

MOST POPULATION III SUPERNOVAE ARE DUDS

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Abstract

One Population III dud supernova produces enough oxygen to enable 10^7 solar masses of primordial gas to bind into M dwarfs. This is possible because radiation from other Population III stars implodes the mixture of oxygen ejecta and primordial gas into a globular cluster. Model atmosphere calculations for oxygen dwarfs show that water blocks most of the infrared flux. The flux is redistributed into the visible to produce an unfamiliar, distinctive energy distribution. One million dud supernovae in a large protogalaxy are sufficient to produce the “dark matter” halo.

Subject headings: supernovae — dark matter

Introduction

Most of the physics and literature on Population III star formation and on Population III supernovae are speculative, as is this paper. The goal of supernova modelling is always to produce supernova explosions and products. Methods and physics that do not work to produce an explosion on the computer are not interesting, are not funded, and do not produce jobs. How can we ever discover how to make duds, or that duds even exist? Here I make predictions about dud supernovae and about “dark matter”.

Population III stars, dud supernovae, supernovae, oxygen dwarfs

In prestellar times small perturbations cool by radiating in HD, LiH, and other light molecules and start to collapse. If the perturbations are too massive or have too much angular momentum, they cannot successfully collapse to form a star.

At some threshold of mass or angular momentum, a small perturbation ($> 1000 M_{\odot}$) can collapse by somehow ejecting enough mass and angular momentum to produce a Population III star of, say, $200 M_{\odot}$ that is rapidly rotating and oblate. As it evolves, the star continues to lose a significant fraction of its mass and angular momentum through a radiatively-driven wind from the loosely bound mass at the equator. The star produces a huge prolate “Stromgren sphere”. The core of the star is rapidly rotating, oblate, and hotter and faster burning at the

poles and along the axis than in the equatorial plane. There is a strong meridional circulation that mixes in fresh fuel. The star radiates about 10^{51} ergs/ M_{\odot} over its lifetime that is only on the order of 10^5 years. It burns to an oxygen core, but then, because of the rapid rotation, the oblateness, and the rapid evolution, the star cannot stably collapse. It flies apart in the attempt. It explodes with, say, 10^{-3} of the energy of a supernova and produces ejecta that move at only 10^3 km s $^{-1}$ instead of 3×10^4 km s $^{-1}$. It is a dud that produces, say, $25 M_{\odot}$ of oxygen, unburned dregs of lighter elements, no heavier elements, and no remnant. The ejecta mix with the previously lost mass and with the surrounding primordial gas, but much more slowly than would a supernova remnant.

Larger perturbations produce (several) smaller Population III stars with less angular momentum. One of these stars, with 150 to 100 M_{\odot} , evolves more slowly and stably than a more massive star. It is less rapidly rotating and less oblate. It loses a significant fraction of its mass and angular momentum through a radiatively-driven wind at the equator. It produces a prolate “Stromgren sphere”. The star radiates about 10^{51} ergs/ M_{\odot} over its lifetime that is on the order of 10^6 to 10^7 years. It may also be a dud, but it likely produces a supernova with iron or alpha elements, or both, and leaves behind a black hole.

When radiation from a Population III star hits an oxygen blob from a dud supernova, it compresses the gas and the gas radiates in OH and H $_2$ O to cool rapidly. Ultraviolet radiation from the star is down-converted to visible-, infrared-, and radio-line radiation that cannot be absorbed by the primordial gas surrounding the oxygen blob but is strongly absorbed within the blob (and by other blobs). Any other elements present from the dud explosion add to the molecular mix and increase the line opacity. The illuminated blob surface forms a wall of low mass oxygen-dwarf stars. The process repeats forming layers of stars. Radiatively-driven implosions are described in Kurucz (2000). Stars formed in this way have not yet evolved off their main sequence at the present time.

I have computed ATLAS12 (Kurucz 1995; 2005) model atmospheres for oxygen dwarfs with Teff 3500K and 3000K; log g = 5; for fractional abundances by number H = .911, He = .089, log Li = -10, log O = -4,-5,-6. The pinch of Li adds a few electrons. Figure 1 shows the temperature-Rosseland optical depth relations compared to those for Population I and extreme Population II M dwarfs of the same Teff and gravity. Note that these are photospheric models with no temperature minimum and no chromosphere. The temperature distributions are radically different from those of Population I and Population II stars. Figures 2 through 7 show the energy distributions for these models. Strong water absorption in the infrared of the oxygen dwarfs forces the stars to radiate in the visible to maintain energy balance. Oxygen dwarfs have a nearly featureless spectrum in the visible except for H α which would be affected by a chromosphere. If the parent dud supernova had some carbon, the oxygen dwarf daughters bind the carbon in CO which produces additional absorption in the infrared.

