PRIMA The PRobe far-Infrared Mission for Astrophysics

GO and GI Science with PRIMA

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prima.ipac.caltech.edu

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PRIMA is designed primarily as community resource

- **75% of observing time for general observer (GO) programs** -> ~ 32,000h over 5 years
- PI surveys producing high-impact legacy datasets for archival research (Guest Investigator [GI] science)
- Archive with access to all science and calibration data, software

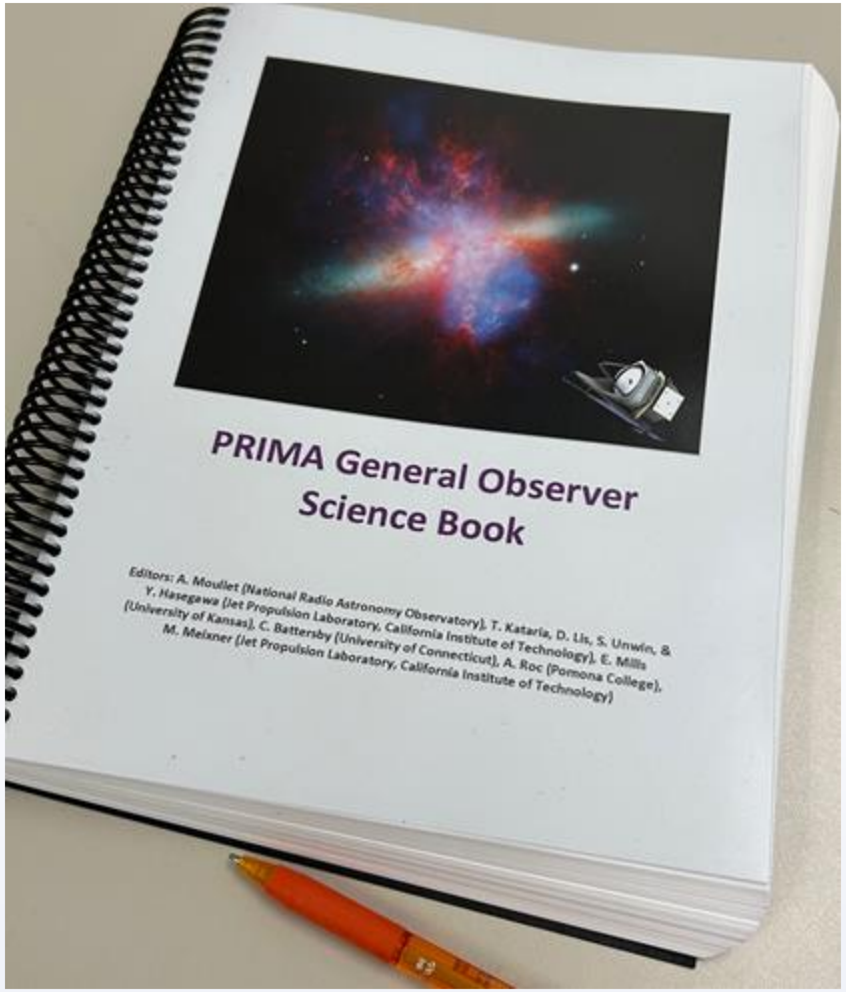
Astro2020 Science Panel	Astro2020 Questions addressed	# GO Science Book cases
Compact Objects and Energetic Phenomena (Appx. B)	B-Q2, B-Q3, B-Q4, B-DA	9
Cosmology (Appx. C)	C-Q2, C-Q3, C-Q4	3
Galaxies (Appx. D)	D-Q1, D-Q2, D-Q3, D-Q4, D-DA	31
ExoAstroSolar (Appx. E)	E-Q1, E-Q2, E-Q3	3
ISM & Star/Planet Formation (Appx. F)	F-Q1, F-Q2, F-Q3, F-Q4	25
Stars, the Sun, and Stellar Populations (Appx. G)	G-Q1, G-Q2, G-DA	5

Most of PRIMA's scientific impact will come from community-led studies (GO, GI). Based on PRIMA GO Science Book, Vol 1, GO program can address >70% of Astro2020 science questions

To develop a concept that is most responsive to community needs, PRIMA continues to solicit community engagement in phase A

PRIMA GO Science Book Volume 1

- Volume1 published on ArXiv in November 2023 (arXiv:2310.20572)
- Collection of 76 community-contributed cases, spanning scientific areas from comets to high-z polarimetry
- Volume 1 totals about ~21,000 h of observations, or **about 65% of the expected time available for GO observations.**
- Approximately use requests for PRIMAger (35% of cases), FIRESS (32%) or both instruments (32%).



Thank you to all case writers!

GO Science Book Volume 2 is now in preparation

Any member of the international astronomy community is encouraged to develop and submit a case for Volume 2. A great way to **contribute to the scientific development of the PRIMA concept, and be an active part of the PRIMA community**

- **Submission deadline (through Google form): May 31, 2025**
- Expected publication late Summer 2025
- Includes new and revised cases

Google Form for GO cases submissions

We are here to support contributors
Main contacts: Arielle Moullet (amoullet@nrao.edu), Denis Burgarella (denis.burgarella@lam.fr)
A team of editors + PRIMA team is available for general support

Are you considering submitting a new GO case? How to get started

	PRIMA Hyperspectral Imager	
Parameter	PHI1	PHI2
Wavelength (μm)	24-45	45-84
Spectral resolving power	10	10
Polarimetry	-	-
Band center FWHM (")	4.1	7.4
Pixel size (")	4.1	7.4
Pixel count	63×23	33×14
Field of view	3.6'×1.5'	3.6'×1.7'

General guidelines:

- All observing modes available
- We are soliciting GO program observations up to 1000s of hours
- Contributions are ~3-8 pages, based on provided template

References

- GO Science Book Volume 1
- Instrument page/Fact Sheet/**Exposure Time Calculator**
- Upcoming PRIMA JATIS special section
- Science page for information on PI science. **Please reach out to editors if you think your idea is based on PI survey observations. We welcome archival (Guest investigator/GI) cases**

Are you considering submitting a new GO case? Use the PRIMA ETC

PRIMA Exposure Time Calculator

Step 1: Choose your instrument
Step 2: Choose your mode

If FIRESS…

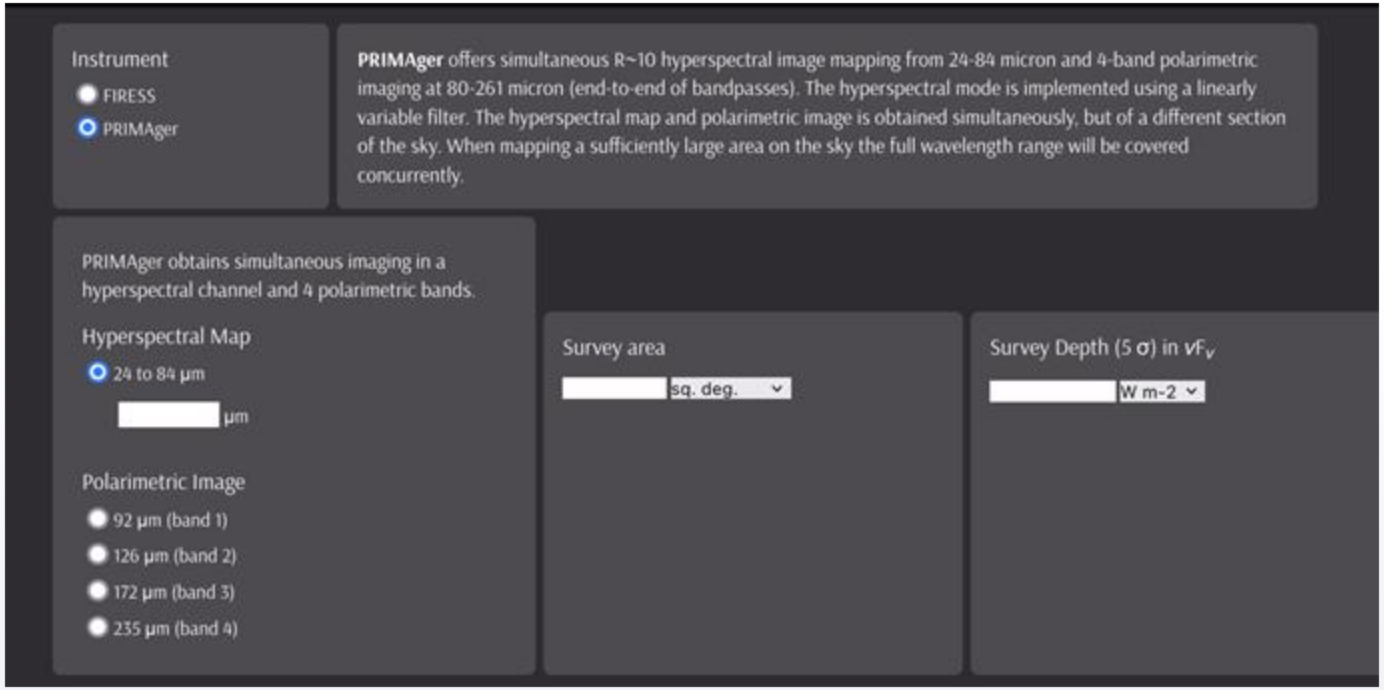
- Low-res point source → Specify line flux
- Low-res mapping→ Specify wavelength, survey area, survey depth
- High-res point source → Specify wavelength, continuum flux density, line flux

If PRIMAger…

- For either mode (Hyperspectral or Polarimetric), provide survey area, survey depth

Read ETC notes for important considerations

Please reach out to editors for questions about more capability information (time domain constraints, continuum subtraction, saturation levels, etc.)



Are you considering resubmitting a Vol 1 GO case?

Table of Contents

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Thank you for your work on a Vol 1 contribution! A revision will allow for consistency with latest specs, and updated science.

Template is very similar to Volume 1

Main considerations:

- Check against updated instrument descriptions
- Use ETC for time estimates
- Adapt to new instrument table in the template
- Update science based on results from the last 2 years

GO Book Template Sections: Science Case

Science Justification: [~ 2 pages]

Content to address:

- Broader context
- Science question
- Need for PRIMA
- Interpretation methods
- Link to testable hypotheses

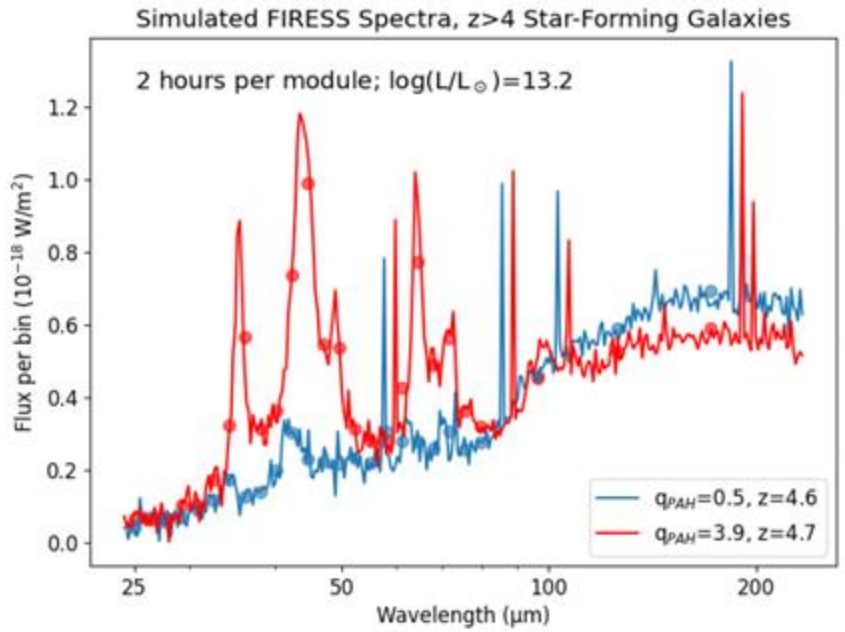


Figure 4: Simulated PRIMA/FIRESS spectra of two luminous galaxies at z > 4.5, with realistic noise model reflecting current best estimate FIRESS sensitivity. The overlaid points illustrate selected R ≥ 10 PRIMAger hyperspectral coverage, which will be available for more than 10,000 galaxies at z > 2.

