Has our black hole been blowing bubbles?

December 1 2011, by Pete Wilton, OxSciBlog

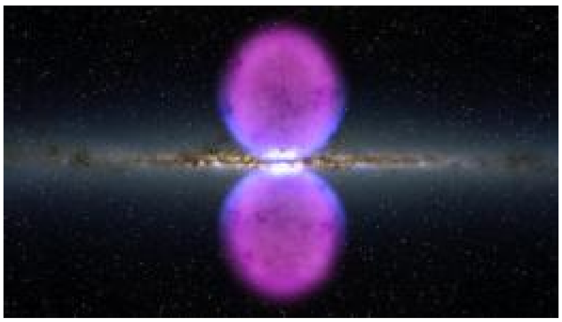

Image: illustration showing the gamma-ray bubbles (highlighted in purple) extending 50,000 light-years, or roughly half of the Milky Way's diameter, either side of the Milky Way (the line across the centre). Credit: NASA's Goddard Space Flight Center

Our galaxy is a relatively quiet neighbourhood with the supermassive black hole at its heart gently dozing: or is it?

The recent discovery of huge gamma-ray emitting 'bubbles' around the Milky Way is challenging this assumption and posing a new puzzle: just where do these bubbles come from?

Philipp Mertsch and Subir Sarkar of Oxford University's Department of Physics recently reported in *Physical Review Letters* a model that could explain the origins of these strange phenomena. I asked them about bubbles, 'feeding' black holes, and how their ideas could be tested...

OxSciBlog: What are 'Fermi bubbles' and where are they found?

Philipp Mertsch: The 'Fermi bubbles' are gigantic structures above and below the centre of our Galaxy which were discovered by astrophysicists at Harvard in a gamma-ray sky map made by NASA's Fermi satellite.

The bubbles extend ~50,000 light years above and below the galactic plane, i.e. they are about the same size as the disk of the Galaxy. A correlated structure can also be seen in the X-ray map made by the ROSAT satellite.

It may seem surprising that such huge structures have gone unnoticed earlier - this is a testimony to how advances in astronomical instrumentation lead to serendipitous discoveries!

OSB: Why is it important to understand them?

Subir Sarkar: The bubbles are important for a variety of reasons. First, their origin is very likely related to an energetic outflow from the the supermassive black hole lurking at our Galactic Centre - it is supposedly not "feeding" but clearly was doing so as recently as a million years ago. Understanding the mechanism of their gamma-ray emission also holds clues as to what is powering them.

Moreover this region of the sky is a prime target for dark matter annihilation signals - while the bubbles are themselves very unlikely to be due to dark matter annihilations, we need to understand them in meticulous detail if we want to look for the much smaller signal in gamma-rays expected from dark matter.

OSB: How have scientists previously tried to explain

them?

PM: So far, scientists have considered the same processes that are believed to produce gamma-rays in astrophysical sources, for example decays of neutral pions created by interactions of high energy protons with ambient matter, and inverse-Compton scattering of background photons by high energy electrons.

High-energy protons are certainly present in the disk of the Milky Way, but it is not easy to explain how they could be transported to such large distances from the disk and be contained inside the bubbles for billions of years.

The problem with electrons is that they lose energy rapidly and would need to be reaccelerated - it has been suggested that this happens at hundreds of shock fronts inside the bubbles. However, there is no evidence for such an onion-like structure, in fact, the bubbles have a smooth surface and a well-defined, sharp edge.

OSB: What do you suggest may have produced the bubbles?

SS: The X-ray data from the ROSAT satellite suggest only one shock front which delineates the outer edge of the bubbles. This shock produces turbulence in the plasma behind it which can accelerate electrons to very high energies through a stochastic process first discussed by Enrico Fermi.

These electrons then transfer their energy to low energy photons from the microwave and infrared backgrounds as well as starlight, producing the gamma-rays observed.

It turns out that the variations of the plasma properties inside the bubbles can exactly reproduce the observed, namely the smooth surface and the sharp edges of the bubbles. The other models cannot explain this.

OSB: If you are correct what does this tell us about our galaxy/galaxy formation in general?

PM: An important question is of course where does this shock front come from? Looking at other galaxies we see similar bubbles being produced by jets powered from the central black hole. This is certainly a possibility for our own Galaxy.

In fact it is rather peculiar that the black hole at the centre of the Milky Way is so quiet - it now appears that this may just be a transient phase.

This picture is further supported by numerical simulations which have shown that a jet shooting out from the centre above and below the galactic plane can easily produce structures of the size and shape of the Fermi bubbles.

OSB: How could your ideas be tested?

SS: Our model for the gamma-ray emission predicts a unique energy-dependence: at lower energies, the surface of the bubbles is very smooth but at higher energies, the bubble inside should become fainter while only the edges stay bright. The energies at which this happens are beyond the reach of the Fermi satellite but with data from the forthcoming Cherenkov Telescope Array this shell-like structure should become observable.

Provided by Oxford University