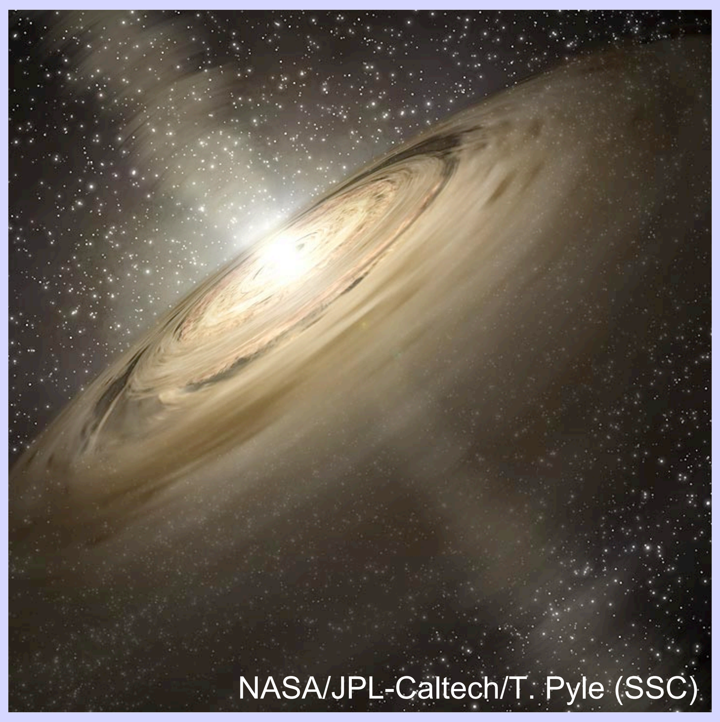
Quiescent phase mid-infrared variability of EX Lupi-type stars: clues to disk structure and accretion



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Sterrewacht Leiden

INTRODUCTION

❖ EX Lupi-type stars (EXors) are low-mass pre-main sequence stars exhibiting large, repetitive optical outbursts, thought to be powered by enhanced accretion from the circumstellar disk onto the star.

❖ The temporal variability of EXors in the near-to-far infrared regime has never been studied, although this is the wavelength range where the emission is dominated by the circumstellar material.

❖ By analyzing how changing accretion and illumination affect different parts of the disk, infrared flux variations help us to gather information on disk structure and energetics, and to clarify the role of the circumstellar material in the eruption.

THE SAMPLE

We investigate the brightness evolution of four well-known EXors: the prototype EX Lup, as well as DR Tau, VY Tau and UZ Tau E. Spitzer IRS and IRAC observations (P3716) were executed in 2005 February-March. We complemented these data with archival IRS and IRAC measurements obtained either one year earlier (for the Taurus stars) or half year earlier (for the Lupus star).

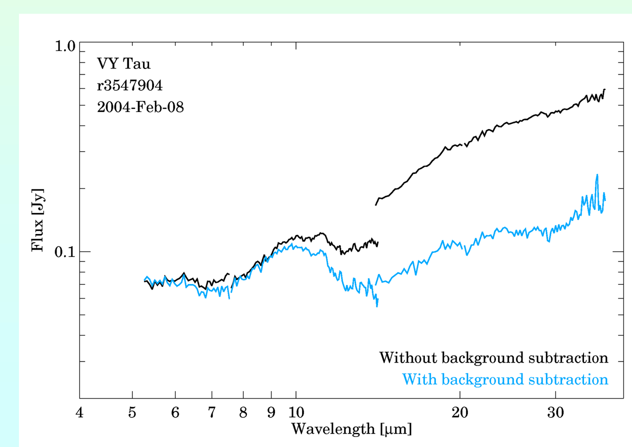
Star	2004		2005	
	IRS	IRAC	IRS	IRAC
EX Lup	5645056	–	11570688	11570944
DR Tau	3533568	3966720	12287744	11566336
VY Tau	3547904	–	11565824	11565568
UZ Tau E	3531264	3963648	12288000	11564800

AORs of Spitzer observations used in this study

DATA REDUCTION

IRAC:
- ❖ with MOPEX in case of full array mapping;
- ❖ with own IDL routines in case of subarray mapping.

IRS:
- ❖ process BCD files with SPICE; correct for bad pointing using self-developed correction datacubes;
- ❖ subtract zodiacal sky background using either actual observations (low resolution channels) or fitted background (high resolution channels);
- ❖ in case of UZ Tau E: using the IRS beam profiles to separate the contribution of UZ Tau E and UZ Tau W;

