Future Facilities and General Astrophysics across the Electromagnetic Spectrum in the 2030s

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May 2016
HabEx Face-2-Face
Washington, D.C.

Outline / Philosophy

- By definition, wide open, but **essential** topic for HabEx
- For better of for worst, I had a similar role for WFIRST, née SNAP

- Approach for first face-2-face:
  - Landscape of the 2030's: summary of approved future facilities
  - Breakdown by likely HabEx wavelength regimes
  - Look at previous (and current) related efforts:
    - HST
    - LUVOIR / HDST
    - Theia
    - NASA Astrophysics Roadmap

- Longterm plans:
  - Identify a few of the most compelling 'killer aps'
  - Figure(s) of merit? Not obviously a good (or bad) idea: could do for certain topics, and/or could do something etendue/capabilities-related?
  - Engage the community, both in a general way, but also experts in topics that we think are 'killer aps'

TESS

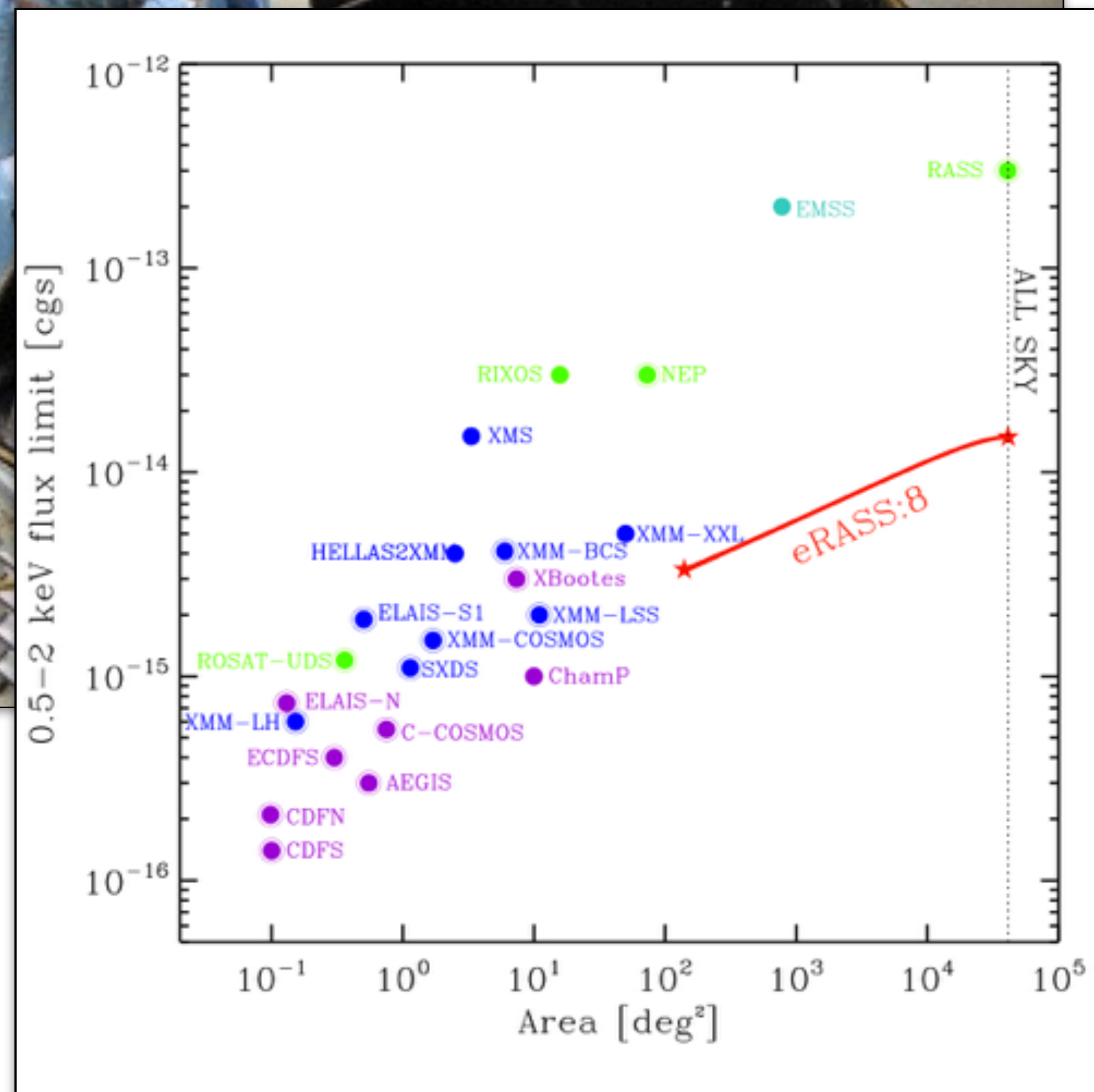
Transiting Exoplanet Survey Satellite
NASA Explorer
launch date: **August 2017**
transit exoplanet

Spectrum-Roentgen Gamma (SRG): eROSITA + ART-XC

German-Russian collaboration
launch date: **2017**
4-yr. all-sky survey from L2
followed by 3-yr targeted GO observations

eROSITA: all-sky 0.5-10 keV survey
ART-XC: all-sky 6-30 keV survey

expecting to detect:
50k-100k clusters (cosmology)
~3 million AGN
wide range of additional high-energy astrophysics

