Neutrinos (and Nucleosynthesis) from Accretion Disks

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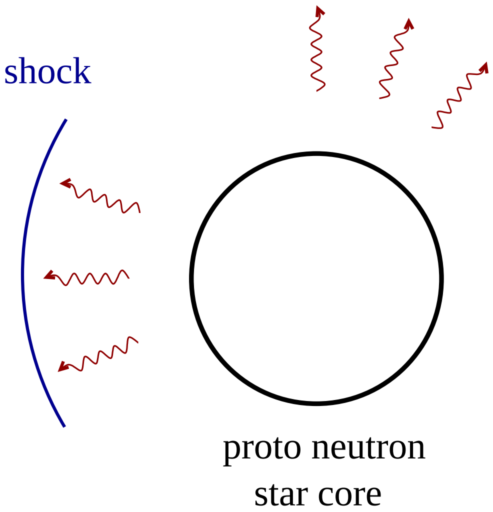
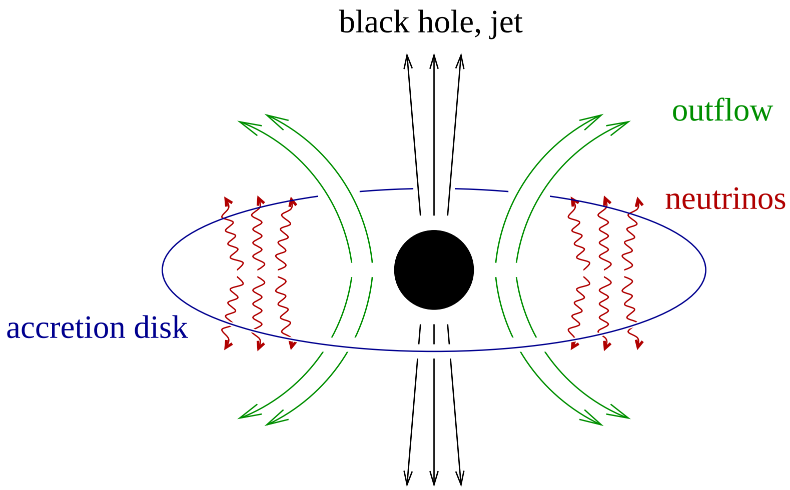
Explosions of Massive Stars: What's happening at the Center?

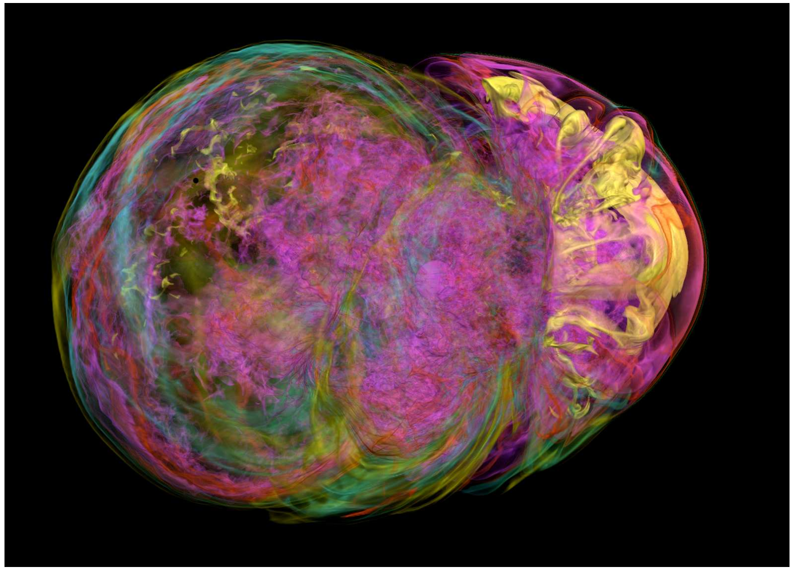




Standard core core collapse SN

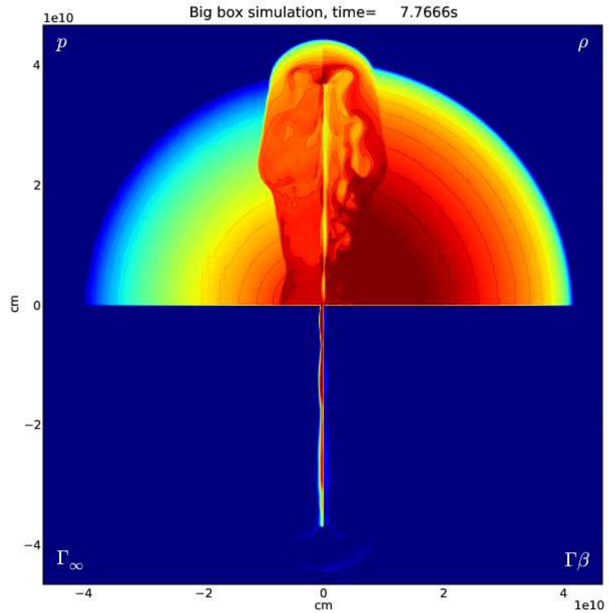
Accretion disk SN, compact object merger, gamma ray burst

