work assessed functions individually and did not address dryland systems, which, as Maestre *et al*. point out, cover 41% of Earth's land surface and support over 38% of the global human population.

Human society needs ecosystems to provide multiple services effectively, especially as we increase pressure on ecosystems from local impacts such as extractive harvesting to global impacts such as climate change (*4*). In drylands, critical ecosystem services include the conversion of solar energy, atmospheric CO_2, and water to plant biomass (net primary productivity), carbon storage, and provision of nutrient pools. This suite of services is vital for arresting desertification trends and sequestering carbon.

Maestre *et al*.'s test of the BEF hypothesis is stringent because they test for a relationship between species richness of primary producer species (perennial plants) and ecosystem functions expressed in soils. Soil functions are subject both to abiotic drivers and many biotic effects other than those due to perennial plants. Confirmation of the BEF hypothesis under these constraints would therefore imply robust general support for it. They also did not shy away from the confounding influence of human management impacts, given that their field sites around the world represent a wide range of intensity of human use, barring major soil disturbances such as farming or mining.

Maestre *et al*. report that perennial plant species richness is a statistically significant explanatory variable for ecosystem multifunctionality both on its own and when considered together with several abiotic explanatory variables. Indeed, only two abiotic variables, mean annual temperature and soil sand content, were more important than plant species richness in explaining ecosystem multifunctionality (hotter, more sandy sites had lower multifunctionality), in a set of variables that included mean annual rainfall.

Maestre *et al*. find that the relationship between species richness and ecosystem multifunctionality rises steeply with fewer than five species and then increases incrementally with the addition of more species. This implies that ecosystem multifunctionality as defined by Maestre *et al*. is well established by relatively few species in these dryland ecosystems, in contrast with results from temperate grasslands (*5*). However, the large spread in Maestre *et al*.'s data suggests that, apart from uncontrolled effects such as land-use history mentioned above, there may be important individual species effects (including keystone species effects) that are not quantified in this natural experimental approach. That is, the stringency and generality of their test have the unfortunate consequence of obscuring important details that seem better revealed by the experimental approaches followed in the temperate grassland studies (*6*).

Given the acknowledged limitations of the experimental design used by Maestre *et al*., future work should focus on teasing out how much variation is explained by plant species richness when potentially powerful factors such as land-use history and intensity of herbivory are controlled for. This will be important in assessing the value of biodiversity in real-world settings and may suggest how rapidly ecosystem multifunctionality could be enhanced under different land management practices aimed at ecosystem restoration.

All considered, Maestre *et al*.'s conclusion that perennial plant species richness matters for ecosystem function in dryland systems is robust. This answer has global relevance, and is especially valuable for many developing and least-developed countries facing desertification trends. Neither Maestre *et al*.'s approach nor the experimental approaches undertaken in temperate grasslands or earlier experimental work (*7*) have yet fully addressed the multilayered question of how biodiversity across trophic levels, in conjunction with abiotic drivers, determines ecosystem function (see the figure).

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ASTRONOMY

Gamma-Ray Binaries Revealed

The Fermi Large Area Telescope is unveiling a large population of otherwise hidden sources of gamma rays.

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Recent ground- and space-based telescopes that detect high-energy photons from a few up to hundreds of gigaelectron volts (GeV) have opened a new window on the universe. However, because of the relatively poor angular resolution of these telescopes, a large fraction of the thousands of sources of gamma rays observed remains unknown. Compact astrophysical objects are among those high-energy sources, and in the Milky Way there is a particular class called gamma-ray binaries. These are neutron stars or black holes orbiting around massive stars (*1*). On page 189 of this issue, the Fermi Large Area Telescope Collaboration (*2*) use the correlated orbital modulation at gamma-ray, x-ray, and radio-wave wavelengths to show that the source 1FGL J1018.6–5856 is a new gamma-ray binary, demonstrating the potential of searches for periodic modulation at gamma rays and other wavelengths to unveil new populations of gamma-ray binaries.

This area of high-energy astronomy presents several challenges: identifying the gamma-ray source with a source observed at other wavelengths; determining the properties of the binary system; and understanding the physical mechanisms by which gamma-rays are produced. In the Milky Way, only a handful of binaries radiating at gamma rays have been unambiguously identified (Cygnus X-3; PSR B1259–63; LSI +61° 303; LS 5039; HESS J0632+057). However, models of the evolution of massive stellar binaries suggest a much larger population of gamma-ray binaries.

The Large Area Telescope (LAT) on board the Fermi satellite has cataloged more than 1400 high-energy sources. Many of them are in the Milky Way, but because of the uncertain positions in the sky provided by the gamma-ray telescope (typically a few arc-min), and the complexity of the star-formation regions where gamma-ray binaries are usually located, the association of these high-energy sources with objects observed at other wavelengths is usually uncertain. The observation of correlated

