Nucleosynthesis of elements in the outflows from gamma ray bursts

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Gamma Ray Bursts (GRB) are the extremely energetic transient events, visible from the most distant parts of the Universe. They are most likely powered by accretion on the hyper-Eddington rates that proceeds onto a stellar mass black hole newly formed in the center of a rotating collapsing star or via a merger of two compact stars. This central engine gives rise to the powerful, ultra-relativistic jets that are responsible for energetic gamma ray emission, as well as to the winds launched with smaller velocities from the accretion disk surface.

We consider the outflows from Gamma Ray Bursts, resulting from the acretion torus wind. The torus is composed of free nucleons, Helium, electron-positron pairs, and is cooled by neutrino emission. The significant number density of neutrons in the outflowing material will lead to subsequent formation of heavier nuclei. We study the process of nucleosynthesis and its possible observational consequences.

__Chemical composition of the disk: e+, e-, p and n__

- we assume the gas to be in beta equilibrium, so that the ratio of proton to neutron satisfies the balance between forward and backward nuclear reactions

- we assume neutrino cooling via electron, muon and tau neutrinos in the plasma opaque to their absorption and scattering

Neutrinos are formed in the URCA process (electron-positron capture on nucleons), e+e- pair annihilation, nucleon-nucleon bremsstrahlung and plasmon decay.

- leptons and baryons are relativistic and may have arbitrary degeneracy level. We compute the gas pressure using the appropriate Fermi-Dirac integrals

Nucleosynthesis of heavier elements in the disk surface

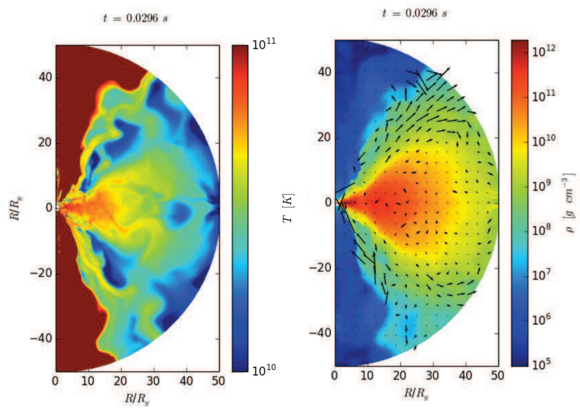
- we use the thermonuclear reaction network code

(http://webnucleo.org) and we compute the nuclear statistical equlibria established for fusion reactions.

- the reaction data are taken from the JINA *reaclib* online database (http://www.jinaweb.org)

- the network is appropriate for temperature ranges below 1 MeV, appropriate to the outer radii of accretion disk in GRB engine

- the mass fraction of all elements is solved for given profiles of density, temperature and electron fraction in the disk



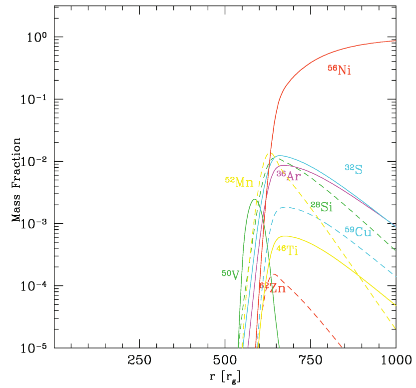
Maps of the temperature, density and velocity field in the innermost 50 R_g of the GRB central engine. Snapshot is taken at the end of an axisymmetric GR MHD simulation. Parameters: black hole mass: M=10 M_{sun}, its spin a=0.9, disk mass 1.0 M_{sun}.

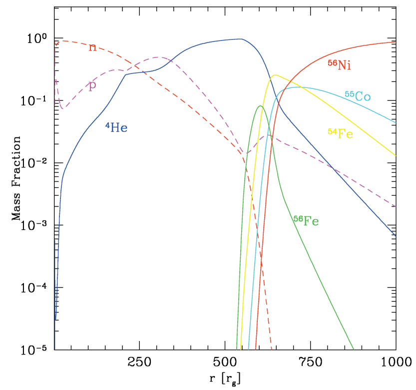
Outflows

- The outflow from accretions disk may be driven by centrifugal force or magnetic fields. Neutrino cooled disks in GRBs have faster outflows.
- The slowly accelerated outflows will allow for production of heavier elements via triple-alpha reactions up to Nickel 56 or above the Iron peak nuclei.
- The radioactive decay of certain isotopes should be detectable via the emission lines observed by X-ray satellites, such as NuSTAR. In XMM, the instrument EPIC may also be able to detect lines below 15 keV, e.g. for ^{45}Ti, ^{57}Mn, ^{57}Co.

References:

- Surman & Mc Laughlin, 2004, ApJ, 603, 611
- Janiuk & Yuan, 2010, A&A, 509, A55
- Janiuk et al., 2013, ApJ, 776, 105
- Janiuk A., 2014, A&A, submitted





Heavy elements formed in the accretion disk. Most abundant isotopes synthesized within 1000 gravitational radii, for a=0.9 and accretion rate 1.0 M_{sun}/s.