# Time-domain Spectroscopic Observatory (*TSO*) for TDA in *Roadmap*

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***Summary*:** *TSO* was proposed to SALSO as an imaging (field acquisition) and spectroscopy (resolution R = 25/4000) telescope with two primary science objectives: i) *Mapping the Epoch of Reionization (EOR) with GRBs* and ii) *Tracing supermassive black hole (SMBH) mass vs. z with LSST transients*. The 2.4m Large Space Optic (LSO) is configured with a focal plane instrument based on the RIMAS instrument (0.9 – 2.4μm) developed at GSFC. GRB triggers are from *Swift, MIRAX-HXI* or future more sensitive GRB imagers are observed (within ~1-3h of trigger) and redshifts measured with a R = 25 objective prism sensitive to AB = 25 in 300sec. Those with z >6 are then observed with R = 4000 for integrations sufficient to measure both host and intervening IGM absorption redshifts to map growth of cosmic structure. JWST is not fast enough and GMT/TMT are not sensitive enough to do this. *TSO* would provide the spectroscopy to enable astrophysics of countless classes of LSST variables, from extreme stellar flares to the most luminous pair instability supernovae (PISNe), each identified uniquely by spectra. The mission would best operate in an equatorial geosynch orbit, which also optimizes LSST overlap. Independent of SALSO, a ***0.5-2.4μm telescope <u>in space</u> is essential for TDA***.

**Primary Science Goals**

1. *The very first stars (Pop III)* are no longer thought to be stars of ~200 $M_\odot$ which would likely explode as PISNe and thus not produce a black hole and GRB, but rather to be more "normal" ~30 – 100 $M_\odot$ which also may have binary companions (see Bromm 2012). Thus both conditions needed for GRBs, namely stellar BHs and high angular momentum, are met and GRBs are very likely from the first stellar populations that are formed and then responsible for the Epoch of Reionization (EOR). This further strengthens the motivation for the long-held notion that GRBs are the best (and in fact only) stellar objects to trace the evolution of the EOR as well as the star formation rate (SFR) vs. z during the EOR, which were the highest science priorities from the Galaxies across Cosmic Time Panel of the Astro2010 Decadal Survey.

2. *The growth of supermassive black holes* in galactic nuclei and their mass scaling with the Bulge mass of their host galaxy (M-sigma relation) are keys to the formation and evolution of galaxies. Of primary importance is the formation epoch of the first SMBHs and the subsequent dependence of the SMBH mass spectrum on z. With the large sample of AGN and QSOs both known (e.g. from SDSS) and to be discovered (e.g. from DES), LSST will have enormous samples ($>10^6$) for which repeated magnitude measures will produce power spectra and break frequencies that scale with SMBH mass (see McHardy+2006). With *TSO* spectra (0.9 – 2.5μm) sampled during large flares, reverberation mapping in emission lines (e.g. Hα at z = 2; or MgII at z = 6) will yield SMBH masses directly for comparison to constrain SMBH mass vs. z. LSST discovery of tidal disruption events (TDEs) will measure quiescent SMBHs and their host galaxy mass.

*More generally, a TSO provides highest sensitivity or priority spectroscopic followup of countless classes of variables discovered each night with LSST, "solving" what is widely recognized as a significant bottleneck for this dominant telescope for Time Domain Astronomy (TDA) for the coming decade*. The NASA Roadmap should include this.