INVESTIGATING THE OPTICAL VARIABILITY OF PROTOSTARS

Teresa Giannini

INAF-OAR

on behalf of

FSTAR (Formazione STellare Area Romana)

Simone Antoniucci, Gianluca Li Causi , Dario Lorenzetti, Brunella Nisini

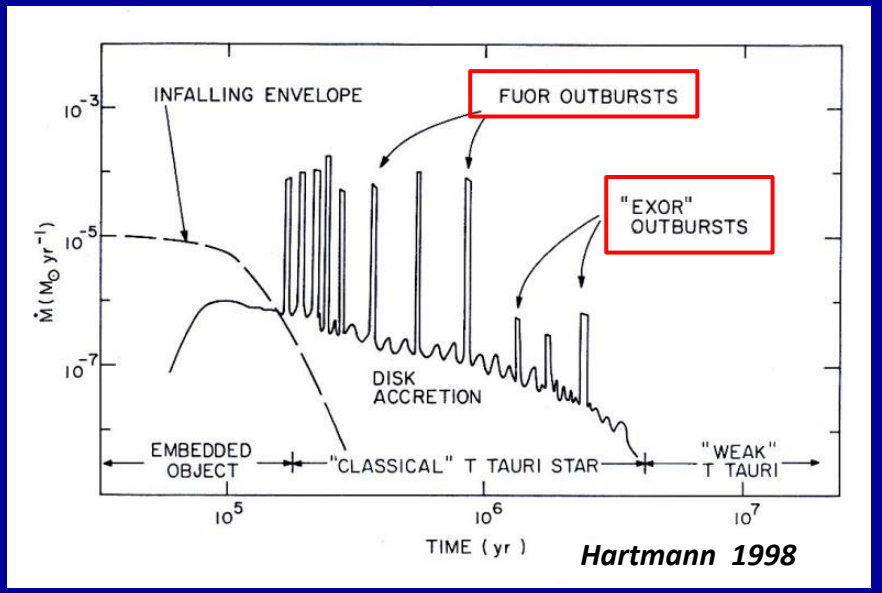
Osservatorio Astronomico di Roma

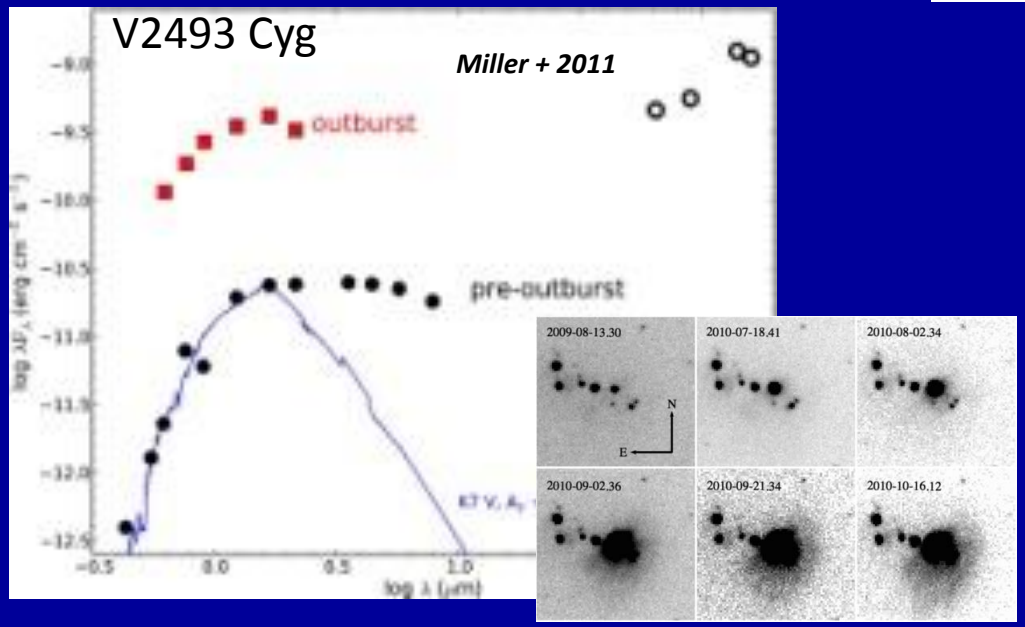
Milena Benedettini, Anna Di Giorgio, Davide Elia, Sergio Molinari, Stefano Pezzuto, Eugenio Schisano, Alessio Traficante