Explosions of Massive Stars: Hydrodynamical Calculations



Core core collapse SN

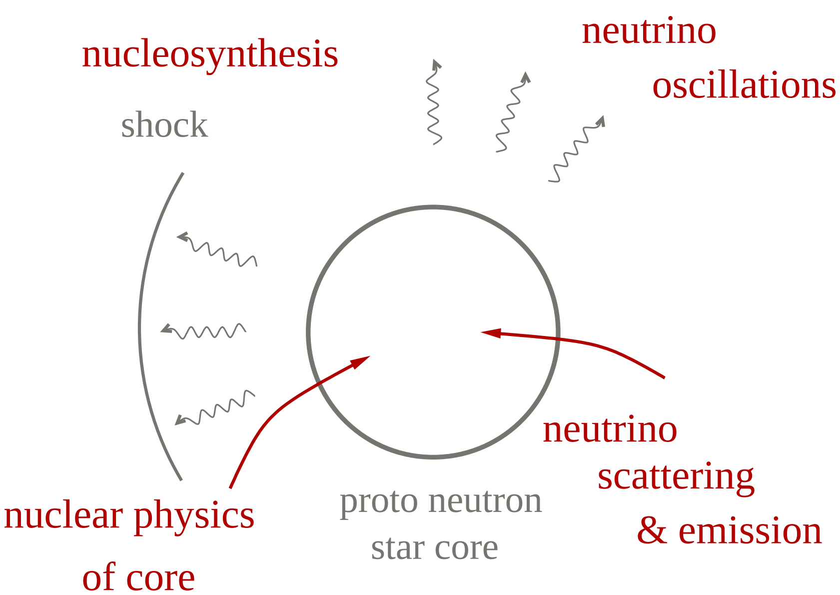
Blondin & Mezzacappa (2007)



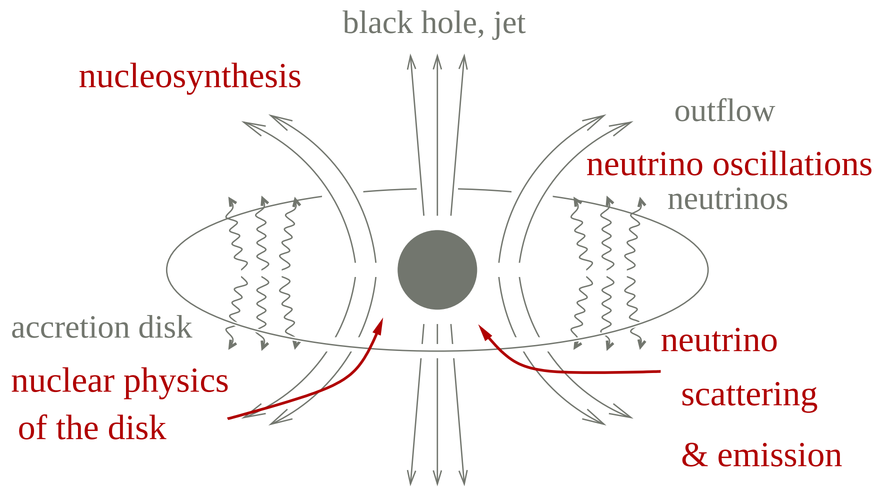
Gamma ray burst jet

Morsony, Lazzati, & Begelman (2007)

Explosions of Massive Stars: Where is the nuclear-neutrino physics?

