Emission from the First Cosmic Explosions

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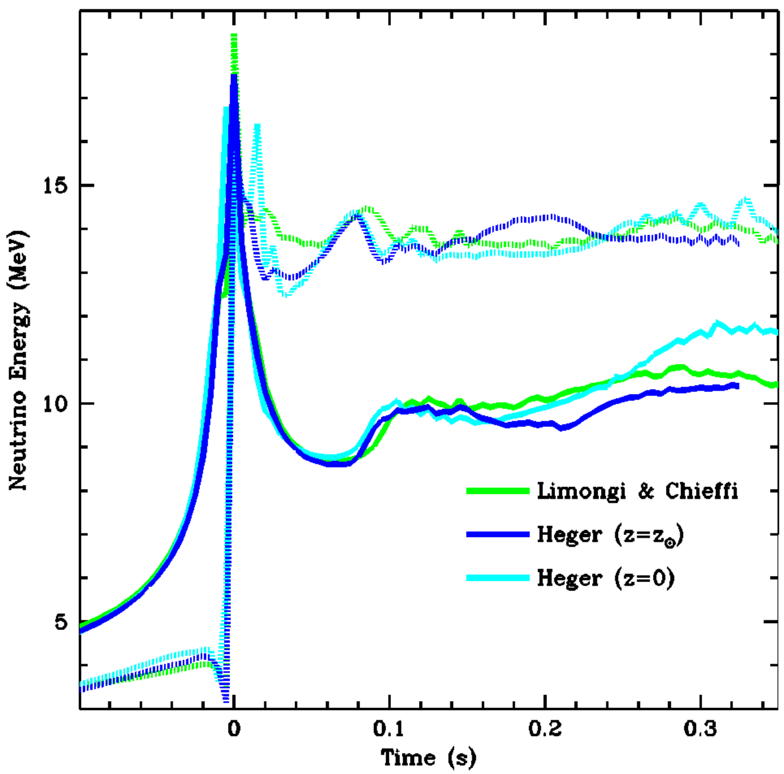
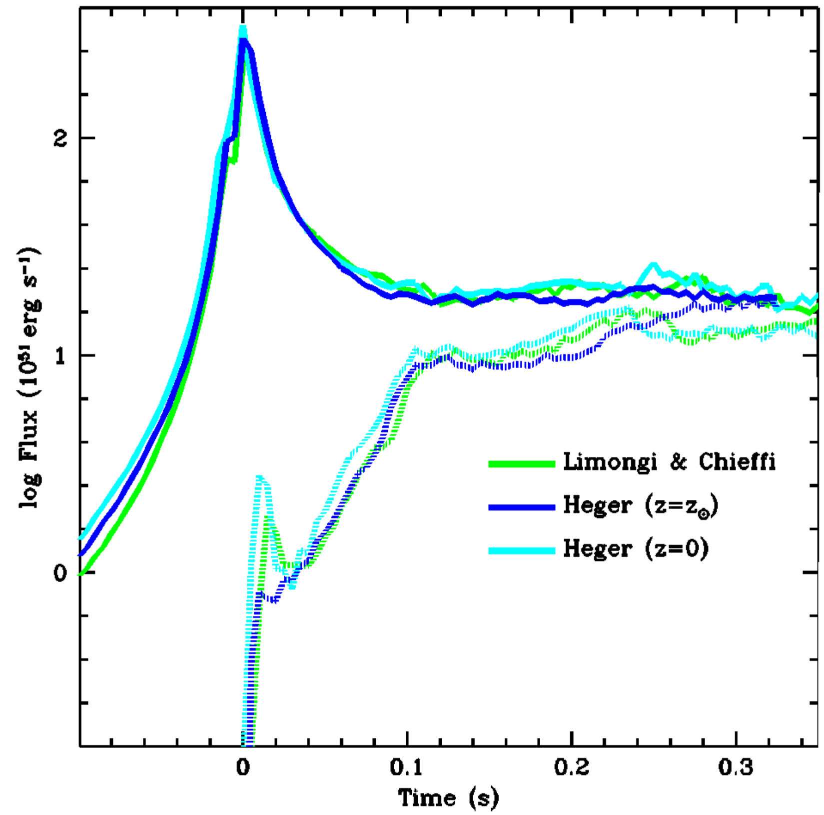
- Neutrinos from First Stars (very massive collapsar has interesting features).
- Uncertainties in calculating photon emission (problems in assuming equilibrium states)
- Rad-Hydro calculations of Pair-Instability Supernovae

Progenitor Effects on Neutrinos: Collapse/Bounce+

- Despite differences in progenitor, the neutrino signal from collapse and bounce are very similar.

