SED Machine Proposal Call
Proposals Due: 20 December, 2018
Period of Coverage: 1 Feb 2018 – 31 Jan 2019

On behalf of the ZTF SSC, we are issuing this call for proposals for usage of the ZTF partnership share of the P60 + SED Machine instrument (65% of the total time on the telescope). The SED Machine (SEDM) is comprised of a (very) low resolution integral field spectrograph, along with the 4-color "rainbow camera" imager – for full details of the instrument, see Blagorodnova et al., PASP, 2018 (http://adsabs.harvard.edu/abs/2018PASP..130c5003B). Proposals should use the template below and be routed through the appropriate Science Working Group before submission.

Questions: Brad Cenko (brad.cenko@nasa.gov)

SEDM Proposal Template

Part I: Summary (1 paragraph)

In the 2019 Semester, the Galactic Science WG would like to propose using the SEDM/IFU for the classification of "quiescent" low-mass X-ray binaries (qLMXBs) and Cataclysmic Variables (CVs), as well as the monitoring of an interesting Be star HO Pup. Candidates for both qLMXBs and CVs will be selected from ZTF triggers, and low-resolution spectra are needed to classify these candidates. HO Pup recently experienced unusual fading events (> 2mag) and back to normal/quiet phase. We would like to monitor the change of Balmer line profiles if HO Pup undergoes a similar event in 2019. In total, we request 37 hours of SEDM time for our program.

Part II: Team Members / Resources

PI / Point of Contact: Chow-Choong Ngeow
Co-Is: Chien-De Lee, Eric Bellm, Paula Szkody, Po-Chieh Yu, Thomas Kupfer
Science Working Group: Variable Stars/Galactic Plane WG
Associated Resources (facilities, etc.):

Part III: Science Objectives (1 page)

A: SEDM Classification of New State-Changing XRBs. X-ray binaries with neutron star and black hole primaries are primarily discovered through their X-ray outbursts detected by all-sky monitors (e.g., Swift-BAT and MAXI). However, this selection function biases against discovery of so-called "quiescent" low-mass X-ray binaries (qLMXBs), of which thousands lurk undetected in our Galaxy. Time-domain signatures from ZTF such as flickering, periodic modulation, and accretion state changes can identify likely counterparts. Discovery of a few tens of high-confidence qLMXB candidates would significantly expand the known field population. As evidence that this approach is feasible, we note that ZTF (and PTF) have detected outbursts from ROSAT sources that later had large outbursts that triggered X-ray monitors, leading to classification as black hole X-ray binaries: e.g., Swift J1858.6-0814 was detected a month before its X-ray trigger as ZTF18abzvvjh. We expect the major contaminant for this search to be CVs. We will also be sensitive to optical outbursts from XRB candidates in M31 and M33 to confirm and characterize their optical counterparts.

B: SEDM Classification of Cataclysmic Variables. Cataclysmic Variables (CVs) are close binaries (periods of hours) that undergo disk instabilities in the accretion disks surrounding the primary white dwarf or changes in mass transfer from the late-type main sequence star that result in large (2-9 mag) amplitude changes in their light curves. While these large amplitudes are detected by ZTF, they can be due to other types of variables other than CVs, so spectra are needed to determine a correct classification. The typical signature of a CV at outburst or high brightness state is broad Balmer absorption (and often HeII4686) caused by the dominant light source being the optically thick, hot accretion disk. As the system returns to its quiescent, low brightness state, the Balmer lines become strong emission lines, the typical signature of a CV. The correct classification of a CV enables a determination of the number density of CVs as a function of galactic latitude, which leads to a test of population models. Since the lowest mass transfer rate systems have the largest amplitude outbursts (>5 mags), most large amplitude outbursts found in ZTF should be from newly discovered unknown systems and be faint at quiescence.