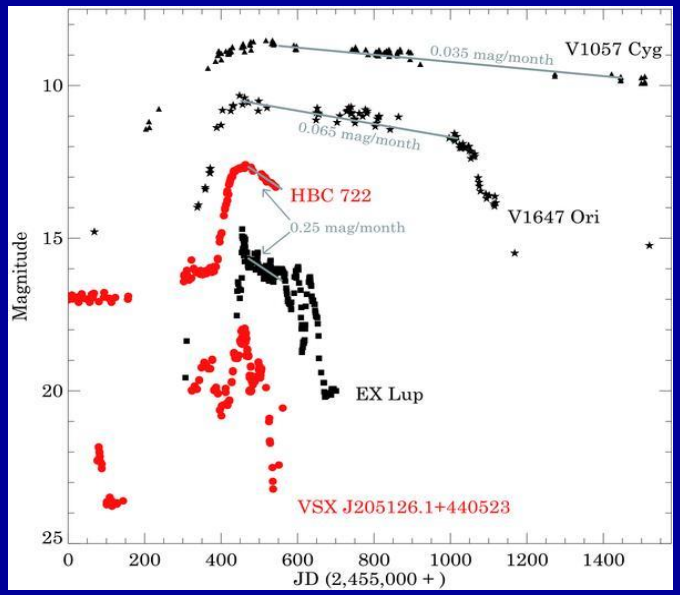
Istituto di Astrofisica e Planetologia Spaziali

Pre-main sequence eruptive variables

- Low-mass **protostars with age 10^6 - 10^7 yr**
- **Intermittent bursts**
- **Accretion driven variability**
- During quiescence have SEDs typical of low-mass classical T Tau stars
- IR excess due to circumstellar disk material







Fundamental questions about FUors and EXors

- **Do they represent peculiar objects or rather a short but common and repetitive phase of the pre-main evolution? → monitoring of known objects and statistics !!**

- **What is the mechanism at the origin of the burst :**
  - ***Intrinsic*: Thermal/gravitational instabilities inside the disk → slow rise/random ligth-curve**
  - ***Extrinsic*: Perturbation of the disk induced by an external body (close companion or orbiting planet) → fast rise/ periodic ligth-curve**

- **What is the role of episodic accretion in stellar and disk evolution ? → eg. mass accretion rates and final mass**

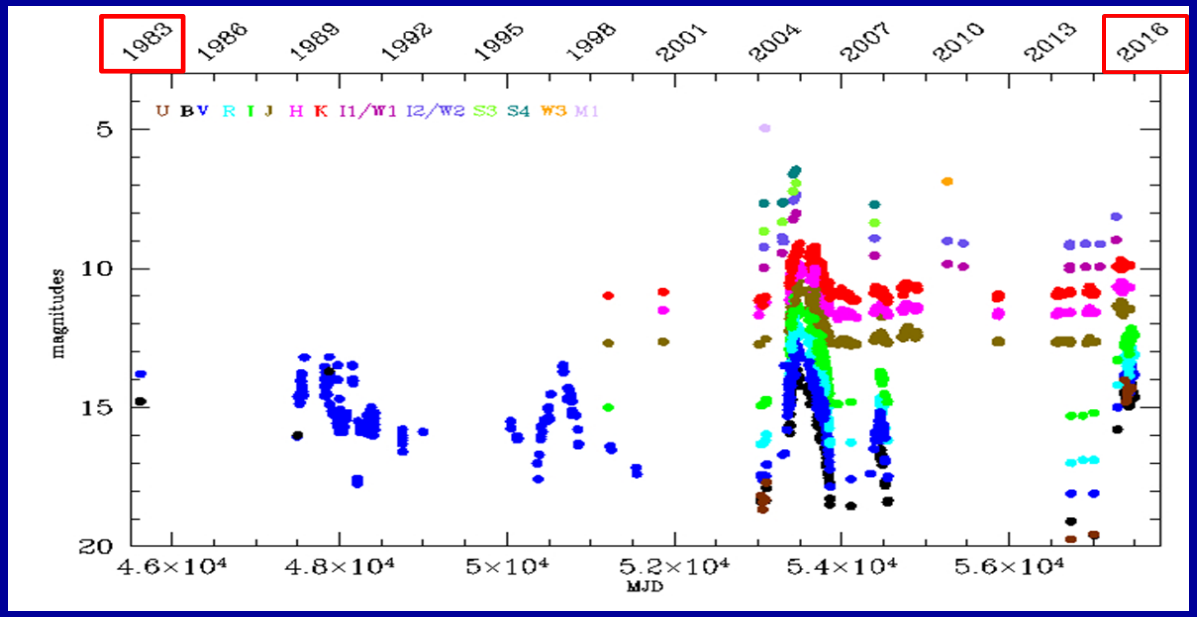
- **Are FUors and EXors distinct objects or rather they represent two subsequent evolutionary stages (with FUors typically younger than EXors) ? → search for variables in different evolutionary stages**

