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Customer Success Is Our Mission

Kilometer Space Telescope

NASA Innovative Advanced Concepts

Phase 2 Study

Devon G. Crowe, Webster Cash, Prakash Joshi, and Christopher Walker

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Kilometer Space Telescope NIAC Phase 2

- This Phase 2 follows a NIAC Phase 1 from 2006-2007 titled *Self-Deployed Space or Planetary Habitats and Extremely Large Structures* (1314)
- The Phase 2 Study will include addressing:
  - Science Requirements
  - Lab Measurement of spherical primary optical quality
  - Telescope Architectural Trades
  - Telescope Design
  - Telescope Performance modeling
  - Launch and deployment methodology
  - Mission Operations
  - Science Data Reduction
  - Simulated Science data, imagery, and results
  - Development and Deployment Plan for pathfinders as well as the KST
    - LEO or GEO or L2 30-meter class with multiple deployable polymer liquid loads and mylar backup
    - L2 100-meter class
    - L2 kilometer class
  - Mission Plan

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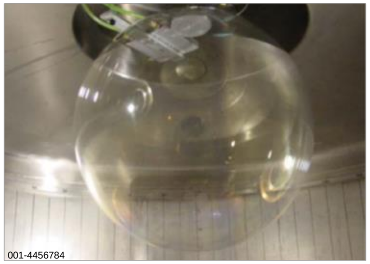
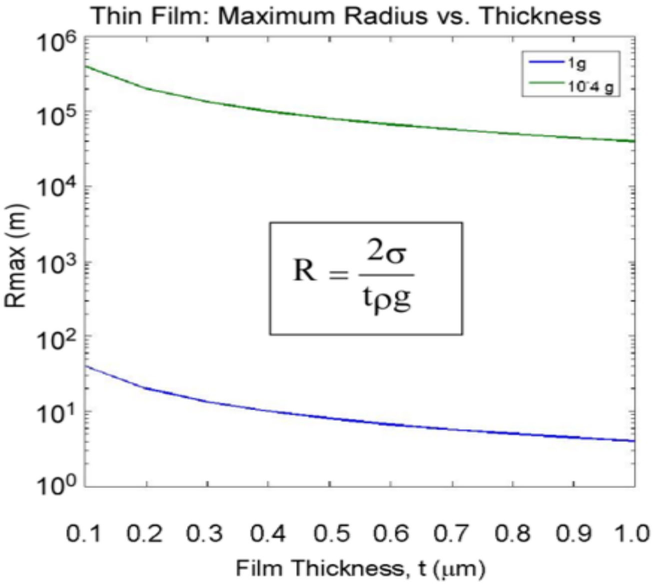
Underlying Technology

- Optical flats and a 70-cm sphere made by inflating a UV curable liquid polymer in a vacuum have been demonstrated



- Scaling laws indicate that a many-kilometer-class sphere is feasible at L2

Upper limit for a 0.5 μm Thickness is about 100-km



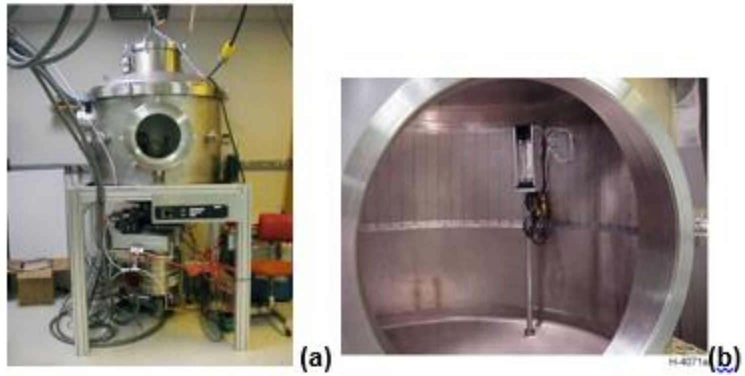


Figure 8. PSI 1-m Vacuum Chamber for Bubble/Film Experiments (a) and UV-curing Lamp (b).

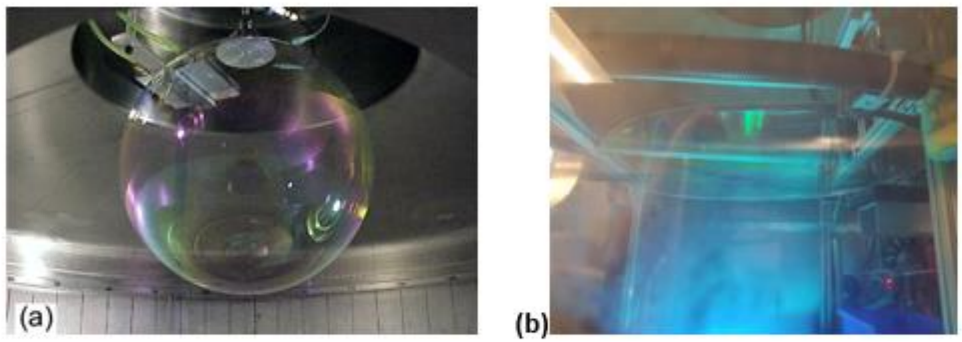


Figure 9. A ~ 40 cm UV-cured Polymer Bubble and a ~ 50 cm UV-cured Polymer Flat Film Polymer Bubble Fabricated in PSI's 1-m Vacuum Chamber Facility Shown in Figure 8.

