melting[5]. Sobolev *et al.* do not disagree with this view, but they present geochemical and petrological evidence that ascending plumes incorporate oceanic crust that has been recycled into the mantle via ocean trenches, to the point where up to 20% of the plume may consist of this material. The consequences of this contamination are profound: it changes the way magma reaches Earth's surface and greatly increases the volume of gas released.

Traditionally, the arrival of a warm, buoyant mantle plume beneath the crust is thought to cause uplift and then stretching that allows magma to erupt[6]. A plume with a component of oceanic crust is considerably denser than a plume of mantle material alone, with the result that the process of ascent is a thermomechanical one: it 'eats' through the uppermost mantle and crust rather than rising by purely thermal processes. The thermomechanical erosion of lower crust requires more magma than is allowed by the traditional model and consequently a greater volume of gases (generated from the recycled oceanic crust). In Sobolev and colleagues' model[1], the volatile volcanic gases are driven off ahead of the basalt melting front, with the result that LIPs should start with a gigantic gaseous burp. The existence of a spectacular, initial explosive phase is supported by evidence from several LIPs, including the Siberian and Emeishan traps, which are closely linked with mass-extinction events[4].

Sobolev and colleagues' model has much strength: it supplies the missing gas volumes, predicts the correlation with extinction and LIP eruption onset, and also explains the contentious lack of pre-eruption uplift (thermal doming) seen in many provinces[7]. Finally, the model provides an explanation for contemporaneous changes in carbon cycling recorded by the carbon isotope record. Mantle $CO_2$ has an isotopic composition that is not very different (it is slightly enriched in carbon-12) from that of the ocean–atmosphere system. This means that even eruption of huge volumes of volcanic $CO_2$ leaves little isotopic record. Despite this, most LIP eruptions, and especially those linked with mass extinctions, coincide with rapid, large swings of carbon isotope ratios that suggest large volumes of $^{12}$C-rich $CO_2$ are reaching the atmosphere. Carbon derived from oceanic crust is more $^{12}$C-rich than that from pure-mantle sources, and it may be this carbon that is leaving its signature in the carbon isotope record.

The work by Sobolev *et al.*[1] focuses on the Siberian Traps LIP (Fig. 1), which coincides with the great end-Permian extinction event around 250 million years ago. It will be instructive to test the model further by examining other LIPs, such as the Karoo-Ferrar Province, which coincides with only a minor extinction, and the Paraná-Etendeka Province, which had no impact on the global biota. Currently, various complex hypotheses[8] are invoked to explain the hit-and-miss environmental impact of LIPs. The missing variable in this relationship may be the degree to which plumes have reworked oceanic crust on their ascent to the surface. ■

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ASTROPHYSICS

# Rough times in the Galactic countryside

**Knowledge of how the Milky Way formed and evolved is deficient. Simulations show that a past encounter with another galaxy may account for the Galaxy's intricate morphology.** SEE LETTER P.301

CURTIS STRUCK

Our Local Group of galaxies, which includes the Milky Way, the Andromeda galaxy (M31) and their many smaller satellites, used to be viewed as a quiet, rural galactic neighbourhood. There was little evidence of significant galaxy collisions or mergers in the group's history, except some involving the Magellanic Clouds. This is in rather stark contrast to some other nearby galaxy groups. The famous Antennae galaxies are violently rearranging each other, as they complete a merger between equals. The galaxies in the M81/M82 group are surrounded by large volumes of streams of interstellar gas

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**Figure 1 | Star stream.** The extended stream of gas and stars that wraps around spiral galaxy NGC 5907, which is here seen edge-on, is thought to be the aftermath of a past encounter between the galaxy and a companion. The models of Purcell *et al.*[2] indicate that the Milky Way's Sagittarius stream, which is fainter and less massive than the stream of NGC 5907, is similarly the result of a past galaxy–galaxy interaction, and that this interaction may also account for the wave morphology in the Milky Way's disk.

and star clusters, which have been scattered by close encounters[1]. But just at the time of year when it is nice to go out to a dark site and view the glorious and peaceful Milky Way, Purcell *et al.*[2] alert us to a prowler in the Galactic house — and evidence that it's been messing things up for some time. According to the authors' models, described on page 301 of this issue, the intruder may be responsible for the spiral-arm structure of the Milky Way, its central bar-shaped component and the flaring of its outermost disk.

The intruder is the Sagittarius Dwarf Elliptical Galaxy (SagDEG), also known as the Sgr Dwarf. SagDEG is not a very impressive object, and was only recognized[3] as a galaxy in 1994. It is difficult to observe because it is near the disk plane on the opposite side of the Galactic Centre from the Solar System. It is also difficult to see because most of it has been ripped apart by the tidal forces of the Milky Way. The debris forms a huge, but very faint, star stream around the Milky Way (see Fig. 1 of the paper[2]). The observational evidence suggests that four or five tightly bound globular star clusters once orbited SagDEG. The cluster M54 may be its core. So the prowler seems to be a 'mouse'.