Observational features:

- **Optical ouburst strength: FUors : 4-6 mag, EXors: 2-4 mag in V**
- **Outburst duration: FUors : ≥ 10-100 yr, EXors: months, years**
- **Mass accretion rate : FUors : 10^{-6}-10^{-4} $M_0 yr^{-1}$, EXors: 10^{-7}-10^{-5} $M_0 y^{r-1}$**
- **Spectroscopy: FUors : absorption lines, EXors: emission lines**

⇒ EXors suitable for a more effective monitoring (wrt human life)

- **…. but so-far only about 50 EXors known !!!**
- **and sparse observations due to the lack of systematic monitoring**

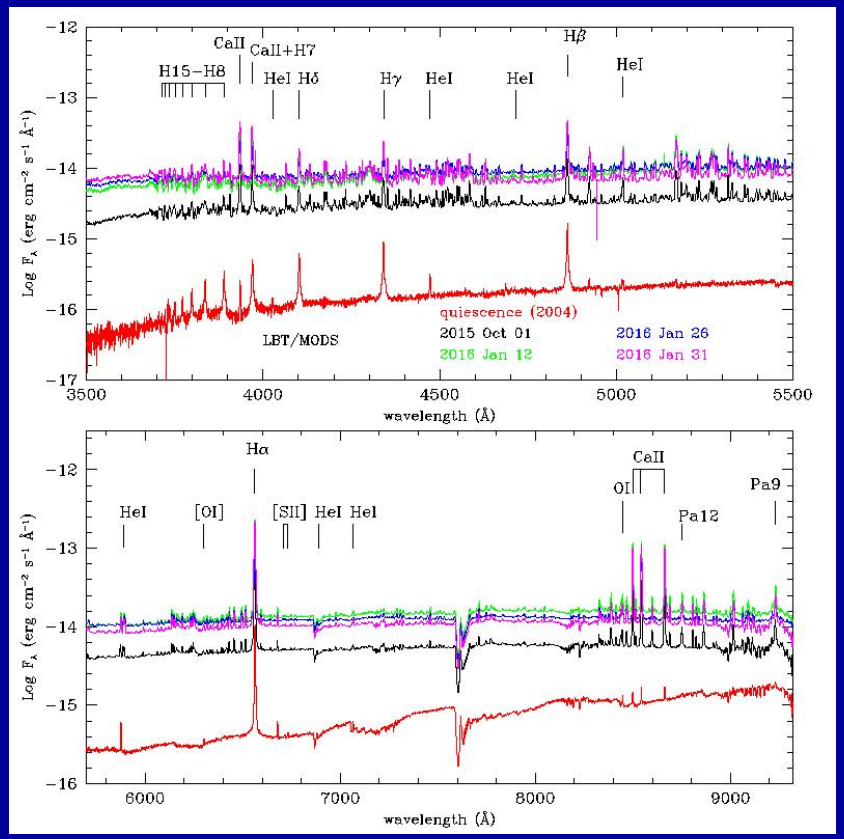


V1118 Ori
Giannini+, 2016

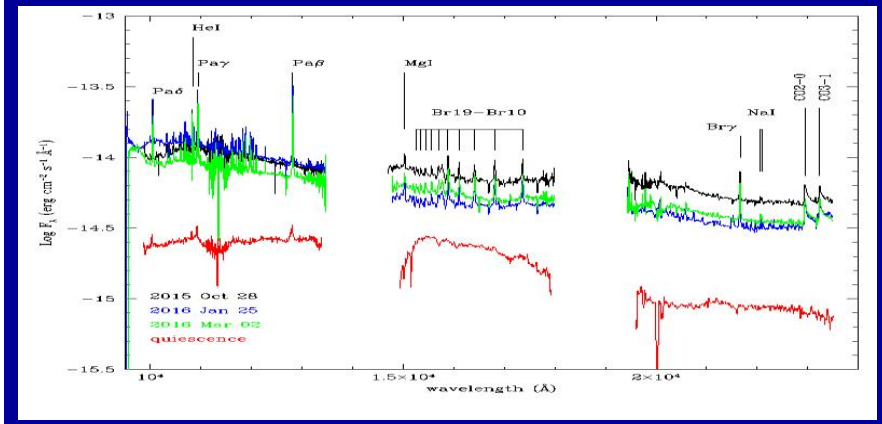
