Trying to Figure Out SS433

A star with odd and complex behavior has caused a supernova-like burst of interest among astronomers

BY DIETRICK E. THOMSEN

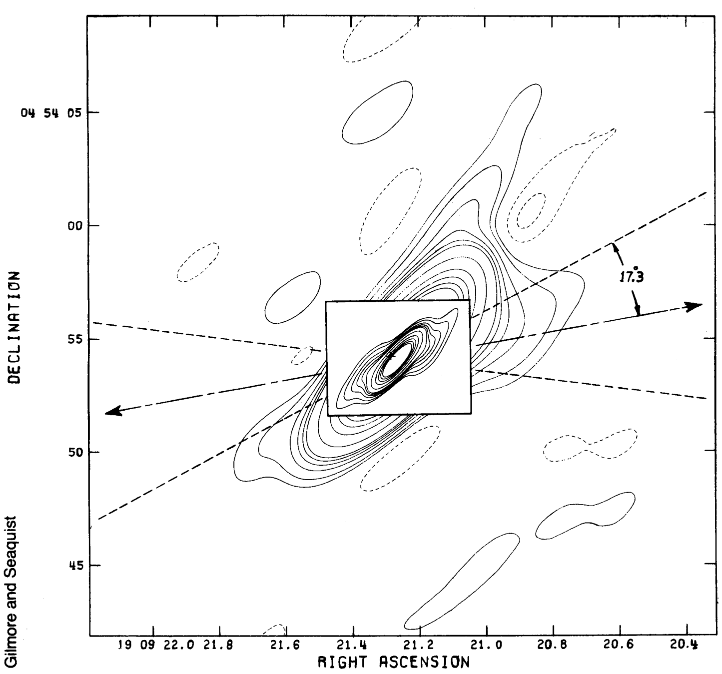
"A year ago nobody had heard of it. Now it has a whole session of the meeting." Thus did an astronomer attending the recent meeting of the American Astronomical Society in San Francisco characterize the rise to stardom of SS433. To more than ordinary stardom. It takes an important subject to rate a whole session: the structure of galaxies, quasars, the cosmic background, the solar system. Dozens of astronomers have to have things to say; hundreds have to be ready to listen.

This is little Sanduleak-Stephenson 433, an obscure number in a catalog of strange objects. Obscure, that is, until study of its weird spectrum got started. Every unusual astronomical discovery is potentially the representative of a new class of astrophysical object. On the basis of what is now known, SS433 is thought to be a hitherto unobserved stage in the evolution of a binary star system. More than half of the known stars in the galaxy live in binary or multiple systems. Any stage in binary evolution is important. It deserves a session. The 46 astronomers represented by the 11 papers here are only part of those who have used International Astronomical Union Circulars, journals and other meetings for their contributions.

Most celestial bodies have spectra based on a background of more or less continuous emission across the wavelengths of visible light. Superimposed on this will be a pattern of emission lines, bright resonance wavelengths produced by particular physical processes in the object, and a pattern of dark lines representing resonant absorptions from the continuum in the various layers of the object.

SS433 has three sets of emission lines. One of them stays still in apparent wavelengths, as the emission spectrum of an ordinary star should. Two of them gradually change, shifting redwards, then bluewards, then back again. This led to the so-called garden hose model of SS433: The stationary lines came from a central object that was spewing out light-emitting gas in two oppositely located, rotating streams. The moving groups of emission lines came from the streams. The motion appeared to be cyclic with a 160-day period, and since the two cycles move opposite to each other, it was supposed that at some point the two streams should cross each other.

Bruce Margon of the University of California at Los Angeles told the AAS meeting that SS433 "did what it was supposed to" in the period since it first came to widespread public attention. He was reporting on work by himself, S.A. Grandi, R. Downes, H.C. Ford, L.H. Aller, M. Plavec (UCLA), R.P.S. Stone (Lick Observatory), Hyron Spinrad, J. Stauffer (U.C. Berkeley), E. Margaret Burbidge, V.T. Junkkarinen, A.T. Koski and H.E. Smith (U.C. San Diego). In a year and a half the lines did meet and separate. The amplitude of the motion was almost as predicted, but not quite. "The good news is that the model fits quite well," says Margon. "The bad news is that it does not fit perfectly." There are "extended episodes of systematic deviations" that the observers hope they can explain by secondary complications in the motions of the SS433 system. The period of the back-and-forth line patterns comes to 164 days, not the 160 or 161 determined by some others.



Gilmore and Seaquist

Radio contour maps of SS433 made by the Very Large Array of radiotelescopes at 6 centimeters (inset) and 20 cm show spurs pointing generally in the direction (arrows) of the bulges of surrounding source W50.

