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language and thought. But there are interesting new opportunities that are opening up with advances in AI where we now have a model system to study language, which is in the form of these large language models such as GPT-2 and its successors. These models do language very well, producing perfectly grammatical and meaningful sentences. They're not so good at thinking, which is nicely aligning with the idea that the language system by itself is not what makes you think.

But we and many other groups are doing work in which we take some version of an artificial neural network language model as a model of the human language system. And then we try to connect it to some system that is more like what we think human systems of thought look like—for example, a symbolic problem-solving system such as a math app. With these AI tools, we can at least ask, "What are the ways in which a system of thought, a system of reasoning, can interact with a system that stores and uses linguistic representations?"

What do large language models do to help us understand the neuroscience of how language works?

They're basically the first model organism for researchers studying the neuroscience of language. They are not a biological organism, but until these models came about, we just didn't have anything other than the human brain that does language. And so what's happening is incredibly exciting. You can do stuff on models that you can't do on actual biological systems that you're trying to understand. There are many, many questions that we can now ask that had been totally out of reach: for example, questions about development.

In humans, of course, you cannot manipulate linguistic input that children get. You cannot deprive kids of language, or restrict their input in some way, and see how they develop. But you can build these models that are trained on only particular kinds of linguistic input or are trained on speech inputs as opposed to textual inputs. And then you can see whether models trained in particular ways better recapitulate what we see in humans with respect to their linguistic behavior or brain responses to language. ⬢

The Darkest Place in the Milky Way

What looks like a hole in space is actually dust

BY PHIL PLAIT

RIGHT NOW, people who love looking at the wonders of the heavens have it better than ever. Every day brings some new jaw-dropping snapshot from at least one of the myriad observatories now operating on the ground or in space, each offering a new view of alien worlds, exploding stars, colliding galaxies or any number of other astrophysical phenomena. Most of these images are paeans to cosmic forces and inconceivable scales that carve stunning beauty from epic violence.

But not everything in our galaxy (or beyond) is the outcome of such ostentatious chaos. Some of the most visually captivating celestial objects are quiet, steady, even calm—and so dark that they not only emit no visible light but actually absorb it, creating a blackness so profound they seem to be a notch cut out in space.

These shadowy expanses have many sobriquets—dark nebulae, dust clouds, knots—but I prefer to call them Bok globules, a name they received in honor of Dutch American astronomer Bart Bok, who studied them.

A Bok globule is a small, dense clump of cosmic dust; millions of them are scattered around our galaxy. They are cold and opaque to visible light, so much so that until quite recently the only way to see them was in silhouette against brighter background material. Though not as splashy as their star-factory cousins, such as the Orion Nebula, Bok globules can still make stars, albeit in a more artisanal way: they make one or a few at a time that are largely hidden from our prying eyes in the dust's abyssal depths.

Phil Plait is a professional astronomer and science communicator in Virginia. He writes the *Bad Astronomy Newsletter*. Follow him on Beehiiv.

Of all the dark globules we can see with our telescopes, my favorite beyond a doubt is Barnard 68, colloquially called B68. Located about 500 light-years from Earth, it's a vaguely comma-shaped and coal-black cloud a mere half-light-year wide, spanning some five trillion kilometers. We see it easily because it's in the constellation Ophiuchus, with the star-packed center of our Milky Way galaxy as its backdrop. B68 appears to us as negative space, an absence of stars.

Why is it so dark? Although mostly made of hydrogen gas (like pretty much everything else in our galaxy), B68 also has an abundance of carbon. Some of this element is locked up in small molecules such as carbon monoxide, but much of the rest instead resides in long, complex molecules that make up what astronomers generically call dust. One distinguishing (or extinguishing) characteristic of dust is its capacity to block visible light.

And dust clouds can be dark indeed. In the case of B68, any star located on the other side from us will have its light diminished by a factor of *15 trillion*. To put this in perspective, dimming the sun in our sky by this much would reduce it to a fourth-magnitude star difficult to spot in even mildly light-polluted skies. If you were on one side of B68 and the sun on the other, the sun's light would be so attenuated across that half-light-year that it would become invisible to the naked eye.