On-going studies (I)

EXORCISM (EXOR optiCal and Infrared Systematic Monitoring) (Antoniucci+ 2014, Lorenzetti+ 2012)

- **Optical and near-infrared photometric monitoring of 50 EXors during quiescence**
- **Trigger for photometric/spectroscopic follow-up during burst**
- **Involved facilities: AZT24@Campo Imperatore, REM, St.Petersburg, MODS-LUCI@LBT, NICS-Dolores-GIANO@TNG, Echelle@Asiago, NOTcam@ NOT**



LBT optical/near-infrared spectrum of V1118 Ori from quiescence to outburst (Giannini+ 2015, 2016, Lorenzetti+ 2015)



On-going studies (II)

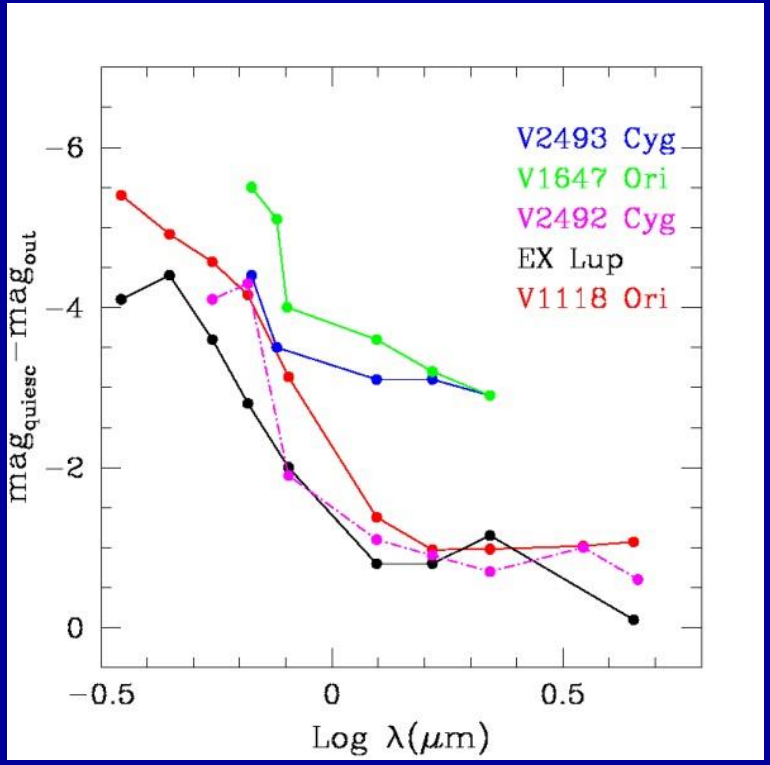
SEARCH OF NEW CANDIDATES:

