There is yet another possibility. Our shared mammalian evolutionary history may have provided tamarins with perceptual systems that make all the same discriminations that humans have for speech perception. It would then appear that the perception of speech by tamarins might be analogous to human speech perception. But is it really? Perhaps the difference lies at a later point in perceptual processing, one requiring more complex integration of these discriminations. What might then be unique to humans is not the ability to make appropriate auditory discriminations, but rather the ability to coordinate these auditory discriminations in the service of language acquisition. By 6 to 7 months of age, human infants can use overall rhythm to "predict" clause and phrase boundaries (*5*), and by the age of 9 months, human infants not only discriminate rhythmic structure and syllable sequence, but also coordinate these two sources of information to pull out "word-like" multisyllabic rhythmic units (*6*).

The integrative tasks that infants perform are arguably crucial for language acquisition. Do nonhuman primates coordinate the output of their auditory discriminations in the same way as humans do? And are they, like human infants, selective in just which kinds of information they combine? If they are not, then the defining characteristic of human language processing would lie not only in the types of auditory discrimination that are made, or where in the brain these discriminations occur, but also in the integration of auditory discrimination and the brain areas performing these operations.

In revealing our sometimes naïve conceptions of what makes language special, Ramus and his colleagues allow us to revisit past work and redirect the inquiry. It will be essential to explore not only what is similar between human neonates and other species, but also to investigate just what allows the human mind to negotiate its own complex invention that is language.

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PERSPECTIVES: ASTRONOMY

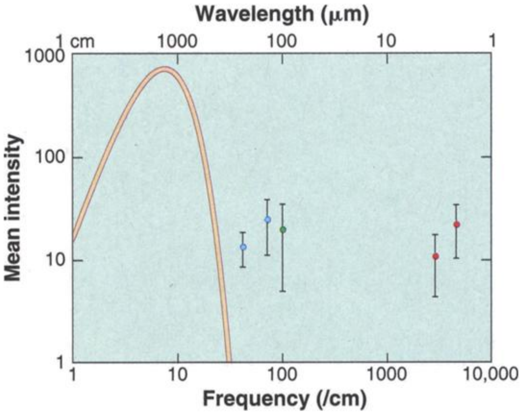
An Infrared Look Behind Stars

Craig J. Hogan

A quick glance at the night sky reveals that the sky is mostly dark, a profound fact that in itself reveals much about the history of the universe and of the stars within it. Of course, it is not perfectly dark: It glows from Earth's atmosphere and from the zodiacal light of sunlight reflected from dust between the planets, and is peppered with stars because we are viewing the universe from inside the disk of a fairly large galaxy. If we could get outside our Galaxy, the Milky Way, the sky would look much darker but would still glow faintly because the universe is full of galaxies.

Because most of the volume of the universe is far away, that light comes mostly from very distant galaxies. Two forthcoming papers (*1*, *2*) demonstrate that it is now possible to subtract the foreground emission and peer between the stars of our Galaxy to estimate the glow of the universe at large, which is dominated by the time when the universe formed most of its stars. This has enabled the total global conversion of matter into stars and starlight to be directly measured, amounting to a complete audit of the overall energy budget of starlight in the universe.

Most of the light in the universe was produced in the Big Bang, the inflationary event that started the cosmic expansion. This light appears today as background radiation coming almost perfectly evenly from all directions on the sky. It has been redshifted by the cosmic expansion and now has the spectrum of a simple Planck blackbody at a cool 2.728 ± 0.002 K, with most of the energy at wavelengths of 0.8 to 3 μm. Light emitted since the Big Bang has come from various sources, such as stars, quasars, and clouds of hot gas. The sum of all of these sources, even those too faint to observe individually, blends to form an extra, nonprimordial background. Cosmic backgrounds at various wavelengths carry information about the total light emission history of the universe in all forms.



Mean energy densities of light in the universe. At long wavelengths (left), the mean energy is dominated by the microwave background (solid curve). Extragalactic dust emission dominates from 100 to 300 μm (blue and green points with error bars) (*2*, *5*). New measurements show direct, redshifted starlight that dominates at 2 to 3 μm (red points with error bars) (*1*, *2*). The near and far infrared backgrounds are comparable to each other (an indication that roughly half of starlight has been absorbed and reradiated by grains) and together contain about 30 times less total energy than the microwave background. Mean intensity in nW/m². [Adapted from (*2*)]

Anyone can see that a lot of starlight is emitted at visible wavelengths. The visible-light background is now known to be dominated by galaxies that can be directly imaged in deep surveys such as the Hubble Deep Field; the sum of visible light from invisibly faint galaxies is less than that already accounted for in visible ones. However, most starlight is emitted in the infrared, and in the expanding universe the light gets further shifted to the red by the cosmic expansion. If light is absorbed by cosmic dust, it gets reemitted at even longer wavelengths, corresponding to the cool temperature of the dust grains. Therefore, a full census of starlight (as well as quasar light, which can also be absorbed by dust) requires a measurement of cosmic background far into the infrared.

The Cosmic Background Explorer (COBE) satellite has provided critical data sets for these measurements. The Far Infrared Absolute Spectrophotometer (FIRAS) instrument, which made the spectacularly precise measurement (a few parts in ten thousand!) of the blackbody character of the primordial cosmic spectrum at 0.8 to 3 μm, also detected small deviations from a blackbody at wavelengths shorter than 0.8 μm, which become dominant below about 0.4 μm. The deviations are

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caused by emission from dust grains that, although cool (tens of kelvin), are much hotter than the primordial background and therefore emit most of their light at these shorter wavelengths. Detection of the extragalactic cosmic submillimeter background required modeling to subtract foreground emission from dust in the Galaxy; several different approaches to this problem (*3–5*) now appear to give concordant results.

