View From the West Coast

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QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

UCSB Involvement with JINA

- Built on strong collaboration between Bildsten and Schatz, managed as a sub-contract (2003-2006) from MSU to support 2 theoretical graduate students and Santa Barbara workshops.

- Phil Chang's (now Miller Fellow at Berkeley) thesis (3 JINA papers) was on NS redshift measurements with Chandra, and resulting limits on nuclear EOS.

- Tony Piro's (=> TAC Fellow at Berkeley) thesis was on neutron star oscillations (4 JINA papers, see poster!) as well as WD accretion (3 JINA papers) that led to work by Balsara and Fisker.

- Ken Shen (current UCSB graduate student) looking in detail at Starrfield's claim of stable burning on WDs at low accretion rates.

- Crossover when Dean Townsley (UCSB PhD) was hired at Chicago as a JINA postdoc. Classical novae work continued (2 JINA papers). UCSB students participate in the theory telecons run by Dean.

Santa Barbara Workshops

Organized three informal 2 day workshops in Santa Barbara, which had the distinction of time for discussion and collaboration building and size < 50. Emphasis placed on getting young participants..

• "Final Days of Burning in Massive Stars" (2006) (Austin, Bildsten and Wiescher)

• "Classical Novae and Type Ia Supernovae" (2005) (Bildsten and Brown)

• "Neutron Star Nuclear Burning" (2004) (Bildsten and Schatz)

Hiatus in 2007 due to Bildsten overload (running Jerusalem Winter School for Theoretical Physics in January 2007, and KITP program, scientific conference and teacher's conference on "Accretion and Explosion" February-May 2007).

Low Mass X-Ray Binaries (LMXBs)

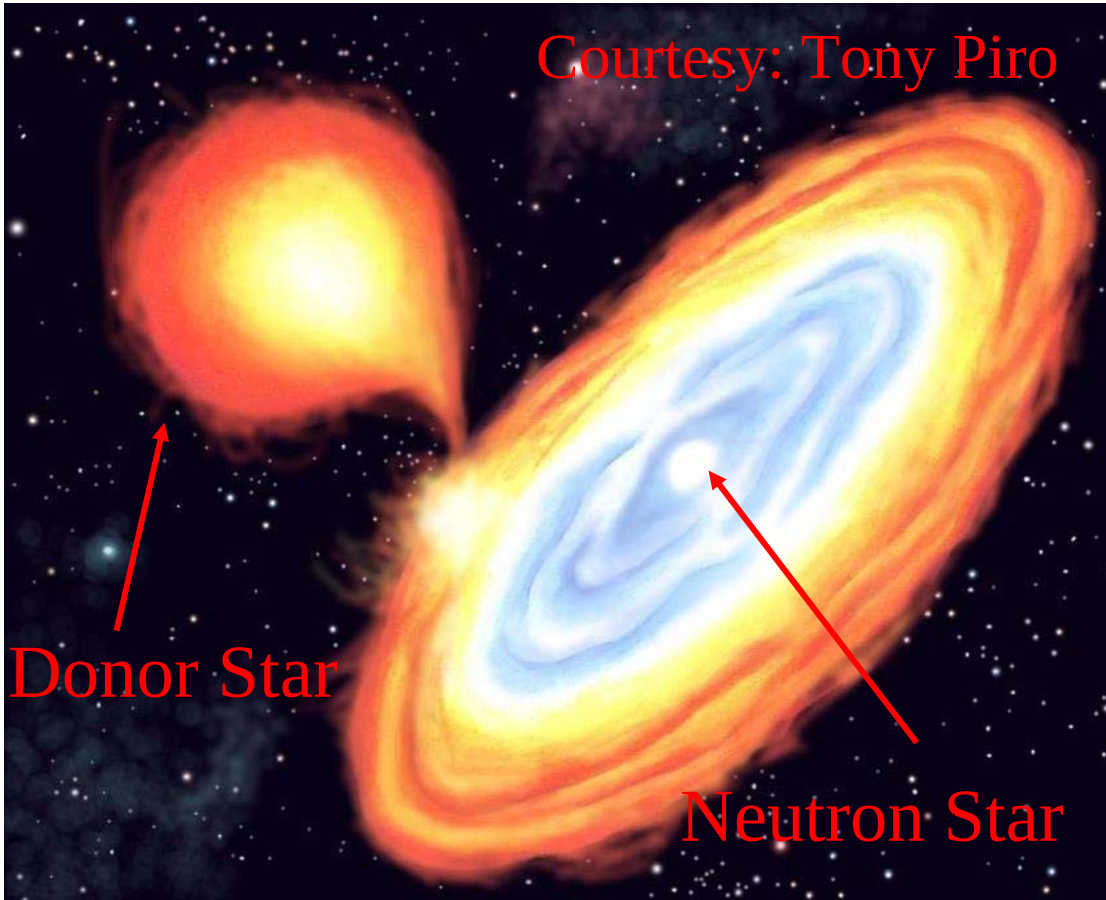
The "typical" neutron star has a mass of 1.4 solar masses and R=10 km.

