Astronomy & Astrophysics: Planck 2013 results

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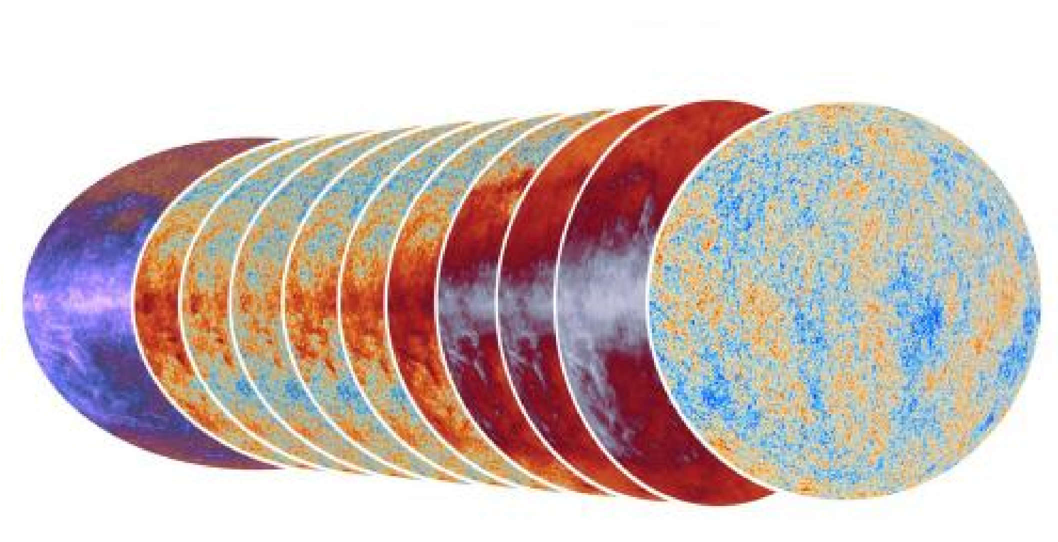

The stack of images in the figure shows: in the center, the nine all-sky images ranging from 30 GHz (left) to 857 GHz (right); at far left, a combined view of all frequencies; at far right, the all-sky image of the temperature anisotropies of the CMB derived by Planck.

Astronomy & Astrophysics is publishing a special feature of 31 articles describing the data gathered by Planck over 15 months of observations and released by ESA and the Planck Collaboration in March 2013. This series of papers presents the initial scientific results extracted from this first Planck dataset.

The Planck satellite was launched in May 2009. With the highest accuracy to date, it measures the remnants of the radiation that filled the Universe immediately after the Big Bang. It is the oldest light in the Universe, emitted when it was 380000 years old. This light is observed today as the cosmic microwave background (CMB). Its maximum intensity is at about 150 GHz (2 mm), and its temperature about 3K. The study of the CMB is currently a very active field of research in cosmology because it provides strong constraints on the cosmological models. In particular, observations of the CMB confirms the key prediction of the Big Bang model and, more precisely, of what cosmologists call the concordance model of cosmology.

Planck was designed to measure the emission from the entire sky at nine distinct wavelengths, ranging from the radio (1 cm) to the far-infrared (300 microns). Several distinct sources of emission — both of Galactic and extragalactic origin — contribute to the features observed in each of the nine images shown here. Radio emissions from the Milky Way are most prominent at the longest wavelengths, and thermal dust emission at the shortest. Other galaxies contribute to the mix, mostly as unresolved sources. In the middle of Planck's wavelength range, the CMB dominates the sky at intermediate and high Galactic latitudes. The spectral and spatial signatures of all these sources are used to extract an all-sky image of the tiny temperature anisotropies of the CMB with unprecedented accuracy. The properties of these fluctuations are used to derive the parameters characterizing our Universe at early times.

Papers II to X in the series describe the huge dataset obtained from the Planck satellite and released in March 2013. Using this dataset, the Planck team established the new "cosmic recipe", i.e., the relative proportions of the Universe's constituent ingredients. Normal matter that makes up stars and galaxies contributes just 4.9% of the energy of the Universe. Dark matter, to date detected only indirectly by its gravitational influence on galaxies and galaxy clusters, is found to make up 26.8%, more than previous estimates. Conversely, dark energy, a mysterious force said to be responsible for accelerating the expansion of the Universe, accounts for 68.3%, less than previously thought. The Planck team also published a new value for the age of the Universe: 13.8 billion years (see Paper XVI).

The Planck team also studied the statistical properties of the CMB in great detail. Papers XXIII, XXIV, and XXVI explore the statistical distribution of its temperature anisotropies. There is no evidence of any deviations from isotropy on small angular scales. While the observations on small and intermediate angular scales agree extremely well with the model predictions, Planck has now provided the first indisputable evidence that the distribution of primordial fluctuations was not the same on all scales and that it comprises more structure than expected at larger scales. One anomalous signal appears as a substantial asymmetry in the CMB signal observed in the two opposite hemispheres of the sky, which is that one of the two hemispheres appears to have a significantly stronger signal on average. Among the other major results, Paper XXIII of the series explores how the Planck data can constrain theories of cosmic inflation; this paper currently puts the tightest constraints on inflation.

The CMB is not only a picture of the Universe taken 13.8 billion years ago, but it was also distorted during its journey because the CMB photons interacted with the large-scale structures that they traveled through (such as galaxy and galaxy clusters). In Paper XVII of the series, the team extracts from the Planck data a map of the gravitational lensing effect visible today in the CMB and covering the whole sky. The map published in this paper provides a new way to probe the evolution of structures in the Universe over its lifetime.

A byproduct of the Planck all-sky maps are catalogs of compact sources. Paper XXIX describes the production of the largest catalog of galaxy clusters based on the Sunyaev-Zeldovich effect, a distortion of the CMB spectrum caused by very energetic electrons in a galaxy cluster, which kick CMB photons to higher energies. This catalog was used to estimate cosmological constraints, as described in Paper XX.

With the 2013 release of the intensity signal measured during the 15 first months of observation, Planck data are providing new major advances in different domains of cosmology and astrophysics. In the very near future, the Planck Collaboration will release a new dataset that includes all of its observations in intensity and in polarization. This new dataset will be a lasting legacy for the community for many years to come.

More information: A&A special feature: Planck 2013 results, *Astronomy & Astrophysics*, volume 571, November 2014. Table of contents of the A&A special feature (free access)

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