Donnelly et al., 2023

If possible, 1 figure highlighting measurements or discovery space enabled by PRIMA

GO Book Template Sections: Observing Plan

FIRESS Spectrometer			
Pointed High-res (R~4400@ 112 microns)	Mapping High-res (R~4400@ 112 microns)	Pointed Low-res R~100	Map Low-res R~100
[specify number of pointings]	[specify size (x,y in arcmin) and number of maps]	[specify number of pointings]	[specify size (x,y in arcmin) and number of maps]

PRIMAger Imager		
Mapping details	Hyperspectral band (24-84 microns; R=8-10)	Polarimeter band (96, 126, 172, 235 microns; R=4)
[specify size (x,y in arcmin) and number of maps] *	[check if necessary to your science case]	[check if necessary to your science case]
If you selected Polarimeter Band, do you need polarimetry information? Yes/No		

*note that the minimum usable map size is 5'x5' for the hyperspectral band and 10'x10' for the polarimeter band

FIRESS:
- Fill boxes for each mode used
- Note pointed high-res mode (multiple pointings) – details available on demand

PRIMAger:
- Fill mapping details box
- Check which bands you are interested in

Be sure to use PRIMA ETC to guide your estimates!

Book editors will come back to you if anything is unclear

GO Book Template Sections: Observing Plan II

Approximate integration time, for each instrument mode. Do not include overheads (slews, calibration, etc.)

Special capabilities needed (if applicable, e.g.: Non-sidereal targets, timing requirements, non-interruptible, special calibrations

Synergies with other facilities

Description of Observations
Narrative of observational strategy

Approximate Integration Time:

A sample of 50 transient sources in the far-IR, detected by future CMB experiments and selected to be brighter than 10 mJy (significantly above the confusion limit in most bands) in the far-IR will lead to quite short individual integration times – 5 minutes or less. To follow these sources for 10 epochs of observation then this project will require about 50 hours of observations.

Special Capabilities Needed:

Monitoring over days to weeks timescales depending on the nature of the transient. Some specific objects (e.g., dust embedded TDEs) may need monitoring over year time scales.

Synergies with Other Facilities:

Synergy directly with CMB experiments that will provide event triggers, and with other monitoring projects such as VRT-LSST.

Description of Observations:

Single source photometric observations in all PRIMAGER bands with 5-minute integration time. Observations to be repeated on timescales determined to be appropriate for each specific source by other observatories that can characterize the timescale of variation.

Clement et al., 2023

What to expect after submission

- A managing editor will be assigned to your submission
- Over the Summer, editors will check consistency, observing details
- You will be contacted for clarifications and to validate the edited draft
- You will be contacted to validate the formatted draft that will be included in the compiled Volume

We are here to support contributors at any stage of case development

Main contacts: Arielle Moullet (amoullet@nrao.edu), Denis Burgarella (denis.burgarella@lam.fr)
A team of editors + PRIMA team is available for general support

For Japan-based submissions, researchers who would like to have their document proof-read by a native English speaker are welcome to send their draft to Elizabeth Tasker at JAXA. The deadline for this is May 16, 2025.

Become a PRIMA WG member to interact with others on GO Book cases!

AGN Across Cosmic Time
Sylvain Veilleux (University of Maryland)

Cosmic Ecosystems
Rebecca Levy (Space Telescope Science Institute)

Galaxy Evolution from Cosmic Dawn to Cosmic Noon
Irene Shivaei (Centro de Astrobiología, Madrid)
Jed McKinney (University of Texas at Austin)

Mapping Magnetic Fields in the Local Universe
Enrique Lopez Rodriguez (University of South Carolina)
Kate Pattle (University College London)

Milky Way Interstellar Medium and Star Formation
Frédérique Motte (IPAG, CNRS, Univ Grenoble Alpes)
Dylan Paré (Villanova University)
Yao-Lun Yang (Star and Planet Formation Laboratory, RIKEN, Japan)

Protoplanetary Disks and Exoplanets
Andrea Banzatti (Texas State University)
Ke Zhang (University of Wisconsin)

Debris Disks
Meredith MacGregor (Johns Hopkins University)
Christine Chen (Space Telescope Science Institute)

Solar System and Planetary Science
Dariusz Lis (Jet Propulsion Laboratory)

Stars and Stellar Evolution
Olivia Jones (Royal Observatory, Edinburgh)
Sundar Srinivasan (Institute of Radio Astronomy and Astrophysics, National Autonomous University of Mexico)

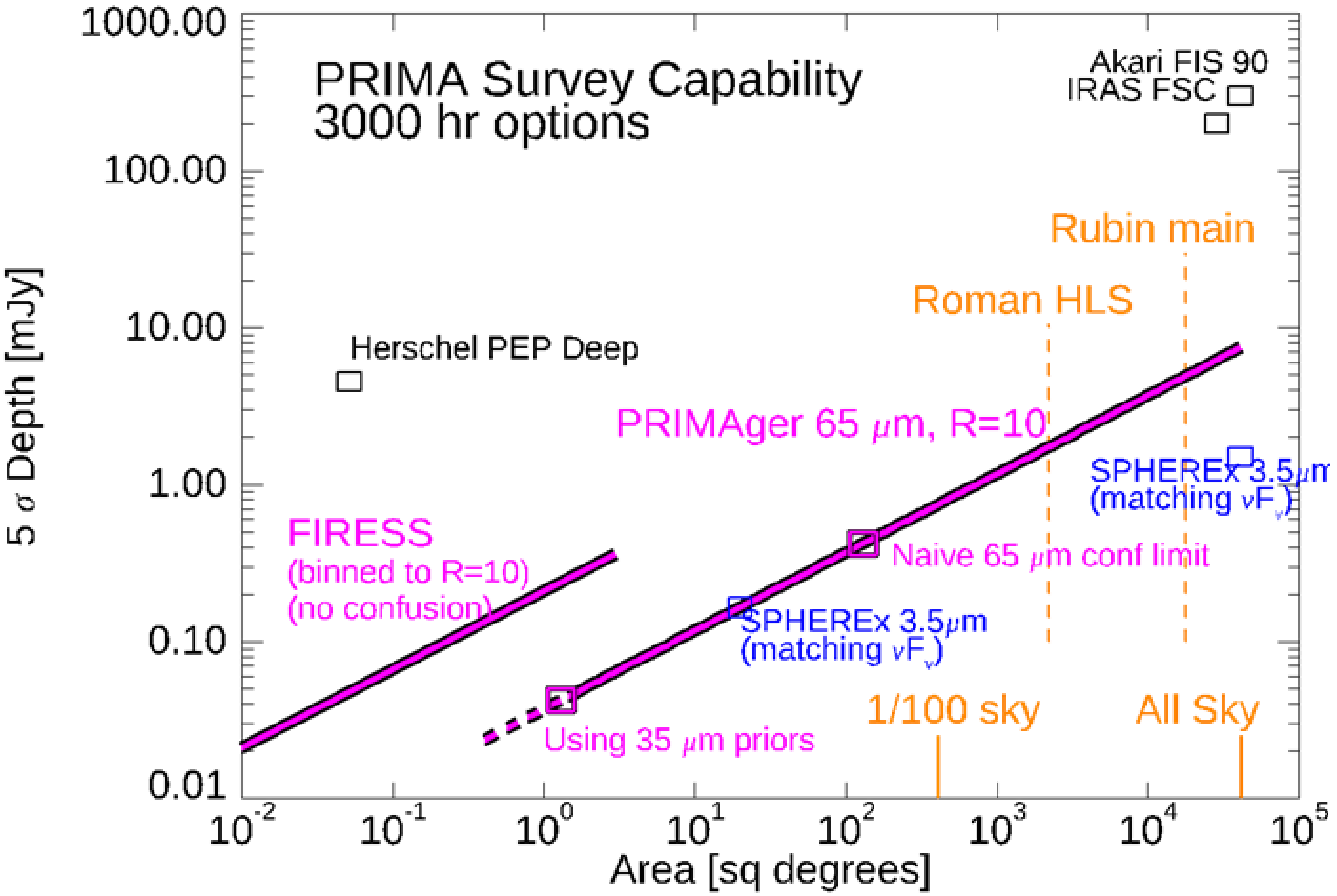
Time Domain and Transients
Mansi Kasliwal (California Institute of Technology)
Kishalay De (Columbia University)

Working group sign-up

We strongly encourage early career participation in WGs!

In PRIMA GO Science Book Volume 1: Large Surveys

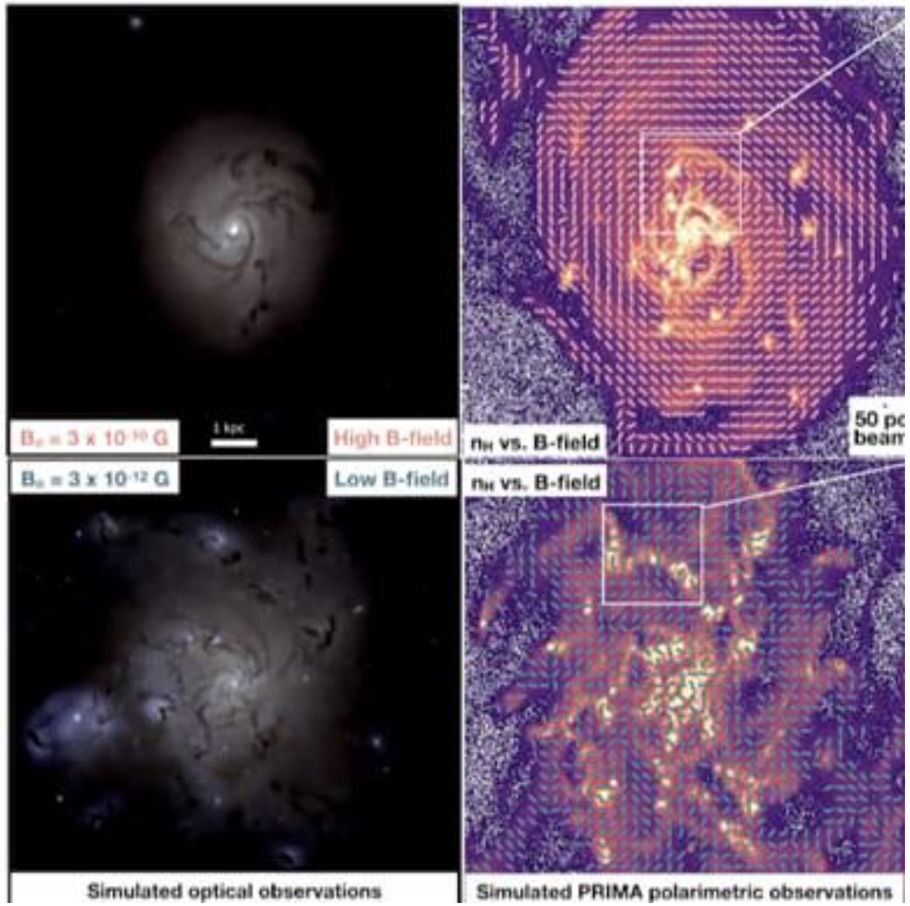
- PRIMA has high efficiency map modes provided by both observatory scan and the steering mirrors.
- In 5,000 hours, **an all-sky survey** can reach a depth comparable to Herschel extragalactic deep fields or sensitivity 100x better than the Infrared Astronomical Satellite (IRAS) all-sky survey (Wright et al., 2023)
- In 500 hours, a 200 square degree area of the **Small and Large Magellanic Clouds** can reach a sensitivity that allows separation of their dust emission from the Milky Way foreground and the Cosmic Infrared Background. (Galliano et al., 2023)



In PRIMA GO Science Book Volume 1: Magnetic Fields

- In 400 hours, an **extragalactic polarization survey** (400 sq degrees) to detect 10,000 galaxies at z<2 to verify coherent large-scale B-field. Any local correlations in orientation? (Bethermin et al., 2023)

- In 100 h, **magnetic fields in giant molecular clouds** can be mapped in 6 local galaxies at <100 pc spatial resolution: information about collapse and regulation of star formation (Lopez Rodriguez et al., 2023)



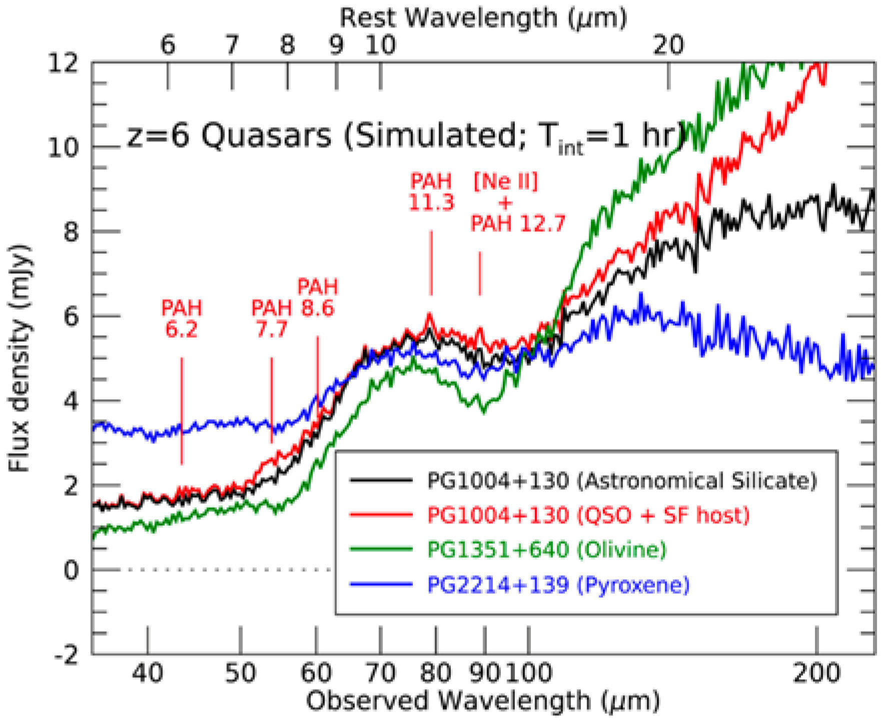
Lopez Rodriguez et al., 2023: Simulated optical and FIR polarimetric observations of a face-on view of a MW-like galaxy. High (top) and low (bottom) magnetization at 50 pc resolution.

