Pair Instability Supernovae and Hypernovae

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Overview

- Introduction
- Pair instability Supernovae in Population III stars
- Summary
- References

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Classification of Supernovae

Spectra without hydrogen lines

- Supernovae Type Ia (SN Ia)
- Supernovae Type Ib (SN Ib)
- Supernovae Type Ic (SN Ic)

Spectra with hydrogen lines

- Supernovae Type II (SN II)
- $M \approx -17^m \pm 2$ mag
- $v_{exp} \approx 10\,000$ Km/s ; $E_{tot} \approx 10^{51}$ erg

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Classification of Supernovae

Further classification of Type I Supernovae

- Supernovae Type Ia (SN Ia)
  - SiII lines (e.g. 620 nm)
  - $M \approx -19^m$
  - $v_{exp} \approx 20\,000$ Km/s
  - $E_{tot} \approx 10^{53}$ erg
  - complete disruption, no remnant

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Classification of Supernovae

- Supernovae Type Ib (SN Ib)
  - HeI lines
  - M $\approx -17^m .. -18^m$
  - $v_{exp} \approx$ 10 000 Km/s
- Supernovae Type Ic (SN Ic)
  - no HeI and SiII lines
  - M $\approx -17^m .. -18^m$
  - $v_{exp} \approx$ 10 000 Km/s

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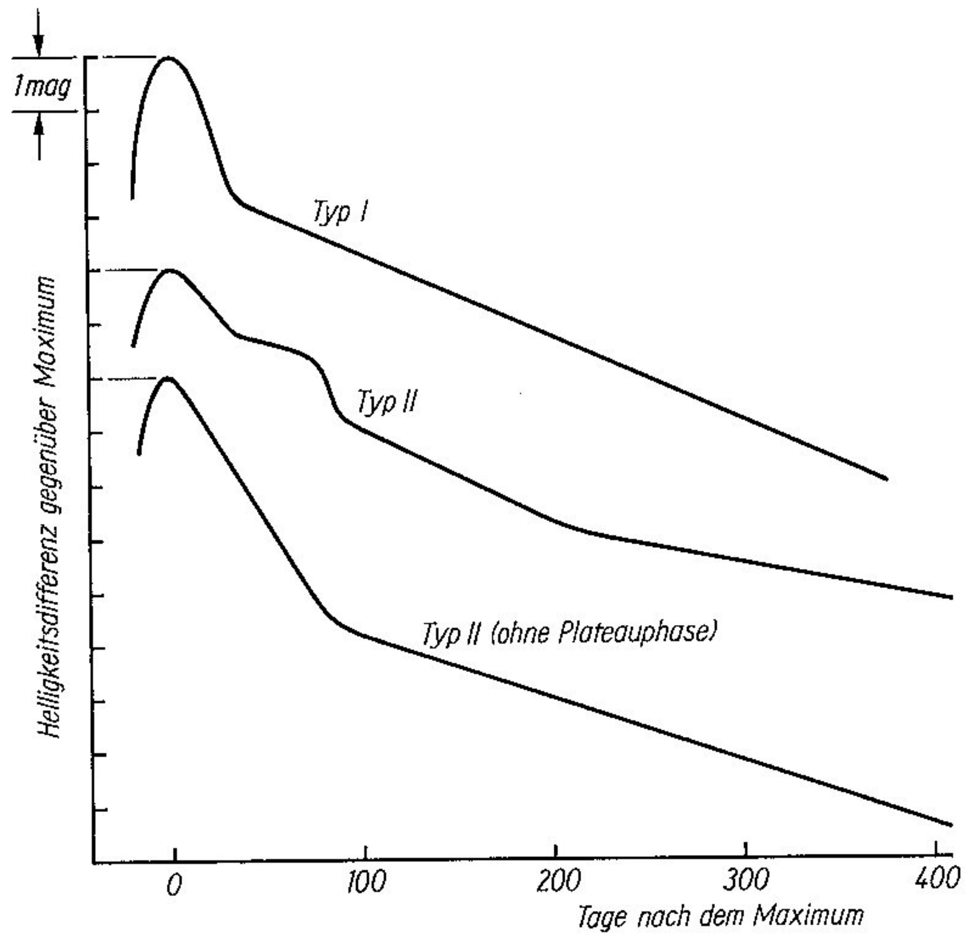

