Search for Long-term Infrared Variability in Young Eruptive Stars with the Spitzer Space Telescope

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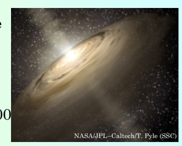
ABSTRACT

We investigate the brightness evolution of young eruptive stars in the infrared wavelength regime. We combine IRAC, IRS and MIPS data to obtain the spectral energy distributions (SEDs) of the stars, and compare them with earlier ones derived from IRAS, ISO, MSX, as well as ground-based observations. By comparing our results to existing models for young eruptive stars, the observed flux variations can be used to gather information on the structure, composition and energetics of the circumstellar material and on its role in the eruption.

YOUNG ERUPTIVE STARS

Low-mass star formation:

- ❖ Compact dusty gas cloud ⇒ protostar + disk system
- ❖ Accretion through the circumstellar disk at a steady, modest rate (10^{-7} $M_\odot$/yr, characteristic for classical T Tauris).
- ❖ Episodic outbursts: due to gravitational/thermal instability in the inner disk region, the accretion rate increases by 3 orders of magnitude.
- ❖ Outbursts occur unpredictably and they may increase the brightness of the system by as much as a factor of 100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Two types of eruptive stars:

- ❖ FU Orionis-type stars (FUors):
  - Brightening: some months – some years
  - Fading: several years or decades
  - Spectral type: F–G giant (according to the optical spectrum), K–M giant/supergiant (according to the infrared spectrum)
- ❖ EX Lupi-type stars (EXors):
  - A unique subclass of T Tauri stars
  - Outbursts: last some weeks – some months
  - Time between outbursts: some months – some years
  - Spectral type is K or M dwarf

MOTIVATION

Importance:
Statistics indicate that most low-mass stars undergo major eruptions during their pre-main sequence evolution and they accrete about 5-10% of their final mass during these episodic outbursts. Thus eruptive phenomena play an important role in star formation.

Method:

- ❖Thermal emission of circumstellar dust can be observed at infrared wavelengths.
- ❖Multi-epoch IR observations can reveal long-term infrared evolution.
- ❖Existing models can be used to predict how a star + circumstellar material system reacts for the brightness changes of the central source.
- ❖Model predictions can be confronted with measurements, and information on the geometry, composition and energetics of the circumstellar material can be derived.
- ❖Currently we know about 19 FUors and 14 EXors (including candidates), and some of them have well-documented optical/near-infrared history. Mid- and far-infared observations are, however, rare and scarce. As a continuation of our previous study of 5 FUors (Ábrahám et al. 2004), *our aim is to reduce and analyze all Spitzer data available on young eruptive stars and establish their long-term evolutionary stage*.

Difficulties when measuring infrared variability:

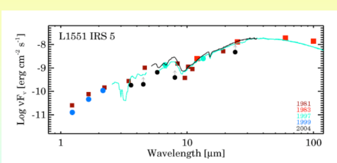
- ❖Limited temporal coverage
- ❖Instrument-related photometric artifacts
- ❖Beam confusion

Difficulties with Spitzer/IRS: in some cases the source was not well-centered in the slit ⇒ part of the stellar PSF falls outside of the slit ⇒ we loose flux ⇒ absolute photometry should be calibrated carefully (see bottom panel).

L1551 IRS 5

Type: FUor

Eruption: no eruption observed



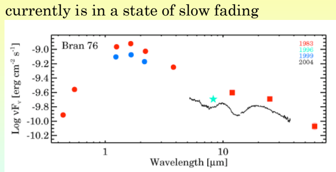
SED: rising towards longer wavelengths, deep H_2O ice and silicate absorption, obscured stellar continuum + thick flared disk + envelope (Men'shchikov & Henning 1997)

Flux evolution: no flux changes between 1981 and 2004.

Bran 76

Type: FUor

Eruption: probably some time before 1900, currently is in a state of slow fading



SED: stellar continuum + steady accretion disk + envelope (Reipurth et al. 2002), silicate emission

Flux evolution: self-similar fading between 1.25 and 25 μm.

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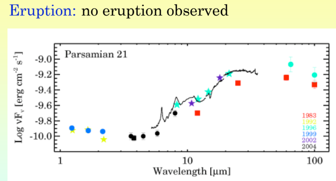
Type: FUor

Eruption: no eruption observed



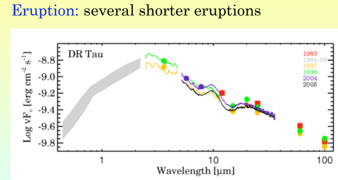
SED: flat/rising towards longer wavelengths, silicate and PAH emission (Polomski et al. 2005)

Flux evolution: slow brightening between 1983 and 1997, steady bright state since then.

DR Tau

Type: EXor

Eruption: several shorter eruptions

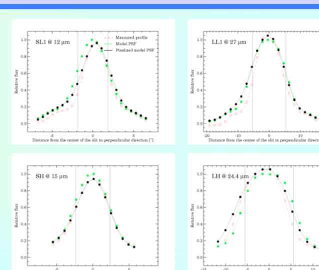


SED: highly veiled stellar continuum + accretion disk (Kenyon et al. 1994), silicate emission

Flux evolution: low state in 1997, high state in 1998, high state in 2004, low state again in 2005.

SPITZER/IRS AS A PHOTOMETER

- ❖We used dedicated IRS calibration measurements taken in spectral mapping mode in a regular grid.
- ❖We devided the measured spectra with synthetic model spectra (Decin 2005).
- ❖We resampled the resulting correction maps to finer spatial grid and smoothed in wavelength.
- ❖We checked if we can reproduce the measured profiles with the PSFs provided by Spitzer's Tiny Tim (J. Krist).
- ❖The graphs to the right show the ratio between the observed and the model spectrum at different distances from the slit center. The slight difference between them can be attributed to pixelization effects and to small uncertainties in the exact position of the star with respect to the slit.
- ❖Based on our analysis, we decided to use the measured profiles to correct our science measurements, and to use the model profiles to estimate the uncertainty of the correction.
- ❖Using this correction, the absolute flux level of IRS spectra has an uncertainty of 10%, but individual measurements can be much more precise if the source is well-centered in the slit.



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