In PRIMA GO Science Book Volume 1: Dust Mineralogy

- **Dust formation at epoch of reionization**: In 1 h per target, obtain spectra of quasars at z>5 – epoch of reionization – to constrain dust formation mechanisms: AGB stars, supernovae, ISM grains growth (Egami et al., 2023)

- Measure the crystalline silicate content on **star forming galaxies at 1.5<z<4 (~1h/source) to** characterize the dust formation in mass-losing stars, around cosmic noon (Kemper et al., 2023)

- In 10h, obtain a spectrum of dust in **supernovae** to evaluate mass and composition of dust created ($MgSiO_3$, FeO, SiO_2, FeS, Al_2O_3) and its contribution to ISM (Matsuura et al., 2023)



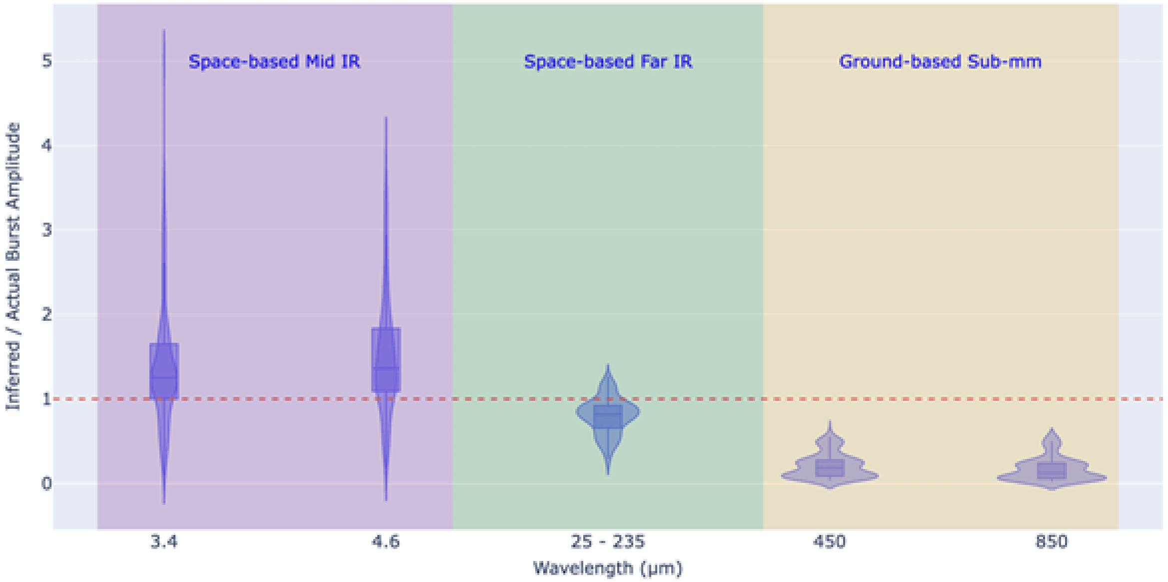
Egami et al., 2023: Simulated PRIMA/FIRESS low-resolution (R=130) spectra of quasars at z=6 (Tint=1hr)

In PRIMA GO Science Book Volume 1: Time Domain and Transients

- In 600 hours, PRIMA can monitor 2,000 protostars over the mission's lifetime with a range of revisit timescales, to obtain the first well-sampled, systematic study of **protostellar accretion variability**. The goal is to determine the frequency and types of bursts that protostars undergo (Battersby et al., 2023)

- In 5 minutes, detect **transient sources discovered by CMB experiments**, enabling efficient monitoring of hundreds of sources over day to week timescales (Clements et al., 2023)

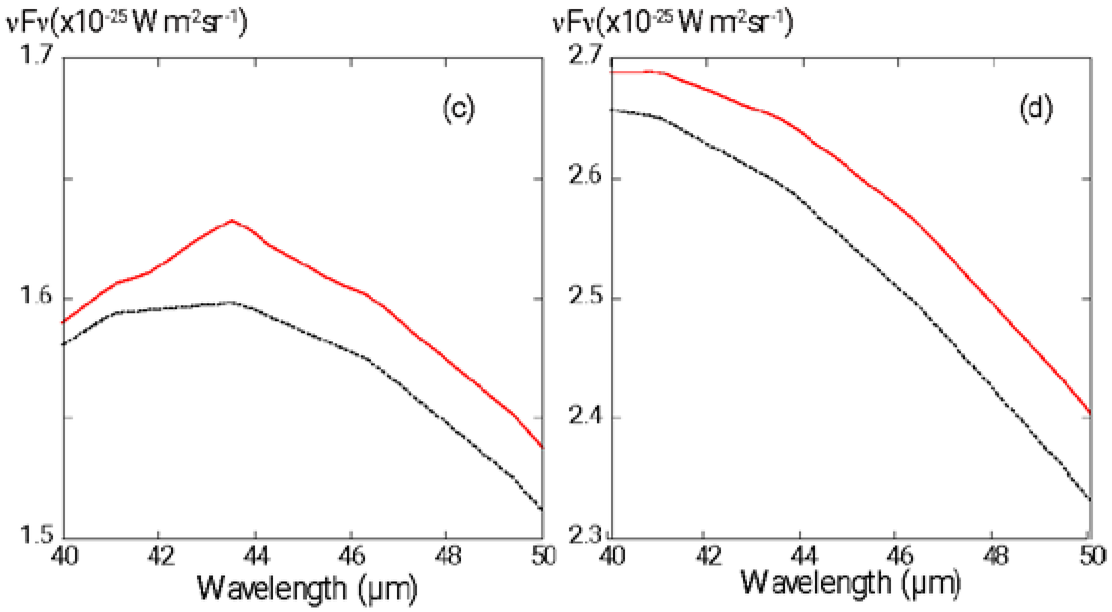
- PRIMA is an agile telescope, with a rapid slew and settle time. We are currently exploring the feasibility of responding to events within ~1 day (requires appropriate scheduling, ground system support, etc).



From Fischer et al., 2023: Ratio of inferred to actual burst amplitude for bursts in 86 Class 0 protostars. Far-IR is the only wavelength sensitive to the amount of mass being accreted onto a protostar during an accretion event

More potential GO science with PRIMA …

- **ISM chemistry**: FIRESS can perform fast mapping of Milky Way ISM. Integration times to detect the bright fine-structure transitions (CII, OI, OIII, NII) are seconds, so several tens of square degrees of the Galaxy could be envisioned.
- Can also use ISM spectra can assess the presence of large (>1 μm) water ice grains, which could be the missing reservoir for oxygen (Onaka et al., 2023)
- **ISM evolution**: In 60 hours, map ~25 regions at the interface of AGB/PNEs circumstellar shells and ISM, to explore mechanisms for ISM seeding through stellar winds (Ueta et al., 2023)
- **Circumgalactic medium**: In 75 hours, detect the CGM in emission through fine-structure lines to constrain cooling rate (Tarantino et al., 2023)



Onaka et al, 2023 : (Left) Expected FIR emission with (red) and without (black) crystalline water ice grains of 5 μm; (Right) Expected FIR emission with and without amorphous water ice grains of 2 μm

Possibilities for PRIMA GI Science: PI Surveys

More details to be posted on PRIMA website

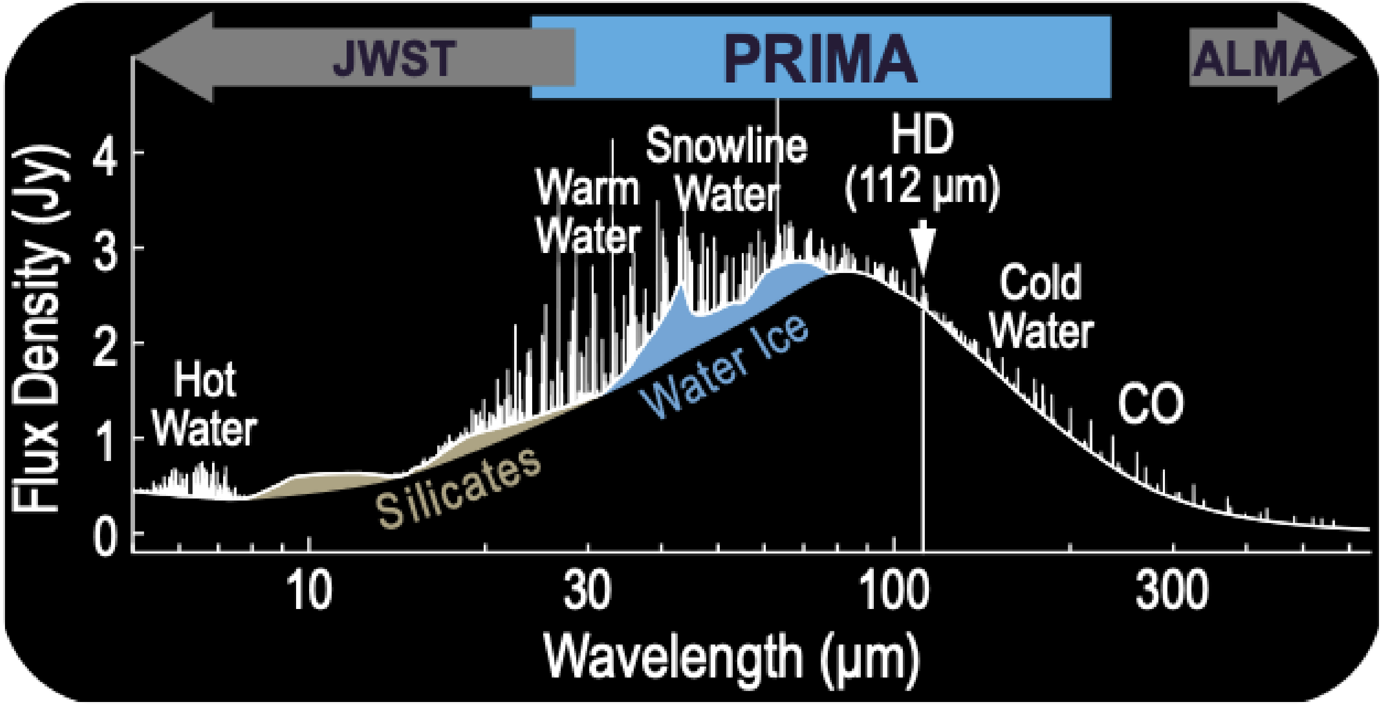
PI Theme 1: Origin of Planetary Atmospheres

What is the elemental composition and water content/distribution of planet forming disks?

