US Extremely Large Telescope Program Project Science Overview

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Objectives of the US ELT Program

All US astronomers should benefit from national participation in a US ELT Program

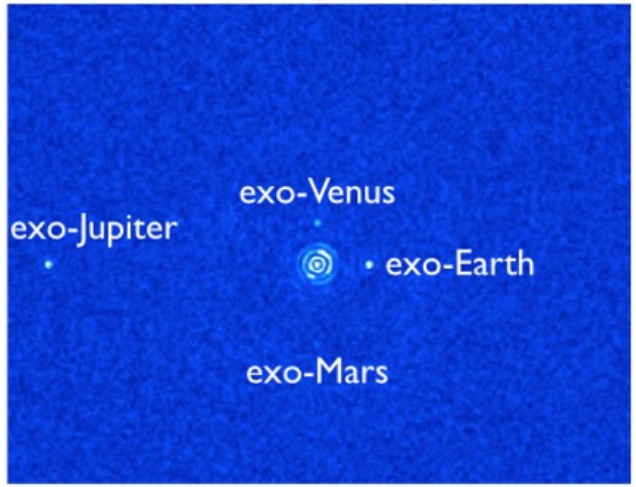
- Enable **transformational science** through US access to a bi-hemispheric ELT system
- Enable and support large-scale, systematic, collaborative research (**Key Science Programs**)
- Provide **outstanding user support** commensurate with the proposed US-ELTP investment
- **Broaden participation in TMT/GMT science** and foster research inclusivity
- **Engage and represent the whole US community** in GMT and TMT governance, scientific planning, and instrumentation development

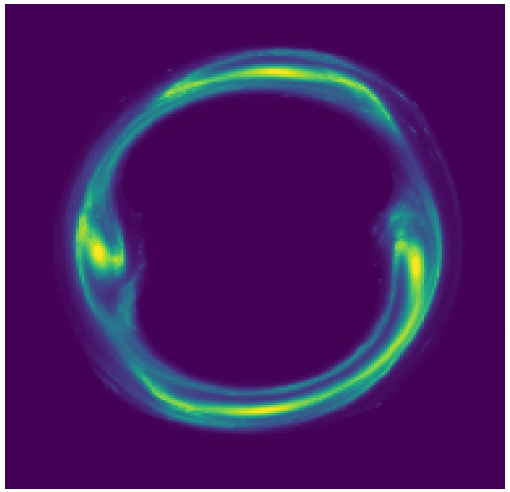
Modes of Investigation

- **Key Science Programs (KSPs)**
  - **Scientific legacy** through systematic investment in **large-scale, transformative research projects**
  - Projects on scales difficult to realize within time shares of current GMT/TMT partners
  - **Broad, inclusive scientist participation** in KSPs via open collaboration models
  - Data products with **high archival reuse value**
- **Discovery Science Programs (DSPs)**
  - Smaller PI-class proposals, allocated more frequently
  - Nimble, responsive to new discoveries, new opportunities, new ideas
- **Archival Research**
  - Community research using **all archived data** from TMT+GMT

Community-Developed KSP Concepts

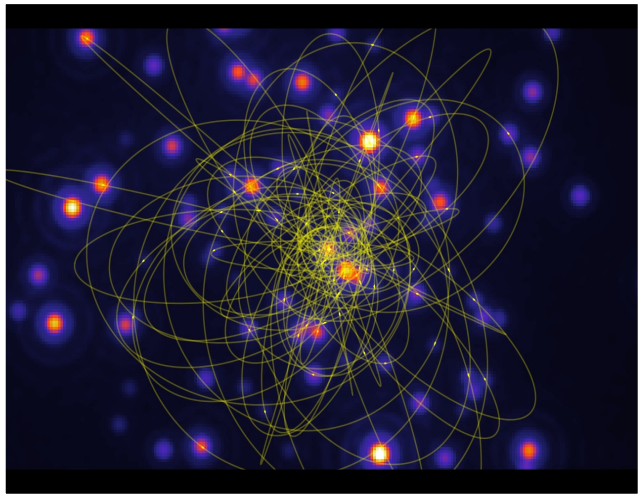
Extrasolar Planets and the Search for Extraterrestrial Life

