NASA Astrophysics Decadal Survey: Large Missions & Probes

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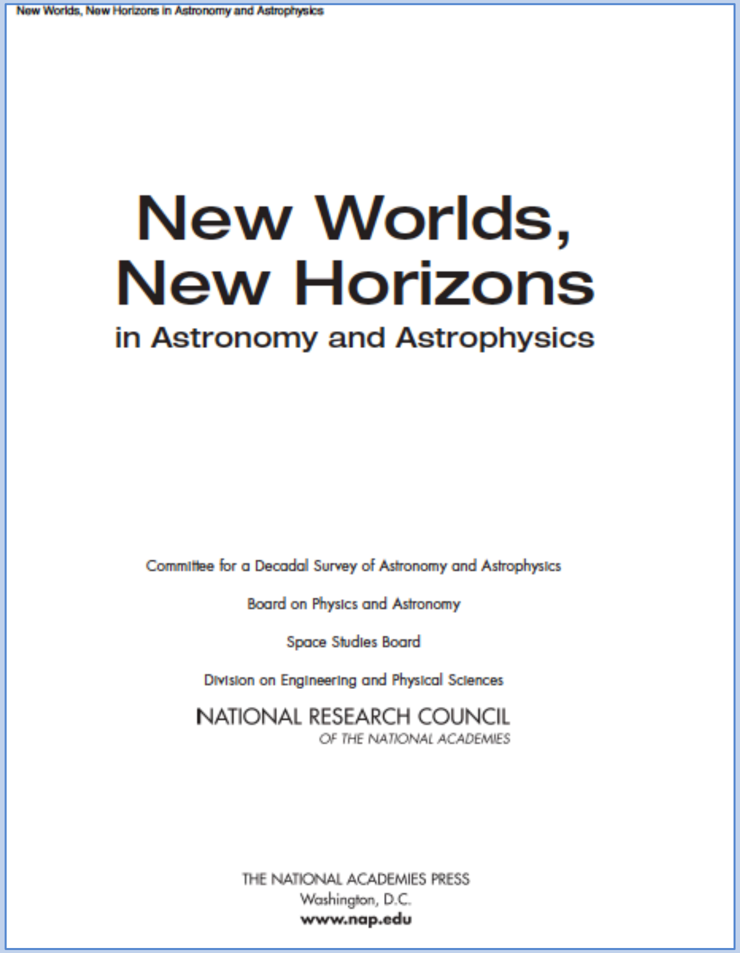
Outline

- Brief overview of Astrophysics Decadal Survey Process
- 2020 Decadal Activities – Current Mission Studies
- Example: Probe Missions – TAP & CETUS
- Example: Large Missions – OST & LUVOIR

2010 US Decadal Survey



New Worlds, New Horizons in Astronomy and Astrophysics

New Worlds,
New Horizons
in Astronomy and Astrophysics

Committee for a Decadal Survey of Astronomy and Astrophysics

Board on Physics and Astronomy

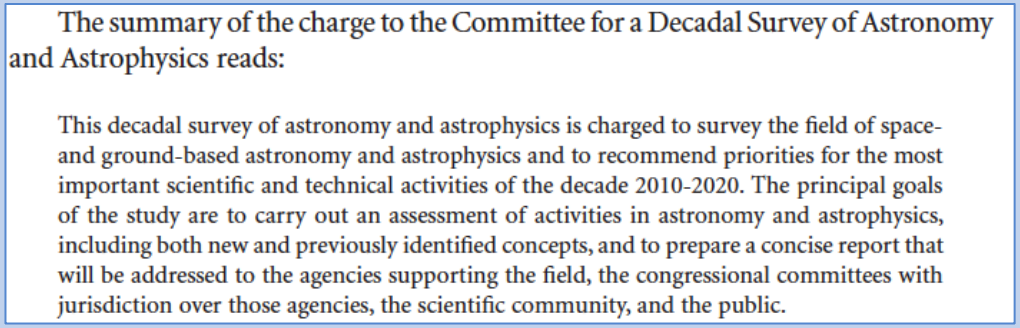
Space Studies Board

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

From Preface to 2010 Survey:



The summary of the charge to the Committee for a Decadal Survey of Astronomy and Astrophysics reads:

> This decadal survey of astronomy and astrophysics is charged to survey the field of space- and ground-based astronomy and astrophysics and to recommend priorities for the most important scientific and technical activities of the decade 2010-2020. The principal goals of the study are to carry out an assessment of activities in astronomy and astrophysics, including both new and previously identified concepts, and to prepare a concise report that will be addressed to the agencies supporting the field, the congressional committees with jurisdiction over those agencies, the scientific community, and the public.

The survey covers ground and space based astronomy and astrophysics.

Here we focus on NASA and space based astronomy and astrophysics

NASA Science Organization

- Four Divisions under one Directorate, currently led by Dr. Thomas Zurbüchen. Before NASA he was a senior professor at University of Michigan. The overarching organization for Science at NASA is the Science Mission Directorate.
- The four Divisions are: Astrophysics, Earth Science, Heliophysics, and Planetary Science (also known as Solar System Science).
- Each Division has a separate budget for its own activities, i.e., a separate line item in the NASA Budget for Science.
- Some activities are funded by one or Divisions, such as the Exoplanet Research Program (small grants) funded by Astrophysics and Planetary, but the Divisions are mostly *Stovepiped*.

But what about the Centers? How are they organized?

- There are about 10 Centers that NASA runs, spread around the US.
- The main science centers include Goddard, JPL,& Ames. Langley is mostly focused on Aeronautics and has some science, and to some extent Marshall. Glenn is a small research center. The other Centers are focused on rockets or manned space like Marshall, Stennis, Kennedy, Johnson.
- Goddard is the largest science center with about 9,000 employees, JPL is about ½ the size of Goddard.

What about Goddard Astrophysics?

- Five Labs and three Offices, about 300 people (?)
- LABS – Astroparticle Physics, Gravitational Waves, Exoplanets and Stellar Astrophysics, X-Ray Astrophysics, and Observational Cosmology
- OFFICES – HEASARC (High Energy Data Center), Instrument Development Group, and Scientific Computing

The NASA Science Budget

Science Division	Budget (Annual in USD $1 B units, rough numbers from memory)
Astrophysics (including JWST)	1.3
Heliophysics	0.6
Earth Science	1.6
Planetary Science	1.8

The total is about $5.3 B.

Question: What happens with Astrophysics budget after JWST? The budget for JWST runs about $500 million per year.
Answer: Astrophysics has WFIRST for part of the budget wedge and hopefully a new mission line called Probes for the rest. For FY18, WFIRST's budget is about $150 M.

Question: How big is the science budget compared to the overall budget?
Answer: About ¼ of the budget is for science. The overall budget is ~$20 B.

The 30 Year Vision
Developed in 2013

- Enduring Quests, Daring Vision – NASA Astrophysics in the Next Three Decades

- Led by Chryssa Kouveliotou + distinguished astronomers from all over US

Chryssa is well known X-Ray astronomer from NASA Marshall Space Flight Center, now at George Washington University in DC

The Future?
The 2020 Decadal Survey Overview

- Preparations begin about 2 years before survey is published. Usually around October of the year of the new decade. Last one around 10/10, next one around 10/20
- White papers on various topics like Astrobiology Strategy and Exoplanet Strategy have already been submitted as of 3/2018. Additional calls for white papers expected in 2018 and early 2019.
- Mission concept studies managed by NASA Headquarters
- Two kinds currently being studied:
  - Large missions defined as >$1 B lifecycle costs
  - Probe missions defined as $>400 M and <$1 B.

Why Probes?

- Astrophysics has no line of missions in the $400-1000 M price range, only small missions like SMEX and MIDEX, and Large missions like HST, JWST, Chandra.
- But – Planetary Science has New Horizons type missions in the $800+ M price range, which have been very successful.
- A line of Probe missions is highly desirable, also easier to manage than the very large missions, like JWST, due to budget flexibilities not possible on large missions.
- Call for Probe concept studies was made in 2016, selections in March 2017, 8 fully funded, 2 partially funded from 27 proposals submitted.

Purpose of Probe Studies (from NASA HQ briefing)

- NASA is supporting the Probe Studies for submission to the Decadal Committee
- These Studies are chartered by NASA and the Study PIs are responsible for delivering the final products (a Study Report report and an Engineering Concept Data Package) to NASA
- NASA will submit the Studies' final products to the Decadal Committee, as defined later in this package
- The Decadal Committee will have the option to prioritize any of these mission concepts, or recommend a competed line of Probes (similar to Explorers)
- Selections will be based on science merit

Selected Probe Mission Concept Studies

PI	Affiliation	Short title	Design Lab/Prog Office
Camp, J.	NASA's GSFC	Transient Astrophysics Probe	IDC/PCOS-COR
Cooray, A.	Univ. California, Irvine	Cosmic Dawn Intensity Mapper	TeamX/ExEP
Danchi, W.	GSFC	Cosmic Evolution through UV spectroscopy	IDC/PCOS-COR
Glenn, J.	Univ. of Colorado	Galaxy Evolution Probe	TeamX/ExEP
Hanany, S.	Univ. of Minnesota	Inflation Probe Mission Concept Study	TeamX/ExEP
Mushotzky, R.	Univ. of Maryland	High Spatial Resolution X-ray Probe	IDC/PCOS-COR
Olinto, A.	Univ. of Chicago	Multi-Messenger Astrophysics	IDC/PCOS-COR
Plavchan, P.	Missouri State Univ.	Precise Radial Velocity Observatory	No design lab funded/HQ grant
Ray, P.	Naval Research Lab	X-ray Timing and Spectroscopy	IDC/PCOS-COR
Seager, S.	MIT	Starshade Rendezvous	TeamX/ExEP

Final Study Products (from HQ directions)

- Each 18 month Probe Study is required to generate two major products for submission:
  - A Study Report, and
  - An Engineering Concept Definition Package

- The principal product of the 18 month Probe Study is a Study Report.
  - Your Study Report is due at the end of either the 18-months or the no-cost extension, but absolutely no later than December 31, 2018.
  - Submit your Study Report to your Point of Contact, your POC will then forward it to HQ with a qualitative internal assessment. HQ will append the Independent Cost Estimate to it and deliver that package to the Decadal Committee.
  - At initial delivery, the Decadal will only receive your Study Report and the Independent Cost Estimate, but not your Engineering Concept Definition Package. Upon request from the Decadal, HQ will also deliver to them your Engineering Concept Definition Package after removal of any ITAR sensitive information.

- The other major study product is your Engineering Concept Definition Package.
  - The Engineering Concept Definition Package is originally generated by the Concurrent Design Lab supporting your Study. You may later choose to create a modified version of it. The final version of your Engineering Concept Definition Package gets submitted to the Independent Cost Estimator organization (SOMA) alongside your Study Report for an independent cost estimate.
  - The Independent Cost Estimator organization will see both your Study Report and your final Engineering Concept Definition Package.

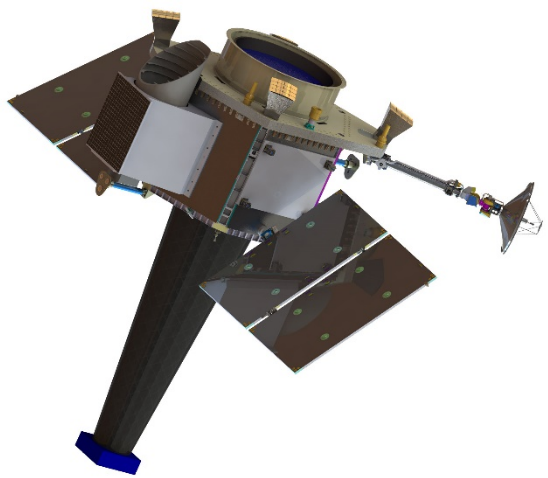
- For more guidance on your Study Report and your Engineering Concept Definition Package refer to the following pages.

