Solar System Science with SED Machine

ZTF Solar System Science Working Group

Summary

The low-resolution and fast turn-around time of SEDm are ideal for studying the composition of solar system objects and transient phenomena. We propose to obtain spectra of approximately 100 asteroids and cometary outbursts with the SEDm.

Time request: an average of 13 hours per month.

Team Members / Resources

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Science Working Group: ZTF Solar System SWG
Associated Resources: Lulin Observatory 1-m telescope, ARC 3.5-m telescope, Gemini

Science Objectives:

Rotationally resolved spectra

It is a long-standing assumption that the surface property of an asteroid is homogeneous, which is mostly due to the difficulty of obtaining rotationally resolved asteroid spectra. However, recent studies showed the slope of asteroid spectra can vary along with rotational phase, such as (21) Lutetia (Lazzarin et al. 2010) and (16) Psyche (Sanchez et al. 2017). Moreover, the images obtained from asteroid space missions also showed diverse surface properties. Therefore, it is interesting to understand how often such variation in asteroid spectral slope can happen, what the root cause is and how long such variation can be maintained. To measure asteroid surface properties, only low resolution spectra are required. Combining the rotation periods measured by ZTF and the SEDm, we will be able to conduct a survey on rotationally resolved spectra.

Monitoring of main-belt active asteroid candidates

The sizes of the MBCs are normally in the range of a few km. This makes spectroscopic measurements by SEDm impractical. However, one interesting recent development has to do with the finding of new candidates for active asteroids by Busarev et al. (2017). These authors showed that main-belt asteroids, 145 Adeona, 704 Interamnia, 779 Nina, 1474 Beira and near-Earth asteroid 162173 Ryugu displayed spectral changes in the short wavelength range from aphelion to perihelion suggesting the transient formation of a thin dust coma composed of icy grains. The Busarev et al. study therefore indicates that it is worthwhile to document the spectra of medium-sized main-belt asteroids, especially, those of the C- and B-types at aphelion and perihelion to search for spectral changes.

NEA spectra

Near-Earth Asteroids (NEAs) are defined as asteroids having perihelion distance smaller than 1.3 au and aphelion distance larger than 0.983 au. Many of them have orbits which cross or approach the orbits of major planets, and typical dynamical lifetime of NEAs is the order of million years. It indicates that there must be a continuous supply from other regions of solar system. The main asteroid belt is suggested to be a very likely source region of NEAs. Asteroids are believed to be transported from the main asteroid belt into near-Earth space by a combination of Yarkovsky drift and resonance sweeping. One of the great advantages of NEAs research is the fact that one have opportunities to observe them in the close vicinity when they approach to the Earth. It is not rare to have a close approach of NEA to the Earth at the distance smaller than 0.05 au. The absolute magnitude of 22 corresponds to the diameter of 140-m. We are able to observe tiny asteroids which we cannot detect in the main asteroid belt. NEAs are important also in the point of view of the space guard. It is essential to understand physical properties and chemical composition of NEAs in order to discuss the deflection of their orbits to avoid the impact to the Earth. Here, we propose to carry out low resolution spectroscopy of NEAs at the close approach to the Earth.

Cometary Outbursts

ZTF is expected to discover or otherwise observe several moderate to large cometary outbursts per year ($\Delta m \geq 2$ mag, typically 1 every few months). Outbursts can result from a variety of physical phenomena, including rotationally induced mass loss, exothermic phase transitions in water ice, or subsurface gas pressure build-up, each of which is believed to expose or excavate sub-surface material. These spontaneous events present an opportunity to study nucleus structure and sub-surface composition, and to evaluate outburst mechanisms in general, across a variety of cometary dynamical classes (e.g. long-period, Jupiter Family, and Centaur comets). We propose to use SEDm to examine the dust and gas characteristics of the ejecta, especially gas taxonomy (carbon-chain typical vs. depleted; A'Hearn et al. 1995) and dust scattering properties (typical red scattering vs. neutral or blue due to the presence of ice or small dust grains). For this we require two SEDm spectra for each moderate to large outburst observed by ZTF. The first would be obtained as soon as possible (hour to day timescales) after the discovery of an outburst, and the second would target the comet once it has returned to its baseline quiescence (~week timescales). SEDm spectra of comets contain dust continuum and gas emission lines (CN, C_2, C3, NH2).

Past Usage:

20 minutes to observe the outburst of 129P/Shoemaker-Levy 3. The spectrum has a neutral/blue shape suggesting the presence of water ice. It is being combined with Gemini/GNIRS spectra taken 5 days later in a paper in preparation.

Observing Details:

Rotation resolved spectra

Triggering Criteria: regular observation for asteroids of < 16 mag with reliable rotation period
Trigger Method: by email
Observing Sequence: 4 spectra at different rotational phases for each target. Averagely, there are 5-6 asteroids of < 16 mag with reliable rotation period for observation each night. We request ~1-2 objects per month. Each object has 4 exposures and each exposure is 1930s (including overhead), and therefore, the total time of each object is ~2 hours.
Total Time Request: 4 hr/month

Monitoring of main-belt active asteroid candidates

Triggering Criteria: regular observation of the aforementioned large targets (m < 15 mag or diameter > 50km, 27 C-type asteroids in 2019)
Trigger Method: by email
Observing Sequence: 4 spectra per month or 2 spectra per target (i.e., at different orbit position) of each target. Each exposures is 1380s (including overhead), and therefore, the total time of each object is ~1.5 hours.
Total Time Request: 1.5 hr/month

NEA spectroscopy at close approach to the Earth

Triggering criteria: The ephemerides of NEAs are available and we have 74 close approaches of NEAs (with minimum distance smaller than 0.05 au and absolute magnitude brighter than 22.0 mag) from Mar/2019 to Mar/2020.
Trigger method: by e-mail
Observing sequence: 2 spectra for each close approach. Typical apparent magnitude of NEAs of H = 22 at the distance of 0.05 au is 14-15 mag. 2000 sec is required per exposure (including overhead). For 74 close approaches, 85-hr is requested in total.
Total time request: 7 hr/month

Cometary outbursts

Triggering Criteria: cometary outbursts with brightness increase of >2 mag
Trigger Method: by email
Observing Sequence: Two-epochs of IFU spectroscopy per event, with the expectation of ~1 event per 2 months. Spectra will generally be limited to 2000 s.
Total Time Request: 8 hours per year

Publication Plan

We plan to collect up to ~20 rotational resolved spectra to discuss the general taxonomic dependence on asteroid surfaces. Once a possible taxonomy-changing object was found, we will propose using Gemini for follow-up observation. We plan to publish the result in a summary paper.

The cometary outburst spectroscopy will either be published in a summary paper or, for especially interesting events, in papers focused on individual outbursts. Typically, the spectra will be combined with ZTF, GROWTH partnership, and Las Cumbres Observatory photometry, and/or near-infrared spectroscopy from the IRTF or Gemini, depending on the successful follow-up and details of each event.