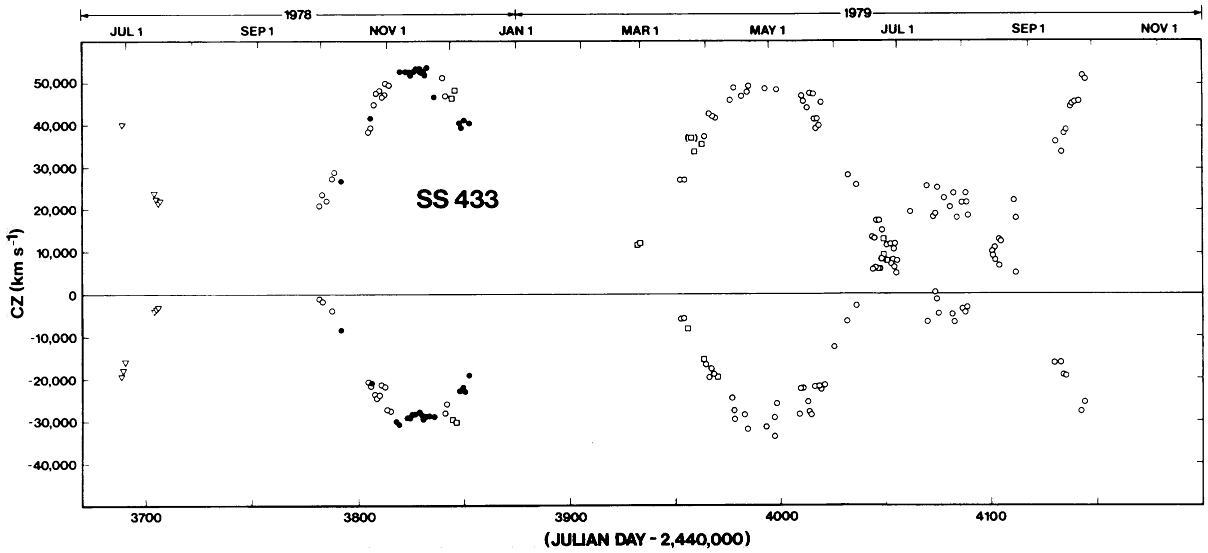
A recent complication is the discovery by David Crampton of the Dominion Astrophysical Observatory in Victoria, B.C., Canada, that the so-called stationary set of lines also has a small periodic Doppler shift. He proposes the body responsible for them is rotating with a period of 13 days. All of this, says Margon, suggests that SS433 is a close binary.

Crampton, reporting his own recent work, gives further evidence for the 13-day period in the stationary lines and an independent indication from a similar variation in the brightness of the H-beta line, one of the strongest in the hydrogen spectrum. Crampton favors the binary star idea too: a compact body girdled by a disk of matter falling onto it, an accretion disk. This body would be orbiting a companion (the source of the accreting matter) every 13 days. Crampton sees the 164-day period of the moving lines as related to the aspect, that is apparent tilt, of the accretion disk. "If you disregard those jets, it's a normal X-ray binary," he says. (Among other things it's an X-ray source.)

How normal is normal? To explain all the motions S.P. Hatchett, representing himself and M.C. Begelman of the University of California at Berkeley and C.L. Sarazin of the University of Virginia, invokes the Lense-Thirring effect, an arcane piece of mathematical physics in which one rotation causes a drag on the local frames of reference in space-time and so influences the other. K. Davidson and R. McCray of the Joint Institute for Laboratory Astrophysics find it necessary to postulate a triple system, a pair of stars with an orbital period of about three days orbiting a third star every 13 days.

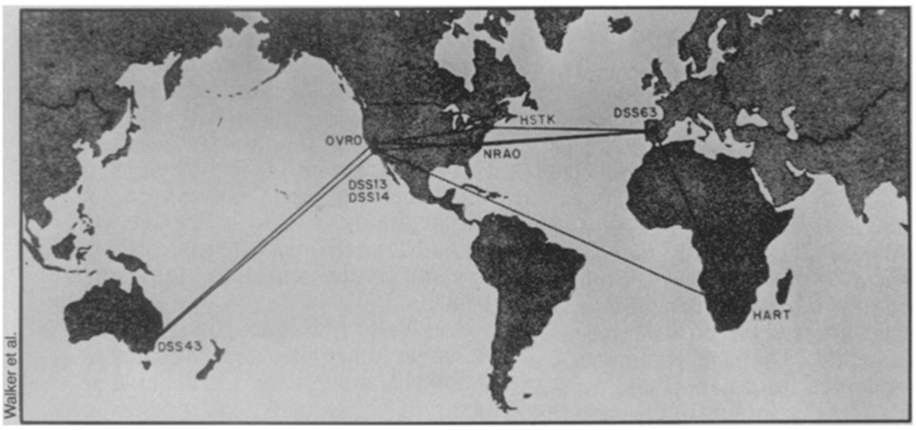
Of course astronomers can't disregard the jets. The jets make SS433 truly unique in the annals of astronomy up to the moment. Begelman and collaborators presented one model of their formation and radiation, and Davidson and McCray presented another. There are some differences between the two, but both are complex and strange. "We are trying to look sober. We have to admit we're as crazy as the rest," McCray remarks.

