The Ups and Downs of Coordinated Observations

C. Bertout, Landessternwarte Heidelberg-Königstuhl

T Tauri stars are certainly not the only celestial objects for which coordinated observations are of interest. But their behaviour is sometimes so erratic that it is crucial to learn more about the range of the variations and about the correlations between variations in different wavelength domains than is allowed by one-telescope observations. Coordinated observations can overcome this limitation, but bring in their own problems.

The question of the mass-flux in the envelopes of T Tauri stars can serve as a first example of how coordinated observations can help. By the end of the nineteen-fifties, it was accepted that T Tauri stars were newly-formed stars, still associated with the clouds from which they were born, and that they were losing mass. Observational evidence of mass-loss was confirmed when L. V. Kuhi derived, by modeling line profiles, mass-loss rates up to $6 \cdot 10^{-7}\ M_{\odot}\,yr^{-1}$. The belief that T Tauri stars had strong stellar winds went unchallenged until the late sixties, when M. F. Walker reported that a subclass of T Tauri stars, which he named YY Orionis stars, showed spectroscopic evidence for mass accretion. Our group at the Heidelberg Observatory studied active T Tauri stars extensively, and was able to show that a number of them were, at times, apparently accreting material. Even more confusing, Krautter and Bastian (1980, *Astronomy and Astrophysics* **88,** L6) reported changes in the direction of the mass-flow on time-scales of days in DR Tauri, and even found evidence for simultaneous infall and outflow.

In the last years theoretical concerns have also led to questions about the magnitude of the mass-loss rates. It seems extremely difficult to produce the mass-loss rate of $10^{-7}\ M_{\odot}\,yr^{-1}$ often quoted in relation to T Tauri stars without also assuming that the energy input necessary to drive the wind is much larger than the bolometric luminosity of the star. The low X-ray luminosities of these stars likewise imply that a large mass-loss cannot be caused by thermal expansion of the corona, and complicated wind-driving mechanisms must be called upon to minimize the radiative losses. As a result of all these problems, doubts were raised recently about the methods of mass-loss rates determination (cf. DeCampli, 1981, *Astrophysical Journal* **244,** 124).

It seems at this point that both the direction of the mass-flow in T Tauri envelopes and its magnitude are highly uncertain. There seem to be some stars with well-established mass-loss, some with well-documented accretion, some objects in which the flow changes its direction in a more or less random manner, and many stars for which the existing observational material does not allow an unambiguous determination of the flow sign and rate. It will by now be obvious to the reader why world-wide observations that follow the spectroscopic variations twenty-four hours a day can be very useful.

Four observatories participated at the end of 1980 in one such world-wide spectroscopic study of two stars mentioned earlier, YY Orionis and DR Tauri: Okayama Observatory, Heidelberg, ESO, and Lick Observatory. The scientists involved in the project are I. Appenzeller, S. Isobe, M. Walker, B. Wolf, and myself. Originally, we had planned also to observe from the Calar Alto Observatory in Spain, where the instruments are more appropriate for a project of this caliber than the smaller Heidelberg telescope, and where the weather is often good at the turn of the year. Unfortunately, it turned out that for pecuniary reasons, the Calar Alto Observatory was closed between Christmas and New Year, our observing period. Fig. 1 shows the time covered by each participating observatory; bad weather was responsible for the scarce results gained at Heidelberg and only two nights had been allotted to this programme at Lick. That a twenty-four-hour coverage was indeed possible is apparent from the figure.

The main difficulties encountered in the data interpretation are due to the inhomogeneous specifications of the different spectrographs used. We are now trying to reduce the data in such a way as to minimize this problem; but it is a serious limitation to be kept in mind for later, similar programmes. This problem has delayed considerably the interpretation of otherwise very promising observational data.

I should now like to mention a second aspect of the T Tauri stars' properties which makes another kind of coordinated observations desirable: namely, their variations in different spectral ranges. Little is known about possible correlations between these variations. To illustrate the resulting difficulty in data interpretation consider the spectral appearance of the class prototype, T Tauri (Fig. 2). In this figure, I show data from the ultraviolet IUE range to the radio range collected from a number of sources. In the optical and near-infrared ranges, the error-bars represent a variation of one sigma around the average of the measurements. In the UV, far-infrared and radio ranges, the error-bars represent the incertitude on the individual measurements. The solid line is the computed contribution to the spectrum of the gaseous envelope and of the star's photosphere (Bertout and Thum, 1982, *Astron. Astrophys.* **107,** 368). Most of the infrared excess beyond about 2μ is probably due to the newly discovered infrared companion of T Tauri (Dyck et al., 1982, *Astrophys. J.* Letters **255,** L103), although the presence of circumstellar dust is probable in view of the large extinction which can be derived for the star.