Let there be, say, 10^6 dud supernovae per large protogalaxy. The protogalaxies become full of oxygen blobs. Let there be, say, 10^6 Population III stars smaller

than $150 M_{\odot}$ that radiate 10^{51} ergs/ M_{\odot} and then supernova. If the Population III stars and the oxygen blobs are randomly positioned relative to each other in the protogalaxy, the blobs will be illuminated on all sides by radiation from the Population III stars. Four Population III stars arranged in a tetrahedron are sufficient to implode an oxygen blob of $10^7 M_{\odot}$ into an oxygen-dwarf globular cluster. One million globular clusters become the “dark matter” halo of large galaxies.

As the oxygen blobs are used up by forming stars, they are replaced by the Population III supernova remnants that have iron or alpha elements or both. Supernova remnants are energetic and mix through much larger volumes of primordial gas than the oxygen blobs were able to; the average abundances are much lower. The admixture of metals to the primordial gas increases its opacity and makes it possible to form Population II stars much smaller than Population III stars. Radiatively-driven implosions produced by less massive, longer-lived Population III stars yield individual Population II stars and Population II globular clusters. Massive Population II stars also produce implosions. The Population II mass function varies from high to a low limit set by the local opacity.

The galaxy-size perturbations that fill the universe are themselves filled with oxygen-dwarf and Population II globular clusters, with oxygen-dwarf and Population II field stars, and with black holes from Population III supernovae. Most of the gas has been formed into stars. The evolutionary details are discussed in my paper on radiatively-driven cosmology (Kurucz 2000). Without much gas, stars and clusters act dynamically like point masses. The globular clusters violently relax into elliptical galaxies. The globular clusters eventually lose stars or accrete stars or disintegrate or merge. Only a few peculiar Population II globular clusters that are dominated by low mass stars, and a few dwarf galaxies, are still visible, although there can be many that are too faint to see. “Spiral galaxies” are just minor structures made from Population II supernova remnants and Population II mass loss material that collect at and around the centers of large, mostly invisible, elliptical galaxies.

Prediction

The “dark matter” halo consists of 10^6 , or so, oxygen-dwarf globular clusters, up to 25 per square degree. The clusters would appear 10” to 60” in diameter and would have thousands of stars per square arcsecond, but would still be transparent. The observational test is to produce $[M_{RED} - M_{IR}]$ color maps in various filter systems with the galaxies and stars blocked out. The globular clusters would appear as bumps of color excess. The “dark matter” halo also has 10^{12} to 10^{13} oxygen dwarfs in the field that have escaped from clusters. There could be up to 20 oxygen dwarfs per square arcsecond that would not be individually detectable.

References

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Figure captions

Figure 1. Temperature-log Rosseland optical depth relations for model atmospheres with $T_{\text{eff}} 3500\text{K}$, $\log g 5.0$. The colors are the same in all the figures. Red is Population I solar abundance. Green is Population II 1/300 solar abundance with alpha elements enhanced by 2.5. Cyan is an oxygen dwarf with log fractional O abundance by number = -4. Purple is an oxygen dwarf with log fractional O abundance by number = -5. Black is an oxygen dwarf with log fractional O abundance by number = -6.

Figure 2. Energy distributions at resolving power 500 for the wavelength range 0 to 3000 nm. The smooth curves represent the continuum level. The models shown are Population I, Population II, and oxygen dwarf -4. Full scale is 1.5×10^7 ergs $\text{cm}^{-2} \text{s}^{-1} \text{nm}^{-1}$ at the star.

Figure 3. As Figure 2 but for the wavelength range 3000 to 10000 nm. Full scale is 7.5×10^5 ergs $\text{cm}^{-2} \text{s}^{-1} \text{nm}^{-1}$ at the star.

Figure 4. As Figure 2 but for oxygen dwarfs -4, -5, and -6.

Figure 5. As Figure 4 but for the wavelength range 3000 to 10000 nm.

Figure 6. As Figure 4 but for $T_{\text{eff}} 3000\text{K}$, $\log g 5.0$.

Figure 7. As Figure 6 but for the wavelength range 3000 to 10000 nm.













