neighbors. Blocking DAT-mediated DA release could thus be neuroprotective in the early stages of the disorder. We should not be surprised to see the ideas of Falkenburger *et al.* generalized to other transporters and pathways. Schwartz has shown that GABA transporters in the retina release GABA in response to electrical stimulation (*21*). Serotonin efflux triggered by MDMA ("ecstasy") is a well-known facet of this psychostimulant's action (*22*). The glycine required to allow glutamate stimulation of *N*-methyl-D-aspartate receptors may arise from transporter-mediated glycine efflux (*10*). More ideas regarding how transporter-dependent neurotransmitter efflux shapes the excitability of neurons and influences pathology will undoubtedly come to mind as neuroscientists become more forward-thinking in embracing transporter reversal.

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PERSPECTIVES: ASTRONOMY

A Stellar Merry-Go-Round

Thierry Montmerle

Imagine a giant torus, like a tire tube, filled with hot gas and rotating around a star like a merry-go-round. This is what astronomers have recently found in detailed modeling studies of the light signatures of several stars. The signatures were obtained by widely different techniques, including absorption in the ultraviolet (UV) (*1*), optical spectrophotometry and emission of x-rays (*2*), and analysis of radio waves (*3*).

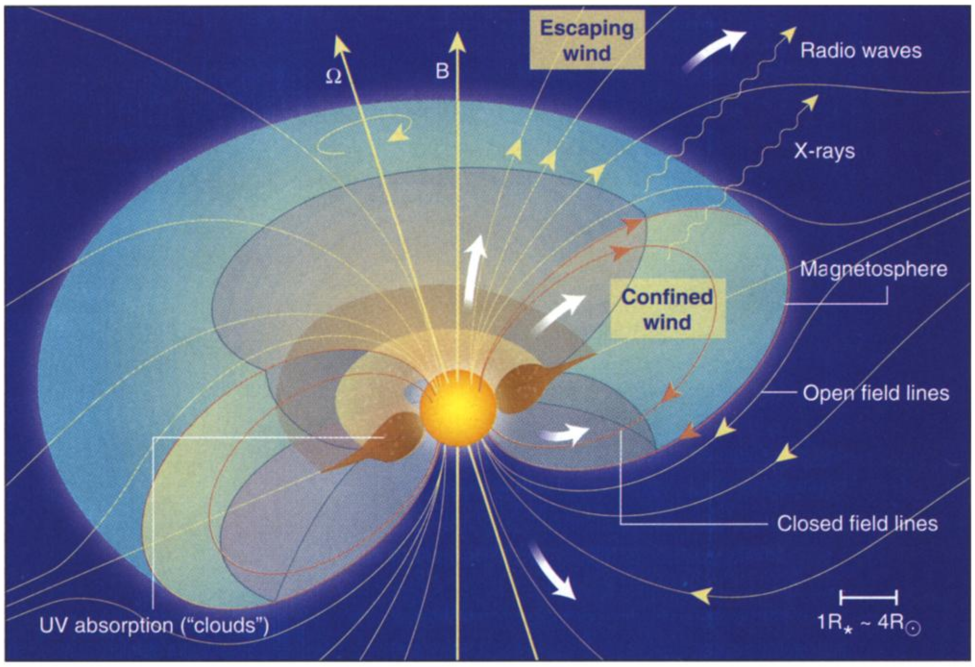
The stars investigated in these studies are special. Called "magnetic stars," they were discovered by Babcock in the 1940s (*4*, *5*). Their magnetic fields typically have field strengths of several kilogauss, although they may reach field strengths of up to 50 kG (100,000 times the Earth's magnetic field). Several indications, especially the rotational periodicity, suggest that the magnetic structure is mainly dipolar and rotates with the star, the magnetic axis being at an angle (sometimes even 90°) to the rotation axis.

Theoretical studies have predicted for some time that gaseous tori should exist around magnetic stars, as a result of the confinement of a stellar wind within a dipolar magnetic structure (see the figure). The confirmation of these predictions is an important step toward understanding the plasma physics of stellar atmospheres in cases where the magnetic field dominates the spatial structure of the gas near the stellar surface.

Stellar magnetism is widespread. The magnetic field of the Sun and Sunlike stars is structured on small spatial scales (much less than the solar radius) and is believed to originate in the dynamo mechanism, which is driven by convective motions in their external layers. However, in stars with masses much larger than the Sun, the external layers are radiative and do not generate magnetic fields. The radiation pressure is so strong that it creates a massive "stellar wind," which leaves the star at very high velocities.

Between these two broad categories lie the so-called intermediate-mass stars (with masses a few times that of the Sun), which are entirely radiative and drive weaker winds. They are quiet stars that should normally not have magnetic fields. How, then, can some of them be magnetic? The answer is still unclear, but it is thought that their magnetic fields are "fossil"; that is, they were initially interstellar and were trapped somehow while the star was forming.

In such stars, the fine-tuning between a strong, dipolar magnetic field and a weak,



The wind environment of a magnetic hot star. In hot stars, UV radiation drives the outer layers into a fast (~1000 km/s) wind. This wind normally leaves the star freely, but if the star has a strong dipolar magnetic field, the wind is "bent" by the magnetic field. The magnetosphere separates two regions: the "escaping wind" region, similar to normal hot stars, and the "confined wind" region, where the wind is forced to collide with itself, producing a shock that heats the gas to x-ray temperatures (several million K). The gas eventually cools, forming a torus of equatorial "clouds." The clouds absorb the stellar UV radiation, producing characteristic signatures in the UV spectrum. At larger distances, high-energy electrons accelerated by the shock emit radio waves. All these emissions have been observed and make up a fairly consistent picture of the environment of a magnetic hot star.

