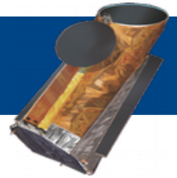

The need for a multi-purpose, optical–NIR space facility after HST and JWST

The case for an ESA-led HabEx Workhorse Camera

Knud Jahnke, Oliver Krause, Hans-Walter Rix (MPIA)

White Paper Team

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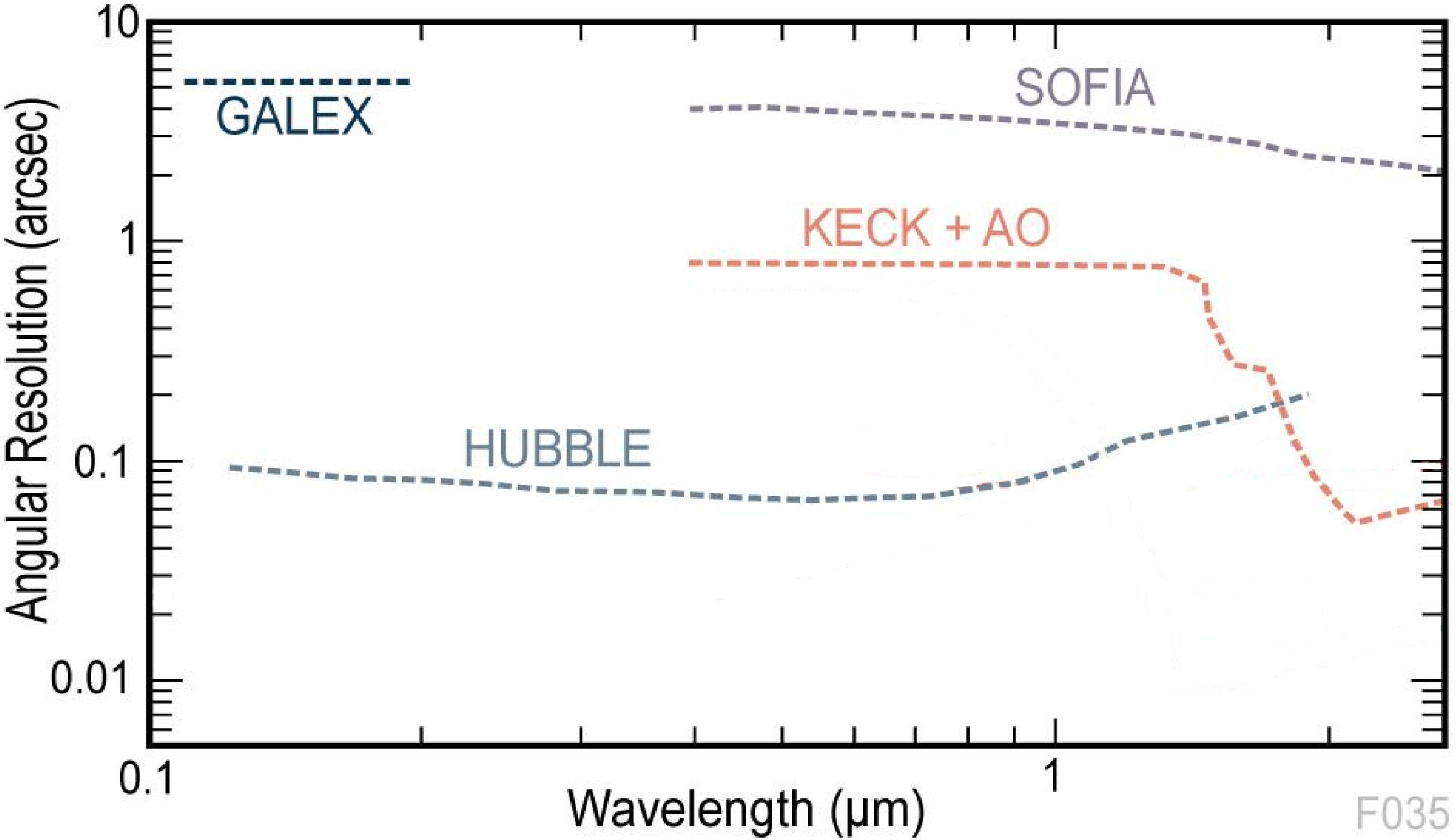
Keith Warfield (JPL/USA)

