TAG: PATT	**LIVERPOOL TELESCOPE** **APPLICATION FOR TELESCOPE TIME**	**Ref: PL/15A/xxx**

Semester: 15A **Duration (Semesters):** 1 **PROGID:** XJL13A08

Applicants (PI First)	Institution	email
S.J. Smith	**Port Sunlight University**	**s.j.smith@psu.ac.uk**
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Title: The temporal link between accretion and outflow in T Tauri stars

Abstract:

Our campaign to monitor emission line variability in T Tauri stars has proven to be ideally suited to FRODOspec on the LT, and is generating some very interesting results. Spectra obtained each month demonstrate that well-known emission-line tracers of accretion and outflow vary strongly in almost all sources. Indeed, there is a suggestion from these data that a change in mass accretion onto the central object - evident as a steady increase in the permitted, high-density gas tracer Hα - translates a few months later into a boost in the outflow mass loss rate - which we trace predominantly in [OI] emission.

TIME REQUESTED

This semester (hours):	25.0
Total (hours):	25.0
Min. Useable %:	60
Sky Brightness:	Any
Photometric:	N
Seeing (arcsec):	<2.5

Constraints:	Monitor	**Group Cadence (days):**	20
ToO:	N	**ToO Likelihood (%):**	0

Which month(s) of the year would you ideally like your observations taken?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Y	Y	Y	Y	Y							Y

Instrument(s)		Details	
IO:O		**Filters**	
IO:I		**Filters**	
RINGO3			
RISE			
SPRAT			
FRODOSpec	Y	**Gratings**	High resolution VPH
Other*			

Always consult the Call for Proposals and LT web-pages before applying to use ANY instrument.

Summary of Progress on previous related LT Programmes:

This proposal is a continuation of programme XJL13A08 (proposals JL13A08, JL13B01 and JL14A04), for which 20 hrs were allocated in 13A and 43 hrs in 13B.

List of previous related and unrelated LT Publications:

Smith S.J., Baker, T., 2000, "Time and Relative Dimensions in Space", ApJ, 999, 1234

Related Proposals: LCO: WHT:**Y** INT: ESO: Other:

Details of related/complimentary proposals to this or other facilities:

30 hrs allocated on the WHT for the same programme, but using a low-resolution spectrograph. We will also observer fainter targets.

TARGET LIST:

Target	RA (2000)	Dec (2000)	Magnitude	Type	Ref
CW Tau	04 14 17.0	+28 10 58	R∼12.8	CTTS	1,2
RY Tau	04 21 57.4	+28 26 35	R∼ 9.7	CTTS	2
FS Tau B	04 22 02.2	+26 57 31	R∼14.0	CTTS	2
DG Tau	04 27 04.7	+26 06 16	R∼12.3	CTTS	1
Haro 6-10	04 29 23.7	+24 33 00	R∼14.6	CTTS	2

References:

1. Coffey D., et al. 2008, ApJ, 689, 1112
2. Hirth G., Mundt, R., Solf, J. 1997, A&AS, 126, 437

SCIENTIFIC CASE:

The empirical link between winds and jets from classical T Tauri stars (cTTS) and their accretion flows is well known [1,2], although the precise mechanism that links infall to outflow is still hotly debated [12]. Most of the standard models assume that accretion and outflow are coupled together in a steady-state fashion, the jets being launched magneto-centrifugally along magnetic field lines that thread the disk and extend along the flow axis [3,4,5]. In reality, however, young stars are known to vary photometrically on time scales as short as a few years to hundreds of years. Such EXor and FUor type outbursts are almost certainly caused by periods of enhanced accretion [13]. Similarly, Herbig-Haro jets, visible tracers of mass loss and, importantly, its history, are known either directly or indirectly to vary on essentially the same time-scales [6,7].

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TECHNICAL CASE:

We request FRODOSpec in its high-resolution mode. The technical feasibility of this project is dependent on the detectability of Hα at 6563Å, which is a well-known tracer of accretion, and [OI]λ6300, which is quenched in high-density accretion hot-spots and is thus confined to the outflow close to the source [7,12]. Our observing campaign in 13A and 13B has demonstrated that these two lines are clearly detected in all sources.

Based on published line equivalent widths and the zero-point sensitivities of FRODOSpec, in our 13A proposal we predicted a line SNR with respect to the continuum of 10-30 in 15 minutes on-source integration time. The Exposure Time Calculator predicts a similar SNR in 10-30 mins. For each of our targets we have therefore obtained three 300 sec exposures at each epoch. Median averaging of these three spectra allows us to correct for cosmic ray spikes. Some of the data were acquired through thin cloud and/or in relatively poor ≥ 2.0 arcsec seeing. Even so, the spectra in Fig.1 demonstrate that this observing strategy is sound and that the observations are repeatable. We therefore propose continuing with this strategy.

Just under 30 minutes of physical time is needed to acquire, calibrate, and obtain 15 minutes of integration time on each target. We have set the monitoring cadence of our observations to 20 days so that each target is observed roughly once a month. Our target list now includes 13 objects. Nine of our targets are "winter" objects (RA ~ 4 or 5 hrs; mostly in Taurus); the remaining four are "summer" targets (RA $\sim 19 - 22$ hrs). The winter targets are accessible from LT for seven months in 15A (Aug-Feb); the summer targets are observable for four months in 15B (Aug-Nov).