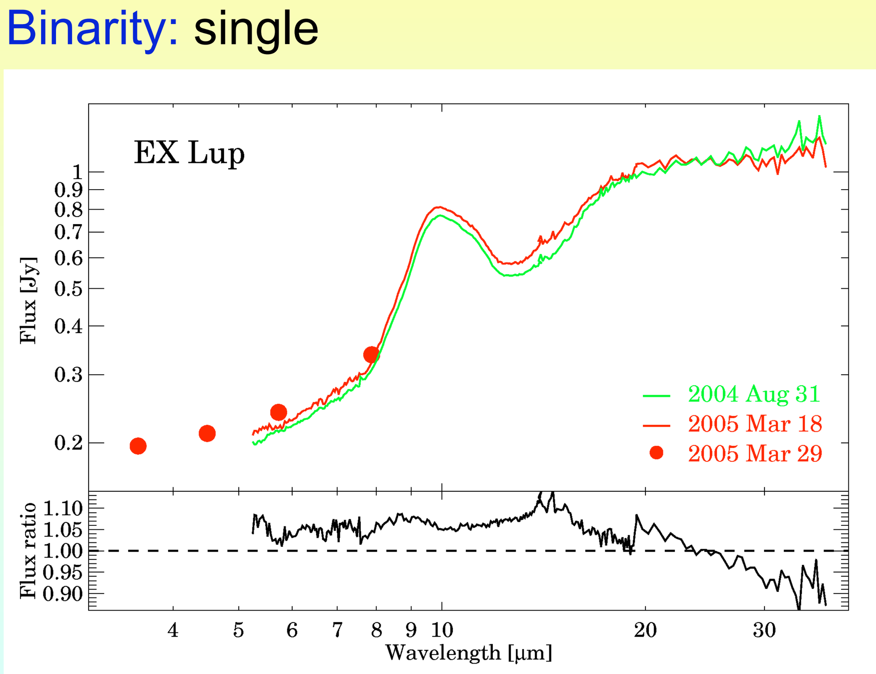


❖ the repeatability of IRS observations is 2-3% for SL and SH channels, thus changes higher than 5% are considered significant.

Example for background subtraction: after removing the zodiacal light contribution, the different channels fit together

EX Lup

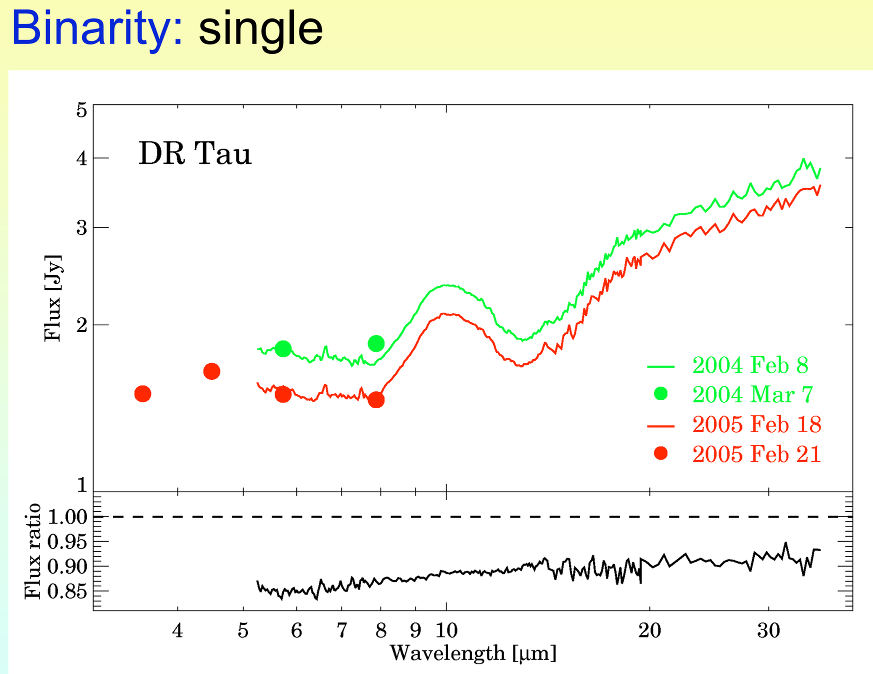
Sp. type: M0
Location: Lup 3
Binarity: single



Variability: weak, probably wavelength-independent flux change of about 5% at < 15 μm

DR Tau

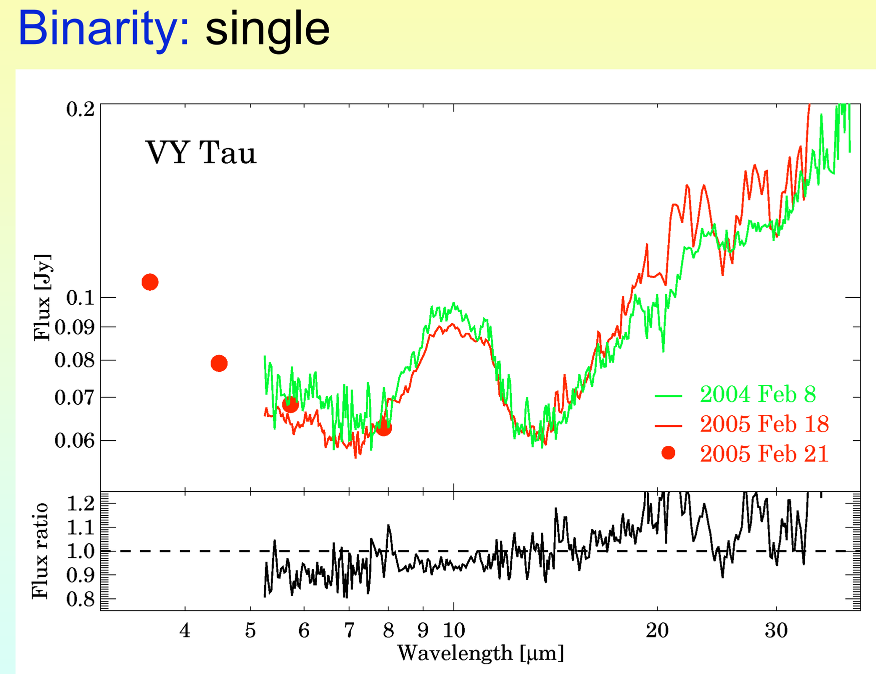
Sp. type: K4
Location: L1558
Binarity: single