+major input from full HabEx study team

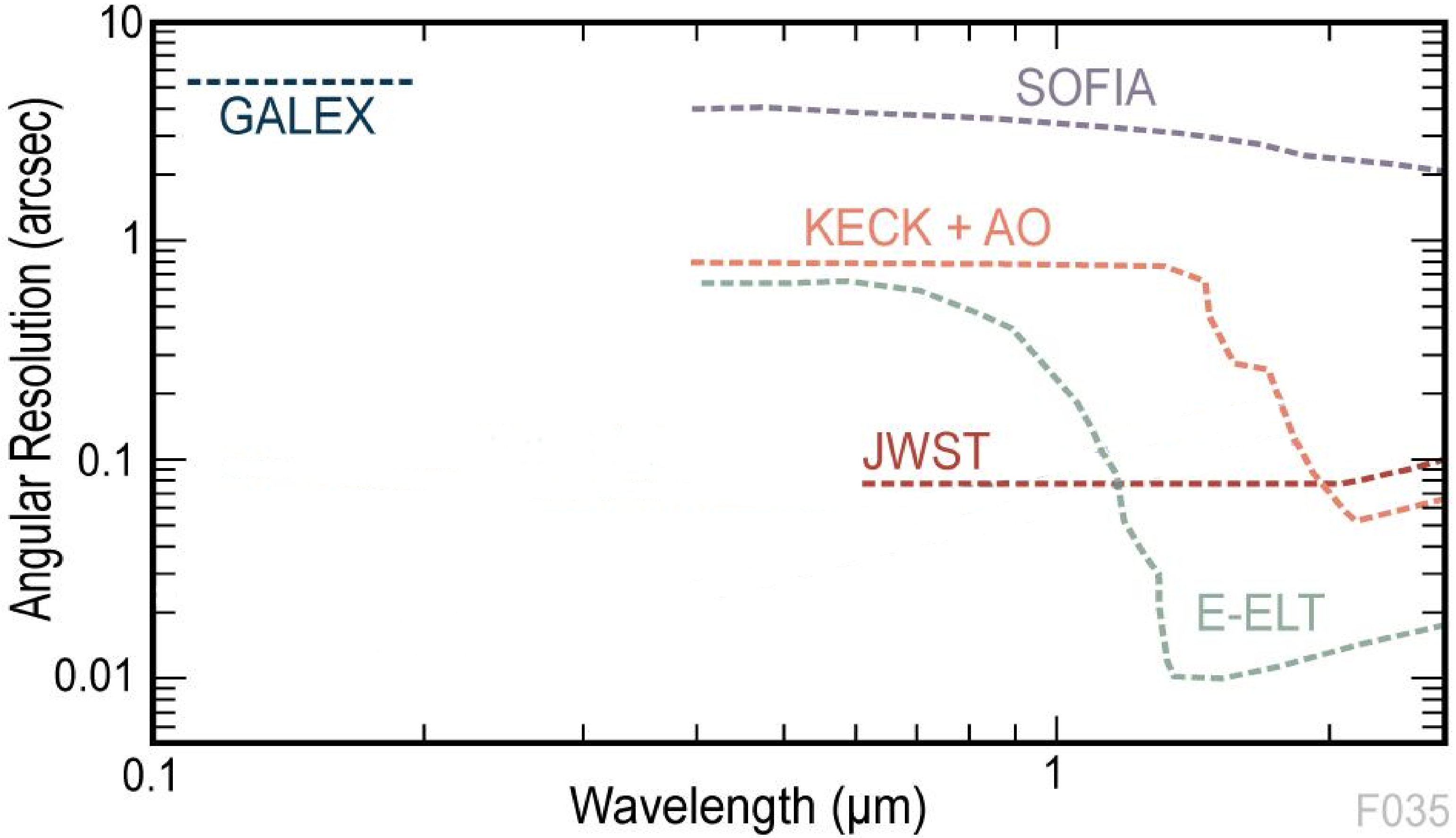
Observing facilities: 0.1–3μm

2019
2025
2035



Observing facilities: 0.1–3μm

2019
2025
2035



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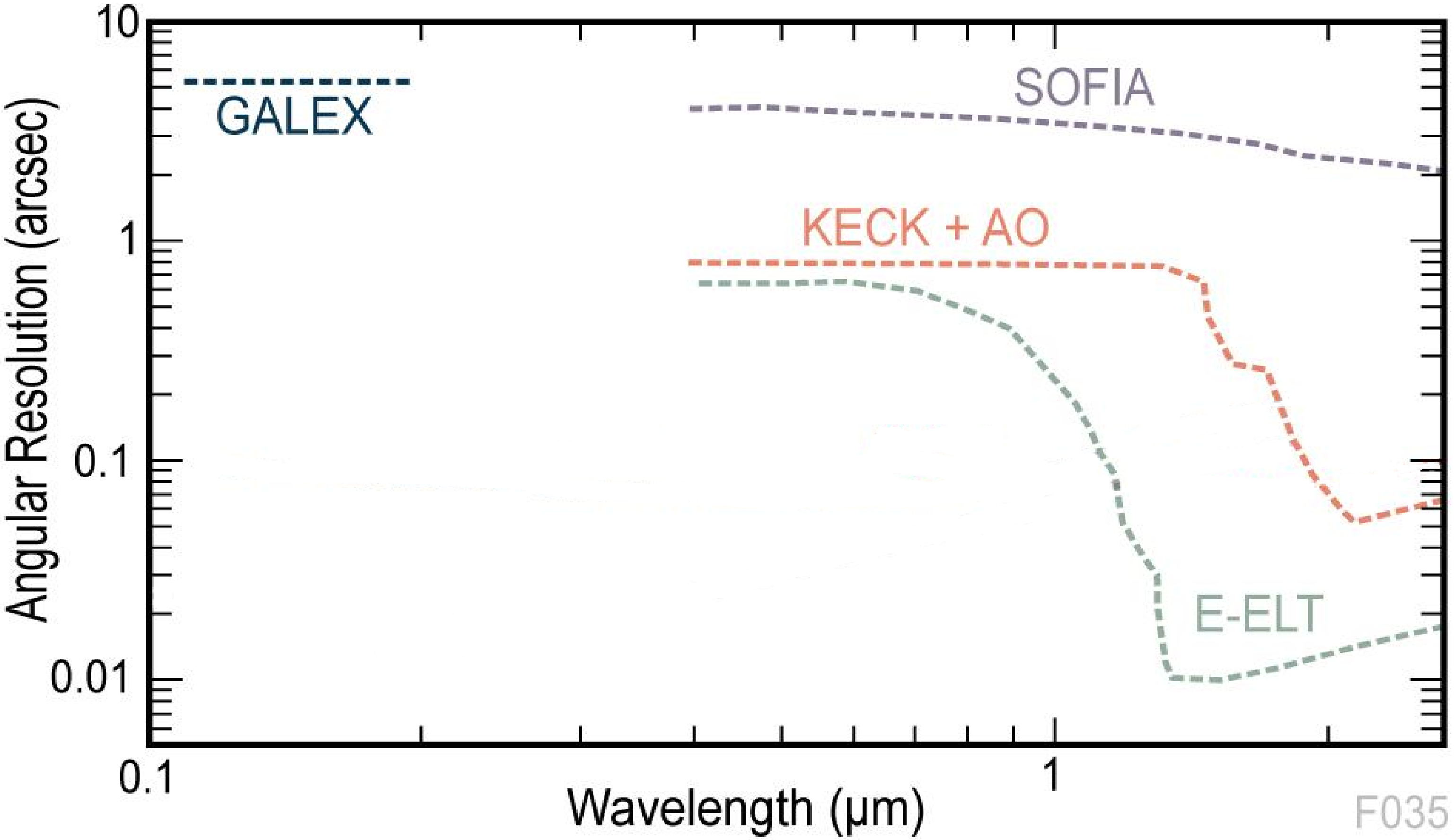
2019
2025
2035



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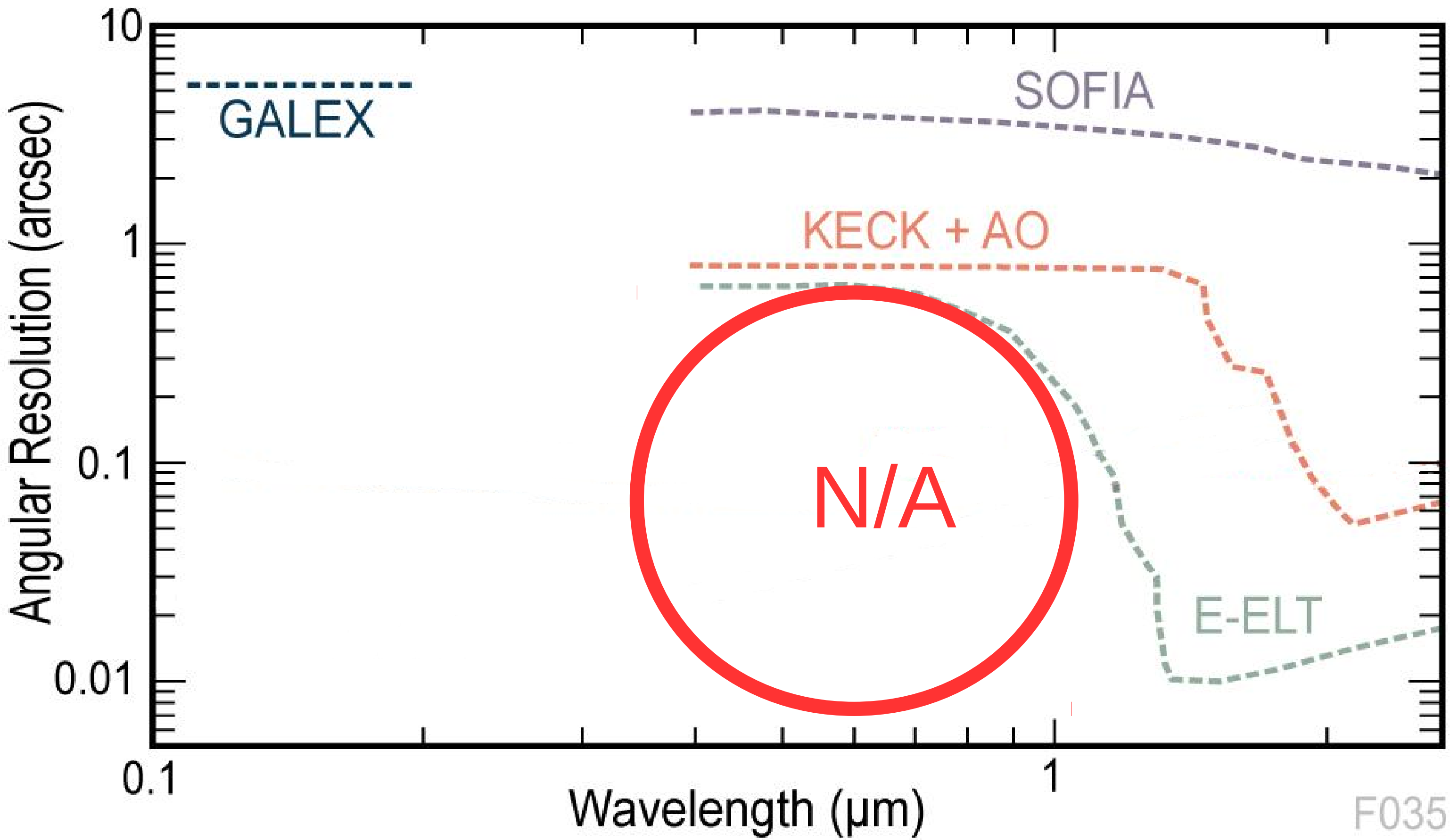

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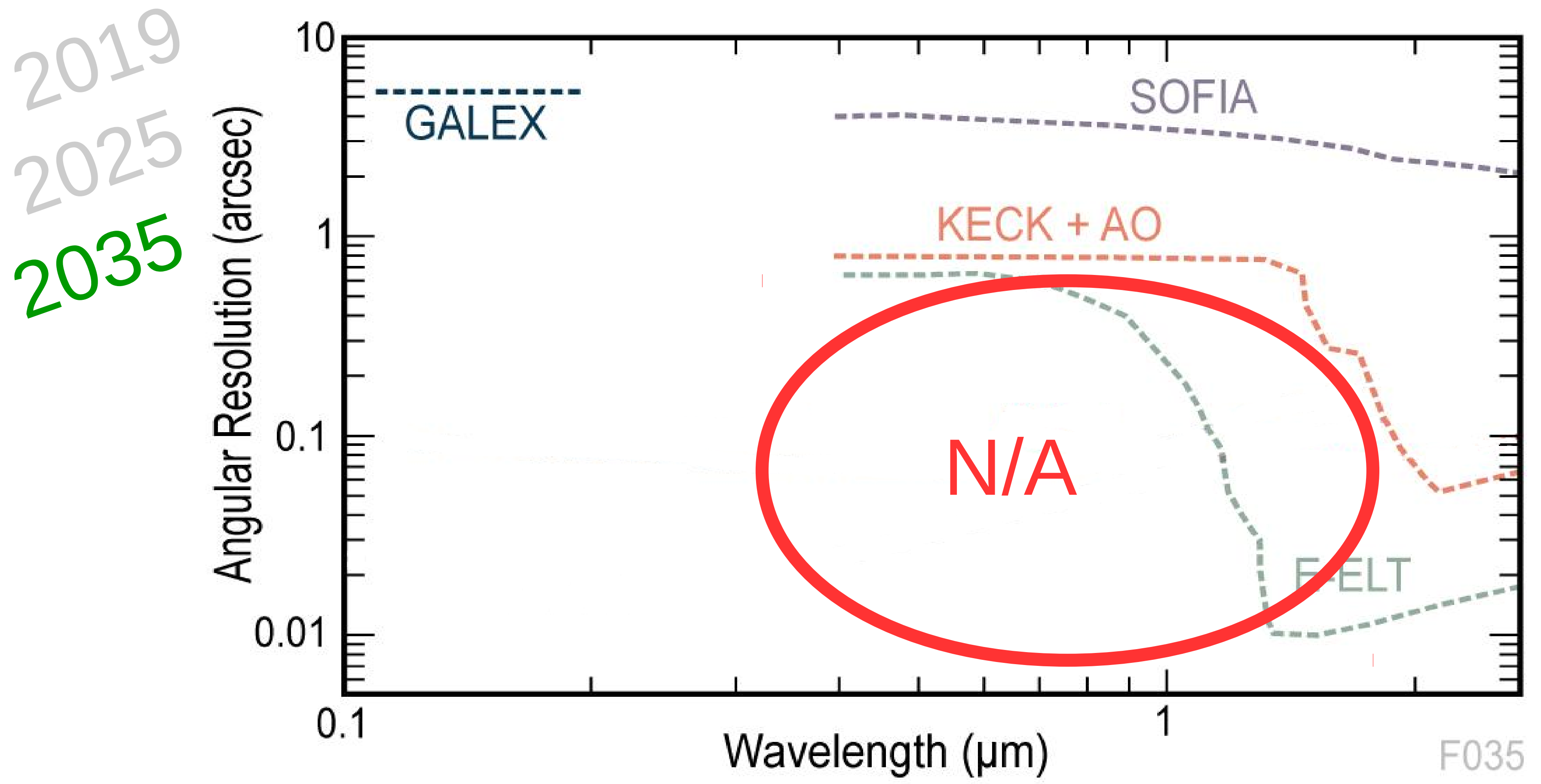
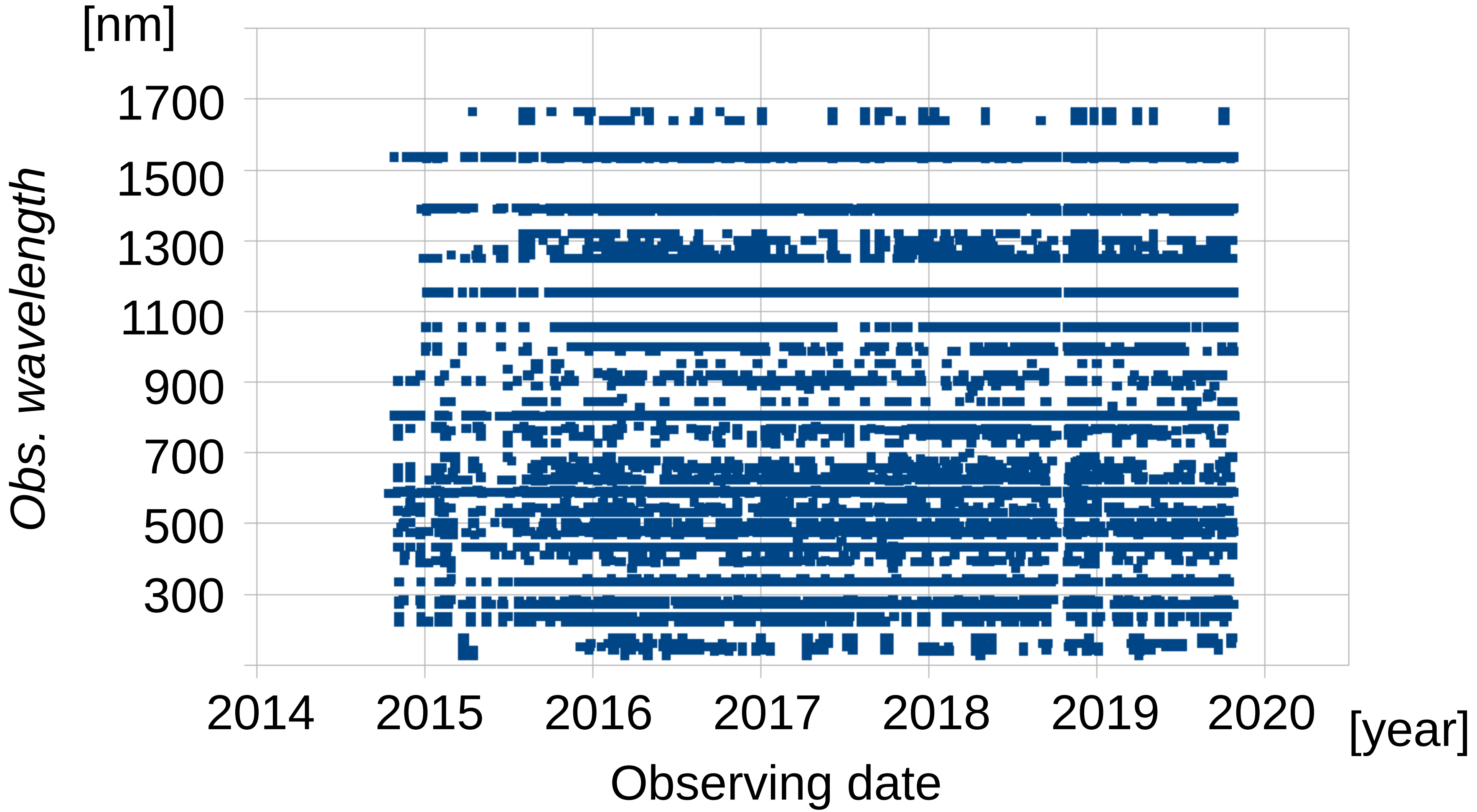


