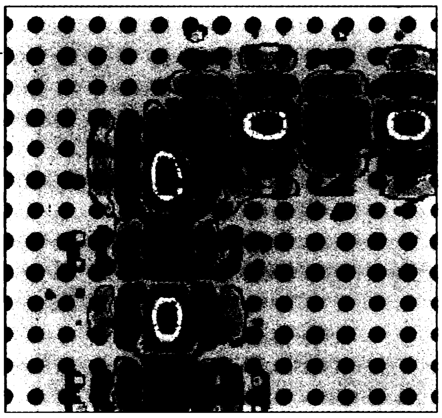
Light gets the bends in a photonic crystal

Normally a straight arrow, light usually doesn't turn a corner. Now, researchers have worked out a novel way to make a beam change direction. This trick isn't done with mirrors, the usual way to send light on a new path, but with a photonic crystal, a structure that excludes light in a chosen range of wavelengths.

Computer simulations performed by John D. Joannopoulos and his colleagues at the Massachusetts Institute of Technology show that a specially constructed photonic crystal could steer light around a sharp bend with nearly perfect efficiency. In contrast, a simulated material with reflective properties similar to those of fiber-optic cables can guide only about 30 percent of the light, at best, around a corner. Their analysis appears in the Oct. 28 PHYSICAL REVIEW LETTERS.

Joannopoulos



In this computer simulation, light propagates around a sharp bend in a photonic crystal with 100 percent transmission.

The calculations are modeled on a photonic crystal first built a few years ago (SN: 9/25/93, p. 199). The simulated device consists of a two-dimensional array of equally spaced gallium arsenide rods, whose spacing and size determine a range of wavelengths to which the crystal is opaque. Removing a row of rods forms an empty channel, or waveguide, through which light of the chosen wavelength can travel freely.

Moreover, turns and corners can be built into the waveguide. The MIT group's analysis shows that 100 percent of the light can swing around a slightly rounded corner and 98 percent can sweep around a 90° bend.

"I like the analysis and the way they presented it," says Costas Soukoulis, a physicist at Iowa State University in Ames, "but I'd like to see it done experimentally."

Waveguides made from photonic crystals would be promising components for electronic devices driven by light instead of electrons, such as optical computer chips. "It's a drive toward integration—making circuits as small as possible," Joannopoulos says.

Photonic crystals can also trap light in small areas, opening up the possibility of constructing miniature lasers.

The photonic crystal waveguide combines the best features of two existing technologies. Simple metal waveguides can direct microwave radiation around tight corners efficiently, but they don't work at visible or infrared wavelengths. On the other hand, waveguides made of insulating materials, like fiber-optic cables, carry visible light well but not around sharp corners.

One issue that will affect whether photonic crystals can be practical waveguides, Soukoulis says, is the effective velocity at which light moves around the bend—which might be quite slow. Because the light creates a standing wave by bouncing back and forth as it travels along the waveguide, it follows a circuitous, time-consuming path.

Joannopoulos and his group plan next to carry out computer simulations to predict what will happen in three dimensions and then to demonstrate the effect experimentally. Determining how the system would work in three dimensions is critical, Soukoulis says, because if the incident wave hits the channel at even a slight angle, most of it might go out of the plane of the crystal and not along the waveguide. — *C. Wu*

Distant galaxies dazzle in the infrared

They look like the Clark Kents of galaxies, ordinary and not very bright. But viewed in the infrared, they turn into supergalaxies, seething with a hidden fire.

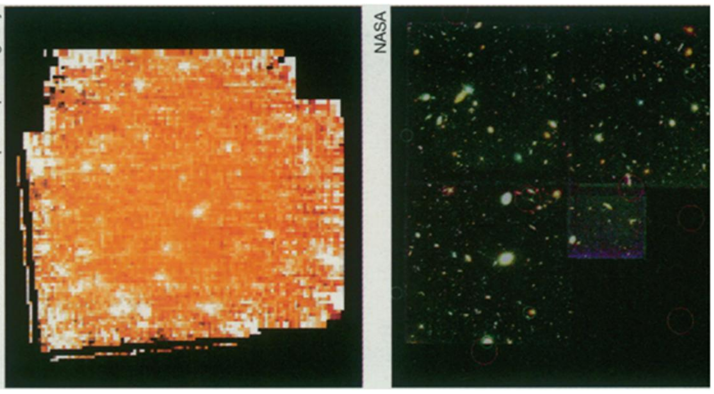
New findings from an orbiting infrared telescope suggest that many galaxies were star-making factories in their youth. Scientists estimate that annually each of these galaxies churned out new stars with a total mass 10 to 700 times that of the sun. At that rate—considerably higher than astronomers had calculated from observations in visible light and the near-ultraviolet—early episodes of star birth would have been even stormier and more intense than researchers have thought. If most galaxies produced stars so prodigiously, they could have formed the bulk of their stars in just 1 billion years.

"Essentially, a large fraction of the energy in galaxies is being emitted in the infrared and has not been counted in the ultraviolet and optical," says Michael Rowan-Robinson of Imperial College in London. He reported the findings in London last week at a Royal Astronomical Society meeting on the Hubble Deep Field, a patch of sky imaged in unprecedented detail by the Hubble Space Telescope (SN: 1/20/96, p. 36).

Rowan-Robinson and his colleagues base their results on a survey of the deep field conducted by the Infrared Space Observatory (ISO). At wavelengths of 7.5 and 15 micrometers, ISO found seven sources of radiation that were two to three times brighter than they appeared in Hubble's visible-light images. Five of the sources lie so far from Earth that the light they emitted took about half the age of the universe to get here and reveals how the galaxies looked when they were about half their current age.

Rowan-Robinson/European Space Agency

NASA



Left: ISO view of the Hubble Deep Field at 15 micrometers. White indicates infrared sources that could be hotbeds of star birth. Right: Circles overlaid on the deep field show the sources detected by ISO.

Their infrared brilliance has a simple explanation, notes Rowan-Robinson. In the Milky Way and nearby galaxies, interstellar dust grains absorb the visible light emitted by newborn stars and radiate that energy in the infrared. The same process, he says, appears to be taking place in the galaxies detected by ISO.

Critics note that the seven galaxies recorded by ISO rank among the nearest and oldest of those in the Hubble survey (SN: 2/24/96, p. 120) and therefore don't represent galaxies in the first throes of star birth. However, "the pattern of what we're seeing may apply to the most distant galaxies as well," Rowan-Robinson says.

Mark E. Dickinson of the Space Telescope Science Institute in Baltimore notes that, rather than being powered by star birth, the infrared glow of these galaxies may be driven by a black hole or quasar at their heart. More important, he says, if most galaxies are forming stars at the rate inferred from the handful of galaxies detected by ISO, they would have made far more stars than astronomers observe in the universe today. — *R. Cowen*