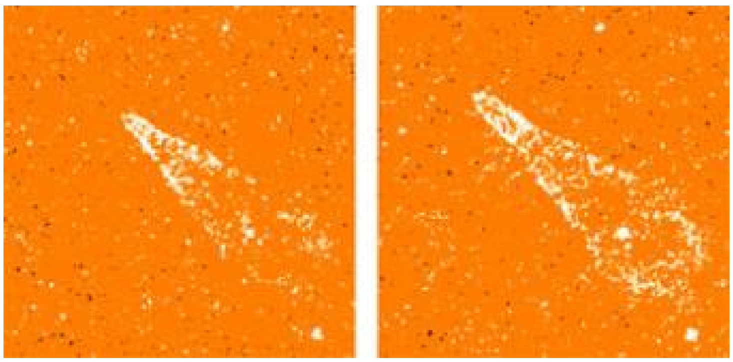
Did 'Dark Matter' Create the First Stars?

March 15 2006



Head of the "guitar nebula". The formation contains a fast moving pulsar followed by a tail of gas. Biermann and Kusenko's postulations about dark matter could explain puzzlingly high pulsar velocities, which lead to such cone-shaped features. Images are from the Planetary Camera aboard the Hubble Space Telescope in 1994 (left) and 2001 (right). Image: Hubble Space Telescope (NASA/ESA), Shami Shatterjee 200

Dark matter may have played a major role in creating stars at the very beginnings of the universe. If that is the case, however, the dark matter must consist of particles called "sterile neutrinos". Peter Biermann of the Max Planck Institute for Radio Astronomy in Bonn, and Alexander Kusenko, of the University of California, Los Angeles, have shown that when sterile neutrinos decay, it speeds up the creation of molecular hydrogen. This process could have helped light up the first stars only some 20 to 100 million years after the Big Bang.

This first generation of stars then ionised the gas surrounding them, some 150 to 400 million years after the big bang. All of this provides a simple explanation to some rather puzzling observations concerning dark matter, neutron stars, and antimatter.

Scientists discovered that neutrinos have mass through neutrino oscillation experiments. This led to the postulation that "sterile" neutrinos exist - also known as right-handed neutrinos. They do not participate in weak interactions directly, but do interact through their mixing with ordinary neutrinos. The total number of sterile neutrinos in the universe is unclear. If a sterile neutrino only has a mass of a few kiloelectronvolts (1 keV is a millionth of the mass of a hydrogen atom), that would explain the huge, missing mass in the universe, sometimes called "dark matter". Astrophysical observations support the view that dark matter is likely to consist of these sterile neutrinos.

Biermann and Kusenko’s theory sheds light on a number of still unexplained astronomical puzzles. First of all, during the big bang, the mass of neutrinos created in the Big Bang would equal what is needed to account for dark matter. Second, these particles could be the solution to the long-standing problem of why pulsars move so fast.

Pulsars are neutron stars rotating at a very high velocity. They are created in supernova explosions and normally are ejected in one direction. The explosion gives them a "push", like a rocket engine. Pulsars can have velocities of hundreds of kilometres per second - or sometimes even thousands. The origin of these velocities remains unknown, but the emission of sterile neutrinos would explain the pulsar kicks.

The Guitar Nebula (see image) contains a very fast pulsar. If dark matter is made of particles which reionized the universe - as Biermann and Kusenko suggest - the pulsar’s motion could have created this cosmic guitar.

Third, sterile neutrinos can help explain the absence of antimatter in the universe. In the early universe, sterile neutrinos could have "stolen" what is called the "lepton number" from plasma. At a later time, the lack of lepton number was converted to a non-zero baryon number. The resulting asymmetry between baryons (like protons) and antibaryons (like antiprotons) could be the reason why the universe has no antimatter.

"The formation of central galactic black holes, as well as structure on subgalactic scales, favours sterile neutrinos to account for dark matter. The consensus of several indirect pieces of evidence leads one to believe that the long sought-after dark-matter particle may, indeed, be a sterile neutrino", says Peter Biermann.

Original work: P.L. Biermann & A. Kusenko, Relic keV sterile neutrinos and reionization, *Physical Review Letters*, 10 March 2006

Source: Max Planck Institute for Radio Astronomy