Deducing the main physical parameters of the gas emission region from the data shown in Fig. 2 by using the method of Bertout and Thum is in principle a straightforward task.

Because of the emission variability at all wavelengths, a reliable modeling of the envelope would however require simultaneous observations in the far ultraviolet, in the optical (especially in the Balmer jump region) and at two different frequencies in the radio range. This project, requiring simultaneous observing time on one satellite, on two large radio antennas and on an optical telescope in the 3-metre range, has

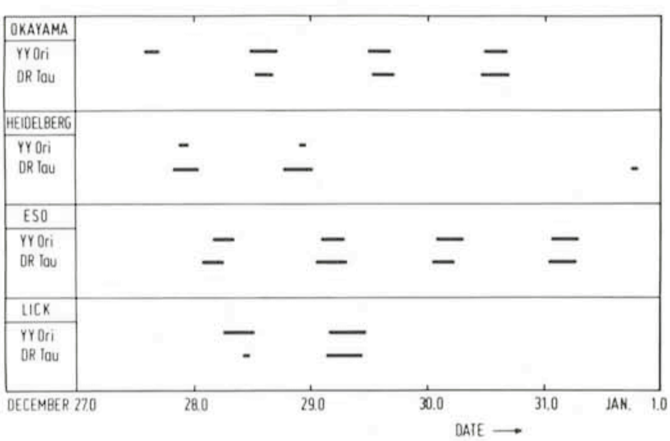

Fig. 1: *Times at which the programme stars were observed at the participating observatories.*

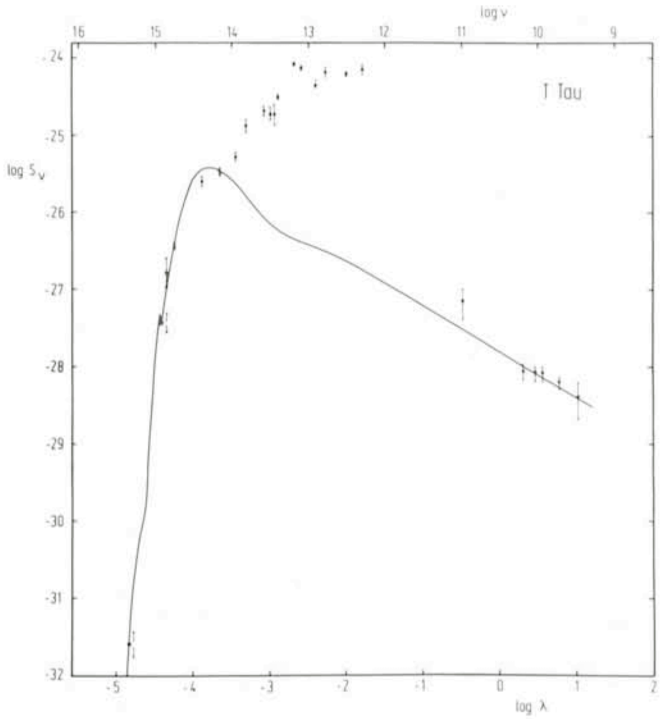

Fig. 2: *Observed energy distribution of T Tauri. The solid line represents the computed contribution of the photosphere and of the gaseous envelope. The units of $S_ν$ are W m^{-2} Hz^{-1}, λ is in cm, ν in Hz.*

not been attempted yet ... So far, we have contented ourselves with less ambitious, but more realistic, projects.

The most recent of these programmes involved the collaboration of P. Bastien, L. V. Kuhi and myself and was concerned with simultaneous polarimetry, photometry (both at La Silla) and spectrophotometry (at Lick Observatory) of a few stars known for their variable polarization. The goal of this programme, conducted last February, is to try to get clues to the polarization origin. The difficulties which arose this time were not of instrumental, but of a human nature: a mean streptococcus knocked me out at the beginning of the observing run. Fortunately, part of the time could be saved by the kindness of the French cooperants, particularly Auguste Le Van Suu, who agreed to perform the photometric observations. The data are now being reduced.