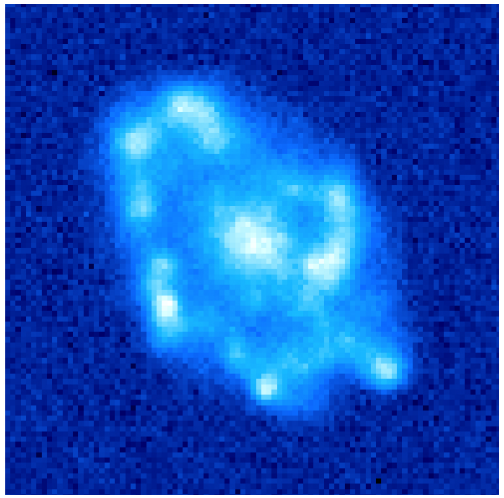




The Dark Universe and Physics Beyond the Standard Model

Extreme Gravity: from Gravitational Waves to Supermassive Black Holes





Resolving the Physics of Galaxy Evolution

+ Solar System, Stars & Stellar Evolution, Explosive Transients, and more

Actual, future KSPs would be selected by peer-review

Research Inclusion

Research Inclusion is central to NOIRLab's US-ELTP mission to enable participation by all astronomers in TMT and GMT science

- Particularly directed toward researchers at **smaller and/or under-resourced institutions (SUIs)**
- **Science-ready data products** will make TMT and GMT more accessible to all observers
- **Archival research creates science opportunities** that scale beyond the bounds of PI observing, and involves researchers from a broader range of institutions
- US-ELTP Data Science Suite will provide an **open platform for user training in data analysis**
- **Key Science Project teams** will be organized following **open collaboration models**
  - Research inclusion will be an element of KSP merit review

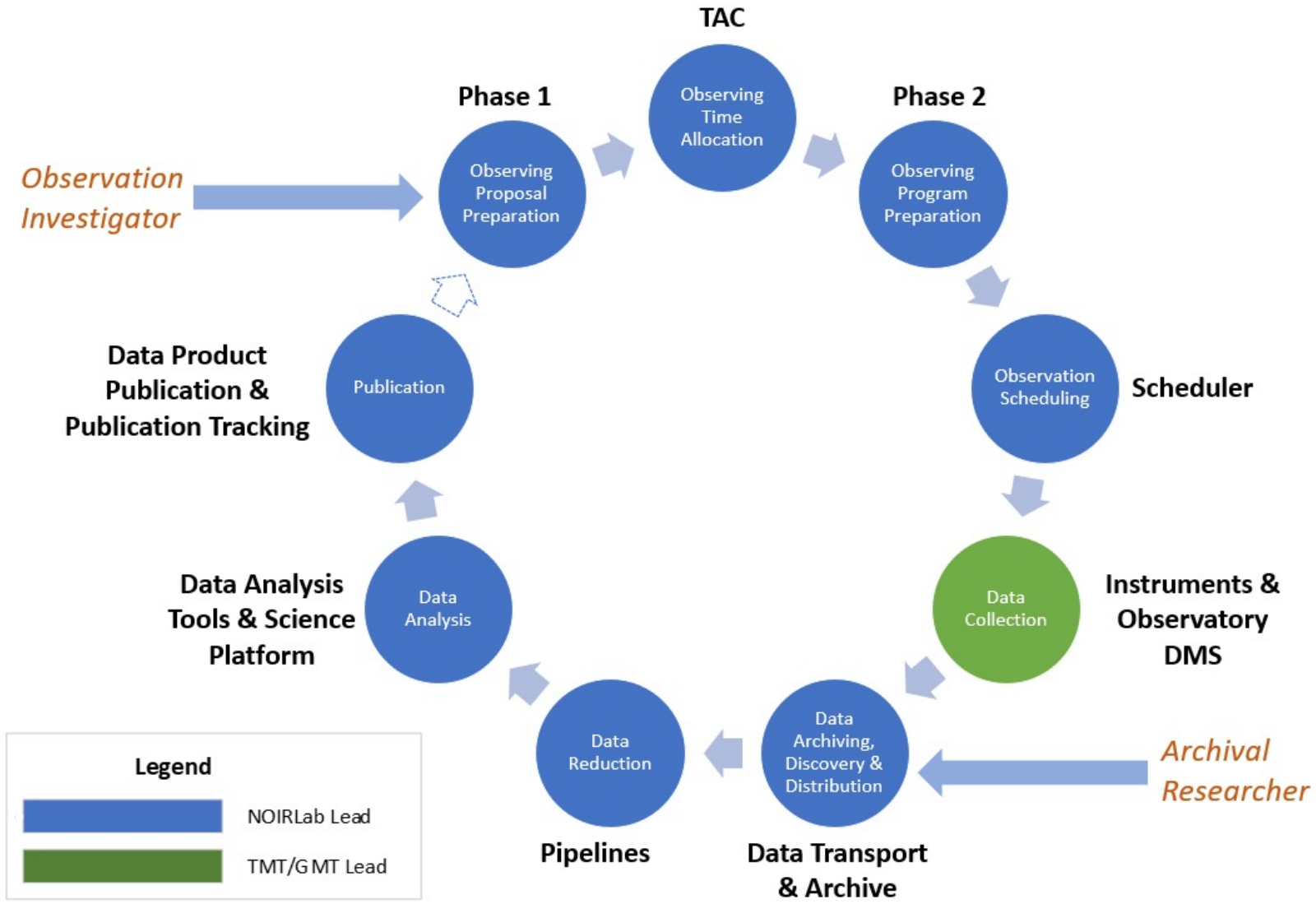
Astro2020 Priorities, NOIRLab Priorities

