THE T TAURI STARS

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Abstract

The T Tauri stars are described, and several interesting examples of this class of star in relation to the work of the AAVSO are discussed.

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It is a very real pleasure for me to speak on this occasion. It is the first meeting of the AAVSO that I have attended, but even so, I may actually by the senior member present from the point of view of the date on my membership certificate. It was issued in 1936 and is signed by Harlow Shapley as President and William Tyler Olcott as Secretary, very famous figures in the history of this organization.

I joined the AAVSO when in high school, observed actively for several years with an 8-inch reflector of my own construction, and then went on to the university and a career in professional astronomy, beginning at the Lick Observatory in 1949. That early exposure to the subject of variable stars had much to do with the direction of my subsequent research activity, which has ever since my Ph.D. thesis been deeply concerned with the T Tauri stars. It is about the T Tauri stars that I would like to speak today.

If one looks at the classic book **Variable Stars**, written by the Gaposchkins in 1938, one finds a chapter on the so-called extrinsic variables. These were stars which were believed, building on a 1924 investigation by Shapley on the stars in the Orion nebula, to be ordinary dwarfs which owe their irregular variations to obscuration by nebular material. Many of what we now call "T Tauri stars" are mentioned by the Gaposchkins, but now our point of view is completely different. Today we believe that the light and spectral variability of these objects are of evolutionary origin, arising from atmospheric or circumstellar activities that are left over from the time when these stars were formed, and which will slowly subside as they age. This concept has many fascinating aspects, one of them being that our Sun presumably passed through the T Tauri stage some 4 1/2 billion years ago, so that studies of the T Tauri stars may be able to tell us something about the early history of our own star and its planetary system.

But let me talk just about those aspects of the T Tauri phenomenon that are relevant to the AAVSO's work. The first dozen of these objects that were recognized were known variables, picked out of the variable star catalogue by Alfred Joy, and recognized as being something unusual on the basis of their odd spectra. Joy was struck by the fact that these spectroscopically distinctive stars, all irregularly variable, lie "in or near large areas of heavy obscuration by Milky Way clouds". We now know why this is so: those stars were born in those dark clouds, within the last 10 million years or so, and there has not been enough time for them to move very far from their birthplaces.

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Many hundreds of T Tauri stars are now known, most of them picked up in spectroscopic surveys, because we now know how to recognize a member of the group from a glance at its spectrum. All of these objects that have been looked at subsequently have turned out to be variable to some degree, but often by very small amounts, so that variability is now regarded as a secondary characteristic, although it was crucial in drawing attention to these objects in the first place.

Nevertheless, considerable attention has been devoted to the light curves of variables associated with nebulosity, to determine if there is some unique characteristic that might set them apart from other irregulars. In the 1950's it was believed that the "RW Aurigae variables," distinguished by their occasional bursts of very rapid activity, were the photometric equivalents of the T Tauri stars. It is true that many T Tauri stars do behave in this way, but many other unrelated variables do so as well, so that the RW Aurigae appellation is no longer used.

I do not mean that there is nothing of interest in the light variations of the T Tauri stars - far from it! Let me discuss a few examples.

T Tauri itself is an extraordinary star: certainly a binary, possibly a triple, it illuminates a reflection nebula about 45" away (NGC 1555) which has varied spectacularly in brightness and structure since its discovery over a century ago. This changing appearance of NGC 1555, known also as Hind's Variable Nebula, is probably due to the play of light and shadow on the surface of a nearby dust cloud, caused by moving material very near the star. This circumstellar dust is probably responsible for some of the variability that we observe in the star itself. (I should mention that Hind's Nebula has been quite bright since the late 1930's: it is not difficult to see it in a modest-size telescope, especially if the light of the star is blocked off in the eyepiece.)

