the decreasing trend in glacial ice volume observed during the late Pleistocene.

To understand these different responses of tropical climate to high-latitude climate change, it is crucial to consider what oxygen isotopic variations in stalagmites represent. Stalagmites build up from groundwater precipitate recharged by meteoric water (that is, water in the ground that originates from precipitation). Stalagmite records therefore reflect the isotopic composition of past tropical precipitation. The main driver of the isotope ratio of tropical precipitation is precipitation amount (*7*). However, in northern Borneo, isotopic seasonality in modern precipitation is linked not to local precipitation but to seasonal migration of the tropical convective rainfall band, called the intertropical convergence zone (ITCZ) (*8*). Relatively lower isotopic values correspond to periods when moisture propagates from the ITCZ region to Meckler *et al.*'s study site during the boreal fall; relatively higher isotopic values correspond to periods when the ITCZ moves southward and northeasterly monsoon winds transport relatively dry air from the western Pacific region during boreal winter. Thus, a shift in the $^{18}O/^{16}O$ ratio to lower (higher) values may indicate a relative increase (decrease) in the contribution of convective rainfall associated with the ITCZ (see the figure).

Meckler *et al.*'s stalagmite data reveal that ITCZ activity and position did not respond to interglacial change across the MBE. With small changes in tropical sea surface temperatures during the interglacials—suggested by tropical marine sediment records (*3*)—we can infer that increasing interglacial CO_2 concentrations did not affect low-latitude climates. On the other hand, insolation plays a key role in tropical convective activity. Meckler *et al.* find that a prolonged period of ITCZ activity was maintained over the western Pacific during MIS 11 (an interglacial between 420,000 and 360,000 years ago), when the amplitude of insolation change was low due to Earth's orbital cycle. Based on these results, the authors suggest that precessional insolation plays a dominant role in tropical Pacific convective activity during interglacials, irrespective of high-latitude climate change.

However, the situation is very different during deglaciations, when environmental changes in the Northern Hemisphere have a strong impact on ITCZ activity and position over the tropical Pacific region (*9*). The weak convective activity over northern Borneo that Meckler *et al.* deduce for deglaciations is consistent with the recently proposed southward shift of the ITCZ during the last deglaciation (*9*).

The following mechanism may explain these observations. During the early stages of deglaciation, freshwater discharge from the northern ice sheet to the Northern Atlantic triggers widespread reorganization of atmospheric and ocean circulation, causing a southward displacement of the ITCZ, as well as warming of the Southern Hemisphere and a rise in atmospheric CO_2. Rising atmospheric CO_2 leads to further melting of the ice sheet; this positive feedback loop may have held the ITCZ in a southerly position during the deglaciation period. The fact that every interglacial is characterized by similarly intense convective activity over the tropical Pacific implies that the ITCZ is displaced northward whenever a new interglacial-sustaining steady state is reached, independent of atmospheric CO_2 levels.

Meckler *et al.*'s long-term stalagmite record provides insight into past ITCZ displacement associated with the reorganization of large-scale atmospheric circulation. The exact mechanism behind the south/north movement of the ITCZ and the climate feedback involved in ITCZ displacement is still under debate. Nevertheless, the stalagmite record provides a plausible benchmark from which the reliability of climate sensitivity model estimates can be tested, as well as the ability of such models to reproduce different climatic phases.

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ASTRONOMY

Gathering Interstellar Gas

Seth Redfield

Observations by the IBEX spacecraft reveal details of the heliosphere—the boundary between our solar system and the rest of the universe.

Our solar system is plowing through the gas and dust that resides between the stars, the interstellar medium. The result is a bullet-shaped structure surrounding the Sun—called the heliosphere—that demarcates the balance between the outward pressure of the solar wind and the inward pressure of the surrounding gas. Every day, the heliosphere encounters a mass equivalent to Mount Everest, of what is often referred to as empty space, but which actually consists of atoms (mostly hydrogen), molecules, and dust. Some of that material is trapped at the nose of the heliosphere, some is diverted around it, and some passes right through it. On page 1291 of this issue, McComas *et al.* (*1*) present a new view of the heliosphere based on recent measurements by instruments onboard the Interstellar Boundary Explorer (IBEX) spacecraft (*2*) of those interstellar atoms that have passed through the heliosphere and traveled into the inner solar system.

One of the ironies in astronomy is that in some cases, nearby objects are actually more difficult to observe than more distant ones. Observations over large distances measure a large accumulation of starlight-blocking gas and dust that is easy to detect, whereas nearby stars are viewed through very small amounts of material that leave only a weak signature in our observations. In the past 20 years or so, as a result of a dedicated ultraviolet spectrograph onboard the Hubble Space Telescope, we have been able to study the interstellar medium structures in our local cosmic neighborhood by measuring how gas blocks light from the nearest stars (*3*).