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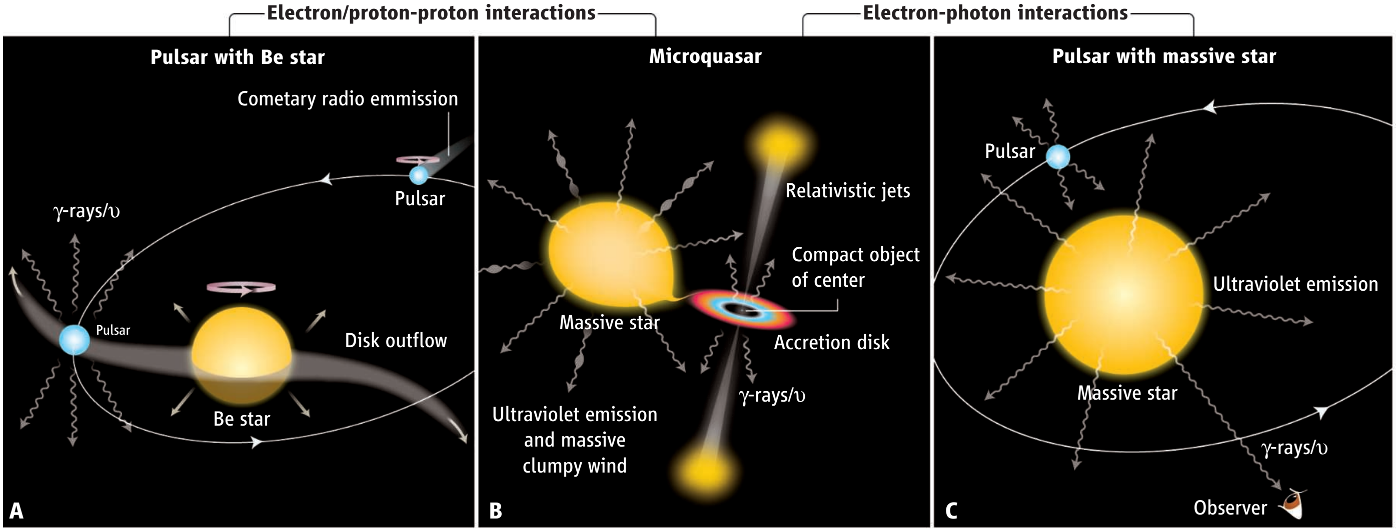

Gamma-ray binaries. Pulsar winds are powered by the rapid rotation of magnetized neutron stars. Gamma rays can be produced either by the interaction of the relativistic particles of the pulsar wind with the outflowing protons in the disk or envelope of a Be star (**A**) (e.g., PSR B1259–63 and LSI +61° 303), or by their interaction with UV photons from a very massive main-sequence star (**C**) (e.g., LS 5039 and 1FGL J1018.6–5856). (**B**) Microquasars are powered by compact objects (neutron stars or stellar-mass black holes) via mass accretion from a companion star. When the donor star is a massive star with a high-density UV flux and wind, gamma rays can be produced by electron-proton and/or electron-photon interactions. ν, neutrinos.

time variation of flux at different wavelengths was used to identify Cygnus X-3 as a gamma-ray binary (*3*), a microquasar (*4*) source of collimated relativistic jets, which was also observed at gamma rays with the Agile satellite (*5*).

1FGL J1018.6–5856 is a compact object orbiting with a period of 16.6 days around a star of more than 20 solar masses. On the basis of phenomenological similarities with other gamma-ray binaries, it is most likely a pulsar that produces strong bipolar winds of particles accelerated to highly relativistic speeds by the rapidly rotating, strong magnetic field of the spinning neutron star. The dominant physical mechanisms to produce the gamma-ray emission and its orbital modulation depend on the specific type of massive star in the compact binary (see the figure). When the star is very massive and produces a high-density field of ultraviolet (UV) photons, the main mechanism would be the up-scattering of UV photons from charged particles up to gamma-ray energies (*6*, *7*). In this scenario, maximum gamma-ray emission takes place when, relative to the observer, the compact object is on the opposite side of the star and close to the line of sight (superior conjunction). This may occur in both types of gamma-ray binaries: in high-mass microquasars such as Cygnus X-3, or in pulsars orbiting around very massive stars that produce high-density fields of UV photons, as with the stars in LS 5039 and 1FGL J1018.6–5856.

An alternative dominant mechanism to produce gamma rays that results in a somewhat different orbital modulation may operate when the star in the compact binary is of Be type. These stars are characterized by a massive outflow with disk and/or flattened envelope geometry, in fast rotation. Here, the gamma rays may be produced by the interaction of the pulsar wind particles with the ions in the massive outflow. This could be the case in the Be compact binaries PSR B1259–63 and LSI +61° 303, where the phasing of gamma-ray maximum at GeV energies is delayed relative to periastron (*2*). Detailed hadronic mechanisms that produce gamma rays have also been proposed in a diversity of astrophysical contexts (*8*, *9*).

High-energy neutrino flux could also be produced in gamma-ray binaries of the type shown in the figure, emerging from the decays of secondary charged mesons produced at proton-proton and/or proton–gamma photon interactions (*10*). In microquasars, relativistic protons from the jets interact with cold protons in clumps of the massive stellar wind, at large distances from the compact object (*11*). In the case of a pulsar-Be binary, neutrino bursts could be produced by the interaction of relativistic protons from the pulsar wind with high-density clumps of cold protons in the massive outflowing disk or envelope of the Be star. Depending on the specific parameters of these gamma-ray binaries, it remains an open question whether neutrino signals may be detected from this type of astrophysical object.

Emission at higher energy (TeV) has been detected by Cherenkov telescopes (PSR B1259–63; LSI +61° 303; and LS 5039), but it is not clear whether 1FGL J1018.6–5856 is also a TeV source. Its position is consistent with the TeV source HESS J1018–589 (*12*), but due to possible confusion with other objects in this complex star-forming region, it is unclear whether the Fermi source and a component of the HESS source are the same object. Resolving this question by using time modulation and/or more accurate positions of TeV sources will require improving the sensitivity and angular resolution of ground-based Cherenkov telescopes. The large collecting area and separation of the telescope elements in the future Cherenkov Telescope Array (*13*) will provide the sensitivity and angular resolution to consolidate this emerging research area in high-energy astrophysics.

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