- **YSOvar :** Spitzer variability (mainly 3.6, 4.5 μm) in some star forming regions (NGC1333, GGD 12-15, Lynds 1688, ρOph, ONC, IC1396A)
- **WISE-Spitzer** variability (eg. Scholz+ 2013, Giannini+ 2009, 2014, Antoniucci+2013 , Safron+ 2015)
- **Herschel** variability (Schisano+ , in preparation)

BUT ….

1) **Often very few photometric points (2!!)**
2) **'Wrong' bandpasses ⇒ ΔV >> ΔK**

…. And indeed very few new candidates found !!! (about 1% of protostars)



Lorenzetti+, 2012

On-going studies (III)

VISTA VARIABLES in the VIA LACTEA : promising results!! (Contreras+ 2016)

- **816 variables in 119 deg^2 with ΔK > 1 mag in 2010-2012**
- **Z, Y, J, H, Ks filters ⇒ complementary to LSST filters**

LSST monitoring

IDEALLY SUITED BECAUSE:

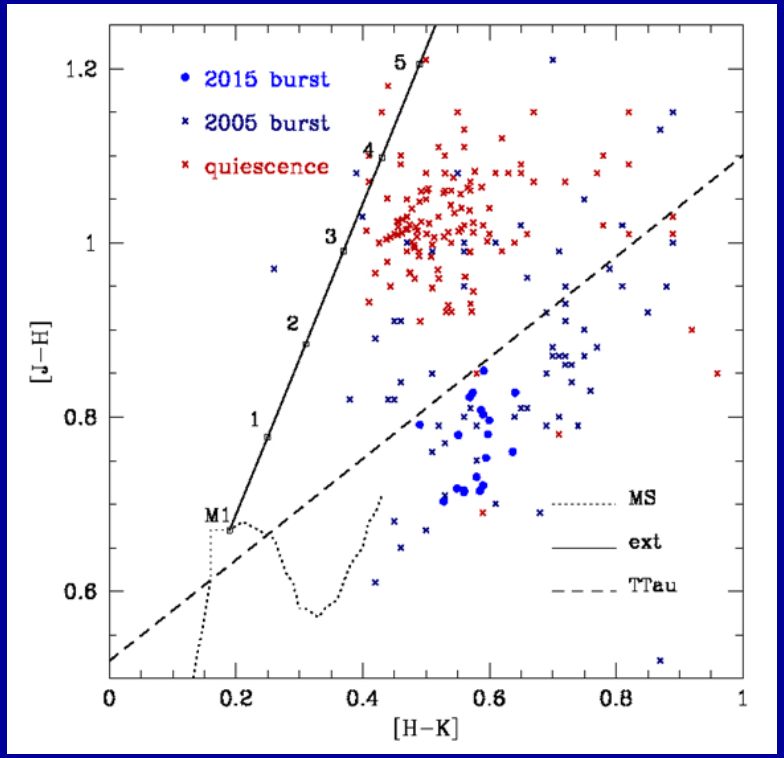
- **Frequency of monitoring (EXors timescale variations of years)**
- **Filters (major variations at shorter wavelengths)**
- **Large FoV (statistics)**
- **Sensitivity**

LSST answers

FROM THE STATISTICS:

- Are EXors common or peculiar sources ?
- Bursts frequency : do bursts influence the stellar mass and the IMF?
- Do EXors bursts occur also in the very late star-formation phases (> 10^7 yr) and when do they stop?
- Candidates for spectroscopic follow-ups
- Possible detections of FUors

Giannini+, 2016



FROM THE LIGHT CURVES:

- Valuable tools to infer on the triggering mechanism
- Periodicity investigation
- Accretion- vs extinction -driven variables distinguished by means of col-col diagrams