Variability: flux ratio increases from 0.85 to 0.90 in the 5–20 μm range, and stays 0.90 at longer wavelengths

VY Tau

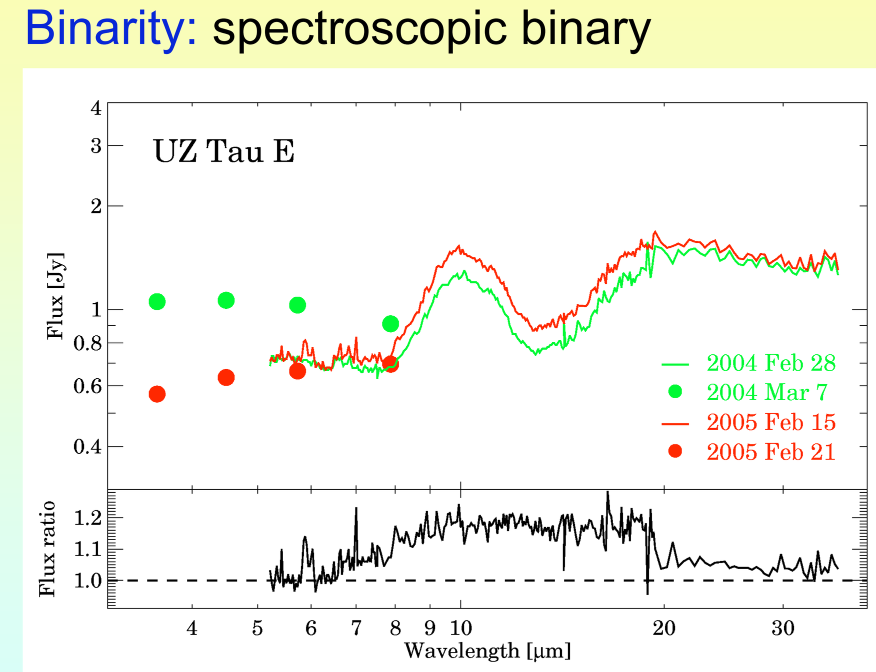
Sp. type: M0
Location: L1556
Binarity: single



Variability: noisy spectra, but a slight increasing trend with wavelength may be seen in the flux ratio

UZ Tau E

Sp. type: M2
Location: B19
Binarity: spectroscopic binary



Variability: significant flux change of about 15% between 8 and 20 μm

DISCUSSION

OVERALL SHAPE OF THE SED

❖ The SEDs of all four stars are similar to each other in the sense that the flux density is increasing with wavelength and they exhibit prominent silicate emission features at 10 and 20 μm ⇒ possible similarities in disk structure

❖ The 10 μm silicate feature is amorphous for all objects, except for VY Tau, where probably some crystalline contribution can also be seen ⇒ in most cases there is no evidence for grain processing

VARIABILITY OF THE SED

❖ All four stars were in quiescence; no big EXor-outburst was captured. Significant flux changes can be observed for 3 out of 4 stars, some trend can be seen even for VY Tau; flux changes are usually below 20% ⇒ evidence for small-scale flux fluctuations in the quiescent phase of EXors

❖ Despite of the changing SED, the shape of the 10 μm silicate feature does not change ⇒ indicates homogeneous chemical composition and the lack of grain processing due to variable illumination

❖ The flux changes are wavelength-dependent: larger at <20 μm, smaller at >20 μm ⇒ emission at <20 μm is coming from either an optically thick accretion disk with changing accretion rate, or an optically thin, reprocessing disk atmosphere that follows the variability of the central source; emission at >20 μm is more and more dominated by the optically thick disk mid-plane, which has approximately constant brightness on the temporal baseline of our observations (1 year)

FURTHER READING

ON YOUNG ERUPTIVE STARS IN GENERAL:
Herbig 1977, ApJ 217, 693
Hartmann & Kenyon 1996, ARA&A 34, 207
Ábrahám, Kóspál et al. 2004, A&A 428, 89
Herbig 2008, AJ 135, 637

ON THE RECENT OUTBURST OF EX LUP:
Poster #38 by Attila Juhász
Kóspál et al. 2008, IBVS 5819, 1

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