Photon drag: New spin on making a black hole

Some galaxies have a heart of fire, a center so luminous that it outshines the rest of the starlit body. Most astronomers believe that a black hole fuels the fireworks at the core of such galaxies, known as active galactic nuclei. But astrophysicists are uncertain how a massive black hole – an object that represents the extreme of gravitational collapse – could form, especially so early in the history of the universe.

Though black holes may be exotic, one of the puzzles in understanding their creation lies in ordinary physics, notes Abraham Loeb of the Institute for Advanced Study in Princeton, N.J. Early in the universe, random fluctuations in the density of matter may have prompted some huge gas clouds to begin collapsing. But long before becoming a black hole, a cloud's own rotation, or angular momentum, would halt the process. Just as Earth's rotation provides a centrifugal force that prevents our planet from falling into the sun, the swirling motion of the cloud prohibits complete collapse.

In order to form a black hole, the cloud must lose much of its angular momentum. Ordinary viscosity, caused by collisions between particles in the gas, won't suffice, Loeb says. But in the Feb. 1 ASTROPHYSICAL JOURNAL, he suggests a possible solution to the problem.

Loeb notes that the cosmic background radiation – photons left over from the universe's explosive birth – had a high density in the young universe. He calculates that the interactions of these photons with electrons or dust in a gas cloud could produce a drag force, slowing the rotating cloud. Like a falling water droplet that encounters resistance from surrounding air molecules, electrons and dust in the cloud lose energy as they scatter off the cosmic photons inside the cloud. Loeb says that the collisions may significantly reduce the cloud's angular momentum, enabling a black hole to form.

Photons may also play an important role later on, after the cloud has succeeded in forming a black hole and outside matter begins spiraling in, forming an accretion disk around the condensed mass. To fall into the hole, this matter must also lose angular momentum. Cosmic photons can't do the job, since their density is too low at later times in the expanding universe. However, the quasar-like radiation emitted just outside the black hole as previous matter fell into it may provide the answer, Loeb says.

As the quasar photons stream outward, they slam into electrons, enabling the radiation to carry angular momentum away from the interior of the accretion disk. This allows material robbed of its angular momentum to fall into the hole, Loeb suggests. As this material gets sucked in, it emits light and the process repeats. Loeb estimates that this photon-electron interaction increases the viscosity of gas in the accretion disk to about a trillion times that of water.

In this model, a black hole and the quasar powered by it are created first; surrounding gas eventually forms a galaxy around them. But astronomers don't yet know if this sequence is correct, in part because visible-light studies don't easily permit searches for extremely distant quasars – those that might have been born before the universe attained even 7 percent of its current age.

Loeb proposes in an upcoming ASTROPHYSICAL JOURNAL LETTERS that a highly sensitive array of radiotelescopes, looking for a specific wavelength of radiation emitted by singly ionized carbon atoms, may find more distant quasars. Ultraviolet light from quasars prompts surrounding gas clouds to produce such radiation, which is emitted in the far-infrared but redshifted to millimeter wavelengths. Detecting this light from the far reaches of the cosmos may indicate whether quasars and massive black holes existed before galaxies did, Loeb says.

– R. Cowen

Floods flow from small climatic shifts

Day after day, currents of carbon dioxide and other greenhouse gases waft over the planet, threatening to bring about potentially disastrous shifts in the global climate. Given a shifting climate, what sorts of changes will people actually experience?

Geologist James C. Knox of the University of Wisconsin-Madison has probed the geologic record of past floods to provide one answer. And in the Feb. 4 NATURE, Knox reports that relatively modest shifts in the globe's average annual temperature and precipitation may have dramatic regional effects on the frequency of catastrophic floods. The new study is one of a handful that link climatic change directly to local flooding, Knox says.

Computer simulations of global climate change emphasize long-term, gradual trends. However, "we should not assume that things will always be gradual," Knox points out. "The stratigraphic record shows many examples where things have changed rather quickly and abruptly."

Knox probed the sedimentary records of 68 floods along tributaries of the Mississippi River. During the past 7,000 years, he discovered, the largest floods carried 3-foot-wide boulders in their torrents and covered surrounding floodplains with over 16 feet of water.

However, Knox emphasizes the large effect that relatively minor climatic change can have on flood size. After the shift to a cooler, wetter climate some 3,300 years ago, the largest floods in the upper Midwest – equivalent to those now seen about every 500 years – occurred more frequently.

The changes in precipitation and temperature that apparently brought on these floods are significantly less dramatic than those predicted for the future by global climate models. Based on indirect fossil evidence, Knox determined that the increase in flood size came with temperature shifts of 1°C to 2°C. In contrast, some models of global change predict future temperature increases of 4°C to 5°C.

Geologist Victor R. Baker of the University of Arizona in Tucson has also conducted research on ancient floods. These historical studies, he notes, show nature in action, whereas today's sophisticated, yet theoretical, global climate models show how we *think* nature works. Thus, Knox' findings are valuable because "they provide a complement – that is, they fill in what the other studies leave out." *– D. Pendick*

Counting photons in a cleaned-up crystal

Expressing data – whether scientific measurements or the sounds of a symphony orchestra – as strings of ones and zeros has proved a remarkably versatile means of handling and conveying information. Such digital information can be readily encoded as electrical signals or light pulses.

It's possible to conceive of using the presence or absence of a single electron or photon to represent a bit – either 1 or 0. But quantum effects limit the efficacy of such a strategy, even when the pulses contain more than one electron or photon. For example, because of quantum effects, laser-generated light pulses typically display random fluctuations in the number of photons present in each pulse (SN: 5/30/92, p.356).

Now, theorist Gershon Kurizki of the Weizmann Institute of Science in Rehovot, Israel, and his collaborators have proposed a scheme that could lead to precise control of the number of photons in light pulses. By reducing the energy required to extract a given pulse from a noisy background, such a technique represents a potential means of transmitting digital information more efficiently than at present.

The researchers describe one version