Two Probe Examples

- Transient Astrophysics Probe (TAP) -- PI Jordan Camp
- Cosmic Evolution Through UV Spectroscopy (CETUS) -- PI Danchi, Science PI Heap

Transient Astrophysics Probe

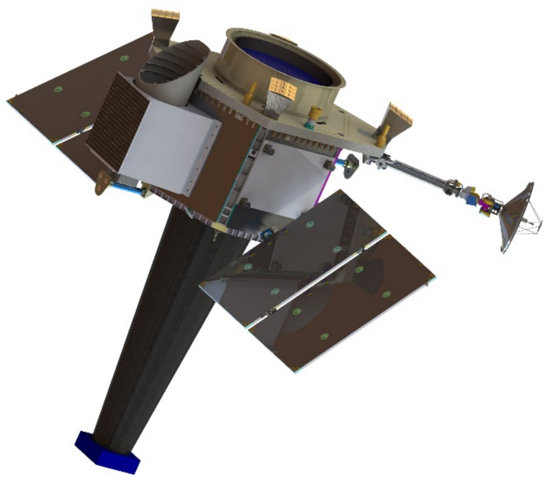
Jordan Camp
AAS 231st Meeting
Jan 9, 2018



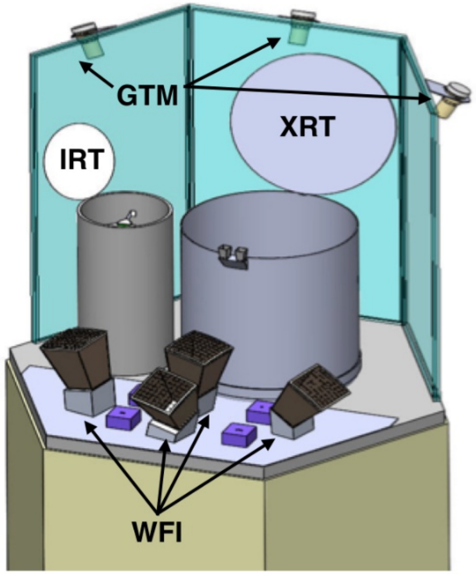
https://asd.gsfc.nasa.gov/tap/

Transient Astrophysics Probe (TAP)

- TAP comprises *wide-field* X-ray, Gamma-ray, and Infrared telescopes designed to address two major Frontier Discovery Areas of the 2010 Decadal Survey
  - EM Counterparts to Gravitational Waves
  - Time-Domain Astrophysics



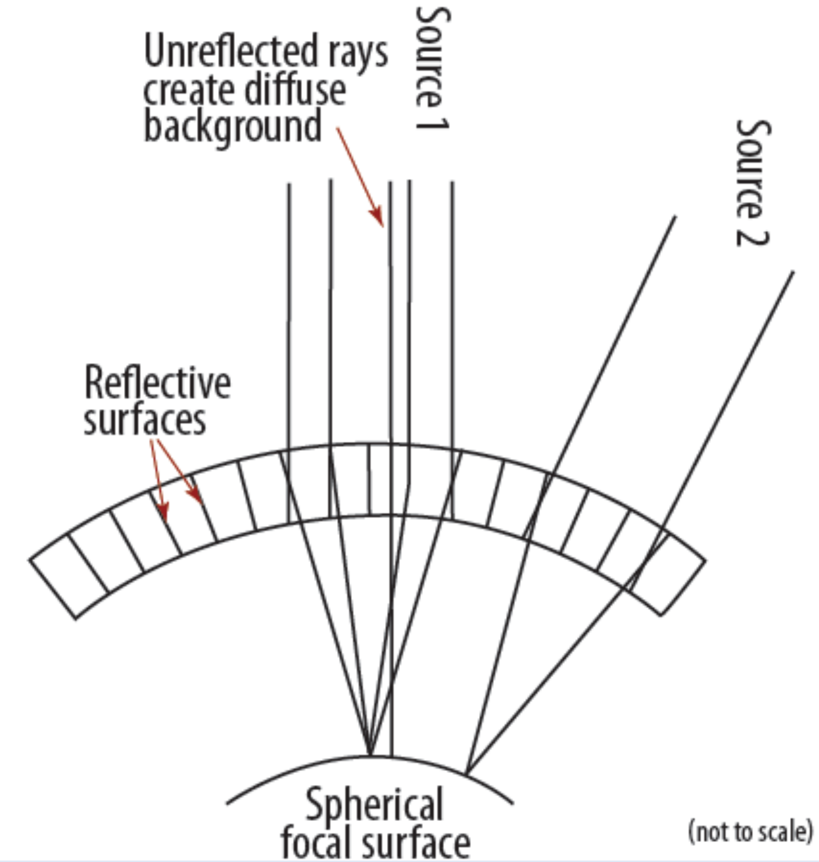
TAP Telescopes: Wide and Deep



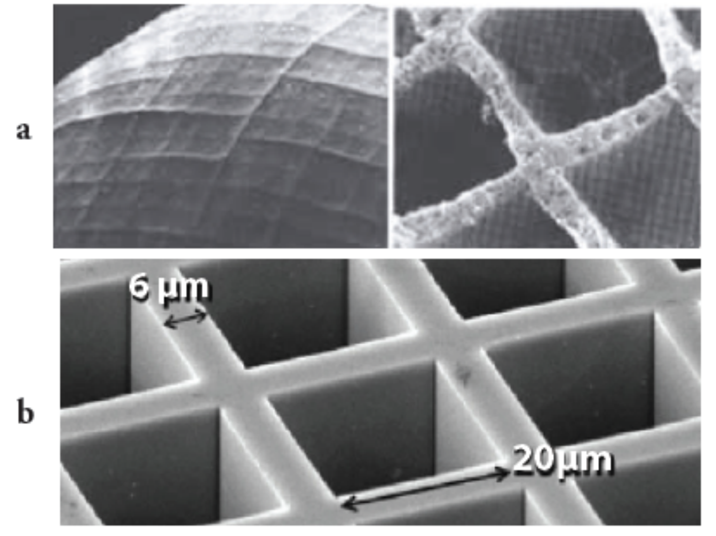
- WFI (Lobster) modules (4)
  - 2000 deg^2 FoV, 1 arcmin
  - 10^{-11} $erg/cm^2/sec$ in 1000 sec
- IR Telescope
  - 1 deg^2 FoV
  - 0.3 – 2.5 micron, 70 cm diameter
  - 23-24 Mag in 500 sec
- X-ray Telescope (single crystal silicon mirror)
  - 1 deg^2 FoV
  - 3 x 10^{-15} $erg/cm^2/sec$ in 3000 sec
- Gamma-ray Transient Monitor (8)
  - 10 - 1000 keV, 4pi FoV

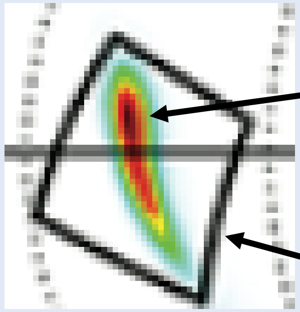
Lobster Optics for All-Sky Monitor

New Technology → Breakthrough Science



Lobster Eye



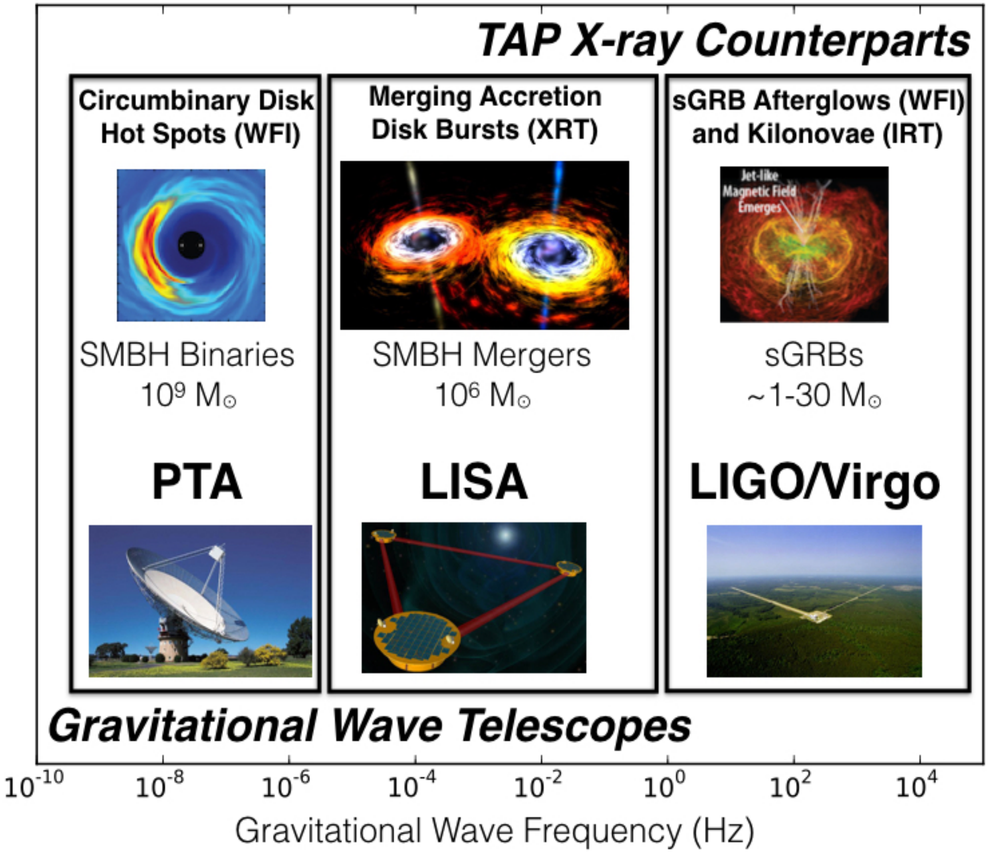


LIGO-Virgo skymap of BNS merger (100 deg^2)

Lobster FoV

Lobster-Eye geometry provides *simultaneous* large FoV, high position resolution and high sensitivity → Time Domain Astronomy

TAP will observe EM Counterparts across wide GW Band



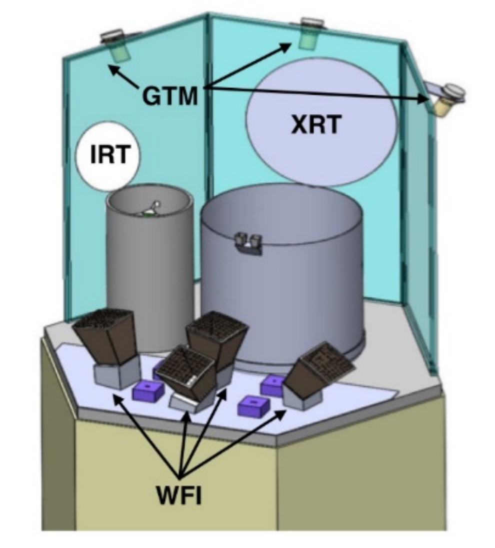
$\Delta\theta_{GW}$	100 deg^2	1 deg^2	20 deg^2

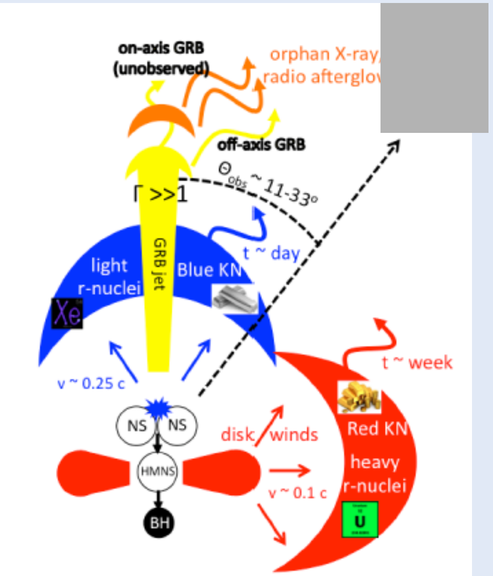
Counterparts → localization → astrophysical context:

- Host galaxy
- Redshift
- Environment
- Accretion disk interactions

X-ray and IR Counterparts of LIGO-Virgo GW detections

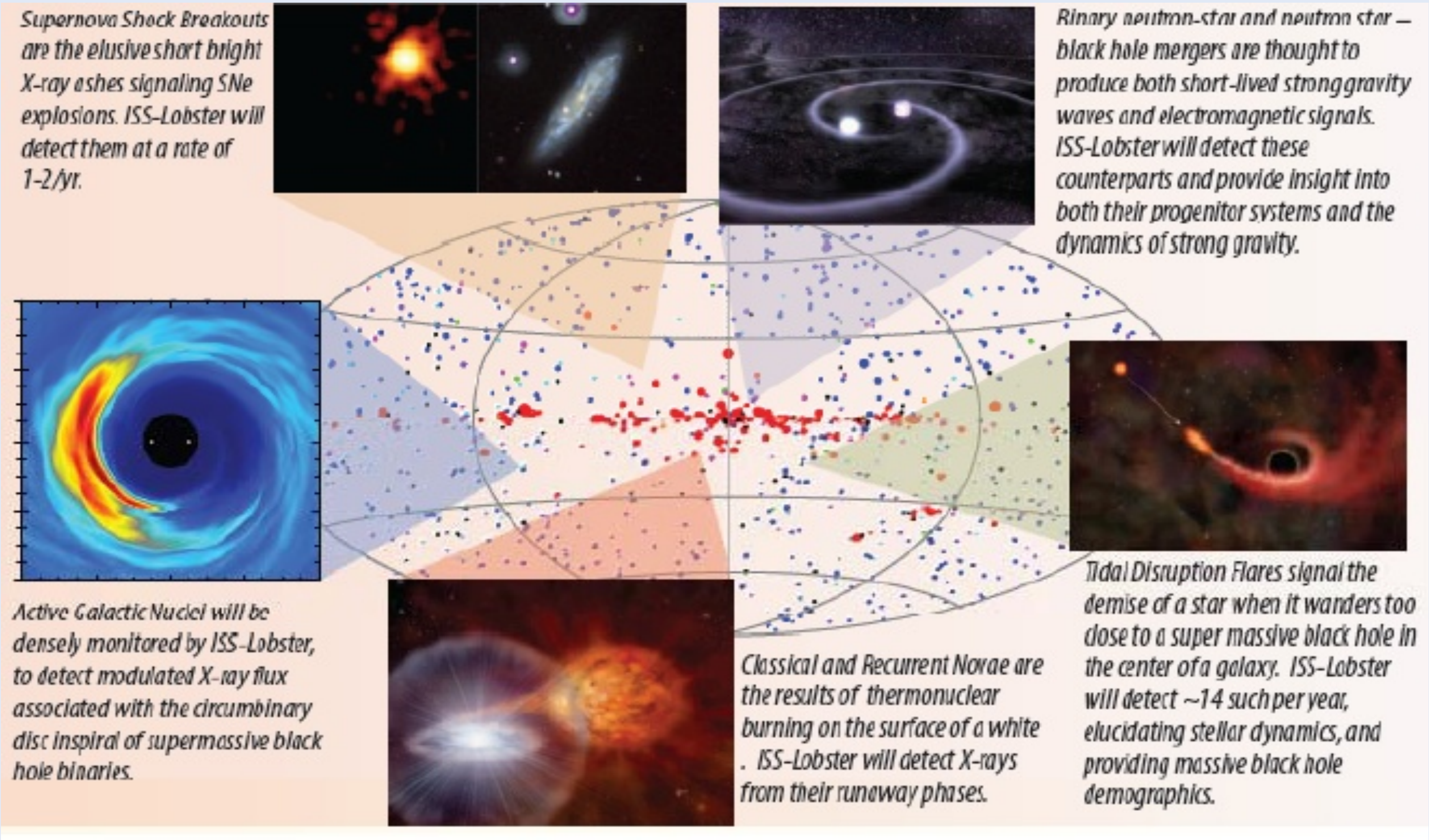
Detector	Counterpart	Source	Rate (yr^{-1})
WFI	Beamed X-ray	sGRB	20
XRT	Off-axis X-ray	sGRB	10
IRT	Isotropic IR	Kilonova	100
IRT	Polar blue	Kilonova	50





Metzger, arXiv 1710.05931 (2017)

TAP Time-Domain Astrophysics



Supernova Shock Breakouts are the elusive short bright X-ray flashes signaling SNe explosions. ISS-Lobster will detect them at a rate of 1-2/yr.

