THIRTY METER TELESCOPE

# ‘Polarimetry and Time Resolved science Working Group’
# Time Domain ISDT Discussion
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# Exploring the Need for Requirements for Polarimetric and Time Resolved Observing Capabilities with the TMT

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Warren Skidmore on behalf of The Polarimetry and Time Resolved Working Group

TMT.PSC.PRE.14.023.REL01

## Abstract

The observatory requirements needed to support Polarimetric and Time Resolved observing programs are being explored. Many different observing programs covering a range of different science areas are being considered. Technical and cost implications will be balanced with scientific impact, new requirements will be generated with supporting science cases. Science areas include Exoplanet Characterisation, GRBs, Supernovae, Kilonovae, CVs, LMXBs, Neutron Stars, White Dwarfs, Star Formation, Starburst Galaxies, Galactic Structure, QSOs and AGN, Asteroids and Kuiper Belt Objects. This work is being carried out by a large number of people.

## Polarimetry Observing Programs

| | |
|---|---|
| Star and planetary formation | Searches for biomarkers on exoplanets |
| Kinematics around young stars | Flare stars |
| Direct detection and characterization of exoplanets | Magnetic field mapping of solar type stars peculiar stars, variable stars, evolved stars, etc. |
| Exoplanet magnetic fields | Brown Dwarf atmospheric processes |
| Studies of organic molecules, their formation and delivery mechanisms | Dust structure, outflow geometries and emission mechanism in QSOs |
| Soft γ-ray repeaters | Galactic magnetic field structure |
| Cataclysmic Variables | Structures and kinematics in starburst galaxies |
| Interstellar polarization and diffuse interstellar bands | Dust distribution and magnetic field structure in the solar neighborhood |
| Anisotropy of supernovae explosions | γ-ray bursts |
| Characterizing NEOs for sample return missions | Magnetic fields of compact objects |

## Time Resolved Observing Programs

| Observing program | Resolution | Wavelength range | Observation details[2] | Integration time[3] |
|---|---|---|---|---|
| White dwarf surface Calcium pulsation mapping | 6000 | 370nm to 640nm | Time resolved spectroscopy for a few hours of Mg II (4480Å) & Ca K (3933Å) to identify oscillations | 12s |
| White dwarf and sdB star asteroseismology | 4000 | 340nm to 610nm | Time resolved spectroscopy to get pulsation spectra of different modes | 5s |
| | 50,000 | 370nm to 520nm | Mode identification | 5s |
| Pulsar non-radial oscillations and rotation | ~100 | 340nm to 1200nm | Spin phase resolved spectroscopy with frame transfer EMCCDs | 0.1ms |
| Prompt observations of GRBs & GRB afterglow | ~100 | 400nm to 2200nm | TOO time resolved spectroscopy with Mv of 18 to 22 | 1s |
| Supernova core collapse shock breakout | 2000 | 525nm to 950nm | TOO time resolved spectroscopy of targets from surveys | 15s |
| | | 4500nm to 5100nm | TOO time resolved spectroscopy of targets from surveys | 15s |
| Detached WD-WD merger candidates | ~5000 | 370nm to 450nm | Time resolved spectroscopy to get orbital radial velocities[4] | 30s |
| Doppler tomography of Cataclysmic Variables | >4500 | 320nm to 2400nm | Time resolved spectroscopy of orbital changes in line profiles | 15s |
| Cataclysmic Variables: Spectral eclipse mapping | ~1000 | 320nm to 950nm | Rapid spectroscopy to look at line profile changes during eclipse | 100ms |
| Cataclysmic Variables: Studies of rapid variability | ~3000 | 320nm to 950nm | Rapid spectroscopy to look at rapid continuum and line variability | 50ms |
| LMXB echo mapping and Bowen blend secondary star measurements | 1000 | 450 to 700nm | Correlation between X-ray and optical continuum and line emission (especially Bowen Blend 464nm and HeII 469nm) | 100ms |
| Magnetic fields and habitable zones around dwarf flare stars | 4000 | 350nm to 700nm | Time resolved spectroscopy of emission line & continuum changes | 0.1s |
| Exoplanet studies: Transits, secondary eclipses & surface mapping | 1000 | Parts of 700nm to 5000nm | Time resolved spectroscopy of ingress and egress lasting about 30 min around Mv>10 host stars | <30s |
| Exoplanet studies: Rossiter-McLaughlin effect | 60000 | 550nm | Time resolved spectroscopy of 2hr transit around Mv>15 host star | 96s |
| Asteroid morphology, binarity and composition | ~1000 | 800nm to 2500nm | IFU observations of 0.03" sized resolved target rotating in 2 mins or unresolved objects in a binary each with 2 min light curves and a separation of 0.02" | 15s |
| Asteroid orbits | Broadband imaging | Optical/NIR | Wide field AO assisted astrometric observations with an astrometric error of 0.03" | 72s |
| TNO/Kuiper Belt object occultations | ~1000 | 340nm to 5000nm | Rapid spectroscopy of background star with occultation event lasting between 1s and 200s | 10ms |