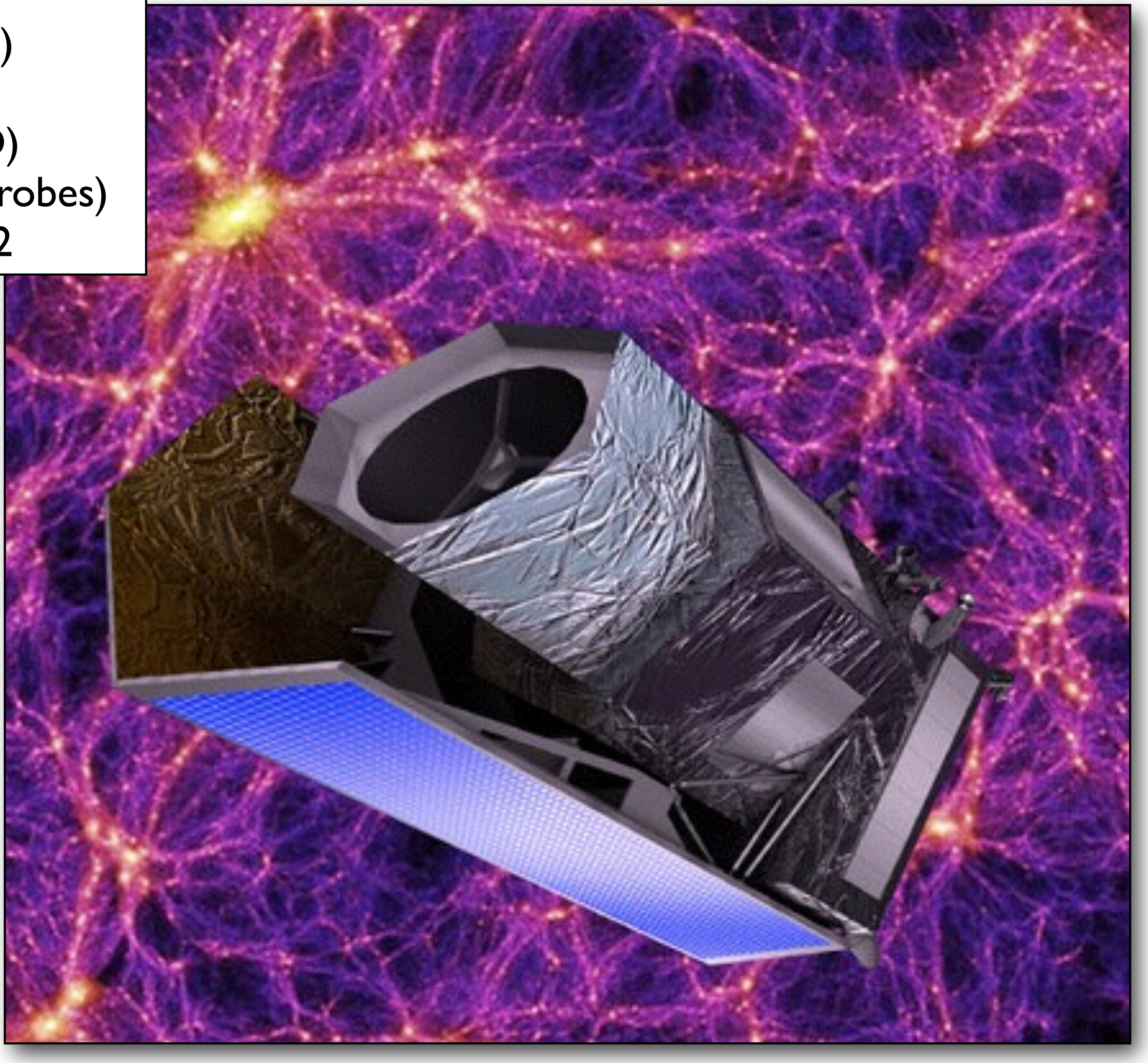


Webb Telescope

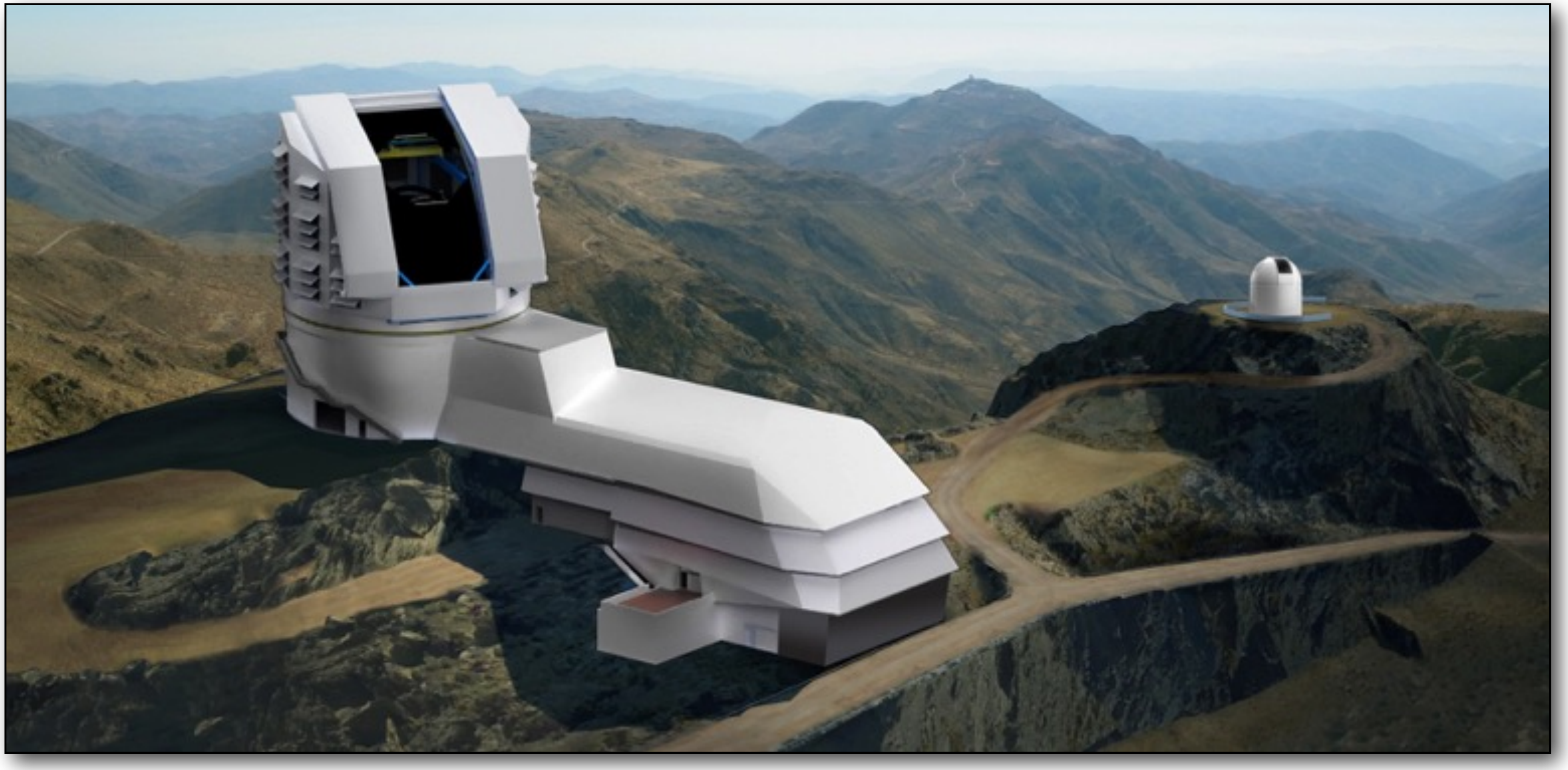
NASA Flagship
launch date: **October 2018**
requirement: 5 year mission; goal: 10(+) years
extremely sensitive at optical to mid-IR wavelengths
pointed observations, not wide-field surveys
mainly for guest observers (and GTO)

Euclid

ESA M-Class (w/ NASA participation)
launch date: **December 2020**
optical imaging (wide *r*+*i*+*z*; shapes)
near-IR imaging (*YJH*; colors)
near-IR spectroscopy (*R*~250; BAO)
primary science: cosmology (multiple probes)
6-yr. survey of 15,000 deg^2 from L2



LSST



Large Synoptic Survey Telescope
8.4 meter mirror
25,000 deg^2 deep optical survey (*ugrizy*)
first light: **2021**
10-yr survey begins: **2023**