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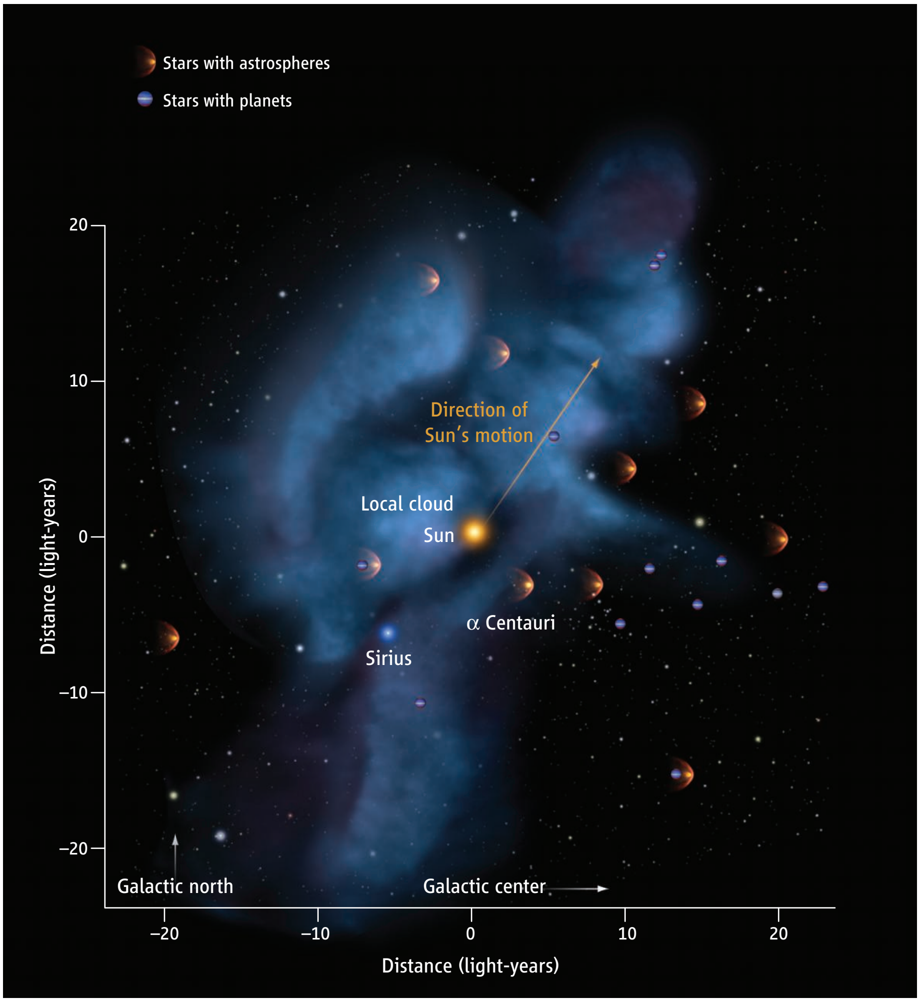

Star collections. The Sun is traveling through a collection of interstellar clouds, the properties of which determine the structure of our heliosphere. As the Sun moves in and out of the clouds, the heliosphere expands and contracts. Analogous structures, astrospheres, have been detected around many nearby stars, as have exoplanetary systems.

The new measurements presented by McComas *et al*. extract the speed and direction of the interstellar gas that directly surrounds the heliosphere from the atoms that stream through unimpeded. The results enable a rare comparison between astronomical observations of starlight, which retain the magnitude and direction of motion of 10^{18} interstellar particles distributed over tens of light years, with in situ measurements of the motion of individual interstellar particles measured by IBEX, which orbits a mere light second away. Remarkably, these two measurements are in excellent agreement. The macroscopic and microscopic measurements are self-consistent and indicate that the interstellar particles are moving slower than previous measurements had implied. This result impacts the canonical view of the basic structure of the heliosphere—a lower velocity brings into question the existence of a shock at the leading nose of the heliosphere.

Although the Sun is currently moving through a relatively sparse region of the galaxy, referred to as the Local Bubble, there have been times in our past, and will be times in our future, in which we will travel through regions with very different properties. Within the Local Bubble, interstellar clouds span six orders of magnitude in density (*4*, *5*) and the size and structure of the heliosphere is dramatically affected even in encounters with modest increases in interstellar density (*6*, *7*). McComas *et al*. provide a vital measurement of the current heliosphere that can be used with the map of the interstellar gas (see the figure) to explore the structure of the heliosphere with time. The solar system will pass out of the local interstellar cloud relatively soon, perhaps in a few thousand years (*8*), which will change the structure of the heliosphere.

Just as Earth's magnetic field protects us and our atmosphere from harmful energetic charged particles emanating from the Sun, the solar magnetic field extends out to the heliosphere and protects all the planets from even more energetic particles produced by supernova explosions that are pervasive in the galaxy. If the heliosphere is expanding and contracting with time, so will the effectiveness of this shield. Indeed, if the heliosphere were to shrink within the orbit of Earth, it could have consequences for our planetary atmosphere and even life (*9*).

The Sun is not the only star that is encountering interstellar gas and dust. Structures like the heliosphere around the Sun are likely present around most stars throughout the universe. The analogous structure around another star is called an astrosphere (*10*). Each astrospheric structure will be dictated by the properties specific to that star and its environment, including the density and motion of the interstellar gas surrounding the star, the motion of the star, and the strength of its stellar wind. As we explore the diverse array of astrospheric structures, the heliosphere will be the standard against which all others will be compared. It will be models of the heliosphere, such as those presented by McComas *et al*., that will be vital to understanding other astrospheres.

Just like the heliosphere, these astrospheres are likely to encircle and protect planetary systems of their own. Within a radius of 20 light years, in which the nearest 100 stars reside, we know of 10 stars with astrospheres (including our nearest stellar neighbor, α Centauri) and 16 stars with detected planets in orbit around them (see the figure). We know of two stars with both, but given that detecting either astrospheres or planets around other stars has only recently become possible, our inventory is incomplete. As we gain a more detailed knowledge of our heliosphere and discover more astrospheres, exciting work will explore the relationship between a given planet and its heliospheric (or astrospheric) shield and the interstellar gas that surrounds them.

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