Lightcurves of different Supernovae types Zimmermann & .Weigert (1999)

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Core Collaps Supernovae

- Supernovae Type II, progenitor mass $M_\star \approx 8..13\,M_\odot$
  - trigger mechanism: $p + e^+ \longrightarrow n + \nu_e$
  - remnant is a Neutron Star (NS)
- Supernovae Type II and Ib/c, progenitor mass $M_\star \approx 13..100\,M_\odot$
  - trigger mechanism: $\gamma + {}^{56}Fe \longrightarrow 13\,{}^4He + 4\,n$

    $\gamma + {}^4He \longrightarrow 2\,p + 2\,n$
  - remnant is a NS or black hole (BH)
- Supernovae Type II and Ib/c, progenitor mass $M_\star \gtrsim 100\,M_\odot$
  - trigger mechanism: $\gamma \longrightarrow e^- + e^+$
  - remnant seemed to be BH

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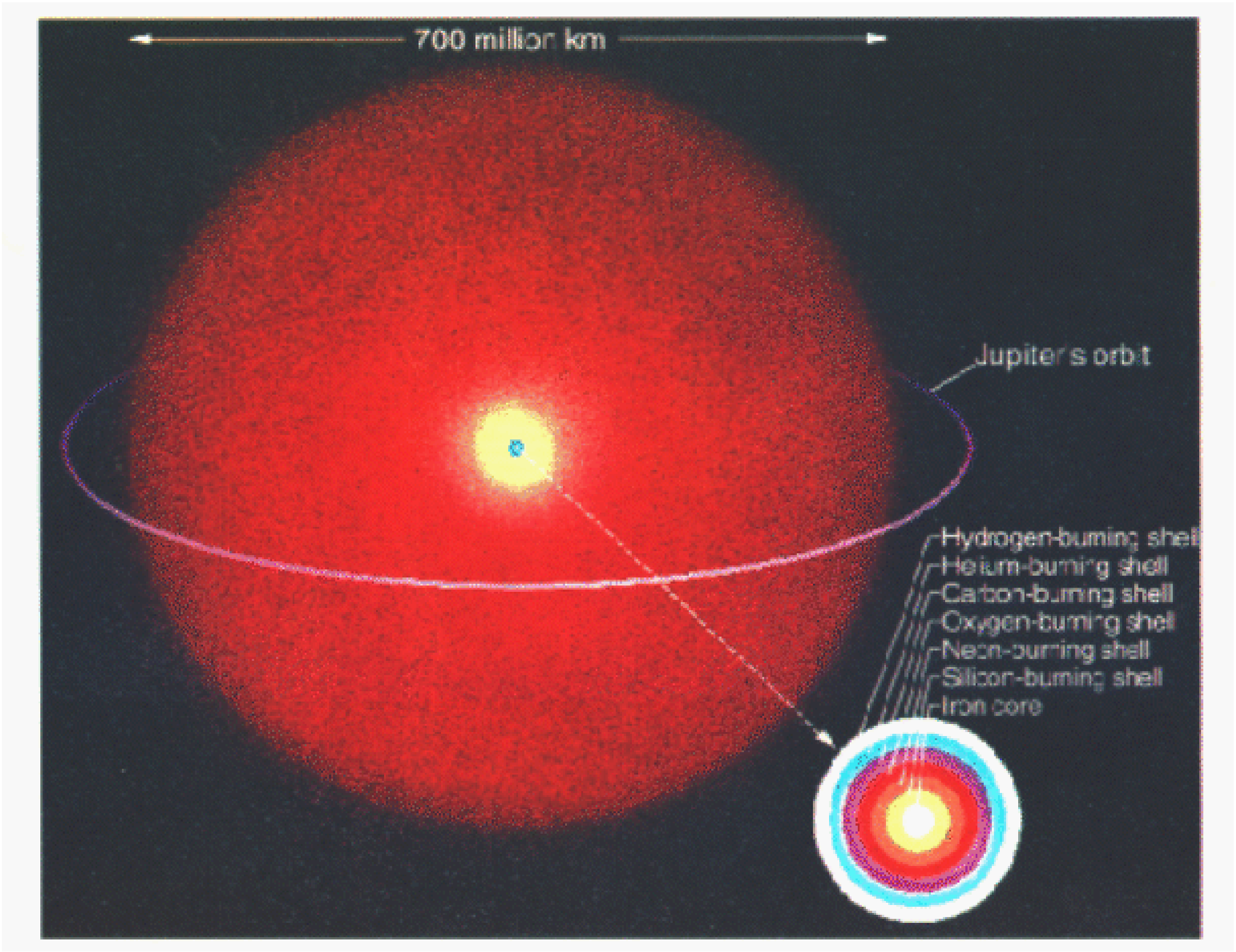