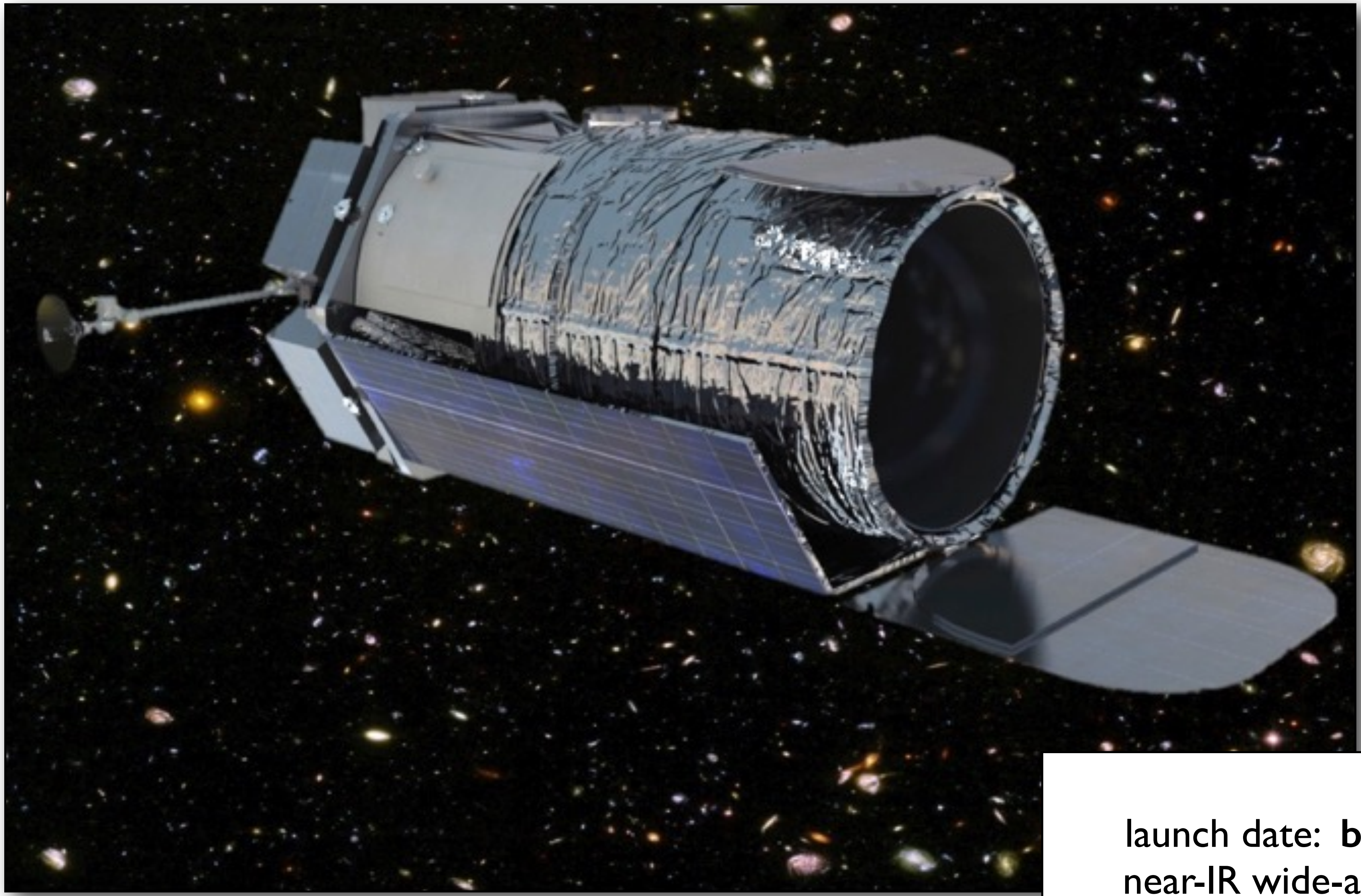
ELT's

ELT, TMT, GMT

Extremely Large Telescopes
first light dates: ~**2022?**

WFIRST-AFTA

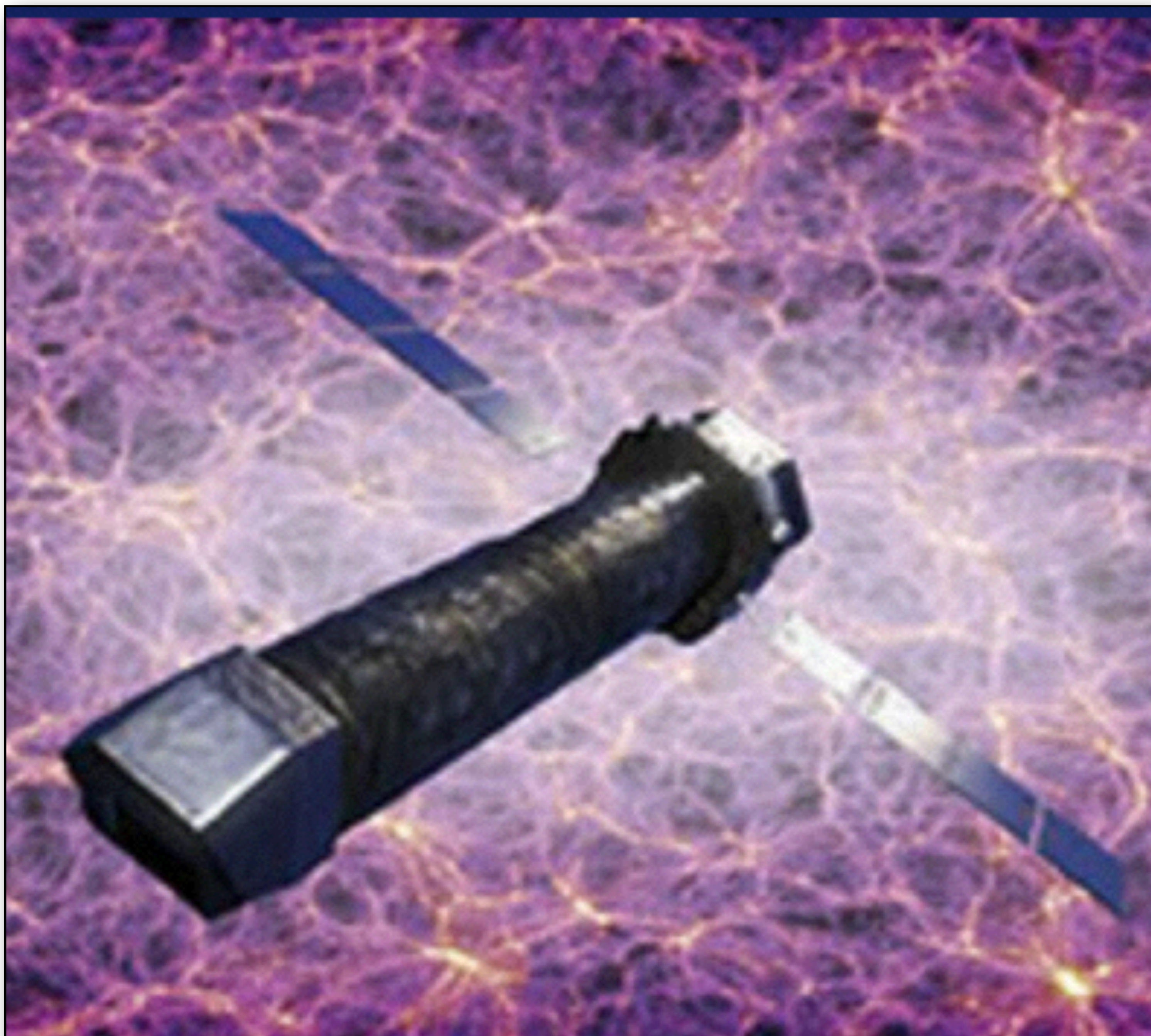
Wide-field Infrared Space Telescope -
Astrophysics Focused Telescope Asset

