The Physics of the Cosmos Program Analysis Group

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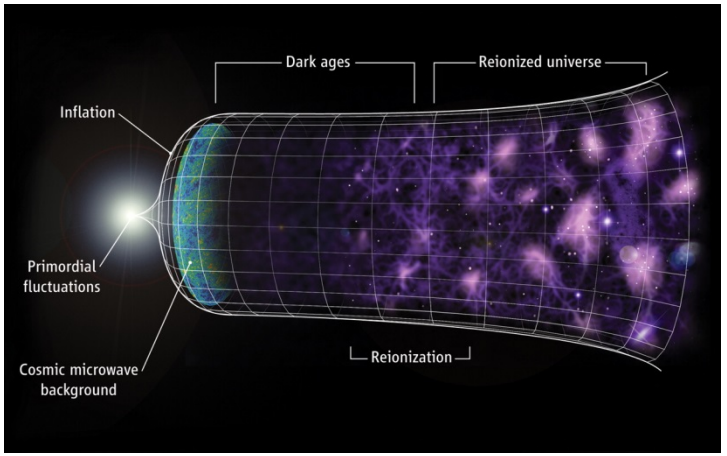
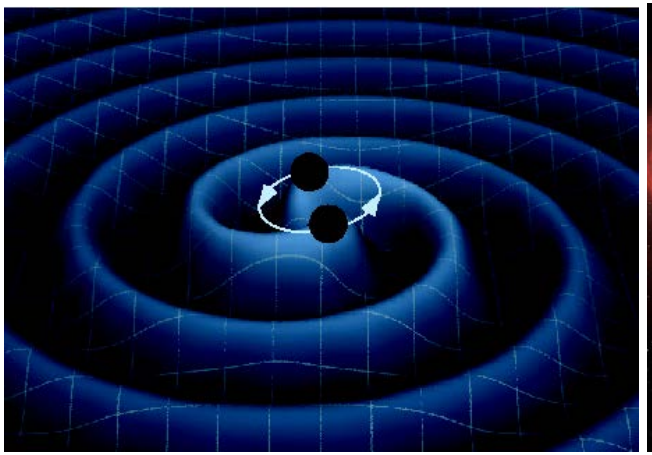
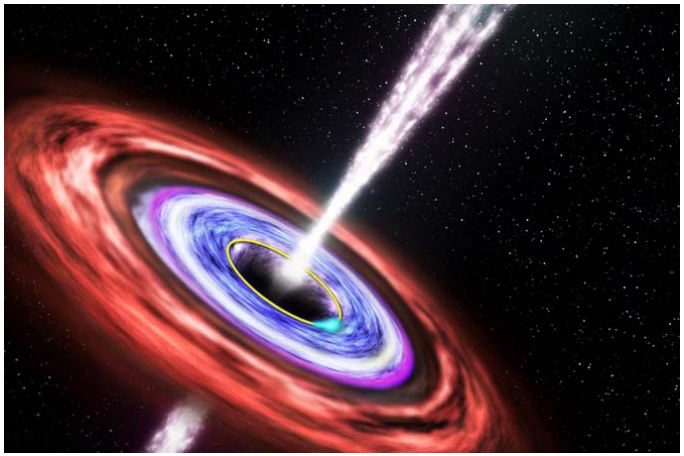






Goals of the PhysPAG

To understand nature of the Universe

- What are its constituents? What are the laws that govern its birth and evolution?