Far-IR range includes fundamental HD (112 μm), hundreds of water lines and features (ice/gas)

PI survey with full spectra of 200 disks:

- Elemental abundances
- H_2 masses
- Water vapor content



PI survey can be used by to measure the total ice–rock mass ratio; uncover the primary molecular carrier of nitrogen (Bergner et al., 2023); and more

PI Theme 2: Evolution of Galactic Ecosystems

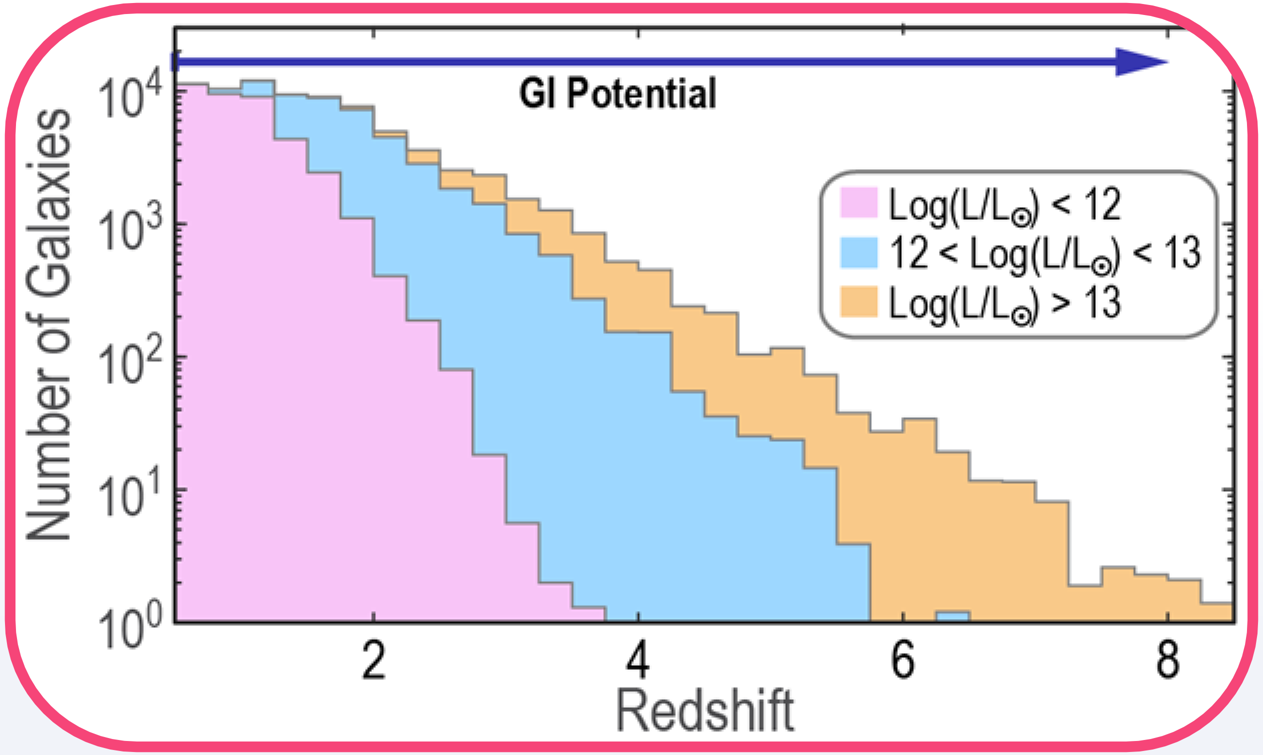
How do supermassive black holes and their host galaxies coevolve?

Mid-infrared spectra provide crucial diagnostics of:

- black hole accretion rate (BHAR) – [OIV]
- star formation rate (SFR) –[NeII]

Blind photometric survey will measure redshifts, black hole accretion rates and star formation rates. >60,000 galaxies at z 0.5-2.5; spectra on 160 targets; Spectral outflow survey on 50 galaxies

PI survey can be used to derive relation between SFR tracers at high redshift (z>6); population studies below confusion limit (Clements et al., 2023) ; fraction of obscured AGNs; and more



PI Theme 3: Buildup of dust and metals

How do interstellar dust and metals form and build up in galaxies over cosmic time?

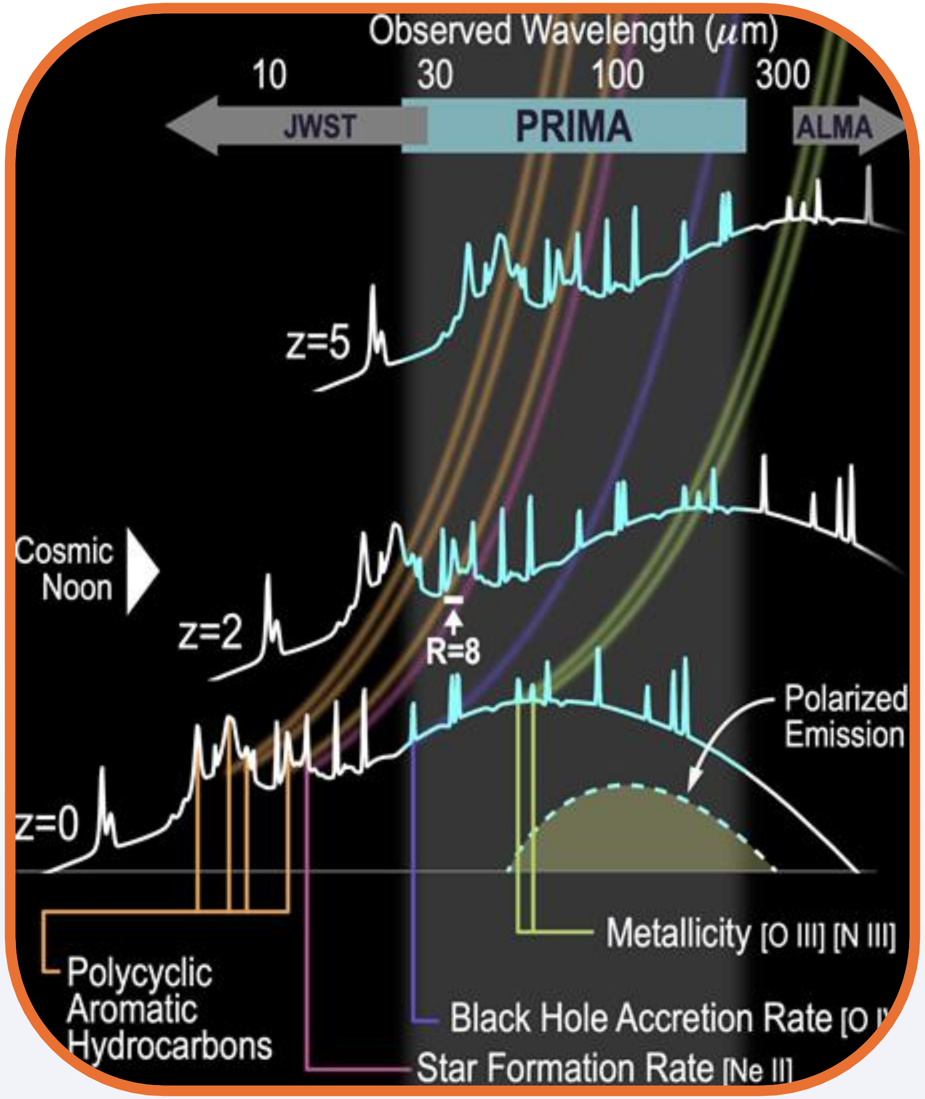
Mid-infrared spectra provide crucial diagnostics of:

- dust properties (polarized emission)
- metallicity (FIR fine structure lines and PAHs)

PRIMA will observe 100 z=2 galaxies to measure:
Gas phase abundances of O and N via [OIII], [NIII]
qPAH from rest-frame 11.3 and 12.7 um bands

Metallicity survey on ~100 galaxies
Polarimetry survey in 30 nearby galaxies

PI surveys can be used to study dust properties in z>2.25 galaxies through PAH bands; probe the rise of dust and metals in the early universe out to z < 6 (Donnelly et al. 2023); and more



Conclusions

PRIMA’s Phase A selection was possible thanks to strong community support: **Thank You!**

To develop a concept that is most responsive to community needs, PRIMA team continues to welcome community engagement during Phase A

Phase A is well underway – Concept Study Report (CSR) is due December 18, 2025

Ways to connect:

- Community events: Pasadena (May 2025), AAS (June 2025), EAS (June 2025). Other IR meetings
- PRIMA newsletter
- P-CAST
- PRIMA working groups
- PRIMA GO Science Book Vol. 2 contributions

Anticipated that NASA will announce the final probe selection in Summer 2026.

Additional slides

Become a working group member

During proposal development, topical working groups (WGs) provided input to PRIMA science

- For Phase A, we now invite the community (any career stage!) to sign up to WGs, meetings resume February
- Opportunity to work closely with the PRIMA team to determine PRIMA's impact to your science
- WG members can contribute by defining **precursor studies:** simulations and observations laying the groundwork for PRIMA science.

Working group sign-up

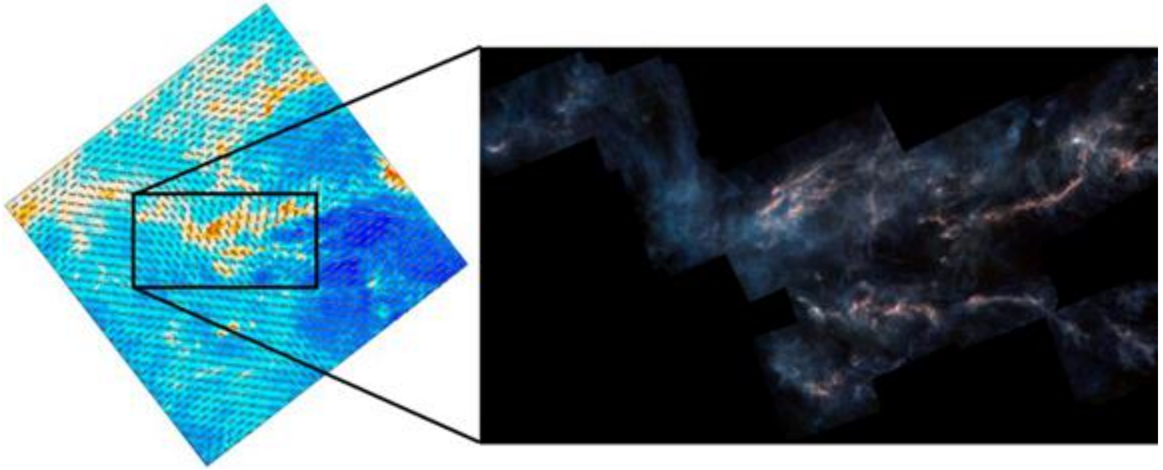
We strongly encourage early career participation in WGs!

In PRIMA GO Science Book Volume 1: Magnetic Fields

- In 1000 hours, a 160 sq degree area can be mapped to survey the magnetic field distribution of all **star-forming regions within 0.5 kpc**, allowing to connect the all-sky Planck maps to the structure within individual star-forming filaments and cores. (Pattle et al. 2023).

- In 5 h, magnetic fields can be mapped in a sample of **evolved stars environments** (Planetary nebulae, Symbiotic Stars, WR, SN remnants), providing unique information on the interaction between magnetic fields and stellar winds (Sabin et al., 2023)

Pattle et al., 2023: The Taurus Molecular Cloud by Planck (Planck Collaboration 2015), and column density structure on ~10 arcsecond scales at the resolution of PRIMA (right; ESA/Herschel/NASA/JPL-Caltech; R. Hurt).