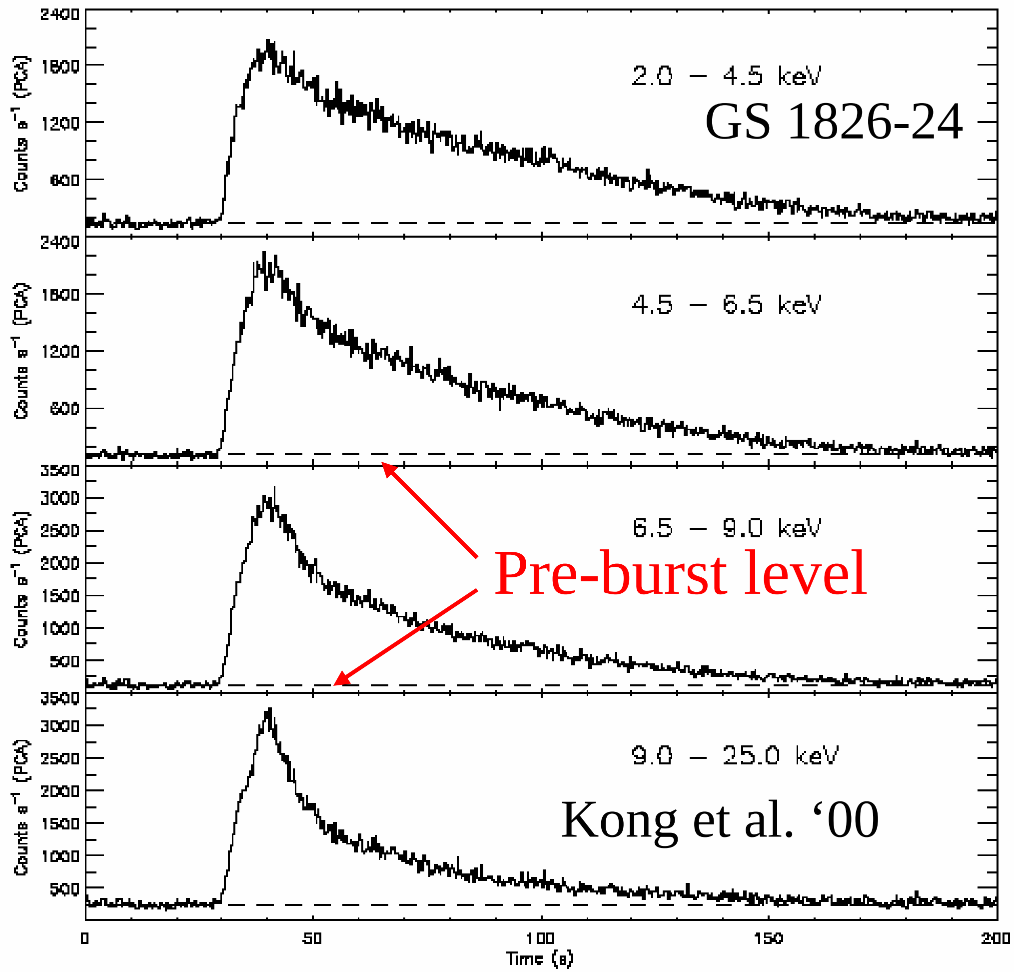
Matter is supplied at a rate set by binary evolution, most have

$$\dot{M} \sim 10^{-10} - 10^{-8} M_\odot \ \mathrm{yr}^{-1} \rightarrow L_{acc} \approx \frac{G\dot{M}M}{R} \approx 10^{36} - 10^{38} \ \frac{\mathrm{erg}}{\mathrm{s}}$$

The surface temperature is a few 10MK, so these are X-Ray sources

- Most donors are main sequence stars consisting of Hydrogen/Helium with orbital periods of 100 minutes to a few days.
- Longer (and shorter) orbital periods are also seen, which require an evolved donor.