pre-Supernovae The Electronic Universe Project, University of Oregon

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Definition of Population III stars

Population III stars are the stars of the first generation.

- metallicity $Z_\star < 10^{-4}$, in simulation normally set $Z_\star = 0$
- made from primordial material (76% H and 24% He)
- the initial mass function (IMF) was very different
  $\Longrightarrow$ a large number of stars with masses $M_\star \approx 10^2..10^3\,M_\odot$
- very short lifetimes ($\sim$ Myr) for the upper end of the IMF

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Pair instability Supernovae in Population III stars

super heavy Population III stars are making core collaps super- or hypernova

- mass of progenitor star $M_\star \lesssim 140 M_\odot$
  - trigger: instability by pair production
  - remnant seemed to be a BH
- mass of progenitor star $140 M_\odot < M_\star < 260 M_\odot$ (e.g. $M_\star = 250 M_\odot$)
  - trigger: instability by pair production
  - compete disruption, no remnant
- mass of progenitor star $M_\star \gtrsim 260 M_\odot$ (e.g. $M_\star = 300 M_\odot$)
  - trigger: photo desintigration
  - remnant seemed to be a BH

Bromm et al. (2003), Fryer et al. (2001)

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progenitor star, $140\,M_\odot < M_\star < 260\,M_\odot$

core collaps of an Population III star with lower $260\,M_\odot$

- after He burning ($M_{core} \approx 130\,M_\odot$)
  $\Longrightarrow$ electron-positron pair instability
  $\Longrightarrow$ explosive O and Si burning
- helium core mass increases $\Longrightarrow$ stronger explosions
  $\Longrightarrow$ more ^{56}Ni is produced
- the explosive O and Si burning reverses the collaps into a giant nuclear-powered explosion
- $E_{expl} \approx 10^{52} erg$, ligth curve $\sim 10^{44} erg\,s^{-1}$ and ejected ^{56}Ni mass $M_{Ni} \gtrsim 40\,M_\odot$
- star complete disrupted, material complete cycled back to the ISM

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progenitor star, $M_\star > 260 M_\odot$

core collaps of an Population III star with more than $260\, M_\odot$

- at the end of He burning ($M_{core} \approx 180\, M_\odot$)
  - $\Longrightarrow$ photodesintegration instability
  - $\Longrightarrow$ explosive O and Si burning
  - $\Longrightarrow$ all energy eaten up by photodesintegration
- massiv BH is born inside the stare
  - $\Longrightarrow$ accretion of material
  - $\Longrightarrow$ magnetic field driven jets ($\approx 10^{54} erg$)

model is not abel to explain normal GRB ($\rightarrow$ time), but maybe a type off gamma ray transient (GRT)