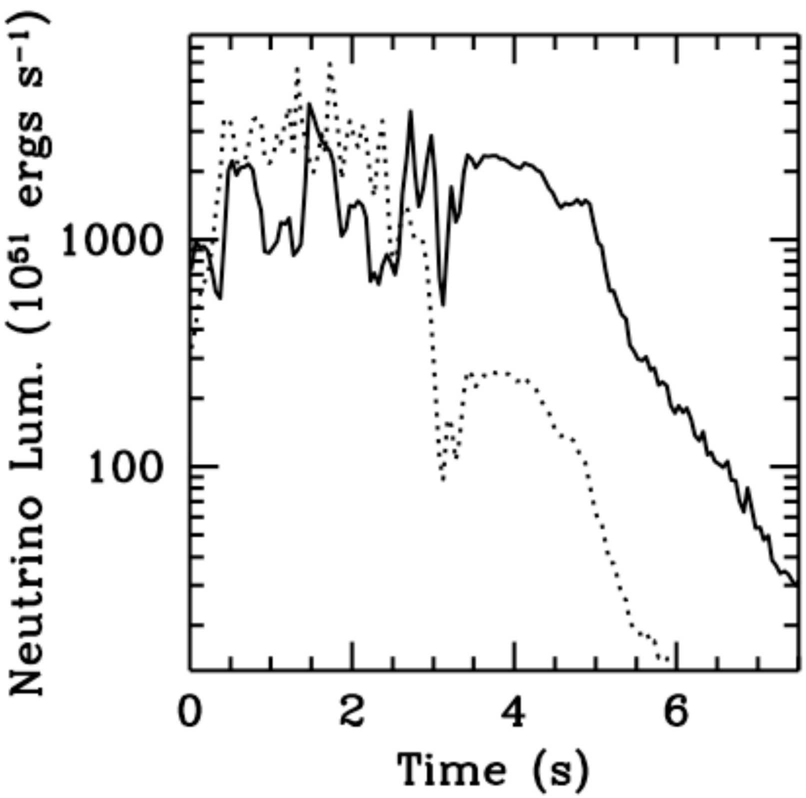


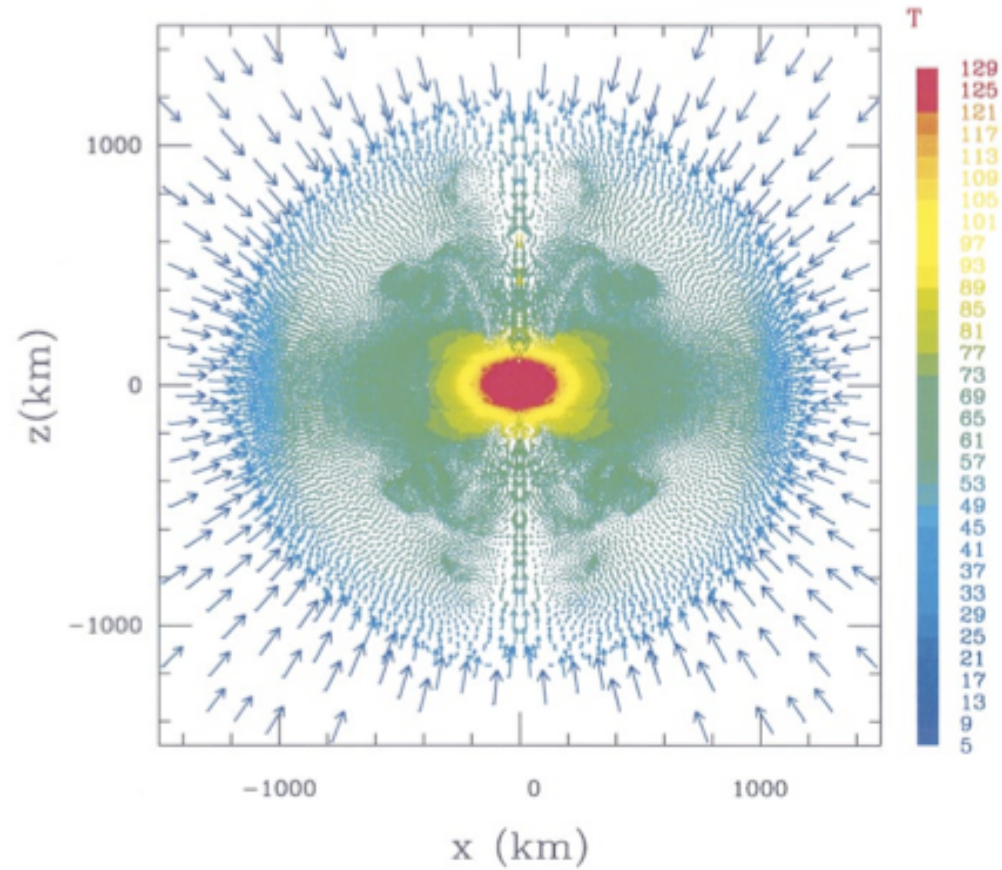


- Ultimately, the subsequent convective evolution and the amount of fallback will cause differences (~20% level).

Massive Stars

Very massive stars evolve very differently than massive stars, producing large proto-black holes that take seconds to collapse.

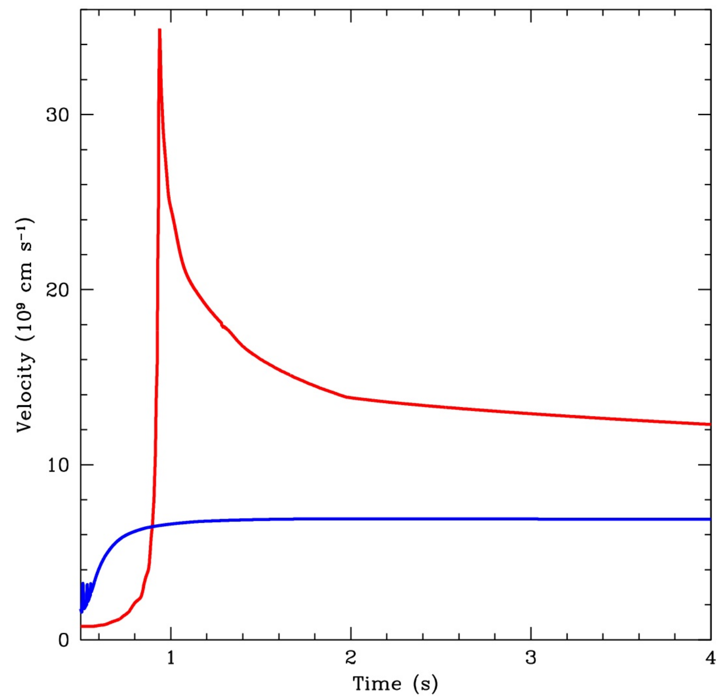


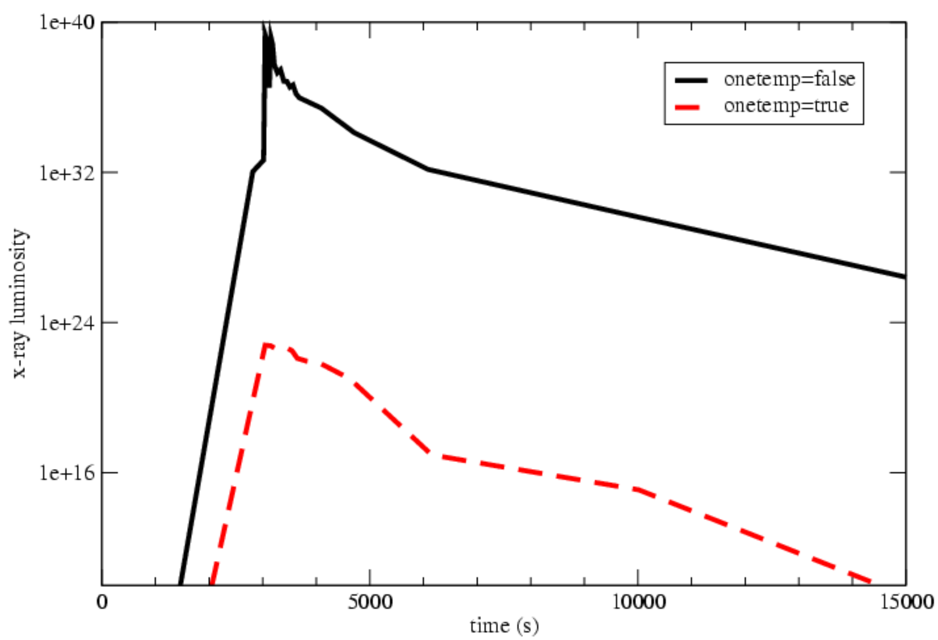


The neutrino signal from these stars peaks higher than normal supernovae and the luminosity remains high for several seconds. Depending on the spectra, these may be detectable by GADZOOKS!