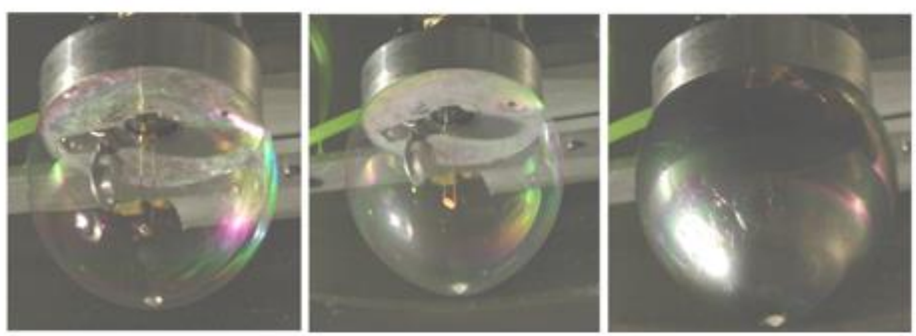
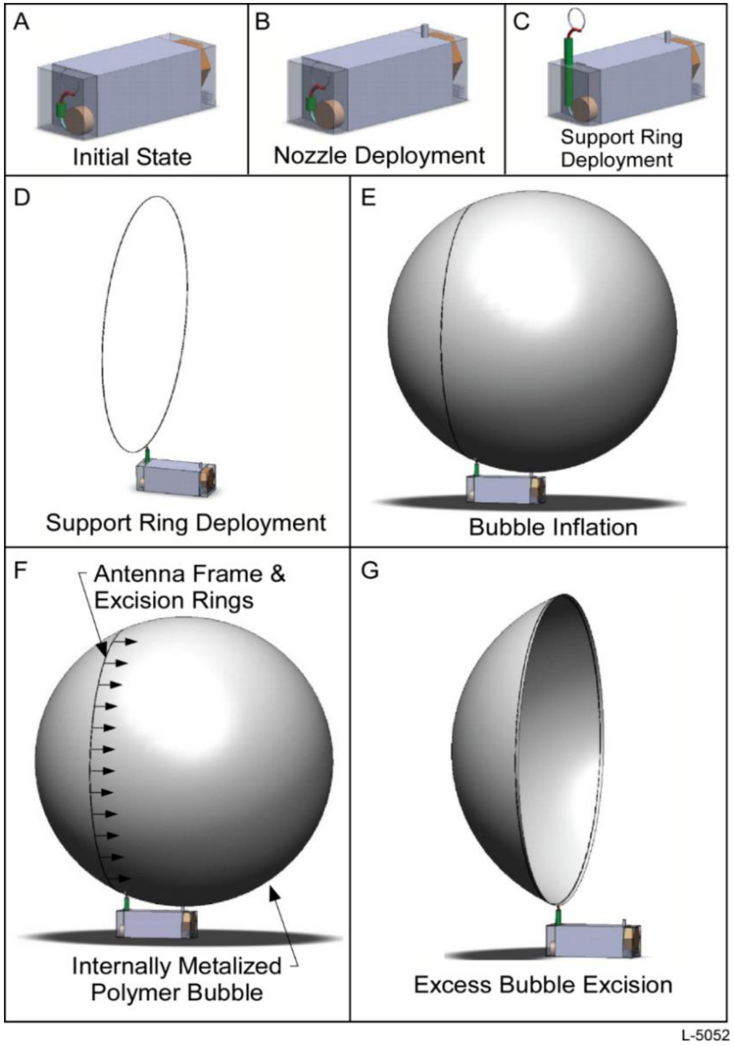


Figure 10. Metallization of a ~ 15 cm Spherical Bubble from Inside by Flash Vaporization of Zinc from a Brass Filament.

Phase 2 Laboratory Experiments

- The surface accuracy of a laboratory spherical reflector will be measured to allow prediction of deployed telescope optical quality
  - Flats such as can be used for the sunshade were previously demonstrated
  - Fabricate test mirror
    - Inflate sphere from liquid polymer
    - UV rigidize the sphere
    - Metalize the sphere using a filament
    - Excise the test objective from the sphere
  - The spherical surface will be measured with optical interferometry
  - Measurements of thin mylar optical flats suggest that the surface inaccuracy can be smaller than the material thickness. The material thickness with this technology is about 0.5 micrometer.

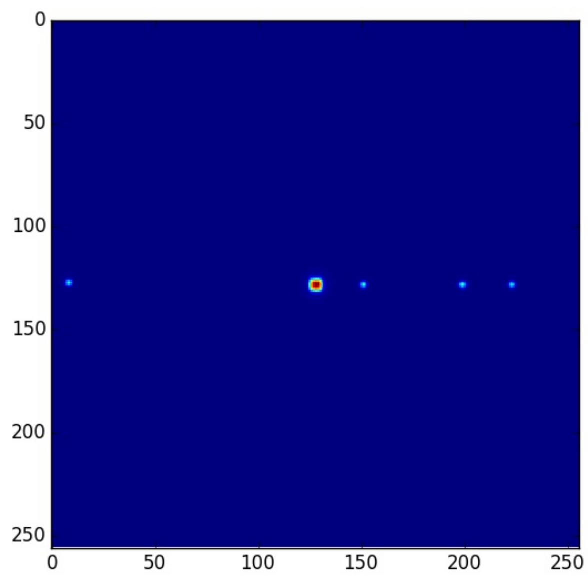
Schematic Illustration of Deployment in Space



