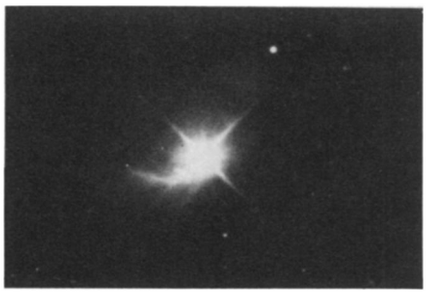
A Funny Thing Happened on the Way to the Main Sequence



Lick Observatory

FU Orionis: An infant star's outburst.

Certain very young stars show strikingly anomalous behavior, a kind of infantile outburst, that poses questions for the theory of stellar evolution

BY DIETRICK E. THOMSEN

In astronomy one example of something strange is an anomaly; a second raises questions, and a third defines a class. And a class demands an astrophysical theory. Such, in capsule, is the history of a certain strange behavior of T Tauri stars as observed between 1939 and 1975.

T Tauri stars are very young stars just on the verge of entering what astronomers call the main sequence of evolution. The behavior in question is an odd type of eruptive activity that changes the brightness, the spectrum and even the apparent shape of the star. One example of such a happening was considered a curiosity. Now that several are known, astronomers are beginning to wonder whether this is not something that can happen to many T Tauri stars. It might be "an infant disorder of very young stars," as George Herbig of the Lick Observatory puts it, an ailment that needs to be considered significant in stellar evolution theory.

If it is a fairly widespread disease of young stars, it could even have an importance close to home for earthlings. Many older stars have apparently gone through the T Tauri stage at one time. The sun is possibly one of these, and if it in fact suffered the malady at one time, that could explain the presence of chondrules in meteorites.

The story begins in 1939 with Arthur Arno Wachmann of the Hamburg Observatory, who noticed a ninth-magnitude star that had suddenly appeared in a nebula, FU Orionis. At the time the world was not ready for a new phenomenon, says Herbig, so people tended to call it a nova.

But it didn't act like a nova, and it didn't look like one. Old plates of that part of the sky showed it as a 16th-magnitude star that had brightened in 1937. But the rise in brightness was apparently slower than a nova's, and it didn't fade quickly as a nova does but tended to stay at peak brightness. Its spectrum was unique, looking like a luminous F type star. It showed lots of lithium, and the hydrogen alpha lines came and went. There is no nova explanation for that sort of thing. Finally there appeared a curious hook-shaped nebulosity curving out from the surface of the star.

FU Orionis was definitely something strange, but there was only one of its kind known, and until 1970 nothing much happened. Then in the North America nebula, a 16th-magnitude star flared in a similar manner. This was V1057 Cygni. In 370 days it rose from 16th to 10th magnitude (extremely sluggish for a nova, by the way). After the outburst the same sort of hook-shaped nebulosity appeared. This star's spectrum, too, looked like an F type star with lots of lithium. For V1057 a previous spectral record, taken in 1957, existed. It was that of an unstable T Tauri star. So it began to appear that the fuoro phenomenon (as the Armenian astronomer Viktor Ambartsumian has dubbed it from the initials of FU Orionis) was a happening that came to stars early in life.

In 1975 the third known member of the fuoro group made its appearance. This, also in Cygnus, is UGC 6914. In 1917 this was a 17th-magnitude star. In September 1975 it was at 13½ magnitude. (This was the most snailpaced rise yet seen in fuoro phenonomena, having taken 11 years to reach maximum light.) UGC 6914 showed the same lithium-rich spectrum as the others.

So now there are three. And what do they mean?

First, is fuoro a phenomenon that can happen at random to any T Tauri star of at least a certain brightness? The known three were found more or less by accident; nobody was really looking for them. How many have been missed? How many would a systematic search uncover? How many thousands of years would an astronomer have to watch a given T Tauri star to see a fuoro explosion happen?

The spectrum and brightness changes seem to indicate a change in steller classification. If so, is this a link in stellar evolution that leads on to more or less normal progress, or is it an aberrant byway?

There seems to be a little evidence that the change may not be permanent. Although two of the fuoro stars have remained close to peak brightness for years, V1057 appears to be sliding back to its previous condition. It has declined by a magnitude and a half in five years. So perhaps the fuoro phenomenon is not permanent, and after *n* number of years, the star goes back to the T Tauri class again. Perhaps the phenomenon is even recurrent.

What triggers the explosion? Is it infalling matter from the surrounding nebula that causes an energy imbalance? Is it some internal change, a switch in the star's nuclear burning cycle that provokes the outburst?

What is the nature of the hook nebulosity? Is it matter ejected from the star? Herbig, who discussed the subject at the recent meeting of the American Astronomical Society in Chicago, suggests it may be a cavity blown in surrounding interstellar matter by ejecta from the star. V1057 happens to be a strong infrared emitter, and it seems that this radiation comes from surrounding interstellar matter that is heated by the star's outburst.

The sun may once have been a T Tauri star. If so, it was most likely surrounded at the time by the nebula out of which the planets are believed to have condensed. If the sun underwent a fuoro outburst, that may explain why certain meteorites exhibit chondrules, nuggets that appear to have been melted and resolidified. Perhaps the passing heat from the fuoro explosion did that to them.

There are many questions and no certain answers. "No adequate explanation exists," says Herbig. "There may not even be a place in current theory" for the fuoro phenomenon. Ironically there seems to be also "no demand." The problem has been around at least in part for 35 years, and recently it has heated up. But, "the concrete problems of the subject have not received the attention they should from theoreticians."

The harvest seems promising, but the laborers are few. There are many more unsolved puzzles in astrophysics. The supreme irony is that at a time when there is more unfinished work in astronomy than ever, sources of support are contracting, and positions in which astronomers can make their livings are becoming fewer. Nevertheless, Herbig hopes that more astronomers will find time and energy to devote to the fuoro phenomenon. "This has been a recruiting pitch," he says. □