Modeling Shock Breakout

- As the shock breaks out of the star, the high pressure at the boundary leads to an incredible acceleration of the shock (Colgate 1970, Matzner & McKee 1999 argued this could for relativistic ejecta). If radiative losses are included, the acceleration is much less drama
- But radiative acceleration is also important, driving the shock front further than pure hydrodynamics will. Pure hydrodynamics calculations lead to errors in velocity profiles!

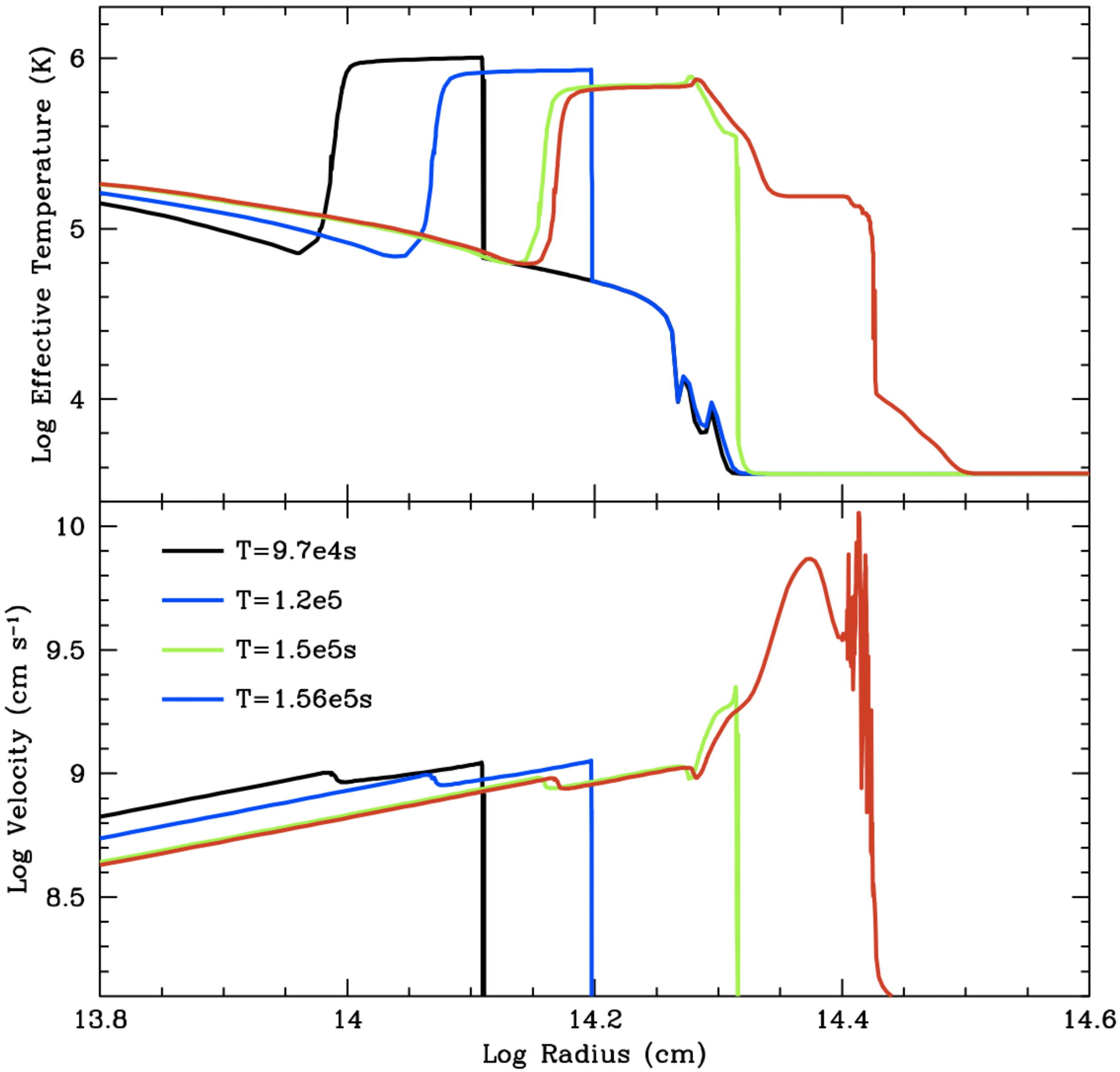




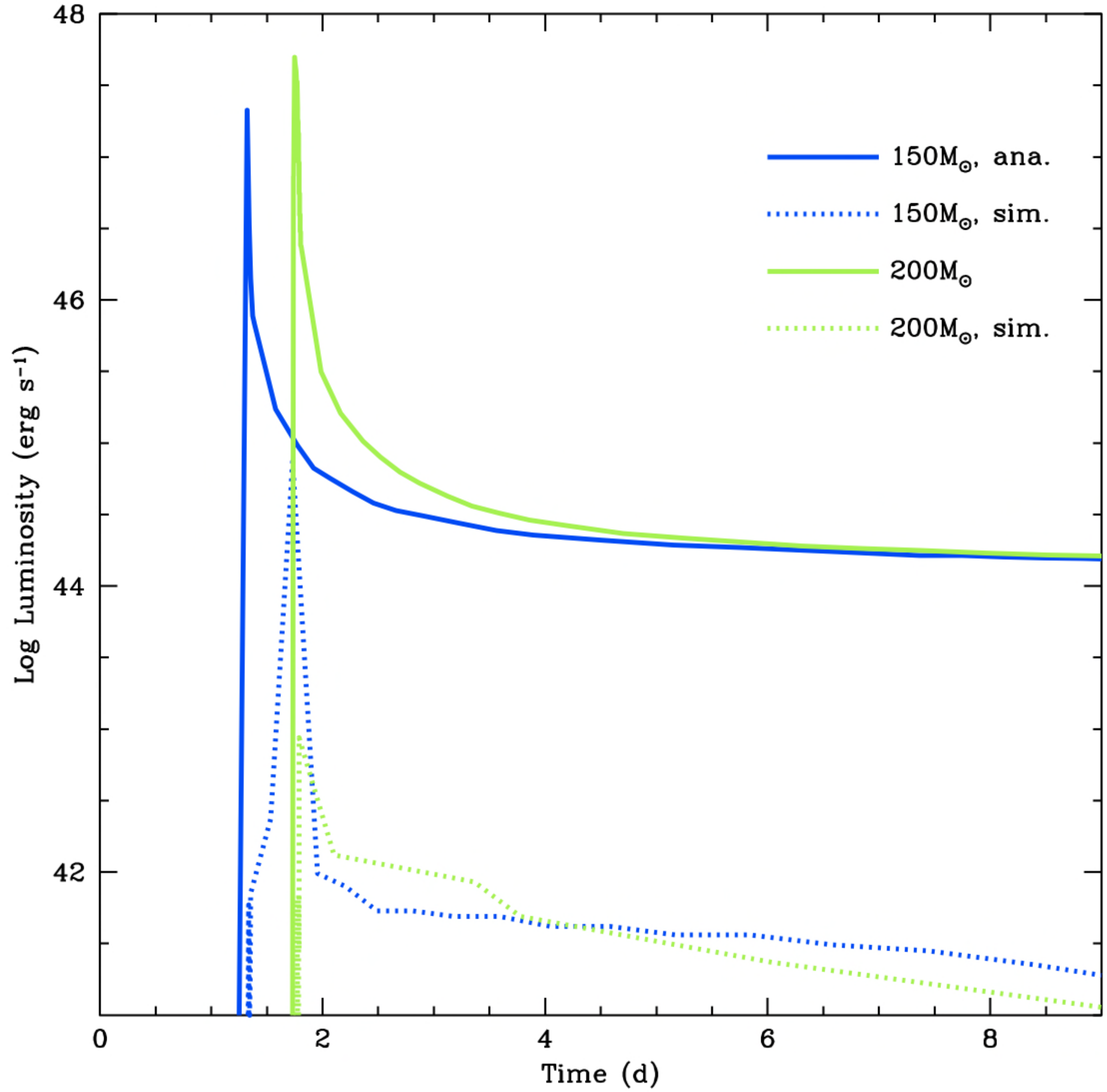
- At breakout, radiation and matter are not in equilibrium. For high energy emission, equilibrium calculations can lead to large errors.

More Shock Breakout Features

- Even when the radiation is trapped, it can lead the shock – the shock position moves faster than Sedov solution would predict.
- After breakout, the radiation begins to decouple from the material.



Slight modifications in the radius where shock break-out occurs can dramatically alter the light curves – making accurate analytic estimates difficult.