- *Pathways to Discovery* emphasizes the importance of data archiving, curation and pipelines to enhance the scientific return from ground- and space-based observatories.

> **Recommendation: The National Science Foundation and stakeholders should develop a plan to address how to design, build, deploy, and sustain pipelines for producing science-ready data across all general-purpose ground-based observatories (both federally and privately funded), providing funding in exchange for ensuring that all pipelined observations are archived in a standard format for eventual public use.**

- NOIRLab/CSDC 5-year plan includes enhanced unification of data services for NOIRLab facilities, increased support for data reduction pipelines, and expanded archiving for non-federal ground-based OIR facilities
- Plans for US-ELTP data services are closely aligned with these visions and will be coordinated with new development in CSDC, Gemini and elsewhere within NOIRLab.

Science Data Life Cycle



- NOIRLab will provide user support systems and tools for researchers using TMT, GMT and their data throughout the **Science Data Life Cycle (SDLC)**
- Support will be provided by the **US-ELT Program Platform (UPP)**
- Provide researchers with uniform interfaces to TMT and GMT and their data
- NOIRLab's services and tools will be available to all GMT and TMT partners

Guiding Principles for the UPP

- Provide a level of support unprecedented for US ground-based OIR telescopes
- Provide researchers with uniform interfaces to TMT and GMT and their data
- Partner with TMT and GMT technical teams to develop requirements and define interfaces
- Minimize duplication of effort and define clear roles and responsibilities
- Inform design from existing NOIRLab systems where appropriate
- Upgrade based on lessons learned & specific US-ELTP requirements

Guiding Principles for the UPP

- NOIRLab's US-ELTP user support services are available to all TMT/GMT partners
- All UPP software will be open-source
- Partners may choose which services to use, and wherever possible, may adapt or configure them to meet their particular requirements, e.g.:
  - Phase 1 tools to support partner proposal requirements or joint proposals with other observatories
  - TAC tools to support partner's own Time Allocation processes
  - NOIRLab archive and data services are open to all partners, or they may establish their own
- Place control where it belongs, e.g.:
  - Review of observing proposals handled by each GMT/TMT partner for its own community
  - Observation scheduling carried out by observatories
  - TMT/GMT partners are primarily responsible for supporting their own individual users

UPP and NOIRLab heritage

- UPP will build off decades of experience with user support at NOIRLab and its programs
- Most UPP subsystems have precursors within the current NOIRLab programs
- Significant expansion planned in some areas (e.g., data reduction / pipelines)

