GUSTO Update

PI: Chris Walker

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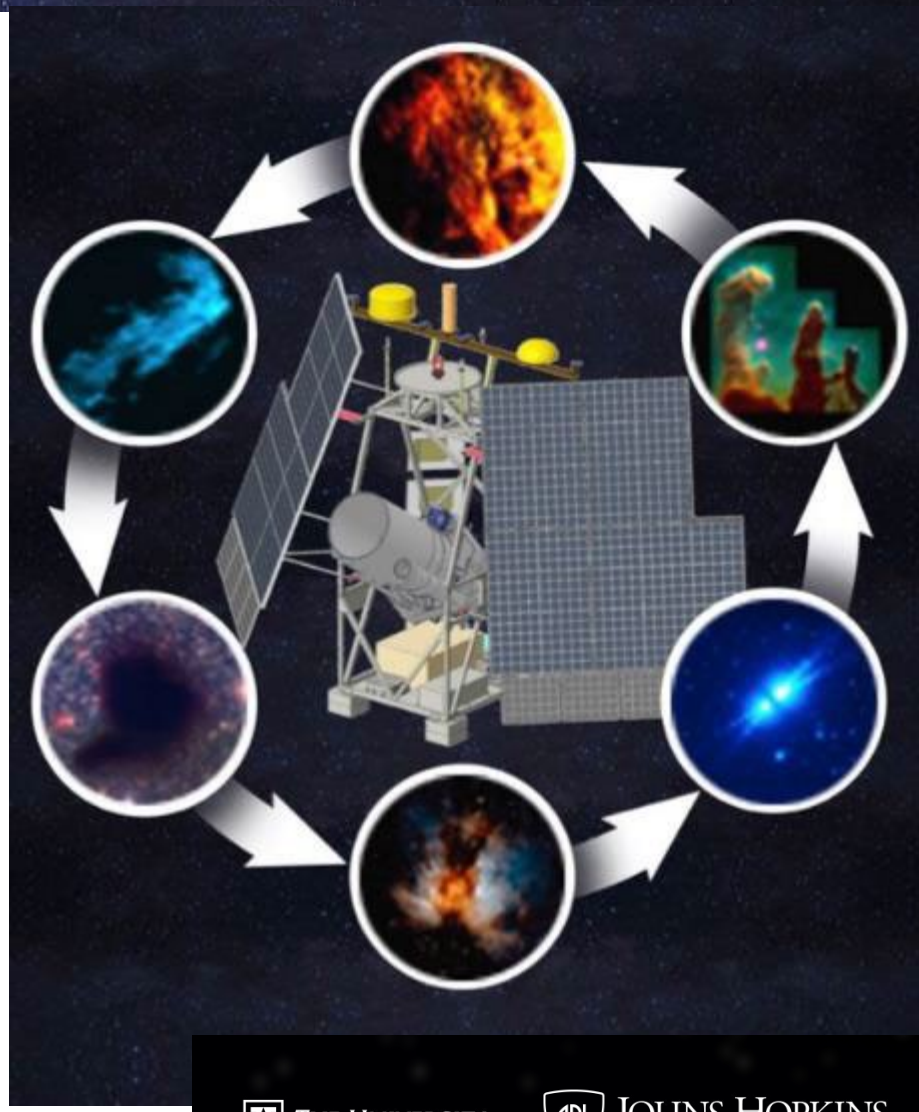
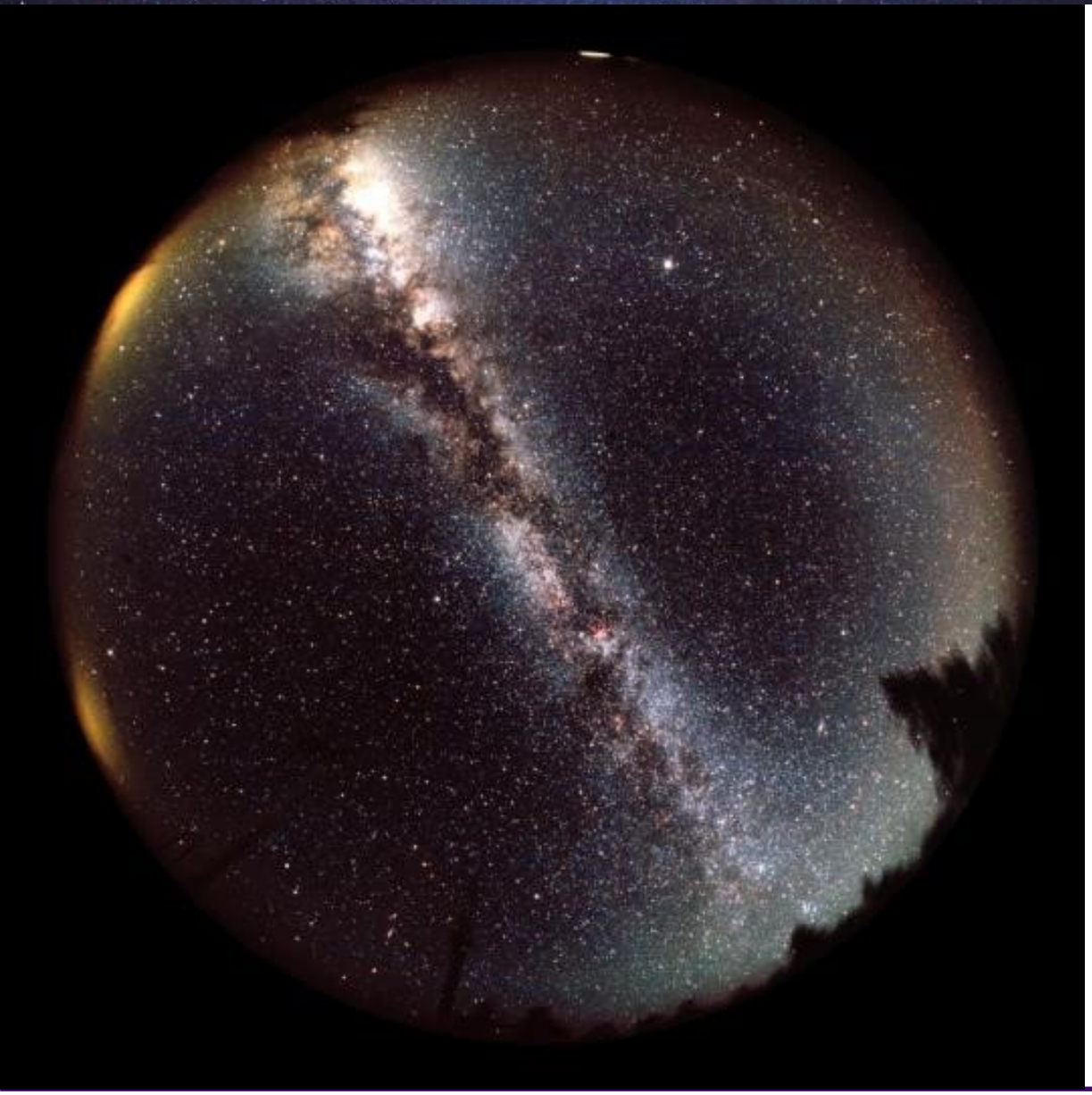