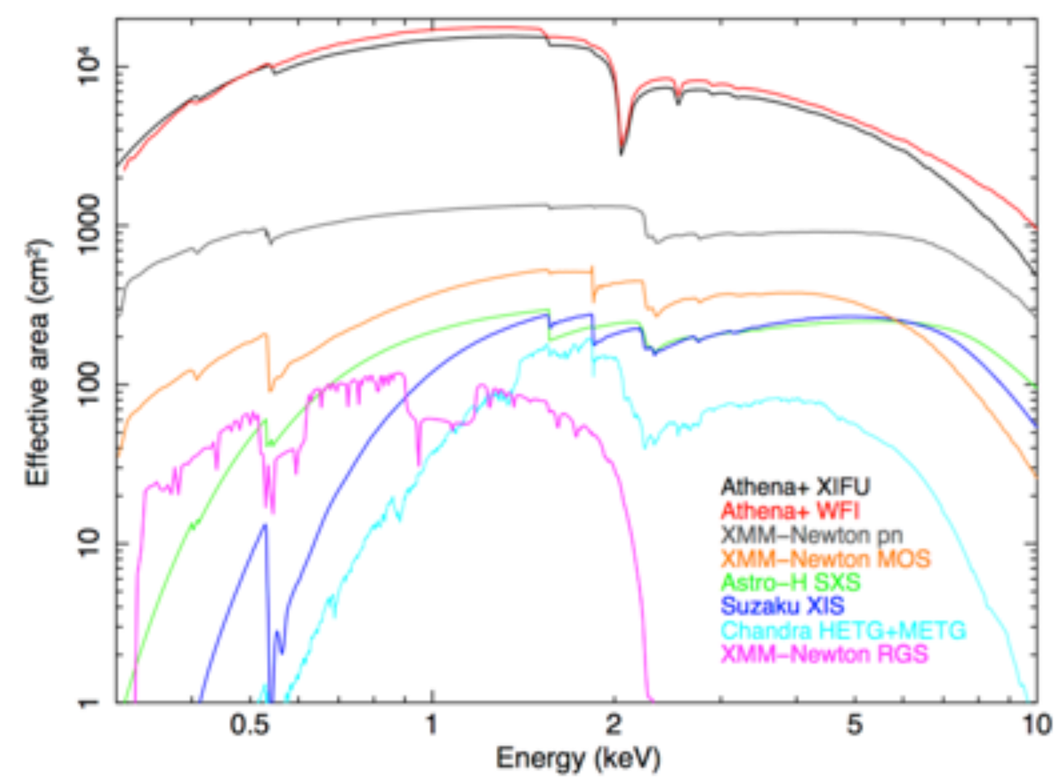


NASA Flagship
launch date: **by 2024** (as per March 2015 report)
near-IR wide-area camera + IFU (+ coronagraph?)
multiple science objectives:
- cosmology (multiple probes)
- microlensing survey of Galactic bulge
- infrared survey science
(- exoplanet coronography)
- 25% of time for guest observers

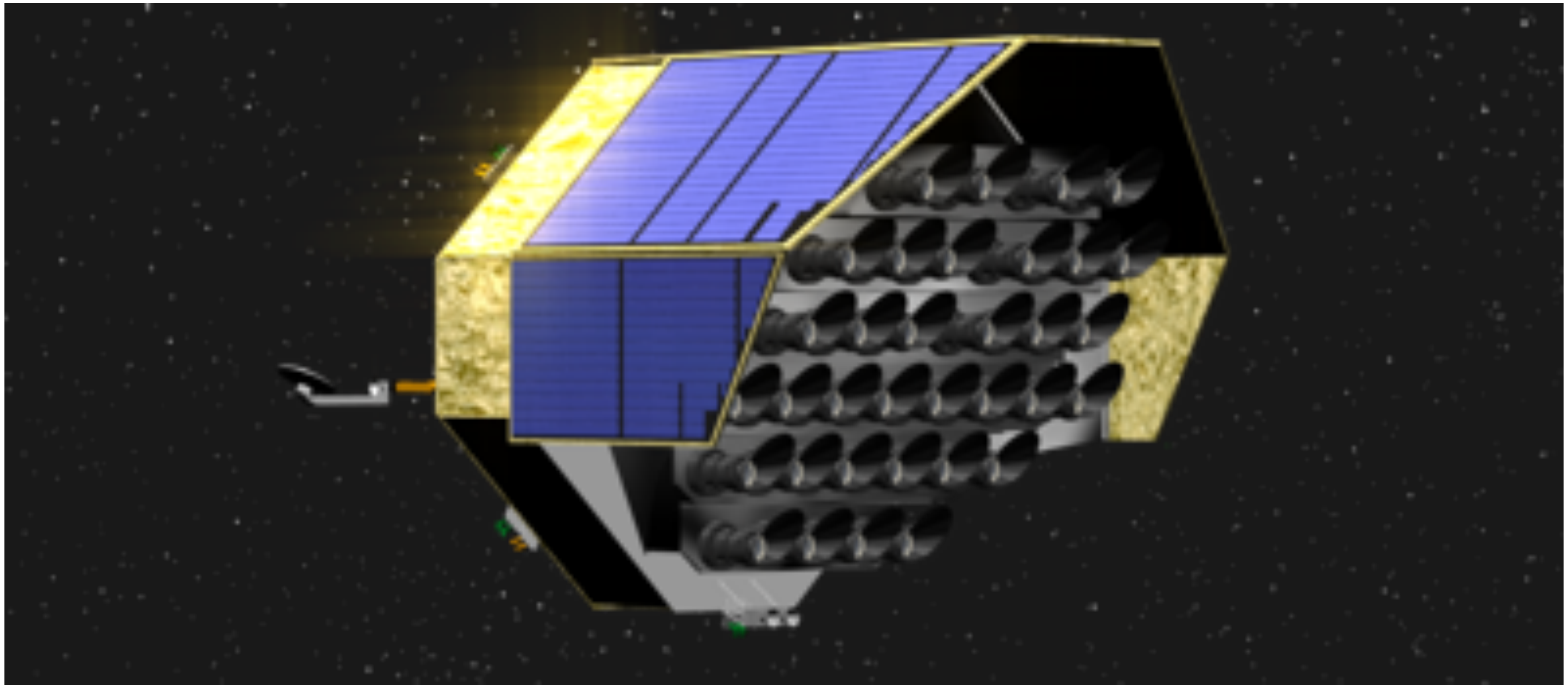
Athena

ESA L-Class (w/ NASA participation)
launch date: **2028**
high-resolution "microcalorimeter"
wide-field imager (WFI)