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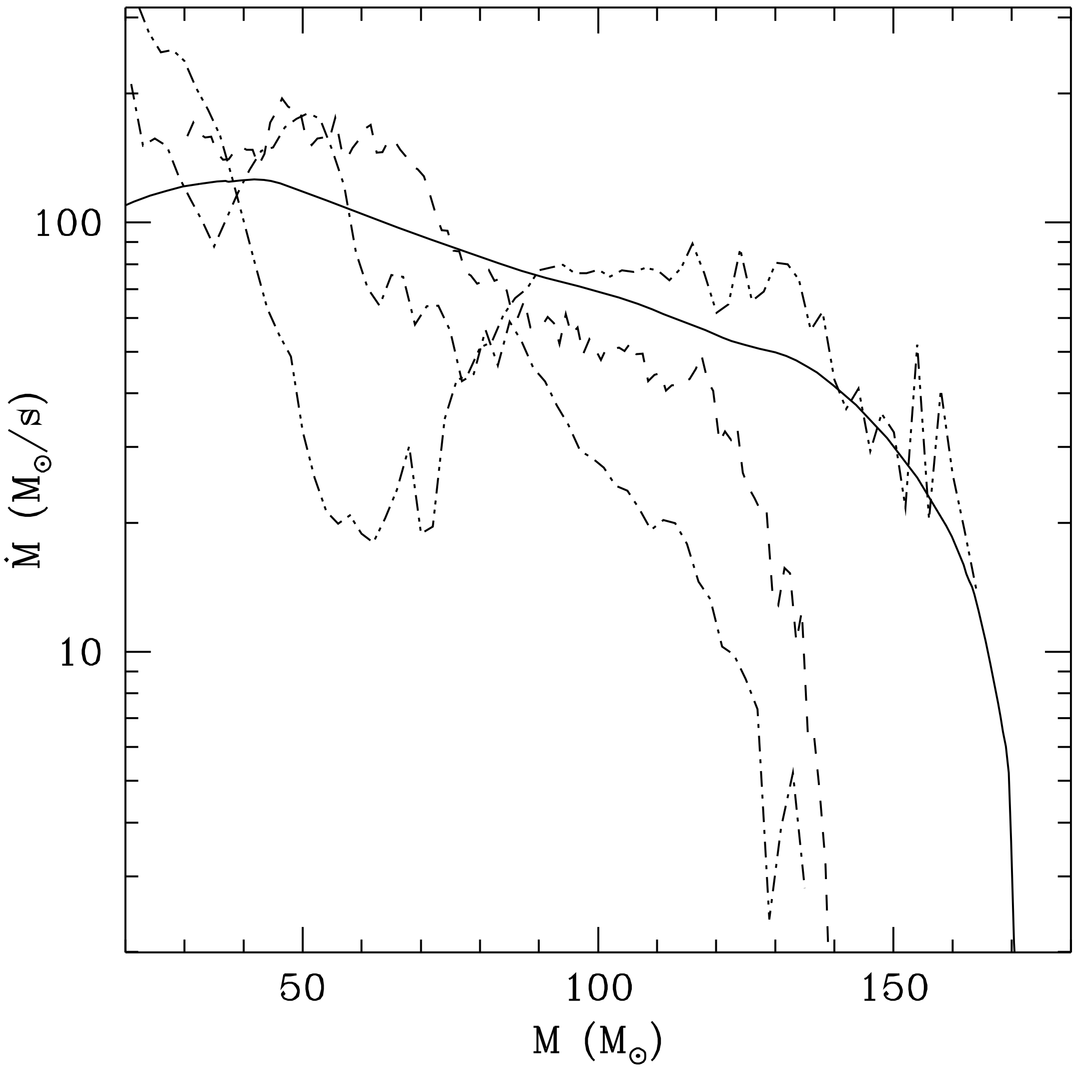

accretion rate over BH mass Fryer et al. (2001)