THE UNIVERSITY OF ARIZONA

JOHNS HOPKINS APPLIED PHYSICS LABORATORY

Far-IR Astronomy from *Near Space*

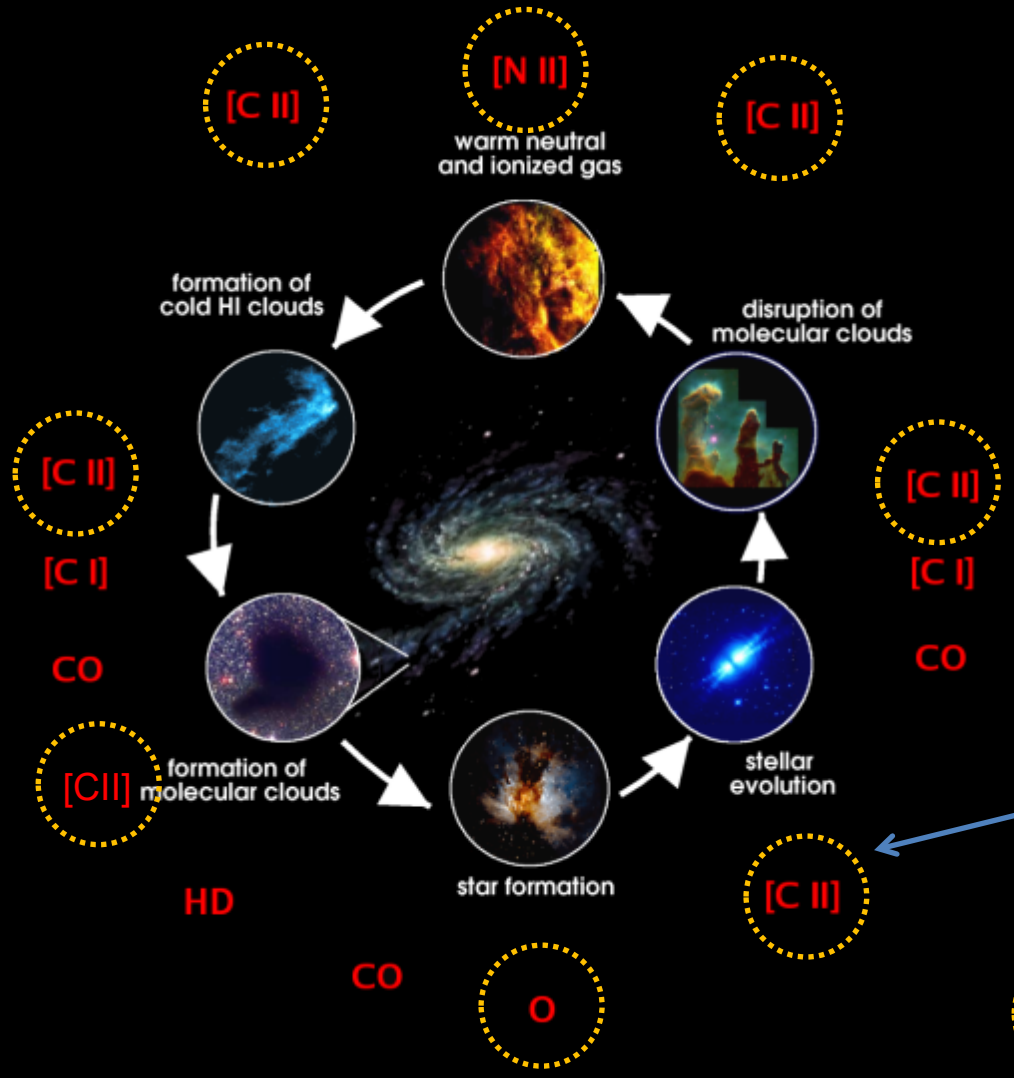


We live in a Galaxy comprised of stars, planets, and people.

Where did it all come from?

Interstellar Medium

GUSTO **First** to Trace **Full Cycle**



GUSTO surveys will provide Milky Way and LMC templates from which star formation can be understood throughout cosmic time.

