

Galactic cosmic ray model works without physics, and that is bad

Fermi gamma ray image of the huge bubbles originated at the center of the Milky Way. Follow-up radio and microwave observations revealed magnetic fields and ridgelike structures in these bubbles.

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Way back when the world was young and I still attended physics conferences, I got very excited by galactic cosmic rays. There seemed to be more cosmic rays than expected coming from the center of our galaxy. Those excess cosmic rays might be evidence for dark matter, which would be a big breakthrough if confirmed. Later modeling of cosmic ray sources showed that the extra cosmic rays were probably not coming from the annihilation of dark matter. But, now it seems we are back to square one, because that model may not have been accurate.

How'd they get here?

It is now reasonably certain that the cosmic rays that are observed to be coming from the center of the galaxy are more numerous than can be accounted for by known sources of cosmic rays. That doesn't mean too much because cosmic rays scatter, so we don't see clear dots of cosmic ray sources in the galactic center. Instead, like looking at the Sun on a foggy

day, there is a diffuse glow of cosmic rays with some brighter areas. To determine how that diffuse glow is constructed, scientists look at known sources of cosmic rays, like supernovae, and use these observations to estimate the total amount and energy of cosmic rays expected from the galactic center.

What we see, however, does not match this model. There were several issues. First, there are cosmic rays with energy far beyond what can be produced by supernovae. Unlike other very high-energy cosmic rays, these almost certainly originated inside our galaxy.

Another problem was that there seemed to be too many cosmic rays, for which there could be a number of explanations. But the two that seemed most likely were more point sources (supernovae) than we could see, also known as unresolved point sources. The second explanation was very exciting—the first non-gravitational evidence for dark matter—dark matter particles annihilating to produce cosmic rays.

The source for higher-energy cosmic rays was eventually resolved. Supernovae produce lower energy cosmic rays that are subsequently accelerated by things called Fermi bubbles. Between these three sources—extra supernovae, dark matter, and Fermi bubbles—we can explain the cosmic rays from the center of our galaxy. But how much of a contribution do each of the sources make? Can we still explain things if we set dark matter annihilations to zero?

A statistical knife cuts through the fog

To estimate the balance, scientists use a statistical fitting procedure that places point sources at random in the galactic center. Alongside that, the dark matter concentration in the center (a rather evenly distributed gas of particles)

contributes cosmic rays. And, finally, Fermi bubbles generate high-energy cosmic rays from some fraction of the lower-energy cosmic rays. These contributions are jiggled about until the calculated cosmic ray flux and its energy spectrum match the observation data.

This procedure is at the heart of the discussion: how should that fit be performed?

Scientists have constructed a method for fitting and tested it on model data—that is, data that creates a cosmic ray distribution via known physical processes—and shown that it works pretty well. And, since scientists are relatively confident in their supernova physics and cosmic ray scattering models, they were reasonably sure that the statistical fit wasn't too bad either.

The upshot was that researchers thought that they could explain all but two percent of the cosmic rays from the center of the galaxy without including any dark matter annihilation at all. That seemed to be the death of the first direct evidence for dark matter.

Your supernova fits beautifully madame

Except that the fitting procedure turns out to be not so robust after all. A pair of scientists performed the fitting procedure on model data but modified the availability of the types of sources that could be fit (called templates) and played with the amount of cosmic rays from dark matter. They found that the model almost always drove the dark matter contribution to zero. The net result was that, even if up to 15 percent of the cosmic ray flux was due to dark matter, the model would still report a dark matter contribution that was near zero.

The researchers also tested the fit on real data. They took observational data and modified it by adding a dark matter contribution to it. As with the model data, they found that the fitting procedure attributed all the dark matter signal to other sources. Only if they set the dark matter contribution to around 15 percent or higher would it start showing up in the fitting results.

Although the results might be explained by a coincidence, it seems more likely that the statistical procedure is simply not good enough. The consequence is that the dark matter explanation for the cosmic ray excess is back on the table.

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