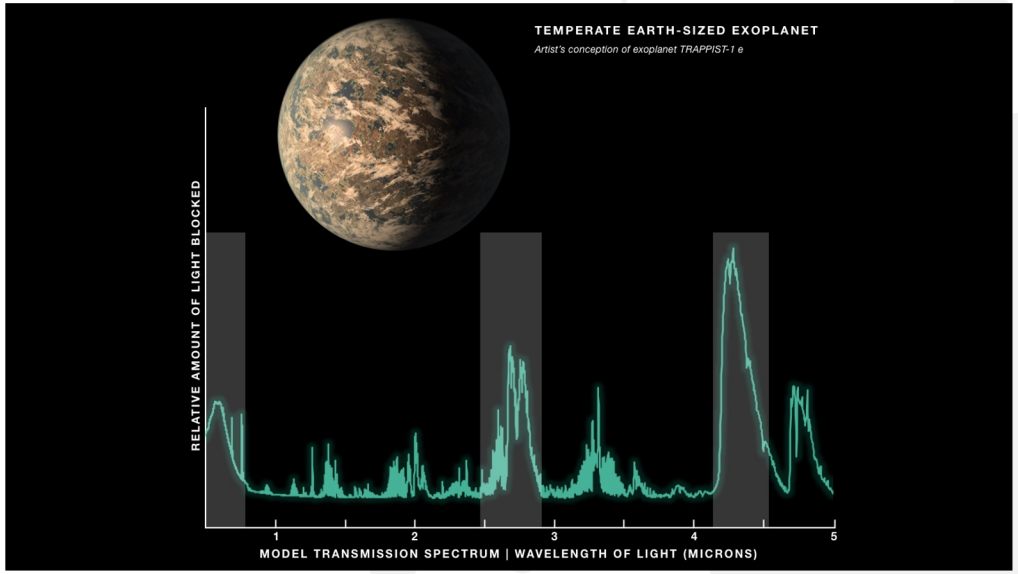
UPP service / system	NOIRLab precursor
Observing time allocation	NOIRLab Time Allocation System
Observing proposal preparation Observing program planning	Gemini Program Platform (GPP)
Observing program scheduling	Gemini automated scheduler
Data transport	CTIO/KPNO, Gemini, Rubin data transport systems
Data archive	CSDC and Gemini archives
Data reduction	CTIO/KPNO pipelines; Gemini DRAGONS; Rubin DM
Data analysis / Data science tools	CSDC Astro Data Lab; Rubin Science Platform
Documentation, Training, and Help Desks	NOIRLab documentation & help desks

EXAMPLE

KSP: Exoplanet Atmospheres

A systematic survey of exoplanet atmospheres: physical conditions, chemical composition, and potential biosignatures

- High resolution exoplanet transit spectroscopy for atmospheric transmission
  - Time critical observations during transits
  - Use GMT + TMT for extended time baseline
  - Use GMT + TMT for simultaneous optical + IR observations
  - Long term program for monitoring many planets through repeated orbits / transits
  - ToO to include new targets discovered during KSP duration



Spectroscopy of transiting exoplanets allow us to assay their atmospheres for signs of biochemistry

- Direct imaging and low/medium resolution spectroscopy of reflected light (optical/NIR) and/or thermal emission (mid-infrared)
  - Multiple epochs to sample phase variations during orbit and planetary rotation

→ Researchers form a team and write a proposal!

Proposal Preparation and Time Allocation

- Phase 1 (Observing Proposal Preparation):
  - Propose for coordinated GMT + TMT (+ Gemini and other NOIRLab telescopes)
  - UPP Phase 1 tool (“Prepare”) helps users find optimal instrument choices and configurations
  - Integrated with ITCs, instrument simulators, archive (e.g., check for previous observations), documentation
  - Research Inclusion (RI) toolkit provides guidance for organizing inclusive collaboration and writing RI plan
  - “Prepare” tool and notification system facilitate team’s collaboration on proposal preparation and submission
  - Helpdesk for queries about Phase 1 preparation
- Time Allocation System (TAS)
  - Dual anonymous peer-review process to mitigate conflicts of interest and bias
  - TAS tools manage and support all stages of proposal review from proposal receipt through merging of ranked programs from all observatory partners
  - Research Inclusion toolkit provides guidance for reviewing and grading RI plan
  - Program information tracked from proposal submission through publication & archived data products