C: Spectroscopic Follow-up of the Disk Formation and Dissipation Process in an active Be Star: HO Pup. Be stars are known to be spectroscopic and photometric variables with heterogeneous semi- or irregular variations. With the launch of ZTF, we have initiated a program to investigate the (short-term) variability of Be stars, especially for the faint Be stars excluded in previous work. ZTF data taken during the commissioning phase revealed that one Be star, HO Pup, displayed multiple ~2.5 mag fading events (13.5 to 16 mag; referred to here as active phase) from Nov 2017 to Jan 2018. These fading events were confirmed with ASAS-SN light curve data. Furthermore, neither the long term ASAS-SN light curve in the past few years nor the recent ZTF data taken in late 2018 exhibit such fading events. Therefore, comparing the spectral change of HO Pup during its active and non-active phases could reveal the nature of such fading events, especially from the change of the line profiles of the Balmer series. Since the fading events are sporadic, HO Pup may undergo such events in 2019, and we would like to take spectra during those events to compare with the SEDM spectra (shown to be similar to a typical Be star) taken in late 2018 during its non-active phase.

Part IV: Past Usage (1 page)

Description:

In 2018, we used 75 minutes of SEDM to obtain time-series spectra for two Be stars, HO puppies and V722 Tau. For the CV program, a few targets were requested via the Growth Marshal, however none were accomplished (bad weather in Dec prevented many targets to appear in the Growth Marshal).

Publication List:

A paper is currently under preparation for HO Pup and V722 Tau.

(For details of previous requests, see:
http://www.oir.caltech.edu/twiki_ptf/bin/view/ZTF/SEDMachineWhitePapers)

Part V: Observing Details (1 page)

Triggering Criteria:

Past selection from the Growth Marshal since June 2018 has identified about 30-40 CVs each month when the weather is good, with ~half previously known CVs and the rest new sources. While some are easily identified from their unique light curves, the others are questionable and need confirmation which can be provided by SEDM spectra. Szkody leads the CV section on the Growth Marshal and will be responsible for the selection of CV candidates for SEDM. Similarly, SEDM observations of qLMXB will be triggered on ZTF alerts that crossmatch to major X-ray all-sky catalogs (e.g., ROSAT), as well as X-ray surveys of M31 and M33, and show significant state changes (>0.5 mag). Trigger of HO Pup will be based on the ZTF and ASAS-SN light curves collected in 2019 when it shows fading events (>2mag) again.

Observing Sequence:

For both qLMXB and CV candidates, we will obtain a single epoch of SEDM spectroscopy in order to confirm the presence of broad z=0 Balmer lines (and He lines). We expect 1-3 triggers per months for the combined qLMXB and CV candidates. For HO Pup, we would like to obtain weekly SEDM spectra when it shows the fading events (i.e. at active phase). Considering HO Pup can be visible at Palomar Observatory for ~4 months, hence the maximum number of weeks to perform the weekly monitoring is 16 weeks.

Total Time Request:

The qLMXB and CV candidates are expected to be 18-20th magnitude objects, with an estimated 30 triggers in 2019. At 41 min (including overhead) for each trigger, this amounts to about 21 hours to take single epoch SEDM spectrum to classify the qLMXB and CV candidates. The M31/M33 X-ray cross-correlations are expected to be 19-21st magnitude objects with about 4 triggers in 2019. At 120 min (including overhead) for each trigger, this amounts to 8 additional hours. In contrast, the weekly monitoring of HO Pup using SEDM will take 8 hours (spread out in 16 weeks). Altogether, the total requested time for our program is **37** hours.

Part VI: Publication Plans (0.5 page)

We are working on a paper to report our finding of the interesting Be star HO Pup. The SEDM spectra collected in 2019 will be included in our second paper in a series papers focused on the study of Be stars variability, both photometrically (light curves from ZTF) and spectroscopically (spectra from SEDM).

Given the small number of known qLMXBs, candidates confirmed with SEDM spectra will receive additional detailed follow-up spectroscopy with APO and other facilities and published in individual or small-sample papers. The candidate CVs identified in the first year are planned to be published by summer 2019.