Binary neutron-star and neutron star – black hole mergers are thought to produce both short-lived strong gravity waves and electromagnetic signals. ISS-Lobster will detect these counterparts and provide insight into both their progenitor systems and the dynamics of strong gravity.

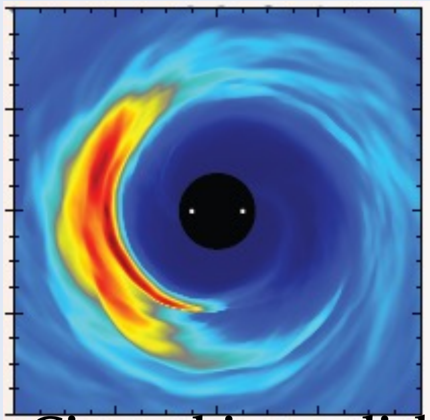
Active Galactic Nuclei will be densely monitored by ISS-Lobster, to detect modulated X-ray flux associated with the circumbinary disc inspiral of supermassive black hole binaries.

Classical and Recurrent Novae are the results of thermonuclear burning on the surface of a white . ISS-Lobster will detect X-rays from their runaway phases.

Tidal Disruption Flares signal the demise of a star when it wanders too close to a super massive black hole in the center of a galaxy. ISS-Lobster will detect ~14 such per year, elucidating stellar dynamics, and providing massive black hole demographics.

LSST, ZTF, SKA transient followup and MW classification

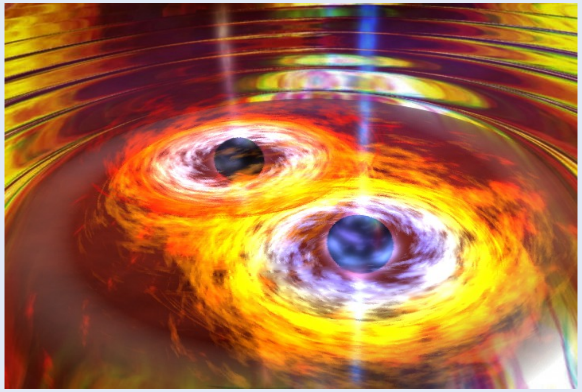
TAP observations of SMBHB counterparts from SKA, LISA



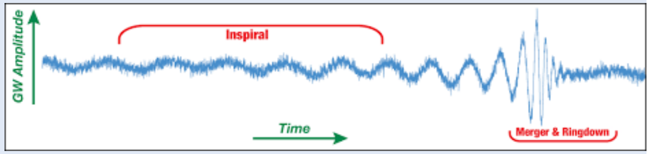
Circumbinary disk
"hot spot"
Noble et al, ApJ 755, 51 (2012)

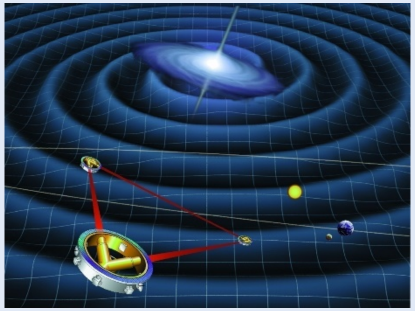
Square kilometer array (SKA)

- SKA, LISA will be observing GWs from SMBHBs by ~2035
- XRT could detect X-rays from SMBHB merger (LISA)
- WFI, XRT could localize X-ray hot spot of SMBHB (SKA)
- MHD codes at GSFC now simulating these sources to predict TAP detection rates



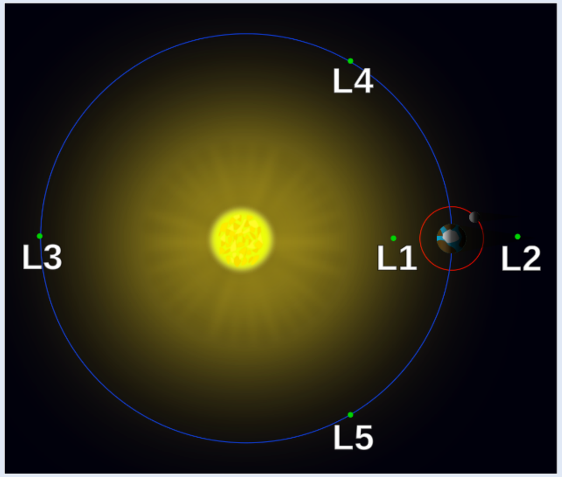
$10^{6-7} – 10^{6-7}\ M_{\odot}$ BHB





LISA

TAP Orbit and Cost



- L2 Orbit
  - Thermally stable
  - Minimal Earth occultation (<10%) enables rapid ToO response time
  - Low latency up and down-links
- < $ 1B Cost
  - Instrument costs well understood from previous mission proposals (ISS-Lobster, STAR-X, EXIST, Fermi-GBM)
  - Mission Design Lab Study done in November
    - Ball Aerospace helped review Spacecraft cost

TAP Summary

- TAP is a wide-field GW followup mission
  - X-ray and IR telescopes will observe 100s of GW counterparts per year
- TAP will also deliver abundant Time-Domain Astronomy
  - Supernovae
  - Tidal Disruptions of Stars
  - High redshift GRBs
  - Synergy/followup with LSST, ZTF, SKA
- Mission costing and prior instrument costing shows TAP will fit into $1B cost cap
- Please stop by Probe Poster Session for more information…

Cosmic Evolution Through UV Spectroscopy (CETUS) Probe Mission Concept Study

William Danchi (PI)

Sally Heap (Science PI)

\+

CETUS Study Team

American Astronomical Society Meeting

1/9/2018

The CETUS Study Team

William Danchi (PI, GSFC), Sara Heap (Science PI, GSFC Emerita)

Co-Investigators: Steve Kendrick (Kendrick Aerospace Consulting), Tony Hull (Kendrick Aerospace Consulting, Univ. NM), Robert Woodruff (Woodruff Consulting), Jim Burge & Martin Valente (Arizona Optical Sciences), Kelly Dodson & Greg Miehle (Orbital ATK), Steve McCandliss (Johns Hopkins Univ.)

Science Team *(Collaborators)*: L. Bianchi, T. Heckman, A. Szalay, R. Wyse, (Johns Hopkins Univ.); E. Dwek, J. Rigby (GSFC); J. Greene, D. Spergel (Princeton); I. Roederer (U. Michigan); D. Stark (U. Arizona); J. Trump, K. Whitaker (U. Conn.)

Technical Collaborators: S. Nikzad (JPL); O. Siegmund, J. Vallerga (U.C. Berkeley SSL); Q. Gong, S.H. Moseley, L. Purves, B. Rauscher (GSFC)

GSFC Engineering Support Team: Mike Rhee, Mike Choi, Walt Smith, Eric Stoneking

Key Scientific Objectives

Understanding galaxy evolution:

- Why did rate of conversion of gas into stars and the growth of black holes peak 10 billion years ago (at redshift, z~2) and then decline?
- What explains the co-evolution of galaxy bulges and nuclear black holes (AGN’s)?
- How did the Hubble Sequence emerge?
- How did galaxies come to look like the ones we see today?

Understand sources of gravitational waves and other transient events:

- Localize and determine key heavy elements created in neutron star merger events and other transient sources
- Determine if neutron star mergers account for half of all elements heavier than iron in the universe

Cosmic Origins Science:

- Perform stellar paleontology. Search for and characterize very metal poor stars to determine nature of first stars and supernovae.
- Discover analogues to high-redshift, star-forming galaxies by providing a large sample of nearby galaxies with gas-phase metallicities below 20% solar.

Key Requirements

- CETUS shall make a targeted UV survey of galaxies via a UV camera and multi-object spectrograph (MOS) utilizing a Micro-shutter array (MSA)
- The CETUS MOS shall obtain > 10^5 near-UV (rest frame far-UV) spectra of redshift z~1-2 galaxies already observed by Subaru's Hyper Suprime Camera and Prime Focus Spectrograph
- The CETUS MOS shall enable R~1000 spectroscopy of 50-100 redshift, z~1-2 galaxies simultaneously
- The CETUS cameras shall observe in parallel with the MOS, so target galaxies observed by the MOS will have additional observations supplied by the cameras
- Each CETUS camera will include 5 spectral filters and will have angular resolution of 0.41'' for the near-UV and 0.55'' for the far-UV, approximately a factor of ten better than GALEX (~5'')
- The single object near-UV and far-UV spectrographs shall operate with R~2000 and R~40,000

Derived Requirements for the CETUS MOS & Camera

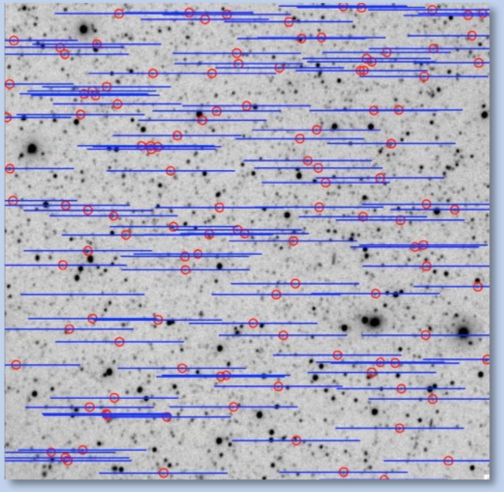
Parameter	Requirement	Design
Field of View	>1000”	1045”
Angular Resolution	≤0.70”	0.55” (FUV) 0.55” (NUV)
Spectral Range	Far-UV and near-UV	1150-1750 Å (FUV) 2000-4000 Å (NUV)
Spectral Bandpass	LP filters, λ_{min}>1150 Å 300-500 Å	100-150 Å (FUV) ~410 Å (NUV)

IN THE CONTEXT OF THE CETUS SYSTEM CONCEPT

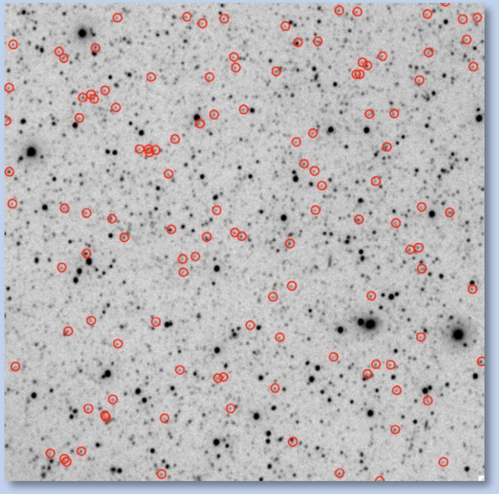
Requirement	Derived Requirement
MOS requirement: 100 S/N>7 spectra in a single exposure	MOS FOV 1045” square Tel. diameter = 1.50 m
Camera requirement: Observe in parallel with the MOS	Cam FOV 1045” square
Detector realities: NUV: CC pixel = 0.42” FUV: MCP resolution elements	Resolution = 0.55” for both MOS and CAM (not diffraction limited!)
Nyquist sampling requirement	Dither a pixel on the MOS and CAM
MOS requirement: no dithering of telescope	Dithering of MOS and CAM images via mechanism on M2 optic
Camera requirement: 5 spectral filters for higher spectral resolution & calibration filters	8-position filter wheel for both FUV and NUV camera