Brightest Line in *the FIR over cosmic time*

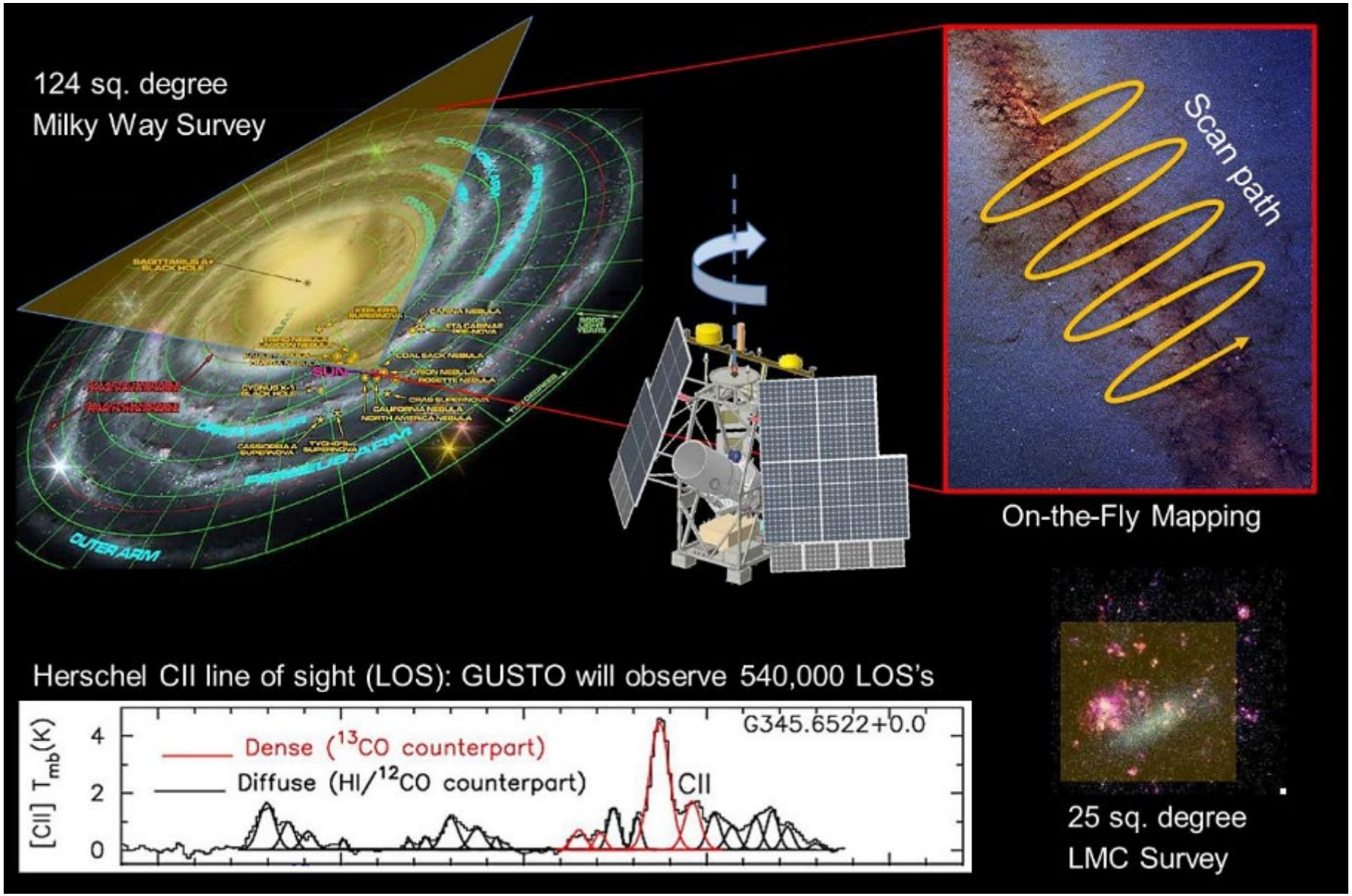
GUSTO Lines

GUSTO Science Goals

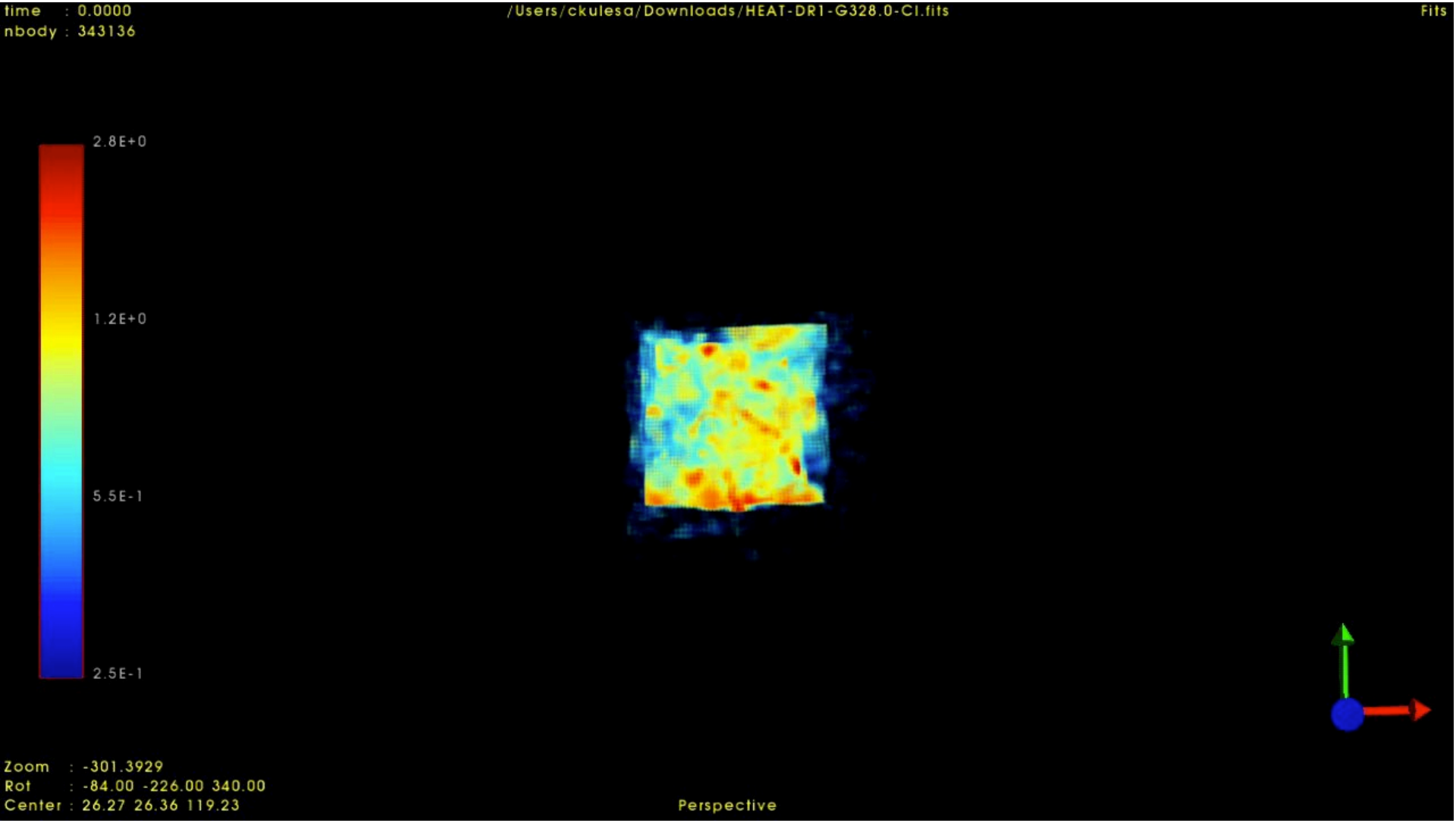
- Goal 1: Determine the constituents and life cycle of interstellar gas in the Milky Way.
- Goal 2: Witness the formation and destruction of star forming clouds.
- Goal 3: Understand the dynamics and gas flow into and within the Galactic Center.
- Goal 4: Understand the interplay between star formation, stellar winds and radiation, and the structure of the ISM in the LMC.
- Goal 5: Construct Milky Way and LMC templates for comparison to distant galaxies.