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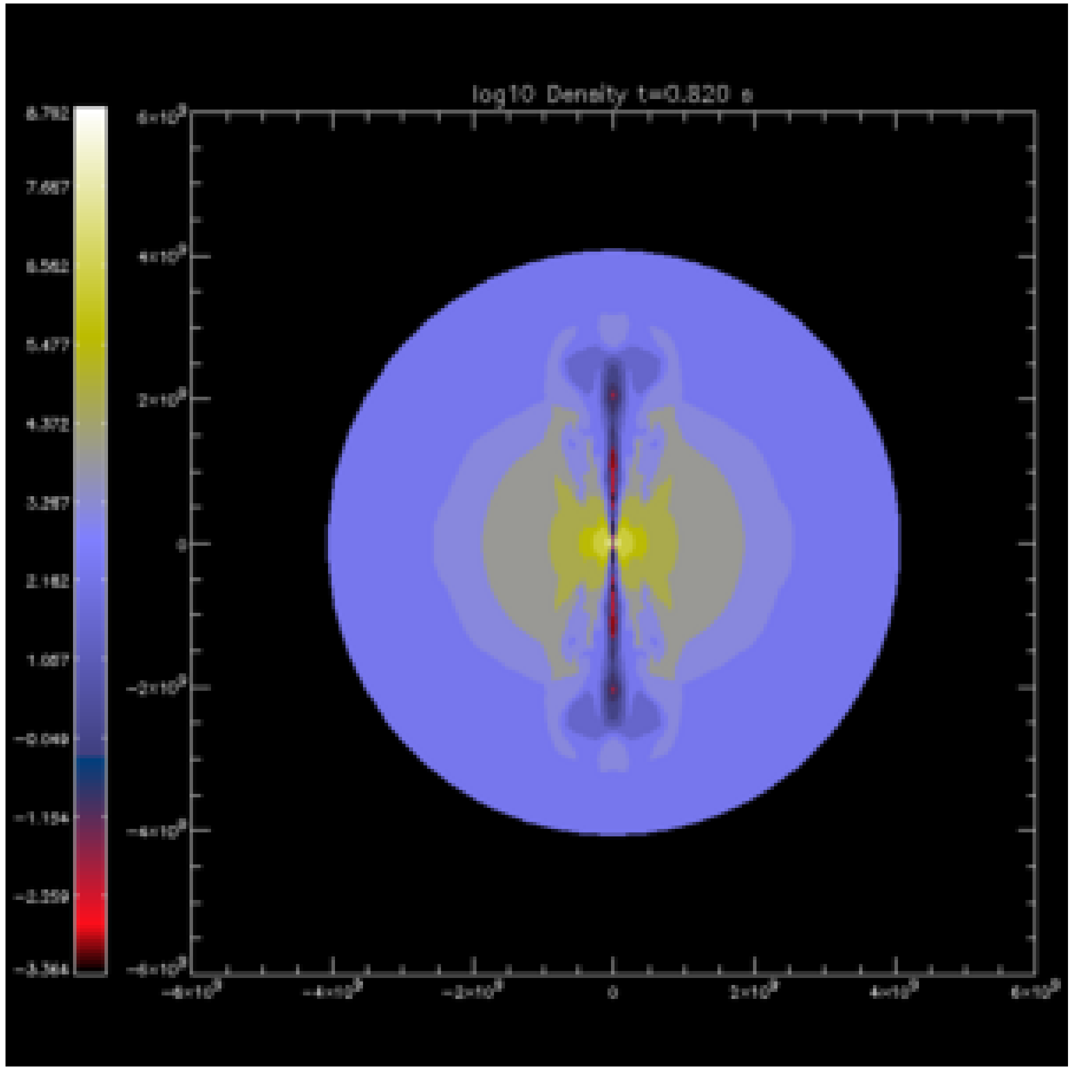

jets inside the progenitor star Hydro Group, MPA

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Summary

- Supernova classification
- Supernova explosion mechanism
- Pair instability Hypernovae of Pop III stars without an remnant
- Jet driven Hypernovae of Pop III
- explanation for GRT/GRB

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References

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Fryer C.L., Woosley S.E., Heger A., 2001, ApJ 550, 372

Zimmermann H., .Weigert A., 1999, Lexikon der Astronomie, Spektrum Akademischer Verlag, Heidelberg Berlin

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