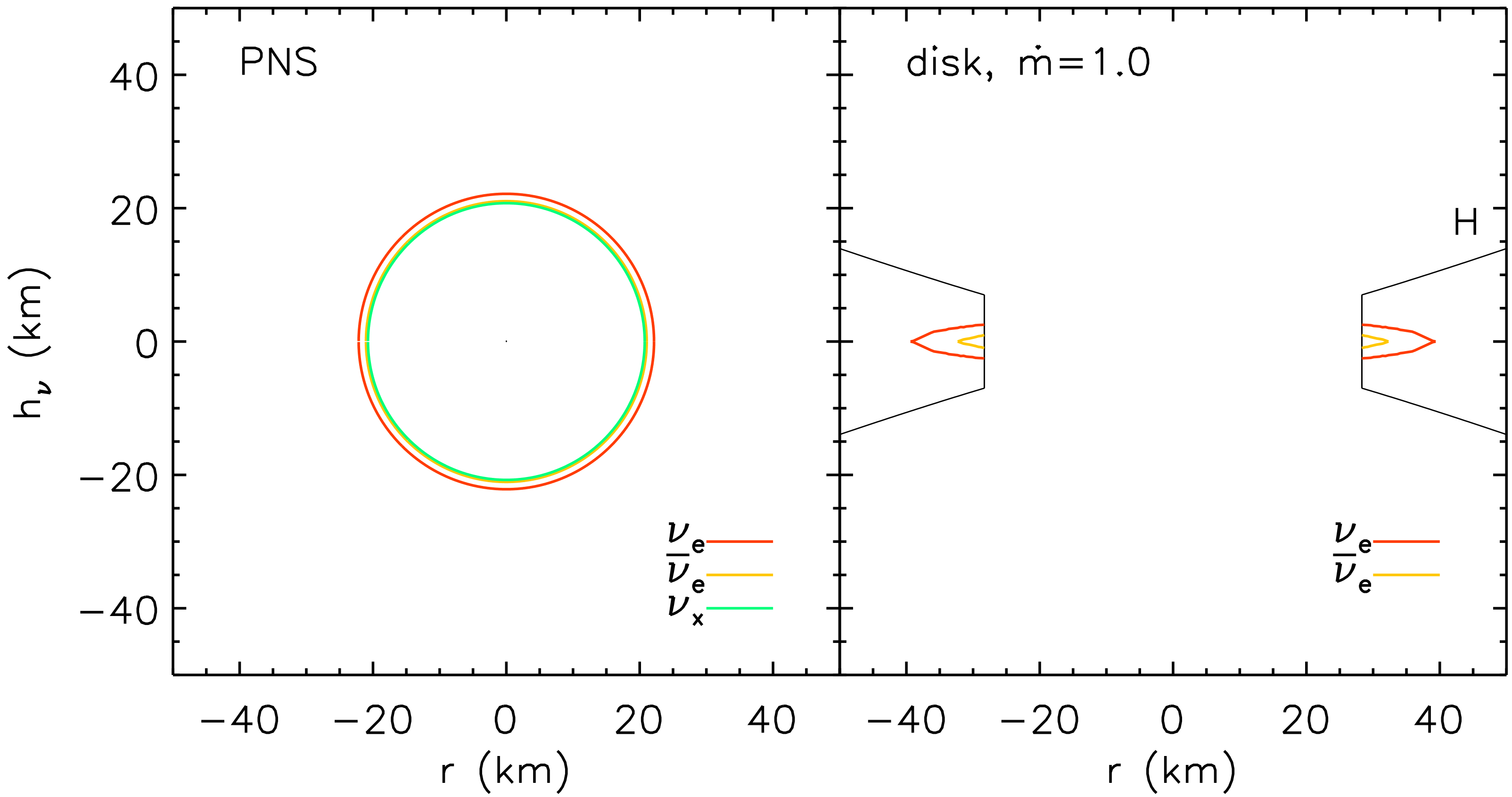


Standard core core collapse SN



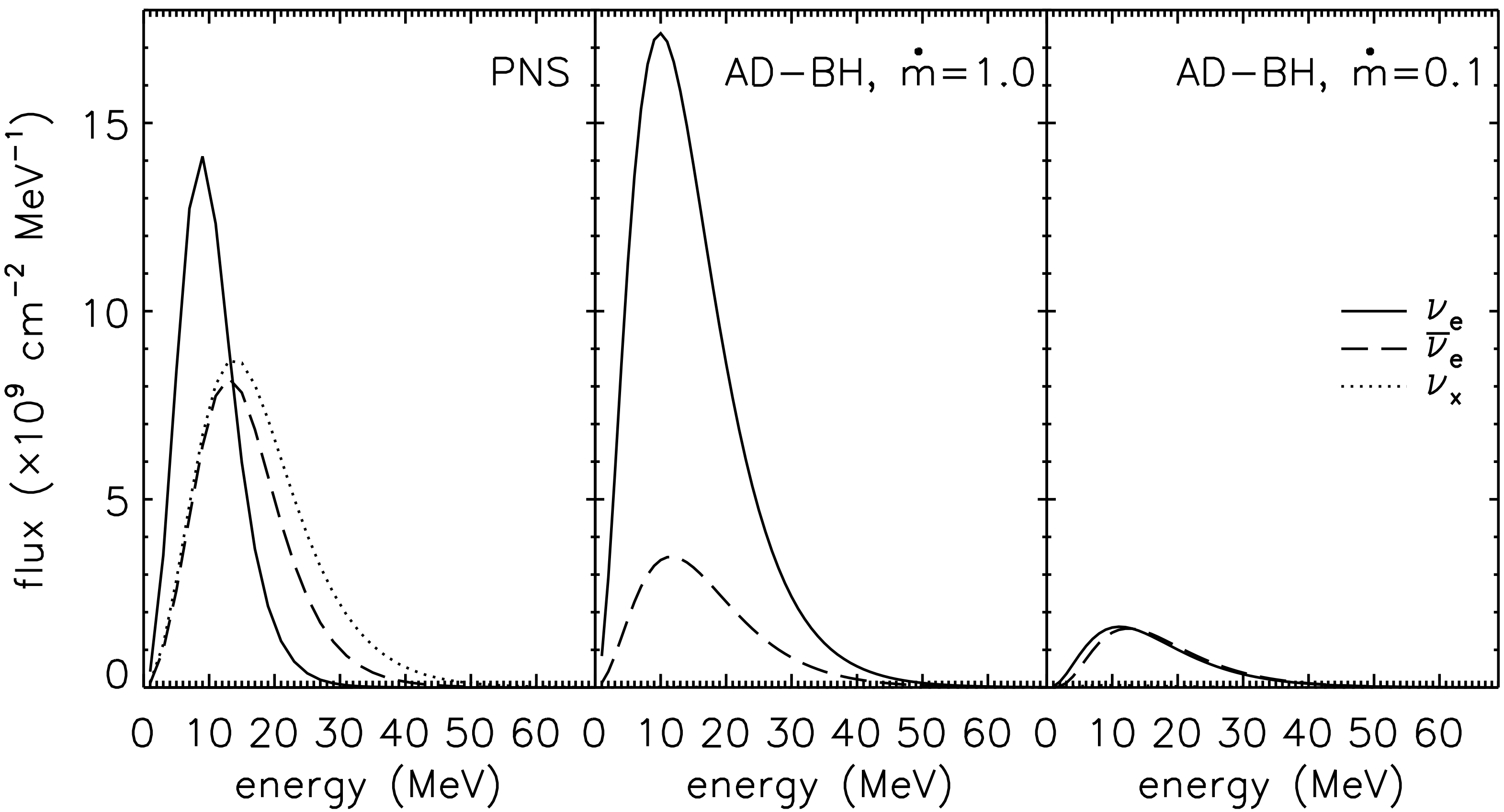
Accretion disk SN, compact object merger, gamma ray burst

Neutrino surfaces:



GCM & R. Surman 2006

Comparison of Spectra: PNS and low accretion rate disks

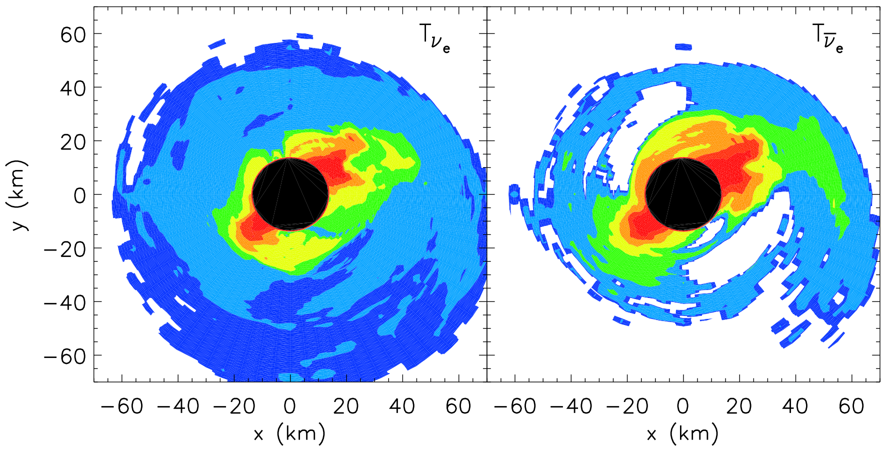


In the disk electron neutrinos and antineutrinos have similar energies to the protoneutron star. Although few muon and tau neutrinos are produced in "collapsar" type disks.

GCM & R Surman 2006

Compact Object Merger Models

- Neutron star and black hole spiral in
- Create an accretion disk around a black hole



Surman et al 2009

Importance of accretion disk neutrinos

1. important for energetics of object
2. in principle they are detectable
3. may help power gamma ray bursts
4. influence nucleosynthesis

Disentangling the signal

Extreme: What if its not a "traditional" core collapse supernova?