HST observing: 2014–now



Observing facilities: 0.1–3µm

2019
2025
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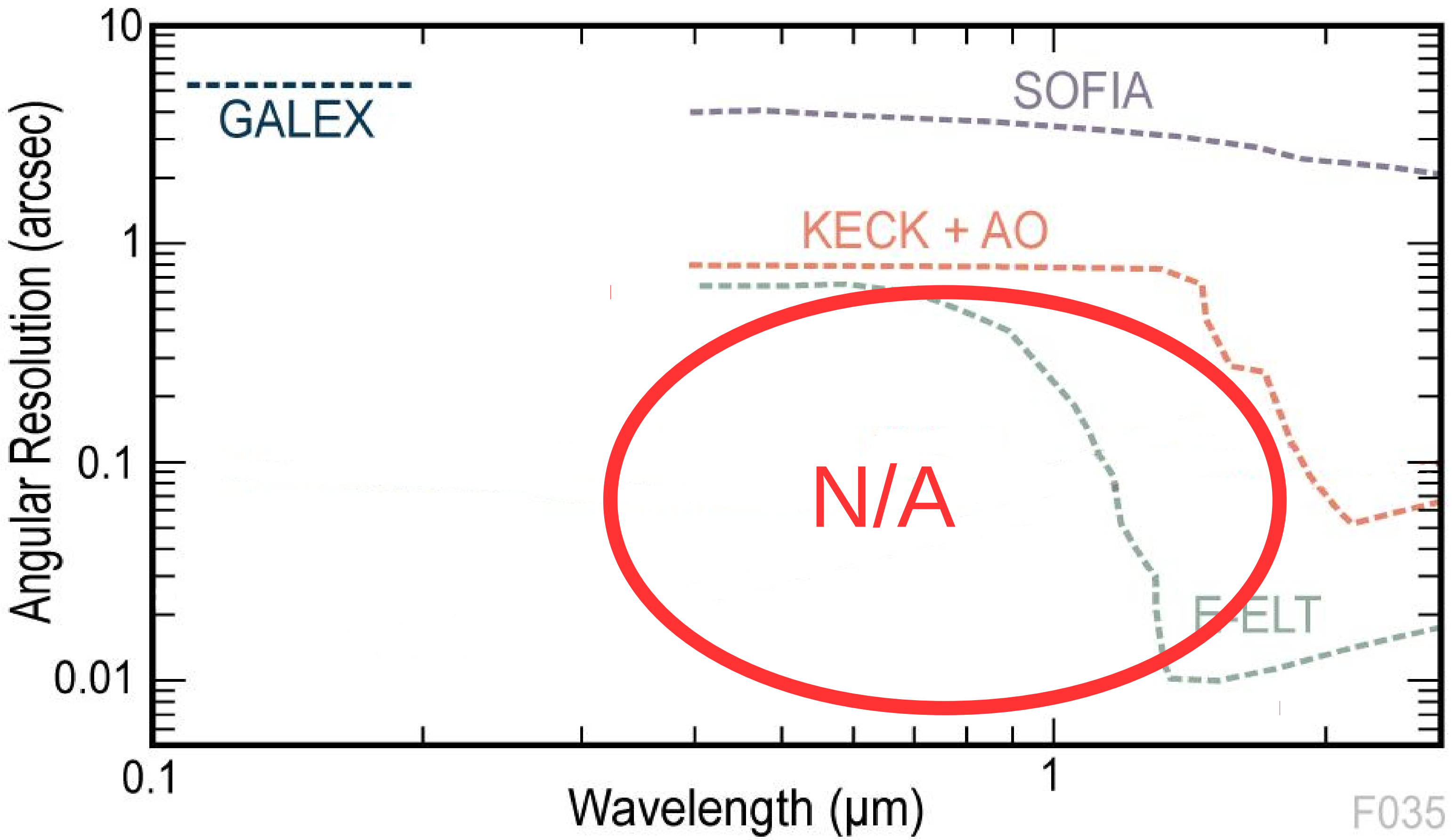
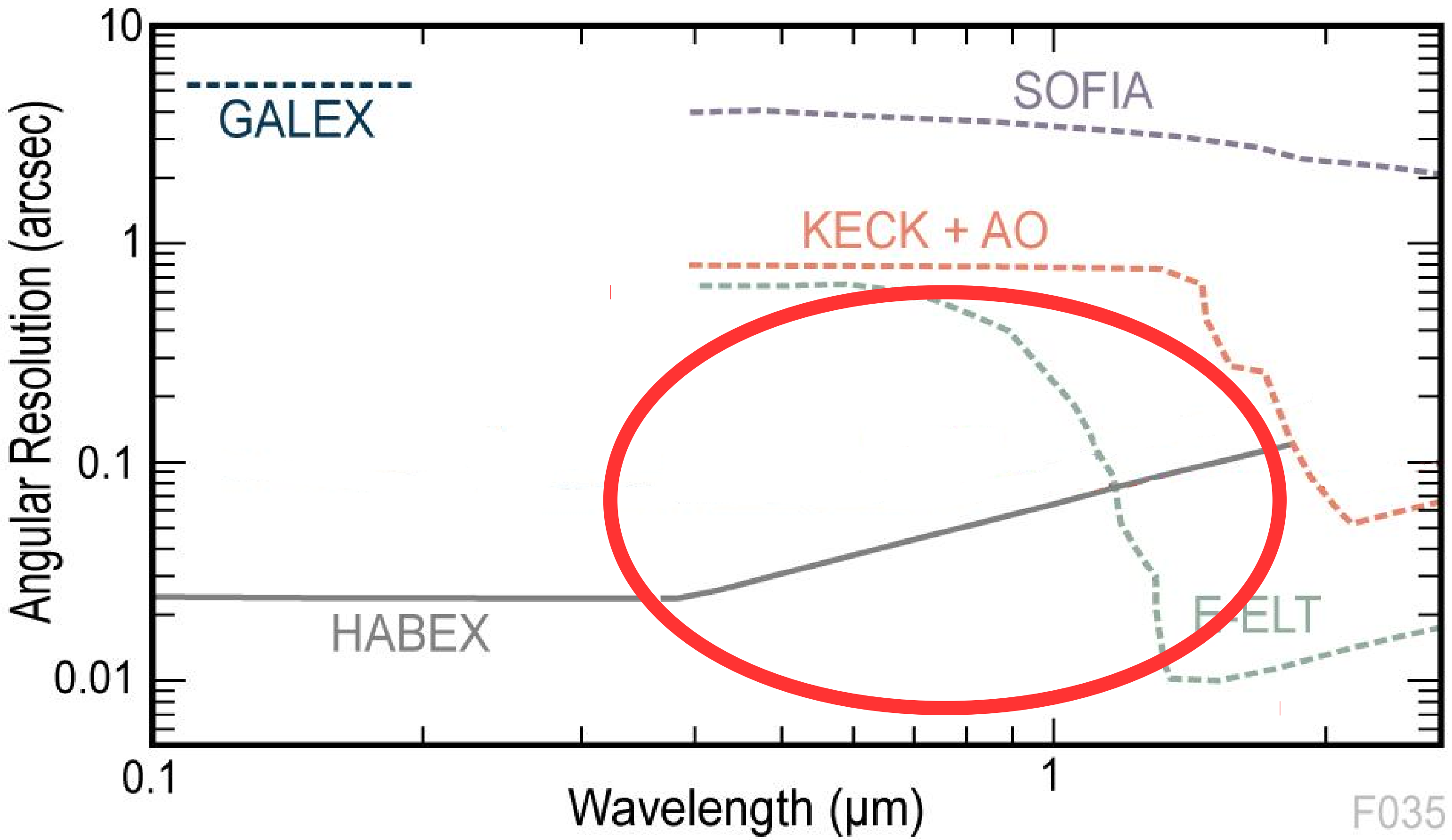
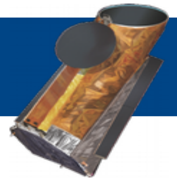


Observing facilities: HabEx to the rescue!