We see a mouse now, but Purcell and colleagues' models[2] indicate that a (shrinking) Galactic 'bear' did the damage to the disk of the Milky Way. Certainly, the visible galaxy would have been much more substantial before most of its stars were scattered. Moreover, the authors point to evidence, from observations and from models of cosmological-structure growth, that dwarf galaxies such as SagDEG's progenitor have massive haloes of dark matter — high mass-to-light ratios, in the jargon. Instead of consisting of a few globular clusters each a few million times the mass of the Sun, like SagDEG now, the progenitor may have been 100,000 times more massive.

The estimated size of the original galaxy is an extrapolation, and Purcell *et al.* consider a range of possibilities. The extent of the range is greater than that in some previous work[4,5], and will probably be a matter of contention in coming years. At the light end, the tidal effect of the galaxy on the Milky Way is reduced, although still significant. Nevertheless, as well as giving a possible history of the Milky Way, the results of this paper[2] are interesting as a demonstration of the possible effects of shrinking visitors in galactic households. There are various reasons to think that such effects could be widespread.

The first is that several dozen other dwarfs and star streams have been discovered around the Milky Way[6] and Andromeda[7], mostly in the past dozen years. With perhaps a couple of exceptions, these generally do not come nearly as close to the Milky Way as SagDEG does, and have not had the same kind of effects. But the progenitor of the Great Stream around Andromeda may have generated significant effects there[8,9]. These dwarfs and streams have very low surface brightness, so they would, in general, be difficult to detect in galaxies beyond the Local Group. A few have been detected in other galaxies (such as NGC 5907; Fig. 1), but presumably those extragalactic streams are among the brightest.

A second reason for considering that the effects are widespread is that, as noted in the paper, the effects of galaxy interactions may be long lived in some cases. A third reason is that high-resolution models of galaxy formation indicate[10] that accretion onto galaxies out of the larger-scale structures that contain them continues throughout their cosmological history. The nature of this 'cold accretion' is not yet known. It may primarily consist of unformed streams of interstellar gas, or dwarf galaxies, or other constituents. The prowlers discovered in the Local Group suggest that at least some of these accreting objects are dwarf galaxies with dark haloes. These objects may therefore be common visitors and an important component of accretion onto the haloes of galaxies.

Because of the collective effects of dynamical friction, the relative orbits of most strongly interacting galaxies decay on timescales of hundreds of millions of years, and the end result is a merger of the two galaxies. Major mergers, which occur between two large galaxies of roughly equal mass, have been well studied, and we are getting an increasingly good understanding of their role in galaxy evolution.

Progress is also being made in understanding the role of minor mergers, which involve a companion a few to ten times smaller than the primary galaxy. Frequent stealthy invasions (and, ultimately, micro-mergers) by even smaller companions than those involved in minor mergers could generate waves in galaxy disks. This might, in turn, have long-term effects on disk evolution, giving us a new wrinkle in galaxy evolution. Beware of the wildlife, even in apparently quiet galaxies. ■

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MULTIPLE SCLEROSIS

# One protein, two healing properties

**Multiple sclerosis is linked to rogue immune cells that attack mature neurons. Remarkably, immature neurons secrete a protein called LIF, which not only inhibits this attack, but also promotes repair of the damaged nerves.**

SU M. METCALFE

Multiple sclerosis (MS) is a disabling autoimmune neurological disease that commonly affects young adults; in Britain alone there are more than 100,000 people with the disease. MS involves damage to the myelin sheath that normally insulates the electrical activity of nerve fibres. This in turn leads to a wide range of symptoms as specific nerves become inflamed and lose function. There is no cure. However, work on animal models has been encouraging, as it has shown that the transplantation of nerve progenitor cells not only inhibits the autoimmune attack that drives the disease, but also promotes the repair of damaged neurons[1]. In fact, in North America, human stem-cell transplantation is commercially available to patients with MS.

But is cell transplantation really necessary? Not according to Cao *et al.*[2], who report an exciting discovery in *Immunity*. They find that, at least in animal models of MS, a stem-cell-related cell-signalling protein called leukaemia inhibitory factor (LIF)[3] can partially cure the disease. This finding opens the way for the development of a cell-free therapy for MS that is simple, safe and widely accessible.

Cao and colleagues studied mice that had experimental autoimmune encephalomyelitis (EAE) — a model of MS. They found that damage to the central nervous system was reduced not only by the intravenous delivery of neural