Noise Sources

- At 0.5 μm, an m=40 star would place 12 photons per second into a single resolution element and be background limited in a few seconds of integration time
- Scattered and diffracted light will be estimated. It may be possible to directly image planets around other stars to ~100 light years or more without a coronagraph, and coronagraphic designs will also be examined. Starshades will also be considered

Simulation of Jupiter at 7 parsecs with KST



Concept of Operations

- Space operations should be first demonstrated on a pathfinder telescope, probably within the 20 or 30-meter diameter range
- Observing with the completed KST would include angular pointing and jitter correction
  - – The telescope field of view (FOV) will be detector array size limited. Multiple very large detector arrays can be accommodated by the optical train.
  - – Increasing the FOV decreases the precision with which acquisition pointing must be performed
  - – Data bandwidth requirements and reduction will also be examined
  - – Tracking within the FOV due to drift and jitter will be addressed in image processing, with active optical tracking available if needed
    - Multiple telescope architectures will be considered
  - – Imagery will be simulated in this Phase 2

Kilometer Space Telescope (KST)

Innovation

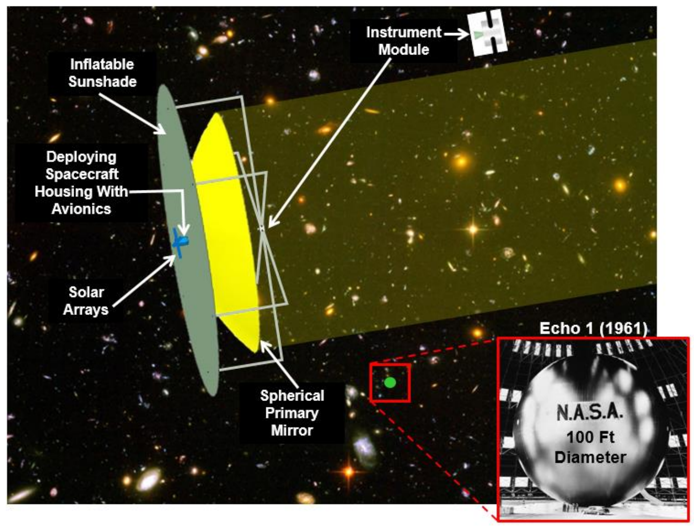
Novel technology to deploy Km-class optics and sunshades 100 million times the volume of the launch vehicle

Enables KST

For LEO, L2/L1, deeper LEO <10-years, L2<20y

Technical Approach

Phase II will measure optical quality, predict full scale performance, simulate full scale image data quality, and outline a plan from 1-m to 10-m to 100-m to 1,000m.