- Dark Energy: Probe the nature of dark energy by studying the expansion rate of the universe and the growth of structure
- Inflation: Test the theory of inflation by measuring the polarization of the Cosmic Microwave Background
- Black Holes & General Relativity: Probe the properties of black holes and test General Relativity in strong gravity environments using x-ray emission and gravitational waves
- Behavior of Matter in Extreme Environments: Explore extreme astrophysical processes with Cosmic rays, X-rays and Gamma-rays

PhysPAG Executive Committee

Name	Institution	Topical Area	Term end
J. Bock, Chair	Caltech/JPL	CMB	December 2016
M. Bautz, Vice Chair	MIT	X-rays	December 2016
R. Bean	Cornell Univ.	Dark Energy	December 2016
J. Bookbinder	SAO	X-rays	December 2015
J. Conklin*	Univ. of Florida	Gravitational Waves	December 2017
N. Cornish	Montana State	Gravitational Waves	December 2016
O. Doré*	JPL	Dark Energy	December 2017
H. Krawczynski*	Washington U. in St. Louis	Gamma-rays	December 2017
M. McConnell	U. of New Hampshire	Gamma-rays	December 2016
A. Miller*	Columbia Univ.	CMB	December 2017
J. Nousek	PSU	X-rays	December 2015
A. Olinto	Univ. of Chicago	Astroparticles	December 2015
Eun-Suk Seo	U. of Maryland	Astroparticles	December 2016
E. Wollack*	NASA/GSFC	CMB	December 2017

*new member

Gathering Input for The Charge

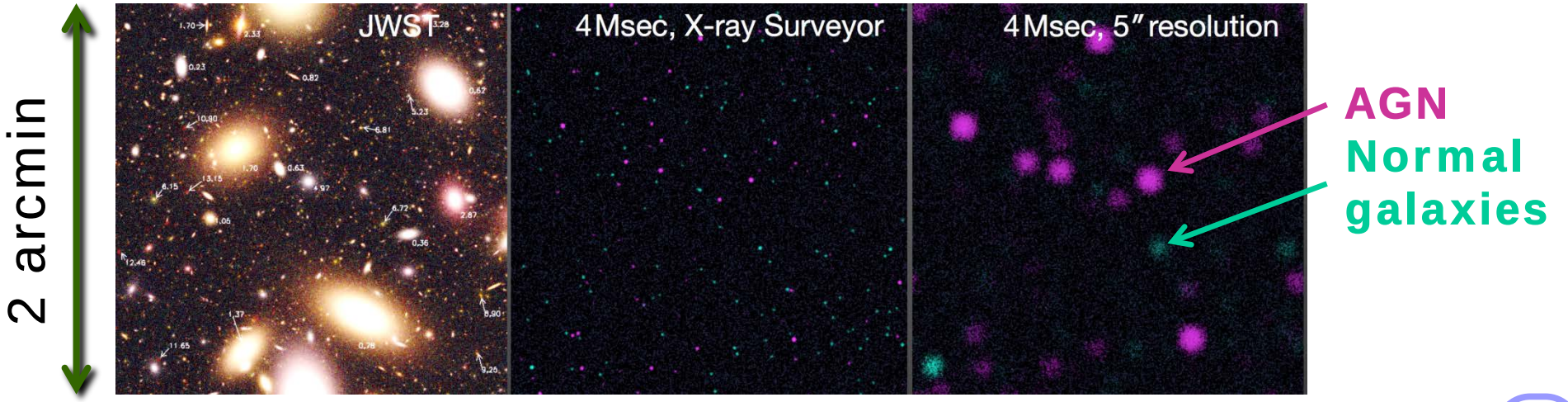
- January AAS, Seattle:
  - X-ray-, Gamma- & Cosmic-SIG, PhysPAG & Joint PAG meetings
- January CMB Pol. Workshop, Minneapolis:
  - IP-SIG discussions
- February 'Future Space-Based Gamma Observatories':
  - Gamma-SIG
- March, Joint PAG EC meeting, Baltimore
- April, APS meeting, Baltimore:
  - Cosmic-, GW- & Gamma-SIG meetings; PCOS & Gamma Mini-symposia
- June/July, HEAD meeting, Chicago:
  - Gamma-, X-ray-SIG & various panels
- Presentations from large missions at PhysPAG EC telecons