T Tauri has shown only minor variations for the last 70 years, but earlier it varied over a range of 4 magnitudes with a light curve rather reminiscent of an R Coronae Borealis variable. One of its deep minima occurred between 1888 and 1891. In 1890, when the star was near magnitude 14, S. W. Burnham (observing with the then very new Lick 36-inch refractor) was astonished to discover that "the star, if it is a star, is placed within a very small condensed nebula" of longest dimension about 4 arcseconds. When T Tauri is at full brightness as it is today, what has since been called "Burnham's Nebula" can be detected only as a bulge extending about 10 arcseconds from the over-exposed photographic image of the star. This tiny nebulosity, unlike the more distant NGC 1555, does not simply reflect the spectrum of the star, but has an extraordinary bright-line spectrum of the kind that one finds in hot gas that has passed through a shock front. No satisfactory explanation of this phenomenon has been found. We eagerly await that time when T Tauri will again decide to fade to magnitude 13 or 14, so that we may have a good look with modern equipment at Burnham's Nebula as he saw it a century ago. I am sure that members of the AAVSO will be among the first to know when that time has come.

I might remark in passing that a very worthwhile project would be for someone to assemble a comprehensive light curve of T Tauri, from its discovery in 1852 to the present, based on all the observations that exist in the astronomical archives.

Another T Tauri star whose revival of activity is eagerly awaited is VY Tauri. Prior to about 1970, it exhibited sudden flare-ups to about magnitude 10 on an almost annual basis, rather like as SS Cygni star, but since that time it has been quiescent near magnitude 14. When bright, it shows a remarkable bright-line spectrum unique among objects of the T Tauri class, so we are impatiently awaiting its re-awakening. A southern star that behaves in a similar way is EX Lupi, whose last outburst was in 1955-56. All we know of the light curve on that occasion is based on observations by the well-known New Zealand amateur Albert Jones. Observers should be aware of the importance of the prompt announcement of a major brightening of either of these odd stars. (Light curves of these two stars are found in Herbig 1977.)

The most spectacular photometric behavior among the very young stars, however, is shown by the small group named after FU Orionis. This star, at first believed to be a slow nova, appeared in 1939 in a small dark cloud not far from Betelgeuse, and is still not much fainter than magnitude 9. Only 5 members of this class are recognized as yet, typically consisting of a faint, small-amplitude variable in a dark cloud increasing in brightness by 4 to 5 (or more) magnitudes over an interval that may be as short as a year or as long as several decades. When the star is bright, it usually illuminates the surrounding dust as a reflection nebula. In the one case where the star has decided to fade back toward minimum light (V1057 Cygni), the bright nebula has quite naturally grown dimmer in step with the variable.

In only one case is the pre-outburst spectrum of the star known: V1057 Cygni was apparently a typical T Tauri star at minimum light, over a decade before its flare-up in 1969. From this fact it is speculated that FU Orionis-like outbursts are related to the T Tauri stage in the evolution of very young stars, and in fact the very limited statistics suggest that a T Tauri star may undergo more than one seizure of this kind during its early youth. One cannot help but wonder what the effect might have been on its young planetary system if our Sun had undergone one or more such flare-up during its early days.

These are examples of the more spectacular activities found among the T Tauri stars. But much more attention is being given by photoelectric observers to a more subtle variation present in a number of these objects, often superposed upon erratic, irregular activity of larger range. Usually of amplitude only a few tenths of a magnitude, but sinusoidal in shape and with periods ranging from about 2 to 9 days, these variations are believed to represent the effect of bright or dark areas on the stars' surfaces that are regularly brought around by axial rotation.

As one may see, the subject of very young stars has grown in many directions since its significance was recognized in the mid- and late 1940's. Astronomers are working energetically on sophisticated studies of T Tauri spectra; they are making infrared observations from the ground, aircraft, and spacecraft; they are pressing ultraviolet and x-ray observations from space; they are carrying out radio observations with single dishes, interferometers, and the Very Large Array radio telescope. In the next decades, these investigations will probably be pressed forward with instruments not yet invented. One cannot imagine what John Hind would have thought of all this when in 1852, in a private observatory near London, he discovered the variability of T Tauri.

REFERENCES

Herbig, G. H. 1977, **Astrophys. Journ 217**, 693.
Payne-Gaposchkin, C. and Gaposchkin, S. 1938, **Variable Stars**, Harvard Observatory, Cambridge, Massachusetts.