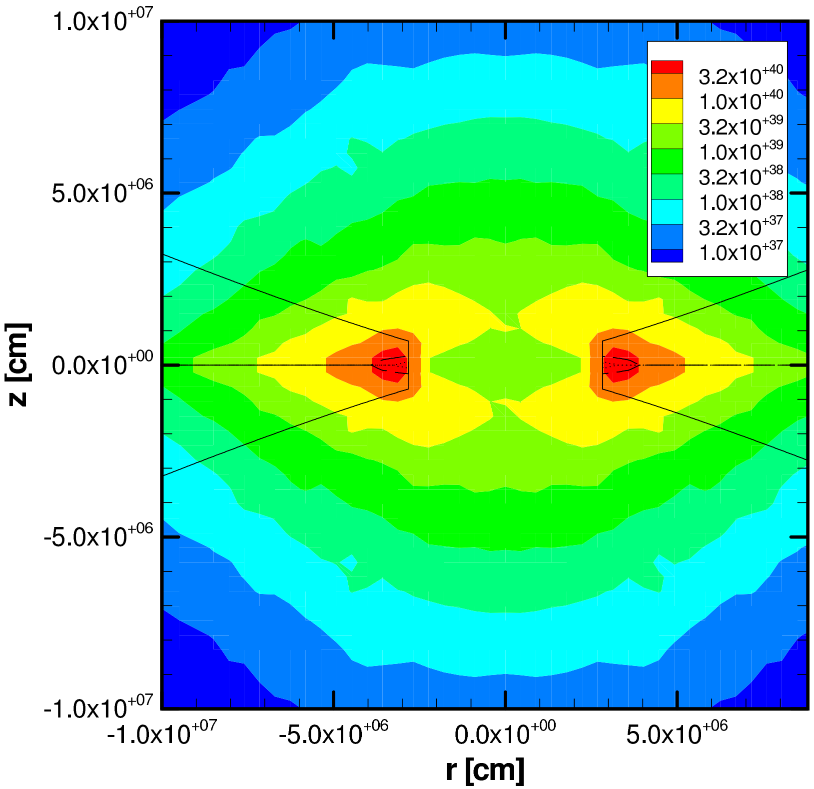
Rates:

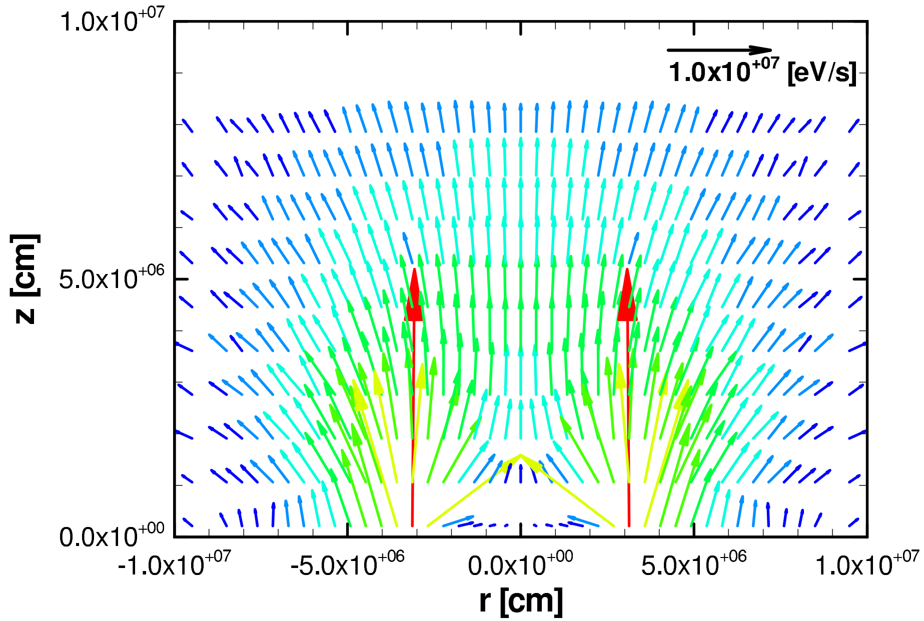
- Regular supernova ~ 7000 events, 10 seconds
- Accretion Disk of $\dot{M} = 0.1M/M_{\odot}$, 1400 events, 10 seconds
- Black Hole - Neutron Star merger, 9000 events, 0.01 seconds

For events at 10 kpc.

