# CALISTO - A Novel Architecture for the Single Aperture Far Infrared Observatory

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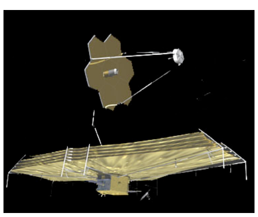
**CALISTO -- the Cryogenic Aperture Large Infrared Space Observatory is a new mission architecture for the SAFIR (Single Aperture Far Infrared) observatory. The goal is to achieve background-limited far infrared operation at ~arcsecond resolution, in an affordable way.**

**Such an observatory will build on Spitzer and Herschel science, and will critically complement major national investments at shorter (JWST) and longer (ALMA, CCAT) wavelengths by opening new discovery space in the far infrared. The observatory will address established decadal science goals, and NASA strategic goals, taking advantage of revolutionary developments in far infrared sensor and observatory cooling technologies.**

CALISTO will critically test our understanding of the history of star formation in the universe. Half the energy of the universe is emitted in the far infrared, and CALISTO will probe its origin in detail.

Where CALISTO comes from …

- Decadal enthusiasm for a large, cold, far infrared telescope -- SAFIR (Single Aperture Far Infrared) observatory.
- NASA Vision Mission study for SAFIR concentrated on an 8 meter architecture based largely on JWST.
- Underlying assumption was that investment in JWST would pave the way for a longer wavelength telescope with similar architecture that was somewhat colder and slightly larger, but with correspondingly relaxed optical precision.



*A credible concept was achieved!*

The Vision Mission version of SAFIR called for a chord-fold deployed (out of a large EELV) 7-segment 8 m aperture relying on passive cooling augmented by active cooling for inner shield and instruments. Equipped with imagers, low and moderate resolution direct detection spectrometers, and high resolution heterodyne spectrometers. Stationed at Earth-Sun L2.

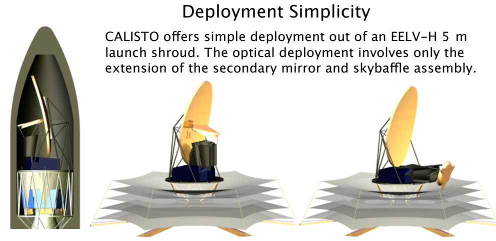
*But the mounting costs of JWST, seriously impacted by deployment complexity and verification needs, along with realistic future constraints on SMD mission budgets, made the Vision Mission design of SAFIR less responsive to community needs than hoped.*

***The infrared community was challenged to develop a mission architecture for SAFIR that met key science needs, was technically credible, and more affordable.***

Building on the Vision Mission study of SAFIR, and using internal JPL funds, a more economical, and in several respects higher performance concept was created in CALISTO. While many observatory design features were preserved, the telecope design departs significantly from earlier concepts.

**We believe that with the CALISTO architecture for SAFIR, this challenge has been met, and we plan efforts to verify and refine this concept.**

## Deployment Simplicity

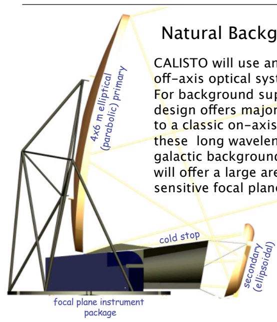


CALISTO offers simple deployment out of an EELV-H 5 m launch shroud. The optical deployment involves only the extension of the secondary mirror and skybaffle assembly.

## Key Parameters of CALISTO Mission

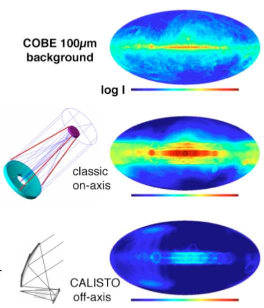
| | |
|---|---|
| Ops location | L2 halo, high efficiency trajectory |
| Launch mass | est 3000 kg |
| Launch vehicle | EELV-H (Atlas 511/Delta IV) |
| Telescope temp | 4K (passive cooling + cryocoolers) |
| Power s/c+coolers | est 800+1200 W = 2 kW |
| Data rate | est 10 Mb/s |
| Instrumentation | cameras, R~100-1000 spectrometers ~30-300+ μm |
| Beamsize [pointing] | 1.2" @30 μm, 12" @ 300 μm [0.4" rms] |
| Primary mirror | 4 x 6 m optical size; 15 m² effective area |
| Optical design | unblocked aplanatic Gregorian |

## Natural Background Control




CALISTO will use an aplanatic Gregorian off-axis optical system with a cold stop. For background suppression, this off-axis design offers major advantages compared to a classic on-axis design, notably at these long wavelengths. With strong galactic background emission, CALISTO will offer a large area of dark sky to the sensitive focal plane instrumentation.