It's not enough simply to say that the



Bruce Margon

Variations in redshifts of emission line patterns in SS433 show two symmetrically opposed cycles.



Walker et al.

A worldwide network of interferometer baselines was used in studies of SS433.

jets are material flung off tangentially from the edges of the accretion disk, which then radiate. The amount of energy radiated, 10^{35} ergs/second in the hydrogen alpha radiation, according to Begelman, and the time factors don't permit such simplicity. In the Davidson-McCray model the jets are shaped by nozzles formed where the accretion disk encounters heating and high pressures close to the central source the disk rotates around. (As Richard Lovelace of Cornell University pointed out, this kind of thing has affinities to what happens in quasars.) The jets—or beams, as Begelman et al. call them—are driven by radiation pressure. The jets produce the emission lines — Begelman says the "stationary" lines as well as the ones with the 164-day back-and-forth period — by interaction with an ambient medium.

That ambient medium is the cloud of matter known as the radio source W50, which radio astronomers have regarded as a supernova remnant, the gas left behind after a star explodes in a supernova and then burns out. Repeated interactions between the SS433 beams and the W50 matter is necessary, Begelman says, because the spectral lines emitted require the jets to be fairly cool. A process in which the matter in the jets is repeatedly ionized and repeatedly recombines, radiating as it recombines, should do, Begelman says.

When distance measurements indicated that SS433 was embedded in W50, radio astronomers began to look for a compact radio source. It was, as Ken Johnston of the Naval Research Laboratory put it, "radio astronomy for fun and profit or profit and fun or some facts about SS433." The facts are that a compact radio source was found. Its position agrees with the optical position to within 1/100 of a second of arc. For the record that position is right ascension 19 hours 9 minutes 21.29 seconds, declination +4° 53′ 54″ .07. The radio output varies on a cycle of 6.6 days, something not explained in the models for its optical behavior. Johnston says that he and his co-workers, J. H. Spencer, and N. J. Santini of NRL and G. Kaplan and W. Klepczynski of the U.S. Naval Observatory, are trying to find a radio correlate of the 164-day optical variation, but up to the time of the meeting they had not.

Radio maps of the SS433 source show a complex structure and a tantalizing relationship to the geometry of W50. Three mapping observations were reported. Two groups used the Very Large Array interferometer near Socorro, N. M.: (1) W. S. Gilmore and E. R. Seaquist of the University of Toronto's David Dunlap Observatory and (2) R. M. Hjellming of the National Radio Astronomy Observatory, Johnston, and G. K. Miley of the Leiden Observatory. Another group, R. C. Walker, A. C. S. Readhead and G. Seilstad of California Institute of Technology, R. A. Preston, A. E. Neill and G. Resch of the Jet Propulsion Laboratory, P. C. Crane and D. B. Shaffer of the National Radio Astronomical Observatory, B. Geldzahler of the Max Planck Institute for Radioastronomy, D. L. Jauncey of the (Australian) Commonwealth Scientific and Industrial Research Organization, I. I. Shapiro of Massachusetts Institute of Technology and J. D. Nicholson of the South African Council for Scientific and Industrial Research, set up very-long-baseline interferometry involving telescopes in South Africa, Spain, Massachusetts, California and Australia.

Only a few mapping observations have been possible in the time since SS433 came to fame, but what they show is basically a compact core source with an extended source or sources around or at the sides of it. The maps differ according to the wavelength of observation (a characteristic of radio sources generally) and also from time to time. Some observers see jets or bumps that may be related to SS433's interaction with the material of W50. The intercontinental interferometry gives a picture that shows a point source, two different elongated components and another point source far from the core.

It begins to seem from the discussion that all this structure is regarded as the result of the presence of SS433 and somehow related to its famous optical activity. Indeed, the long axis of this system of SS433 radio features appears to coincide with the axis of prominent bulges at the edges of W50. It is tempting to see a connection, and if there is one, it seems to mean that the dynamics of SS433 dominate events throughout the volume of W50. That possibility leads several of the participants in the session to suggest that W50 is not a supernova remnant at all, but a cloud of matter pushed out by SS433. If that proves out, SS433-W50 would be something truly new—under heaven if not precisely under the sun. □