Gamma-ray probes lift the fog in intergalactic space

Measurements of two distant quasars reveal that intergalactic space is more transparent to gamma-rays than previously thought.

Astrophysicists using the H.E.S.S. gamma-ray telescopes in Namibia, measuring for the first time very high energy gamma-rays from two rather distant quasars (active galaxies), have deduced that the Universe is more transparent to gamma-rays than previously believed. Gamma-rays (see box), which are produced in the most violent objects in the Universe, are absorbed in their journey from distant objects to us if they happen to hit a photon of "normal" background light near the visible spectrum. This fog of light in which the Universe is bathed is a fossil record of all the light emitted in the Universe over its lifetime, from the glare of the first stars and galaxies up to the present time. So, using the distant quasars as a probe and studying the effect of the fossil light on the energy distribution of the initial gamma-rays, astrophysicists have been able to derive a limit on the maximum amount of this light, which is remarkably lower than what previous estimates had suggested. This result, published in the April 20 issue of Nature, has important consequences for our understanding of galaxy formation and evolution, and expands the horizon of the gamma-ray Universe.

The search for the history of the Universe's light emission:
The light emitted from all objects in the Universe during its entire history (stars, galaxies, quasars etc..) forms a diffuse sea of photons that permeates intergalactic space, referred to as "diffuse extragalactic background light" (EBL). Scientists have long tried to measure this fossil record of the luminous activity in the Universe, but its direct determination from the diffuse glow of the night sky is very difficult and uncertain. Very high energy (VHE) gamma-rays offer an alternative way to probe this background light, so the researchers of the international H.E.S.S. collaboration observed several quasars (the most luminous VHE gamma-ray sources known to date, see box) with this goal in mind. The results turned out to be rather striking.

The fog of intergalactic photons:
When the very energetic gamma-rays (see cartoon below) collide with light near the visible range, matter may be produced, as predicted by Einstein (in this case, an electron-positron pair). A beam of gamma-rays from a distant galaxy is thus attenuated in its way to the Earth, owing to these collisions with the diffuse-light photons. The effect is stronger for more energetic gamma-rays, so the original gamma-ray spectrum gets "reddened", somewhat like the Sun looking redder at sunset because the blue light is more heavily scattered by the atmosphere than the red light. Since the "reddening" depends on the thickness of the absorber (the density of the background light photons, in this case), a measure of this thickness becomes possible.

Gamma rays: Gamma rays resemble normal light or X-rays, but are much more energetic. Visible light has an energy of about one electronVolt (1 *eV*) of energy in physicist's terms. X-rays are thousands to millions of *eV*. H.E.S.S. detects very-high energy gamma-ray photons with an energy of a million million *eV*s, or Tera-electronVolt energies (TeV). These high energy gamma rays are quite rare; even for relatively strong astrophysical sources, only about one gamma ray per month hits a square metre at the top of the Earth's atmosphere.

Measuring the fog of photons:

"The main problem is that the distribution of gamma-ray energies (spectra) from quasars can have many different forms, and up to now we couldn't really say if an observed spectrum was 'red' because of a strong reddening or because it was that way at the origin" says Dr. Luigi Costamante, one of the scientists involved in the discovery. But the gamma-ray spectra from these two quasars (named H 2356-309 and 1ES 1101-232 in catalogues), more distant than previous sources and measured thanks to the unprecedented sensitivity of the H.E.S.S. instrument, have provided a breakthrough: they are too "blue" (i.e., have too many gamma-rays at high-energy end of the measured range) to be compatible with the strong reddening implied by a high level of background light. Unless more problematic or exotic scenarios are brought into play, the most likely conclusion is that the level of the fossil light is significantly lower than previously believed.

Expanding the gamma-ray horizon of the Universe:

The limit that can be deduced from the H.E.S.S. data on the maximum level of this diffuse light is in fact very close to the lower limit represented by the sum of the light of the galaxies we see with our optical telescopes, such as Hubble. This provides an answer to one of the questions that have puzzled scientists for several years: is this diffuse light caused mainly by the radiation from the very first stars born in the Universe, when it was only few hundred millions years old? The H.E.S.S. result seems to exclude such a possibility, and leaves little room as well for a large contribution from different sources, other than normal galaxies.