Many (Woosley & Taam '76; Maraschi & Cavaliere '77; Joss '77, '78; Lamb and Lamb '78) associated Hansen & Van Horn's (1975) thermal instability with the observed (Belian et al '76; Grindlay et al '76) Type I bursts, where:

- Recurrence time of hours to days is time to accumulate a critical pile of fuel
- Decay time is either the time for heat to escape the layer OR the time to burn the fuel
- Energetics consistent with burning most fuel during bursts

The burst spectral evolution is consistent with thermal emission from a cooling NS surface (Swank et al '77; Hoffman, Lewin & Doty '77) Superbursts are even better, as the duration is hours!!

Clear Added Value

• A Caltech graduate student of Marc Kamionkowski, Nevin Weinberg, was looking for something new and approached me for a project while I was on sabbatical at Caltech. I encouraged him to attend the 2003 Santa Barbara JINA meeting on neutron star burning…

• The breadth of research topics presented there allowed Nevin to see a new research problem, the exposure of ashes during Type I bursts.

• While still at Caltech, Nevin and I collaborated with Schatz to bring this idea to fruition and a paper (Weinberg, Bildsten & Schatz (2006), ApJ, 639, 1018).

• Nevin is now a KITP postdoc and will be at Berkeley next year as a TAC postdoc.

• He is now working on detonations during superbursts, and will likely continue in nuclear astrophysics..one conversion accomplished!!

Exposing Ashes during Radius Expansion Bursts

Weinberg, L. B. & Schatz '06

- The convective zone (and hence ashes) do not reach the photosphere, but just how far up in the atmosphere can it get? Is there a typical pressure below which it gets interesting? YES!

- Thermonuclear burning often exceeds the Eddington luminosity

$$L_{\rm Edd} = \frac{4\pi G M m_p c}{\sigma_{\rm Th}} \approx 1.7 \times 10^{38} {\rm erg\ s}^{-1} \left(\frac{M}{1.4 M_\odot}\right)$$

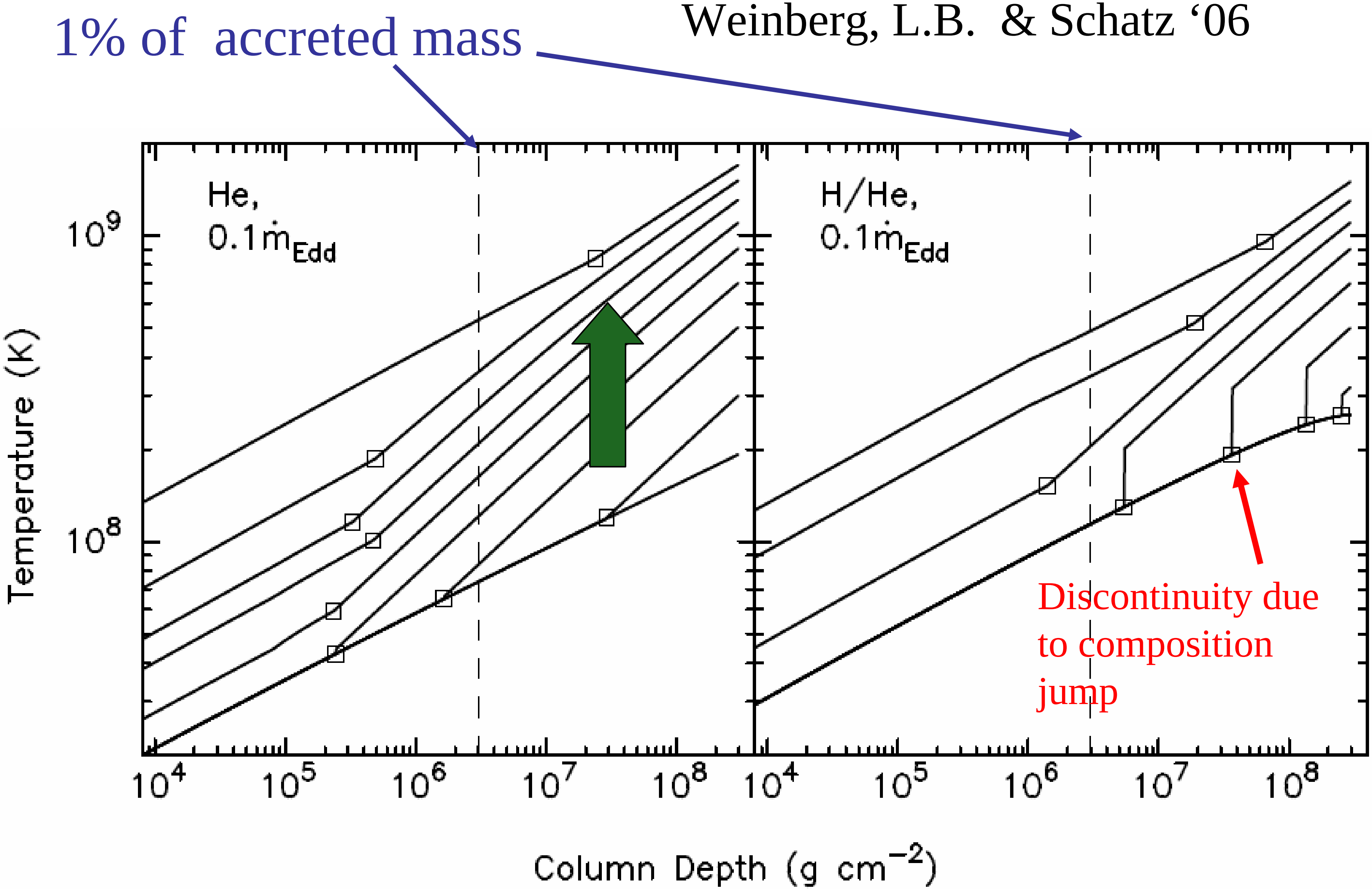
pushing the photosphere out to radii >> R_NS in a radius expansion burst. Any excess luminosity above the Eddington limit drives a slow wind, unbinding material from the outer layers.