PhysPAG Report on Large Missions

- Joint-PAG Executive Summary
- PhysPAG science return from four large mission candidates
  - X-Ray Surveyor
  - LUVOIR & HabEx
  - Far IR Surveyor
- The Gravitational Wave Surveyor and ESA's L3 mission
- The Inflation Probe
- The Probe class mission

The X-ray Surveyor

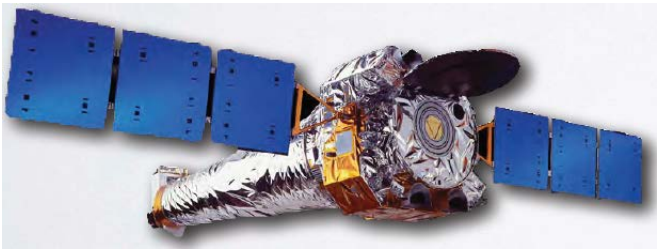
- Origin and growth of the first supermassive black holes
  - Detection of central black holes from earliest galaxies ($z \geq 10$)
- Physics of feedback and accretion in galaxies and clusters
  - Characterize quantity, composition, and energy content of hot gas in Milky-Way sized halos out to $z \sim 1$
- Cosmology and the growth of cosmic structure
  - Provide accurate cosmological growth of structure measurements to $z \sim 1.5$
- Extreme environments
  - Study behavior of matter and spacetime in vicinity of event horizons



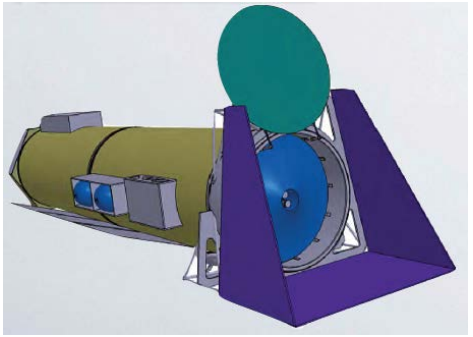
[Gaskin, Vikhlinin et al.]

X-ray Surveyor & Athena

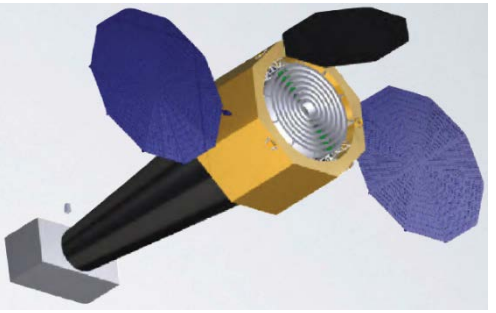
Chandra



Athena (L2)



The X-ray Surveyor



	Chandra	Athena (L2)	X-ray Surveyor
Relative effective area	1	**50**	**50**
Angular resolution (arc seconds 50% HPD)	0.5	5	**0.5**
Point source sensitivity (erg s^{-2} cm^{-2})	5 x 10^{-18} (4 Ms)	2.5 x 10^{-17} * (Survey)	3 x 10^{-19} (4 Ms)
Imaging Field of View	17’ x 17’	**40’ x 40’**	22’ x 22’
Spectral Resolving Power @ 1 keV @ 6 keV	1000 160	400 2400	5000 1200

Sensitivities: Athena: Nandra at al. 2014 Athena Mission Report *confusion limit
X-ray Surveyor: Gaskin at al. 2015 white paper submitted to PhysPAG

LUVOIR (and HabEx)