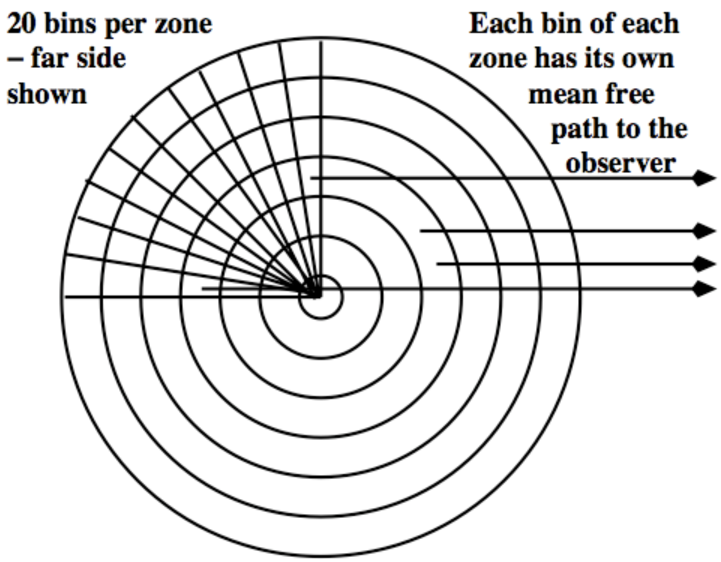


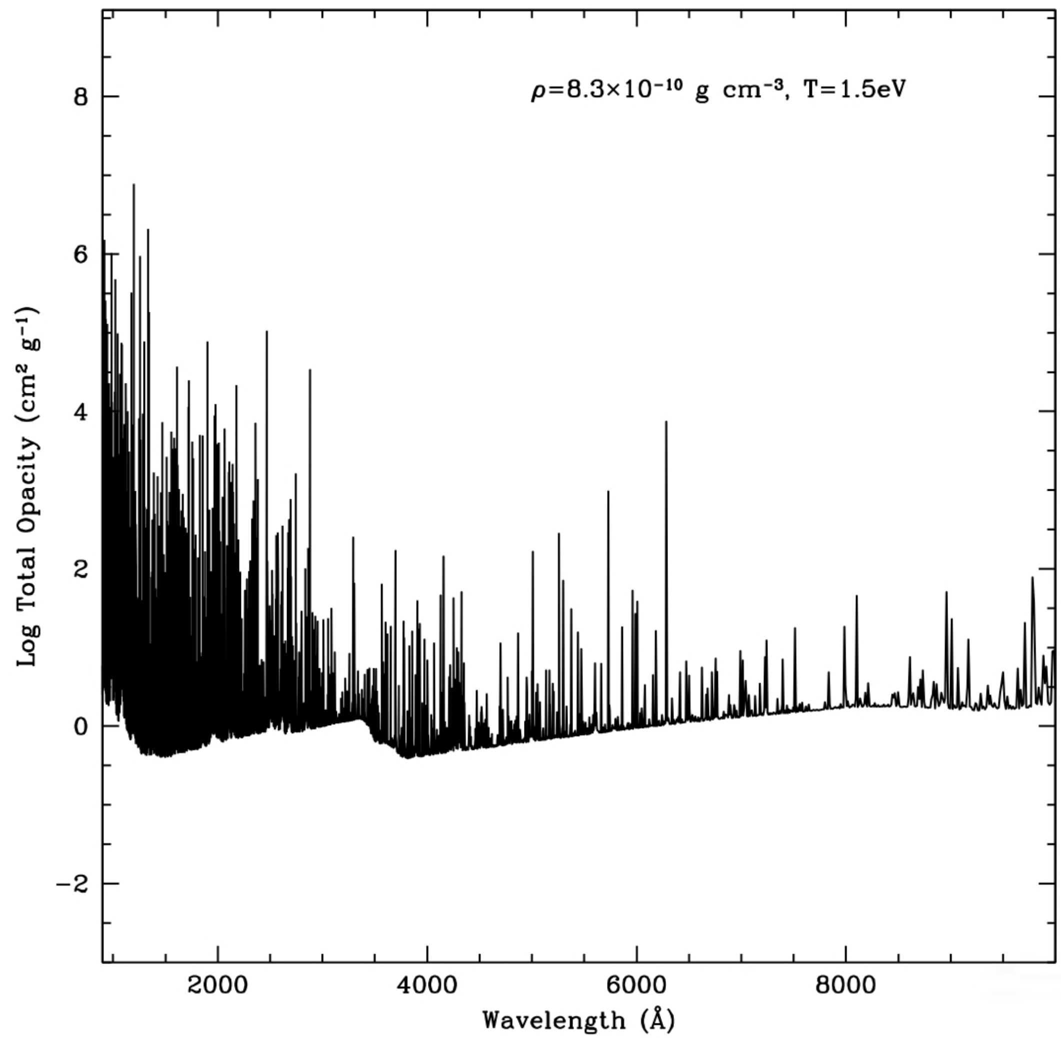
Precision Models of Supernova Spectra

Precision measurements require advanced codes: Here's than LANL approach

- Leverage off of LANL's 1-,2-, and 3-dimensional Radiation Adaptive Grid Eulerian (RAGE) code: an AMR code with flux-limited diffusion radiation transport
- LANL atomic opacities
- Added S_n transport for gamma-rays
- Now running production runs in 1-dimension
- Running test runs using Monte-Carlo thermal transport and 2D – On Roadrunner!
- Studying NLTE effects
- Ideal when shock heating important (can't be done in simulations assuming matter/radiation equilibrium)

Post-process includes detailed LANL opacities

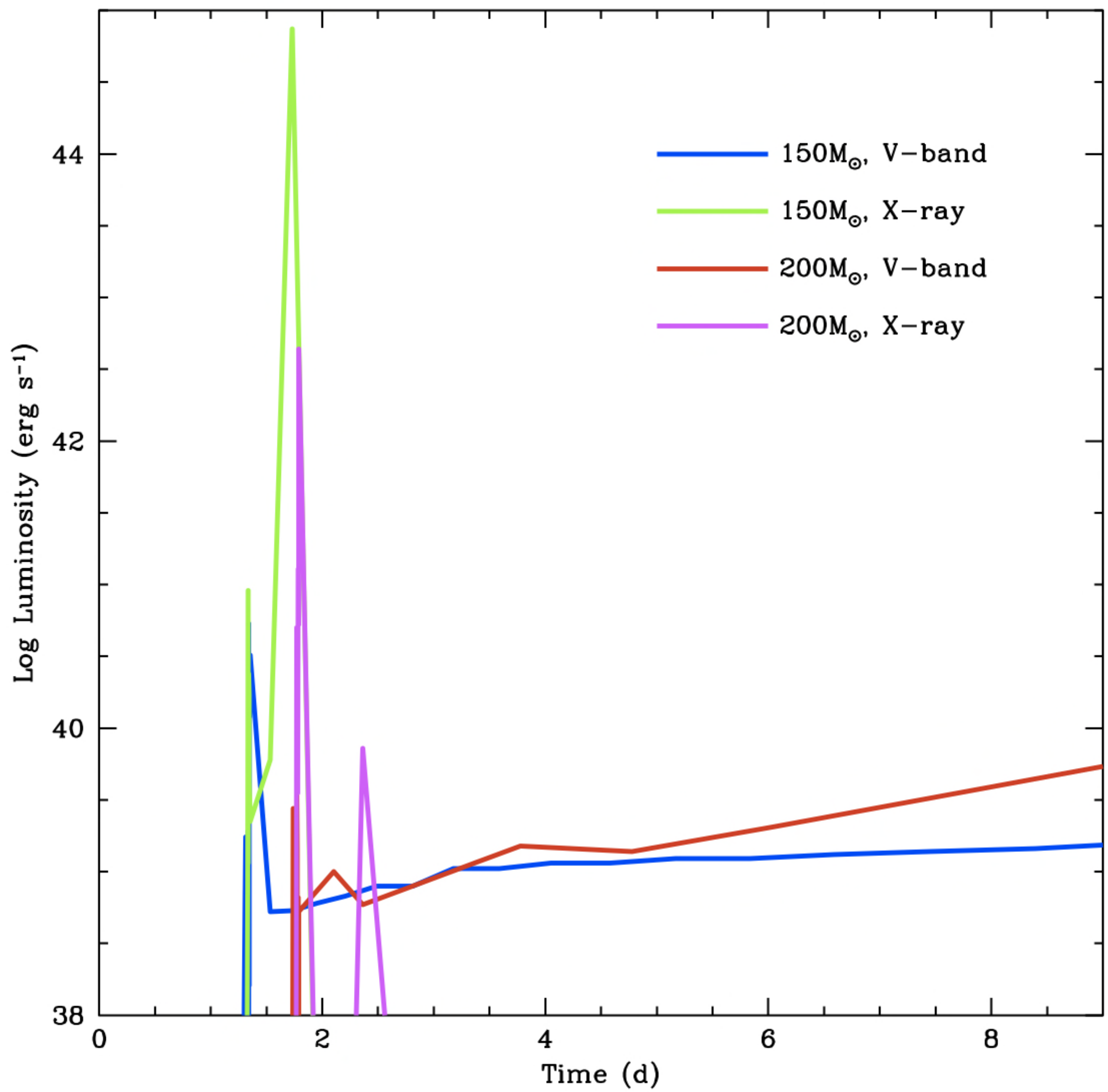




But we are still assuming the atomic levels are in equilibrium!

