The hunt for missing baryons has opened

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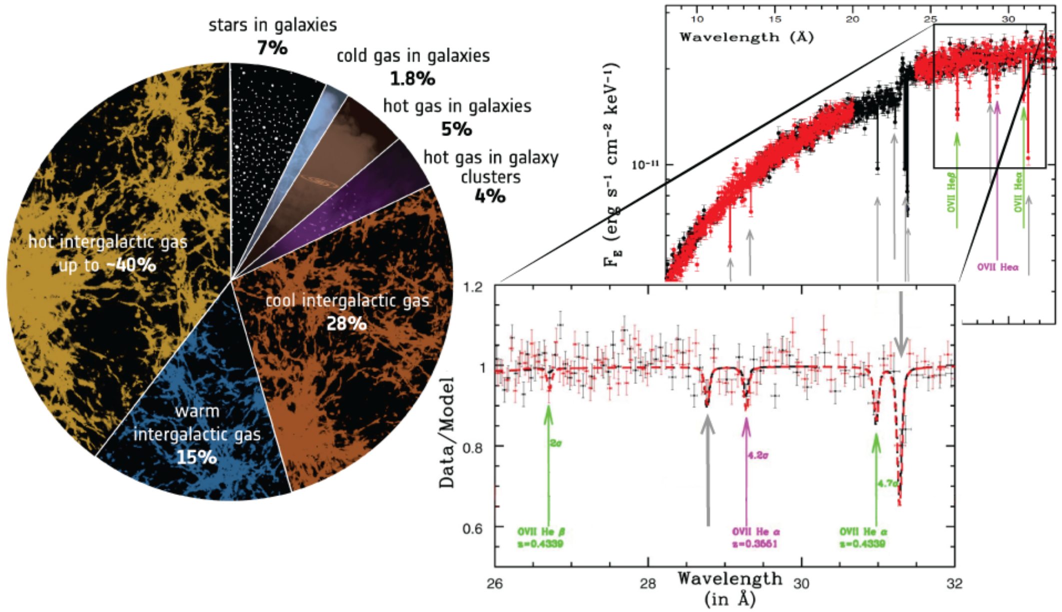
Modern cosmology tells us that the bulk of our Universe consists of mysterious dark energy and dark matter. Only a tiny fraction (about 5%) of the total is normal matter (called baryons). In the distant Universe we have detected this normal matter via its absorption of UV radiation by cold Hydrogen atoms - the so-called Lyman alpha forest. Surprisingly enough, though, while we can see all the baryons far away, close around the corner half of them have gone 'missing.' As far as we know, there is no strange process that destroys the nearby baryons. Instead, we suspect they are hiding in somehard-to-observe physical state.

Sophisticated models of cosmic structure formation predict that these baryons exist in the form of a rarefied ionized gas (plasma) that is linked to the threads of a 'cosmic web', or in the large-scale galaxy haloes embedded in those threads. Because this is a plasma, there are no neutral hydrogen atoms left to absorb UV radiation and reveal its presence. The plasma will emit or absorb soft (low-energy) X-rays, but it is diffuse and embedded in structures that occupy only a tiny fraction of the nearby Universe, so detecting the baryonic plasma has remained a long-standing challenge.



XMM-Newton RGS spectra of 1ES 1553+113. XMM-Newton/RGS1 (black) and RGS2 (red) spectra and best-fitting models (black and red lines) for the blazar 1ES 1553+113. Grey arrows mark Galactic absorption lines; green and magenta arrows indicate absorption lines from the two WHIM absorption systems detected. Credits: Pie chart - ESA, Spectra - F. Nicastro, J. Kaastra, Y. Krongold et al. Nature, 558, 406 (2018).

However, if there is a strong lamp behind this plasma, it will produce tiny absorption features corresponding to specific atomic transitions in a high-resolution X-ray spectrum. How do we find such a lamp that is both bright enough to reveal absorption lines and far enough to enhance the chance to see foreground structures? Fabrizio Nicastro and his colleagues investigated carefully all possible lamps, and found the ideal source in the bright blazar 1ES 1553+113 at a redshift larger than 0.4. So, the team wrote a proposal for XMM-*Newton* and got 1.85 Ms (3 solid weeks!) of observing time (which is not easy to get....).

After a careful analysis of the Reflection Grating Spectrometer (RGS) data, two absorption systems were found, at wavelengths in agreement with constraints from UV spectroscopy. This number of systems is fully compatible with the amount of missing baryons.

Has the mystery been solved by this discovery? Not yet. While the detection is solid, two systems is a small number. Quite some uncertainty remains in the theoretical models about structure formation on exactly how many systems one would expect, about their physical properties, and how this can constrain those models. To get definitive answers to those questions, we need the X-IFU on board *Athena*. Its spectral resolution is comparable to RGS, but with 100 times the sensitivity of the RGS. *Athena* will find and characterize more than a hundred such systems by observing blazars and even more distant Gamma-Ray Bursts. The quest for the missing baryons has just begun!