USING THE ISS TO ASSEMBLE A VERY LARGE TELESCOPE

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A 30-m Very Large Space Telescope (VLST) : Assumptions

- The VLST will have gold-coated mirrors for high reflectivity and low emissivity for $\lambda \geq 700$ nm.
- The telescope will be built at the ISS, flown to L2 for the mission, then returned to station for refurbishment and instrument changes.
- The telescope will be passively cooled for operation in the thermal IR.
- The telescope will have optical and IR cameras and spectrographs.
Optical and IR Reflectivity of Gold
Optical and IR Resolution of the VLST

• Assume the telescope is diffraction limited for $\lambda \geq 500$ nm.
• The resolution is 5 times better than JWST and 12.5 times better than Hubble at the same wavelength.
• The gains in spatial information relative to JWST and HST are respectively 25 and 156.
Optical Resolution of the VLST

The VLST will be to HST as HST is to small ground-based telescopes.
Optical and IR Resolution of the VLST

- The maximum optical resolution of the VLST is 0.004″.
- The VLST resolution at 6 microns is equal to Hubble’s resolution at 500 nm.

ACS Image of CL1252-2927 (z=1.23) $T_{\text{lookback}} = 8.6$ Gyr
The VLST’s Optical Limiting Magnitude

- Sloan r-band, Two 1000-sec Exposures, SNR = 10
- VLST: $m(r)_{\text{lim}} = 33.3$
- HST with ACS: $m(r)_{\text{lim}} = 27.1$
- $\Delta m_{\text{limit}} = 6.2 \implies 300$ times fainter in flux
- The VLST can work 12.5 times further than HST with the same physical resolution, and 17 times further with the same limiting magnitude. The volume of accessible objects increases respectively by a factor of $\sim 2000$ and 5000.
Examples of the VLST Optical Capability in One 2000-sec Exposure

• Detect Cepheids out to 250 Mpc.
• Measure color magnitude diagrams down to the main sequence turnoff at 6 Mpc.
• Search globular clusters for central black holes with masses down to $100 \ M_\odot$.

ACS F330W – 660 secs
Center of 47 Tuc
Spectroscopy of Faint Quasars at z \sim 7: Probing the Epoch of Reionization

• At z = 7, L\alpha is observed at 973 nm. At \( R = 12000 \), in 8 hours Keck can reach \( m_z \sim 19.5 \ (3 - 5 \times 10^{-17} \text{ ergs/cm}^2/\text{s/Ang} \) with a SNR \( \sim 70 \) per resolution element (between OH emission lines).

• The VLST will reach the same SNR in the same time at \( m_z \sim 25.5 \ (R = 6000, \text{ no OH}) \), enormously increasing the number of quasars and AGNs that can be used to probe the epoch of reionization.
Detection of Earth-Like Planets at 10 pc

- An Earth-like planet at 10 pc will be ~ 24.5 magnitudes fainter than its parent star, and at maximum elongation will have an angular separation of ~ 17 Airy rings (0.1″).
- With a conventional Coronagraph and wavefront correction to $\lambda/1000$ rms, the 29.3 mag planet can be detected next to a G2V star with SNR = 10 in four 2000-sec exposures taken with four 10% bandpass filters for spectral deconvolution (Sparks & Ford 2002, 578, 543).
Spectroscopy of an Earth-like Planet at 10 parsecs: Searching for Bio-Markers

• Using an Integral Field Spectrograph with a net efficiency of ~ 20% (coupled with a coronagraph and $\lambda/1000$ wavefront correction), the VLST could take an $R = 1000$ spectrum of an Earth-like planet with a SNR of 10 per resolution element in ~ 7 hours.

• Oxygen and other biomarkers would be easily detected if present.
VLST IR Performance: K-band

- A0 Star, $1 \times 2000$sec exposure, SNR = 10, assuming that the VLST and JWST are both Nyquist-sampled and have the same efficiency (50%).

  VLST Limiting Magnitude = 30.9
  
  JWST Limiting Magnitude = 27.4
  Gemini Limiting Magnitude = 21.4
  HST Limiting Magnitude = 21.3

- The VLST image is 3.5 magnitudes deeper (25× fainter in flux) and has 5 times more resolution than the JWST image, and 9.5 magnitudes deeper than Gemini or HST.
VLST Performance at 15 Microns

- The VLST is 3.5 magnitudes ($25\times$ in flux) deeper than JWST with 5 times the angular resolution in the same exposure time.
VLST Observations of High-z Galaxies

- Measure kinematical masses at $z \sim 7$ from H$\alpha$ redshifted to $\sim 5$ microns.
- Observe restframe optical emission lines (H$\alpha \rightarrow$ [OII] 3727) in AGNs and proto-galaxies at $z \sim 20$ with angular resolution comparable to HST.
- Observe restframe L$\alpha$ at $z = 20$ in the K-band with twice HST’s optical resolution.

ACS g, r (Ly$\alpha$), I (continuum) image of extended (20 Kpc) L$\alpha$ emission from a radio galaxy at $z = 4.1$
So how do you build and service such a beast?

- Assembly at ISS has several advantages.
  - Assembly in parts (like ISS) means no “magic”, reasonable extrapolation of mirror mass. (<10Kg/M2)
  - Core section will including central portion of primary, the secondary and structure. Will use JWST like deployment.
  - Instruments and remainder of the “hex” mirror segments used as “filler” on future ISS supply missions. One meter hex segment =~10kg so 1 to 15 per flight
  - System verification at ISS
Sequence of Assembly

End to end ground testing will not be practical for a 30 meter system, verification at ISS and replace defective part on ISS supply mission.
Smaller Precursor Missions Like JPF Prove concept with Great Science Payback

- JPF will be operated as a full truss payload on ISS
  - Alt-Az pointing gimbal, pallet mounted at S3 truss
- ISS benefits
  - Risk mitigation
  - Low cost implementation
  - Generous power, mass & communication allocations
  - Field rotation
ISS, a perfect assembly point for VLST

Assembly begins with the VLST core module mounted on ST3 Truss
Solar Electric Propulsion for Boost to L2

Electric propulsion systems developed as part of NASA’s NSI will provide the energy and thrust required to transport VLST to and from ISS
Alternatively we can service VLST in place at L2.

This will be a small but significant step in expanded Human presence in space.
SUMMARY

VLST will produce an order of magnitude improvement in angular resolution (12.5 x HST and 5 x JWST).

The flux sensitivity will be 300 times fainter than ACS on HST, increasing the volume of accessible objects by $> 10^3$.

Assembly of ~1 m segments and verification of system at ISS. Transport to L2.