Phase I Results

~1-m Lab demo in 1-G

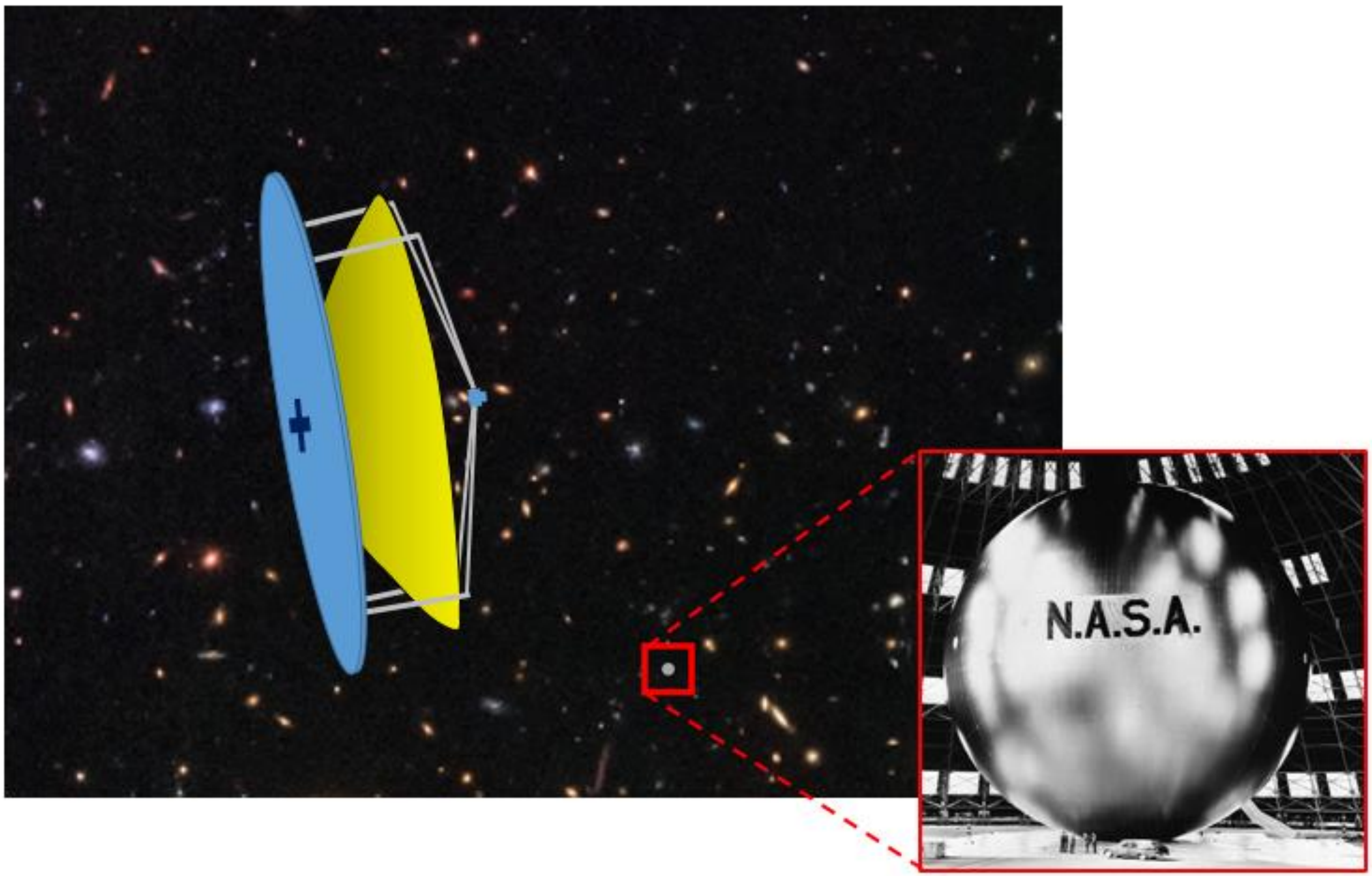
⇒ 100-m+ LEO and

⇒ 1,000-m++ at L2

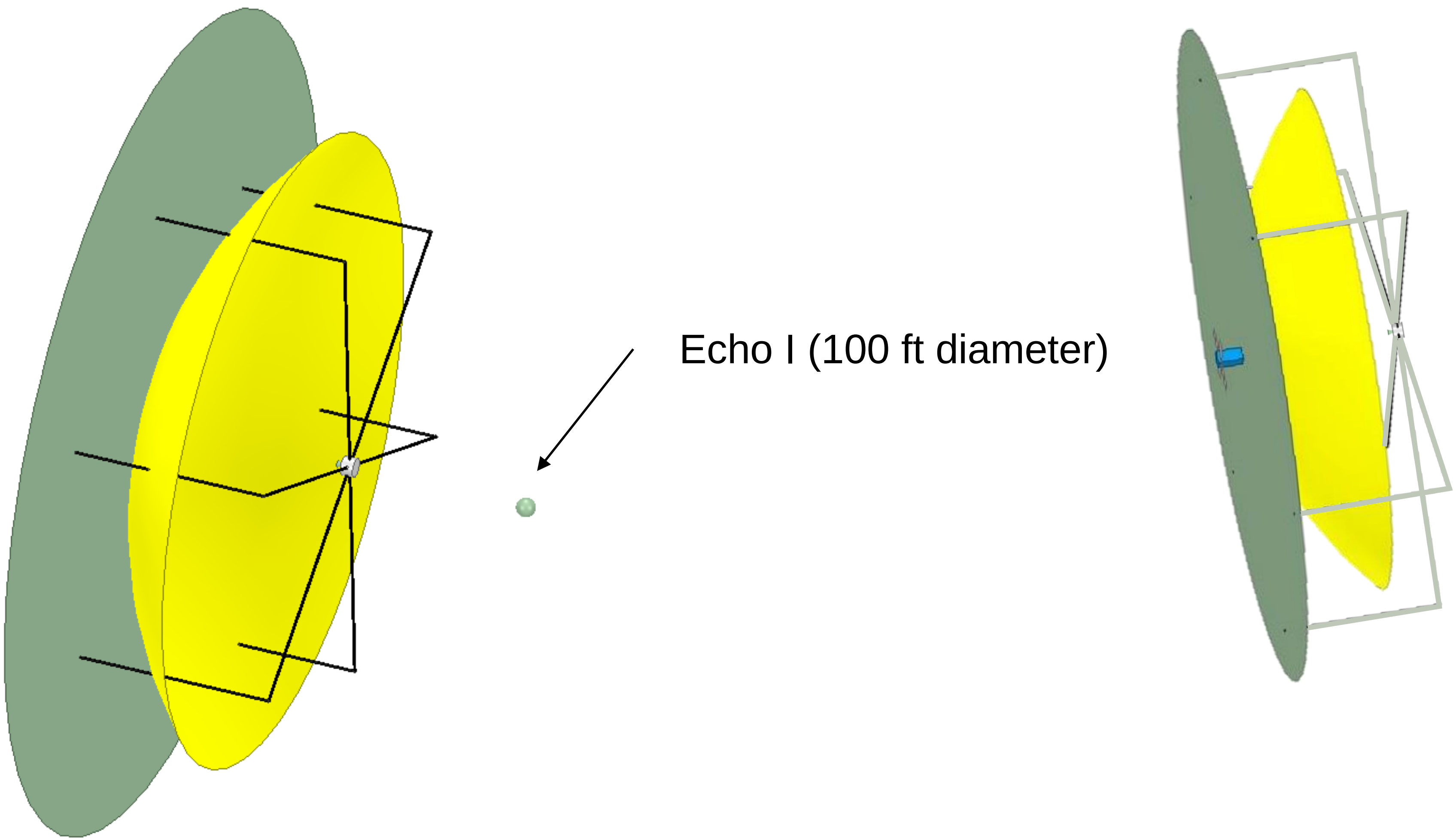
Phase 2 will include measurement of optical surface accuracy, mission design, systems engineering, Imaging data simulations, and Deployment plan.