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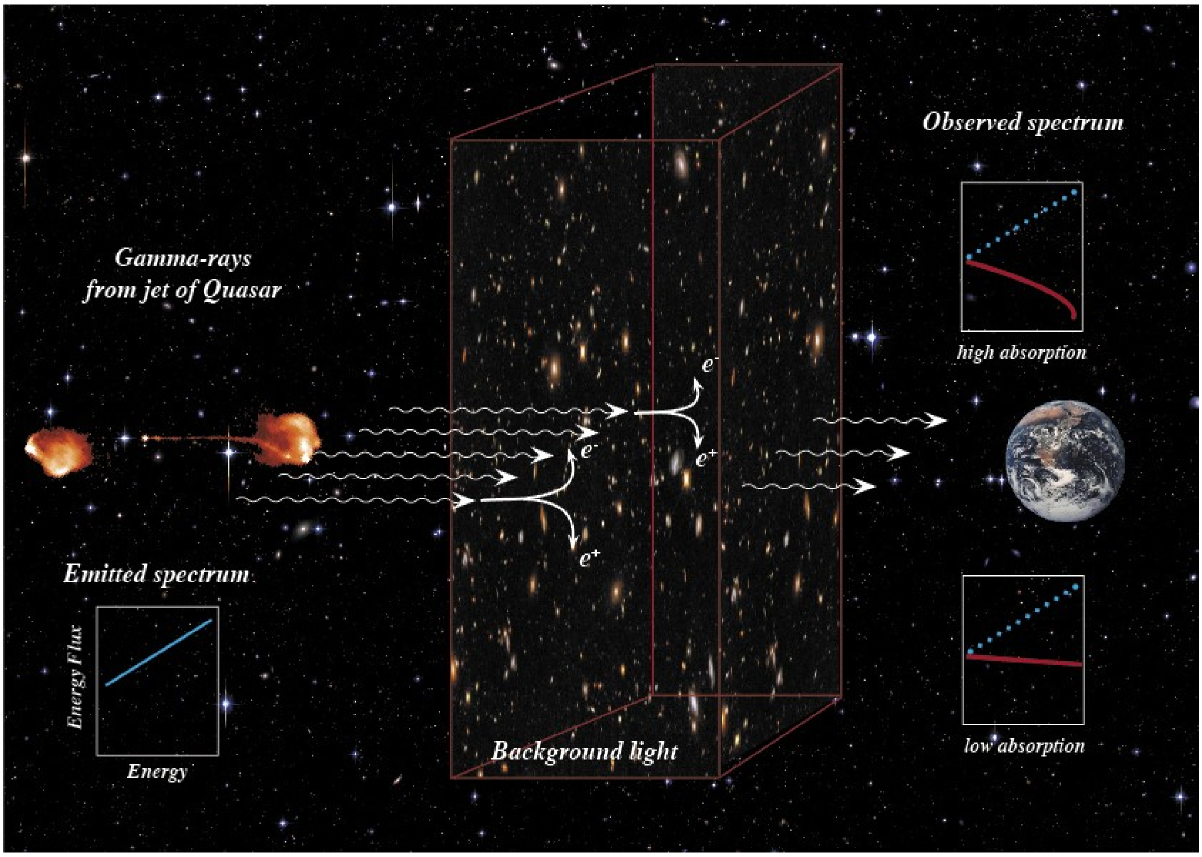
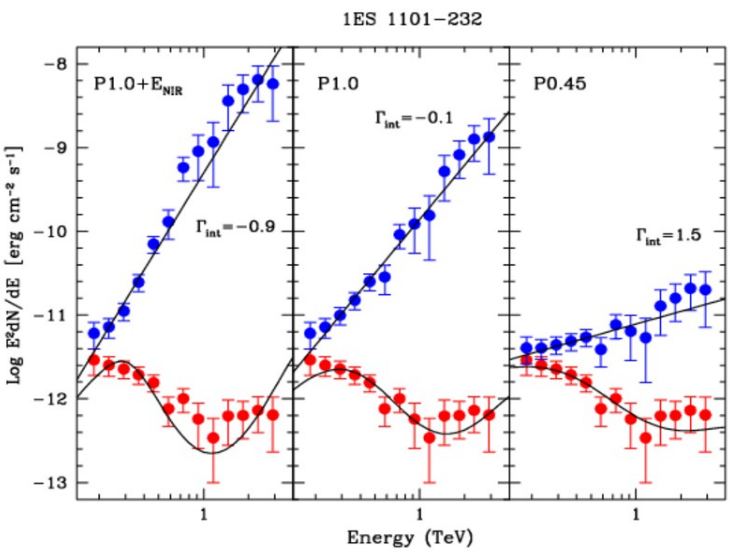
Quasars, active galaxies: All galaxies seem to host a supermassive black hole (up to ten thousand million times the mass of the Sun) at their centre, but in some of them it becomes "active", swallowing gas from the surroundings and launching quantities of plasma (a mixture of electrons, protons and electro-magnetic fields) at velocities very close to the velocity of light. These "relativistic outflows" form narrow jets which can extend over several hundred times the dimension of the galaxy. If the jet happens to point towards the Earth, the radiation emitted by the plasma in the jet is seen highly amplified, and in this case these objects are called "blazars". Their emission extends from radio up to TeV energies, and is very variable, both in intensity and energy distribution. The two objects detected by H.E.S.S. mentioned here are of this type.



