metrical; they consist of two lobes of radio-emitting matter extending on opposite sides of the visible object. Just the geometry suggests that the radio lobes are material expelled from the visible galaxy, but by what mechanism?

Lovelace proposes that a heavy black hole, a hundred billion times the mass of the sun, located in the center of the galaxy, is ultimately responsible. Such heavy black holes in galactic centers have been repeatedly proposed by a number of astrophysicists.

The black hole will be surrounded by an accretion disk, a disk of matter drawn from neighboring stars by the black hole's extremely strong gravity. Matter from the inner edge of the disk continually falls into the black hole; new matter is continually added to the outer edge. Because everything in the neighborhood partakes of the rotation of the galaxy, the accretion disk rotates too, and its axis of rotation is more or less the same as that of the galaxy.

The matter in the disk is ionized (plasma). It carries magnetic fields with it, and from these, the rotation generates electric fields. So the whole thing acts as an electric dynamo that accelerates streams of protons to nearly the speed of light. The protons move in opposite directions along the axis of rotation. As the protons interact with the interstellar plasma that lies thickly in the region of a galactic center, they generate streams of relativisitic electrons that also flow out along the rotation axis. The energy of these electrons becomes the radio waves by the synchrotron process.

"With this model," says Lovelace, "it seems possible [1] to have a large, steady supply of energy to widely separated small radio components, [2] to obtain alignment and symmetry of the two radio components, and [3] to have a correlation between the axis of the radio components and the direction of the angular momentum of the parent galaxy." □

Hidden variables: Too well hidden?

Contemplating quantum mechanics, Einstein remarked: "God does not play dice." He was referring to the indeterminacy of microcosmic physics. A given unstable particle may decay in two or three ways. Quantum mechanics will give you the proportion of a large sample taking each route, but you cannot tag an individual particle and ask its fate. In a large number of unstable nuclei some decay sooner, some later. Quantum mechanics tells you the time when half will be left—the half-life.

Many more physicists than Einstein were dismayed by this quality of quantum mechanics. Classical physics is rigidly and individually deterministic. If a tennis ball has certain qualities of elasticity, weight, etc., putting those numbers in the equation that describes bouncing will yield a prediction of how that particular ball will bounce.

Philosophically, many wanted to redeterminize microcosmic physics, and to do it some physicists have invented so-called hidden-variable theories, which propose that there is a level underneath the quantum mechanics we see, which is deterministic, and that the quantum mechanical laws are merely statistical averages of that determinism and not indications of a fundamental indeterminism in microscopic physics. There are experimental ways to look for evidence of hidden variables, if not for the hidden variables themselves. The latest such attempt, reported by Edward S. Fry and Randall C. Thompson of Texas A & M University in the Aug. 23 PHYSICAL REVIEW LETTERS, gives a negative result. One of three previous attempts supported hidden variables, so the question is not yet entirely settled.

Hidden-variable theories bear a certain analogy to the laws of gas behavior. In principle, it should be possible to write down an equation for the behavior of each individual molecule in a sample of gas and sum them up. In practice, nobody wants to bother, and so gas behavior is represented by statistical laws that apply to the collective. Likewise, the hidden variables are supposed to be individually predictable, if only we could see them, and together they add up to the statistical laws evident in quantum mechanics.

But the hidden variables, unlike individual gas molecules, are physically undetectable, and so believing in them is like a religion, demanding faith in things unseen. Many physicists therefore reject them.

Unseen or not, it turns out that hidden-variable theories of the local variety can have observable effects. (Local theories deal with happenings in which the participants are close together or in contact; in contrast, action at a distance deals with such things as why the earth revolves around the sun.) The effect depends on a theorem published by J.S. Bell in 1965. In certain cases where pairs of photons are produced, as an atom goes from one energy state to another, quantum mechanics predicts a very strong correlation between the linear polarizations of the two photons. Bell's theorem says that if any local hidden-variable theory is correct, that correlation should be diminished.

Fry and Thompson's experiment used certain transitions of mercury 200 and found in favor of quantum mechanics. Of three previous observations, one using calcium found in favor of quantum mechanics; one using mercury 198 tended to favor hidden variables, and the third, using mercury 202, favored quantum mechanics. So the score is now three to one against. □

Dream more to remember better

People often have trouble remembering their dreams, but it may be that dreams help make memories. Recent research suggests that dreaming is a necessary process through which newly learned material is consolidated in the long-term memory. This finding was reported by psychiatrist Chester Pearlman of the Boston Veterans Administration Hospital at the International Congress of Psychology in Paris.

Pearlman has been investigating rapid-eye-movement or REM sleep, which occurs during 20-minute periods three to five times a night. This stage of sleep is believed to be closely associated with normal dreaming because subjects awakened during REM sleep almost always report that they were in the middle of a dream.

Pearlman trained pairs of rats in a cooperative method of avoiding electric shock to get food. Rats who were deprived of REM sleep after the training (awakened at the start of each REM period) showed no later memory for the training. French psychologists have demonstrated the same thing in rats, and Canadian researchers have shown that students who were learning well during an intensive language course had an increase in REM sleep. Those who were not learning well had no such increase.

While the role of REM sleep in learning and memory is still unknown, these findings suggest that during dreaming some of the events of the day may become part of the long-term memory. Animals and humans deprived of REM sleep may be unsuccessful in completely establishing learned behaviors and events in the memory. If this proves to be the case, staying up and cramming the night before an exam may be a mistake. Says Pearlman, "You introduce more facts than you can remember and you certainly will not be able to use any of them in the future—they are not part of you."

Other experiments by Pearlman and Ramon Greenberg suggest that the day's emotional experiments are also assimilated during dreaming, and that dreaming may help people cope with such experiences. Studies of the sleep patterns of psychiatric patients showed that pressure to dream was related to emotional stress experienced by the patient before going to sleep. Nonpatients showed an increase in the need for REM sleep after exposure to an anxiety-provoking film. (People have often reported nightmares following scary movies.)

While there is still much to be learned about sleep and dreaming, it may be that the memory and coping functions of dreaming are related. In both cases, dreams seem to help in the processing of newly acquired information. □