The process of star formation - young stellar clusters:

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Abstract

We have continued and extended our tests for the photometric detection of clusters of low-mass pre-main-sequence (PMS) stars on the basis of carefully selected colors, which will be available using LSST data. Results were presented at conferences and 3 papers published/in press. A white paper was presented with the aim of a higher total depth in the Galactic plane, similar to the main WFD survey. As for variable young stars, existing lightcurves and spectra of known eruptive PMS stars (EXors) were investigated (with 2 papers published), in order to define characteristics variability patterns which will permit to recognize potential eruptive PMS variables in large the nightly stream of LSST alerts. Moreover, a white paper proposing a fast LSST cadence on selected regions rich in PMS stars was submitted, with the aim of discovering and studying variability in these stars on timescales from hours to weeks.

1 Quintuplet Information 2018

PI: Francesco Damiani (ricercatore astronomo, OAPA)
Co-I: Simone Antoniucci (ricercatore, OAR, since July 2018)
Co-I: Rosaria (Sara) Bonito (ricercatore, OAPA, since Dec.2018)
Co-I: Loredana Prisinzano (ricercatore, OAPA)

2 Quintuplet Information 2019 (TBC)

PI: Teresa Giannini (ricercatore, OAR)
Co-I: Rosaria (Sara) Bonito (ricercatore, OAPA, since Dec.2018)
Co-I: Loredana Prisinzano (ricercatore, OAPA)
Co-I: Katia Biazzo (ricercatore, OAR)
Co-I: Alessio Caratti (post-doc, OAR)

Scientific Collaborations:

1. F.Damiani, R.Bonito, and L.Prisinzano have joined the LSST Science Collaboration "Stars, Milky Way & Local Volume (SMWLV)".

2. S.Antoniucci and R.Bonito have joined the LSST Science Collaboration "Transients and Variable Stars" (TVS).

3   Scientific Activity

The LSST view of Galactic star formation regions
Interest in star clusters is driven by several scientific topics: star clusters are laboratories for understanding the physical mechanisms active in stars and are tracers of Galactic chemical evolution thanks to their wide range in ages and distances. Moreover, in star-forming regions (SFRs) we can study star formation in action. Our knowledge of young clusters and SFRs is currently limited to nearby regions, while LSST observations will allow us to discover SFRs at distances 7 times farther than those achievable even with the deepest current wide-area surveys, e.g. PanSTARRS1. This will allow us, for example, to discover the low-mass star population (down to or even below $0.5\ M_\odot$) of even quite extincted SFRs ($A_V \sim 5$) in the volume shell from $\sim$1 kpc up to $\sim$10 kpc, which would remain unexplored by other surveys.

To this aim, we proposed a new approach to select low mass young stars and to discover SFRs based on the $(g - r, r - i)$ colour-colour diagram that will be obtained with LSST. The approach is based on the co-exploitation of several properties of M-type stars during the pre-main sequence (PMS) phase. We have performed several tests on different SFR using available deep, wide-area photometry, with encouraging results indicating the usefulness of that method for LSST data as well (Damiani 2018; Prisinzano et al. 2018, Venuti et al. 2018, in press). To take more fully advantage of the LSST capabilities, we presented a **White Paper (co-PI L.Prisinzano)** with the aim of observing the Galactic plane with the WFD cadence in selected filters (https://arxiv.org/abs/1812.03025).

Young stars are characterized by photometric variability caused by several distinct physical processes: mass accretion events from circumstellar disks, the presence of warps in the inner disks, starspots that rotate across the stellar surfaces, and flares. We aim at investigating in statistical samples in young stellar clusters the stellar variability due to accretion process, also in eruptive bursts (EXors); rotation; stellar activity; etc.

