asymmetric shape. If a localized density depletion ('dark hump') is induced instead, the back edge of the disturbance develops a shock front (see Fig. 1a).

In a classical fluid, wave dynamics is dominated by dissipative effects caused by viscosity in the fluid. This results in well-defined, propagating shock fronts where density and velocity change abruptly in a localized region across the front. But in superfluid BECs, the dynamics of shock waves is governed by dispersion rather than dissipation, and this greatly alters the behaviour. As a consequence of the coherent (lock-step) nature of a BEC, when a density hump is induced, the longitudinal shape of the resulting propagating shock fronts develops pronounced wiggles. These wiggles are a result of nonlinear wave mixing and interference effects in the coherent fluid.

In addition to the potential insights they provide into the physics of BECs and related systems, superfluid shock waves are of interest in their own right for their rich nonlinear excitation behaviour (Fig. 1b and c). The creation of particle-like excitations such as 'dark solitons' and quantized vortices (the superfluid equivalent of classical tornadoes) represents just some of the many peculiar phenomena that have been seen to emerge from the propagation of shock waves through BECs[3]. But, just as in high-energy physics where the most interesting physics is found when two particles collide, the real fun begins when multiple superfluid shock waves interact. For example, in shock collision experiments in sodium BECs, new, compound 'particles' with a very complex structure have been discovered[4]. Clearly, a rich field is emerging where interesting discrepancies with theory exist. In this respect, the platform for studying superfluid-like phenomena presented by Wan *et al.* could be very useful.

The crystal that forms the heart of Wan's system is one that shows a negative, Kerr-type optical nonlinearity. The authors illuminate the input face of the crystal with a laser field that consists of a gaussian peak superimposed on a uniform background (a 'hump-on-background' profile). As the field propagates through the crystal, the nonlinear response of the crystal causes the gaussian peak to spread in a way that directly mimics the outward propagation of a shock wave in a two-dimensional BEC. The light field at the output face of the crystal is imaged by a CCD camera. The strength of the shock is controlled simply by changing the amplitude of the gaussian peak with respect to the background field. And more importantly, by superimposing multiple peaks on this field, the system allows the generation and study of multiple colliding shock fronts.

The theory with which the authors analyse their results is based on Maxwell's equations. Although the Gross–Pitaevskii equation, with which shock behaviour in atomic condensates is usually analysed, provides a similar mean-field description, inevitable differences between the two exist. Moreover, it should be noted that the steep gradients in density and velocity that develop at shock fronts could lead to a local breakdown of the mean-field description, which could exacerbate these differences. Recent calculations indicate that a depletion of an atomic BEC may take place at shock fronts originating from dark humps induced in the condensate[8]. This depletion is associated with local excitations of atoms out of the condensate and would cause non-condensed atoms to fill the otherwise depleted cores of dark solitons and, probably, of vortices as well.

At the very least, being able to compare shock waves propagating in an atomic BEC with those in the optical system should allow the contribution to shock dynamics from the BEC component to be identified and separated from dynamics induced by, for example, interactions of quantized vortices with non-condensed atoms. Indeed, such insight could be of great value to our understanding of the breakdown of superfluidity and superconductivity — an issue that even on its own is of tremendous importance, from a fundamental perspective and for practical applications.

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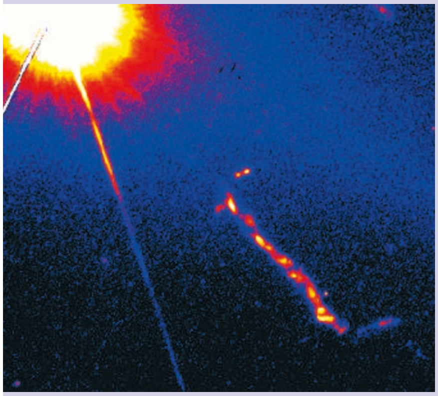
ASTROPARTICLE PHYSICS

X-ray diagnosis of a quasar



Quasars, along with supernovae and γ-ray bursts, are the most energetic sources of electromagnetic radiation in the Universe. About two billion light-years away, the nearest bright quasar, 3C 273 in the Virgo constellation, emits a powerful radio jet.

Markos Georganopoulos *et al.* propose to use X-ray emission from the jet to investigate its origin (*Astrophys. J.,* in the press).

Although most astronomers believe that a quasar is powered by a supermassive black hole, it's not clear how that black-hole engine lights up a quasar. Information on the energy transport mechanism would reveal how black holes were formed in the early Universe. Similarly, it might explain why there are no such quasars in active galaxies nearby.

There are two main theories for the X-ray emission: inverse external Compton (EC) scattering from relativistic electrons that scatter cosmic microwave background (CMB) photons; and synchrotron emission from TeV electrons — the same mechanism as for radio emission from the jet, but from another population of electrons.

To complicate matters, synchrotron radiation would also scatter CMB photons, so would look similar to the EC model. But as the two candidate processes involve electron energies differing by two orders of magnitude, the two energy scales should lead to different γ-ray dynamics. Georganopoulos *et al.* have come up with a set of diagnostics to distinguish the two models using existing and future γ-ray detectors.

If no GeV or TeV emission is detected, or only low-level GeV, there would be no additional constraint for the synchrotron model but the EC model would lose support. Detection of high-level GeV or TeV emission would confirm the synchrotron model. Although the authors believe that the latter is the most likely outcome, they acknowledge that future observations could refute both hypotheses.

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