Interview: Stan Woosley

The detections, and nucleosynthesis

Stan Woosley is a theoretician at the University of California—Santa Cruz and the Lick Observatory. This interview was conducted Feb. 24.

EIR: The Solar Maximum Mission Gamma-Ray Spectrometer has detected nuclear gamma rays from Supernova 1987A, and the results are now in print. But there are also detections by balloon-borne gamma-ray telescopes. What are these experiments?

Woosley: There were three out of Australia. One was by Tom Prince of Caltech, it was a sodium iodide detector which mainly measured the hard x-ray continuum on up to above 1 MeV [million electron volts]. But he also had some sensitivity to the lines—and got fluxes consistent with—what Solar Maximum Mission had been reporting. The other two flights out of Australia were germanium detectors.

One of those was by [William G.] Sandie of Lockheed and Fishman of Marshall Space Flight Center, Gerry Fishman. They detected the 847 KeV line at a flux of about half of what SMM had reported. They made their observations on day 249 of the supernova. Because it was a germanium detector, they could resolve the line, whereas SMM could not. Unfortunately they had a big background line of 844 KeV from aluminum n-n′, so they weren't able to get the really good information we were expecting from germanium detection, and they did not detect the 1,238 KeV line.

Bill Mahoney of Jet Propulsion Lab has the other balloon experiment. That also was germanium and he detected the 1238 KeV line, and it's probably the cleanest signal so far. It's around 10^{-3} photons per square centimeter per second. His flight was on Dec. 5, I believe.

Then there was a flight out of Antarctica which was also germanium, I believe. This was reported in an International Astronomical Union Circular. They reported detecting both lines, but they saw about twice the flux that other groups have seen, and they also reported that the lines apparently looked like they were doublets. That there were two lines at both energies—as if there were jets, you know, doppler shifts both positive and negative. No one I know has seen that data yet, and we're all anxious to do so. A lot of us find it incredible. It doesn't agree very well with what Mahoney saw, for example. He did not see evidence for a doubling of the lines. This was a mission sponsored by DARPA [Defense Advanced Research Projects Agency]. They were really testing the ability to make balloon flights out of Antarctica. They figured they could send the detector up and it wouldn't go anywhere—just go around in a little circle—because it was at the pole. They did get a fairly long flight, but not nearly as long as they hoped. The radiation environment is much higher at the poles, because the cosmic rays come streaming in where the magnetic field comes in. So their background noise was higher. So we are all waiting to see their actual data. Those were the four balloon flights.

Then there's one from which I haven't heard a report—this week, Mattison of the University of California at San Diego, and Bob Lin at Berkeley were supposed to make a balloon flight from Australia to Brazil—very ambitious. This flight should have the best sensitivity and the best detection so far. [The flight was successful, with some problems of ground control of the telescope.] Then, of course, in April there is a whole campaign of about five flights that will go off from Alice Springs, Australia again, as well as a re-flight of the Kuiper Infrared Observatory.

EIR: Did we hypothesize *explosive* nucleosynthesis because we could not account for the existence of certain nuclei without it? Or is it not the *existence* of certain nuclei, but their particular known abundances . . .

Woosley: The s[low]-process and the r[apid]-process are responsible only for the elements heavier than iron. With certain rare exceptions like potassium-40 and iron-58, they only make nuclei heavier than iron. Everything below iron is not produced by the s- and r-processes, and has been made by nuclear fusion in stars and supernovae. It looks like everything in the iron group, including iron itself, has been made explosively. The nuclei from silicon to calcium are partly explosively produced and partly made by oxygen burning [the oxygen-consuming stage of fusion] before the star blows up. The nuclei lighter than silicon are totally made by processes in the star before it blows up, and then just kicked off when the star explodes, without nuclear processing [during the explosion].

EIR: I understand the s-process as a continuous, business-as-usual process in stars.