CETUS MOS and CAMERA Simultaneously Observe Adjacent Fields

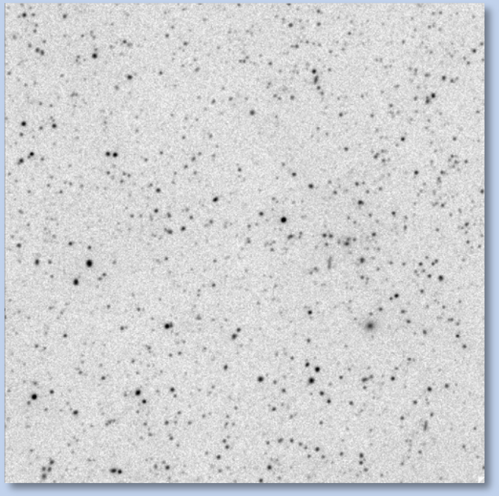
CETUS MOS



CETUS CAMERA



NUV



FUV

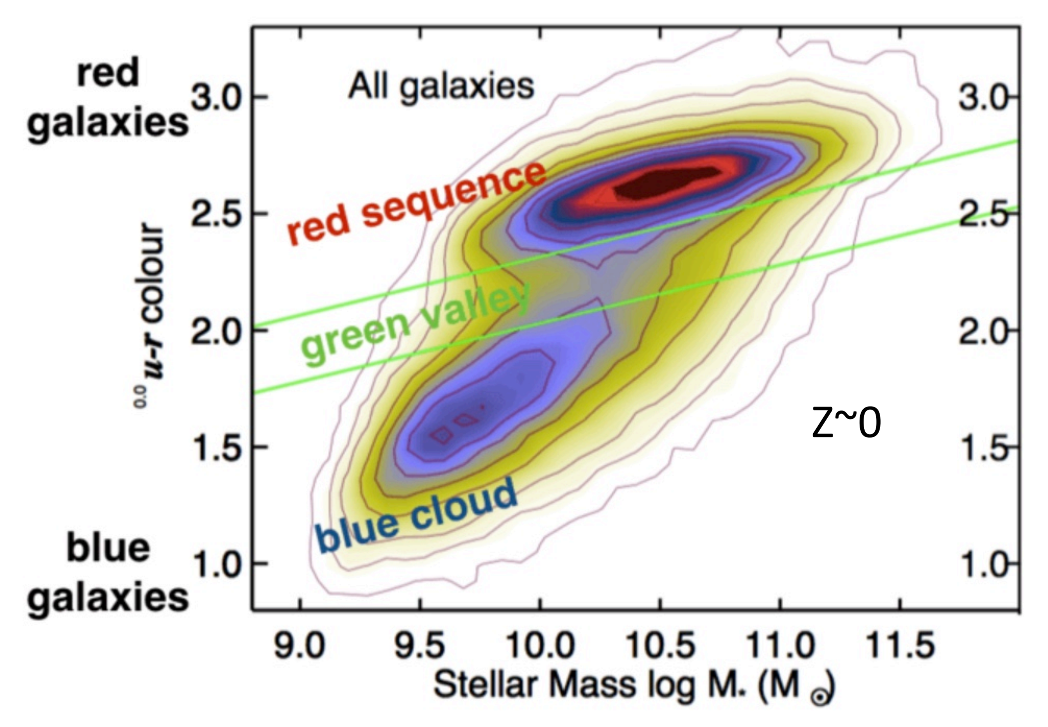
Each survey observation produces:

- one NUV spectrogram with ~100 spectra
- a NUV image ⎫ of an adjacent field
- a FUV image ⎭

Each image is 1045” on a side

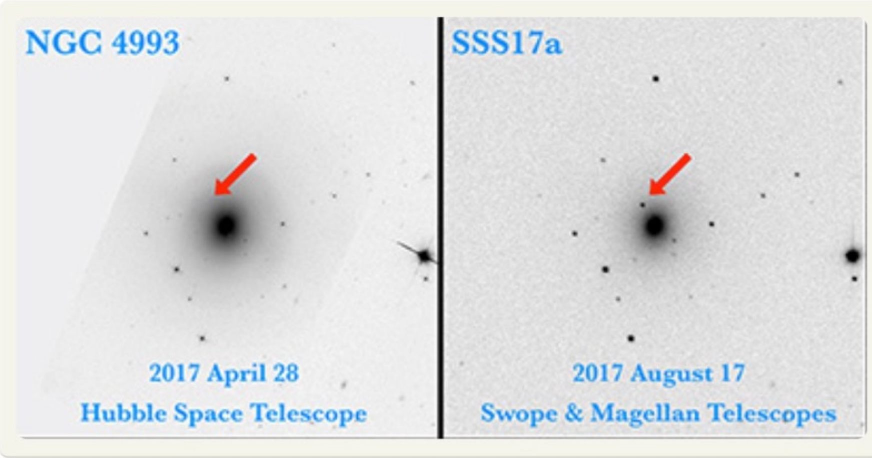
The near-UV camera will pinpoint what kind of z~1-2 galaxies have slowed down or stopped stopped making stars

- via rest-frame (far-UV – optical/IR) color
- via high-resolution imagery (morphology)



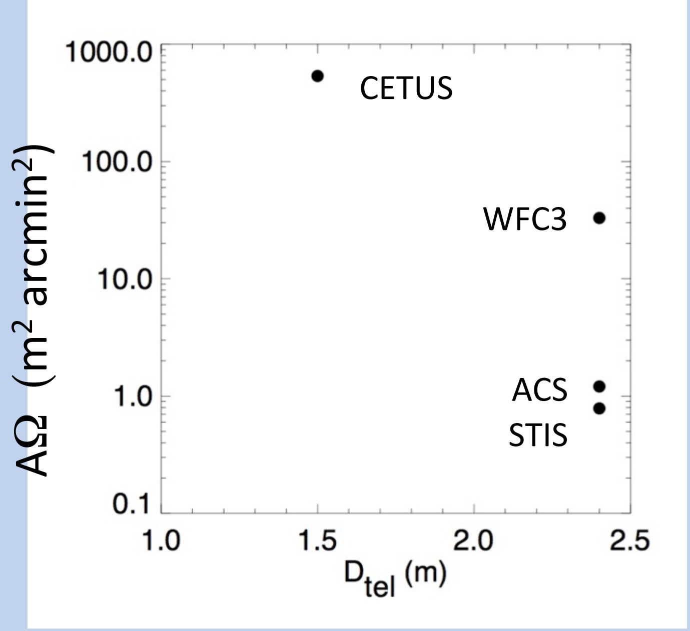
CETUS will observe important transient objects like the gravitational wave source in NGC 4993

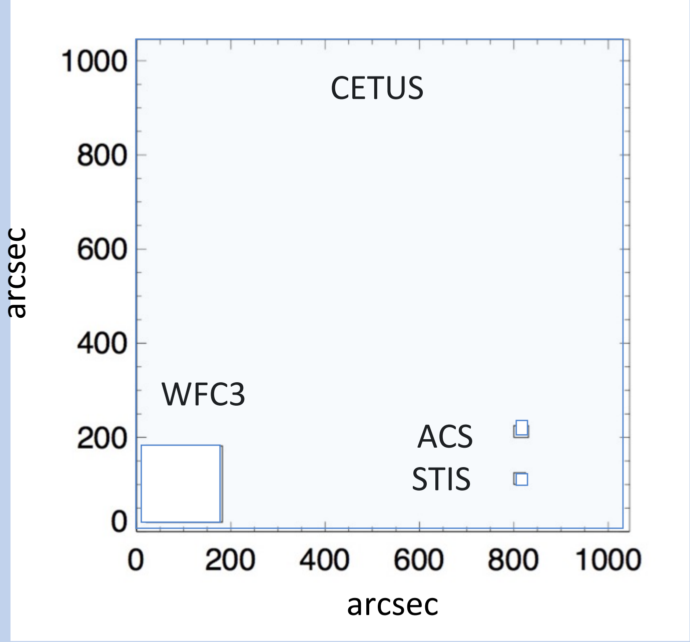
Ramirez-Ruiz (UCSC) has calculated that a single neutron-star merger can generate an amount of gold equal to the mass of Jupiter. The team's calculations of heavy element production by SSS17a suggest that neutron star mergers can account for about half of all the elements heavier than iron in the universe.



The UCSC team found SSS17a by comparing a new image of the galaxy N4993 (right) with images taken four months earlier by the Hubble Space Telescope (left). (Image credits: Left, Hubble/STScI; Right, 1M2H Team/UC Santa Cruz & Carnegie Observatories/Ryan Foley)

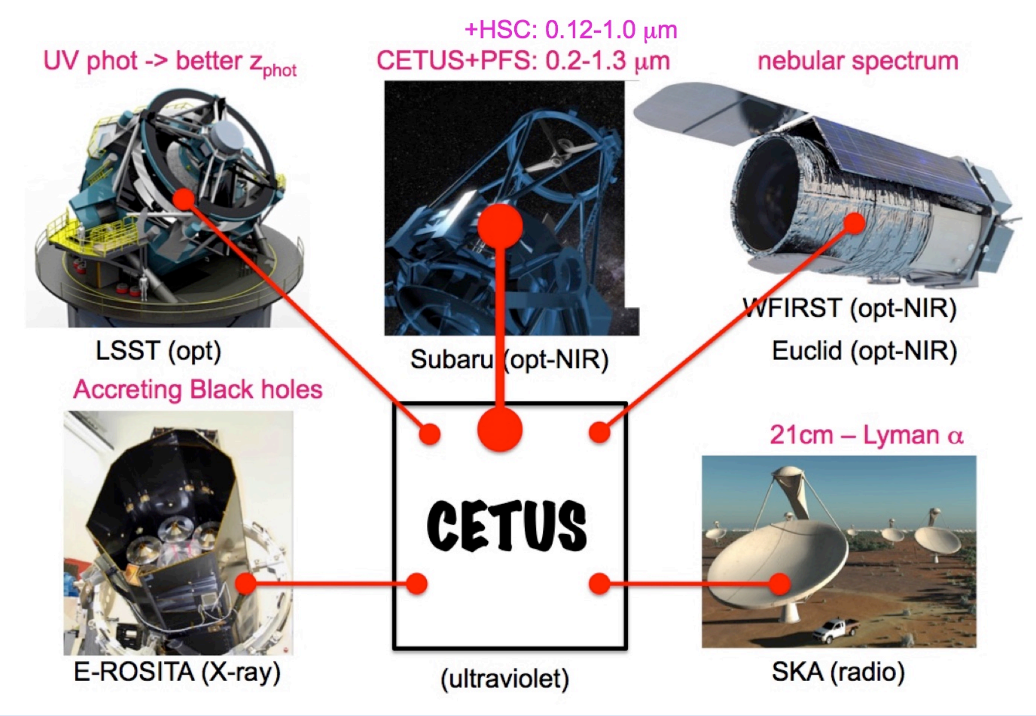
CETUS easily outscores Hubble's UV cameras in the figure of merit, A*Omega = Aperture x FOV



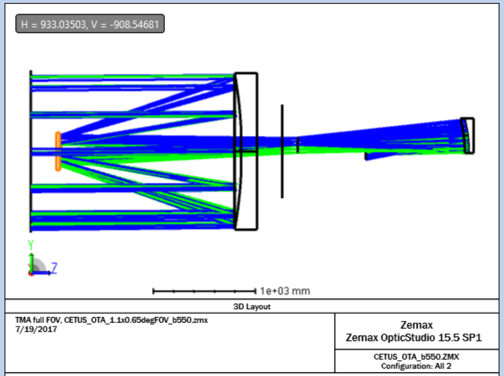


The CETUS camera will work with other survey telescopes in the 2020's to solve major problems in astrophysics

- CETUS will provide UV spectra of selected stellar black holes and massive, accreting black holes (AGN's) detected by E -ROSITA.
- CETUS's cameras will help to refine photometric redshifts and preventing catastrophic redshift errors for sources detected by the LSST.
- CETUS's MOS will observe z~1-2 galaxies based on optical-IR spectral energy distributions and galaxy stellar masses from Subaru PFS.
- CETUS's cameras will observe objects in the far-UV and near-UV from WFIRST IR surveys, which may reveal phenomena first seen by GALEX such as extended star formation , UV halos around galaxies produced by dust reflection of stellar light, and Lyman alpha emission in the circumgalactic medium.
- CETUS will obtain UV imagery of some galaxies mapped in the 21-cm line of neutral hydrogen, and will find Lyman alpha in emission, indicating ionized hydrogen to learn how star formation proceeds in galaxies.



