in X-ray, optical and ultraviolet frequencies[7] — the X-ray signals suggesting the presence of material near the neutron star[2]. The inner region of accretion flow and its emission were also obscured, indicating the presence of material above and below the disk, and shielding regions of the disk itself from the observer.

The authors observed the system for roughly four hours, using several instruments to access many wavelengths simultaneously. NASA's Nuclear Spectroscopic Telescope Array was used to obtain high-resolution X-ray signals; the Hubble Space Telescope accessed ultraviolet frequencies; the Liverpool Telescope in Spain was used for optical frequencies; the European Southern Observatory's Very Large Telescope in Chile covered the near infrared; and the Karl G. Jansky Very Large Array in New Mexico observed radio-wavelength signals.

One of the key results of the campaign was the discovery of 'beats' in the X-ray, infrared, optical and ultraviolet emission from Swift J1858.6−0814. This characteristic variability pattern was very similar to the β-type variability observed in X-rays from GRS 1915+105. Vincentelli and colleagues' analysis indicates that the infrared emission from Swift J1858.6−0814 lags behind its X-ray emission by 2.5–5.5 seconds. This is consistent with the idea that X-rays from the inner disk are intercepted by both the outer disk and the companion star, then reprocessed and re-emitted as infrared radiation a few seconds later.

The authors propose a model to explain the observed multi-wavelength properties of both sources. The model holds that changes in the size of the accretion disk induce rapid variability in the X-rays from both GRS 1915+105 and Swift J1858.6−0814, but that this variability is less obvious in the neutron-star system because the inner disk is obscured. The jets that form during depletion of the GRS 1915+105 disk can be observed directly as infrared and radio emission, whereas those ejected from the Swift J1858.6−0814 disk are obscured and observed only as 'beating' re-emitted radiation at optical and ultraviolet frequencies.

Such beating emission is not observed for GRS 1915+105 because its accretion disk is larger than that of Swift J1858.6−0814, and it is oriented differently with respect to Earth. There is also absorbing material in the neutron-star system that is not present in the black-hole system (Fig. 1), although the reasons for this are unknown.

Vincentelli et al. argue that this physical scenario could be valid for all accreting black holes and neutron stars with high luminosity. Such a conclusion will require further support from other sources, but it's clear that accretion instabilities, jets and the presence of obscuring material are three things to look out for when studying objects accreting with

high luminosity. And although the authors' proposal is plausible, computer simulations are still unable to reproduce such instability models in detail. More observations are needed, both to confirm the predictions of the model and — perhaps more importantly — to better constrain parameters of the model.

Vincentelli and colleagues' achievement was made possible by the use of five telescopes, at locations across Earth and in space, observing signals from the same source at different frequencies. Such coordinated campaigns are difficult to arrange, in part because visibility is determined by the position of a source with respect to Earth, and by the local weather conditions at each facility. But they are also complicated by scheduling — a factor determined by when and for how long a given facility can observe the source, and by the multiple peer-reviewer boards tasked with granting their observing time. Confirming that high-luminosity binaries share a common

accretion mechanism will therefore be tricky. In the meantime, Swift J1858.6−0814 suggests they might, and such a possibility is certainly intriguing.

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Ecology

Rainfall affects interactions between plant neighbours

Meghna Krishnadas

Neighbouring plants affect the performance both of their own species and that of other species. How these interactions vary with rainfall might explain patterns of plant diversity and predict responses to global environmental change. **See p.100**

Does rainfall change the extent to which plants interact with their own species compared with their interactions with other species? On page 100, Lebrija-Trejos et al.[1] investigate this question for seedlings growing in a tropical forest.

Neighbouring plants affect a plant's survival and how well it grows. The nature of these interactions depends on whether the neighbour belongs to the same species (is conspecific) or a different one (heterospecific). The relative effects of conspecific and heterospecific neighbours on plant performance influence plant diversity. Theory suggests that, to maintain species diversity, conspecifics must compete more vigorously with each other than with heterospecifics[2,3]. At the scale of neighbourhood interactions, this manifests as a stronger decline in the performance of individual plants with increased conspecific density compared with the performance with increased heterospecific density[4], a phenomenon called negative conspecific density dependence (NCDD; also known as conspecific negative density dependence).