GUSTO will serve as a Rosetta Stone for understanding the inner workings of the Milky Way and LMC

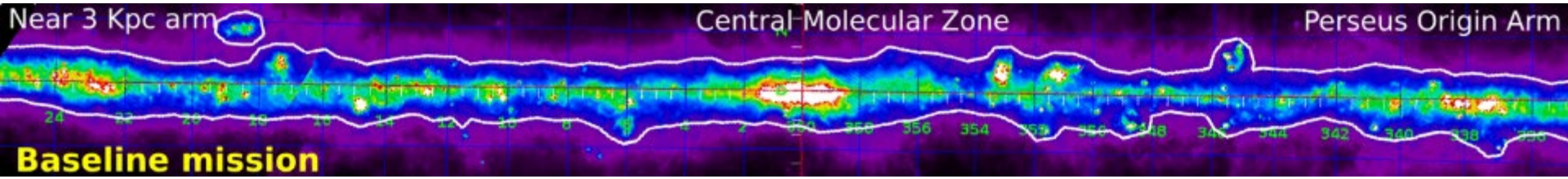
GUSTO is a Spectroscopic Mapping Machine for the Far Infrared



High resolution spectroscopy unlocks the structure of the Galaxy in 3D



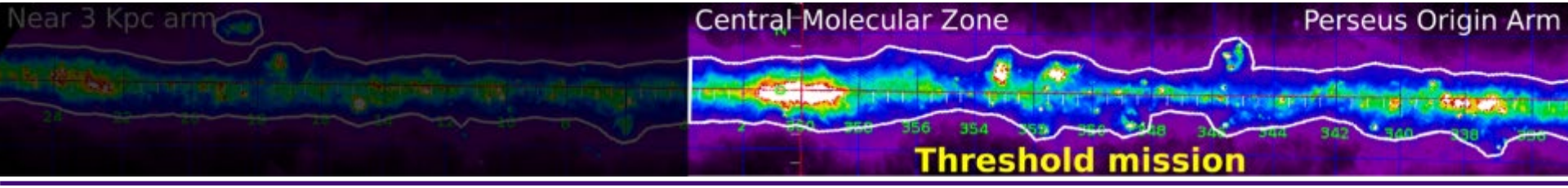
GUSTO Galactic Plane Survey: Threshold and Baseline



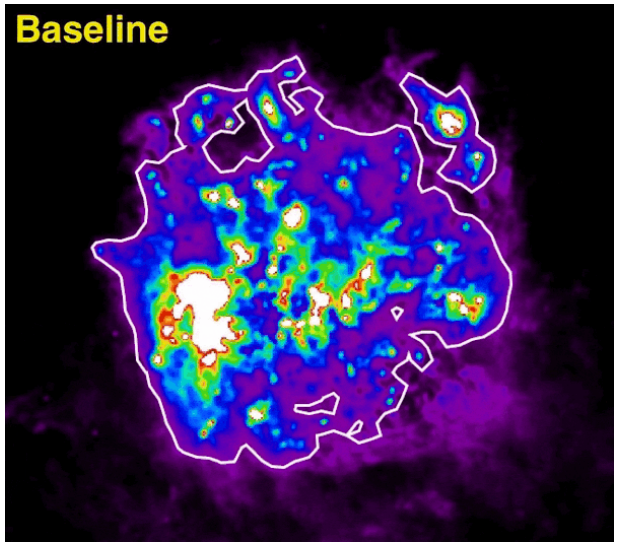
Total Survey Area	Angular Resolution	3σ sensitivity (erg/s/cm^2/sr)	Spectral Resolution
Threshold: 88 deg^2 Baseline: 150 deg^2	0.6-0.9’	1 x 10^{-5} [CII] 5 x 10^{-6} [NII] 1 x 10^{-4} [OI]	1 km/s [CII], [OI] 1.8 km/s [NII]

Since the C/T review with HQ in 2022, GUSTO has been operating toward “achieving the threshold mission in 55 days, with margin”.

GUSTO’s Threshold mission still addresses all 5 proposed scientific objectives and can be completed in under 55 days of mission time.



GUSTO Surveys – Threshold and Baseline



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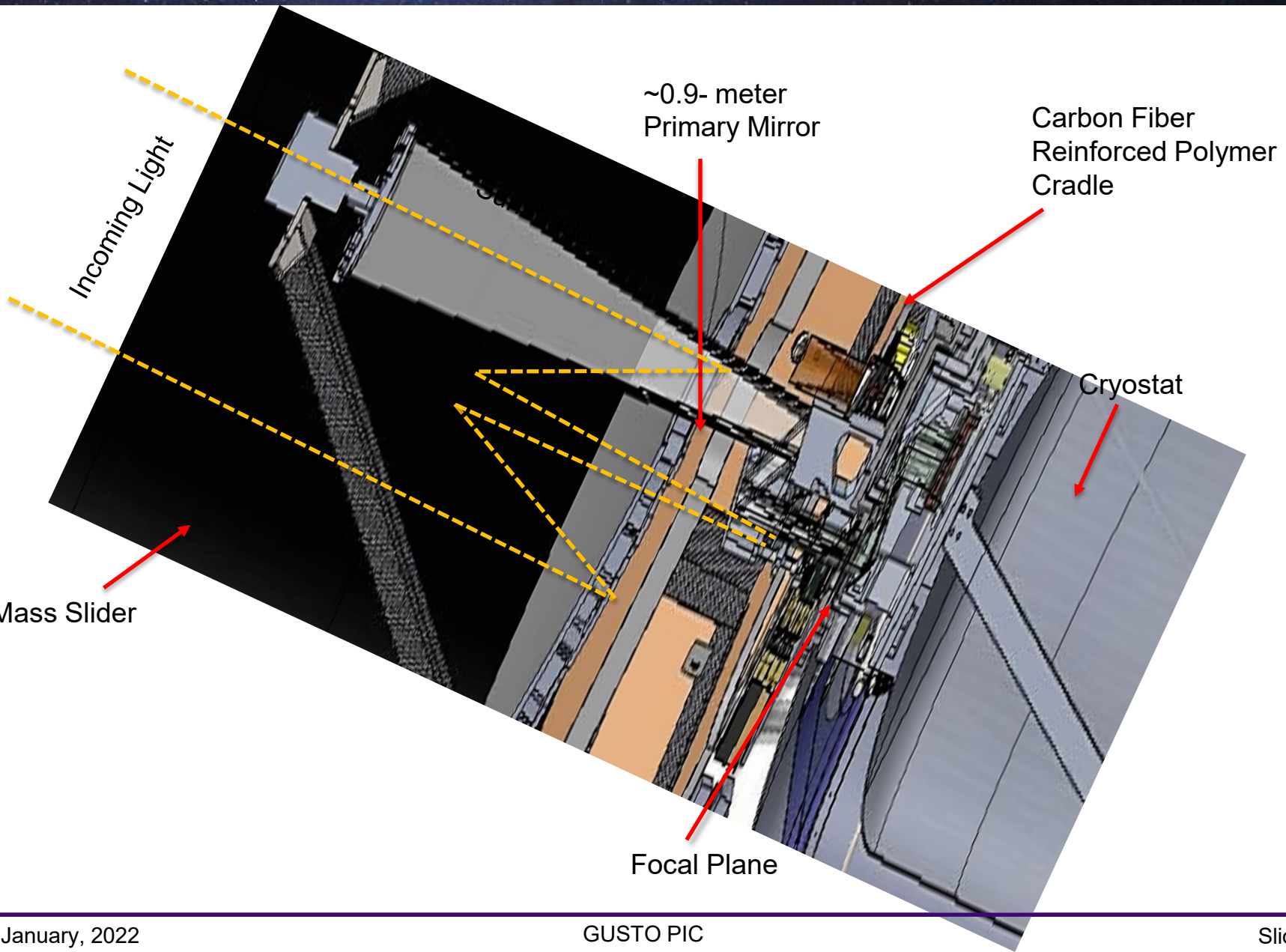
GUSTO LMC survey