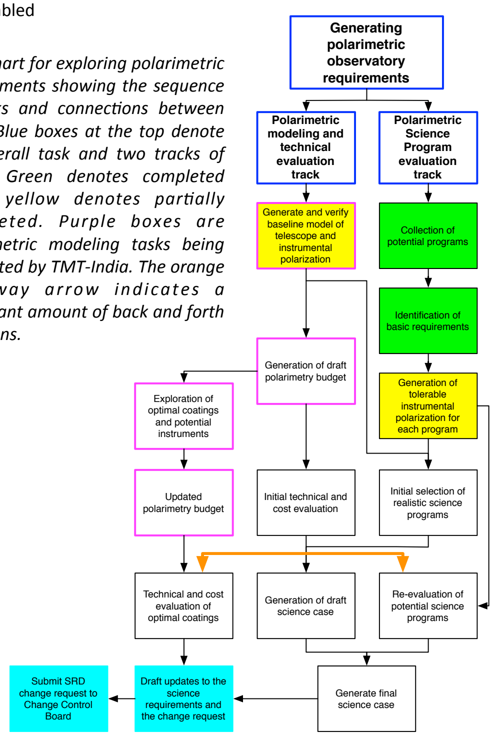
## Ramifications of exploring time resolved requirements

- Lots of high impact science require time resolution between $10^{-4}$s to 100s
- Baseline capabilities of 1st light instruments being explored
- 1st light instrument teams are being 'sensitized' to time resolved science
- Scope for cost neutral changes to reduce dead time and readout rates
- Future instrument designs will respond to community demand
- Development of future instruments will be more rapid than for 1st light
- **Cost neutral emerging new requirement is for a high accuracy time server**

## The process for exploring polarimetric requirements

- We have determined acceptable error bars and observing requirements for a variety of observing programs covering a range of science areas
- We will determine each program's tolerable instrumental polarization
- Zemax modeling is being used to estimate the baseline polarimetric performance for a range of exposure times
- We will explore simple steps that can improve polarimetric performance
- Polarimetry budget and draft subsystem requirements will be generated
- We will determine which science programs can be supported with the baseline and optimal designs
- Technical and cost implications of additional baseline and optimized requirements will be balanced against the scientific merits of programs that are enabled

*Flow chart for exploring polarimetric requirements showing the sequence of tasks and connections between tasks. Blue boxes at the top denote the overall task and two tracks of effort. Green denotes completed work, yellow denotes partially completed. Purple boxes are polarimetric modeling tasks being conducted by TMT-India. The orange two way arrow indicates a significant amount of back and forth iterations.*



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# Lack of Time Resolved Requirements

- No requirements on readout time in the TMT SRD

- But the telescope is required to slew fast (<5 mins)
- Instruments are required to begin observations fast
- Plan for ToO observations of transient objects

- A lot of important science needs time resolved capabilities

- We need some technical requirements to direct the instrument and observatory design and operations

# Aims/Overview

- Definitions
- The stalled process of developing time resolved observing requirements
  - Science areas being considered
  - Emerging requirements
- Issues/difficulties arising during DSC development
  - Lacking specific information on detector capabilities
- The Question to the TD-ISDT
  - Develop detector system performance estimates for time resolved modes? [Task imposed on instrument teams]
- Next steps (assuming ‘yes’!)
  - TD-ISDT to develop possible detector readout configurations

# Definitions

- Time resolved observations for $t_{samp} \leq 6$ minutes
  - Processes with timescales ≤30 minutes.
  - Detector readout schemes and data handling needed proper planning to ensure high (>80%) observing efficiency

# Stalled process

- 'Exploration of Time Resolved Instrument Requirements.'
  - Document circulated to instrument teams, 21st January 2013
  - TMT.PSC.TEC.13.003.DRF01 in DCC collections 7260
    - Wavelength range, spectral and temporal resolution
  - Lacks specific information about required readout modes
    - e.g. how many windows and what size and positions would be needed for multi-object spectroscopy?
    - i.e. How would science observations be gathered in practice
  - No specific feedback received from instrument teams
    - Except for ‘bathroom conversations’ indicating that nothing seemed particularly crazy

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# Emerging requirements

- IEEE 1588 timing signal available
  - Observatory is providing an IEEE 1588 time sever available to all subsystems
- No ‘Quantum devices’
- All targets are point source except asteroids and PHOs
  - Haven’t considered needs for local standards
- Wavelengths 320nm to 5µm
- Spectral resolutions Broad Band to 60,000
- Integration times 0.1ms to 100s (for $t_{dead}<t_{int}/4$)

- None is backed up with comparison against estimated performance

# Issues/difficulties arising during DSC development

- Speculative nature of any proposed programs requiring fast readout
  - Low confidence when proposing ambitious programs

# The Question to the TD-ISDT

Acknowledging that developing proper detector performance estimates requires significant effort by the instrument teams:

‘In order to make proper progress with defining time resolved science requirements, does the TD-ISDT think it necessary that proper detector system performance estimates are developed for appropriate observing modes for the first light instruments and potentially active instrument concepts?'

# Next Steps

- TMT-India is undertaking some instrument mini-studies that relate to detectors
  - Are performance estimates within the scope and timescale of these studies?
- Anna Moore in her talk today asked about ideas for high time reolution
  - Instrument teams are open but communication has not yet happened
  - Request for readout rate studies will ensure that TR cases are communicated to instrument teams
- TD-ISDT could prepare specifications for exemplar detector readout configurations for different programs
  - Instrument teams could estimate how fast a detector system could read out for various readout modes

# Hypothetical target arrangement for estimating a baseline readout time for MOBIE and IRMS

3 comparison stars and 1 science target, centrally located in the MOBIE or IRMS FOV. Diagram shows hypothetical slit arrangement with target stars in the slits, not to scale. Assume slit length to be 10” (or a convenient close value for IRMS)