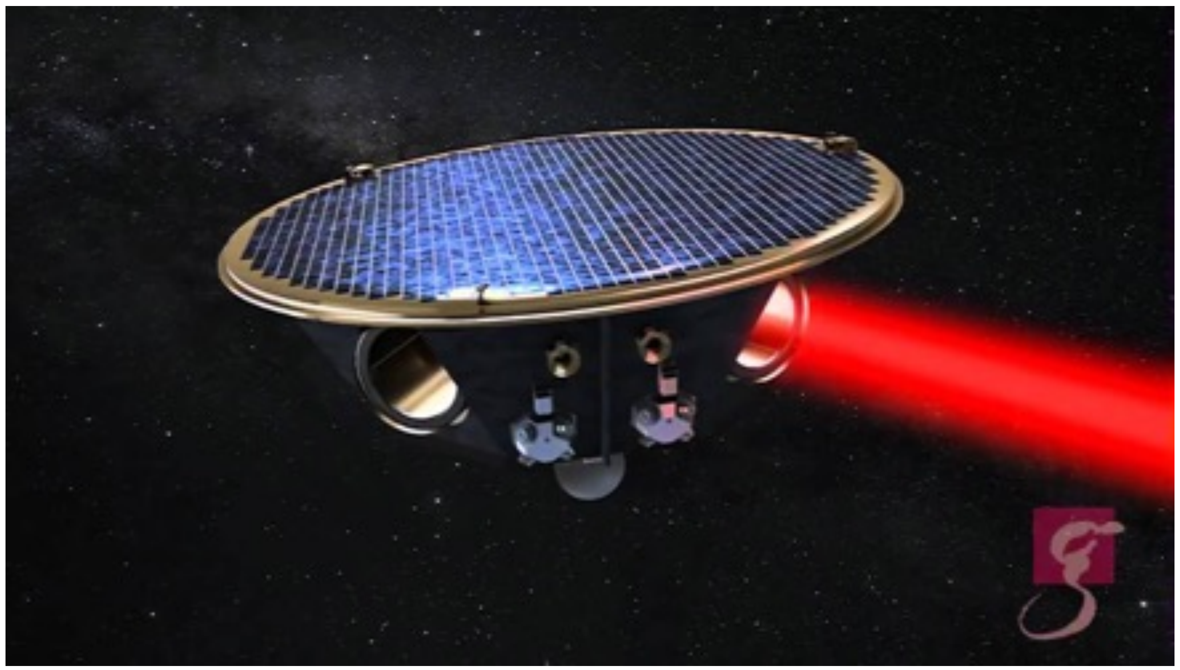


Plato

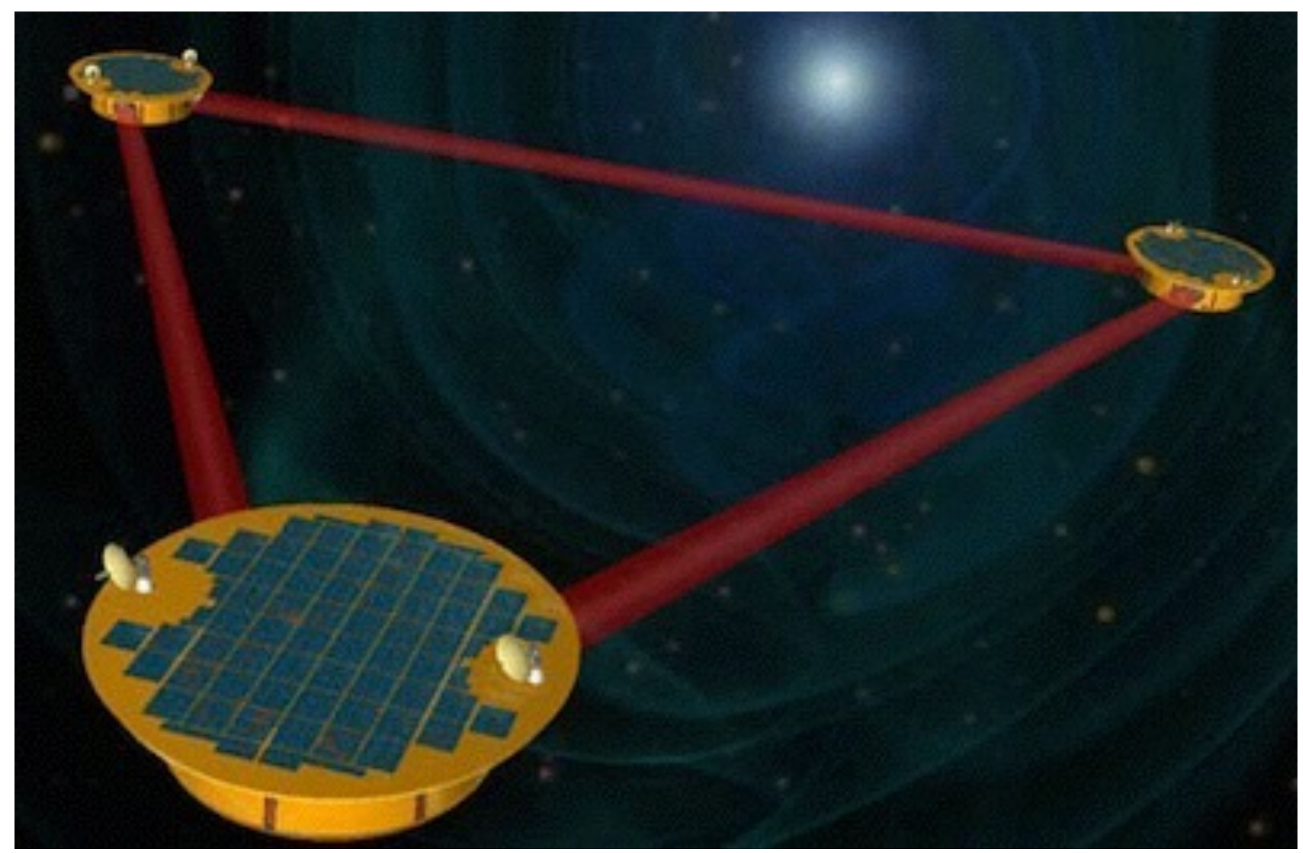


ESA M-Class
launch date: **2024**
transiting exoplanet mission

eLISA



ESA L-Class (w/ NASA participation)
launch date: **mid-2030's**
gravitational waves



Summary of Future Facilities

- Several transiting exoplanet missions
- Several ambitious, deep wide-field (>10,000 deg^2) surveys, over a range of wavelengths (X-ray, optical, near-IR)
    - HabEx could compliment by extending wavelength regime of wide-field surveys (e.g., UV, mid-IR)
    - more likely, HabEx could follow-up interesting sources identified in these surveys
- Several extremely sensitive targeted capabilities (JWST, ELTs)
    - HabEx could compliment, e.g., in wavelength coverage (UV, IR windows), enhanced spatial resolution, coronography
- Some capabilities planned for other communities (e.g., X-ray, gravitational wave), but many communities do not have anything on the table currently (e.g., far-IR, gamma-ray, CMB)

[Note that summary omitted Asia, esp. Chinese, mission plans. Also, several smaller scale opportunities, esp. Explorers, between now and HabEx launch.]