CETUS 1.5-m Wide Field-of-View Three-Mirror Anastigmat Telescope

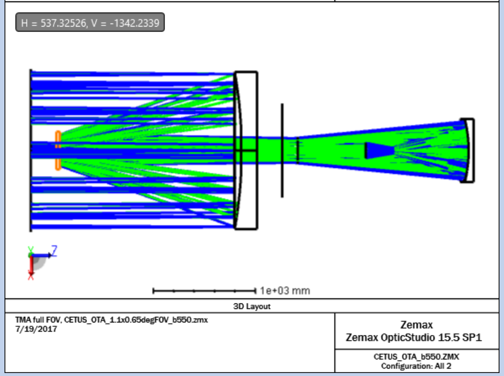


3D Layout

TMA full FOV, CETUS_OTA_1.1x0.65degFOV_b550.zmx
7/19/2017

Zemax
Zemax OpticStudio 15.5 SP1

CETUS_OTA_b550.ZMX
Configuration: All 2

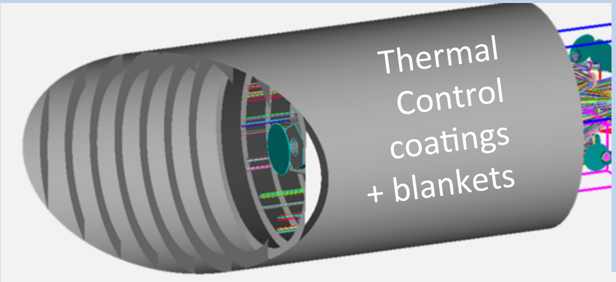


3D Layout

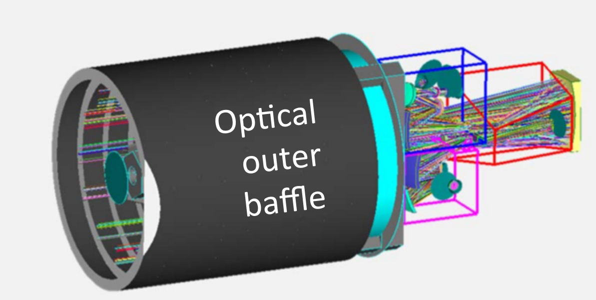
TMA full FOV, CETUS_OTA_1.1x0.65degFOV_b550.zmx
7/19/2017

Zemax
Zemax OpticStudio 15.5 SP1

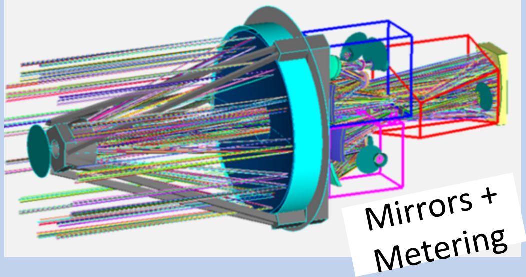
CETUS_OTA_b550.ZMX
Configuration: All 2



Thermal Control coatings + blankets

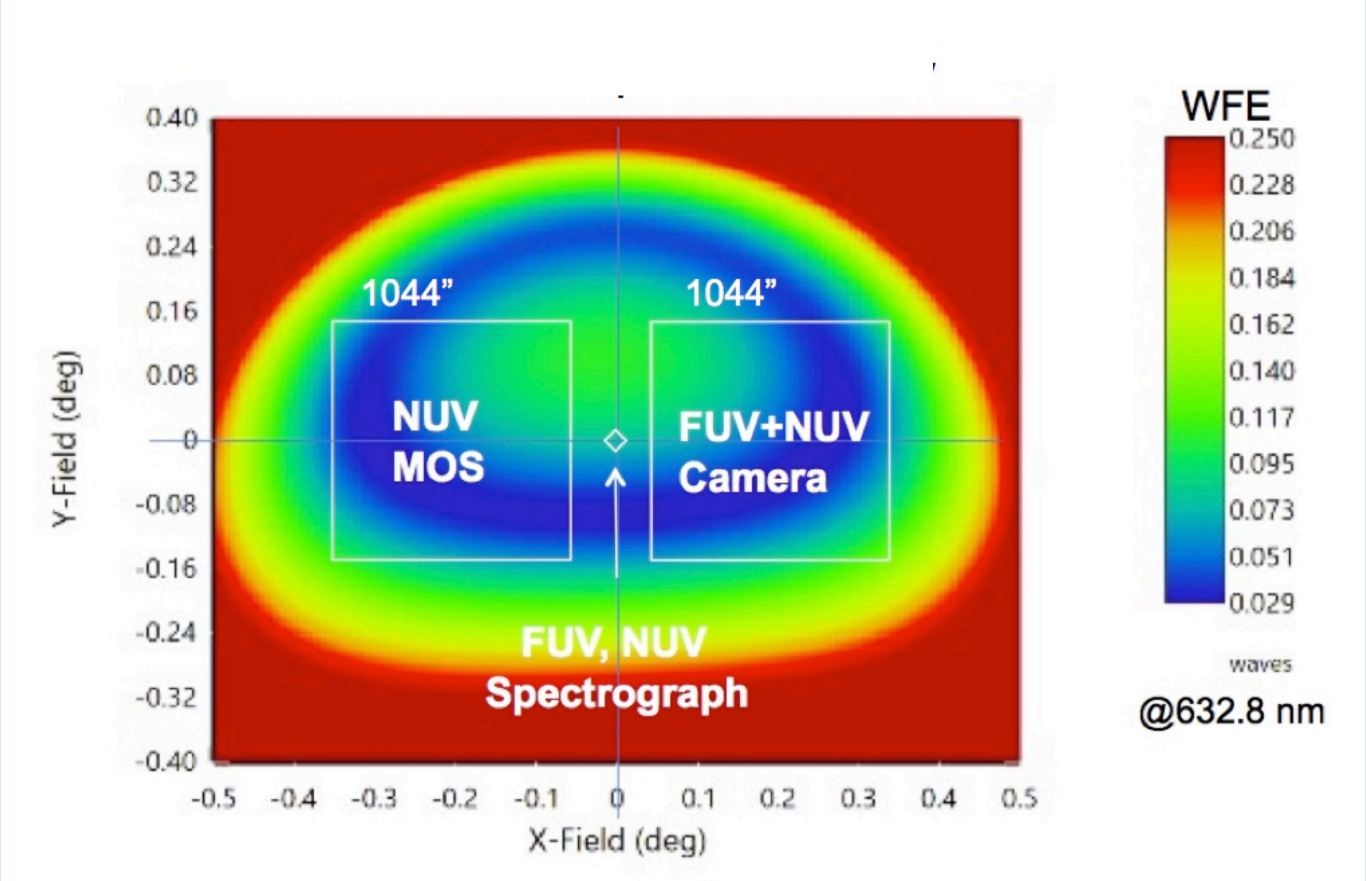


Optical outer baffle



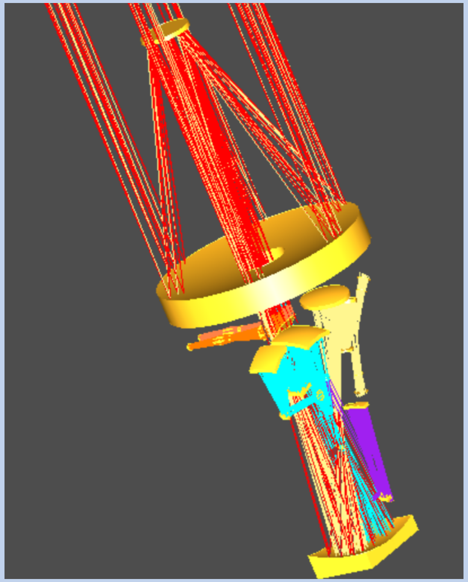
Mirrors + Metering

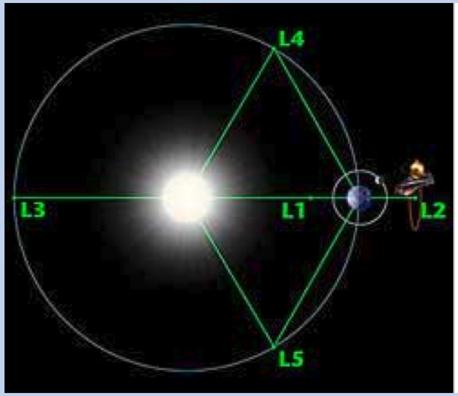
The telescope field of view is large enough to accomodate all three scientific instruments working in parallel

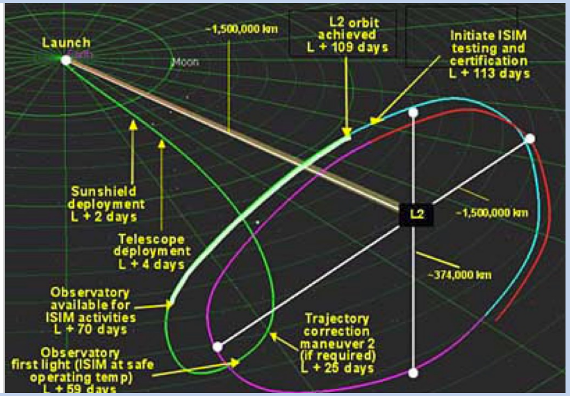


CETUS Systems: Mission Overview

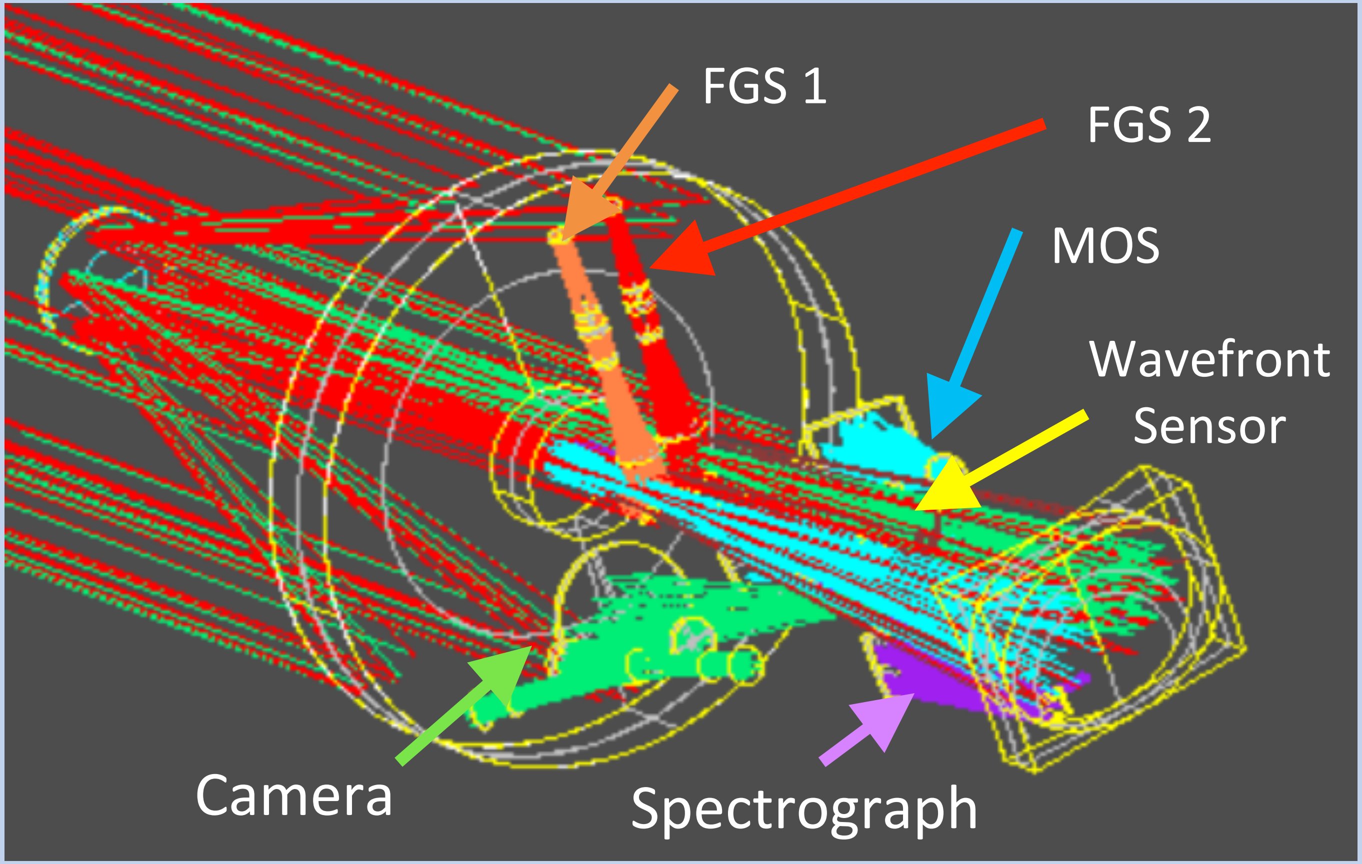
- Probe Class (Class B)
- Mission Life: 5 Years
- Mission orbit: L2, similar to JWST
- Instruments: FUV/NUV Camera, UV Spectrograph, MOS
- Objectives: Obtain >10^5 spectra of galaxies (z=0.8 – 1.3) With SNR > 7
- Launch vehicle: Falcon 9 (Appx. 3400 kg payload mass capability)







