THE EXTENDED Hα COMPONENT OF T TAU*

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Abstract. We report the observation of T Tau by visible speckle interferometry at the CFHT. The observations were carried out at two wavelengths simultaneously. Each image was split into two, allowing improved data processing. The 4-channel photon-counting detector CP40 was used. We have discovered that 30% of the total energy at Hα is emitted by an extended elliptical component, with a FWHM of 70 marcsec. In the neighbouring continuum, T Tau is not resolved by the 3.60 m CFHT. We briefly discuss the astrophysical consequences of this new result.

Key words: Speckle Interferometry – T Tau

Introduction: Why Observe T Tau In The Visible ?

T Tau is the prototype of pre-main sequence stars. Its infrared excess is partly interpreted by the cool companion discovered by speckle interferometry 0.6" south of the optical star (Dyck et al., 1982). The remaining IR excess as well as the UV excess (Bertout, 1989) are interpreted in terms of a circumstellar disk accreting material onto the stellar surface (Bertout et al., 1988); this model is supported by near infrared high angular resolution imaging (Ghez et al., 1991). High angular resolution in the visible could constrain this model. For example, when the amount of light scattered by the accreting disk is measured, physical, chemical and geometrical properties of the dust grains can be derived. Also the inner disc size could be derived at Hα .

Journal Of Observations

T Tau and the reference source SAO-93887 (10' apart) were observed at the 3.60 m CFHT on November 2nd, 1989, with a 20 minute exposures each. FWHM of recentered integrated images are ~0.5". Simultaneous observations were carried out in the Hα emission line at 656±2 nm and in the continuum at 671±3 nm. The flux is typically 50 photons per channel per frame. The magnification provided a scale of 12 marcsec per pixel.

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* Based on observations collected at the CFHT.

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The Instrumentation

THE 4-CHANNEL SPECKLEGRAPH

The O.C.A. specklegraph is equipped with a Courtès monochromator allowing the selection of two bandwidths simultaneously, each with different central wavelengths and widths. The two filtered beams are split both in the pupil plane and in the image plane, so that for each of the two wavelengths two independent photon realisations of the same distribution are observed. An optical layout of this 4-channel specklegraph is shown in Foy (1988a). The splitting of the images is intended to avoid the loss of signal in the central region of autocorrelations (or at high spatial frequencies in the Fourier space), as explained below.

THE CP40 PHOTON-COUNTING DETECTOR

The CP40 (Blazit, 1987; Foy, 1988b) is an ICCD photon-counting detector. The intensified image is divided into 4 quadrants by a fiber optics splitter. Each of the quadrants is read by a Thomson 384×288 CCD chip. The four video signals are sent through fiber optics cables to a photon centroding processor which first digitilizes these signals and then computes on-line the center of gravity of the photon-events. The frame read-out time is 20 ms. The maximum flux per second is $\sim 10^5$ photons, limited by the computer board. The dark count rate is ~16 events per frame for the whole detector.

Preprocessing Of The Data: The Artefacts

Data preprocessing aims at:

- *removing spurious photon-events*: Spurious photon-events are generated by the photon-centroiding processor. They can be removed easily since they appear as very close pairs of photons (less than 2 pixels apart).
- *correcting for the distortion*: Distortion is mainly due to the light intensifiers. We have used a two-dimensional third order polynomial, the coefficients of which have been determined by fitting to the integrated image of a calibration array of bright spots.
- *windowing the frames*: The purpose of windowing is to remove optical reflections at one edge of the field.
- *removing truncated frames*: In some frames, the speckle image can be truncated at the edge of the window, because of image wander due to either atmospheric tilts or telescope guiding errors.

Data Processing: Crosscorrelation Versus Autocorrelation

Classical speckle interferometry derives the modulus of the object spectrum from integrated autocorrelations of frames (Labeyrie, 1970). Due to the photon detection process, photon-events occuring at adjacent pixels within a single frame cannot be detected. This results in a lack of signal at the center of the autocorrelation (the so called *trou du centreur*), and in a bias of the object power spectrum, leading in particular to the loss of the high spatial frequency range (Foy, 1988a).

