Constraints on gamma-ray burst and supernova progenitors through circumstellar absorption lines

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Long gamma-ray bursts are thought to be caused by a subset of exploding Wolf-Rayet stars.
We argue that the circumstellar absorption lines in early supernova
and in gamma-ray burst afterglow spectra may allow us to determine the main properties
of the Wolf-Rayet star progenitors which can produce those two events.
To demonstrate this, we first simulate the hydrodynamic evolution of the circumstellar
medium around a 40 Msun star from the creation and evolution of a wind-blown,
photo-ionized bubble around the star up to the time of the supernova explosion.
Knowledge of density, temperature and radial velocity of the circumstellar matter as function
of space and time allows us to compute the column density in the line of sight to the
centre of the nebula, as a function of radial velocity, angle and time.
While without radiative transfer modeling and without detailed knowledge of the spatial
distribution of chemical elements we cannot produce spectra, our column density
profiles indicate the possible number, strengths, widths and
velocities of absorption line components
in supernova and gamma-ray burst afterglow spectra.
Our example calculation shows four distinct line features during the Wolf-Rayet stage,
at about 0, 50, 150-700 and 2200 km/s, with only those of the lowest and highest
velocity present at all times.
The 150-700 km/s feature decays rapidly as function of time after the onset of the
Wolf-Rayet stage. It consists of a variable
number of components, and, especially in its evolved stage,
is depending strongly on the particular line of sight.
A comparison with absorption lines detected in the afterglow of GRB 021004
suggests that the high velocity absorption component in GRB 021004
may be attributed to the free streaming
Wolf-Rayet wind, which is consistent with the steep density drop
indicated by the afterglow light curve.
The presence of the intermediate velocity components implies
that the duration of the Wolf-Rayet phase of the progenitor of GRB 021004
was much smaller than the average Wolf-Rayet life time,
which strongly constrains its progenitor evolution.

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