Woosley: The Sun doesn't do it. It happens in helium burning, not hydrogen burning. And it only happens in stars where helium burning is going on and it requires that the star already contain some iron, because you start with iron and start adding neutrons there. So it has to be a second-generation star that contains some iron made in supernovae beforehand. And then, during helium burning, some neutrons added on to that iron makes heavy elements, and that material is usually stirred up to the surface by convection and then comes off either as a wind or in the planetary nebula stage. The Sun in particular is not doing that kind of thing.

EIR: How many of these nucleosynthetic processes are there which are postulated to produce nuclei heavier than, let's say—
Woosley: —heavier than iron. We usually say there are three: the s-process that we just talked about; the r-process that also involves neutron addition, but goes on on a very rapid timescale; "r" stands for rapid, and therefore is an explosive process; then there is the p-process which makes some very rare isotopes that are proton-rich. They only account for about 1% of the mass of the very heavy elements, so it's the rarest elements and isotopes of all. That, too, is probably an explosive process. You can read about all this in Donald Clayton's textbook, called *Principles of Stellar Evolution and Nucleosynthesis*, 1968 [University of Chicago Press, available in paperback].

Interview: Thomas Prince

Will we see more gamma-ray lines?

Thomas Prince is an experimentalist at the California Institute of Technology. The interview was conducted Feb. 22.

EIR: Where do we go from here in terms of observing gamma-ray emissions from SN 1987A?
Prince: Right now these are early observations. We made ours later in November, and there were a couple of others. Actually it was surprising that we saw the gamma-ray flux when we did. It meant that the gamma rays were coming out a bit earlier than some of the models had predicted. What is presumably happening right now is that the optical emission is fading quicker than it has been, indicating that the supernova is probably becoming transparent to gamma-ray energies.

EIR: Because of convection and turbulence, I gather.
Prince: No, it's probably just thinning out of the overlying material. If there is a lot of overlying material, the gamma rays essentially are degraded in energy and lose most of their energy inside the nebula, and then it shines in the optical. If the nebula becomes thin enough that the gamma rays can start coming out, the energy that's being put out in the optical starts going down, and the energy in gamma rays starts going up. And that looks like what's starting to happen now. Several groups are going down to Australia again this spring, in fact my crew is already down there, and is going to be making flights this spring to hopefully catch the supernova at about [gamma-emission] maximum.

EIR: How many more lines might we see in 1987A with the technologies that various experimenters are putting up?
Prince: We may see, for instance, the positron annihilation line. We may see one of the higher-energy lines of [the decay to] cobalt-56—it's a possibility, depending on how strong the line is. Beyond that there's a possibility of detecting the lines of cobalt-57 . . . but it's too early to look for them right now.

Interview: Stirling Colgate

The Nickel-56 idea

Stirling Colgate is a theoretician at Los Alamos National Laboratory in Los Alamos, New Mexico. The interview took place Feb. 22.

EIR: I am calling about the detection of the supernova gamma rays.
Colgate: The original work on the gamma rays and cobalt-60 and all of that was in a paper by Colgate and Chester McKee ["Early supernova luminosity," *Astrophys. J.* 157: 623-643 (1969)]. The paper by Clayton, Colgate and Fishman ["Gamma-ray lines from young supernova remnants," *Astrophys. J.* 155:75-82 (1969)] refers back to that paper. The whole business of the decay from nickel to cobalt to iron feeding the light curve was in that first paper. The history is that it was in trying to solve the light curve that I understood that the nickel decay was the key to the whole thing. The Colgate and McKee paper was really the earlier work—it was delayed in publication. I went to Rice University to talk about it.

[Colgate and McKee presented their ideas at the American Astronomical Society meeting in Charlottesville, Virginia, in April 1968. Clayton, Colgate, and Fishman was received by the *Astrophysical Journal* on May 20, 1968, and posed the possibility of detecting the gamma rays. Colgate and McKee—a longer paper—was slower in coming.]