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radiation-driven wind results in two regimes (*6*, *7*). If the wind pressure exceeds the magnetic pressure, the field lines are open. We see this in the solar corona, where the solar wind streams away from the Sun into the interplanetary medium. Conversely, if the wind pressure is dominated by the magnetic pressure, the wind is magnetically confined; that is, it cannot leave the star. The surface where the two pressures are equal defines the magnetosphere. If the stellar magnetic field is dipolar, the magnetosphere has a toruslike shape. This torus is large: Its external radius may reach 10 stellar radii (corresponding to 40 solar radii or half of Mercury's orbit). If the star rotates, the magnetosphere rotates with it, as in a merry-go-round (see the figure).

Inside the magnetosphere, the (charged) atoms follow the field lines like beads on a string. They therefore inevitably collide in the equatorial region with atoms coming from the opposite direction. A strong shock develops, which heats the downstream gas to x-ray temperatures (several million kelvin). This superhot gas fills most of the outer part of the torus (*8*, *9*) (see the figure). The x-ray emission of several magnetic stars can be explained in this way, the latest one being the B-type star beta Cephei (*2*).

One important question was left unsolved, however. Radiation continuously drives particles into the magnetosphere, but they cannot accumulate forever. Havnes and Goertz (*6*) suggested that along the magnetic equator, where the field is weakest but the gas pressure strongest, the pressure equilibrium is unstable, and pockets of gas will be expelled, especially if the star rotates. Babel and Montmerle (*8*, *9*) discussed another possibility, namely that the equatorial gas eventually cools and somehow falls back on the star, thus recycling the wind material.

Smith and Groote now show how this material may return to the star (*1*). They have performed a detailed study of archival UV spectra of several magnetic B stars taken by the International Ultraviolet Explorer (IUE) satellite to test the idea put forward by Shore and Brown (*10*) that a magnetospheric torus could be detected via absorption lines in the star's spectrum. Smith and Groot argue for the presence of "clouds" with temperatures of 17,000 K, about one solar radius in size. The shape of the clouds is uncertain, likely a torus, as proposed by Shore and Brown, possibly flattened into a disk (see the figure). They further argue that at least some of the cloud material settles back to the star. Donati *et al.* also favor this conclusion (*2*).

Other phenomena take place as a result of the wind–magnetic field interaction. Because of wind shocks (and also perhaps because of the expulsion of magnetized gas pockets), electrons may be accelerated to high energies. Because they are embedded in magnetic field lines, they will radiate nonthermal radio waves, in addition to the usual thermal radio waves of the hot gas. This radiation has been detected in a number of cases with the Very Large Array (VLA). Trigilio and his collaborators (*3*) have developed a detailed three-dimensional model of a rotating, radio-emitting magnetosphere. They show how the periodic VLA emission can be explained and what the emission regions would look like if direct imaging were possible (see the figure).

These recent studies provide a wide variety of observational constraints on the magnetically confined tori around magnetic stars. New observations, such as detailed x-ray spectroscopy, magnetic field measurements, and multifrequency radio observations, will provide further important information. But the most promising future probably lies in detailed, three-dimensional modeling of the magnetized plasma and the wind dynamics, in particular to answer the biggest remaining question: Where has the wind gone?

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PERSPECTIVES: SUPERCONDUCTIVITY

The Race to Beat the Cuprates

Elbio Dagotto

Superconductors are materials that lose all electrical resistance below a specific temperature, known as the critical temperature (T_c). Large-scale applications, for example, in superconducting cables, require materials with high (ideally room temperature) T_c's, but most superconductors have very low T_c's, typically a few kelvin or less. The discovery of a layered copper oxide (cuprate) with a T_c of 38 K (see panel A in the first figure) in 1986 (*1*) raised hopes that high-temperature superconductivity might be within reach. By 1993, cuprate T_c's of 133 K at ambient pressure had been achieved (*2*, *3*), but efforts to further increase cuprate T_c's have not been fruitful. Two reports by Schön *et al.* (*4*, *5*) in this issue—applying a similar technique to two very different materials—drastically alter the perception that planar cuprates are the only route to high-temperature superconductivity.

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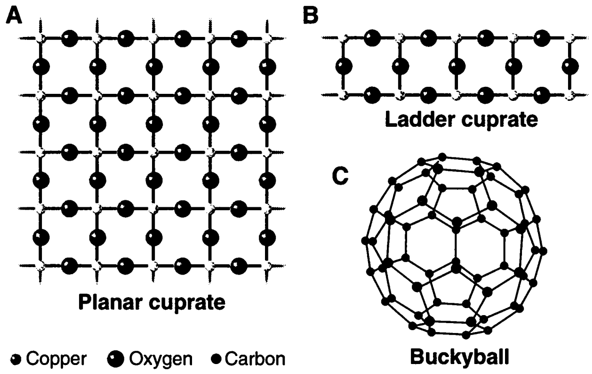
Schön *et al.* use a field-effect device introduced in previous investigations to transform insulating compounds into metals (*6*). On page 2430, they show that copper oxide materials with a ladder structure (panel B in the first figure) can be superconducting (*4*), even without the high pressure applied in previous studies of related compounds. Even more spectacularly, they report on page 2432 that the T_c of a noncuprate molecular material, C_{60} (panel C in the first figure), known before to superconduct at 52 K upon hole doping (*7*), can be raised by hole doping with intercalated $CHBr_3$ to 117 K (*5*), not far from the cuprate record. Simple extrapolations suggest that the T_c could be increased even further, effectively ending the dominance of cuprates in the high-T_c arena.



The structures of superconductors. (**A**) Copper oxide plane, (**B**) copper oxide ladder, and (**C**) C_{60} molecule. Ladders of copper and oxygen atoms, as shown in (B), form spontaneously in some compounds.

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