# Lecture Brijuni "The first stars" long abstract

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The paradox of Olbers basically states, that the sky would be infinitely bright in any wavelength, in neutrinos, or any other particle flux, if space were homogeneous, and non-evolving. It is not, and so we know the universe evolves. There must have been the first stars, and today we know, that was around 13 billion years ago. Stars form in galaxies, and galaxies are dominated by dark matter: dark matter is the key to understanding the first stars: Dark matter has been detected since 1933 (Zwicky) and basically behaves like a non-EM-interacting gravitational gas of particles. From particle physics Supersymmetry suggests with an elegant argument that there should be a lightest supersymmetric particle, which is a dark matter candidate, possibly visible via decay in odd properties of energetic particles and photons: Observations have discovered i) an upturn in the CR-positron fraction (Pamela: Adriani et al. 2009 Nature), ii) an upturn in the CR-electron spectrum (ATIC: Chang et al. 2008 Nature; Fermi: Aharonian et al. 2009 AA), iii) a flat radio emission component near the Galactic Center (WMAP haze: Dobler \& Finkbeiner 2008 ApJ), iv) a corresponding IC component in gamma rays (Fermi haze: Dobler et al. 2010 ApJ, Su et al. 2010 arXiv), v) the 511 keV annihilation line also near the Galactic Center (Integral: Weidenspointner et al. 2008 NewAR), and most recently, vi) an upturn in the CR-spectra of all elements from Helium (CREAM: Ahn et al. 2009 ApJ, 2010 ApJL; for H and He the upturn has been confirmed by Pamela, shown at the COSPAR meeting July 2010). All these features can be quantitatively explained with the action of cosmic rays accelerated in the magnetic winds of very massive stars, when they explode (Biermann et al. 2009 PRL, 2010 ApJL), based on well-defined predictions from 1993 (Biermann 1993 AA, Biermann \& Cassinelli 1993 AA, Biermann \& Strom 1993 AA, Stanev et al 1993 AA). While the leptonic part of these observations may be explainable with pulsars and their winds, the hadronic part clearly needs very massive stars, such as Wolf-Rayet stars, their winds and their explosions. What the cosmic ray work (Biermann et al., from 1993 through 2010) shows, that allowing for the magnetic field topology of Wolf Rayet star winds (see, e.g. Parker 1958 ApJ), both the leptonic and the hadronic part get readily and quantitatively explained, close to what had been predicted, without any significant free parameter, so by Occam's razor the Wolf-Rayet star wind proposal is much simpler. This allows to go back to galaxy data to derive the key properties of the dark matter particle: Work by Hogan \& Dalcanton (2000 PRD, 2001 ApJ), Gilmore et al. (from 2006 MNRAS, 2007 ApJ, etc.), Strigari et al. (2008 Nature), Gentile et al. (2009 Nature); work by Boyanovsky et al. (2008 PRD), DeVega \& Sanchez (2010 MNRAS) clearly points to a keV particle. A right-handed neutrino is a candidate to be this particle (e.g. Kusenko \& Segre 1997 PLB; Fuller et al. 2003 PRD; Kusenko 2004 IJMP; for a review see Kusenko 2009 PhysRep; Biermann \& Kusenko 2006 PRL; Stasielak et al. 2007 ApJ; Loewenstein et al. 2009 ApJ; Loewenstein \& Kusenko 2010 ApJL): This particle has the advantage to allow star formation very early, near redshift 80, and so also allows the formation of supermassive black holes, possibly formed out of agglomerating massive stars in the gravitational potential of a dark matter clump; the stellar wind limit derived by Yungelson et al. 2008 AA does not apply for stars at near zero heavy elements, since such stars have weak winds. Black holes in turn also merge, but in this manner start their mergers at masses of a few million solar masses; the mass is given by the instability of stars at such a mass due to General Relativity and radiation effects. This readily explains the supermassive black hole mass function as the result of mergers between black holes. The corresponding gravitational waves are not constrained by any existing limit, and could have given a substantial energy contribution at high redshift. Our conclusion is that a right-handed neutrino of a mass of a few keV is the most interesting candidate to constitute dark matter. A consequence of this very early star formation should be Lyman alpha emission and absorption at around a few microns; corresponding emission and absorption lines might be visible from molecular Hydrogen H$_2$ (Tegmark et al. 1997 ApJ) and H$_3$ (Goto et al. 2008 ApJ) and their ions, in the far infrared and sub-mm wavelength range. The detection at very high redshift of massive star formation, stellar evolution and the formation of the first super-massive black holes would constitute the most striking and testable prediction of this specific dark matter particle proposal. These first stars would be massive, live very briefly, often agglomerate, and begin the cycle of explosions, enrichment, magnetic fields, cosmic rays, dust formation and life in the universe.