A key process underlying NCDD involves pests (for example, herbivorous insects and disease-causing microorganisms) that attack plants in a density-dependent manner[5,6]. When plant species are abundant, individuals are more likely to encounter their conspecifics and be exposed to the pests that affect them. Rare species, by comparison, have a better chance of escaping their pests[7]. In this way, pests mediate NCDD to slow population growth as species become more abundant, potentially helping rare species to avoid extinction in the community and so maintaining diversity.

However, these biotic interactions can change depending on other factors — for example, abiotic conditions such as rainfall. Pests can be more prevalent and damaging in wetter conditions[8]. Therefore, at a given site, relative to drier years, wetter years might enhance NCDD, with plant diversity following suit. Rainfall-driven trends in the diversifying effects of biotic interactions might be prominent among seedlings, which are highly vulnerable to pests and can experience rapid shifts in community structure[9].

Figure 1 | Seedlings growing on Barro Colorado Island, Panama. Lebrija-Trejos *et al.*[1] investigated how rainfall influenced biological interactions and thus the species diversity of trees at this location.

Lebrija-Trejos *et al.* tested how seedling diversity due to NCDD was affected by changes in soil moisture arising from variation in annual rainfall. The study looked at 20 years of data, assessing seedling survival from the first year of seedling life for 215 species on Barro Colorado Island in Panama (Fig. 1).

The authors' analysis teased apart two possibilities. One is that moisture directly affects seedling diversity because moisture-sensitive species survive poorly in drier years. The other possibility is that diversity is influenced by moisture-driven changes in the effect of neighbouring plants on seedling survival through biotic interactions between neighbours. Species' preferences regarding moisture conditions were assigned on the basis of the distribution of mature trees across a rainfall gradient. The distribution for a subset of the species matched the experimentally determined moisture sensitivity of their seedlings[10].

Across the 20 annual groupings, that is, for the seedlings germinating in the study plots in a given year, the effect of conspecific seedlings in the neighbourhood was more detrimental to survival in wetter years — when soil moisture was higher — than in drier years. Concomitantly, species diversity over the first year of seedling life declined in drier years and increased in wetter years. The increase in seedling diversity after a wet year could persist for at least the subsequent 15 years. Also, by simulating a plant community, the authors showed that changing conspecific effects in a moisture-dependent way could reproduce the observed relationship between diversity and moisture. By contrast, simulating species' survival on the basis of their moisture sensitivity alone did not reproduce the observed trends in seedling diversity.

Together, these results indicate that rainfall might affect diversity less through moisture-dependent survival of species than through its effect on processes that increase conspecific limitation more than heterospecific limitation. That the diversifying effect of a single year had consequences for more than a decade is of note for humid tropical forests, given that the survival and persistence of seedlings have a lasting effect on future tree diversity.

> **"That the diversifying effect of a single year had consequences for more than a decade is of note."**

Single-site studies such as that of Lebrija-Trejos and colleagues provide valuable insight, but they need to be replicated in different systems to provide more-general inferences. For example, would the regulation of diversity by rainfall (mediated by biotic interactions) differ depending on the baseline climate conditions? Ecosystems vary in the extent to which NCDD affects community dynamics and therefore in how diversity might respond to shifts in conspecific compared with heterospecific interactions.

Even with the relationship reported by Lebrija-Trejos *et al.* between rainfall and diversity, mechanisms other than NCDD might determine diversity by their variable effect on species persistence in different climates, especially in the ability of species to recover from times of low population density[3]. For example, environmental change might increase competitive differences between plant species, such that negative feedback effects no longer suffice to buffer communities against species extinction.

Lebrija-Trejos and colleagues' findings should spur deeper forays into the processes involved, for example by examining how abiotic context shifts plant interactions with soil microbes and herbivorous insects, and the resulting outcomes for diversity. More broadly, this study touches on how variability in abiotic conditions affects diversity — a consideration that is well established theoretically but that has been applied to problems such as global environmental change only in the past three or four years.

Along these lines, this work raises questions about how multiple aspects of global environmental change, such as drought, habitat fragmentation and nutrient deposition, affect diversity-maintaining processes[11]. Tackling these questions should ideally harness globally distributed data to compare processes across different sites. Cross-site observational studies should be coupled with experiments into species interactions in various climate contexts, to provide mechanistic insights into how biotic and abiotic processes interact to shape patterns of plant diversity[12].

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