Ray Trace View of Instruments



Two Large Study Examples

- Origins Space Telescope (OST)
- Large UV Optical IR (LUVOIR) Space Telescope

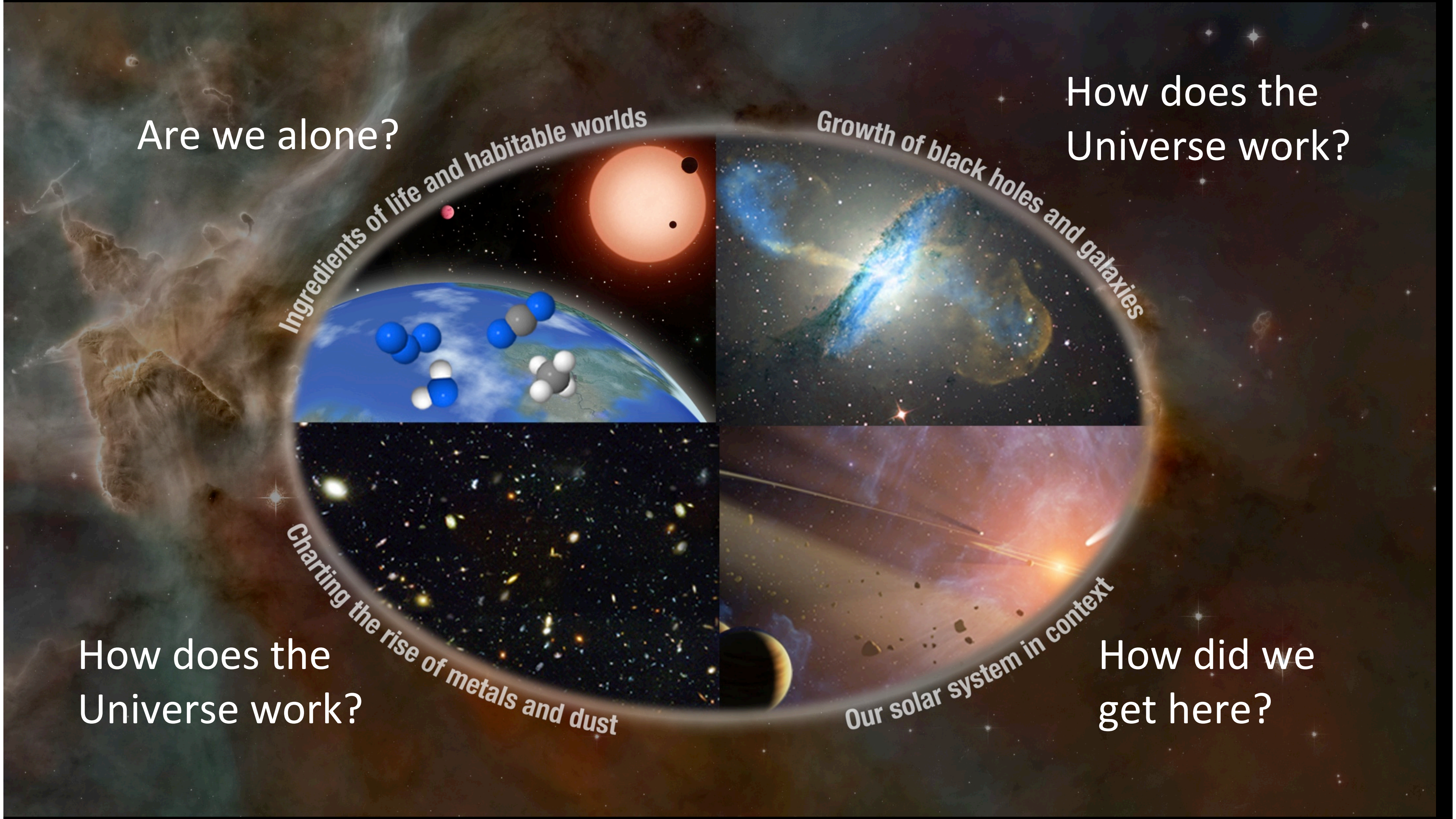
The Origins Space Telescope (OST)

From First Stars to Life

Margaret Meixner, Community co-chair for OST,
STScI/JHU/NASA Goddard
Jonathan Fortney, Exoplanet co-chair for OST, UC Santa Cruz

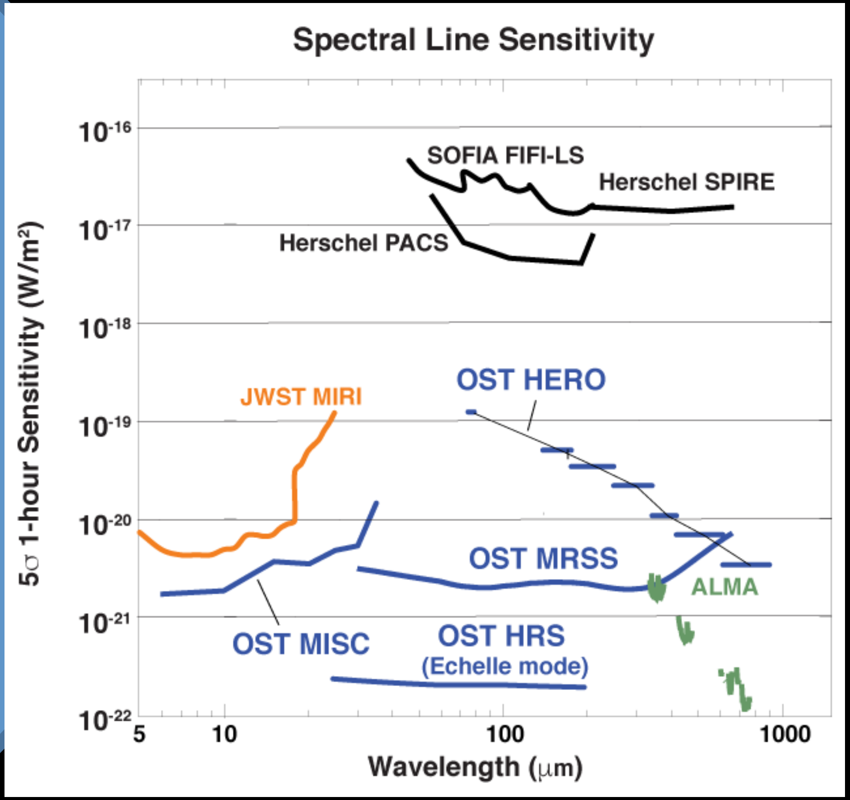
The OST NASA Decadal Study

- Mission concept for NASA Astrophysics Roadmap Enduring Quests, Daring Visions; formerly known as Far-Infrared Surveyor
- Operating wavelengths: 5-660 µm
- Goal: large general astronomy mission with exciting science that is technologically executable in 2030s
- Both Science Definition & Technological Implementation important
- OST study has two concepts:
  - Mission Concept 1, completed, described here
  - Mission Concept 2, started – optimization


Are we alone?
How does the Universe work?
How does the Universe work?
How did we get here?
Ingredients of life and habitable worlds
Growth of black holes and galaxies
Charting the rise of metals and dust
Our solar system in context

OST Gains in sensitivity because it is COLD (4 K)

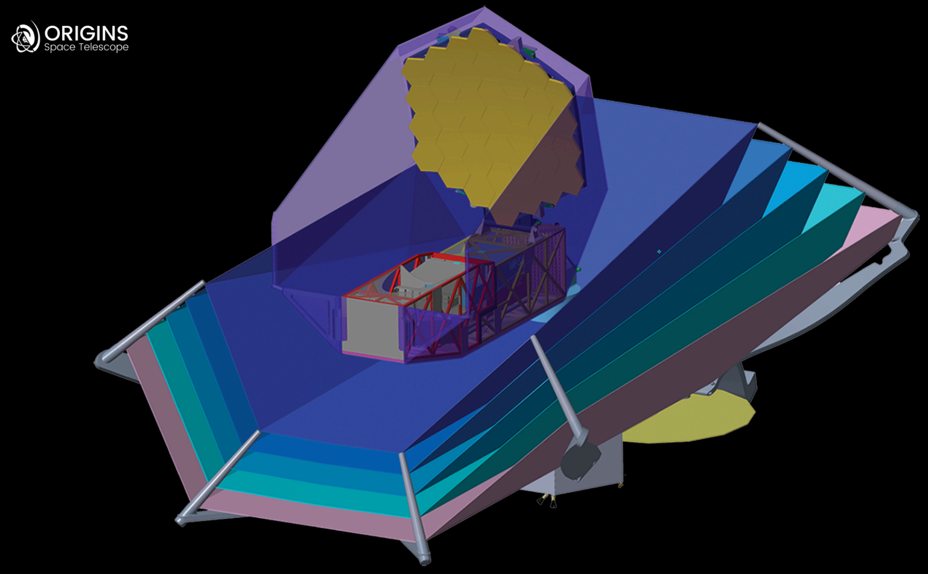
Equivalent telescope diameter difference needed for an optical telescope to achieve 1000 times higher sensitivity



Mission Concept 1

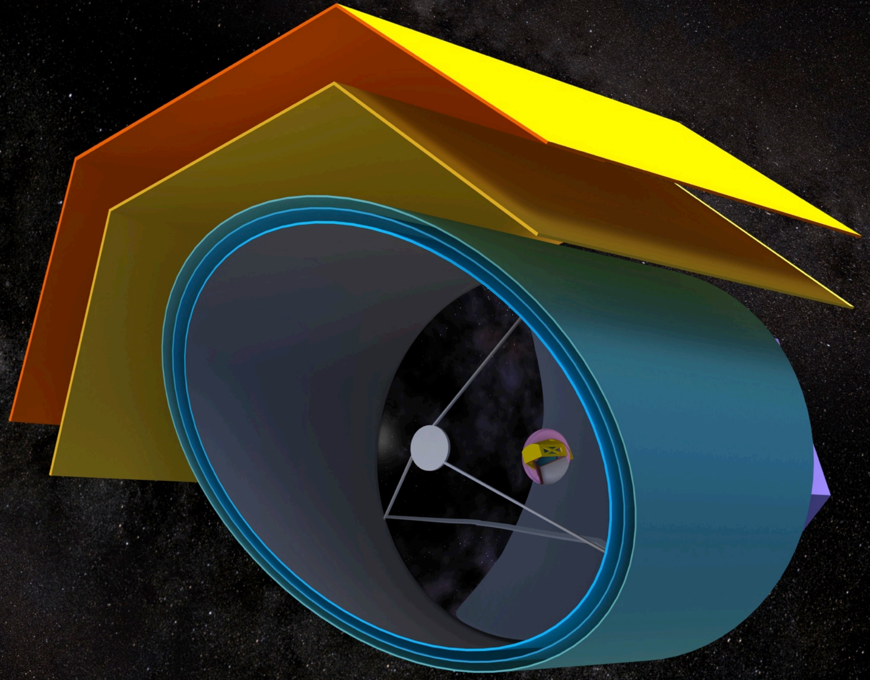
- 9.1 m off-axis primary mirror
- Cold (4 K) telescope
- Wavelengths 5-660 µm
- 5 science instruments:
  - MISC - 5-38 µm
  - MRSS 30-660 µm
  - HERO 63-66; 111-610 µm
  - HRS 25-200 µm
  - FIP 40, 80, 120, 240 µm
- 100 arcsec/sec mapping
- Launch 2030s
- Sun-Earth L2 orbit