Pair Instability Shock Breakout: X-ray

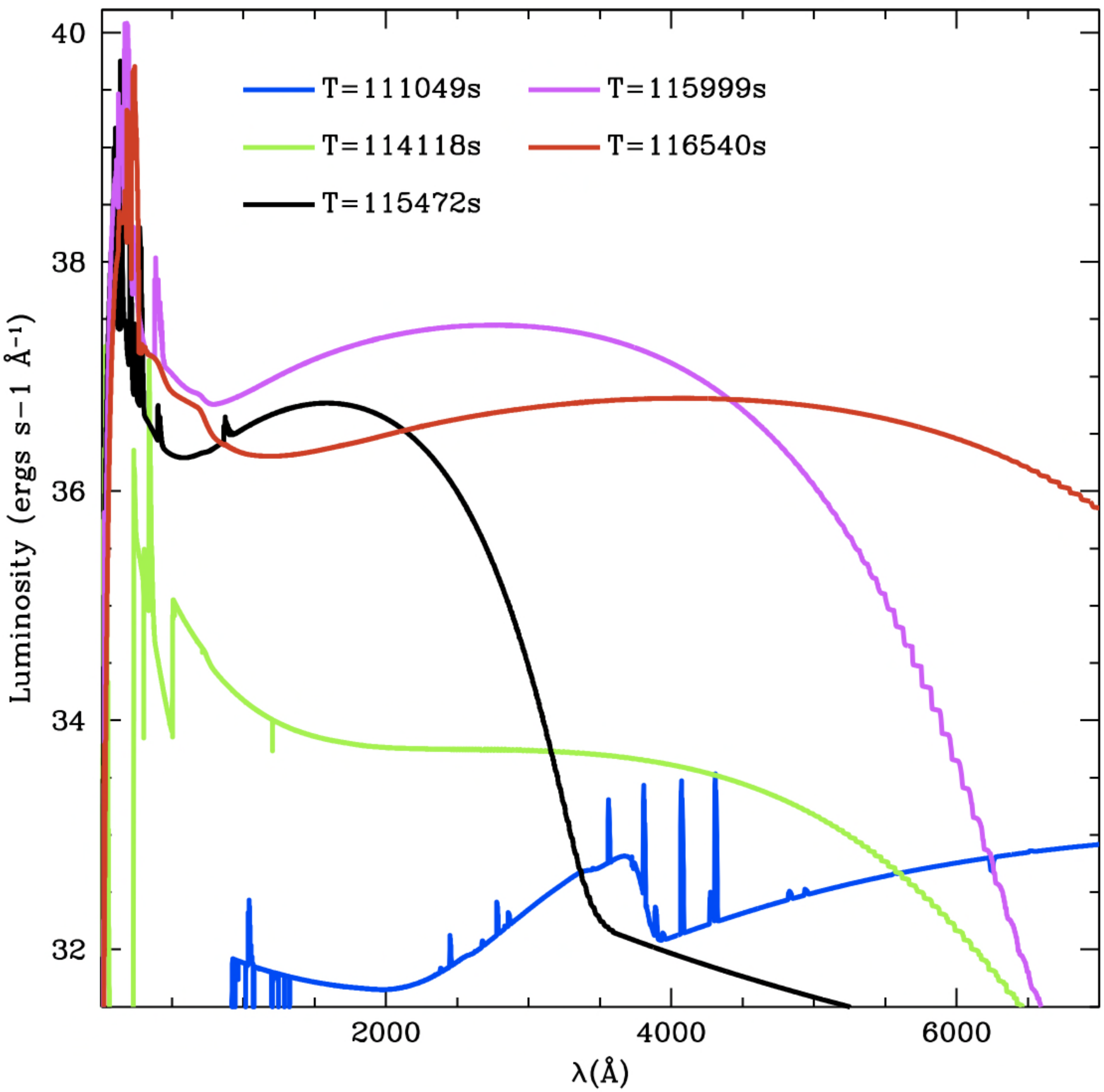
- The X-ray outburst (> 100eV) is brief (hours-long), just at breakout.