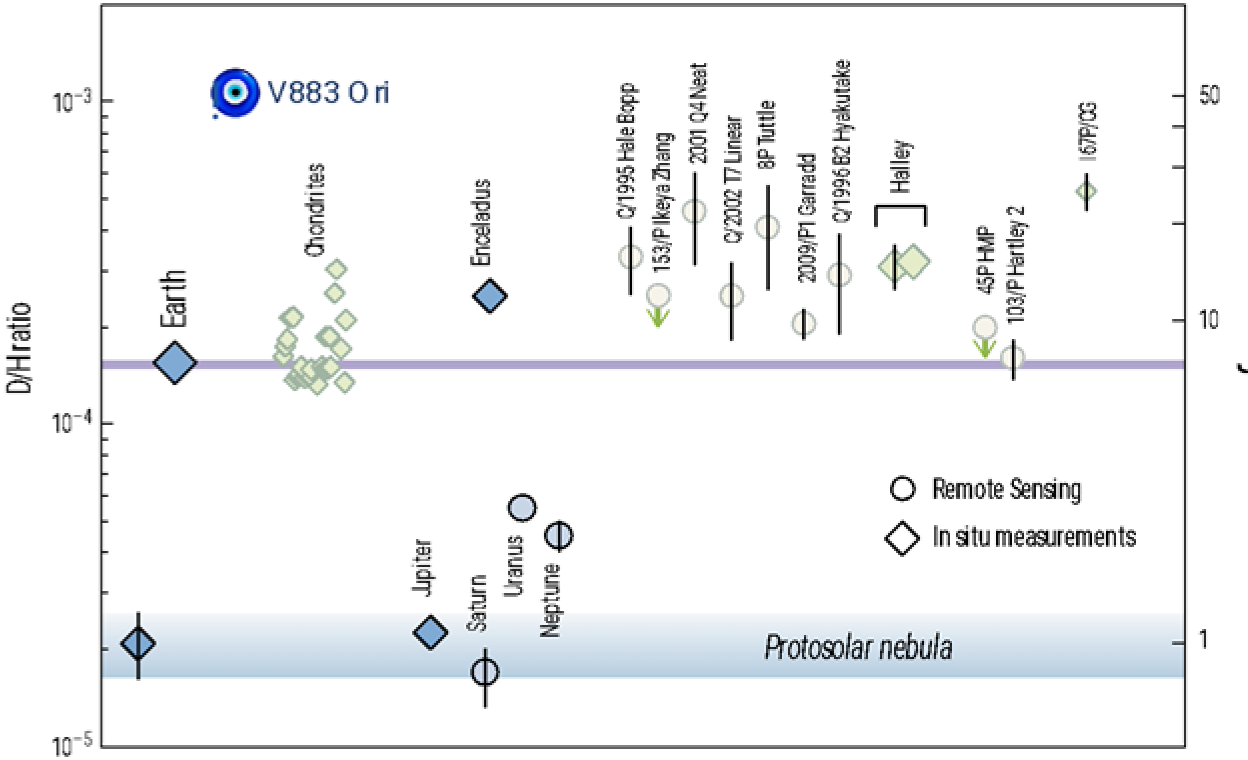


In PRIMA GO Science Book Volume 1: Transients

- In 20 minutes, the first far-infrared dust reverberation mapping study by monitoring one **AGN torus** at over the 5-year long mission: relation between SMBH accretion rate and disk clumpiness (Gorjian et al., 2023)

- In 5 minutes, detect **transient sources discovered by CMB experiments**, enabling efficient monitoring of hundreds of sources over day to week timescales (Clements et al., 2023)

- In 1,200 hours, measure the D/H isotopic ratio in water in ~30 **Solar system comets** to determine how, when, and in what quantity comets contributed to the Earth's water content (Lis et al., 2023)



Lis et al., 2023: D/H ratio in water in the Solar System (from the Origins Mission Concept Study Report after Altwegg et al. 2015). The blue disk marks the first ALMA measurement in the V883 Ori disk (Tobin et al. 2023).

PRIMA

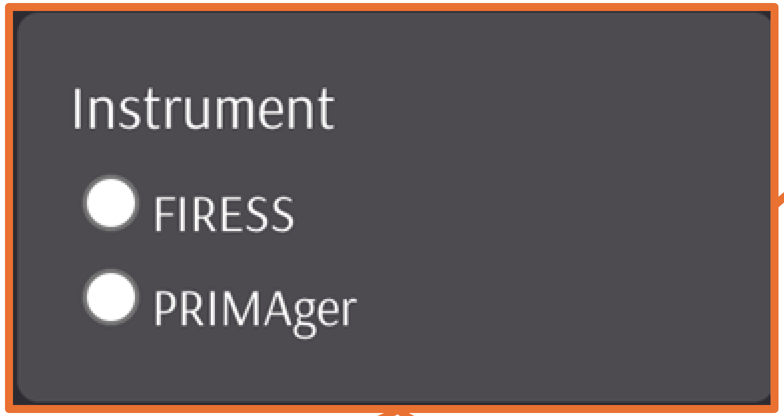
Exposure Time Calculator

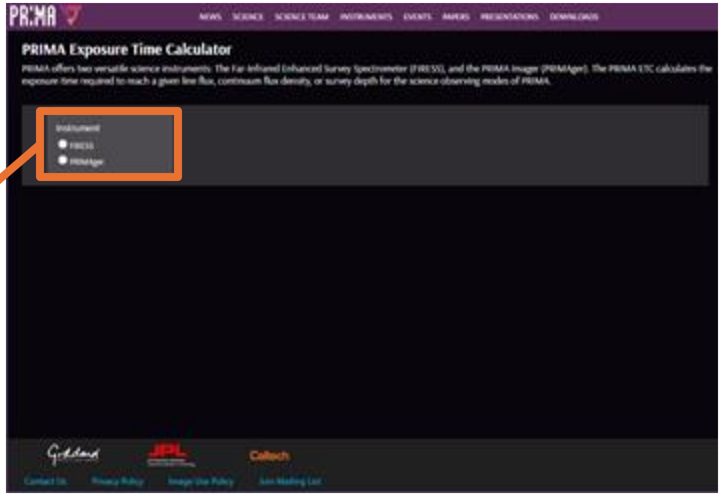
https://prima.ipac.caltech.edu/page/etc-calc

ETC Walkthrough

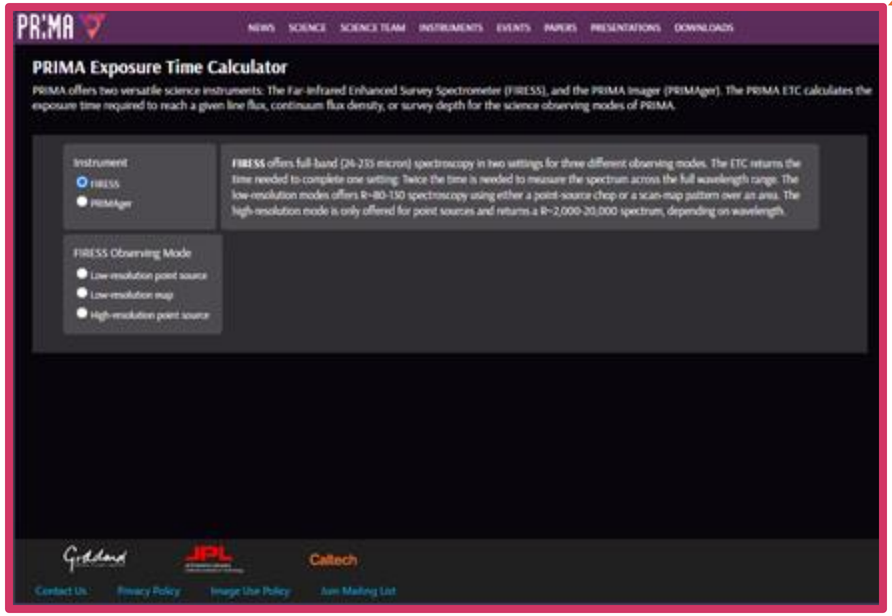
- Choose your instrument
- If FIRESS…
  - Choose your mode
    - Low-res point source → Specify line flux
    - Low-res mapping→ specify wavelength, survey area, survey depth
    - High-res point source →specify wavelength, continuum flux density, line flux
- If PRIMAger…
  - Choose your mode (Hyperspectral or Polarimetric)
  - For either mode, provide
    - Survey Area
    - Survey Depth