This extra light below 0.8 μm was expected and has been interpreted as emission from dust in galaxies at high redshift; the energy ultimately comes from starlight absorbed by the grains (*6*). The interpretation was confirmed (*7–9*) with sensitive imagers on ground-based submillimeter telescopes (such as SCUBA on the James Clerk Maxwell Telescope); much of the background in some narrow fields was found to come from large galaxies forming stars at an extremely rapid rate, when the universe was about one-quarter to one-half of its present size (*10*). It looks like about half the starlight that was ever emitted was absorbed by dust and now appears as submillimeter light (although a substantial part of the submillimeter energy might also originate not from starlight but from quasars).

More recently, the background light in the near infrared (2.2 and 3.5 μm) has been measured (*1*, *2*), with data from another COBE instrument [Diffuse Infrared Background Experiment (DIRBE)] designed to map the absolute flux from the sky at shorter wavelengths than FIRAS. At these wavelengths, the foregrounds to be subtracted include the zodiacal light and that from individual Galactic stars. These again have to be removed by models; in the case of the stars, fields larger than a DIRBE beam have been directly imaged from the ground and the star fluxes removed to find the amount of light coming "from behind," from the universe at large. The total power in this near infrared background is about the same as the submillimeter background. The near infrared background probably comes mostly from starlight that reaches us directly, not absorbed by dust.

Starlight is redshifted by varying degrees by the cosmic expansion; most of the light appears to have been emitted at redshifts between 1 and 3 (when the universe was one-quarter to one-half of its present size), which is why it is at wavelengths two to four times longer than the original emission. This period in cosmic history corresponds to the epoch of greatest conversion of cosmic gas to stars; time before that was short (about 3 billion years), although some stars certainly did form, and after that time the remaining gas was mostly too hot to cool and collapse into galaxies and stars.

The measured strength of the background is close to theoretical estimates based on the stellar populations we see today (*11*). We now see only the low-mass, long-lived descendants of the bright early population that emitted the backgrounds. The measured background tells us, among other things, that the cosmic "dark ages" really were dark; there is no surprising new population of previously unaccounted stars contributing a substantial amount of energy at early times and little room for a population of progenitors to make dark remnants—such as black holes or degenerate dwarfs—in large quantities. The amount of light we see agrees roughly with the global production of heavy elements as estimated from x-ray line emission from hot gas in galaxy clusters. (An interesting conclusion is that a substantial fraction of heavy nuclei are ejected from the galaxies where they are born, because otherwise the galaxies would contain more heavy nuclei, and the cluster gas less, than is observed.) The amount of material forming into stars agrees roughly with the amount of gas available for forming stars, as estimated from quasar absorption systems. The infrared backgrounds thus fit well into the growing list of phenomena that give us a direct view of the birth of galaxies and of most of the stars in the universe.

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PERSPECTIVES: NEUROBIOLOGY

Stay the Executioner's Hand

Mark E. Gurney, Alfredo G. Tomasselli, Robert L. Heinrikson

The French physician Charcot provided the original clinical description of the motor neuron disease amyotrophic lateral sclerosis (ALS) back in 1869. The disease causes astonishingly rapid loss of motor neurons in the cortex, brainstem, and spinal cord over 1 to 5 years with consequent paralysis and death. Patients with ALS (commonly referred to as Lou Gehrig's disease in the United States after the baseball star who died of the illness) are typically 40 to 50 years of age at diagnosis. Why motor neurons are selectively vulnerable to disease, and what triggers their destruction, still remains a mystery more than a century later.

The great leap forward in our understanding of ALS began in 1993 with the demonstration (*1*) that a familial form of the illness could be attributed to mutations in the *SOD1* gene, which encodes the cytosolic antioxidant enzyme, copper/zinc superoxide dismutase (Cu,Zn SOD). At first it seemed that the mutations might cause disease by reducing the amount or activity of Cu,Zn SOD, thereby decreasing the protection from oxidative stress of motor neurons in ALS patients. But mice lacking Cu,Zn SOD do not develop motor neuron disease, whereas transgenic mice overexpressing a mutant human *SOD1* gene do (*2*, *3*). This suggested that the mutant protein itself is in some way selectively toxic for motor neurons, perhaps through altered oxidative chemistry, protein misfolding, or protein aggregation (*4*).

On page 335 of this issue, Li *et al.* (*5*) provide evidence that a mutant *SOD1* transgene causes motor neuron death in mice through caspase-mediated programmed cell death (apoptosis). Initiator caspases—enzymes activated from their dormant precursor forms in response to a variety of cellular insults—act on the precursors of downstream caspases such as caspase-3, which are the executioners in the breakdown of essential cellular proteins (see the figure). Apoptosis is characterized by a complex series of cellular changes leading to the noninflammatory demise of the cell. It is a normal, highly regulated process that is crucial for proper cell growth and development. In pathological states, however, it can be abrogated (cancer) or exacerbated (neurodegeneration), either condition leading to some of the most devastating diseases known.

The idea that motor neuron death in SOD1 transgenic mice is through an apoptotic pathway is bolstered by experiments in which overexpression of *bcl-2*, a well known mitochondrial inhibitor of apoptosis, protects against neuronal loss (*6*). Indeed, mitochondrial involvement in the

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