Although it is apparent from what was said above that coordinated observations are often much more difficult to organize and to conduct than more classical programmes involving only one observer, they are potentially very rewarding. In the *Messenger* **14**, 4, B. Wolf and myself reported observations of two young stars, S CrA and CoD −35°10525, simultaneously at La Silla (spectroscopy) and at San Pedro Martyr, Mexico (13-colour photometry), and a more detailed account of this work has been published recently (*Astron. Astrophys. Suppl.* **47,** 419). The body of observational facts gained during this joint observing run was crucial toward the development of a new and very promising model in which the T Tauri phenomenon is identified with the stellar corona's struggle for expansion into the dense circumstellar medium which still surrounds these young stars (cf. Bertout, 1982, Proc. 3rd European IUE Conference). My conclusion must therefore remain optimistic: it may well be that coordinated observations represent the best way to make further, decisive progress in our understanding of pre-main-sequence evolution.

Visiting Astronomers

October 1, 1982 – April 1, 1983

Observing time has now been allocated for period 30 (October 1, 1982–April 1, 1983). As usual, the demand for telescope time was much greater than the time actually available.

The following list gives the names of the visiting astronomers, by telescope and in chronological order. The complete list, with dates, equipment and programme titles, is available from ESO-Garching.

3.6 m Telescope

Oct. 1982: Melnick/Terlevich, Crane/West/Kruszewski, Shaver/Robertson, Mouchet/Motch/Bonnet-Bidaud, Westerlund/Lindgren, Azzopardi/Breysacher/Lequeux/Maeder/Westerlund, Ulrich/Boisson/Péquignot, Dennefeld, Epchtein/Braz/Nguyen-Quang-Rieu, Koornneef/Lequeux, Engels.

Nov. 1982: Engels, Sibille/Chelli/Léna/Foy/Perrier, Ortolani/Gratton, de Vegt, Chevalier/Ilovaisky/Hurley/Motch, Alcaino/Liller, Thé/Alcaino, Marano/Braccesi/Zitelli/Zamorani, Bonoli/Battistini/Fusi, Pecci/Marano, Azzopardi, Azzopardi/Breysacher/Lequeux/Maeder/Westerlund, Wouterloot/Brand.

Dec. 1982: Ulfbeck/Christensen/Hviid/Thomsen, Collin-Souffrin/Ulrich, Hawkins/Meisenheimer/Röser, Pakull/Motch/Ilovaisky/van Paradijs, de Ruiter/Zuiderwijk, Witzel/Biermann/Fricke, Israel/Koornneef, Koornneef/Israel/de Graauw, Rouan/Leger.

Jan. 1983: Rouan/Leger, Lindblad/Jörsäter, Fusi Pecci/Battistini/Buonanno/Corsi, Grewing/Schulz-Lüpertz, Geyer/Nelles/Hopp, Bergeron, Danziger/de Ruiter/Kunth/Lub/Griffith, Henrichs/van Paradijs/Pakull/Motch/Ilovaisky/Chevalier, D'Odorico/Gillet/Moorwood, Moorwood/Glass, Moorwood/Salinari.

Feb. 1983: Moorwood/Salinari, Landini/Salinari/Moorwood/Oliva, Weigelt, Möllenhoff, Richter/Huchtmeier/Materne, Bertola/Galletta, Ardeberg/Lindgren/Nissen, Persi/Ferrari-Toniolo/Tapia/Carrasco/Roth, Groot/Thé/Lamers/Hearn, Motch/Mouchet/Ilovaisky/Maraschi.

March 1983: Motch/Mouchet/Ilovaisky/Maraschi, Eichendorf, Tarenghi, Ardeberg/Lindgren/Nissen, Kunth, Reimers/Koester, Motch/Pakull/Ilovaisky, Jörgensen/Norgaard-N. de Loore/Burger/van Dessel, Cetty-Véron.

1.4 m CAT

Oct. 1982: Gillet, Barbuy, Spite, F. and M., Gratton/Ortolani.

Nov. 1982: Brand/de Vries/Habing/Wouterloot/de Graauw/Israel/van de Stadt.

Dec. 1982: Pallavicini/Pakull, Ferlet/Dennefeld, Ferlet/Dennefeld/Gry/Vidal-Madjar, Ferlet/Maurice, Querci, F. and M.

Jan. 1983: Querci, F. and M., Querci, F. and M./Bouchet, Querci, F. and M./Yerele, Pohl, Baade, Louise/Maurice, Holweger/Kovacs.