SPACE TIME-DOMAIN ASTROPHYSICS IN THE 2020'S. J. Grindlay, Harvard University, Center for Astrophysics | Harvard and Smithsonian, 60 Garden St., Cambridge, MA 02138

Introduction: Time-domain astrophysics (TDA) from space will (or should) be a major part of the Space Astrophysics Landscape for the 2020's and beyond. *XARM* high resolution X-ray spectra and continued *Chandra* and *XMM* imaging and spectroscopy will study GRBs, transients and extreme variables detected by the current (*MAXI*, *Swift/BAT* and *Fermi/GBM*) wide-field imaging monitors. However these and JWST will still not enable using high redshift Gamma-Ray Bursts (GRBs) as back-lights to probe the formation of structure and galaxies and PopIII massive stars before and in the Epoch of Reionization (EoR), which was the primary motivation for the proposed *EXIST* mission [1]. Neither JWST or WFIRST can slew soon enough to do this and 8-10m ground-based telescopes are limited by atmospheric OH backgrounds, weather and scheduling. Both current and proposed wide-field monitors have FoV's <0.5sky so that most high-z GRBs and LIGO events are missed.

Accordingly, in this talk I present two mission concepts for space TDA in the 2020s that would finally enable a wide range of key NASA science objectives.

Time-domain Spectroscopic Observatory (*TSO*): This is a proposed Probe-class ~1.3m telescope with imaging and spectroscopy simultaneously in 4 bands spanning 0.3–5.5μm. With a cold (110K) telescope in either GeoSynch orbit or at L2, *TSO* can slew (<5min) to ~80% of the sky for prompt identification and photo-z's simultaneously in 4-bands (AB ~26 in 10min) and scientifically unique spectra of GRBs out to redshifts z ~15. This will enable the first direct discovery of PopIII stars, very likely massive and GRB progenitors, by *TSO* spectra with either R = 300 or 1800 (selected by discovery magnitude). GRB090423 (the first high-z *Swift* GRB at z = 8.2 [2]) would be detected with R = 1800 at 10σ per pizel in 5 x 30min spectra to measure the HI ionization fraction in the IGM vs. host galaxy from Lyα damping wing fits. A large sample of GRB spectra with *TSO* (triggered by a full-sky high resolution imaging SmallSat Constellation, the 4π X-ray Imaging Observatory (*4piXIO*; see below) would measure SFR(z) out to z ~8 – 15 from high-z spectroscopy only possible with prompt *TSO* followup.

TSO in GeoSynch "over *LSST*" would provide highest priority *LSST* transients with prompt (<10min) spectroscopy. Reverberation mapping of AGN flares selected (in GO programs) from the *LSST* deluge for AGN out to z ~8 (beyond the current z limit for AGN) would measure SMBH masses from the "gold standard" Hβ time-lags and velocity widths to trace SMBH masses back to their first formation epochs. TDEs in dusty star-forming galaxies discovered as red transients by *LSST* could be rapidly distinguished from SNe by *TSO* spectra and constrain SMBH masses in non-AGN obscured galaxies and measure the SMBH M-σ relation. The *TSO* team is conducting a mission design and cost study for Astro2020 White Papers.

4π X-ray Imaging Observatory (*4piXIO*): Both LIGO/VIRGO and ICECUBE provide instantaneous full-sky (4π) coverage, but no EM radiation TDA survey has been possible with true instantaneous full-sky imaging coverage. We propose a SmallSat Constellation design consisting of 32 wide-field coded aperture high-resolution (~1.5 arcmin; and <10" source locations) telescopes, each with a 30^o x 30^o (FWHM) field of view (FoV). The SmallSat Constellation would be launched into a 600km x 20^o inclination low Earth orbit (LEO) roughly evenly spaced around the Earth.

In order to develop this mission concept, we proposed and were awarded a NASA Astrophysics Small Sat (AS3) Concept Study based on our ongoing High Resolution Energetic X-ray Imager (HREXI) program under APRA. We have developed a design for a single HREXI SmallSat Pathfinder (HSP) in collaboration with Blue Canyon Technologies (BCT) using their flight-ready "S5" spacecraft bus that is well-matched to our HSP imager design. HSP is being designed to be proposed for a Mission of Opportunity launch for a 1 – 2 year mission for Galactic Bulge BH-LMXB/MMXB science and to achieve the TRL, cost and operations to then enable a SMEX proposal for a *4piXIO* mission.

4piXIO (3-200 keV) would provide nearly uniform *full-sky* ~1' imaging sensitivity ~2X deeper than BAT. High-priority GRBs and transients can be imaged simultaneously by 16 SmallSats for 8X deeper 30^o fields. The combined survey capability over the full sky in this "targeted" vs. "survey" (full sky) pointing mode are significant and would open up a new era in both TDA and full-sky Survey science. SmallSats will offer new opportunities for Astrophysics: broad band from LEO should enable secure downlinks to, and instrument commands from, your laptop. Astrophysics and NASA need to be a (major) part of this. WiFi in LEO should not be squandered on "Hotels in Space".

References: [1] Grindlay, J., et al (2010), Proc. SPIE, 7732iX, 19. [2] Tanvir, N.R. et al (2009), Nature, 461, 1245.