Evaluation Notes

Comparison of KST to Echo I

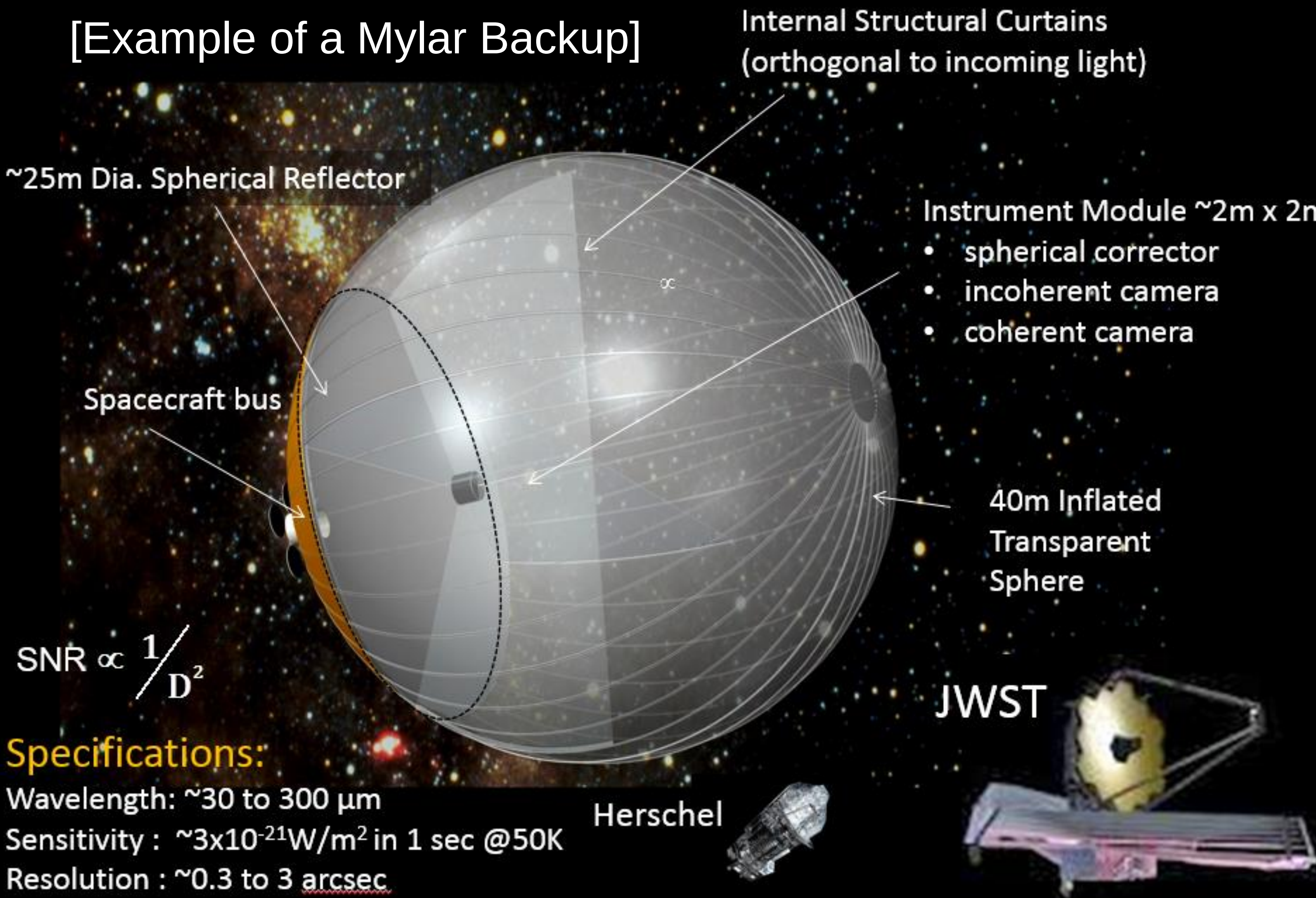


Size Comparison Without Background



TeraHertz Space Telescope

[Example of a Mylar Backup]



$$SNR \propto \frac{1}{D^2}$$

Specifications:

Wavelength: ~30 to 300 µm

Sensitivity : ~3×10^{-21} W/m^2 in 1 sec @50K

Resolution : ~0.3 to 3 arcsec

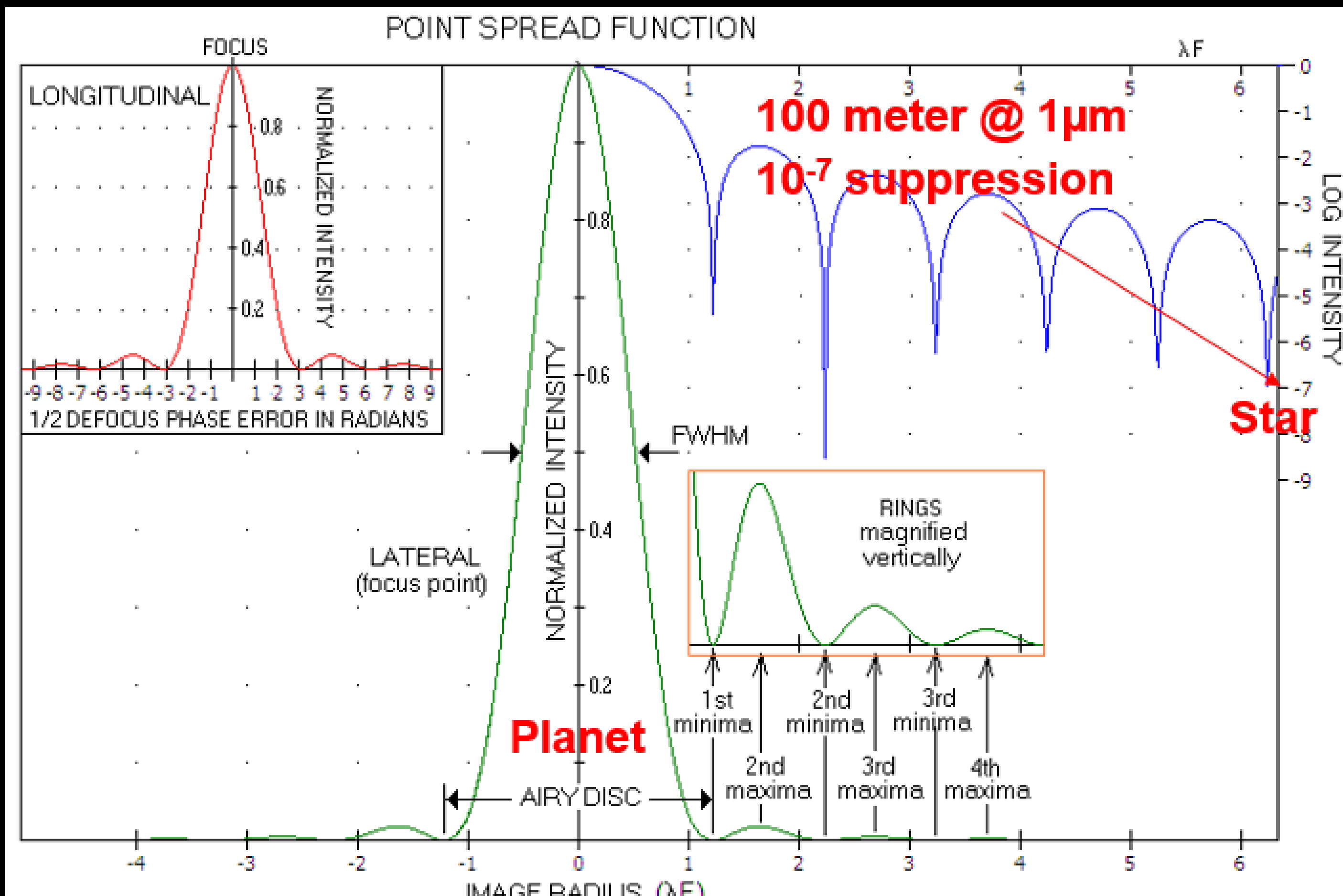
Capabilities of a Kilometer Space Telescope (KST)

- Unprecedented sensitivity and spatial resolution for observations of the universe at millimeter, infrared, and optical wavelengths
- The area of KST would be more than 173,600 times the area of the 2.4 meter HST, and more than 23,600 times the area of the JWST aperture.
- The potential diffraction-limited resolution improves by a factor of over 416 for HST, and more than 153 for JWST.