*In this respect, CALISTO gives much higher performance than earlier (classic on-axis) versions of SAFIR.*

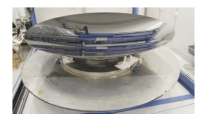



## Monolithic Primary Mirror

**A critical factor for deployment simplicity!**
4.3x6.7 m physical size; launch shroud limited
<20 kg/m² areal density goal
telescope diffraction-limited at 30 μm

Beryllium not an economical choice

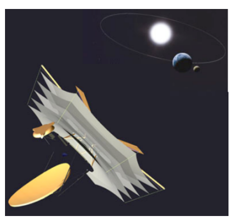
Promising new technologies for SiC and variants (C-Sic, SiC-Si)
Brazing assembly
CVD coating



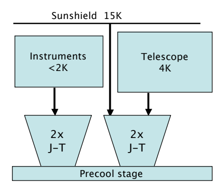
Low scatter ~1.5 μm rms proven for Herschel

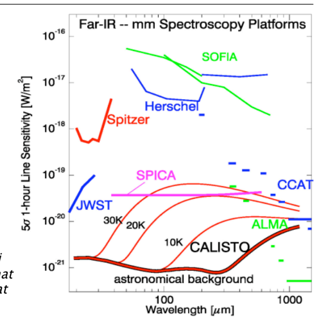
Novel borosilicate designs?
Nanolaminates?

## Cryogenic Operation



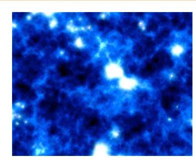
Deployed to Earth-Sun L2 for operation, CALISTO will keep Earth/Moon and Sun behind the 5-layer V-groove radiation shield. This can achieve <40 K passively, as designed for JWST. With optimized thermo-mechanical design, inner shield temperatures of 15 K can be reached. Four MIRI-heritage J-T coolers are then used to provide cooling to the telescope and instrument package, which includes sub-K cooling for detectors.



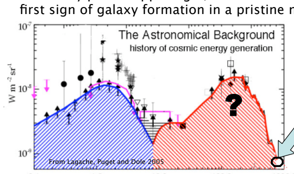




*Keeping the temperature near 4 K allows CALISTO to be limited by the astronomical background, defined by zodi emission and unresolved extragalactic background. In doing so, CALISTO can have spectroscopic performance that exceeds that of other facility investments by orders of magnitude, assuming detector sensitivity development that can be reasonably anticipated from the trajectory of current work.*

## The Astronomical Vision for CALISTO - Compelling Science Enabled

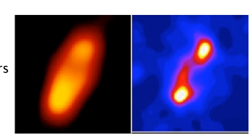


- **Witness development of structure in the early universe:** CALISTO will characterize the first condensing objects in the universe by detecting 0-0 S(1,2,3) $H_2$ cooling lines redshifted to 100-300 μm from the epoch before reionization and earliest nucleosynthesis. Models for collapsing filaments of rapidly forming protostars suggest strengths of ~$10^{-21}$ W/m² which (see sensitivity plot at upper right) is detectable.This would complement future SKA probes of HI at earlier epochs. This would be the first sign of galaxy formation in a pristine medium, and is a key driver for detectors, telescope aperture and temperature.




- **Probe the cosmic history of energy generation :** CALISTO will resolve the bulk of energy emitted in the far infrared that contributes substantially to the luminosity of the universe, and is thought to be mainly the result of star formation in primordial galaxies. CALISTO will study this radiation at its spectral peak, and use line emission to get redshifts. This will yield a history of star formation in the universe. The need for high spatial resolution and survey capability here are drivers for aperture size and array format development.

- **Link our solar system to the global view of star formation:** CALISTO will enable major strides in our understanding of protostars -- in particular conditions in molecular clouds and their linkage to the evolution of planetary systems. CALISTO will help us explore variations in the overall evolutionary theme hypothesized for our own solar system. The figure at near right shows a Spitzer 70 μm image of a Kuiper-Belt like zone. At far right is a ground based submillimeter image of it, showing far more detail, but well off the SED spectral peak. CALISTO will resolve these sources clearly at that peak, allowing us to measure their structure, grain properties, and dust masses.



References

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**"Far-Infrared Astronomy from Space: A Community Workshop about the Future"**
Lester, Goldsmith & Benford
May 28-30, 2008 Pasadena CA