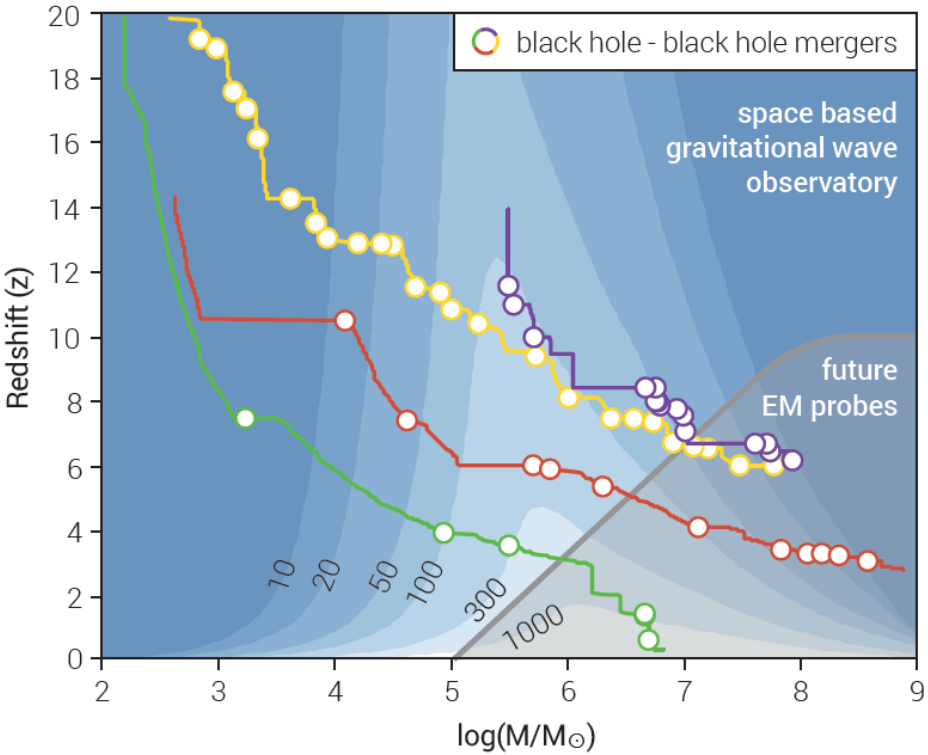
- Unraveling Galactic Dynamics with Proper Motions
  - New level of precision in measuring effects of dark on normal matter
- Precision Measurements of the Growth of Structure
  - Uniquely probe the growth of mass and stellar populations over $1 < z < 3.5$
- Dark Matter Halo Maps with Strong Lensing
  - Expanding Hubble's "Frontier Fields"
- Ultra-Faint Satellite Dynamics
  - Proper motions and radial velocities of stars in dwarf spheroidal galaxies
- Multi-messenger astronomy
  - Large Synoptic Survey Telescope (LSST) at optical wavelengths
  - Square Kilometer Array (SKA) at radio wavelengths
  - Advanced LIGO and Virgo detectors for gravitational waves

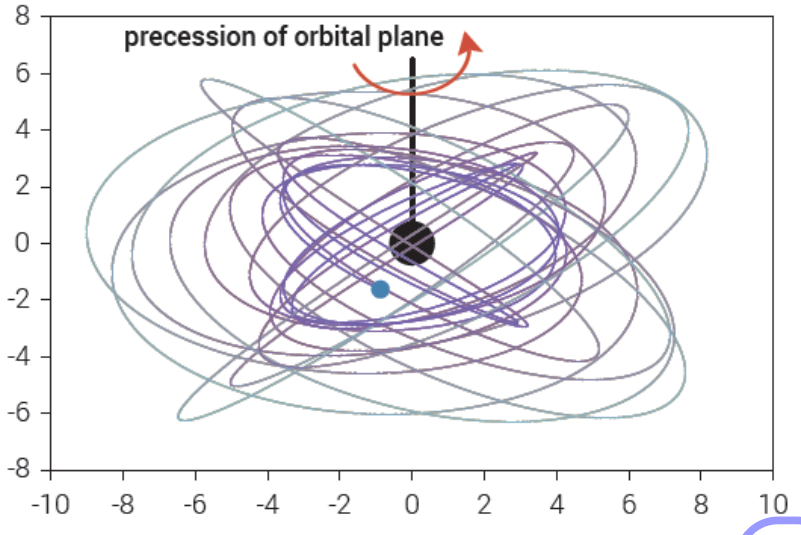
The Far-IR Surveyor

- When did the first supermassive black holes form?
- Evolution of galaxies and their supermassive black holes
- Trace dusty, star-forming galaxies to understand
  - Nature of dark energy
  - Measure certain cosmological parameters
  - Test gravity at cosmological length scales
  - Study the non-Gaussianity of the density distribution
- Complements Euclid and WFIRST by extending clustering measurements to early times ($z > 2$)
- Multi-messenger studies with GW events
- Technology synergies: Inflation Probe, X-ray detectors & optics