Caballero et al 2009

Applications to Gamma Ray Bursts
ν-$\bar{\nu}$ annihilation and ν-e scattering





Kneller et al 2006

Nucleosynthesis in Hot Outflows

Three types of environments

- proto-neutron star supernovae
- accretion disk supernovae
- compact object mergers

Several important types of nucleosynthesis

- r-process
- p-process
- $^{56}\mathrm{Ni}$ - an ingredient in light curves

Neutrino - Nucleosynthesis connection

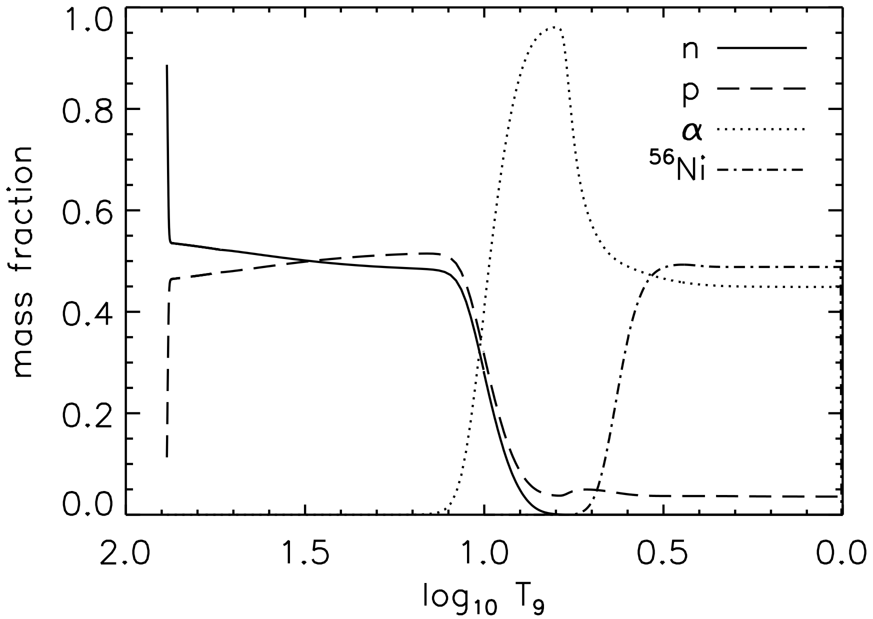
If neutrinos have most of the energy in an object, they are key to determining the astrophysical conditions.

Also, they determine the relative numbers of neutrons and protons...

- $\nu_e + n \leftrightarrow p + e^-$
- $\bar{\nu}_e + p \leftrightarrow n + e^+$

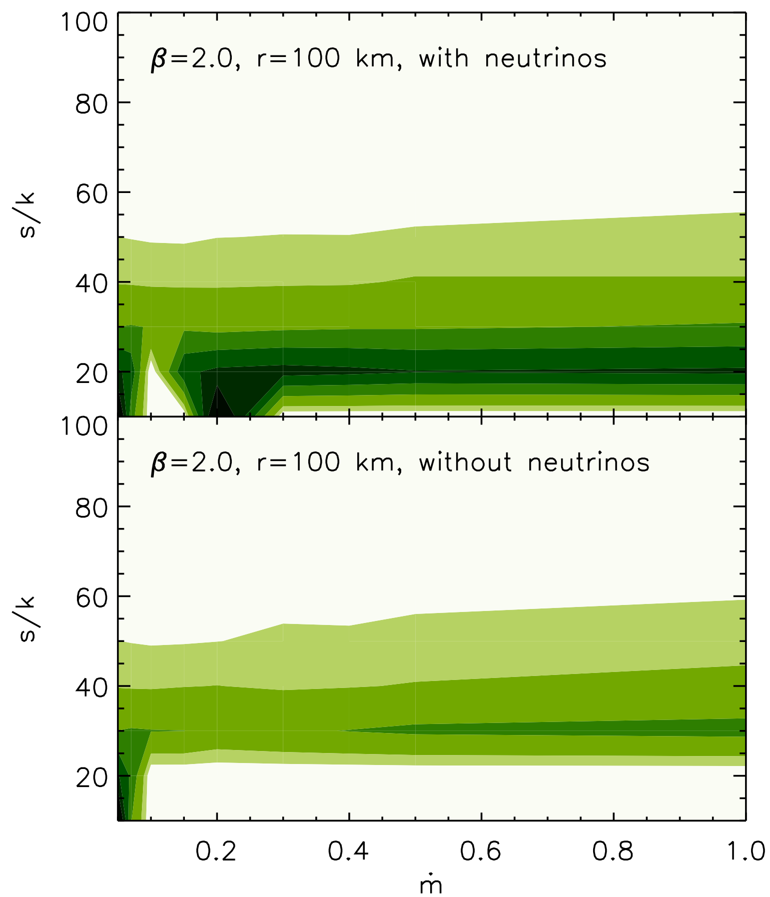
Nucleosynthesis in Hot Outflows

n,p $\longrightarrow^4$ He $\longrightarrow$ iron peak nuclei $\longrightarrow$ heavier nuclei



Nickel in Hot Outflows

n,p $\longrightarrow^4$ He $\longrightarrow$ iron peak nuclei $\longrightarrow$ heavier nuclei