Such extreme darkness makes B68—and Bok globules more generally—subject to continual mistaken identity. Some years ago astronomers discovered the existence of huge volumes of space largely bereft of galaxies; these are called cosmic voids and can be many millions of light-years across. Alas, I've seen quite a few breathless videos and articles about them illustrated with an image of B68. It's irritating to me as an astronomer to see this mistake because these are very different objects, but it's also rather amusing because the actual voids being discussed are millions of times larger than our friendly nearby Bok globule.

B68's prodigious ability to absorb light relies on a surprisingly modest amount of dust.

Even in its center, where it's densest, B68 has less than a million particles of matter per cubic centimeter. That may sound like a lot, but here on Earth it would rate as a laboratory-grade vacuum—at sea level our planet's atmosphere packs about 10^{19} molecules per cubic centimeter, making the air you breathe some *10 trillion times* denser than B68 at its best.

Despite its all-encompassing darkness, we can discern B68's density because, like any cloud, it becomes more tenuous toward its outskirts. This creates an interesting situation: from our viewpoint, we can see some background stars through the relatively thinner material at its edges, but the closer we view to the center, the more that light is absorbed. Stars appear bright at the cloud's perimeter but grow progressively dimmer as we look closer to the center. Because dust tends to absorb bluer light better than rays of red, which can pass through more easily, such stars don't just fade; they also redden. And infrared light traverses B68 more easily yet, so telescopes tuned to those wavelengths can see even more stars. Astronomers can use that reddening and dimming to measure how much dust is inside the cloud.


Barnard 68 (B68) is a dark and dusty nebula some 500 light-years from Earth.

ESO

Using other techniques, they can also measure B68's temperature. Bok globules are terribly cold, and B68 is no exception, registering a bone-chilling –256 degrees Celsius at its edges that drops to only –265 degrees C at its center. This is barely above absolute zero!

Yet that whisper of warmth is enough to support the globule against its own gravity. B68 is not terribly massive, containing only about three to four times the mass of the sun, but that's still typically more than enough to cause a gravitational collapse. The meager amount of internal heat keeps B68 inflated much like a hot air balloon, however (or, more accurately, a bitterly cold, near-vacuum balloon).

But this fragile impasse can't last forever. Careful observations of B68 show what seem to be two distinct "cores" of higher-density material, one near its center and another in the stubby "tail" near its southeastern edge (*seen at lower left in photograph*). Radio-wave observations suggest this tail was once a separate, smaller cloud that is now merging with B68, upsetting the delicate balance of gravity inside the cloud. Consequently, B68 may now be collapsing, which means this dark cloud may literally have a bright future ahead: it will form a star.

As the material collapses in on itself, the density in the center would increase and the temperature with it. This would continue for hundreds of thousands of years until, at the cloud's core, a star is born (perhaps more than one, given there's enough material in B68 to form a couple of sun-like stars). If that happens, almost all the matter remaining in the cloud will be blown away by the light of the newborn star or stars—all, that is, save perhaps for a meager fraction caught in the star's gravitational clutches, which could condense and collapse in turn to create a disk of material destined to form planets.

And who knows? In some few billion years more, perhaps life and eventually intelligence might arise on some of those worlds, so that one day in the far future alien astronomers will peer out and wonder about the universe they see, a vista they could not possibly have glimpsed through B68's youthful, starlight-devouring haze. Perhaps Earth and the sun will be long gone by then, and the galaxy will have transformed into a very different place. But even so, there's comfort to be found in such an end, knowing that once upon a time we began in much the same way; our sun was born in a huge, dust-darkened nebula that eventually lit up with thousands of other stars, a stellar nursery that, like its cosmic children, has long since dispersed.

Everything in the universe is ephemeral and much of it cyclical. We are privileged to be able to observe what we can now, even if what we see is something that is very difficult to see at all. ●

Any star located on the other side will have its light diminished by a factor of *15 trillion.*