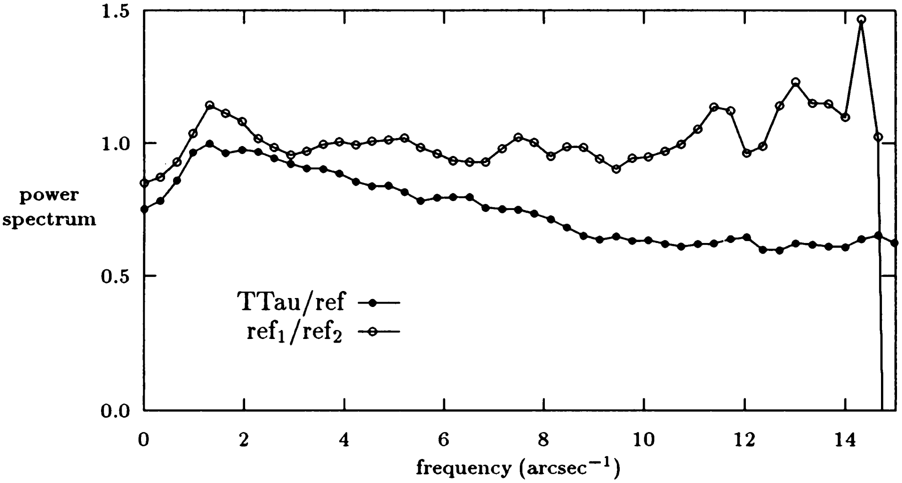

Fig. 1. Average radial power spectrum profiles at Hα .

In order to correct for the severe degradation of the signal due to the *trou du centreur*, we compute instead integrated crosscorrelations of the two images formed at the same wavelength. Compared to the results derived from autocorrelations, the gain in signal-to-noise ratio as well as the increase of the practical cut-off frequency achieved is striking when one uses crosscorrelations.

Results: The Morphology Of The Hα Component Of T Tau

IN THE Hα EMISSION LINE

We have been able to use croscorrelations for the Hα observations of T Tau. For the purpose of comparison, we also computed the power spectrum of the reference, which was obtained using the first half of the data from SAO-93887 as the *object* and the second half as the *reference*. Fig. 1 shows average radial profiles of T Tau and SAO-93887 power spectra. The decrease of T Tau power spectrum at high frequency shows that T Tau at Hα is resolved. The bump at low frequency is due to the incomplete correction for r_0 variations between the observation of T Tau and of SAO-93887. These results could be interpreted as:

- *an unresolved component* which radiates 70% of the total energy of T Tau in our Hα bandwidth. The emission line and the continuum contribute equally to this energy. On can set an upper limit of $\sim$ 20 marcsec to the extension of this component.
- *an extended component* which radiates the remaining 30% of the energy. The 2D power spectrum is not symetrical: in two perpendicular directions the FWHM's are 75±5 marcsec × 57±6 marcsec. The position angle of the major axis is 94±10°.

The energy distribution could be more complex than this simple morphological model. Near the télescope cut-off frequency, an horizontal structure appears at the top and the bottom of the 2D power spectrum of T Tau. At such a high spatial frequency, unidentified artefacts could produce such a feature. If it is real, it could be interpreted either in terms of a companion very close to T Tau (typically 40 marcsec), or in terms of a shift between the position of T Tau and the position of the center of gravity of the extended Hα component.

IN THE CONTINUUM

The failure of one of the channels of the CP40 prevents us from processing the data with crosscorrelations in the continuum. This imposes us a practical cut-off frequency at 30% of the diffraction limit. Up to this cut-off frequency, T Tau appears to be unresolved. Thus, an upper limit of its diameter is $\sim$ 40 marcsec in the continuum.

New Constraints To The Model Of T Tau

T Tau is 140 pc away. The physical size of its extended Hα component is therefore $\sim 11\times8$ AU. This very large extension does not comfort models which claim that the Hα emission originates in rather high density regions, in the interaction zone between the accreting disk and the stellar surface (see the review by Bertout, 1989). Nevertheless, if the Hα extension is not centered on the star, our result does not conflict with the model of an inner accreting disk located very close to the stellar surface.We note that the interpretation of these frequencies in terms of an hypothetical close companion should be confirmed in the continuum as well. Further observations are required to improve the visibilities at high spatial frequencies.

We believe that the extended Hα structure may be the inner part of the jet observed from 2" to 30" till the Herbig-Haro object HH-1555 (Bührke et al., 1986).

We note also that the elongation of the Hα component is roughly perpendicular to the North-South axis, which is also the direction of the cool companion of T Tau.

The lack of detection of any significant amount of scattered light favours large dust grain sizes. Again, further observations are required to set useful constraints.

We have observed several other T Tau stars, which are currently being processed.

We have shown that visible speckle interferometry observations of T Tau stars brings unique constraints on our understanding of these objects.

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