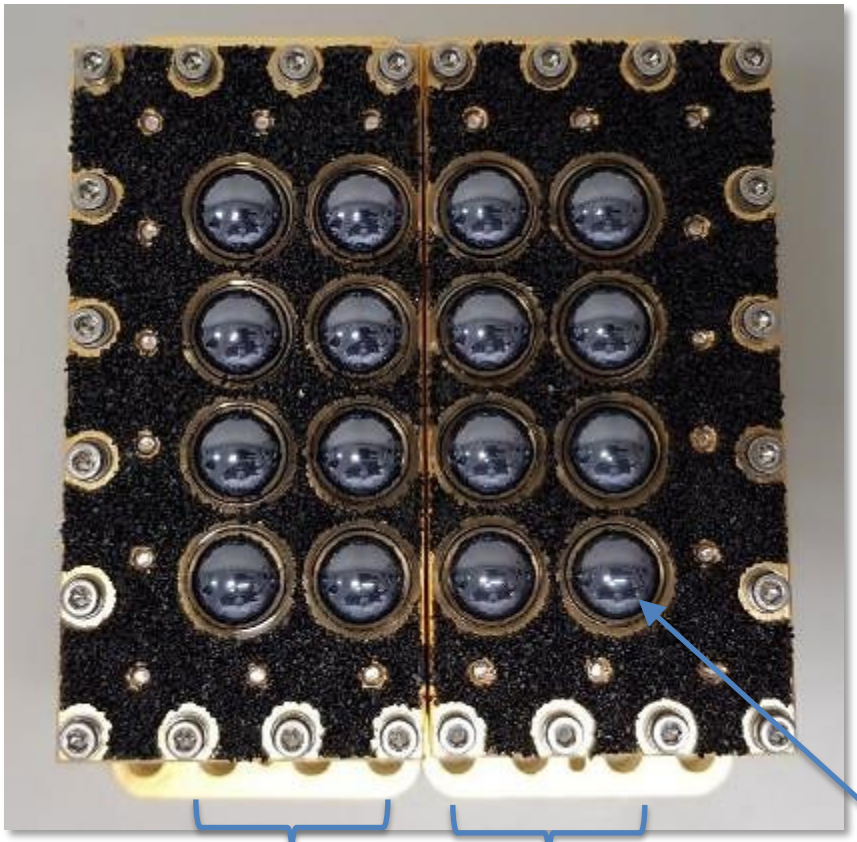
The main “descope” of the threshold mission is survey areal coverage.

“Threshold plus margin” provides the Project with a means to mitigate risk going forward.

GUSTO Payload



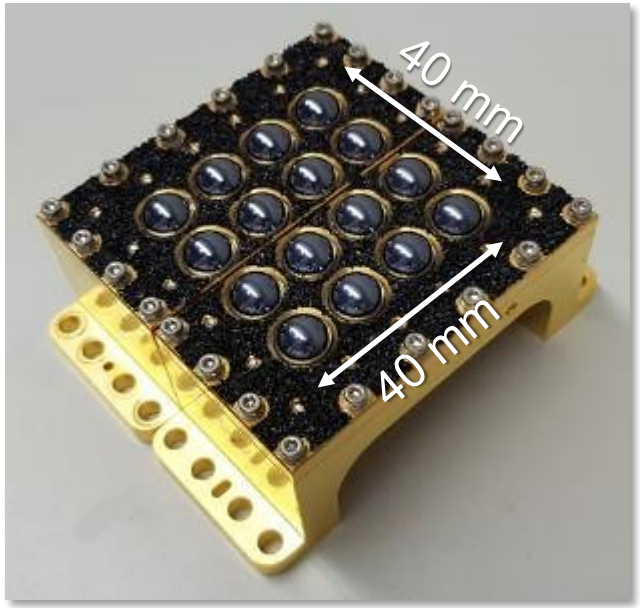
GUSTO Quasioptical HEB Mixer Arrays



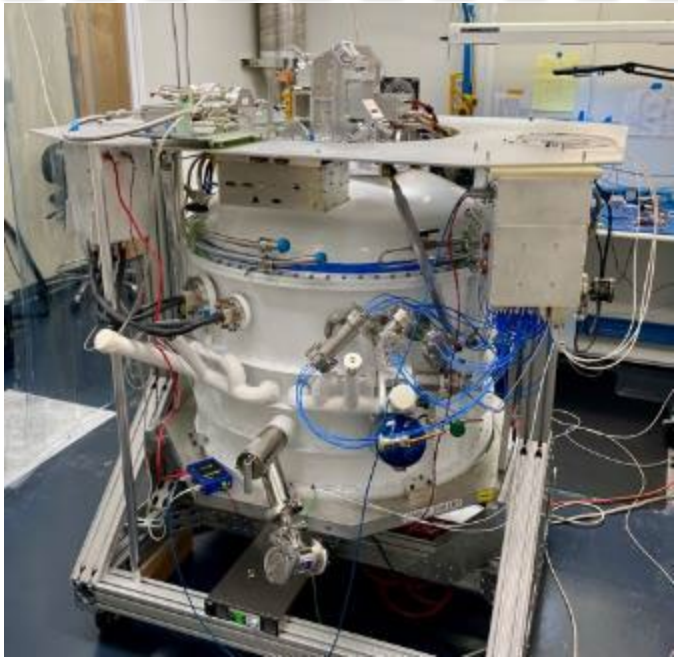
2x4 [NII]
1.46 THz

2x4 [CII]
1.9 THz

Silicon Lenses



Implementation: the GUSTO Observatory



Cryogenic (4K) array receiver with 75-day hold time

24 heterodyne receivers using hot electron bolometers as mixers from 63-205 microns

GUSTO observes [NII], [CII], and [OI] simultaneously!