Using Heger et al. models

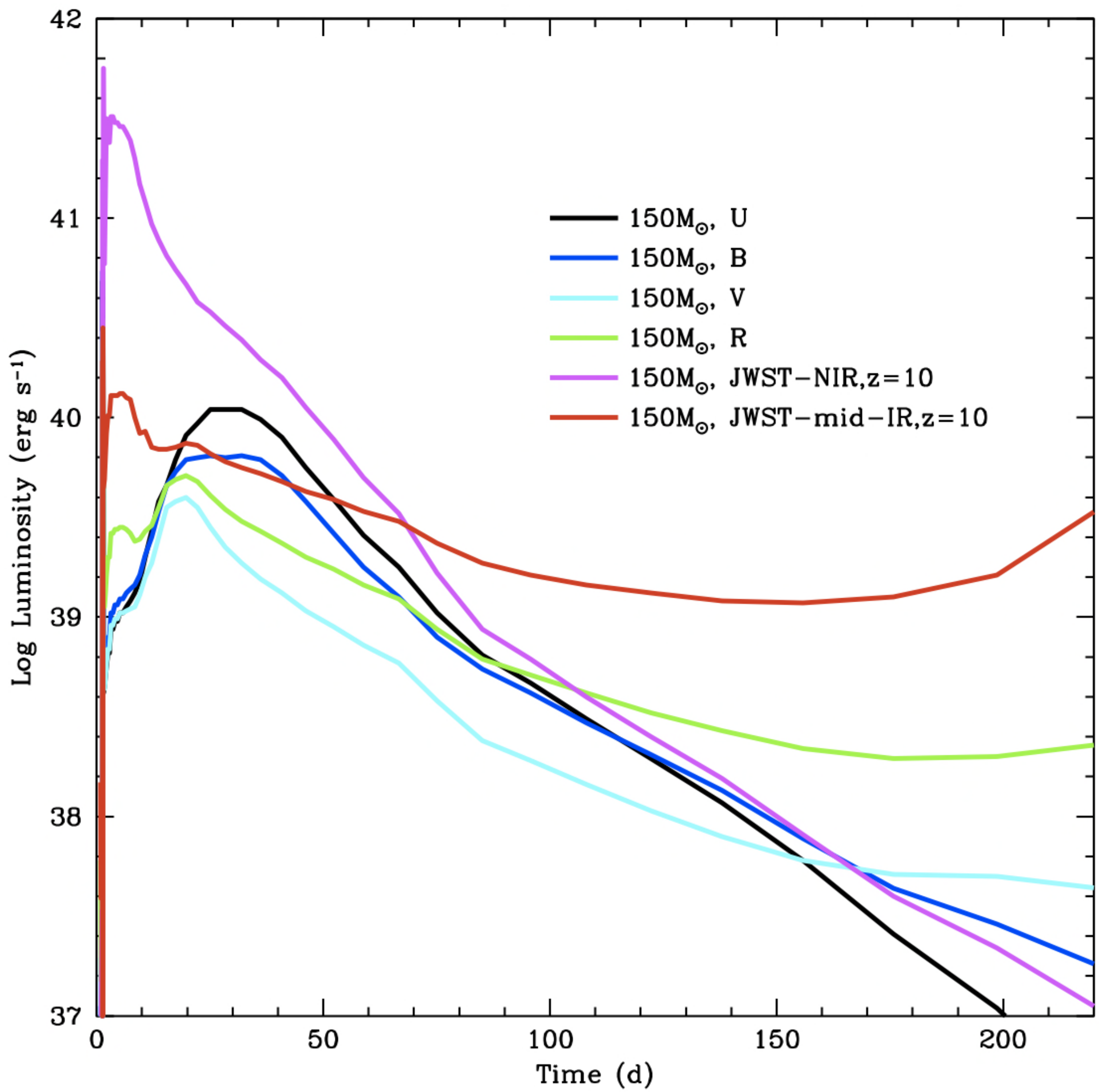
Spectra at Breakout

- The breakout spectra evolve rapidly as the front cools (need higher resolution in our post-process)

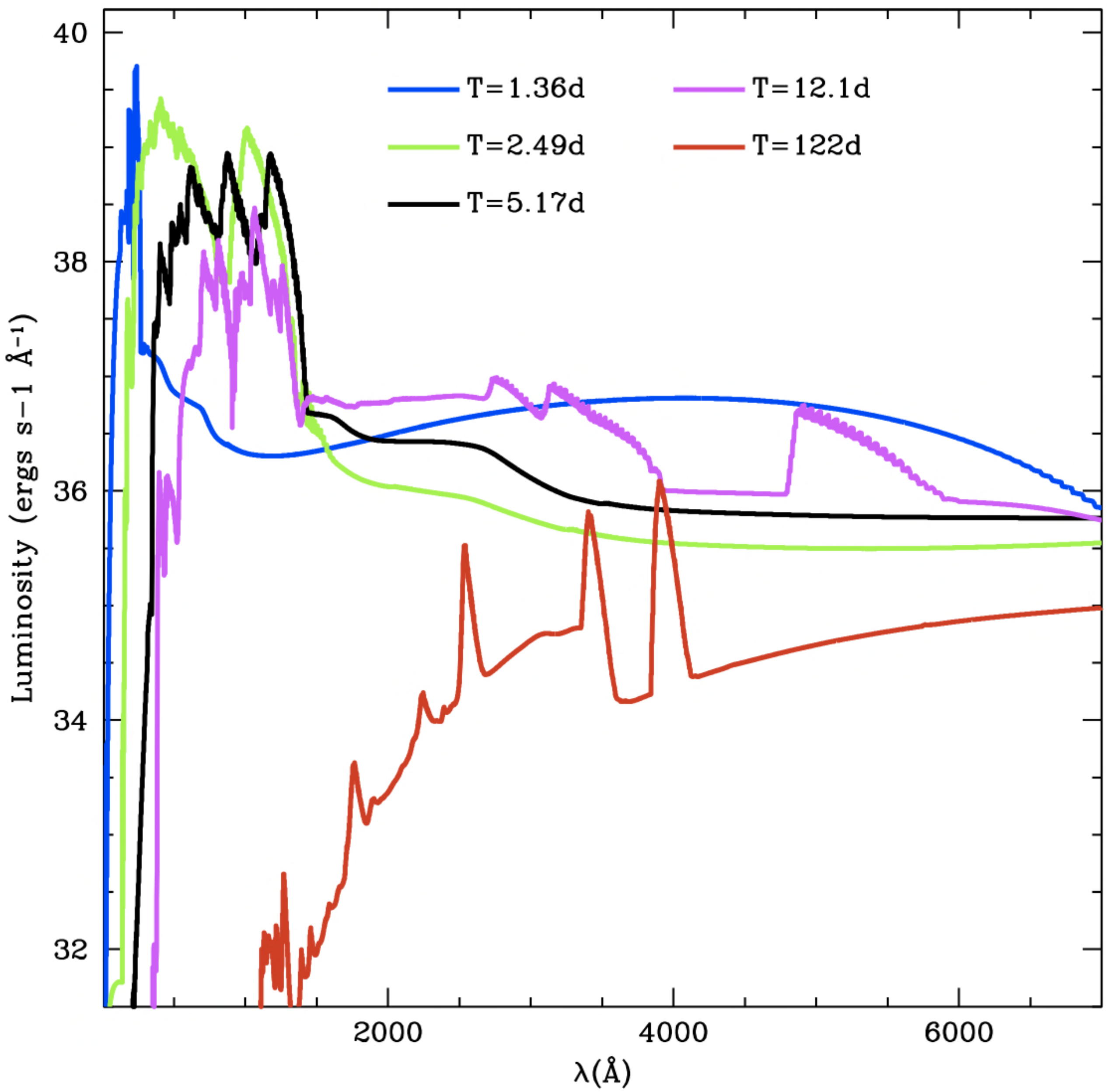


- Long term light-curve evolution:

  A burst at z=10 produces a large signal in the first 50d in the JWST NIR camera wavelength range

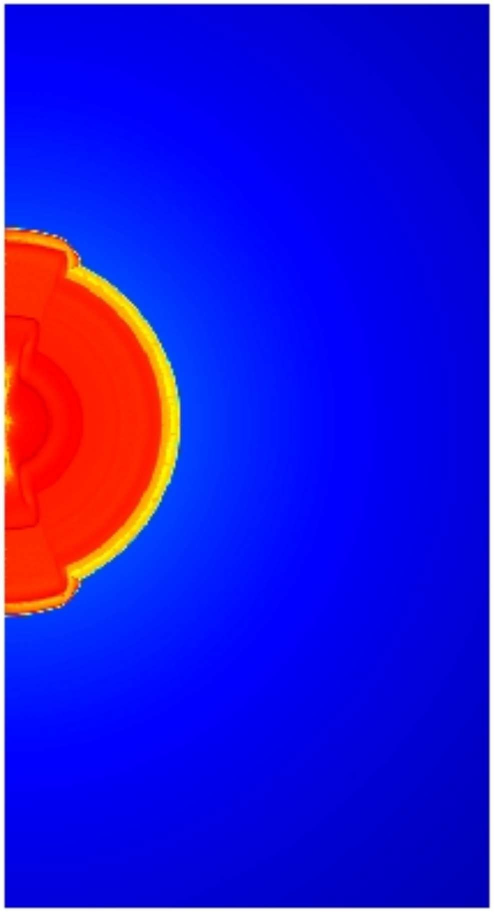


- **Late-time spectra:** Whether the spectral features can be used to distinguish explosions remains to be seen.
- Need full parameter studies with highly-resolved photospheres.



