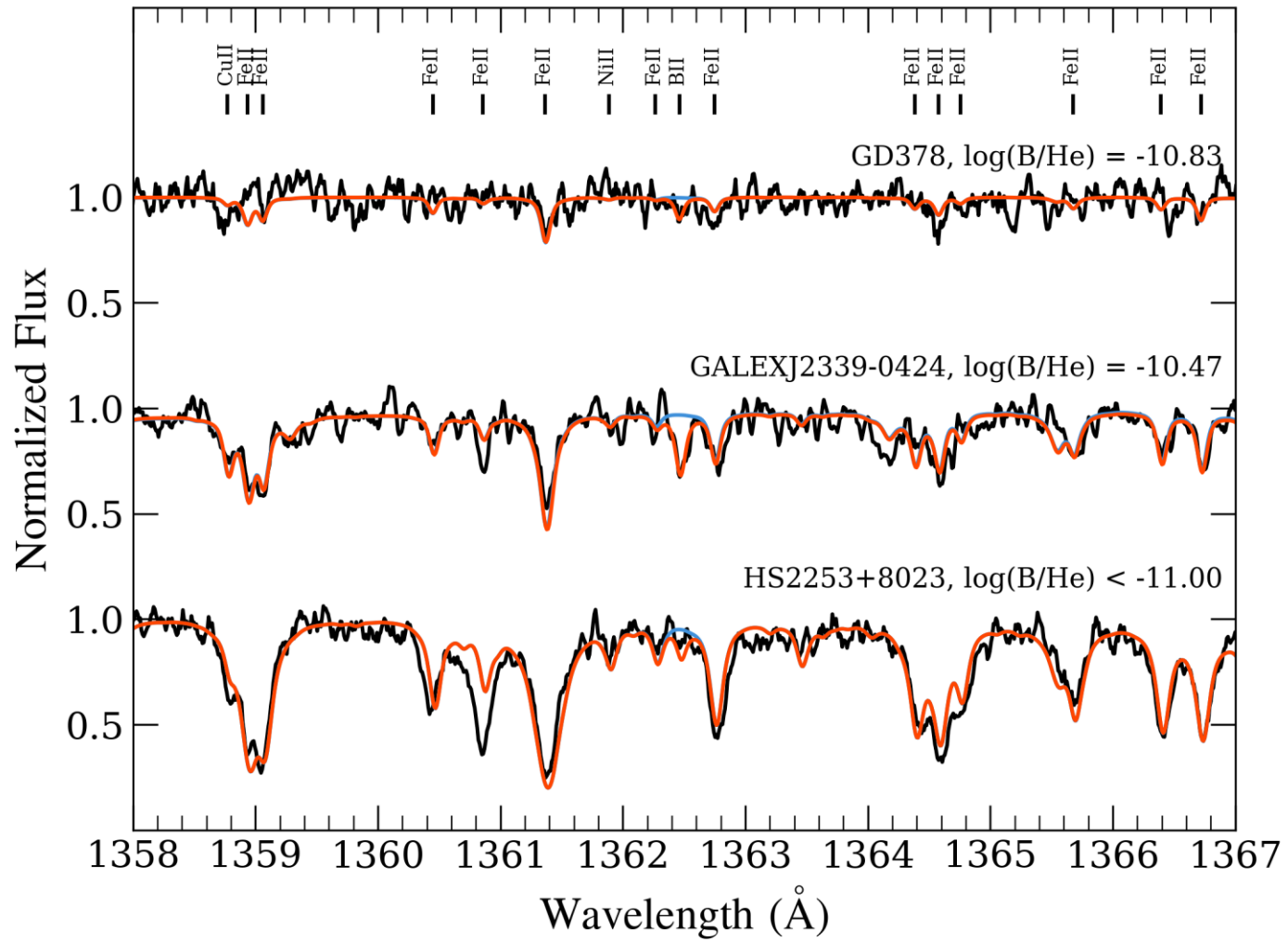




First mystery: How does Nature produce 200 times more beryllium in an extrasolar planetary body than is seen typically in astronomy??

Beryllium is produced in Nature only via spallation of C, N and O nuclei by high energy protons and helium nuclei.

Can observations of boron, also produced only via spallation, help resolve this mystery?



Second mystery: The # of boron (B) atoms in the atmosphere of white dwarf GALEXJ2239 is equal to the # of beryllium (Be) atoms. How can Nature produce equal numbers of B and Be atoms when the spallation cross sections for boron production are  $\sim 10$  times that of beryllium?? In stars the measured  $[B/Be] \sim 15-20$ . In the Sun and in CI chondrites  $[B/Be] = 30$ .

What combination of physics and astrophysics can result in  $[B/Be] = 1$  in the planetary object accreted onto GALEXJ2339?

We have considered two models, neither of which is compelling.

- 1) A giant planet similar to Jupiter, but with a magnetic field 100 times stronger, is orbited by a circumplanetary disk threaded by the magnetic field. High energy particles from the wind of a young star are trapped in the magnetic field. The trapped particles bombard the disk over a very long period of time, resulting in high Be abundances and small B to Be abundance ratios. A moon forms & is later accreted onto the white dwarf.
- 2) The accreted material is similar to Earth's crust and upper mantle which have (relative to typical cosmic) high Be abundances and small B to Be abundance ratios.

Ben Zuckerman  
UCLA Physics & Astronomy  
ben@astro.ucla.edu

Collaborators:

Erika Le Bourdais & Patrick Dufour	Univ Montreal
Beth Klein & Edward Young	UCLA
Carl Melis	UCSD
Alycia Weinberger	CarnegieScience