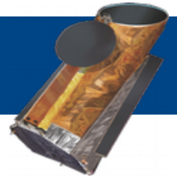
2019
2024
2035

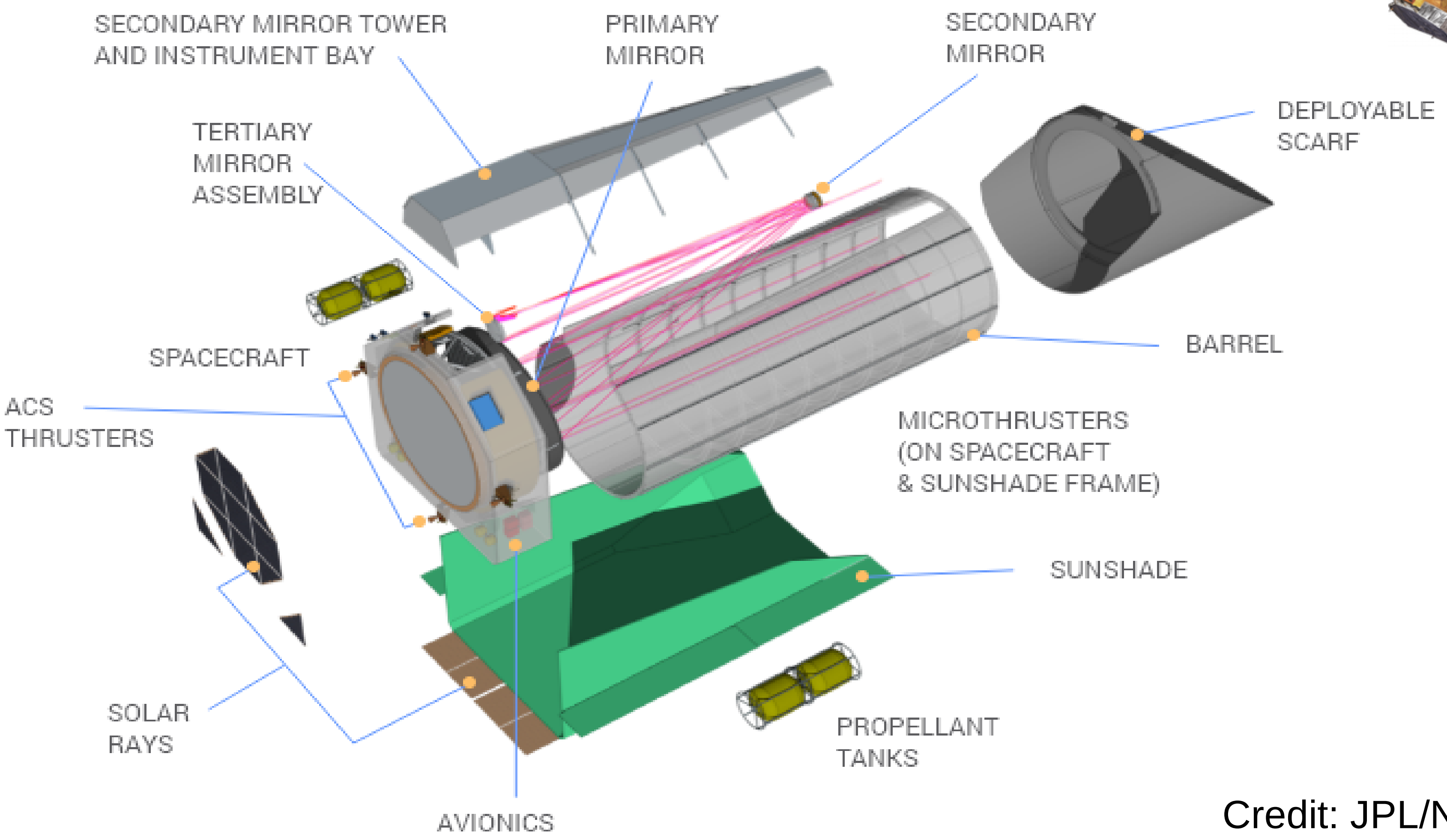




HabEx

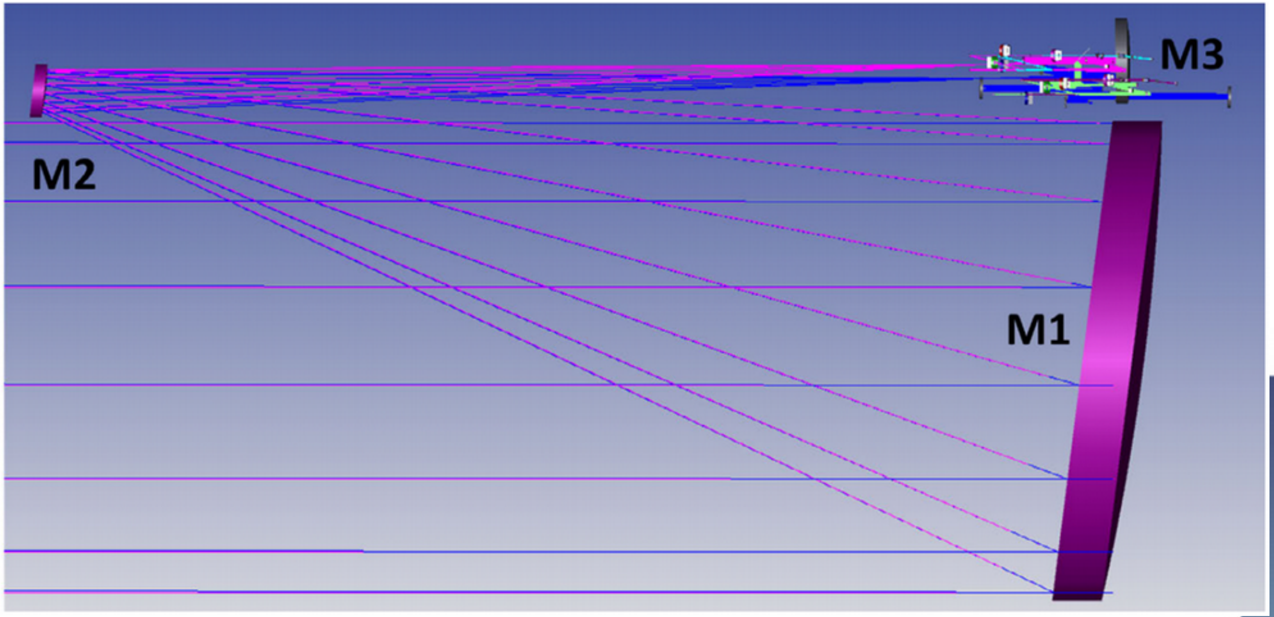
HabEx: Overview



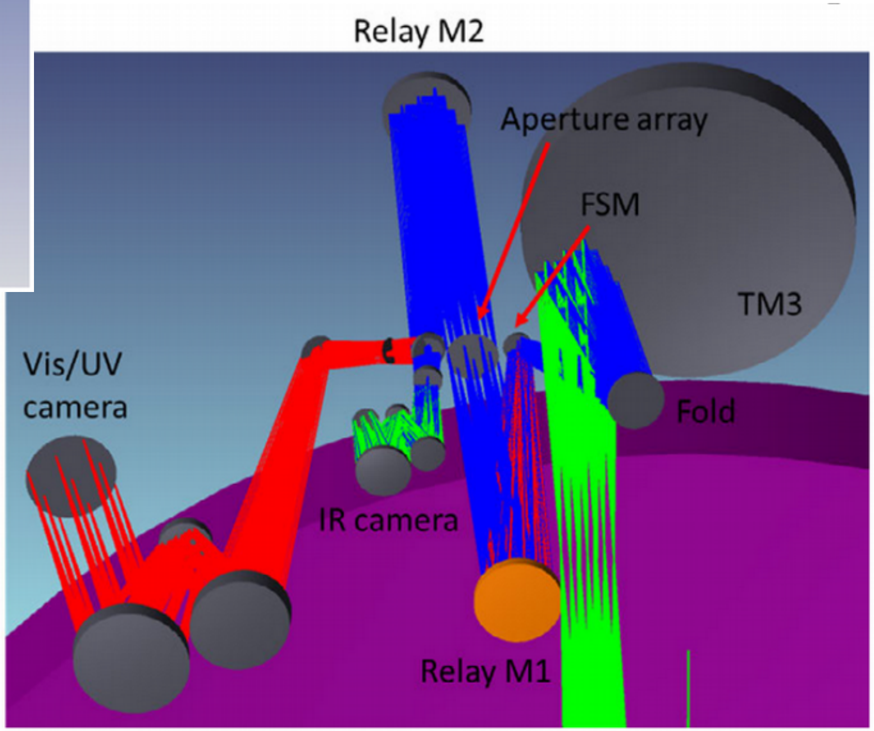


Credit: JPL/NASA

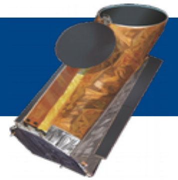
HabEx: Telescope and Workhorse Camera (HWC)