Step 1: Choose your instrument

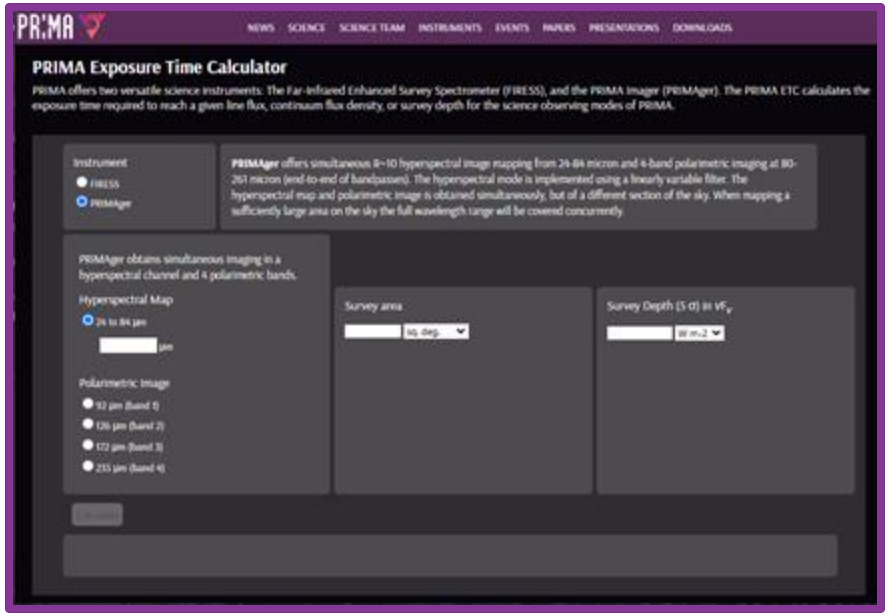




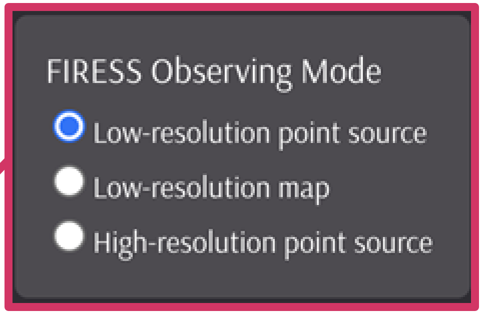
FIRESS

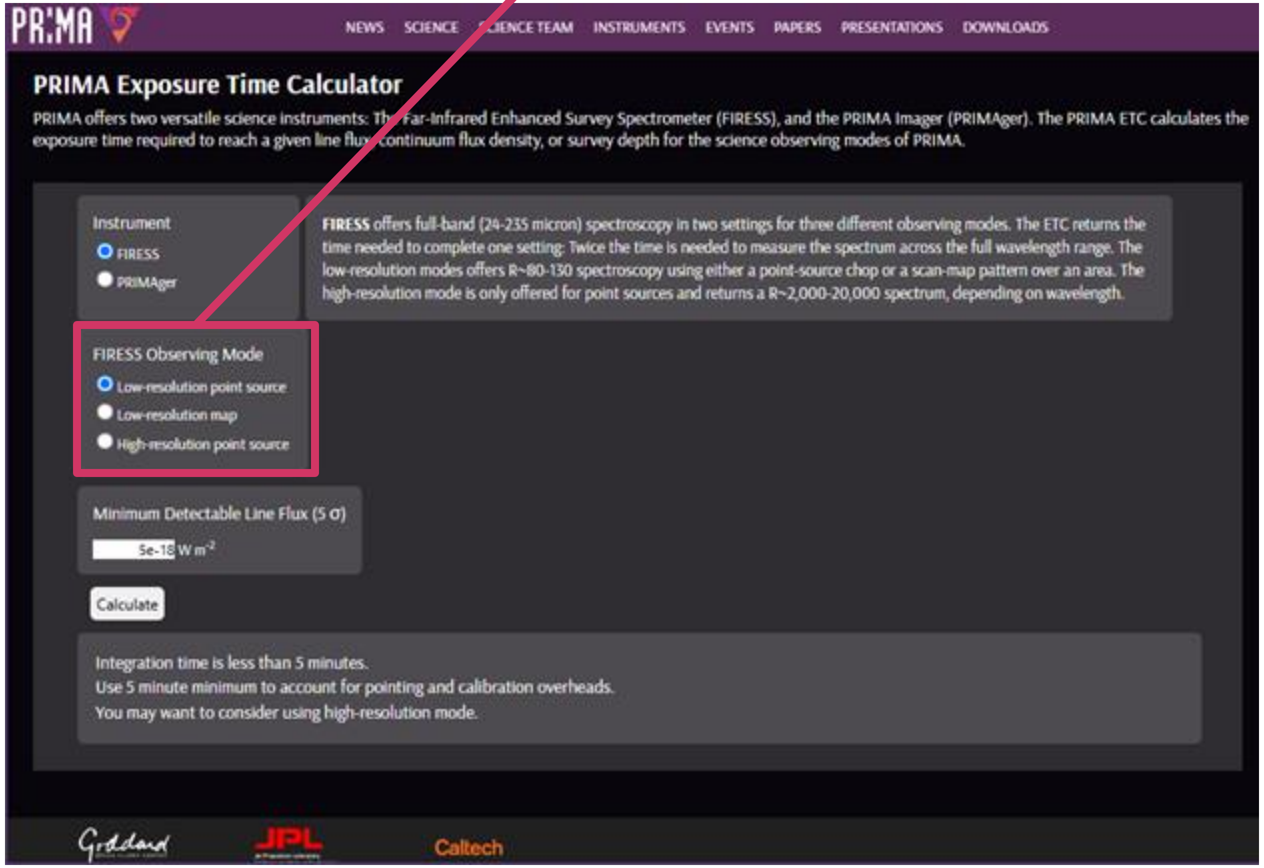


PRIMAGER

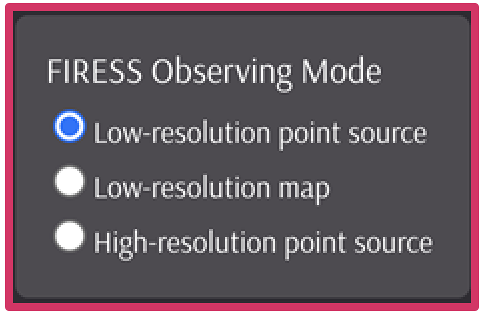


Step 2 (FIRESS): Choose your Mode

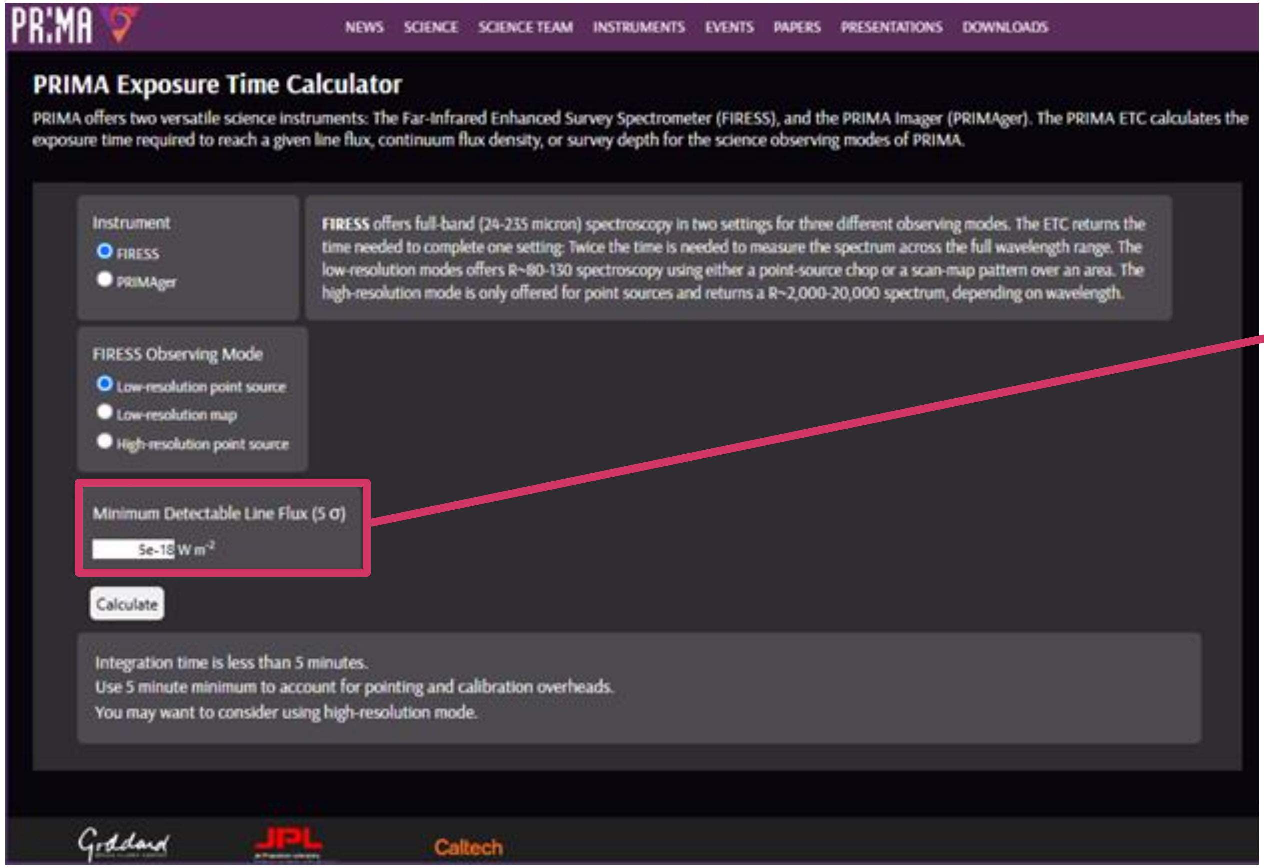




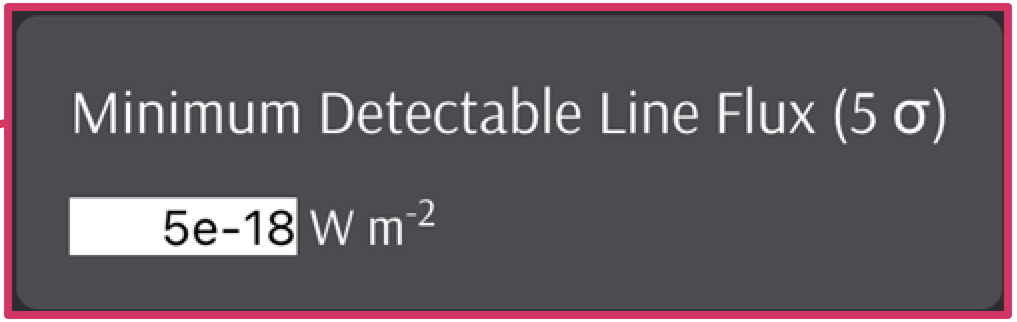
Step 2 (FIRESS): Choose your Mode



Low-Resolution Point Source Mode



Step 3: Provide Line Flux



Step 2 (FIRESS): Choose your Mode

FIRESS Observing Mode
- (selected) Low-resolution point source
- Low-resolution map
- High-resolution point source

Low-Resolution Point Source Mode

Press calculate to generate exposure time estimate

Minimum Detectable Line Flux (5 σ)

1e-19 W m^{-2}

Calculate

Integration time is 3.61 hours.

Watch for warnings

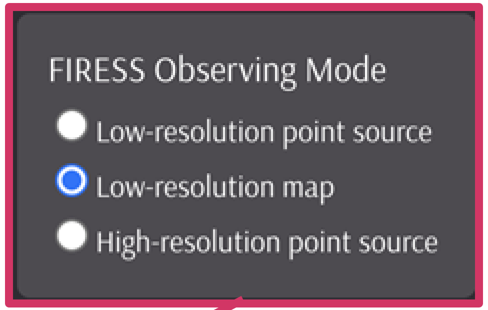
Minimum Detectable Line Flux (5 σ)

5e-18 W m^{-2}

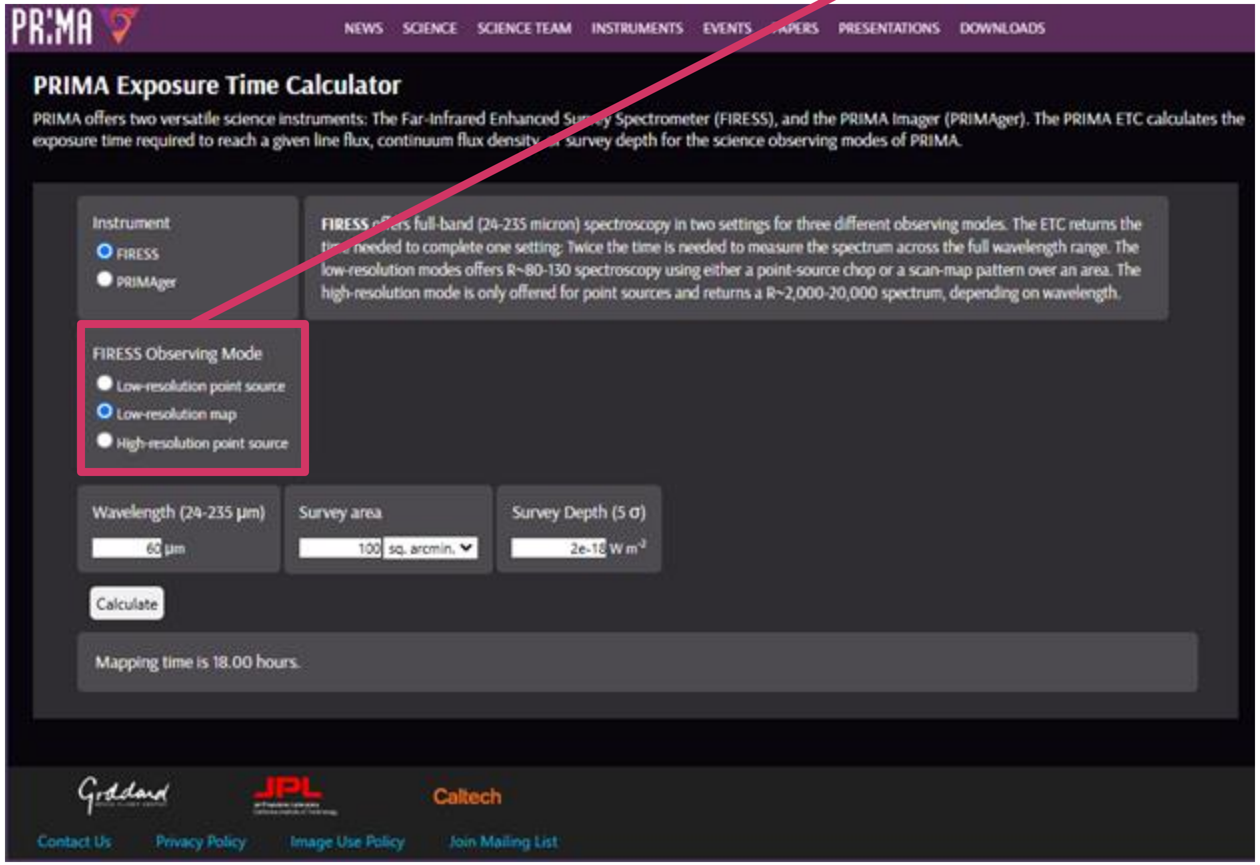
Calculate

Integration time is less than 5 minutes.
Use 5 minute minimum to account for pointing and calibration overheads.
You may want to consider using high-resolution mode.