Observing Program Preparation & Scheduling

- Phase 2 (observing program preparation):
  - Observation preparation starts from saved Phase 1 proposal + Time Allocation results
  - UPP “Prepare” Tool automatically defines observation & calibration sequences and assists user with custom configuration if needed
  - Integrated with guide star selection systems, ITCs
  - Passes all observing information to GMT/TMT program scheduling databases
- Observation Scheduling System
  - Automated, optimized, and adaptive
  - Supports service and visitor modes, GMT+TMT coordination, ToO interrupts, etc.
  - Observatories may use for long- and short-term scheduling
  - Users notified about program execution status

→ Observatories execute observations, collect data, log executed exposures

Data Archiving and Data Reduction

- Data are transported from observatories to NOIRLab and validated before archiving
- Data Reduction Pipelines (DRPs) operating at telescopes and at NOIRLab:
  - “Real-time” quality assessment (QC0) at the telescopes for rapid feedback to observers and observatory staff
  - Detailed quality assessment (QC1) at NOIRLab using appropriate calibrations

    → Save “browse-quality” QC1 data products in archive
  - Standard Data Reduction (SDR) for all SDR-compliant observations + calibrations to produce and archive data products for scientific analysis by team and future archival researchers
  - Community scientists can access and operate pipelines in the UPP environment for customized data reduction

Data Analysis and Publication

- Science platform for data analysis by science teams or archival researchers
  - Computing and data storage resources
  - Library of common astronomical analysis software installed and available
  - Notebook computing environment to script data processing and analysis
  - Documentation and tutorials to assist users
  - Shared workspace, activities logging, and notifications for team collaboration
- Teams can publish high-level contributed science products for long-term archiving and distribution by NOIRLab
- Science program data are tracked through publication and archival data products

→ Archival researchers find new uses for the KSP data products, make new discoveries, write new papers, submit new observing proposals …

Science Community Engagement

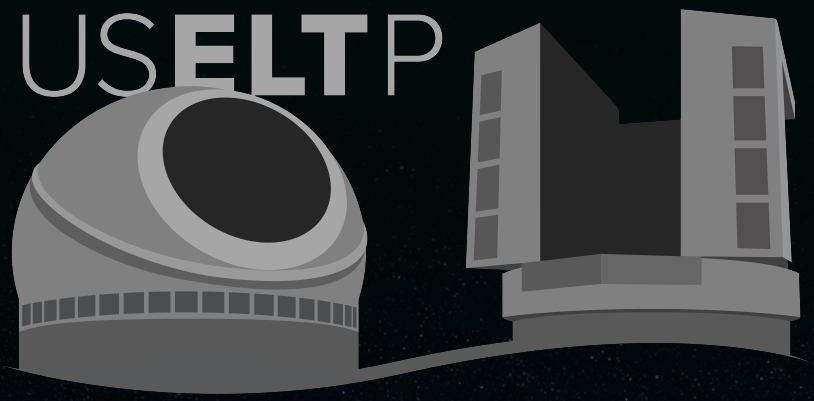
- Goals of NOIRLab's US-ELTP **Science Community Engagement Plan**:
  - Inform the community about scientific opportunities and planned user support services
  - Gather input from a diverse community of stakeholders
  - Engage community contribution to planning and development
- **Inform** via US-ELTP web site, NOIRLab newsletters, AAS and other meetings, webinars, social media
- **Consult** via advisory committees, expert reviewers, topical advisory groups, surveys and questionnaires
- **Involve** community in focus groups, workshops, science meetings, KSP planning
- **Collaborate** within and across NOIRLab, with TMT/GMT partnership and US-at-large scientists and instrumentation groups

Summary

- Open access to both GMT and TMT will enable transformational research by US astronomers
- Outstanding user support will enable researchers to more fully achieve their scientific ambitions
- US-ELTP user services will broaden participation in science with TMT+GMT and their data, growing the research community and enhancing the scientific outcomes
- NOIRLab will work closely with the scientific community throughout the development and construction phases of the US-ELTP to ensure we build the systems that researchers need

AURA

USELTP



TMT
THIRTY METER TELESCOPE

NSF | NOIR Lab

GIANT MAGELLAN TELESCOPE