0.9 m f/10 Cassegrain telescope, under-illuminated at high frequencies

54" beam at [NII], 1461 GHz (Band 1)
44" beam at [CII], 1900 GHz (Band 2)
37" beam at [OI], 4745 GHz (Band 3)

"the Payload"

Gondola provides:
- Observatory power
- Science data telecom
- Pointing control
- Thermal control

Level 1 Requirements = Data Requirements

L1 requirements are stable, defined in document 7503-9029 and the signed PLRA at KDP-C. No changes since SRR/MDR.

Requirement	Baseline Specification	L1 Requirement #
Angular coverage	Galaxy: $-25^o < l < 28^o$, $\|b\| < \sim 1.1^o$ LMC: 25 deg^2	L1-25 through L1-30
Angular resolution	1.2' Galaxy, 1.1' LMC	L1-35, L1-39, L1-43
Spectral coverage	500 km/s near Galactic Center 300 km/s in Galactic Plane ($\|l\| > 5^o$)	L1-46 L1-47
Spectral resolution	< 4 km/s in [CII] and [OI] < 8 km/s in [NII]	L1-36, L1-44 L1-40
GPS and LMCS Sensitivity	• 10^{-5} erg/s/cm^2/sr in [CII] • 8×10^{-6} erg/s/cm^2/sr in [NII] • 10^{-4} erg/s/cm^2/sr in [OI] • x2 deeper for LMC, [CII] and [NII]	L1-32 L1-38 L1-42 L1-33, L1-38, L1-42
TDS sensitivity	2.5×10^{-6} erg/s/cm^2/sr in [CII]	L1-34

Receiver Performance at Secondary

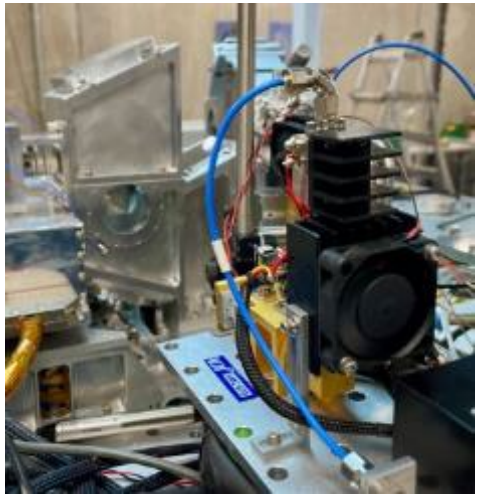
Band 1 and Band 2 noise temperatures through the telescope exceed the L3 requirements without optics losses!

This is what allows us to approach baseline performance with only half of the B1 and B2 focal plane operational (without crosstalk)

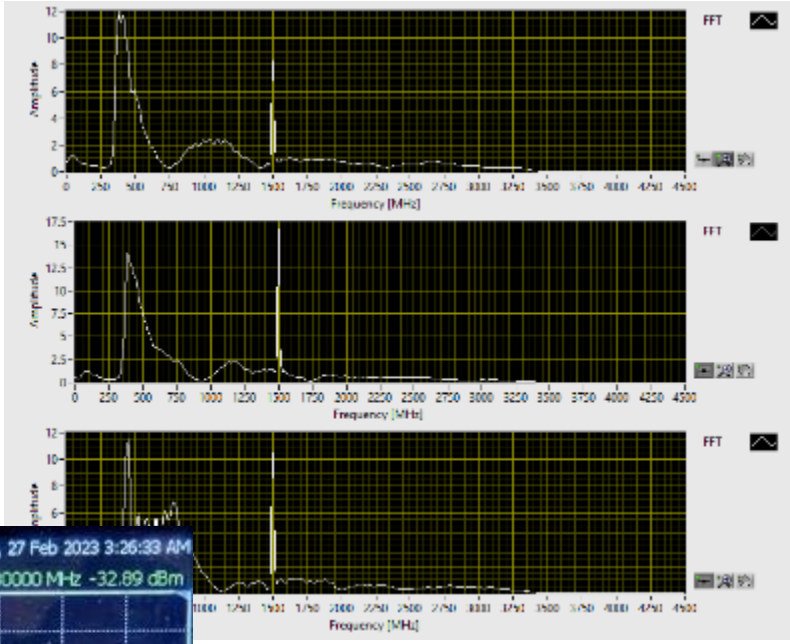
Mixer	Trec @M1 140mm	Trec @M2 140mm	eta_forward
B1M2	963K	1140K (1118K)	87.2%
B1M3	803K	935K (917K)	87.5%
B1M6	848K	975K (955K)	88.8%
B2M2	961K	1175K (1073K)	89.5%
B2M3	1087K	1299K (1186K)	91.6%
B2M5	1332K	1619K (1478K)	90.1%
B2M6	963K	1135K (1036K)	92.9%
B2M8	1171K	1405K (1282K)	91.3%

