Observations cast new light on cosmic microwave background

January 5 2017, by Suraiya Farukhi

The suspended support platform of radio receivers at Arecibo Observatory in Puerto Rico. Credit: USRA

Arecibo Observatory observations of galactic neutral hydrogen structure confirm the discovery of an unexpected contribution to the measurements of the cosmic microwave background observed by the WMAP and Planck spacecraft. An accurate understanding of the foreground (galactic) sources of radiation observed by these two spacecraft is essential for extracting information about the small-scale structure in the cosmic microwave background believed to be indicative of events in the early universe.

The new source of radiation in the 22 to 100 GHz range observed by WMAP and Planck appears to be emission from cold electrons (known as free-free emission). While cosmologists have corrected for this type of radiation from hot electrons associated with galactic nebulae where the source temperatures are thousands of degrees, the new model requires electron temperatures more like a few 100 K.

The spectrum of the small-scale features observed by WMAP and Planck in this frequency range is very nearly flat—a finding consistent with the sources being associated with the Big Bang. At first glance it appears that the spectrum expected from the emission by cold galactic electrons, which exist throughout interstellar space, would be far too steep to fit the data. However, if the sources of emission have a small angular size compared with the beam width used in the WMAP and Planck spacecraft, the signals they record would be diluted. The beam widths increase with lower frequency, and the net result of this "beam dilution" is to produce an apparently flat spectrum in the 22 to 100 GHz range.

"It was the beam dilution that was the key insight," noted Dr. Gerrit Verschuur, astronomer emeritus at the Arecibo Observatory and lead author on the paper. "Emission from an unresolved source could mimic the flat spectrum observed by WMAP and Planck."

The model invoking the emission from cold electrons not only gives the observed flat spectrum usually attributed to cosmic sources but also predicts values for the angular scale and temperature for the emitting volumes. Those predictions can then be compared with observations of galactic structure revealed in the Galactic Arecibo L-Band Feed Array

(GALFA) HI survey.

"The interstellar medium is much more surprising and important than we have given it credit for," noted Dr. Joshua Peek, an astronomer at the Space Telescope Science Institute and a co-investigator on the GALFA-HI survey. "Arecibo, with its combination of large area and high resolution, remains a spectacular and cutting edge tool for comparing ISM maps to cosmological data sets."

The angular scales of the smallest features observed in neutral hydrogen maps made at Arecibo and the temperature of the apparently associated gas both match the model calculations extremely well. So far only three well-studied areas have been analyzed in such detail, but more work is being planned.

"It was the agreement between the model predictions and the GALFA-HI observations that convinced me that we might be onto something," noted Dr. Joan Schmelz, Director, Universities Space Research Association (USRA) at Arecibo Observatory and a coauthor on the paper. "We hope that these results help us understand the true cosmological nature of Planck and WMAP data."

The data suggest that the structure and physics of diffuse interstellar matter, in particular of cold hydrogen gas and associated electrons, may be more complex than heretofore considered. Such complexities need to be taken into account in order to produce better foreground masks for application to the high-frequency continuum observations of Planck and WMAP in the quest for a cosmologically significant signal.

USRA's Dr. Joan Schmelz will present these findings on January 4, 2017, at a press conference at the American Astronomical Society's (AAS) meeting at Grapevine, Texas.

More information: On the Nature of Small-Scale Structure in the Cosmic Microwave Background Observed by Planck and WMAP. *Astrophysical Journal*, December 1, 2016

Provided by USRA