HabEx + HWC: simple optical layout

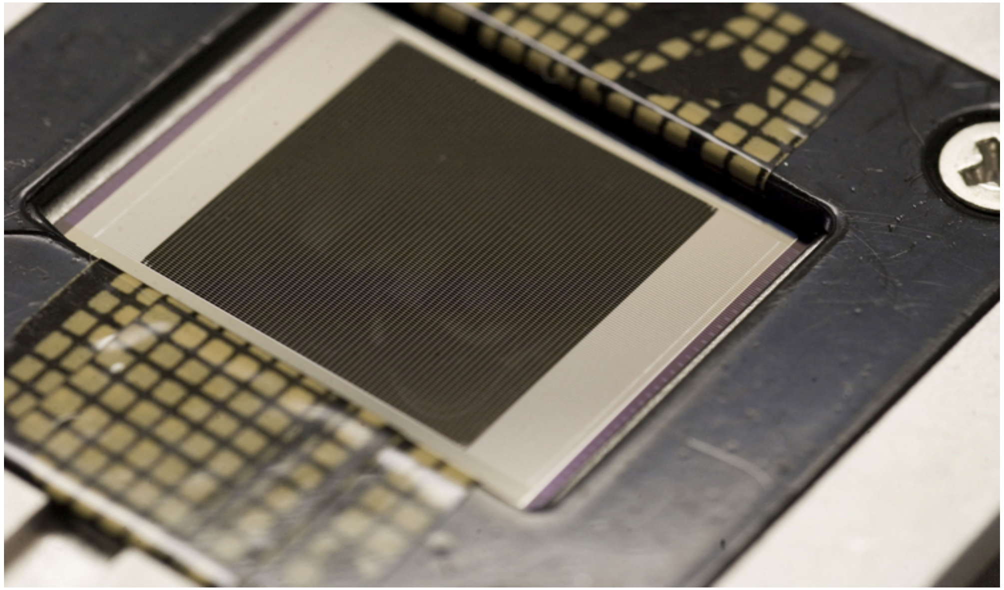


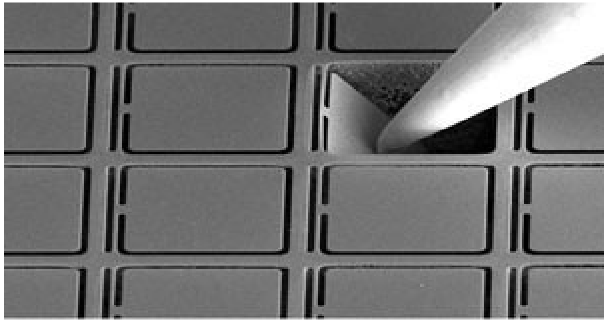
HabEx Workhorse Camera (HWC)



- HabEx: 4m primary mirror
- HWC optical arm: 380–870nm
- HWC NIR arm: 870–1800nm
- Imaging + multiplex spectroscopy
- Microshutter array 350x170 windows
  - R~1000–2000 grism/prism

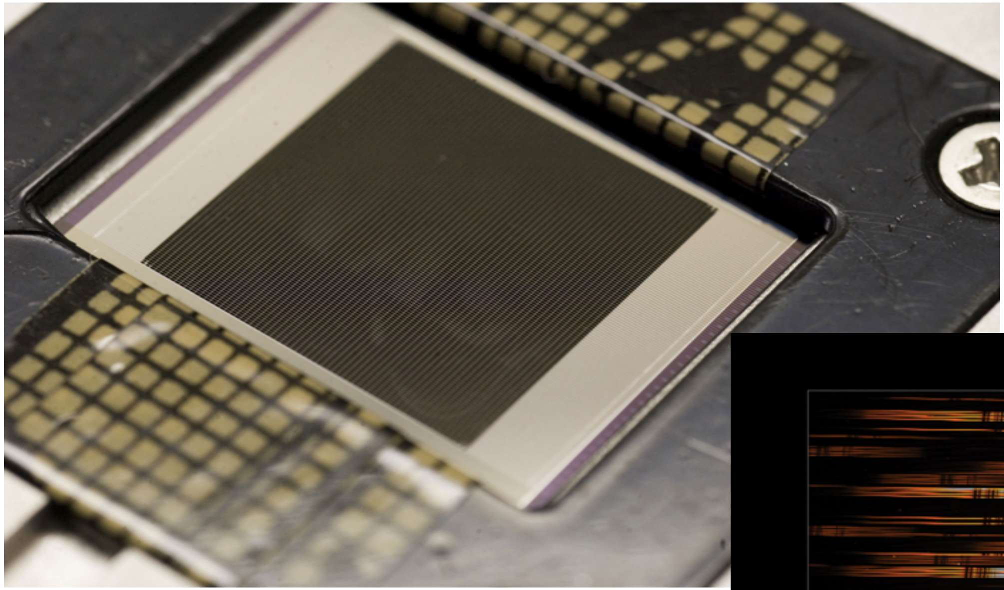
HabEx Workhorse Camera





Microshutter array
(JWST/NASA)

HabEx Workhorse Camera



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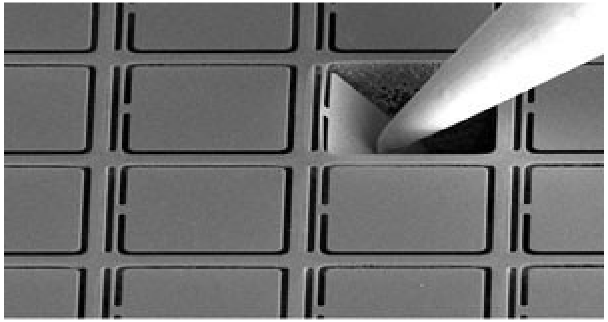
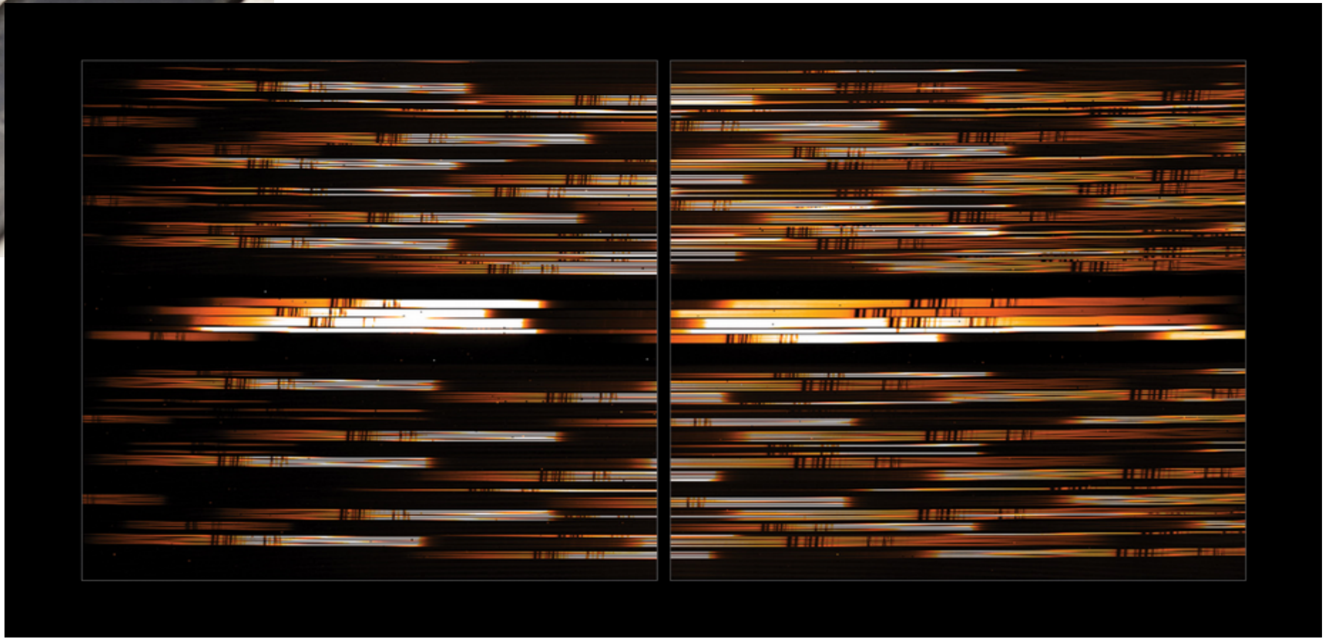
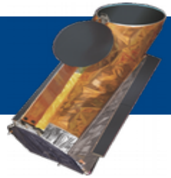




HabEx Workhorse Camera (HWC)



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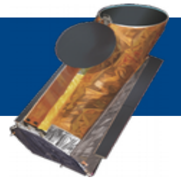