The Gravitational Wave Surveyor

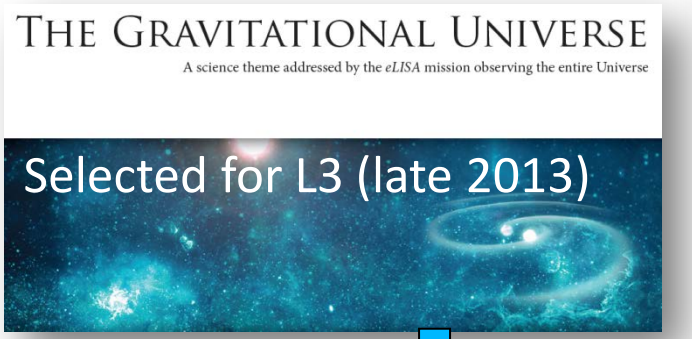
- Broadest & deepest survey
- Evolution of galaxies and their supermassive black holes
- Spin distribution of supermassive BHs throughout universe
- Survey compact stellar-mass binaries
  - Understand structure of Milky Way
  - Population of stellar-mass compact objects in galactic nuclei
- Multi-messenger observations
- Test of GR in strong field regime
- Unknown unknowns

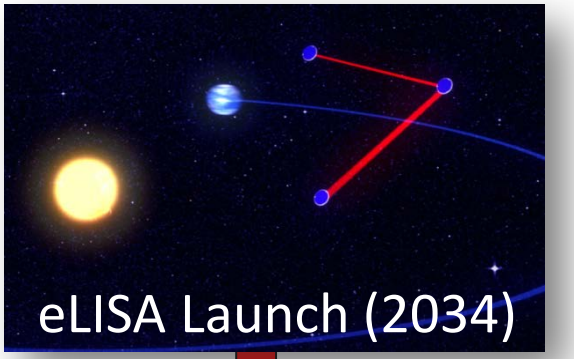




GW Landscape in 2019-2020

aLIGO/VIRG0 detection

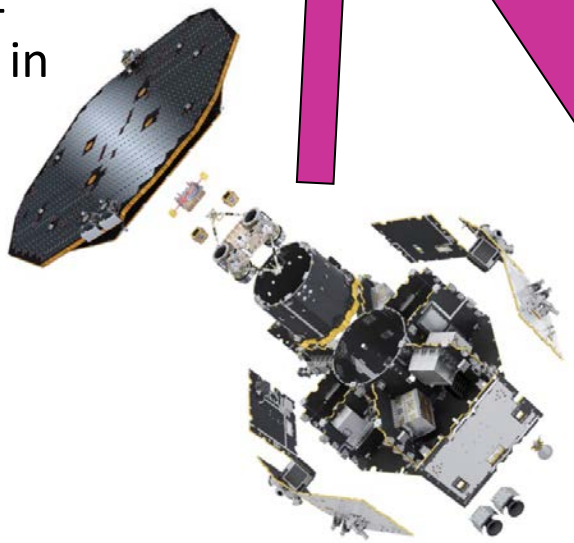




2010 2020 2030

LISA ranked 2nd after WFIRST in NWNH

2020 Decadal



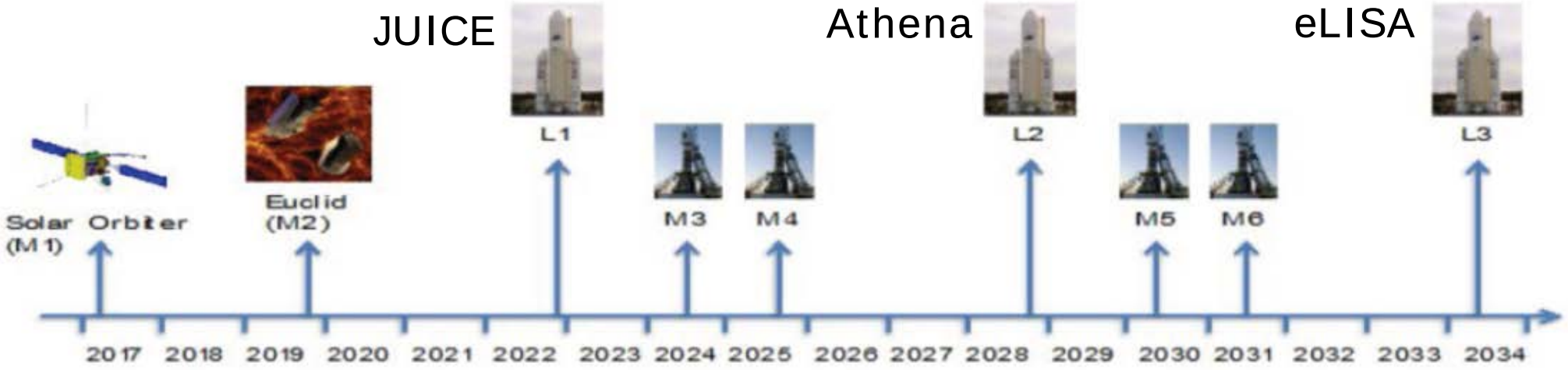
LISA Pathfinder (Nov 2015)

PTA detection

Preparing L3 Collaboration for Decadal

- Viable NASA-ESA partnership on L3 requires:
  - Strong recommendation by 2020 decadal committee
  - Technology development in cooperation with Europe (ESA: TRL 5 by 2020)
- Gravitational Wave Surveyor study to inform the 2020 decadal:
  - Technology assessment: U.S. strengths + new developments
  - Range of options for U.S. participation and contributions
  - Update science case based on knowledge gained since 2010