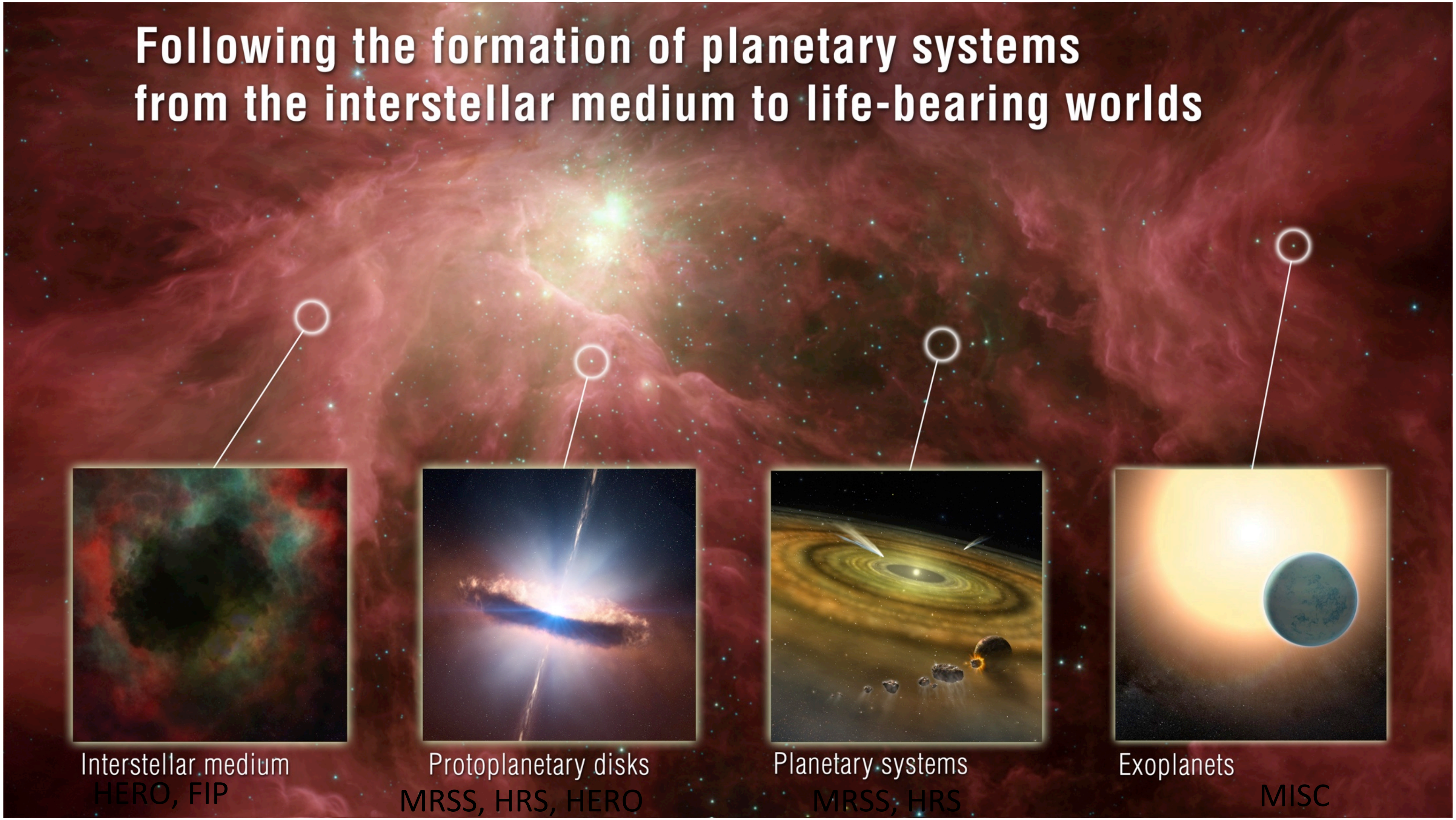
- 5 year lifetime, 10 year goal



Mission Concept 2

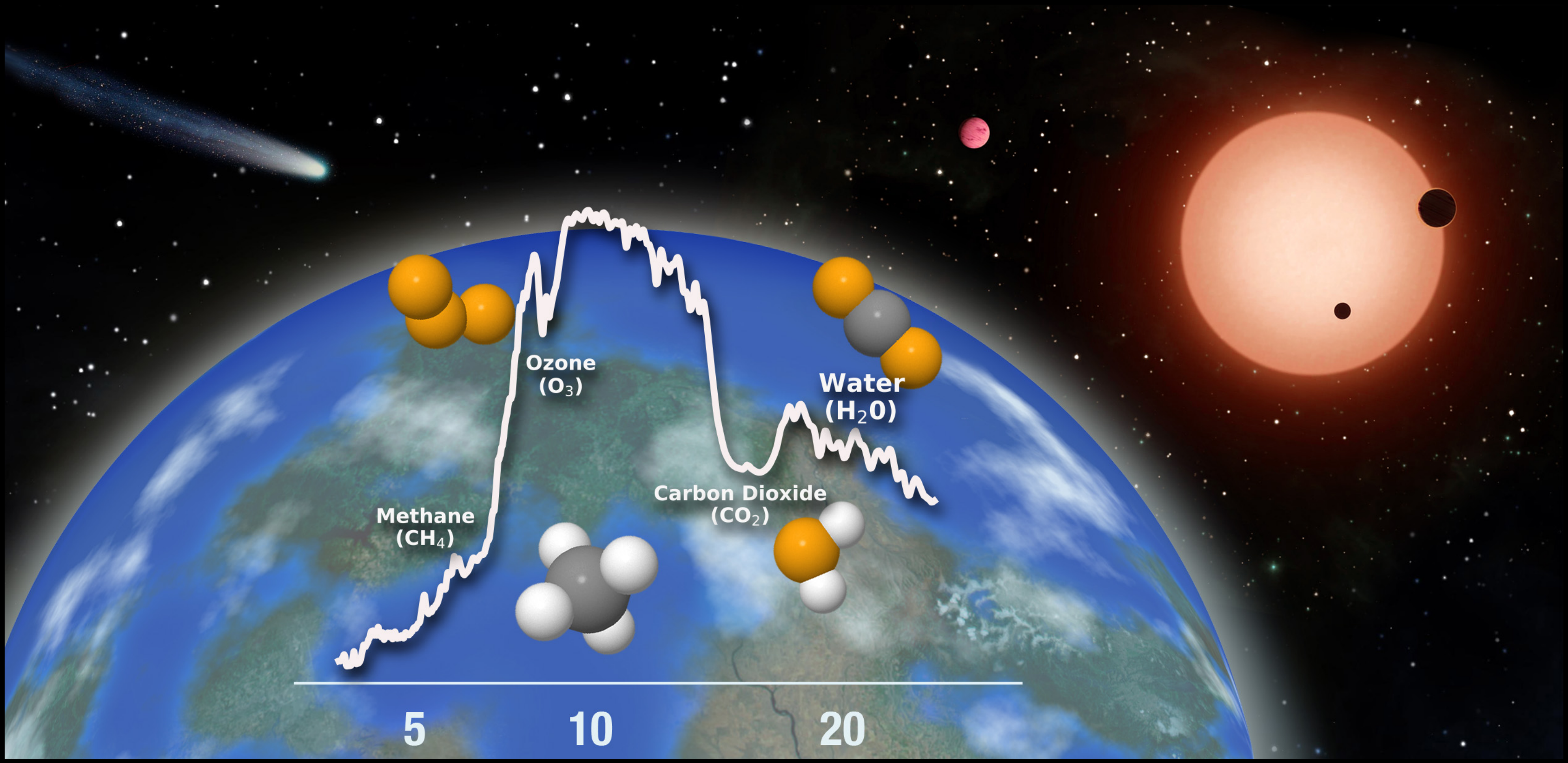
- 5.9-m circular aperture
- Cold (4 K) primary
- Spitzer-like baffle, with Sun shield
- Minimal deployment
- Fewer (≤4), science-optimized instruments
- Preliminary designs started, to be completed by end of summer 2018





Following the formation of planetary systems from the interstellar medium to life-bearing worlds

Searching for biologically significant gasses at mid-IR wavelengths for temperate terrestrial transiting planets around M stars

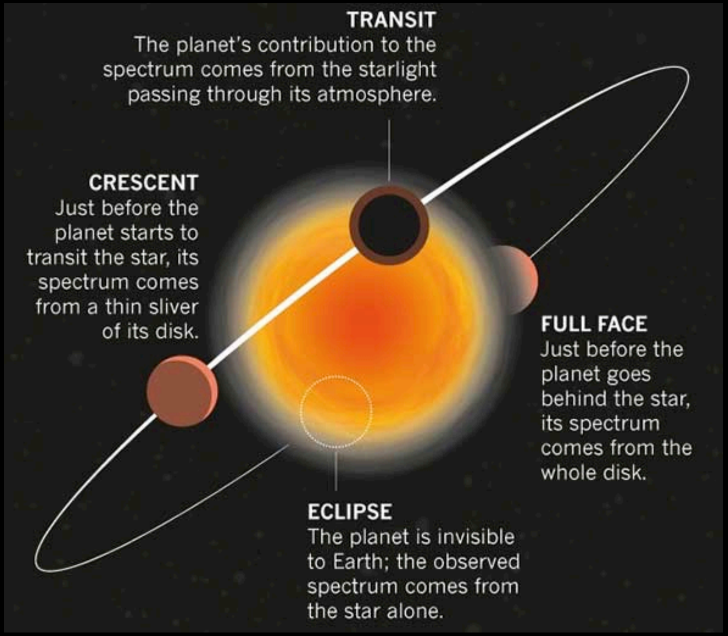


Thermal IR Advantages

- Wavelength coverage where the planets are brightest and contrast is best
- Access to thermal emission and the temperature structure of atmospheres
- Absorption features for a range of interesting gases
- Broad wavelength coverage for context and the detection of the unexpected

Observational Techniques

- Primary transit
  - Molecular abundances and role of clouds
- Secondary eclipse
  - Temperature structure and molecular abundances
- Spectroscopic Phase Curves
  - Presence of atmospheres and atmospheric circulation
- Eclipse Maps
  - Temperature distribution



TRANSIT
The planet's contribution to the spectrum comes from the starlight passing through its atmosphere.

CRESCENT
Just before the planet starts to transit the star, its spectrum comes from a thin sliver of its disk.

FULL FACE
Just before the planet goes behind the star, its spectrum comes from the whole disk.

ECLIPSE
The planet is invisible to Earth; the observed spectrum comes from the star alone.

Conclusions

- The Atmospheres of Transiting Temperate Terrestrial Planets can be Characterized with OST
  - Transits provide known targets with known masses and radii
  - Wide thermal IR wavelength range:
    - Includes many important molecules, such as O_3, CH_4, H_2O, CO_2
    - Enables determination of temperature structure in pressure, longitude, and latitude
- OST disk science informs planet formation and initial conditions
- OST Exoplanet Science is Complementary to Other Large Missions

What is LUVOIR ?

Slides Courtesy of: Aki Roberge

- Large UV / Optical / Infrared Surveyor (LUVOIR)
- A space telescope concept in tradition of Hubble

- Broad science capabilities
- Far-UV to near-IR bandpass
- Two architectures: 15-m and ~ 9-m telescopes
- Suite of imagers and spectrographs
- Serviceable and upgradable
- Guest Observer driven

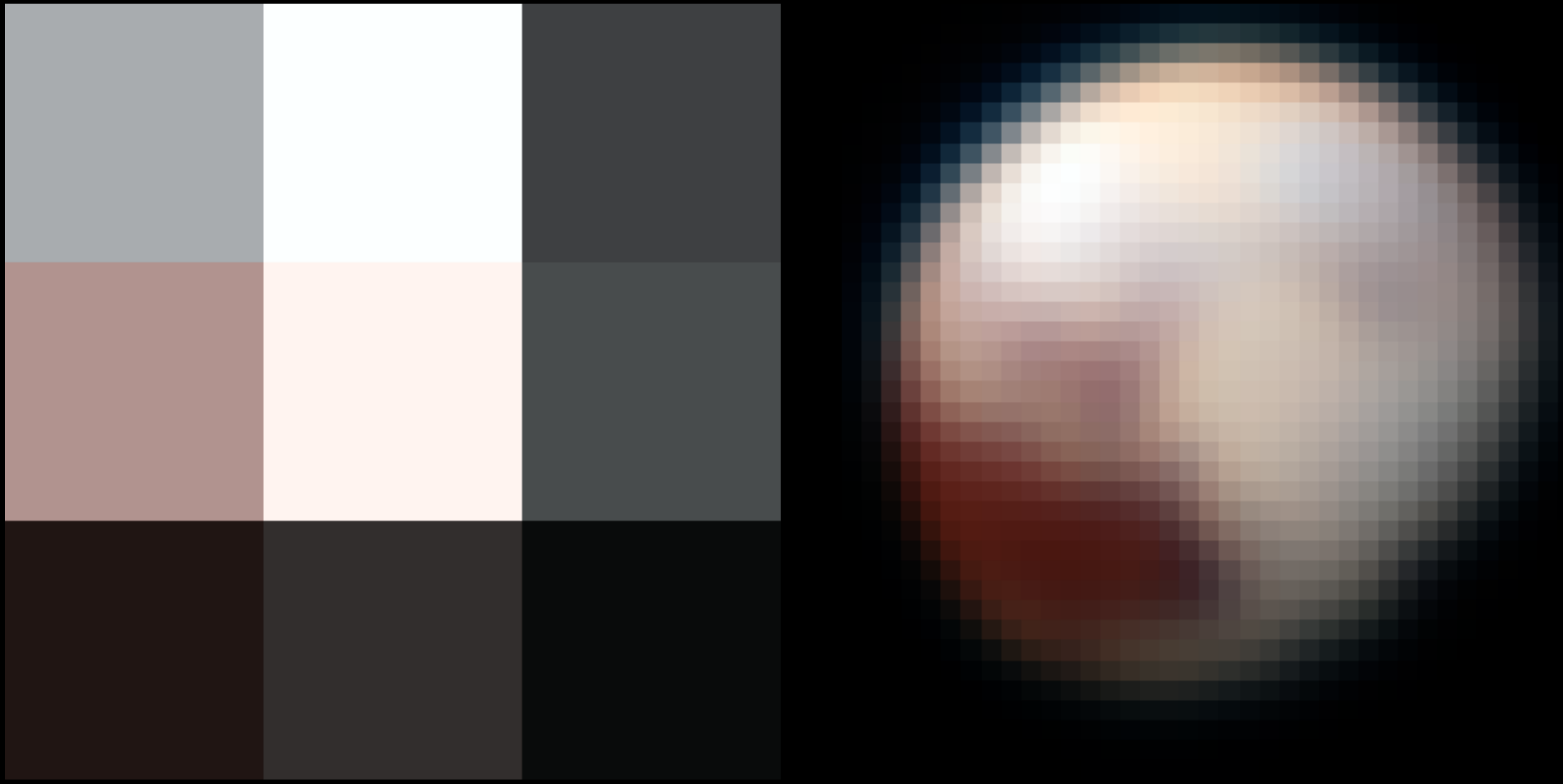
"Space Observatory for the 21st Century"
Ability to answer the questions of the 2030s and beyond

