COBE Photographs the Milky Way in Infrared

Would you believe that this is our own Milky Way? It is not an artist's conception of what the Galaxy might look like to an outside observer, but rather a near-infrared image of the inner reaches of the Milky Way, produced by the Diffuse Infrared Background Experiment aboard the Cosmic Background Explorer satellite. COBE has been in Earth orbit since November. (See PHYSICS TODAY, March, page 17.)

DIRBE looks at the infrared sky through ten different filters, ranging in wavelength from 1 to 300 microns. Its principal purpose is to look for the diffuse infrared cosmic glow expected as a relic of the earliest generation of galaxies. To that end, DIRBE must also study the infrared emission of non-cosmological foreground objects like the Milky Way.

This picture is a superposition of the images in three near-infrared wavelengths: 1.2 μm, 2.2 mμ and 3.4 mμ, shown here, respectively, in blue, green and red. Thus the image appears reddest where intervening interstellar dust strongly absorbs shorter wavelengths. At visible wavelengths (below 0.78 μm), the central bulge of the Galaxy, so prominent here, is completely obscured by dust. The white dots are stars in our neighborhood.

An earlier NASA orbiting infrared observatory, the 1983 Infrared Astronomy Satellite, was restricted to wavelengths longer than 12 microns. The IRAS images of the inner Milky Way (PHYSICS TODAY, August 1984, page 18) were less spectacularly visual than what we see here, because at those farther-infrared wavelengths one sees less starlight and more thermal emission from interstellar dust.

This wide-angle picture, extending 96° to either side of the Galactic center, makes the center seem farther away than its actual distance of 28 000 light years. The edge of the Galactic disk, as seen here, extends over a full 180° of sky. To get a better idea of what the the inner galaxy looks like from our vantage point, the reader should wrap this picture in a semicircle around his eyes like a Cinerama screen.

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simply equals $eB/2\pi M$. For a proton (or antiproton) in a 6-T field, that's about 90 MHz. But in a Penning trap one can't determine M just by measuring the cyclotron frequency, because in the complicating presence of the trap's electric quadrupole field the expression for ν_c also involves the eigenfrequencies of the axial and magnetron oscillations. In the Harvard–Mainz–Washington trap, the 11-kHz magnetron frequency (due to the $\mathbf{E}\times\mathbf{B}$ drift of the cyclotron orbits) is so much lower than the others that one need only measure the cyclotron and axial frequencies. The axial frequency is about 2 MHz.

The center of the quadrupole field is a saddle point. In the axial direction it is the bottom of a harmonic potential well, but in the transverse plane it is the top of a potential hill. One wants to keep the amplitude of the magnetron motion as small as possible, to hold the antiprotons close to the axis. This is accomplished by sideband cooling, an important technique in Penning-trap measurement developed in the late 1970s by Dehmelt, Van Dyck and David Wineland (now at the National Institute of Standards and Technology in Boulder, Colorado) In essence, one pushes the antiprotons up the transverse hill by feeding rf power into the trap at the sum of the axial and magnetron frequencies.

The trap's electrostatic field must have a very accurate quadrupole configuration, minimizing anharmonic higher components in the axial restoring force, so that the resonant frequency of the axial oscillation will be independent of its amplitude. In the conventional design, this has required laboriously machined hyperbolic electrode surfaces and a pair of compensating electrodes flanking the central ring to correct for anharmonic terms in the potential. Gabrielse and his colleagues have concluded, however, that they can achieve the same quadrupole field quality with the open configuration of stacked cylinders they needed for antiproton access *if* the ratio of cylinder lengths is precisely chosen to meet an orthogonality condition that keeps the leading harmonic term fixed while the higher multipole terms are tuned by adjusting the electrode voltage biases.[5] The attractive simplicity of this geometry may in fact make it the configuration of choice in future, even for less exotic ionic species than antiprotons.

The trap's 6-tesla magnetic field is also subject to demanding requirements. It must be spatially uniform, so that the cyclotron frequency will be independent of position. And if one is attempting to compare the masses of different species (in this case protons and antiprotons) to a few parts in 10^8, the field must remain comparably stable as one trap population replaces the other. This temporal constancy is a particular problem at LEAR, where nearby powerful accelerator magnets are cycled every few seconds. Furthermore, conventional magnetic