If these assumptions change, this report needs to be reevaluated



The Inflation Probe

- Science goal:
  - Detection of B-modes produced by primordial gravitational waves
    ⇒ confirmation of inflation and
    ⇒ identification of the energy scale at which inflation took place
- The Inflation Probe is a Probe-Class Mission
  - IPSIG feels the mission fits this category
- PAGs assume the 2010 decadal recommendations will be fulfilled

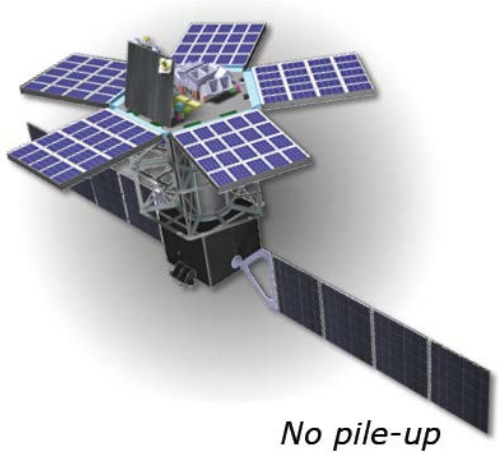
  "The committee recommends a technology program to advance detection techniques … and technology selection and mission development to design a mission to study the signal [if detected]."

If these assumptions change, this report needs to be reevaluated

The Probe Class Mission

- Strong Interest in Probe Missions
- Developing point mission concepts
  - Particularly strong X-ray, gamma-ray, cosmic-ray interest
- Developing a probe category ala Discovery or New Frontiers
- PAGs willing to assist in a future process defined by NASA
- Just a few (randomly selected!) examples of the *many* concepts

LOFT
200 eV, 8.5 m²



Advanced Pair Telescope

Transient Spectroscopic Observatory