Likely HabEx Wavelength Regimes

- Ultraviolet
    - See Paul Scowen's talk

Likely HabEx Wavelength Regimes

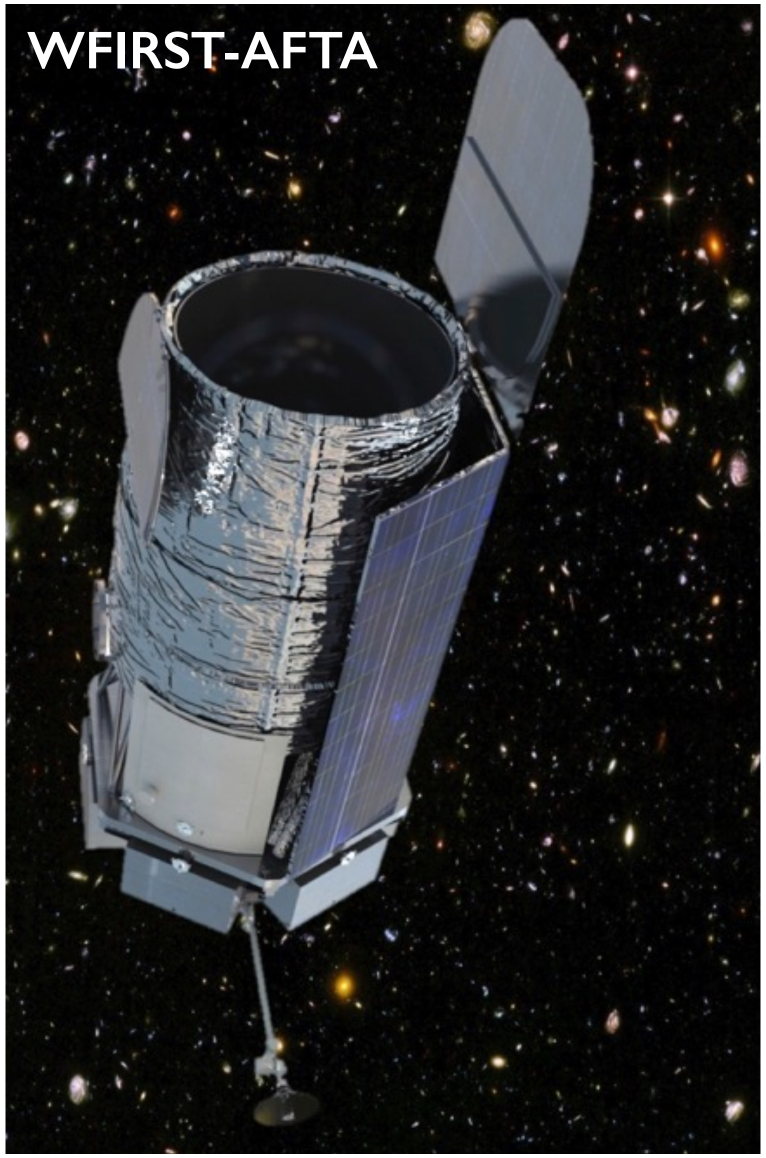
- Optical
  - JWST starts at 6000 Angstroms (and will be done when HabEx launches)
  - ELT's likely seeing limited below 1 micron, so main advantages of HabEx will be in morphologies / resolved spectroscopy / coronagraphic observations
  - back-of-envelope: seeing-limited depth goes as mirror diameter $\sim D^2$, while diffraction-limited point source observations go as $\sim D^4$. So 5.5m in space will be comparable to 30m on the ground in point source sensitivity.
  - Some key science:
    - galaxy evolution - high resolution + background spectroscopic probes; role of feedback
    - local group dwarf galaxies / tidal streams / resolved stellar populations in nearby galaxies
    - galaxy clusters: high redshift, distant lenses, faint end of the galaxy populations, sensitive weak-lensing maps / substructure
    - other gravitational lenses
    - AGN and AGN feedback

Likely HabEx Wavelength Regimes

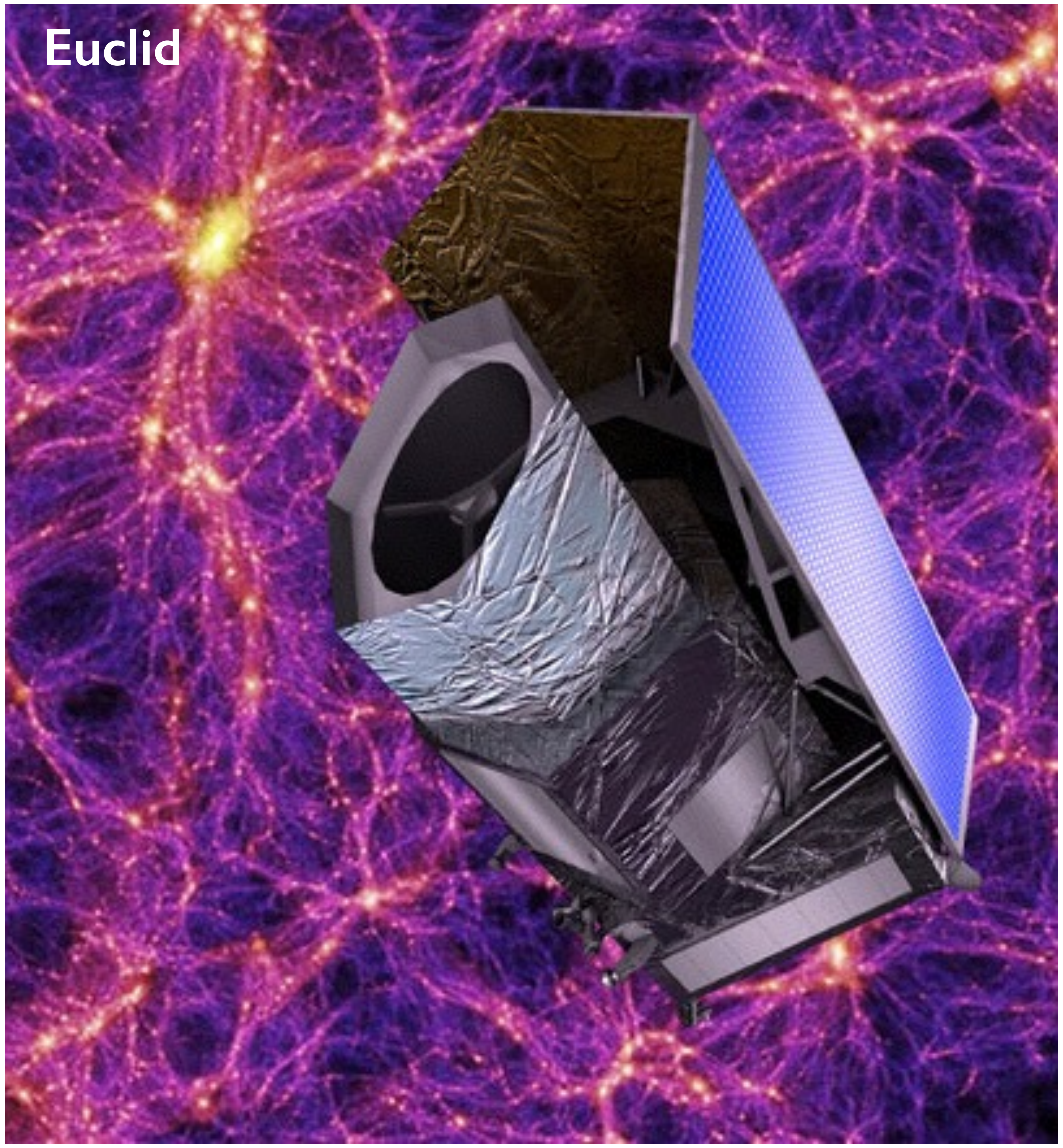
- Infrared
  - MCAO on ELT's could be quite impressive, but TBD — probably something we should have an expert talk about later
  - Atmospheric windows
  - Past *K*-band (~2.5 microns), space beats ground quite handily. With newest technology, can get to ~10 microns with passive cooling.
  - Some key science:
    - slew of science if we went past 2.5 microns, from brown dwarfs to z>10 quasars
    - arguably space will be better for sensitive proper motion studies as compared to ELT ground-based observations