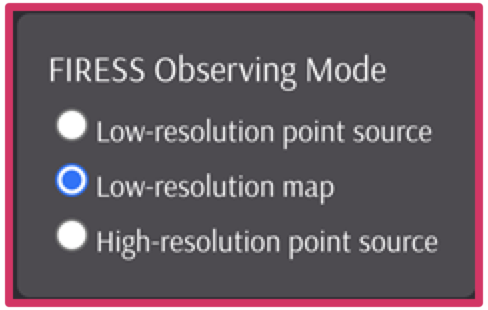
Step 2 (FIRESS): Choose your Mode



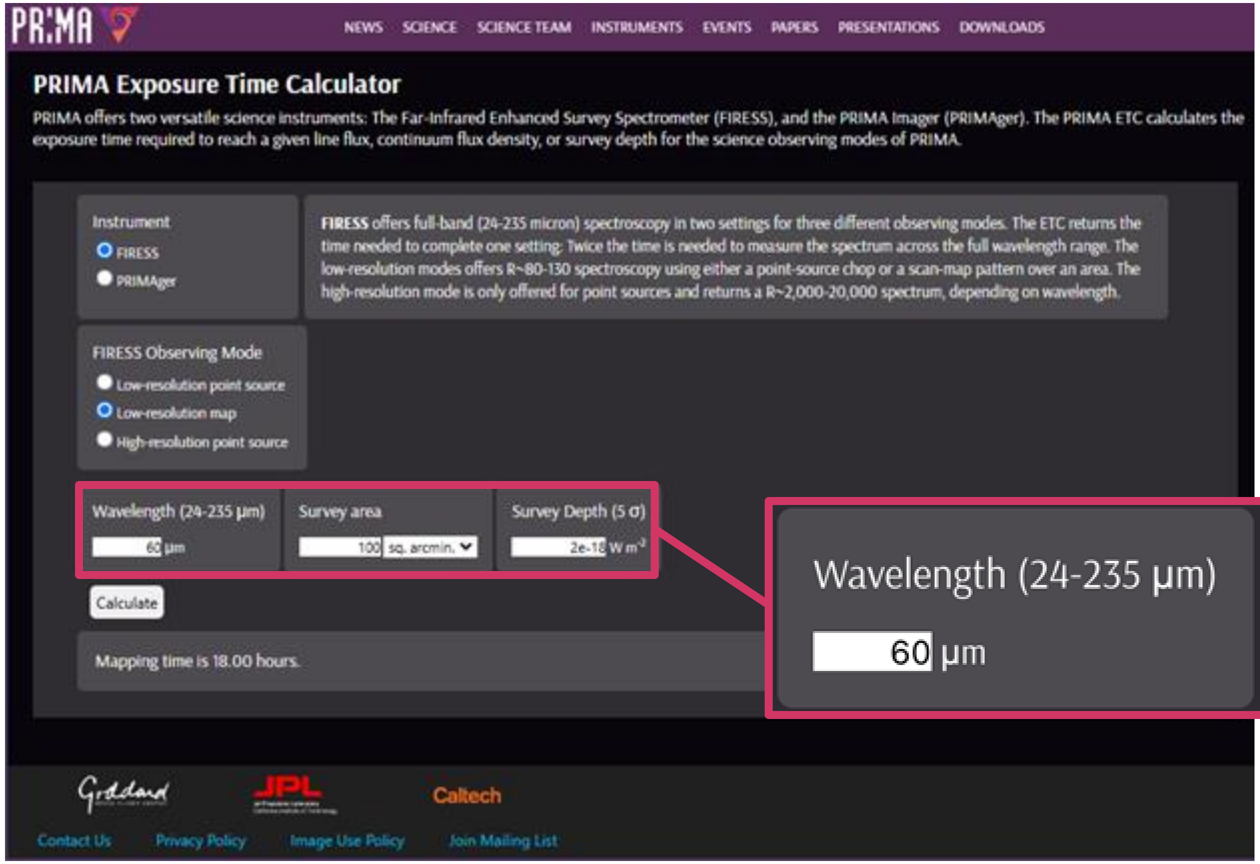
Low-Resolution Mapping Mode



Step 2 (FIRESS): Choose your Mode

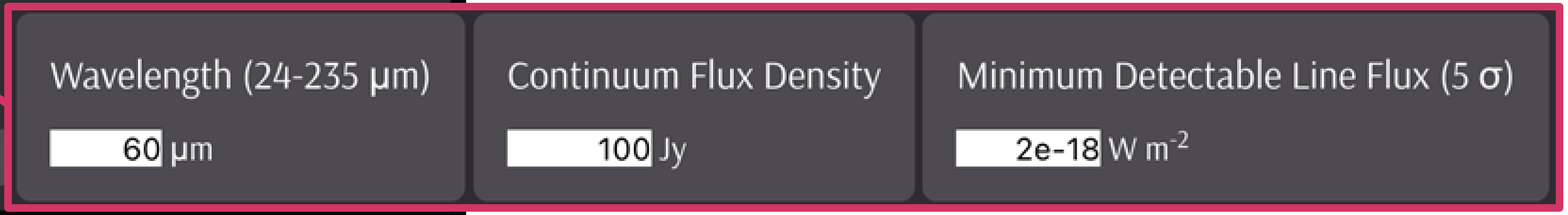


Low-Resolution Mapping Mode

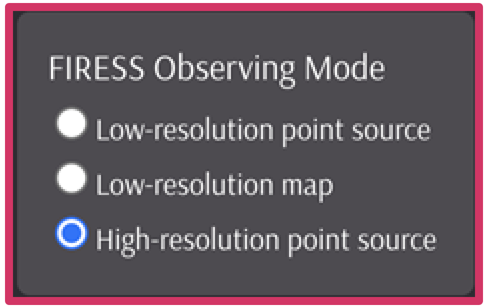


Step 3: Provide

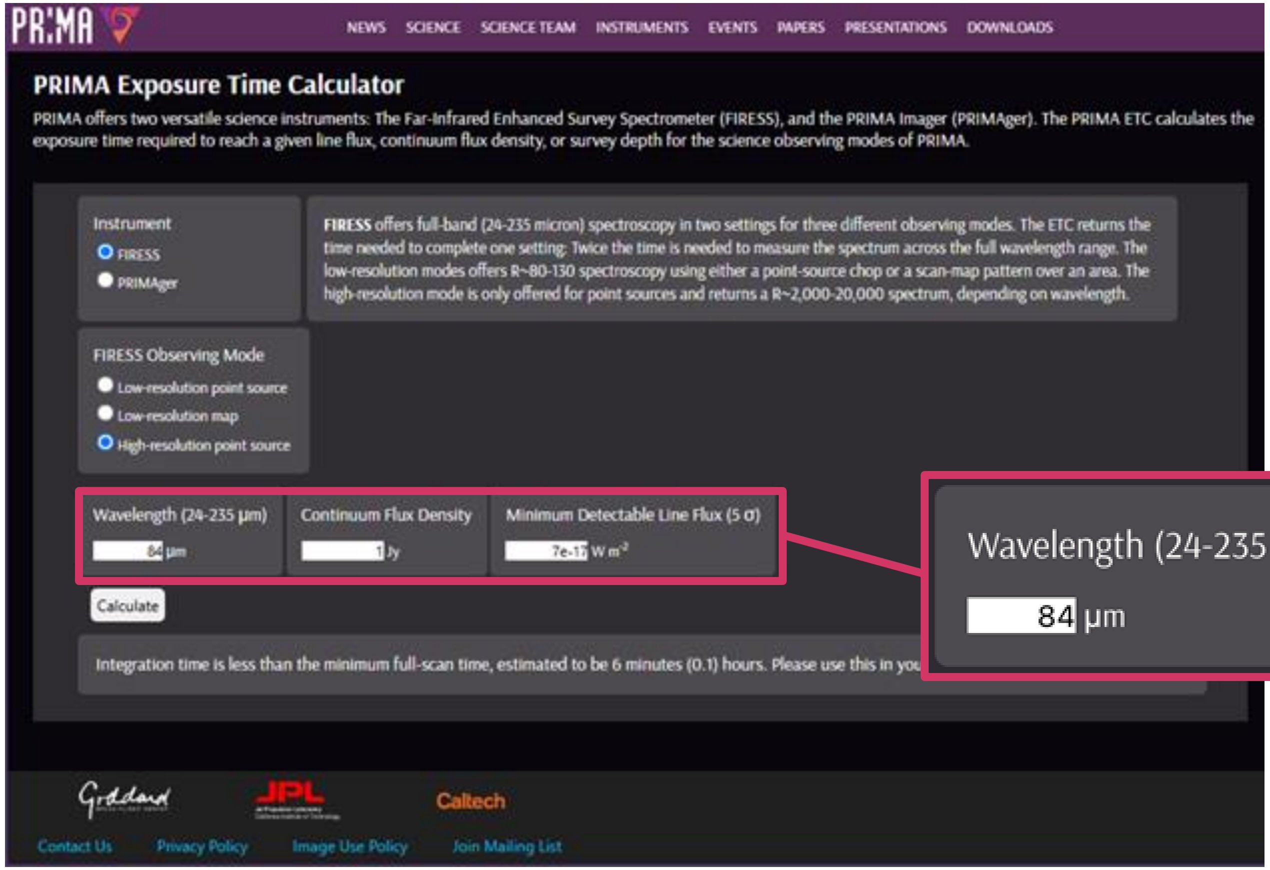
- Wavelength
- Survey Area
- Survey Depth



Step 2 (FIRESS): Choose your Mode



High-Resolution Point Source Mode



Step 3: Provide

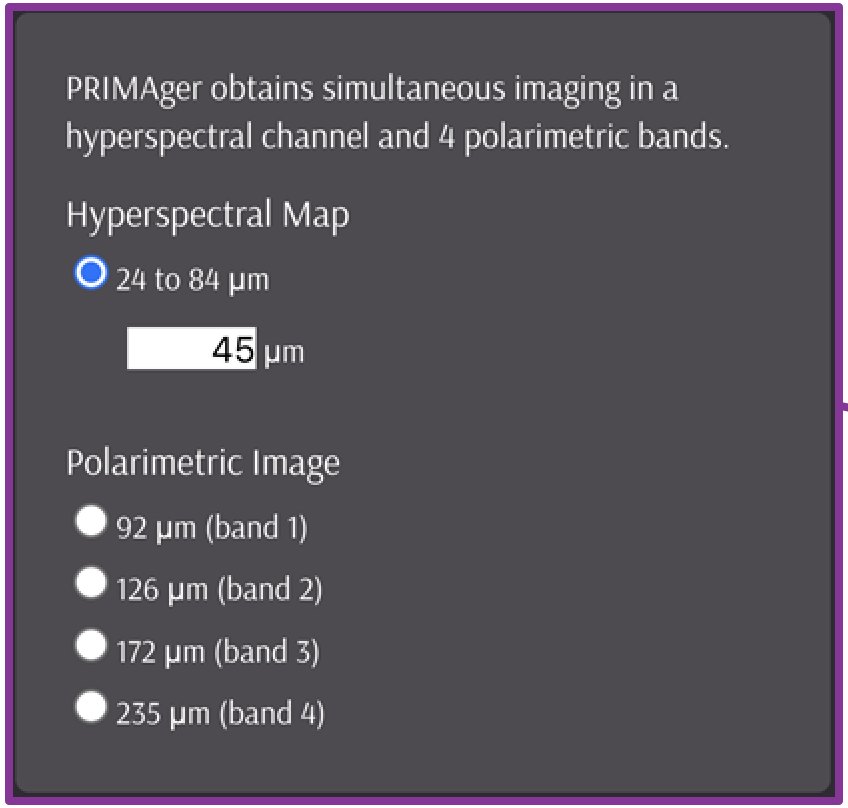
- Wavelength
- Continuum Flux Density
- Line Flux

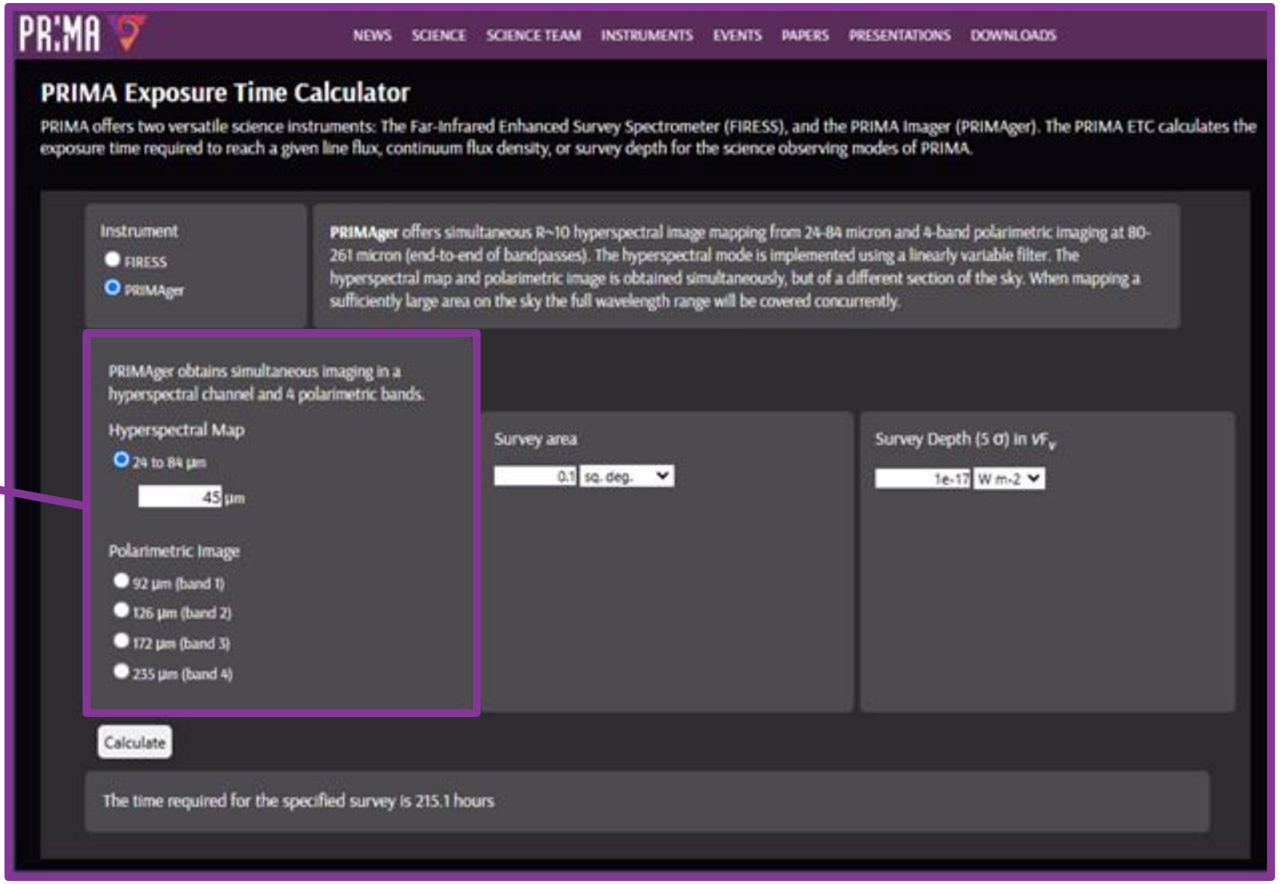
Note: High-Resolution mapping is possible, but is not currently supported by the ETC