To monitor all 13 targets for the maximum time possible, we therefore request $9 \times 7 \times 0.5$ **hrs plus** $4 \times 4 \times 0.5$ **hrs = 39.5 hrs in 15A.**

We have had near-continuous monthly monitoring of all 13 targets since February 2013, with only a single ~3 month break in winter 2013/14 for our summer targets, and similar-sized breaks in Spring 2013 and 2014 for our winter targets. We expect that with this fourth semester (14B) we will have sufficient temporal baseline to search for real changes in accretion and outflow tracers. *Given the tantalising hints at line variability seen in some targets, now is clearly not the time to drop this project!* However, we do foresee a decision point being reached at the end of 2014: targets that appear to show consistent, steady changes would be the subject of a fresh proposal in 15A; those that exhibit no obvious change or exhibit random scatter in their light curves would be dropped. Either way, we expect that a preliminary paper on line variability in T Tauri stars on monthly time scales should be possible, and that a 2 year baseline is a reasonable length of time to monitor for such changes, given the annual breaks mentioned above.

References

[1] Antoniucci, S., et al. 2011, A&A, 534, 32; [2] Coffey, D., Bacciotti, F., & Podio, L. 2008, ApJ, 689, 1112; [3] Cabrit S., Ferreira J., Dougados C., Sunyaev R.A., & Belloni T. 2011, in IAU Symposium, ed. G. E. Romero, 374; [4] Ferreira, J., Dougados, C., & Cabrit, S. 2006, A&A, 453, 785; [5] Pudritz, R. E., Ouyed, R., Fendt, C., & Brandenburg, A. 2007, Protostars and Planets V, p.277; [6] Agra-Amboage, V., Dougados, C., Cabrit, S., Garcia, P. J. V., & Ferruit, P. 2009, A&A, 493, 1029; [7] Hartigan, P., & Morse, J. 2007, ApJ, 660, 426.

FIGURES AND TABLES:

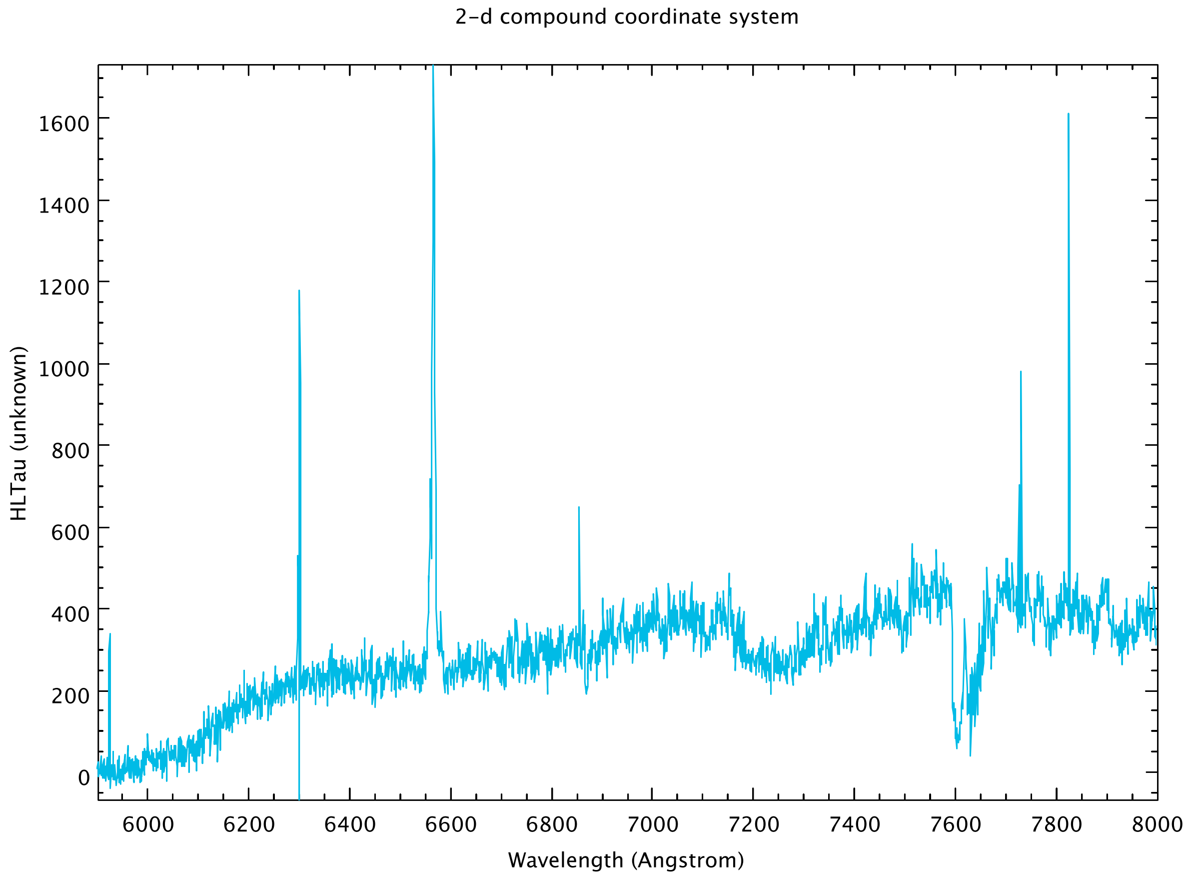

Figure 1: FRODOspec spectrum of a T Tauri star.