Imagine astronomy with LUVOIR

Low-mass galaxy at z = 2
with HST

Low-mass galaxy at z = 2
with 15-m LUVOIR

Imagine astronomy with LUVOIR

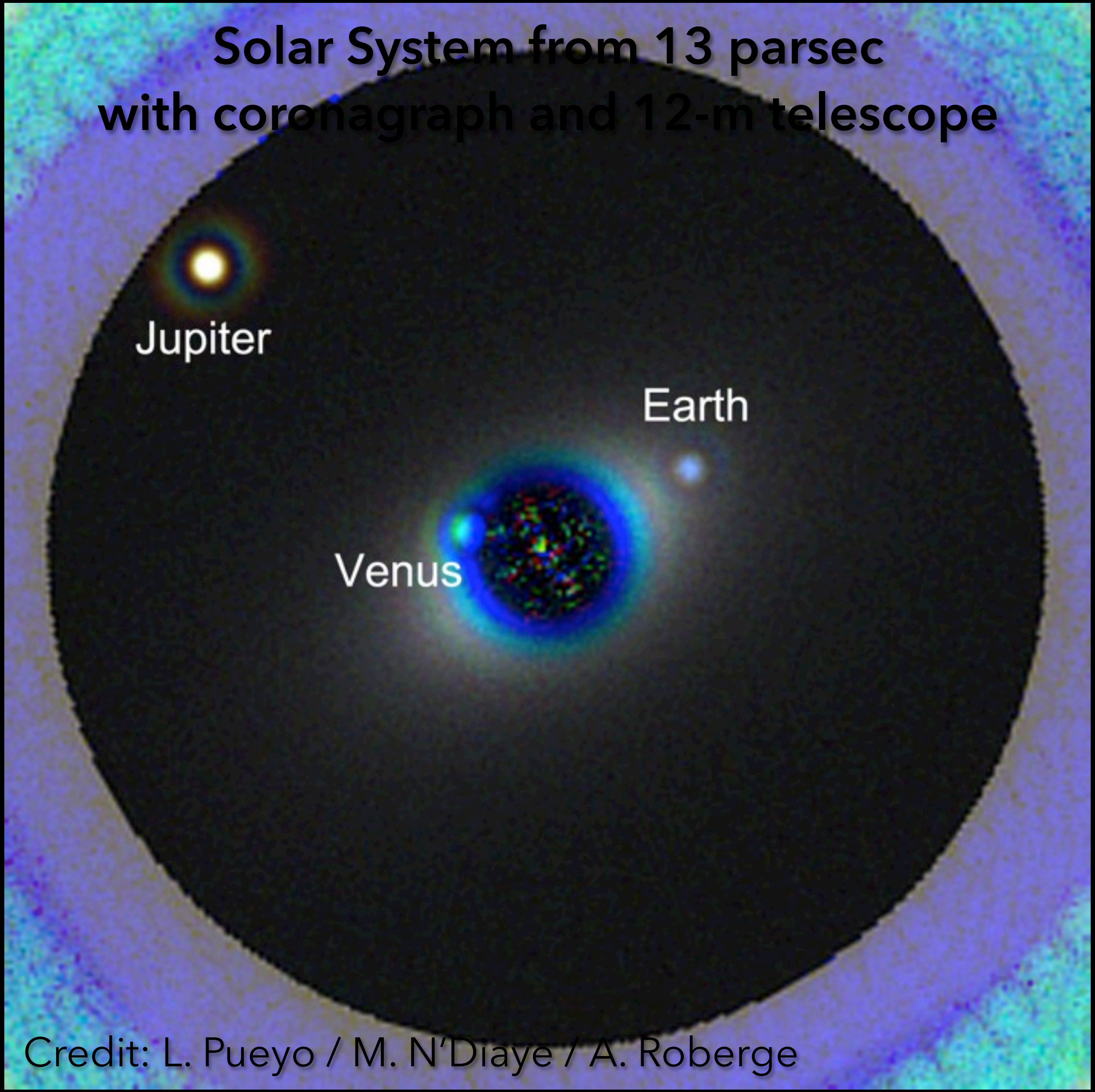


Pluto with HST

Pluto with 15-m LUVOIR

Credit: NASA / New Horizons / R. Parramon

Imaging Earth 2.0



Solar System from 13 parsec with coronagraph and 12-m telescope

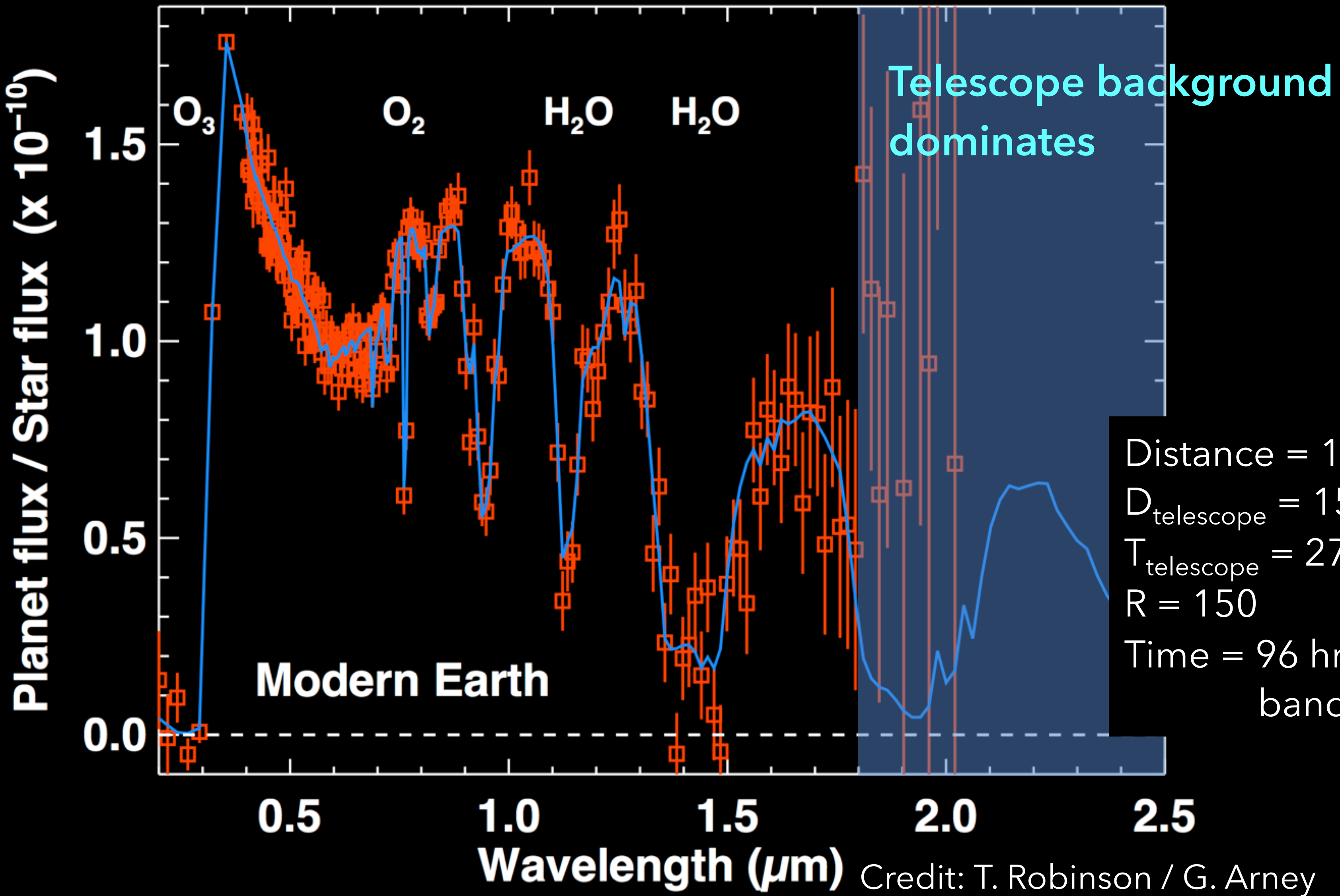
Credit: L. Pueyo / M. N'Diaye / A. Roberge

LUVOIR will observe hundreds of FGKM stars to discover and characterize dozens of habitable planet candidates

Measure *frequency* of habitable conditions

If "Earths" are not extremely rare, LUVOIR will find some

Searching for life - simulated LUVOIR spectrum



Telescope background dominates

Distance = 10 pc
$D_{telescope}$ = 15-m
$T_{telescope}$ = 270 K
R = 150
Time = 96 hrs per band

Credit: T. Robinson / G. Arney

The LUVOIR architectures

Architecture A

- 15-m diameter telescope
- Four instruments
- SLS Block 2 launch vehicle

Instruments
ECLIPS A
LUMOS A
High-Definition Imager
POLLUX

Architecture B

- ~ 9-m diameter telescope
- Three instruments
- Heavy lift launch vehicle w/ 5-m fairing

Instruments
ECLIPS B
LUMOS B
HDI B

Preliminary rendering of LUVOIR-A

15-m telescope

Credit: A. Jones (GSFC)

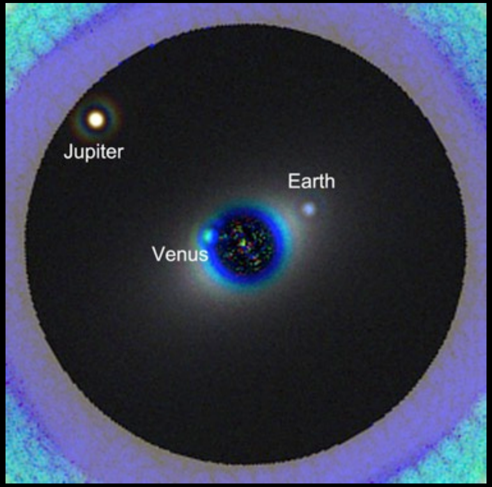
LUVOIR Architecture A (15-m)

Credit: A. Jones (GSFC)

The LUVOIR instruments

Observational challenge

Faint planets next to bright stars



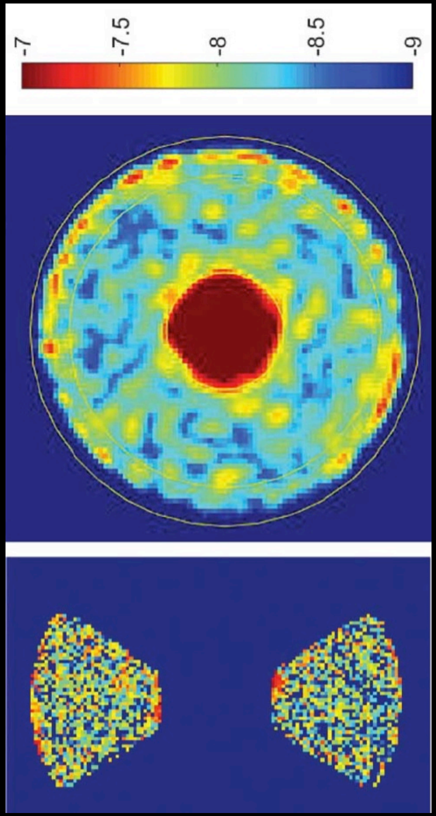
Extreme Coronagraph for LIving Planetary Systems (ECLIPS)

Contrast < 10^{-10}

Low resolution imaging spectroscopy

Bandpass: 0.2 µm to 2.0 µm

Tech development via WFIRST coronagraph



The LUVOIR instruments

Observational challenge

Very cold to very hot gases

LUVOIR UV Multi-Object Spectrograph (LUMOS)

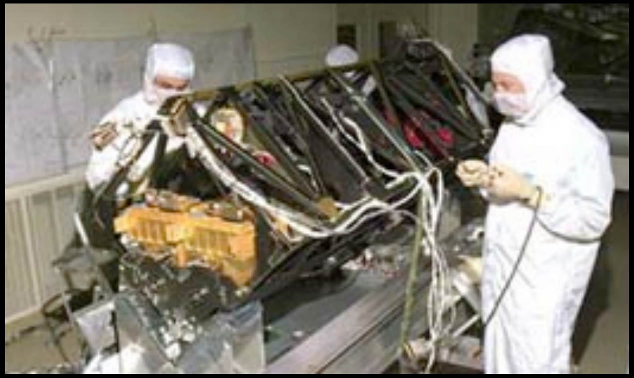
R = 500 – 63,000

Bandpass: 100 nm to 400 nm

FOV: 3′ x 1.6′ (FUV), 1.3′ x 1.6′ (NUV)

FUV imaging channel

Heritage from STIS, COS, & NIRSPEC



The LUVOIR instruments

Observational challenge

Imaging the ultra faint and very small at high resolution

High-Definition Imager (HDI)

2 x 3 arcmin field-of-view

Bandpass: 0.2 μm to 2.5 μm

Nyquist sampled

Micro-arcsec astrometry capability
(measure planet masses, etc.)

Heritage from HST WFC3 & WFIRST

POLLUX: a European contribution to the LUVOIR mission study

- UV spectro-polarimeter with high resolution point-source capability (R ~ 120,000).
- Circular + linear polarizations and unpolarized light
- Defined & designed by consortium of 10 European institutions, with leadership/support from CNES
- Builds off Arago mission concept. Instrument study could serve as basis for a future ESA contribution to LUVOIR

Summary

LUVOIR has multiple primary science goals

① Habitable exoplanets & biosignatures

② Broad range of general astrophysics and Solar System observations

Challenge is to blend goals into single powerful mission

LUVOIR will provide a statistical study of Goal 1, factors of ~ 100 increased science grasp over Hubble for Goal 2

Wide range of capabilities to enable decades of future investigations and unexpected discoveries

Conclusion

As you can see there are a lot of good mission concepts out there.

This presentation only gives information on 4/14 concepts being studied.

Please look at NASA’s web pages and talk to the Pis and their teams

European involvement is encouraged!