Isaac Newton Institute for Mathematical Sciences

Magnetohydrodynamics of Stellar Interiors

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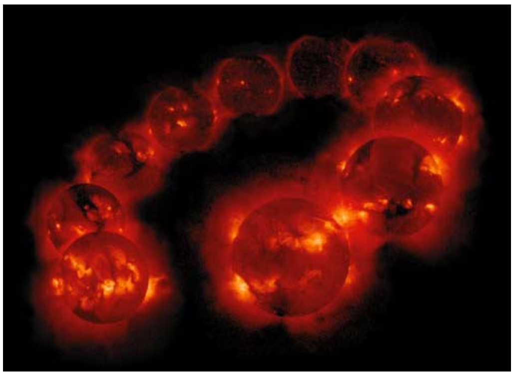

Composite image, showing waxing and waning of cyclic magnetic activity in the Sun, as indicated by the changing X-ray emission from its corona. (From the YOHKOH satellite, courtesy of Lockheed-Martin Solar and Astrophysics Laboratory.)

Magnetic fields in stars like the Sun give rise to a wide range of fascinating phenomena, including flares, spots, prominences and X-ray emission. Although such stars are all magnetically active it is only on the Sun that magnetic features can be observed in detail. The most prominent examples are sunspots, which have been observed through telescopes for 400 years, though their detailed structure has only recently been resolved. These observations reveal a systematic cyclic variation with a period of about 11 years. The amazing fine structure of the hot solar corona, which owes its origin to magnetic fields, can only be observed from space; the satellite images below show how coronal X-ray emission varies through the solar cycle. When the Sun was first formed, it rotated much more rapidly and displayed far more violent activity. Similar behaviour is exhibited by young stars now: they have strong magnetic fields that cover a large fraction of their surfaces, leading to the formation of huge starspots, and generating vigorous X-ray emission.

These features are all caused by magnetic fields that are generated in the star's *interior* and emerge outwards through its surface. Hence it is essential to understand the role of the magnetic field in the ionized, electrically conducting gas (a plasma) of which the star is composed. Magnetohydrodynamics (or MHD for short) deals with the complicated interactions between magnetic fields and motion, usually turbulent, which is influenced by the rotation of the star. On the one hand, such motions influence -- and indeed can generate -- strong magnetic fields; on the other, those strong magnetic fields exert a force back onto the gas, thereby affecting the way it moves.

The equations that govern MHD behaviour are themselves well known -- but they lead to an extremely rich variety of dynamical behaviour and raise many interesting mathematical problems. Moreover, owing to the intrinsic nonlinearity of these equations, they are difficult to solve, especially for the extreme parameter values characteristic of astrophysical plasmas. Advances are made through a variety of approaches, both analytical and computational, usually through the study of simplified model problems that encapsulate certain aspects of the fundamental physics. The subject is currently at an extremely exciting stage, considerable progress having been made recently in our understanding of high-conductivity phenomena, aided by the advent of easily accessible, massively parallel computers that are allowing a whole range of computations that previously simply could not be contemplated. The time is therefore ripe for this programme, which will bring theoreticians and observers together to discuss different aspects of solar and stellar magnetic fields.