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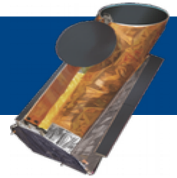
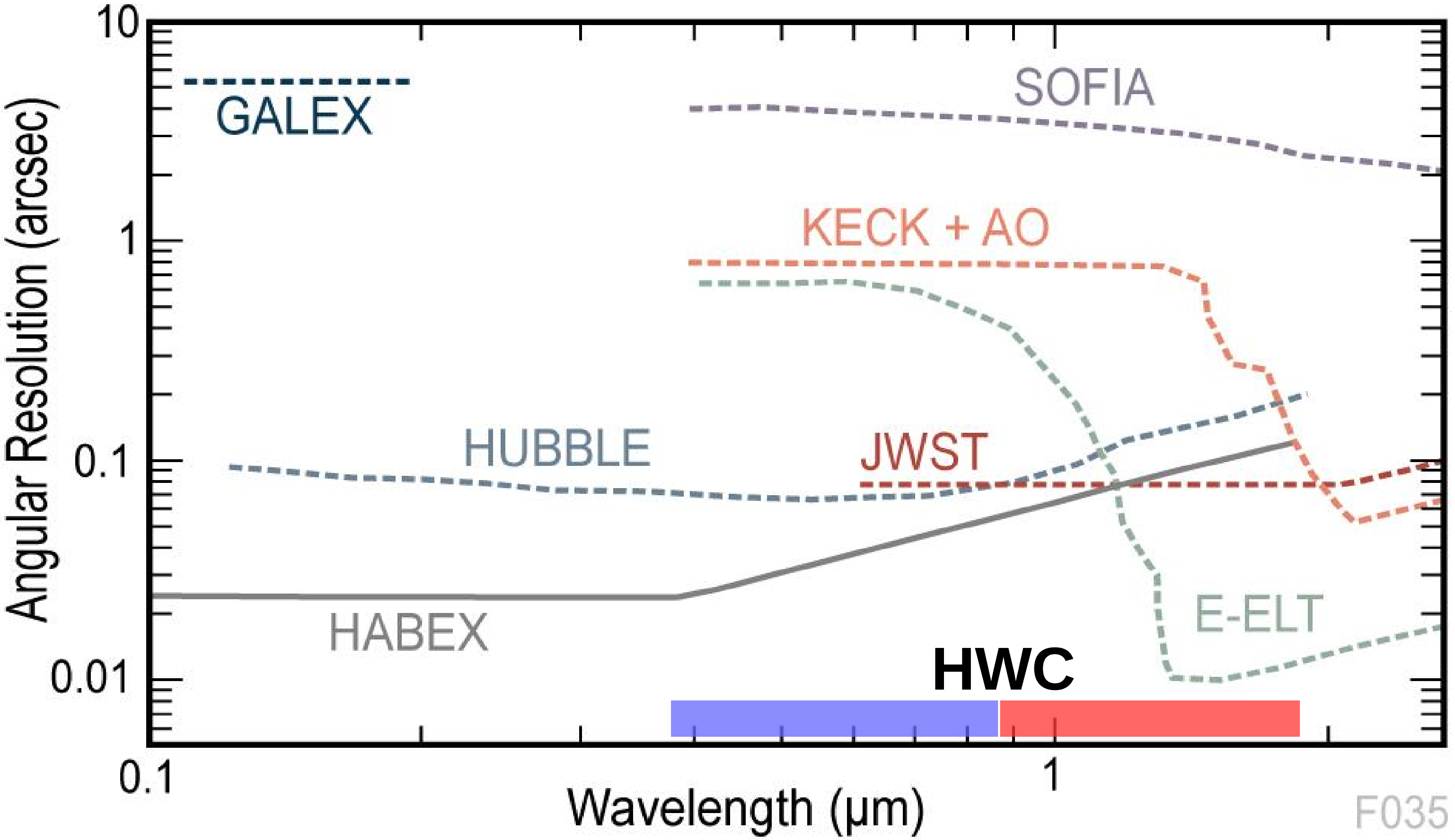
- Imaging + multiplex spectroscopy
- Microshutter array 350x170 windows
  - R~1000–2000 grism/prism
- 3x3 arcmin FOV
- *Diffraction limited at all wavelengths!*

Observing facilities 2030+: 0.1–3μm



2019
2024
2035



2030+ science cases

1. The Local Value of the Hubble Constant
2. The Star Formation Histories of Nearby Galaxies from Stellar Archaeology
3. Probing the Nature of Dark Matter with Dwarf Galaxies

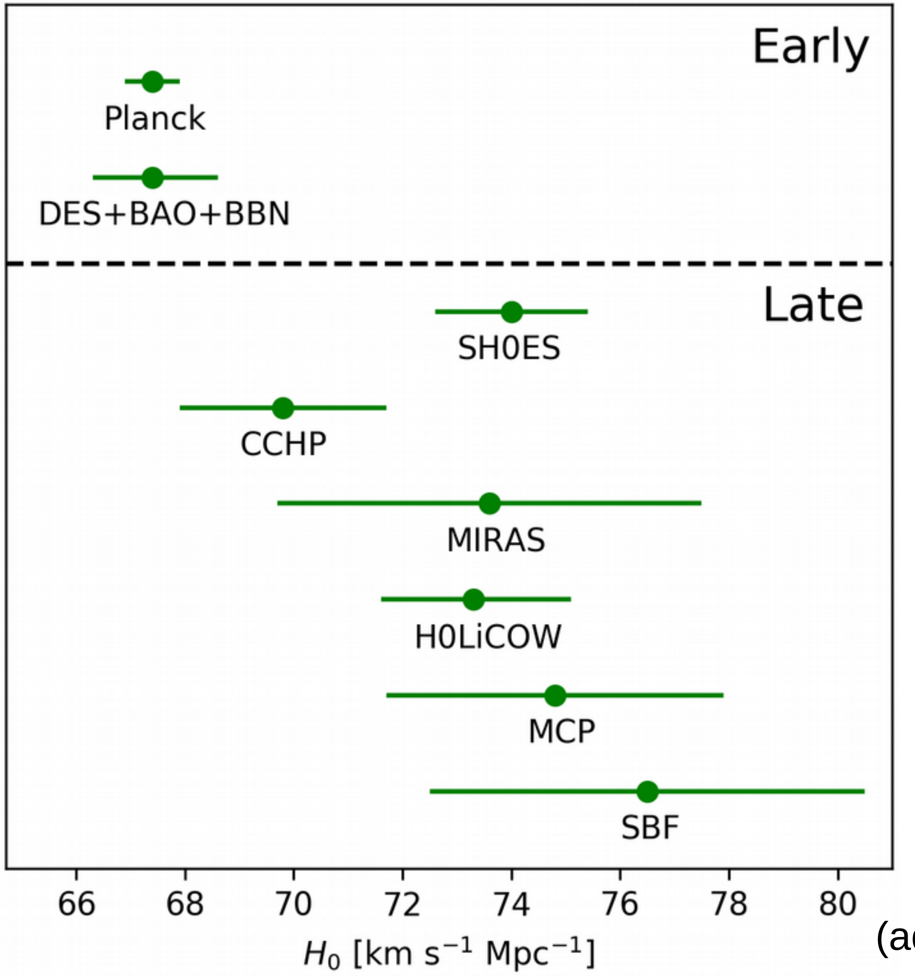
2030+ science cases

1. The Local Value of the Hubble Constant

The Local Value of the Hubble Constant

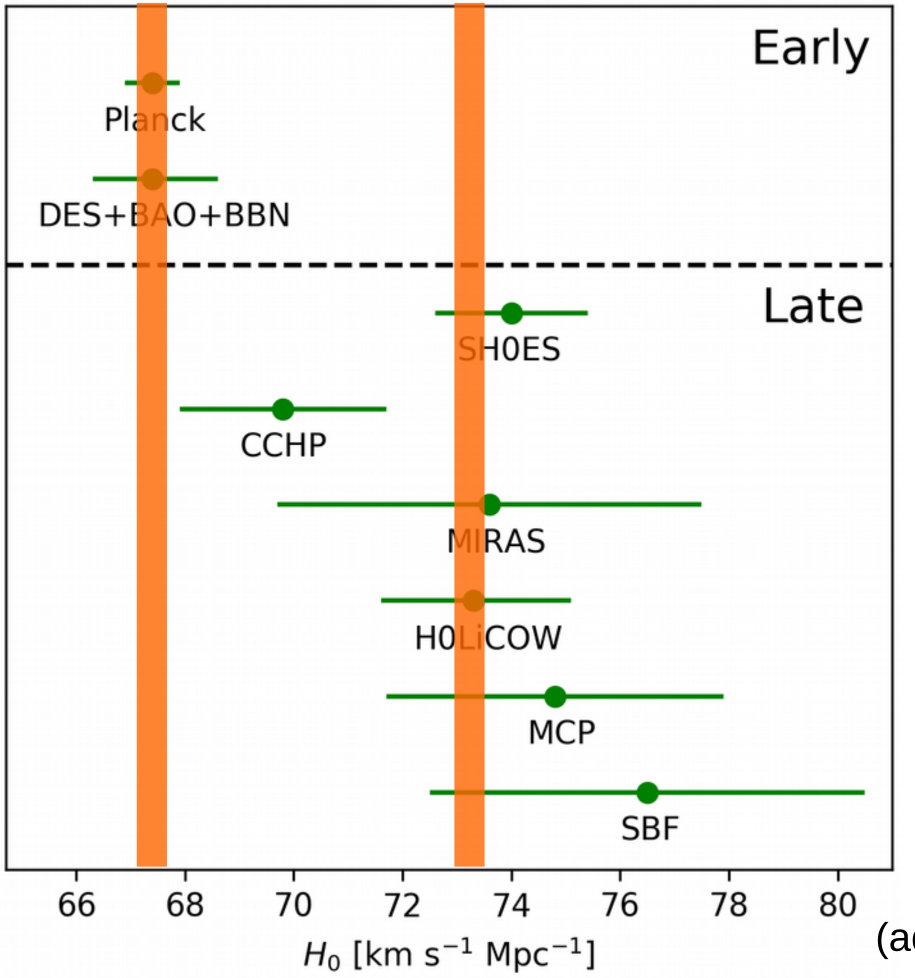
Planck (Cosmic Microwave Background):	H_0~66.9±0.6 km/s/Mpc
Supernovae, grav. lenses and others:	H_0~73.2±1.7 km/s/Mpc

The Local Value of the Hubble Constant



(adapted from Verde, Treu, Riess 2019)

The Local Value of the Hubble Constant



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→ 3–6 σ discrepancy

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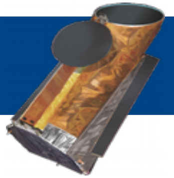
→ 3–6 σ discrepancy

→ H_0 “tension” or H_0 “crisis”?