LSST can make a significant impact by providing large enough samples to allow us to relate these aspects of the young stars and their environments to stellar properties such as mass, age, binarity, and their location in a statistically significant manner. Therefore, we **(R.Bonito, co-PI)** have submitted a **White Paper** with the objective of observing the Carina SFR with a fast cadence (a denser phase coverage with respect to the Wide-Fast-Deep main survey) in different bands to clarify the nature of both the short-term and long-term variability of the thousands of young stars in the Carina region (https://arxiv.org/abs/1812.03135).

A new view of star formation: accretion bursts in EXor protostars
LSST-related activities on the topic of PMS eruptive variables (EXors) include:

- **Optical/IR observations of protostars with accretion bursts** (EXORCISM project: EXor OptiCal and Infrared Systematic Monitoring). Purpose of these observations is to build a database of spectra of quiescent EXors, to both characterize a typical EXor spectrum, and to obtain a reference against the spectra during outbursts. This work is of fundamental importance in view of LSST, since when an alert is issued the spectroscopic follow-up will enable us a prompt identification and classification of these objects. Instrumentation: LBT MODS/LUCI, TNG GIARPS/DOLORES, Campo Imperatore, Asiago. One paper published in 2018, another in preparation.

- **Archival data studies** with the aim of reconstructing lightcurves and SEDs of known objects. The project goal is to build templates for fast recognition of EXor candidates, based on LSST SEDs, lightcurves and colors. Used archives: historical Asiago plates, ASASSN and Gaia databases. One paper was published in 2018, another is in preparation.

- **SOXS** . Definition of scientific case and observing strategy optimization for the spectroscopic follow-up of EXor outbursts using SOXS (Son Of X-Shooter), to become operational on the NTT in the near future.

4   Scientific and technical deliverables

- **White Paper "Investigating the population of Galactic star formation regions and star clusters within a Wide-Fast-Deep Coverage of the Galactic Plane"** (co-PIs: L.Prisinzano and L.Magrini, other co-Is F.Damiani, R.Bonito, et al.)

- **White Paper "Young Stars and their Variability with LSST"** (co-PIs: R.Bonito and Pat Hartigan, other co-Is F.Damiani, L.Prisinzano, T.Giannini, S.Antoniucci et al.)

- **LSST TVS RoadMap Document** (https://www.authorea.com/users/45/articles/281328/_show_react), contributions to "Minisurvey science cases: Intrinsic Galactic and Local Universe transients and variables: Young stars with variability" (Bonito et al.); "Time Critical science: Galactic and Local Universe transients and variables: EXor/FUor" (Giannini et al.); "Non Time-Critical science: Intrinsic Galactic and Local Universe transients and variables: EXor/FUor" (Giannini et al.).

- **ESO Observing Proposal: Systematic search for eruptive stellar objects: benchmark observations in view of LSST**. PI: T.Giannini. Our purpose is to monitor with VST/OmegaCam the Lupus III star-formation region, with the same filters and cadence as the LSST WFD Survey. On the basis of these observations we plan to optimize suitable diagnostics (e.g., color-color diagrams) useful to select LSST sources of our interest. The ESO report is expected before end of the year.

- **e-Rosita Observing Proposal: X-ray counterparts to FUors and EXor accretion bursts in Young Stellar Objects**. PI: Beate Stelzer, co-Is : T.Giannini and R.Bonito.

List of attached documents:

1. White Paper "Investigating the population of Galactic star formation regions and star clusters within a Wide-Fast-Deep Coverage of the Galactic Plane" (co-PIs: L.Prisinzano and L.Magrini)

2. White Paper "Young Stars and their Variability with LSST" (co-PIs: R.Bonito and P.Hartigan

5   Other information

5.1   Organization of meetings and conferences

Our groups (R.Bonito as SOC and LOC Chair, F.Damiani and T.Giannini as SOC members) has organized the 2018 Palermo workshop on "Large Synoptic Survey Telescope - Special Programs Workshop", 8-10 October 2018. R.Bonito held also relevant roles in the organization (SOC) of other LSST meetings:

- Large Synoptic Survey Telescope Corporation Transients and Variable Stars workshop (http://eventi.na.astro.it/lsst-tvs-2018/), 9-11 April 2018, Napoli

- LSST TVS Survey Strategy Proposal Preparation Workshop Conference (https://lsst-tvssc.github.io/DDFMS_meeting_2018.html), 4-8 June 2018, Lehigh University, PA (USA)

Rosaria Bonito has moreover contributed with a special role as:

- Primary Contact of sub-group "Non-degenerate Eruptive Variables" in TVS (https://lsst-tvssc.github.io/index.html#members)

- Chair of Task Force devoted to preparation of DDF and MS Special Programs (https://lsst-tvssc.github.io/MS_DDF_task_force_work_plan.html) for the LSST Cadence Optimization

- PI of project (started Feb. 2018): Young stars with variability: (https://community.lsst.org/t/lets-coordinate-observing-cadence-white-papers/3144)

5.2 Participation to meetings and conferences

We presented talks at several meetings and conferences:

- **F.Damiani** talk at the ESO Workshop: "A revolution in stellar physics with Gaia and large surveys", Warsaw, Sept.2018

- **R.Bonito** invited talk "Minisurvey and DDF proposals"

- **R.Bonito** talk on young stars studies, accretion, variability and future prospects with LSST, European Week of Astronomy and Space Science, 3-6 aprile 2018, Liverpool

- **R.Bonito** talk on accretion processes and outflows in young stars, and future prospects with LSST, meeting on Protoplanetary disks, 25-28 June 2018, Roma

- **R.Bonito** invited talk on WP scientific cases on young stars, workshop on "Metrics Analysis Framework (MAF) for LSST", 17-19 September 2018, Torino

- **R.Bonito** talk on the study of jet and accretion shocks in young stars with disks, and future prospects with LSST, conference JETSET FP6, Jet Simulations, Experiments, Theory - 10 years later, what is next?, 22-24 maggio 2018, Meudon

- **L.Prisinzano** talk at the LSST@Europe Conference, Lyon, June 2018

- **S.Antoniucci** TVS meeting - Osservatorio di Capodimonte - Aprile 2018

- **S.Antoniucci** invited talk on scientific case of Young Stellar Objects observations with SOXS, I Congresso Italiano SOXS - Pavia 10-12 Dicembre 2018.

5.3 Telecons etc.

Group members have participated to (bimonthly) TVS telecons, to SMWLV telecons, and to telecons on TVS Roadmap. R.Bonito has organized telecons for the NDEV group, and for the TVS task force.

6 References

- Damiani, F. 2018, A&A, 615, A148: The low-mass pre-main sequence population of Scorpius OB1

- Prisinzano, L., Damiani, F., Guarcello, M. G., et al. 2018, A&A, 617, A63: Low-mass star formation and subclustering in the H II regions RCW 32, 33, and 27 of the Vela Molecular Ridge. A photometric diagnostics for identifying M-type stars

- Venuti, L., Damiani, F., & Prisinzano, L. 2018, arXiv:1811.02731 (A&A, in press): Deep, multi-band photometry of low-mass stars to reveal young clusters: a blind study of the NGC 2264 region

- Giannini, T., Munari, U., Antoniucci, S., et al. 2018, A&A, 611, A54 : The 2016-2017 peak luminosity of the pre-main sequence variable V2492 Cygni

- Jurdana-Šepić, R., Munari, U., Antoniucci, S., Giannini, T., & Lorenzetti, D. 2018, A&A, 614, A9 : Towards a better classification of unclear eruptive variables: the cases of V2492 Cyg, V350 Cep, and ASASSN-15qi

- Giannini, T., Munari, U., Lorenzetti, D., et al. 2018, Research Notes of the American Astronomical Society, 2, 124 : The Mass Accretion Rate of the Young Variable Star GM Cep

- Giannini et al. : ATel 11658, 11705, 11811, 12054