Receiver performance is maintained through the telescope

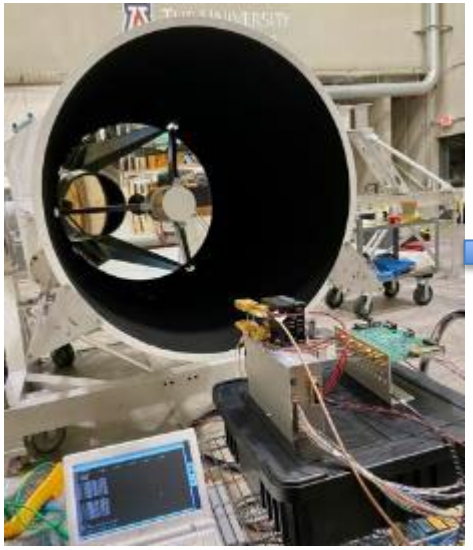
End-to-end Tone tests in B1 and B2



B1



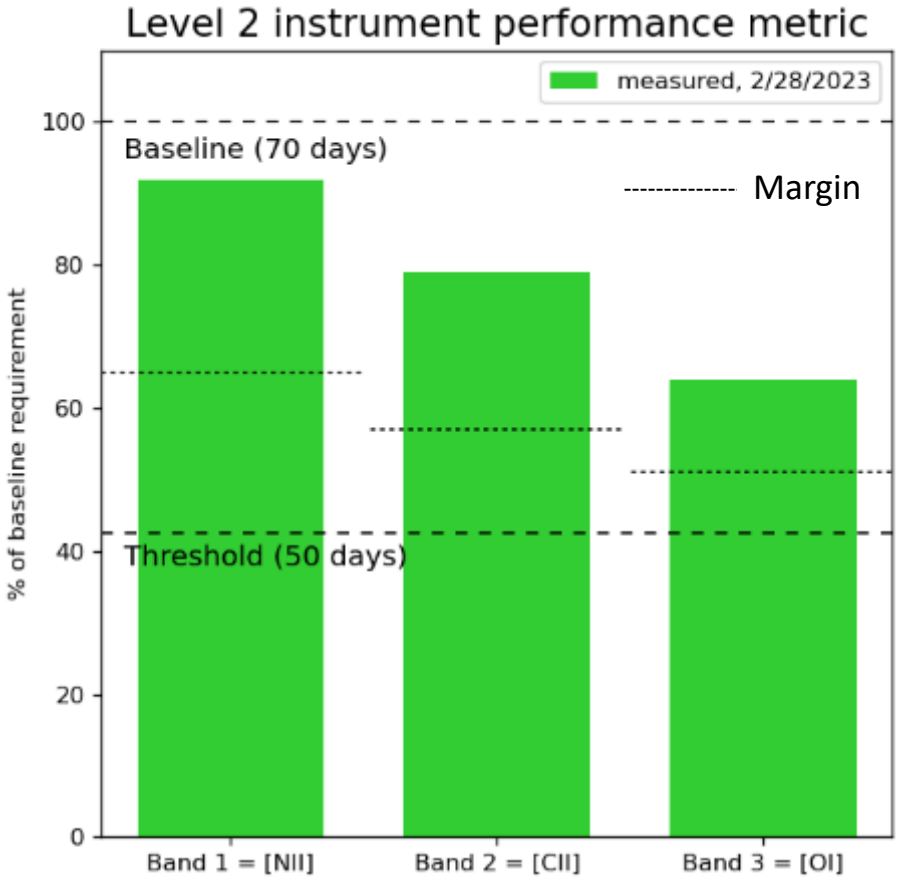
Tone w/ ACS in all 3 B1 mixers

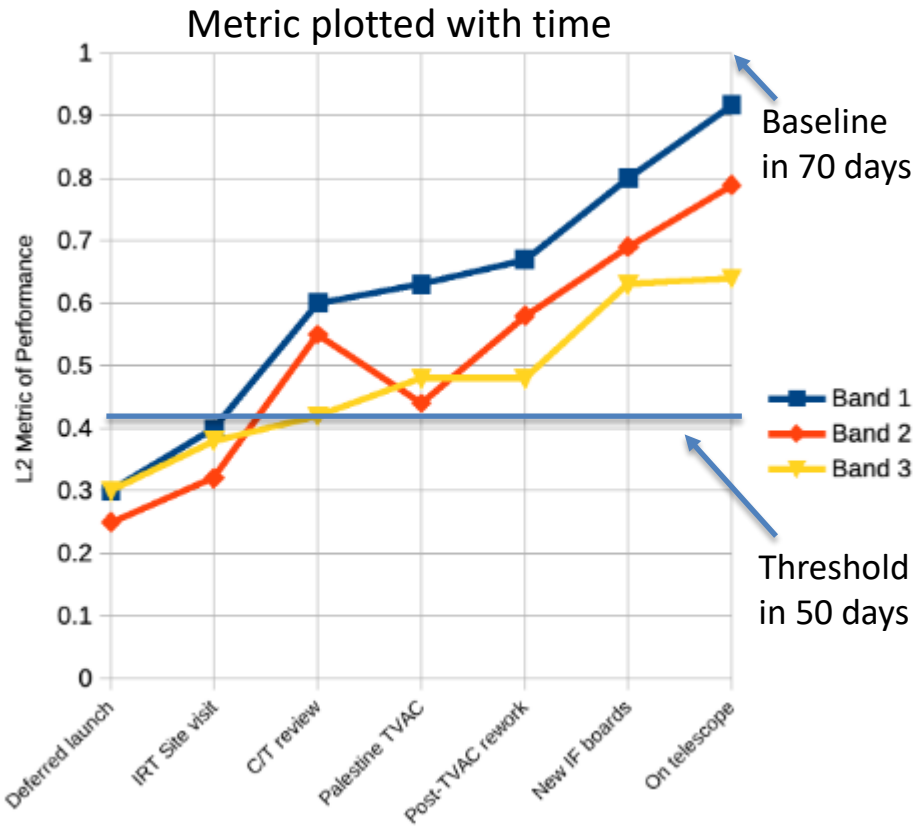


B2

End-to-end tone tests provide strong evidence that GUSTO is fully functional

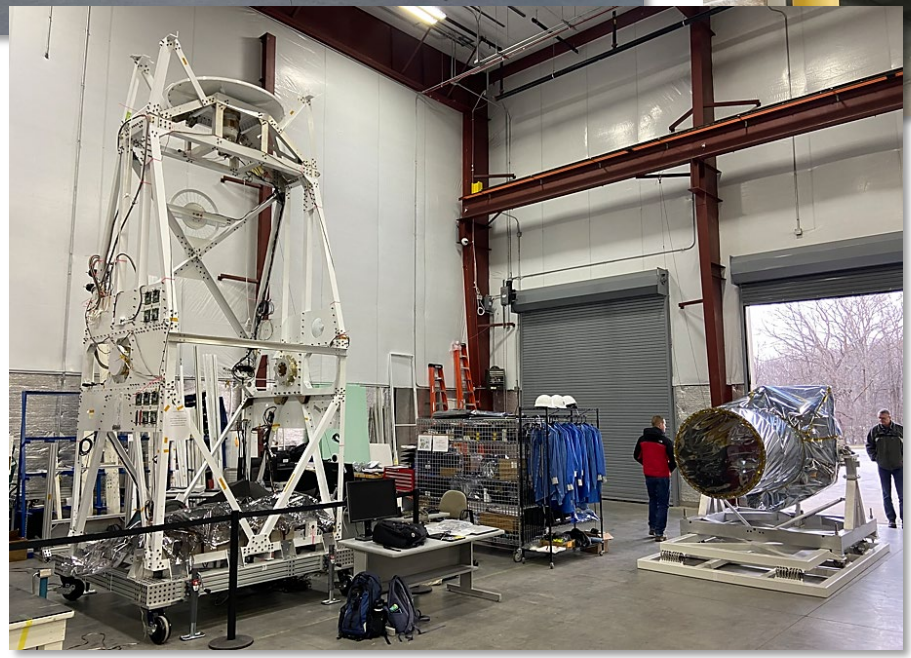
GUSTO Payload is performant at the system level