The Local Value of the Hubble Constant



HabEx case: Workhorse Camera

- Calibrate precision Cepheid distances for SN1a galaxies
  - D^4-scaled sensitivity improvement over HST+WFIRST (4m vs. 2.4m); x8 faster → larger survey volume → many more SN1a
  - requires ≥2.5x2.5 arcmin^2 field-of-view to fit whole galaxies
  - imaging with several filters at 0.4–1.7μm

- High-fidelity mass models for quasar lenses
  - better angular resolution and larger spatial volume → sizable sample

2030+ science cases

2. The Star Formation Histories of Nearby Galaxies from Stellar Archaeology

SF Histories of Nearby Galaxies from Stellar Archaeology

Galaxy formation and evolution, primary goal:

- Lifecycle of Baryons in cosmological context
- Production of heavy elements → conditions for star formation, planet formation, life!

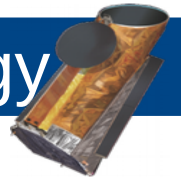
- Fundamental open questions, e.g.:
  - Initial mass function, variation with metallicity?
  - Role of environment: variation of UV-photon density from neighboring stars, remnants, AGN?

SF Histories of Nearby Galaxies from Stellar Archaeology

- One approach: statistical redshift studies

- Complementary and powerful: measure history of individual stars in nearby gals
  - Measure ages, chemical abundances → “fossil record” of birth time and location of these stars

SF Histories of Nearby Galaxies from Stellar Archaeology

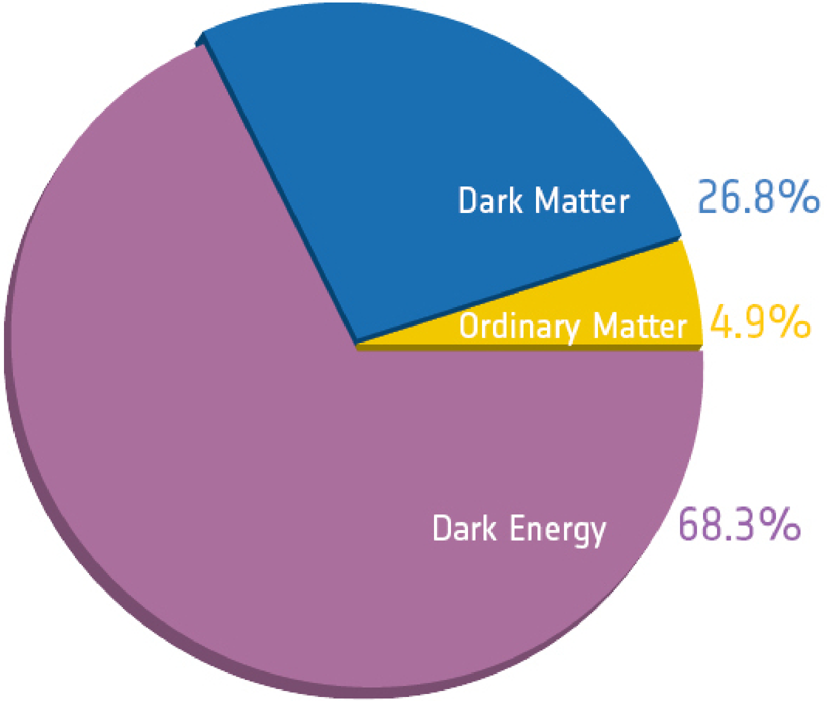


HabEx case:

- Expand HST work beyond local group
  - much larger accessible volume over 2.4m HST+WFIRST → much more diverse environments, masses,…
  - requires: <0.1” resolution for deblending, wide-field imaging in several UV-optical bands, very stable PSF; down to stellar main sequence → only HabEx Workhorse Camera
  - add HabEx UV Spectrograph, multi-object UV spectroscopy at 250nm, to break age-dust-metallicity degeneracy → not possible with JWST

3. Probing the Nature of Dark Matter with Dwarf Galaxies

Probing the Nature of Dark Matter with Dwarf Galaxies



(ESA & the Planck Collaboration)

Probing the Nature of Dark Matter with Dwarf Galaxies

- Dark Matter (DM): 25–30% of total energy density in Universe
- Single particle? Many particles? Which ones?

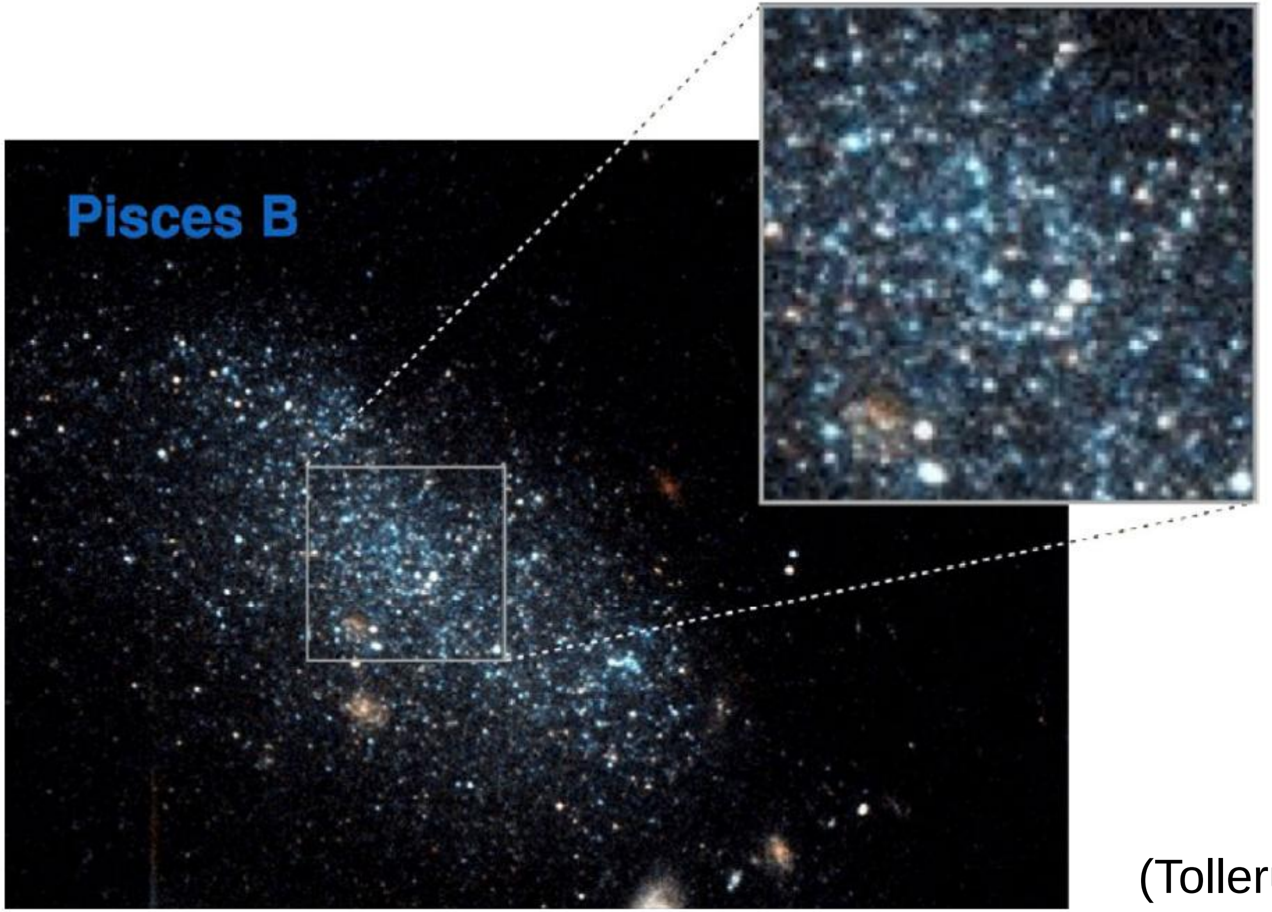
- Two DM options:
  - “Vanilla”, standard DM: solely gravitational (+maybe weak) force
  - Non-standard DM: e.g. self-interacting → testable by astronomy

Probing the Nature of Dark Matter with Dwarf Galaxies

Dwarf galaxies as DM test laboratories:

- Dwarf galaxies dominated by DM all the way to center

Probing the Nature of Dark Matter with Dwarf Galaxies



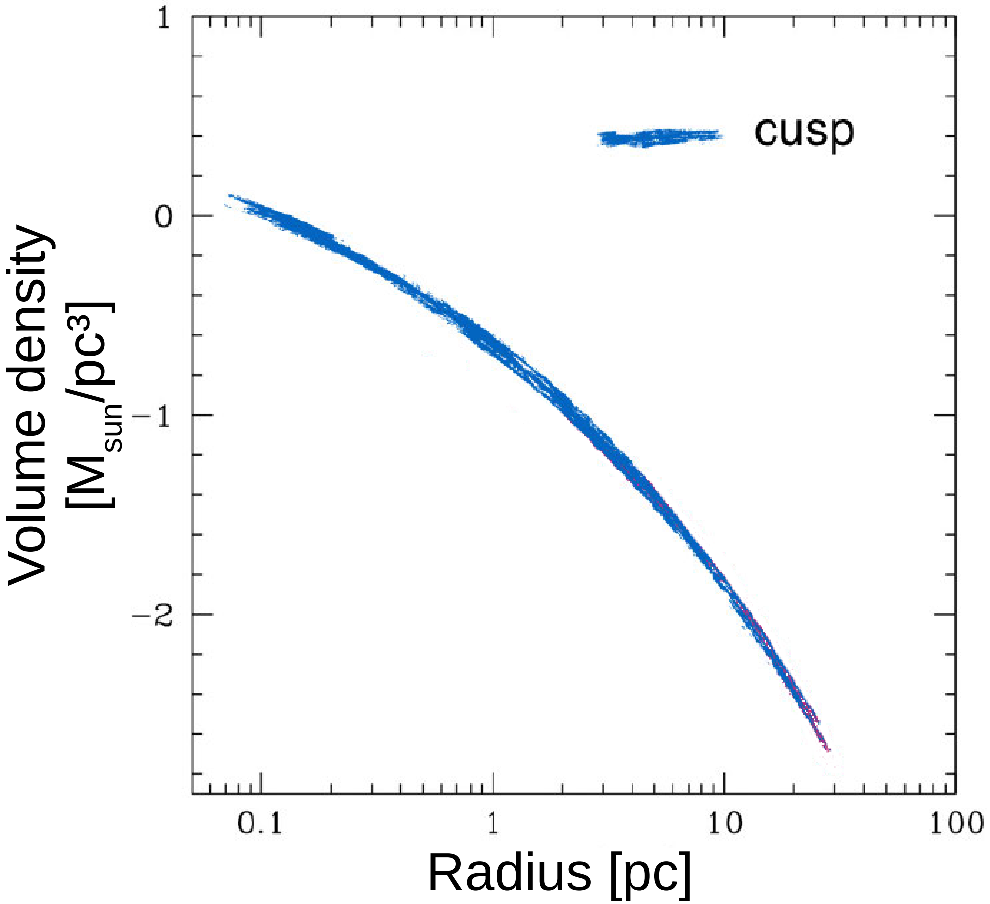
(Tollerud+ 2016)