- The nuclear energy release is a few MeV/nucleon, but the gravitational binding energy is 200 MeV/nucleon ==> At most 1% of the accumulated mass can be ejected (e.g. Paczynski & Proszynski '86)

- The convective zone easily reaches these pressures!!

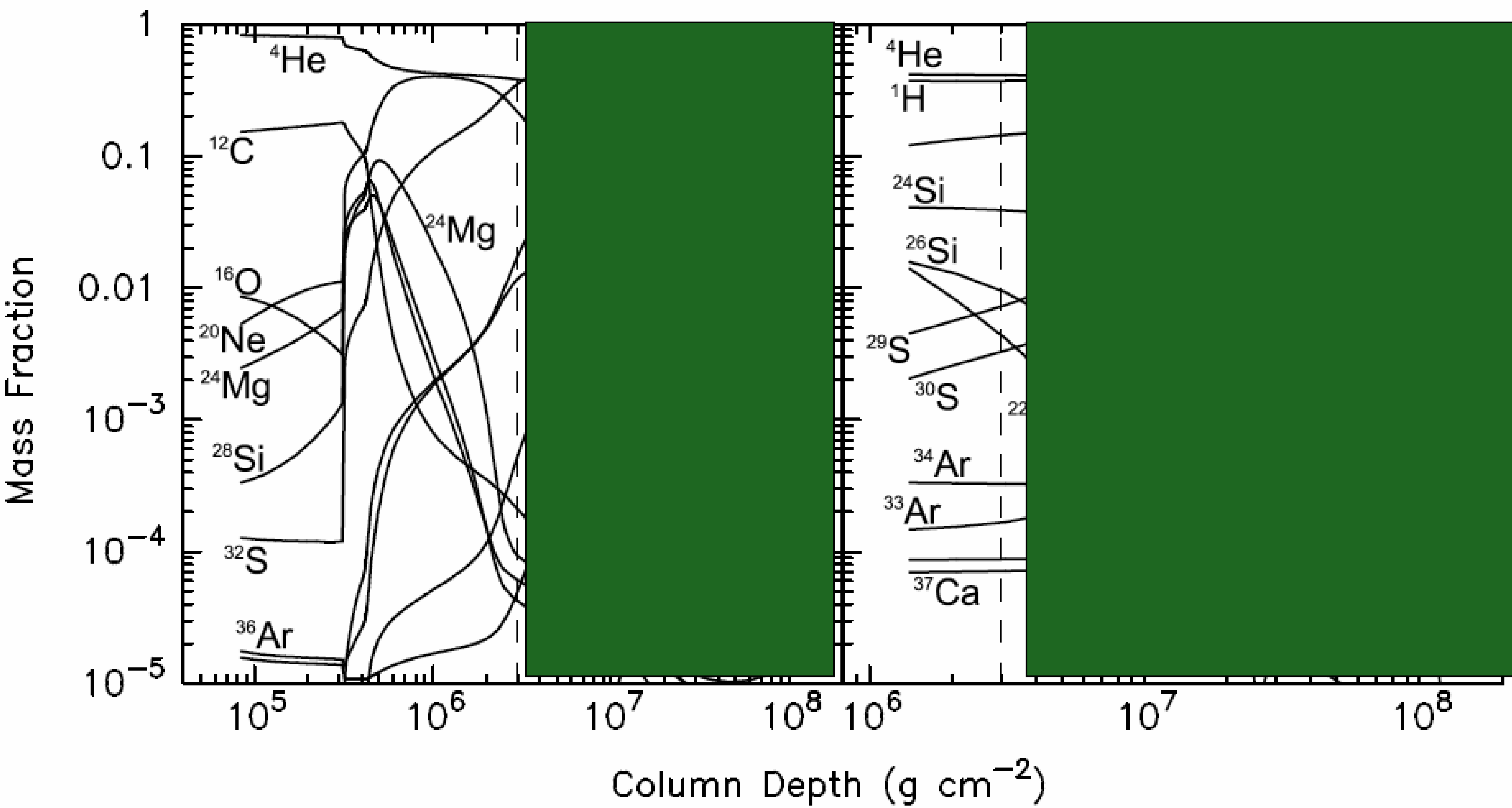
Temperature Profiles During Burst

Weinberg, L.B. & Schatz '06



Abundances at 0.1 Eddington Accretion Rates

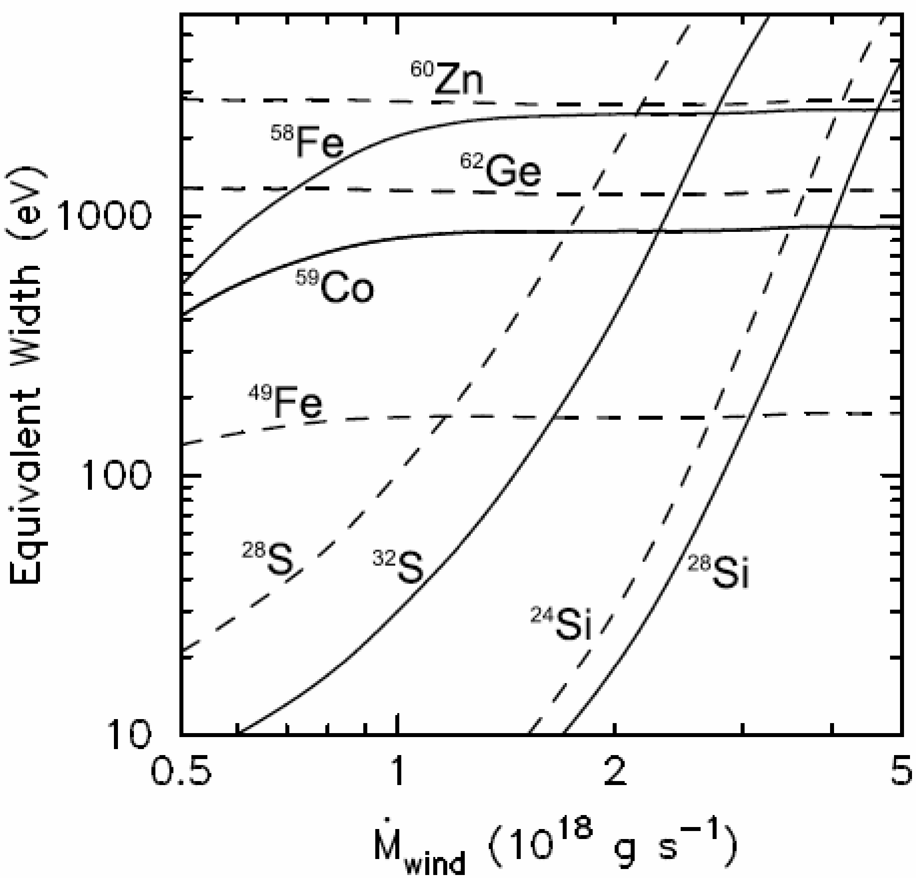
Pure He Burst: 1820-30! H/He Burst (Atoll Source)