Surman et al 2009

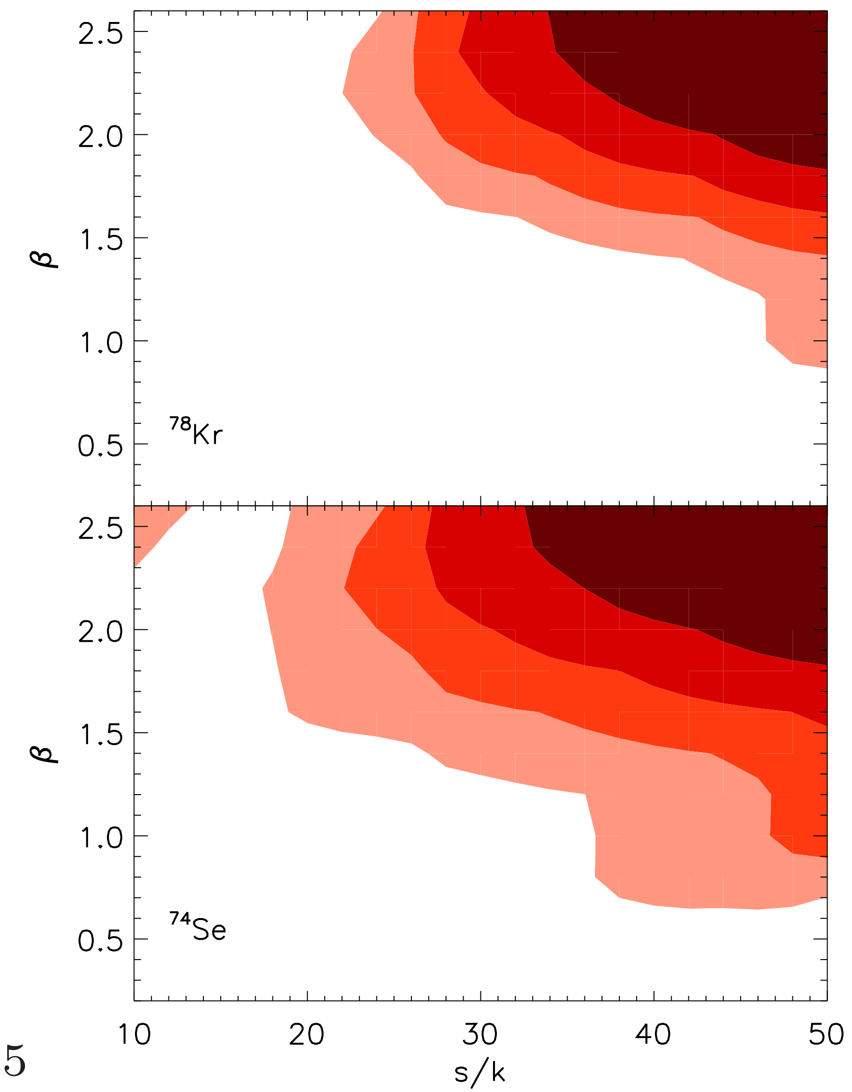
p-process in GRB's

Accretion disk outflows are a "new" site for nucleosynthesis

p-process

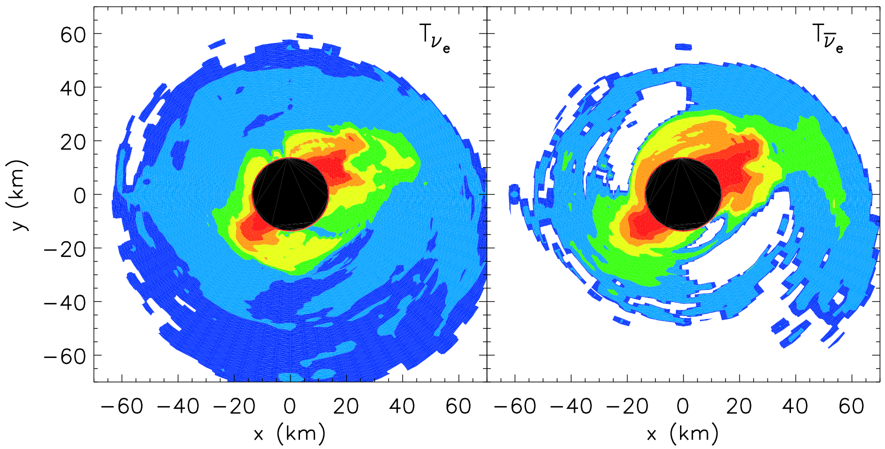
Neutrinos also influence the formation of the p-process elements, though the neutron-to-proton ratio, neutrino captures on protons and neutrino captures on nuclei.