Selected Science

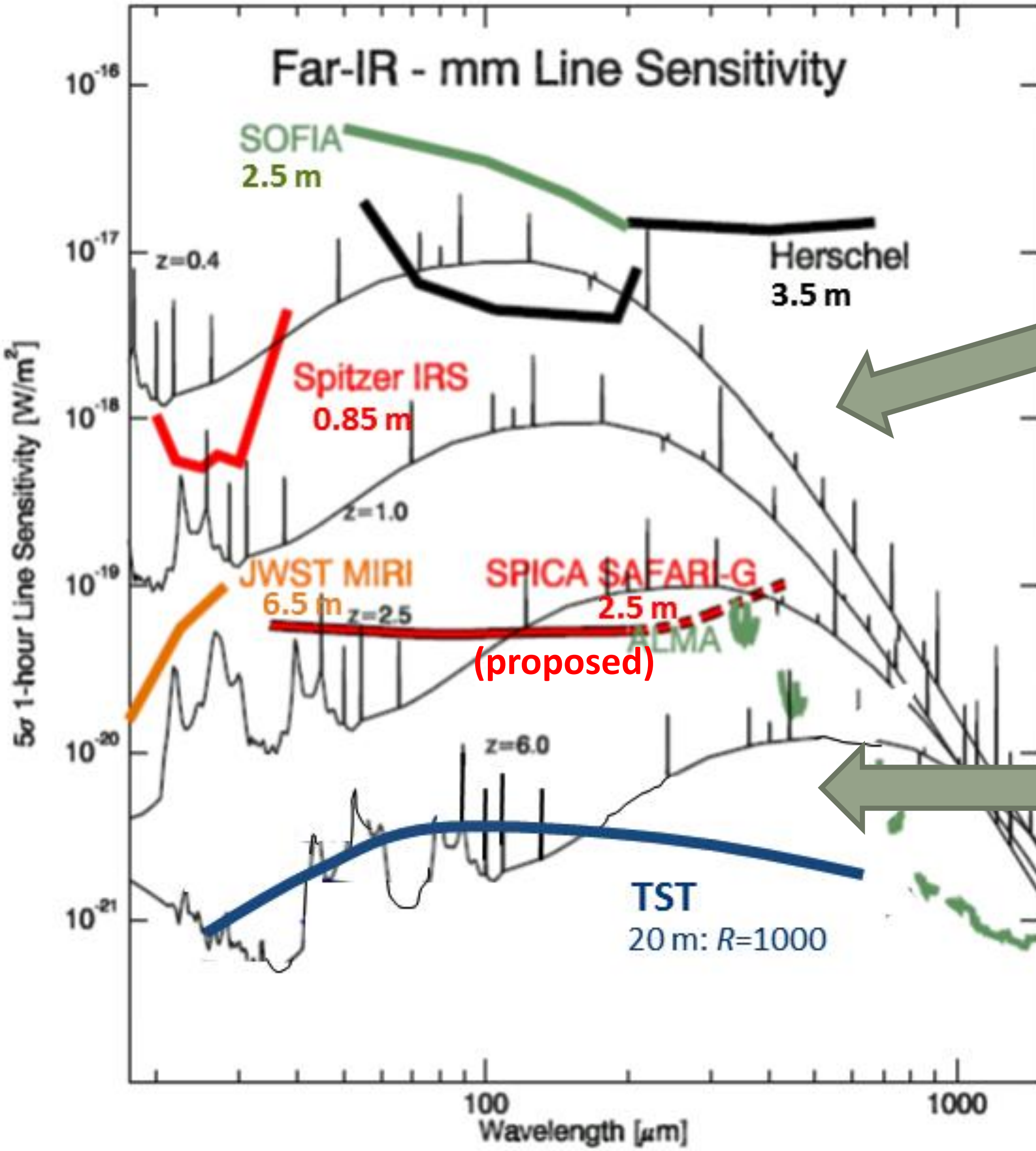
- Direct observation of extrasolar planets
  - In some cases without a coronagraph
  - Coronagraph and star shades are being studied
  - Spectroscopic search for life signatures
- Observation of early stars ~ 200 million years after the big bang
  - m = 40 stars would be photon-noise limited within a few seconds
- Intelligent life signatures
  - Ulvi Yurtsever and Steven Wilkinson have estimated that relativistic space travel by advanced civilizations could be detected at thousands of light years with KST. The signatures are described in *Acta Astronautica* 142 (2018) 37–44
- Kilometer scale physics experiments could fly with KST
  - Test of Many Worlds versus Pilot Wave in Quantum Mechanics