Backup Slides

WFIRST-AFTA / Euclid comparison

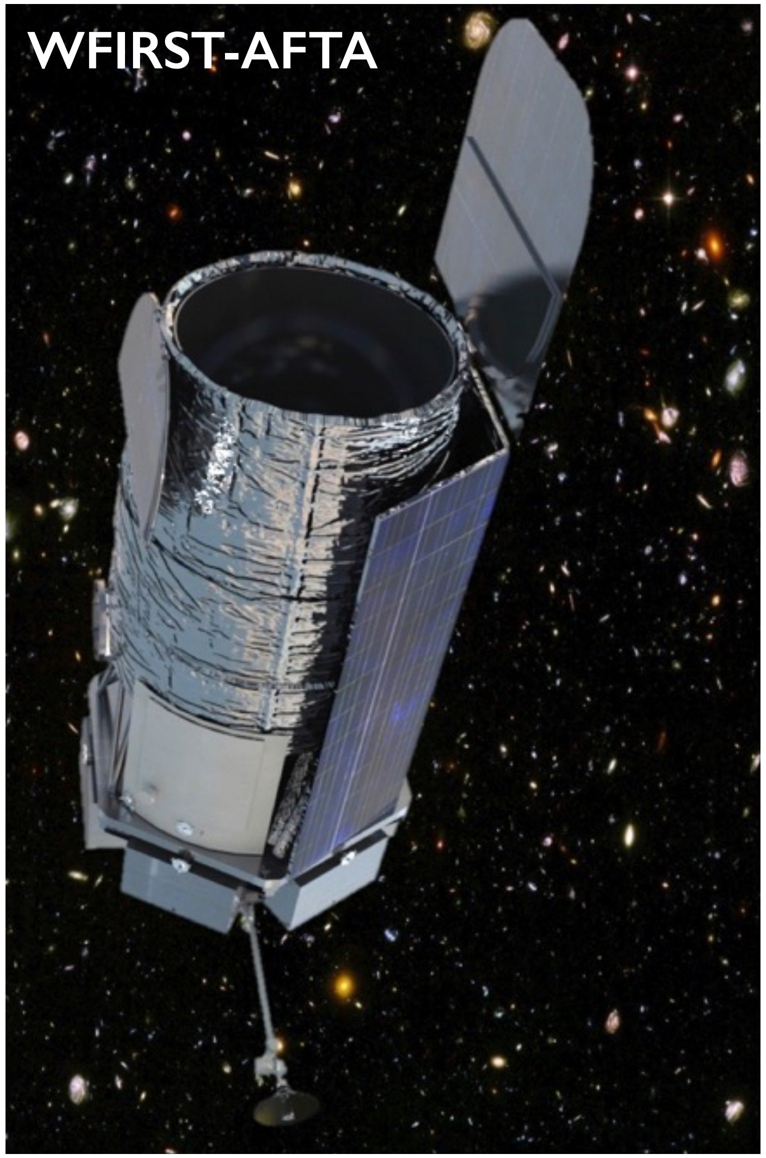


2.4 m TMA ("AFTA")
18 H4RG detectors
0.7 - 2.0 micron bandpass
0.28 sq. deg FoV
4 filter imaging + grism spectroscopy
6 yr. baseline mission

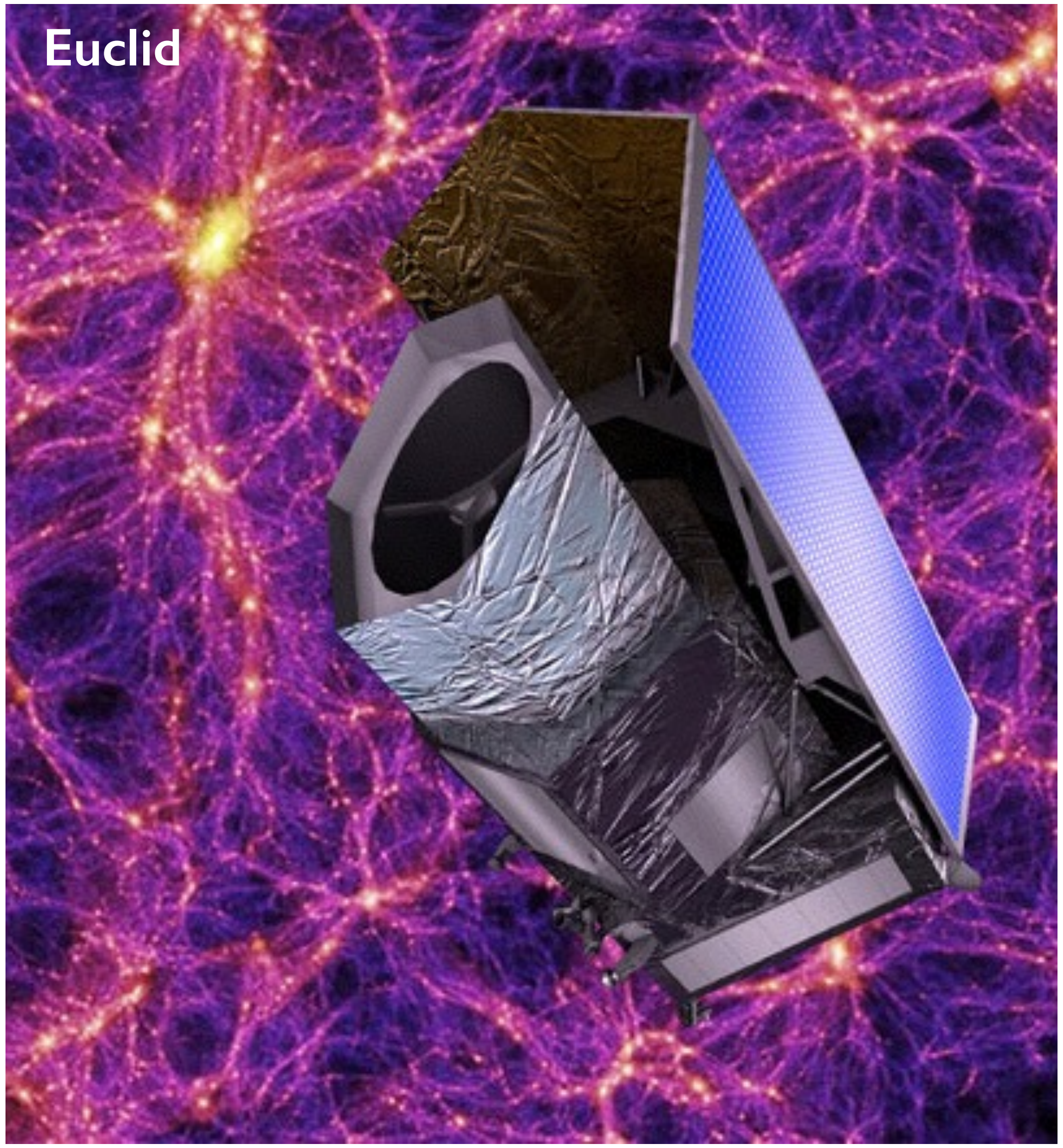


1.2 m TMA
36 4kx4k CCDs + 16 H2RG detectors
0.55 - 2.0 micron bandpass
0.55 sq. deg FoV
4 filter imaging + grism spectroscopy
6 yr. baseline mission