Step 2 (PRIMAger): Choose your Mode

Note: All bands will be observed simultaneously, but a representative wavelength is needed to determine exposure time for your science goal

Hyperspectral Map

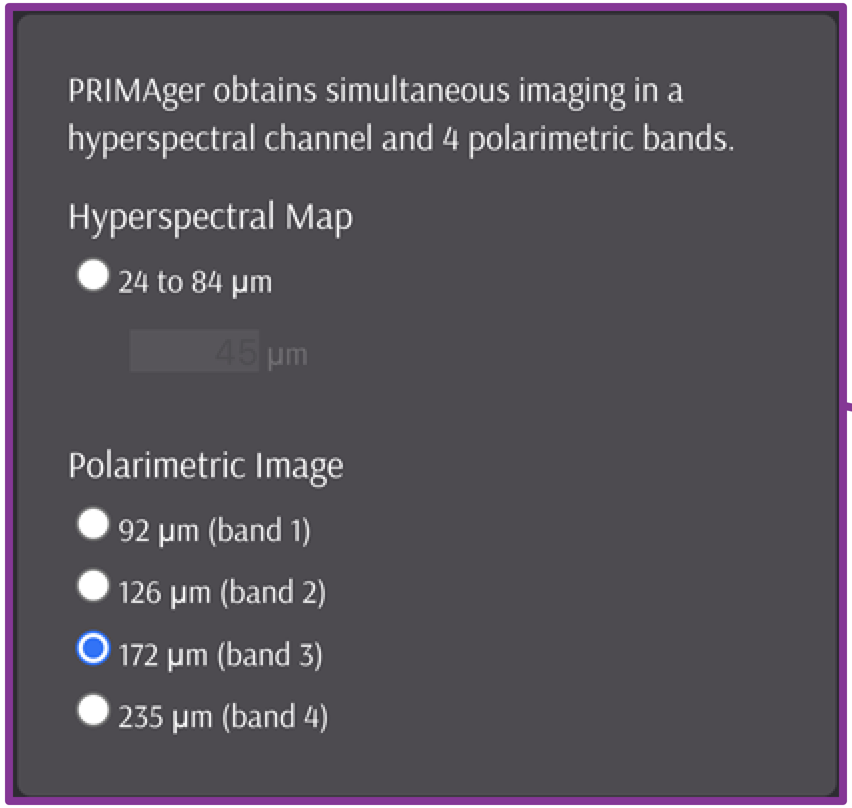


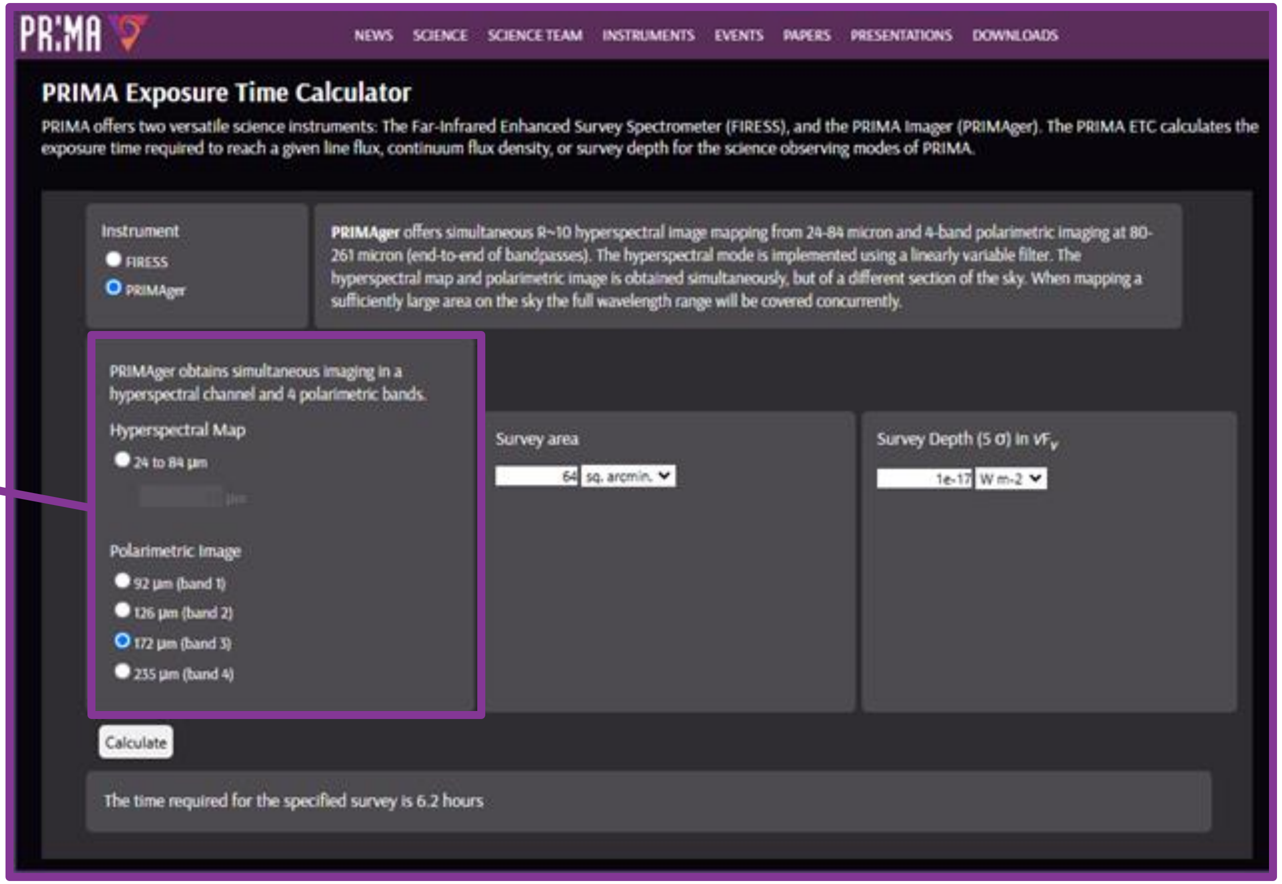


Step 2 (PRIMAger): Choose your Mode

Note: All bands will be observed simultaneously, but a representative wavelength is needed to determine exposure time for your science goal

Polarimetric Image



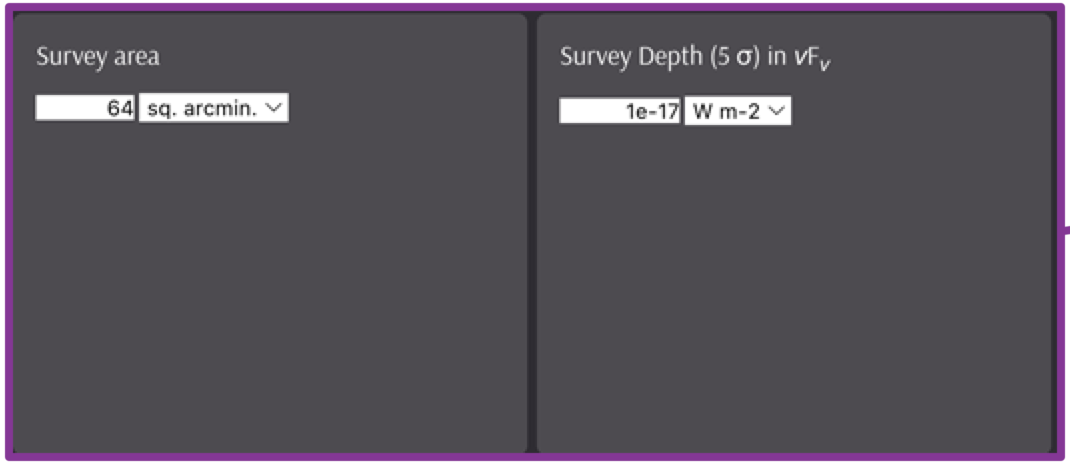


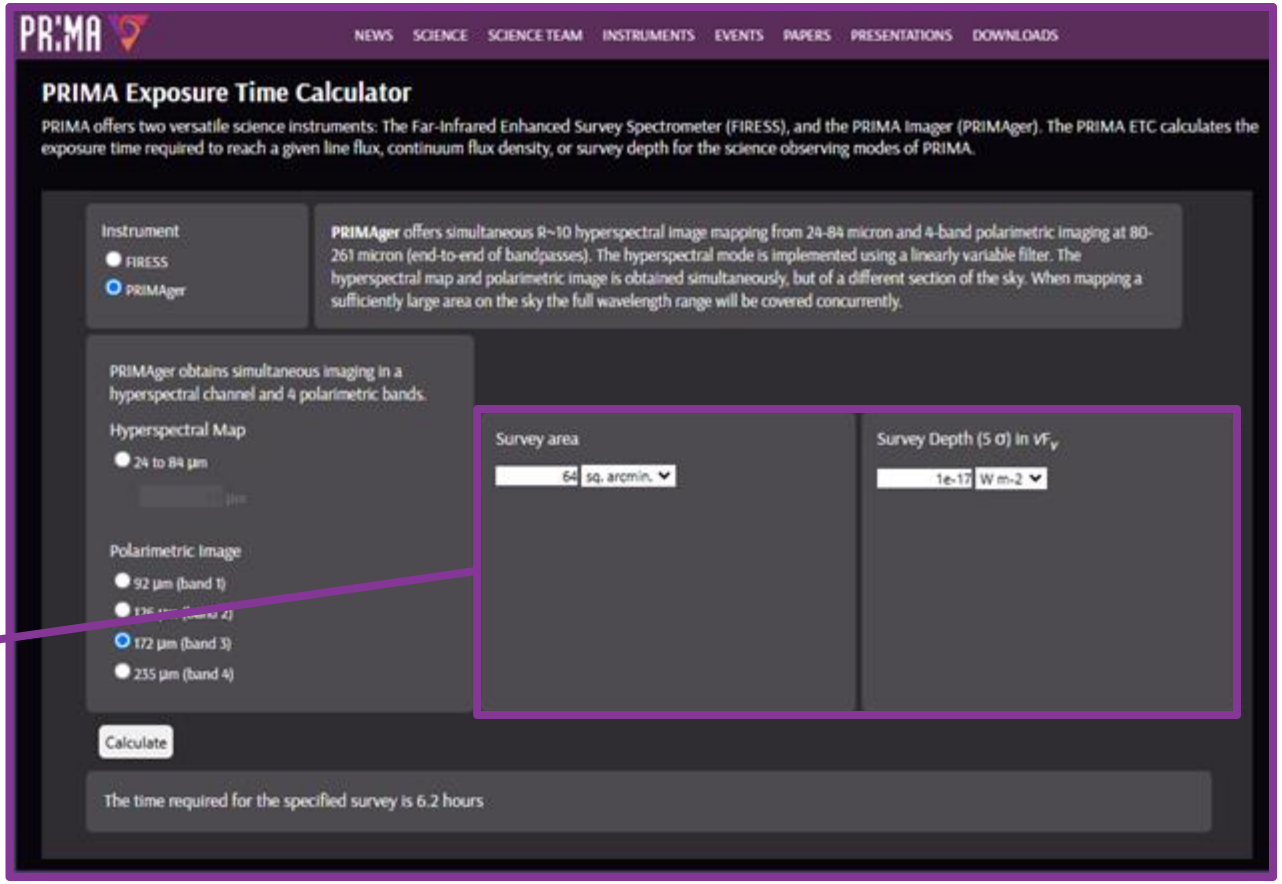
Step 2 (PRIMAger): Choose your Mode

Note: All bands will be observed simultaneously, but a representative wavelength is needed to determine exposure time for your science goal

Step 3: For either mode, provide

- Survey Area
- Survey Depth





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