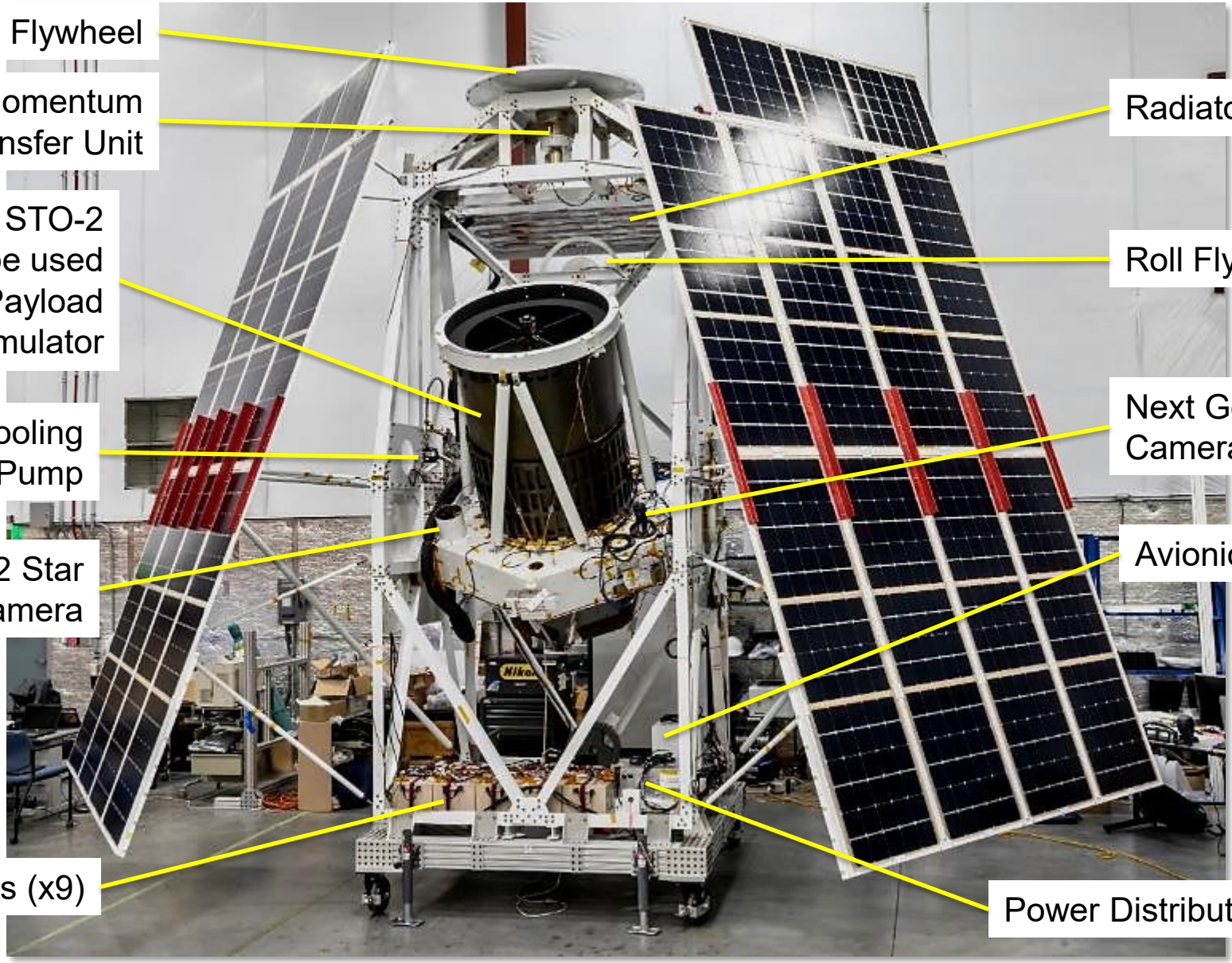


GUSTO Payload Exceeds Threshold Mission requirements with margin

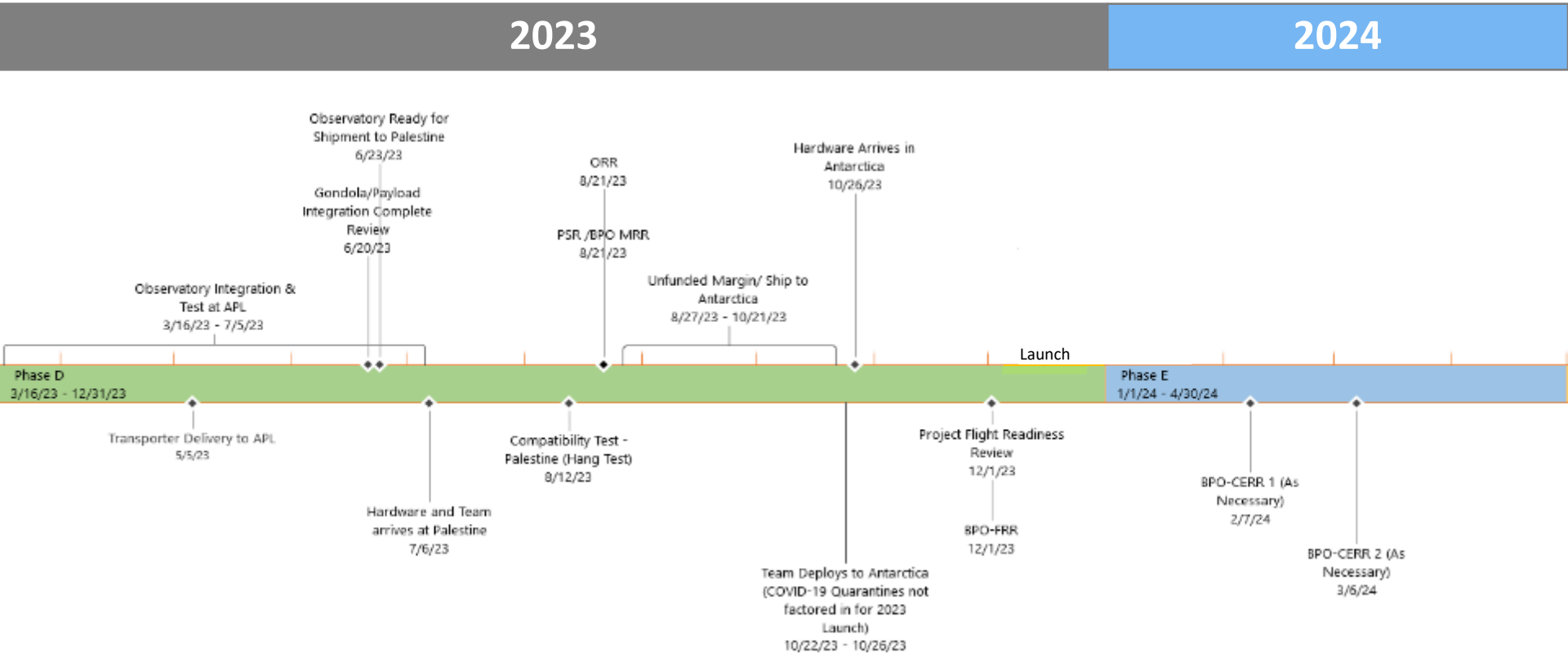
Arrival of Payload at APL



Gondola Configuration with STO-2 Telescope



Schedule Overview



Status as of 2/28/2023