Kizivat et al., in preparation 2009



Nucleosynthesis: Compact Object Merger Models

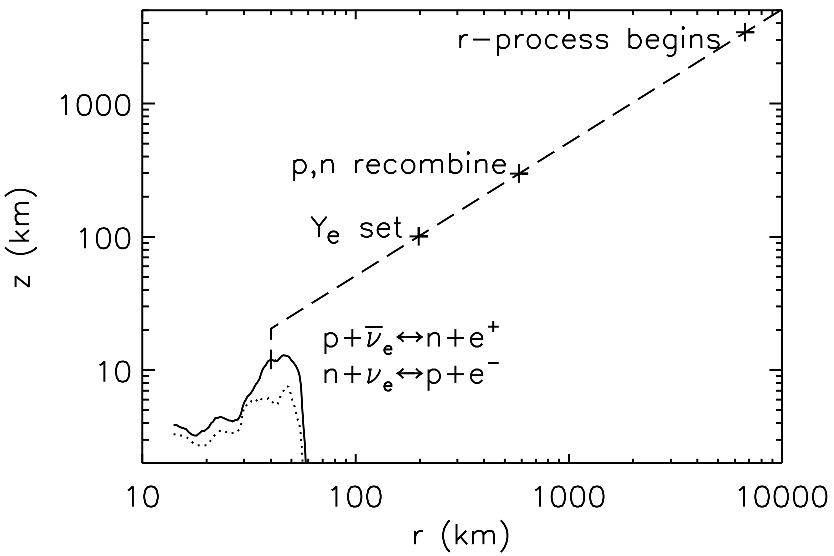
- Neutrino Emission Temperatures
- Electron and Anti-electron Neutrinos



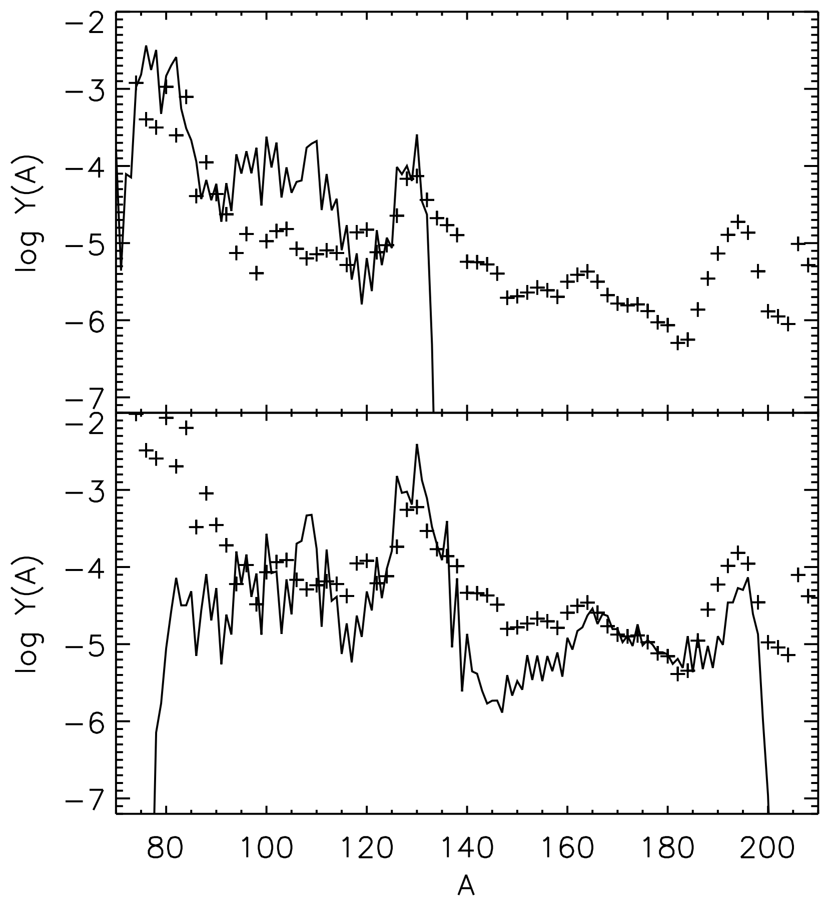
Surman et al 2009

Accretion Flow Nucleosynthesis

Black Hole Neutron Star Merger



Schematic of events in outflow



R-process occurs in the wind

Surman et al. 2008

Summary

- Neutrinos from accretion disks have somewhat similar spectra to PNS neutrinos
- Gamma ray bursts make a lot of nickel, and likely some other rare elements
- Compact object mergers make the r-process in hot outflows
- Neutrinos play an important role in determining the type of elements formed
- More to understand about astrophysical environment, neutrinos, and nuclear data