Direct Imaging of Extrasolar Planets



- Weather
- Geology
- Atmosphere
- Biomarkers

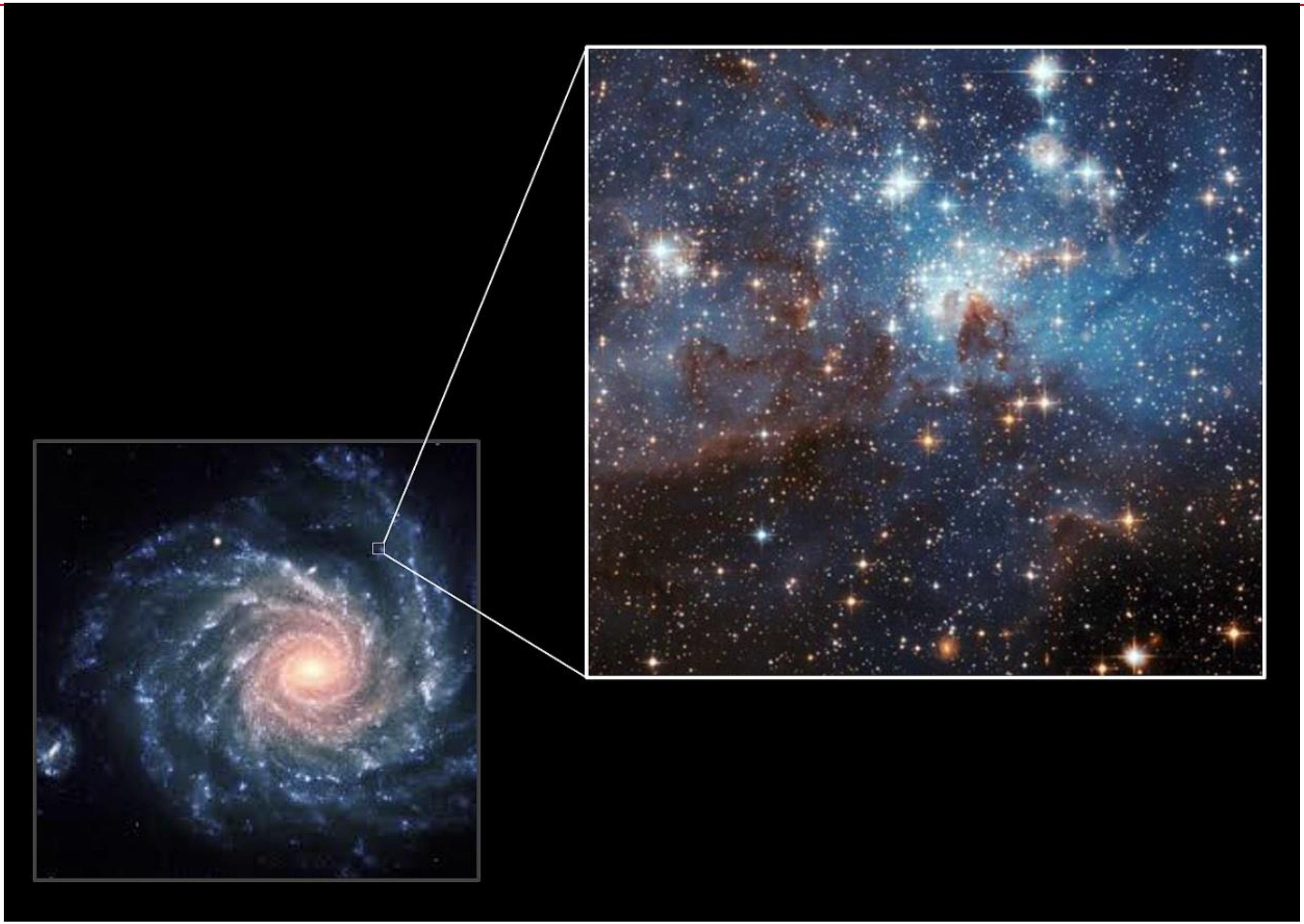
Galaxy Evolution



`Modern' Galaxy

`Primordial' Galaxy

An HST pixel becomes an image with KST



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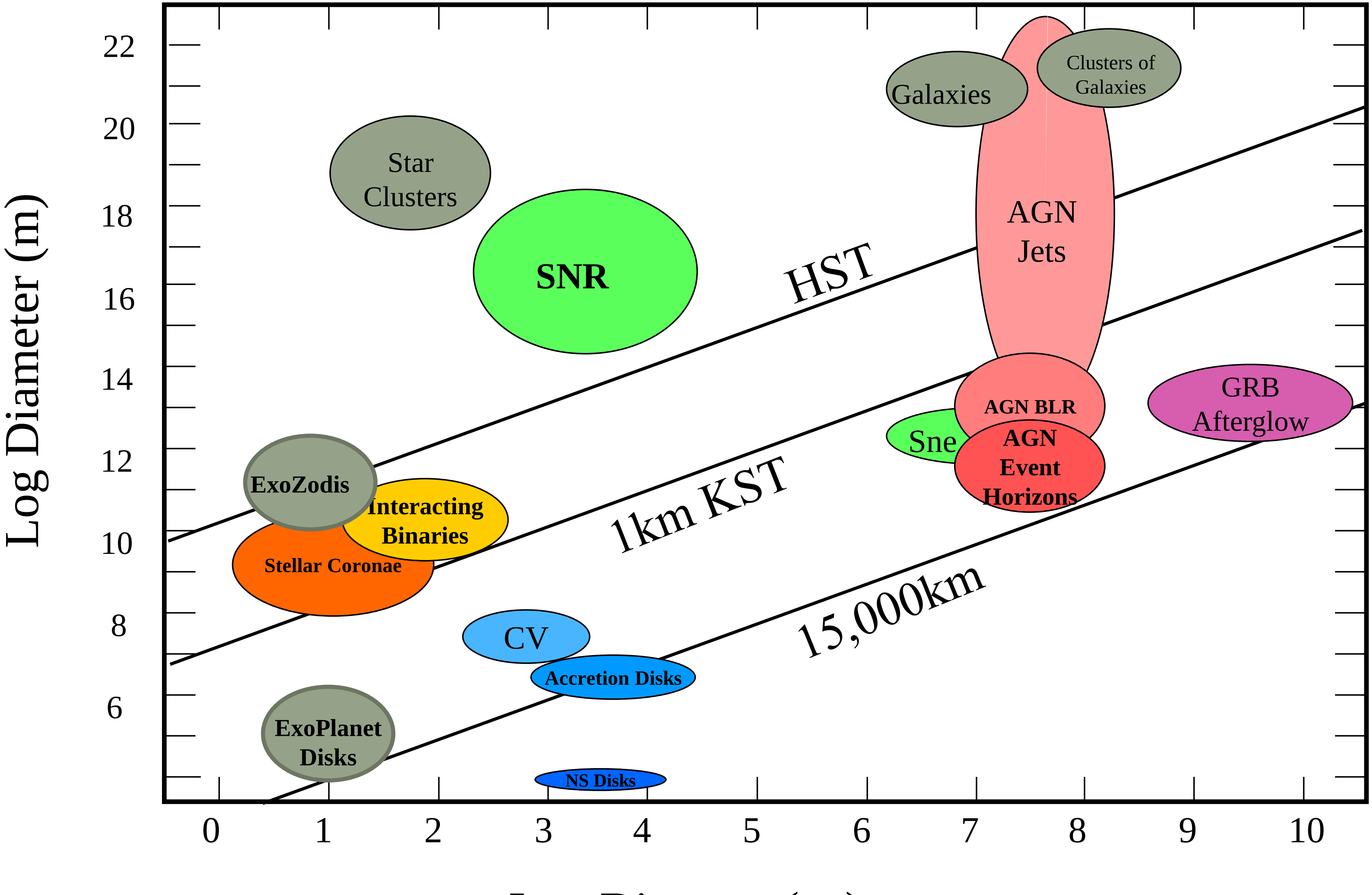
Comparison of Observable Objects



KST Through Cosmic Time...