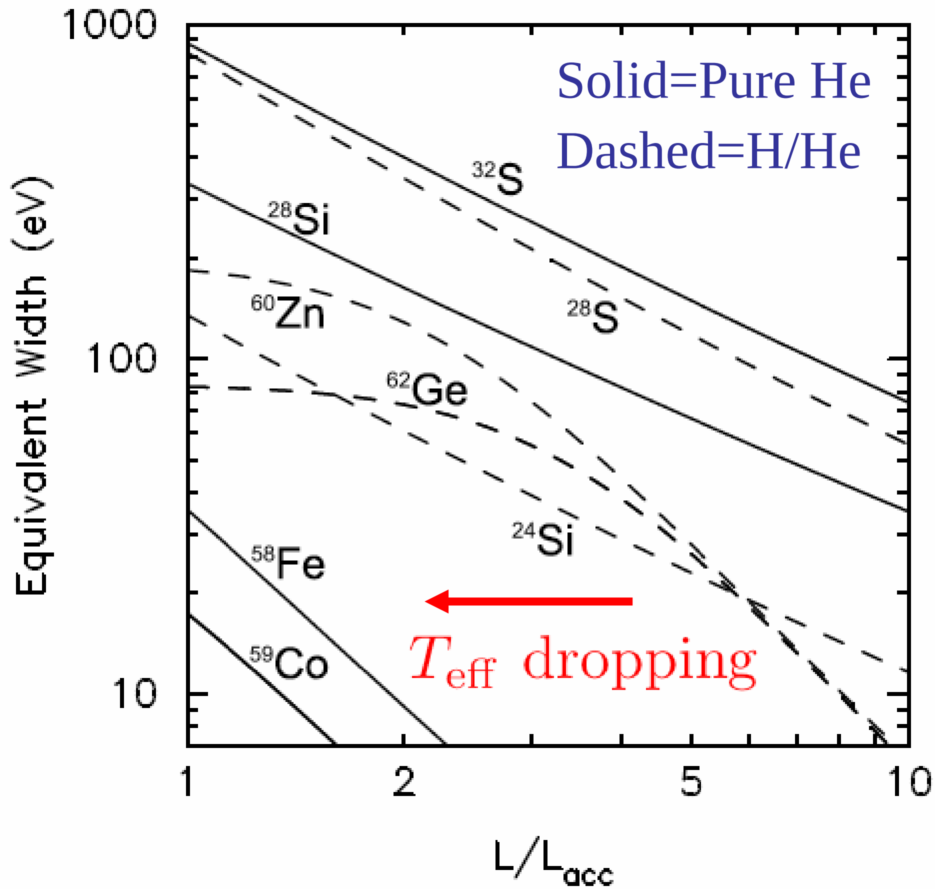


Many heavy elements have enhanced abundances in locations that can easily be exposed by the wind or ejected.

Opportunities during/after RE Bursts

Photoionization Edges in Winds . . . .and in the cooling photosphere





•These ejected nuclei in the wind can imprint photo-edges due to their high column depth

•Once the photosphere recedes, the exposed ashes may yield features useful for redshift measurements prior to sinking

JINA’s Impact on My Research

- Maintained and encouraged my group’s exposure to a broad range of nuclear physics and astrophysics, always a good thing!

- Easy, immediate access to nuclear reaction network calculations and nuclear physics insights

- Excellent venue for the work of Bill Paxton (a retired computer scientist in Santa Barbara) on EZ (an accessible stellar evolution code) that triggered his current work with Frank Timmes

- Triggered new research projects (Nevin’s plus the current work of Ken Shen) and Chandra observing proposals to look for these spectral features

JINA’s Impact on Astrophysics Community

- Meetings provided a venue to reconnect the astrophysics community with the experimental nuclear physics world. . . including getting gamma-ray instrument builders (e.g. Boggs, Wunderer) in touch with nuclear experimentalists

- Graduate students had broader opportunities for scientific interactions via visits (within JINA) and meetings, preparing them for the ‘real’ world of academic life..

- Maintained a focus on the nuclear side for the astrophysics community at a time when it is needed (due to observational breakthroughs), but is otherwise becoming lost… . .