Probing the Nature of Dark Matter with Dwarf Galaxies

Dwarf galaxies as DM test laboratories:

- Dwarf galaxies dominated by DM all the way to center
- Prediction for dwarf gal formation in standard DM halos: “cusps mass profiles → observed for many: “cores”

Probing the Nature of Dark Matter with Dwarf Galaxies



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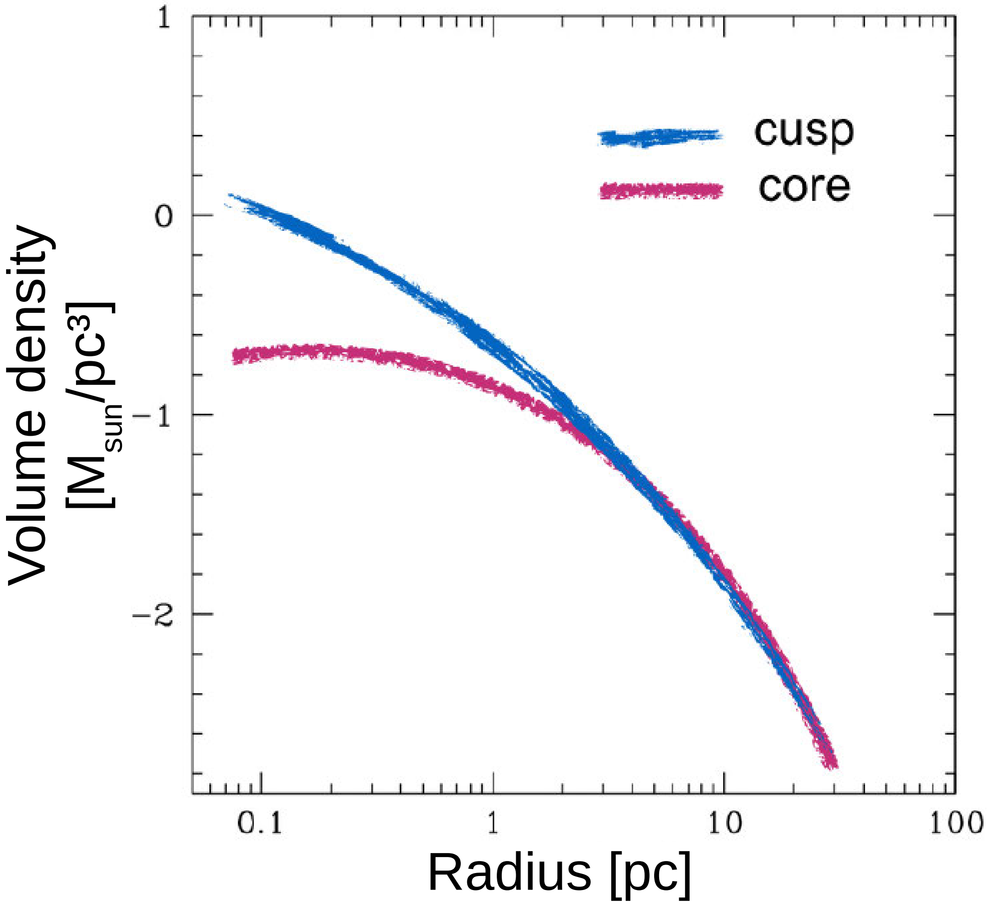


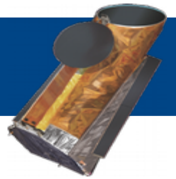
Probing the Nature of Dark Matter with Dwarf Galaxies

Dwarf galaxies as DM test laboratories:

- Dwarf galaxies dominated by DM all the way to center
- Prediction for dwarf gal formation in standard DM halos: “cusp” mass profiles → observed for many: “cores”
- Two solutions:
  1. non-standard DM: near-general prediction cores universal for dwarfs
  2. DM removal by SN explosions: dependency on e.g. SF intensity

  → testable!

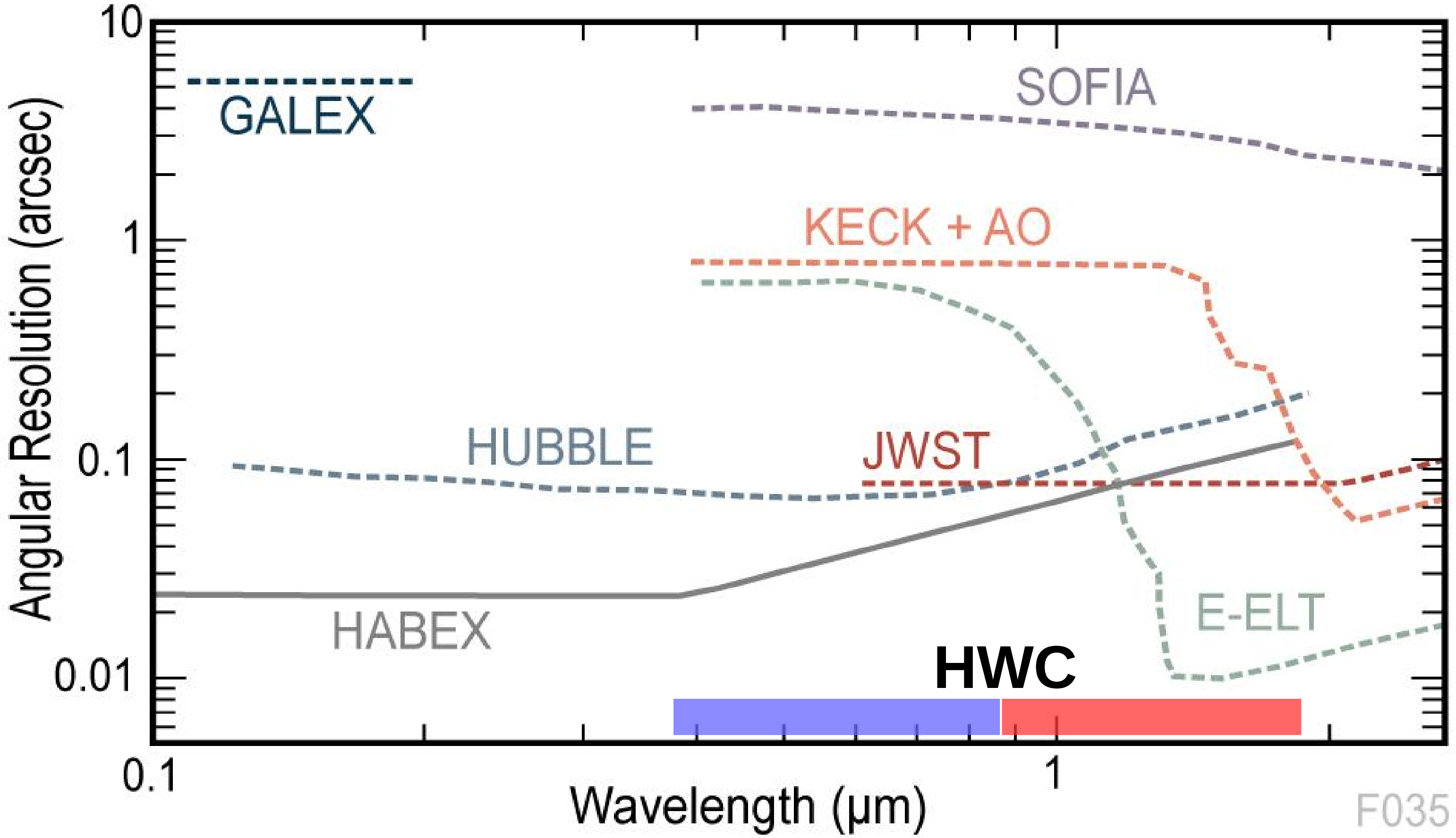
Probing the Nature of Dark Matter with Dwarf Galaxies



HabEx case:

- Dwarf gal sample spanning range in mass and SF histories; Ultra-faint to “classical” dwarfs
- Tracing central potential: 30m stellar spectroscopy + HabEx 40mas/yr proper motions for stellar motions → not possible with ELTs alone
- SF histories: high-resolution very precise photometry for dwarf galaxy light profiles

HabEx Workhorse Camera and Voyage 2050



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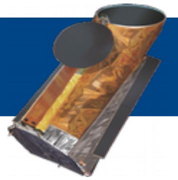
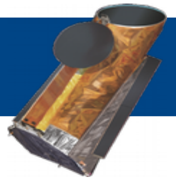


HabEx Workhorse Camera as an ESA contribution to HabEx

- Clean technical and managerial interface to HabEx@NASA
- All components at high technical readiness level → low risks
- Cost: 170M US$ (FY2020, HabEx team estimate)
- *HWC fits into S-class mission contribution + matching funds from involved national agencies*

HabEx Workhorse Camera and Voyage 2050



An ESA-led HabEx Workhorse Camera…

…would provide essential high angular-resolution, wide-field, visible–NIR range capabilities from space not available in the 2030, enabling a diverse range of science

…would fit into S-class mission cost envelope

…would be a low-risk, high-return contribution by ESA to NASAs HabEx mission, for the gain of Europe’s astronomy and astrophysics