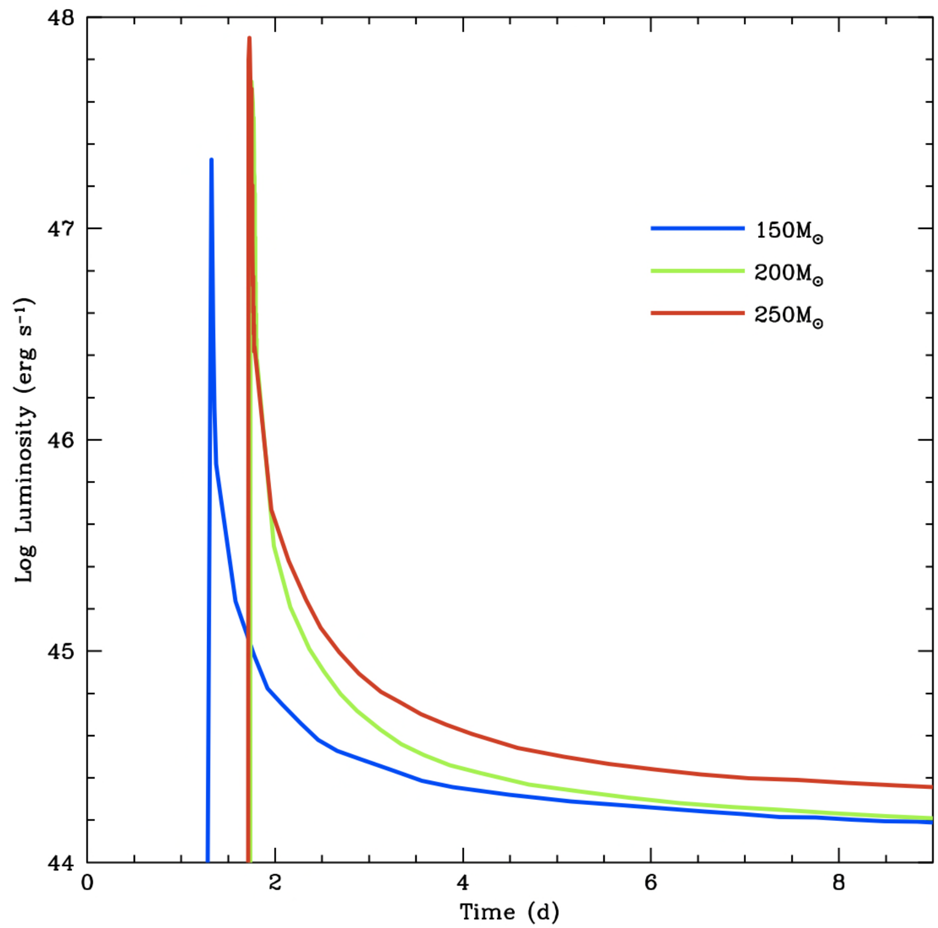
For the Future

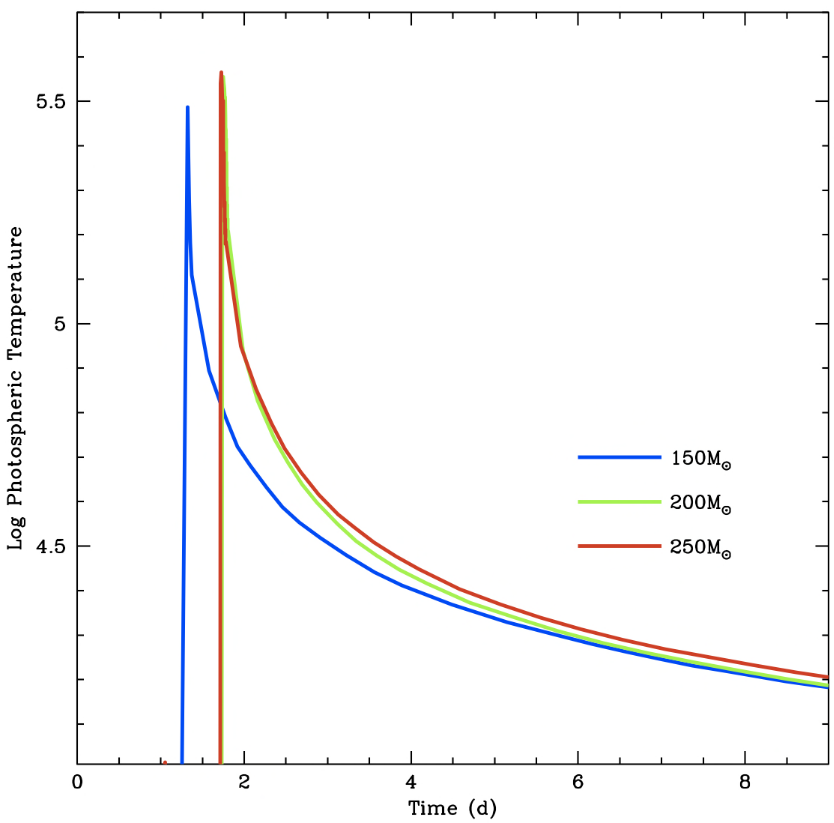
- Surroundings can matter (in Nature and in rad-hydro calculations – Fryer et al. 2009). We need to study the range of possibilities.
- Spectral features require both high spatial resolution of the photosphere and the incorporation of out-of-equilibrium atom levels. Theory can be coupled to experiments.
- Multi-dimensional radiation hydrodynamics with Implicit Monte Carlo on heterogeneous machines with Roadrunner eliminates post-process.



Shock Breakout for First Stars.

Step 1: estimate the break-out luminosity and effective temperature assuming electron scattering dominates.





The drop in luminosity is dominated by a drop in temperature. This will be sensitive to the exact photospheric radius.

The lower metallicity of the first star alters the winds and hence the fate of these stars.