A cartoon of the effects of the diffuse extragalactic background light (EBL) on the gamma-ray emission from a distant quasar, before reaching the Earth. The gamma-rays are partly absorbed by colliding with the EBL photons produced by all the stars and galaxies in the Universe. If the density of EBL photons is high (upper graph), absorption is high and the highest energy gamma-rays are lost. So the distribution of measured energies (spectrum) is strongly changed. If instead the density is low (lower graph), absorption is less and the spectrum is not changed as much.

The H.E.S.S. spectrum of the blazar 1ES 1101-232.

The observed distribution of energies (spectrum) of the detected gamma-rays is plotted in red. In blue is shown the deduced original distribution as emitted at the source, reconstructed supposing different levels of the diffuse background light. If the level is high (left and centre panel), the original spectrum is dramatically different from the typical distribution expected from such objects, and cannot be easily explained as an intrinsic feature. With a low background light level (right panel), the original spectrum becomes compatible with the normal characteristics of this type of quasar.



Notes on H.E.S.S.

The collaboration: The High Energy Stereoscopic System (H.E.S.S.) team consists of scientists from Germany, France, the UK, the Czech Republic, Ireland, Armenia, South Africa and Namibia.

The detector: The results were obtained using the High Energy Stereoscopic System (H.E.S.S.) telescopes in Namibia, in South-West Africa. This system of four 13 m diameter telescopes is currently the most sensitive detector of very high energy gamma rays. These are absorbed in the atmosphere, where they give a short-lived shower of particles. The H.E.S.S. telescopes detect the faint, short flashes of blueish light which these particles emit (named Cherenkov light, lasting a few billionths of a second), collecting the light with big mirrors which reflect onto extremely sensitive cameras. Each image gives the position on the sky of a single gamma-ray photon, and the amount of light collected gives the energy of the initial gamma ray. Building up the images photon by photon allows H.E.S.S. to create maps of astronomical objects as they appear in gamma rays.

The H.E.S.S. telescope array represent a multi-year construction effort by an international team of more than 100 scientists and engineers. The instrument was inaugurated in September 2004 by the Namibian Prime Minister, Theo-Ben Guirab, and its first data have already resulted in a number of important discoveries, including the first astronomical image of a supernova shock wave at the highest gamma-ray energies.

Future plans: The scientists involved with H.E.S.S. are continuing to upgrade and improve the system of telescopes. Construction of a central telescope — a behemoth 30m tall — is underway, including new partner countries such as Poland. The improved system, known as H.E.S.S.-II, will be more sensitive and will cover an increased range of gamma-ray energies, enabling the H.E.S.S. team to see gamma-rays from ever more distant quasars.

More H.E.S.S. Information:

Experiment homepage
Project Chronology
Les H.E.S.S. Telescopes
H.E.S.S. Brochure on H.E.S.S.
(Full resolution ppt 15 MB)