WFIRST-AFTA / Euclid comparison

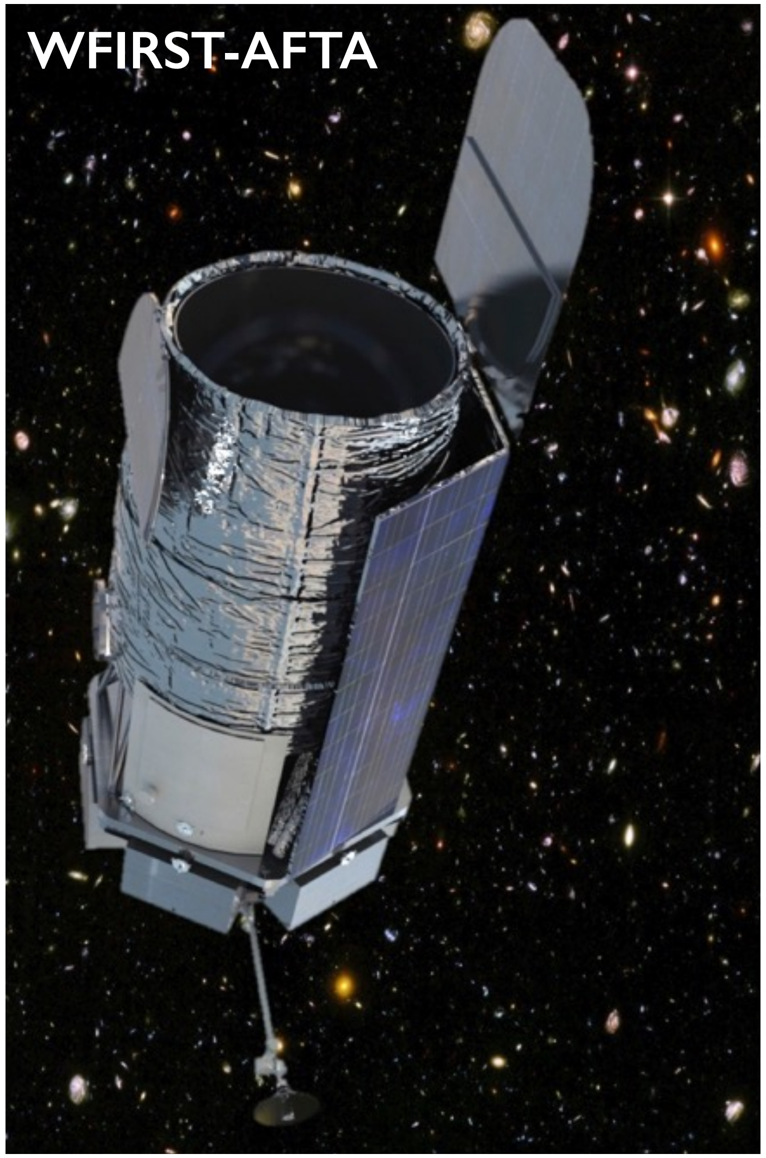


0.11" / pix
wide survey: 2400 sq. deg., ~27 mag (near-IR)
R~600 grism + R~100 IFU
grism survey depth: 3e-17 erg/cm2/s (3.5σ)

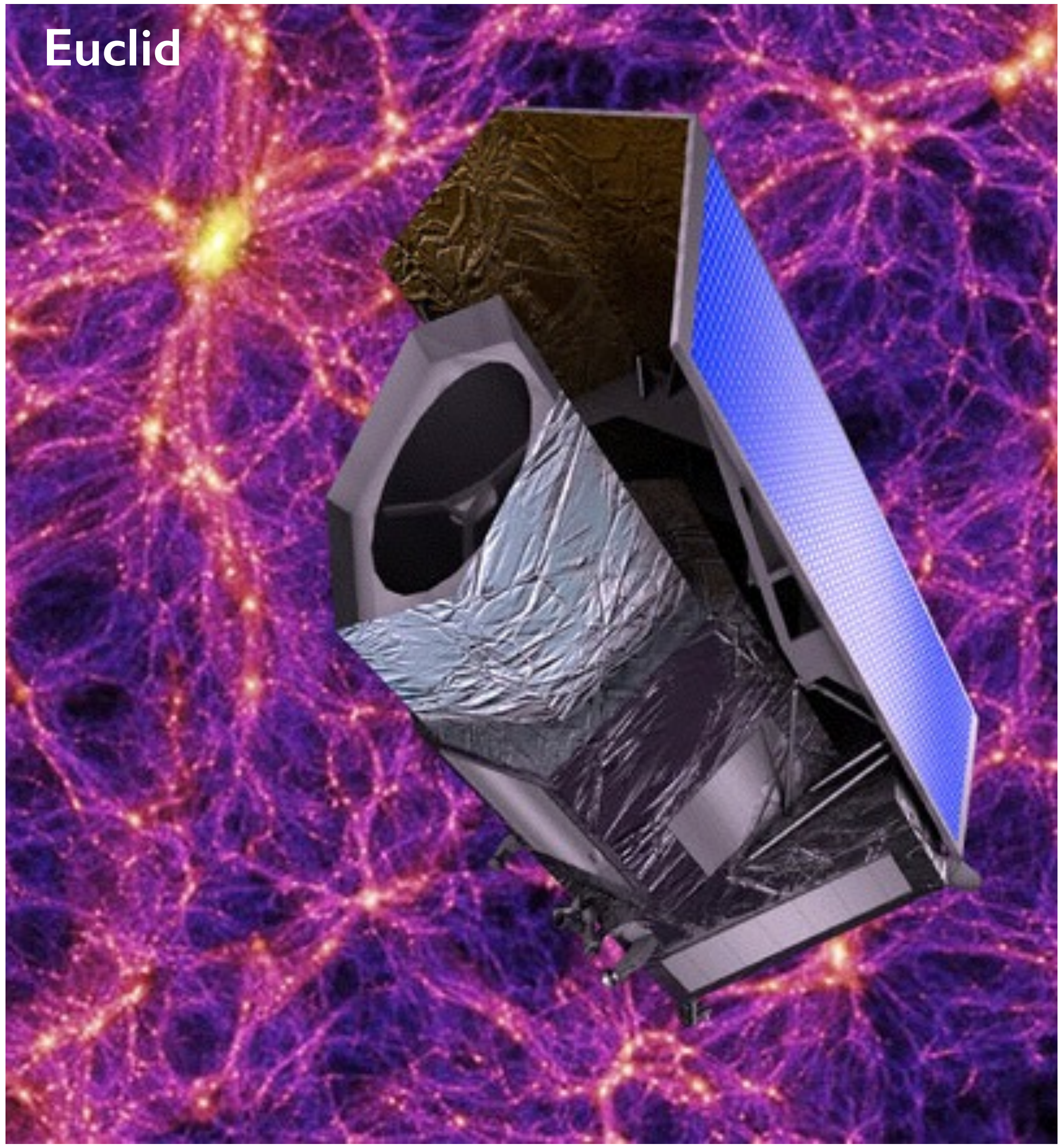


0.10" / pix (optical); 0.30" / pix (near-IR)
wide survey: 15,000 sq. deg., ~24 mag (near-IR)
R~250 grism
grism survey depth: 3e-16 erg/cm2/s (3.5σ)

WFIRST-AFTA / Euclid comparison



cosmology
infrared survey science
microlensing exoplanet survey
(coronography survey?)
guest observer (GO) program: 25% of time



cosmology
optical + infrared survey science
(no microlensing survey or GO program)

WFIRST-AFTA / Euclid comparison