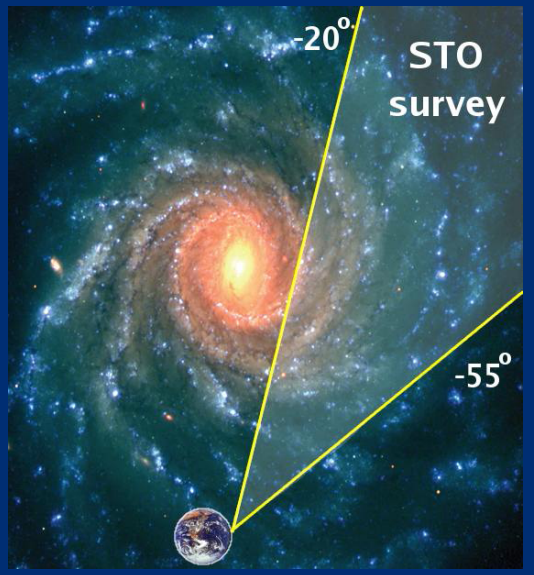
Stratospheric THz Observatory (STO)

Finder's Scope for SOFIA : UAz, APL, CIT/JPL, KOSMA

- 0.8-meter telescope with two
-4-pixel THz arrays
-- platform for THz surveys



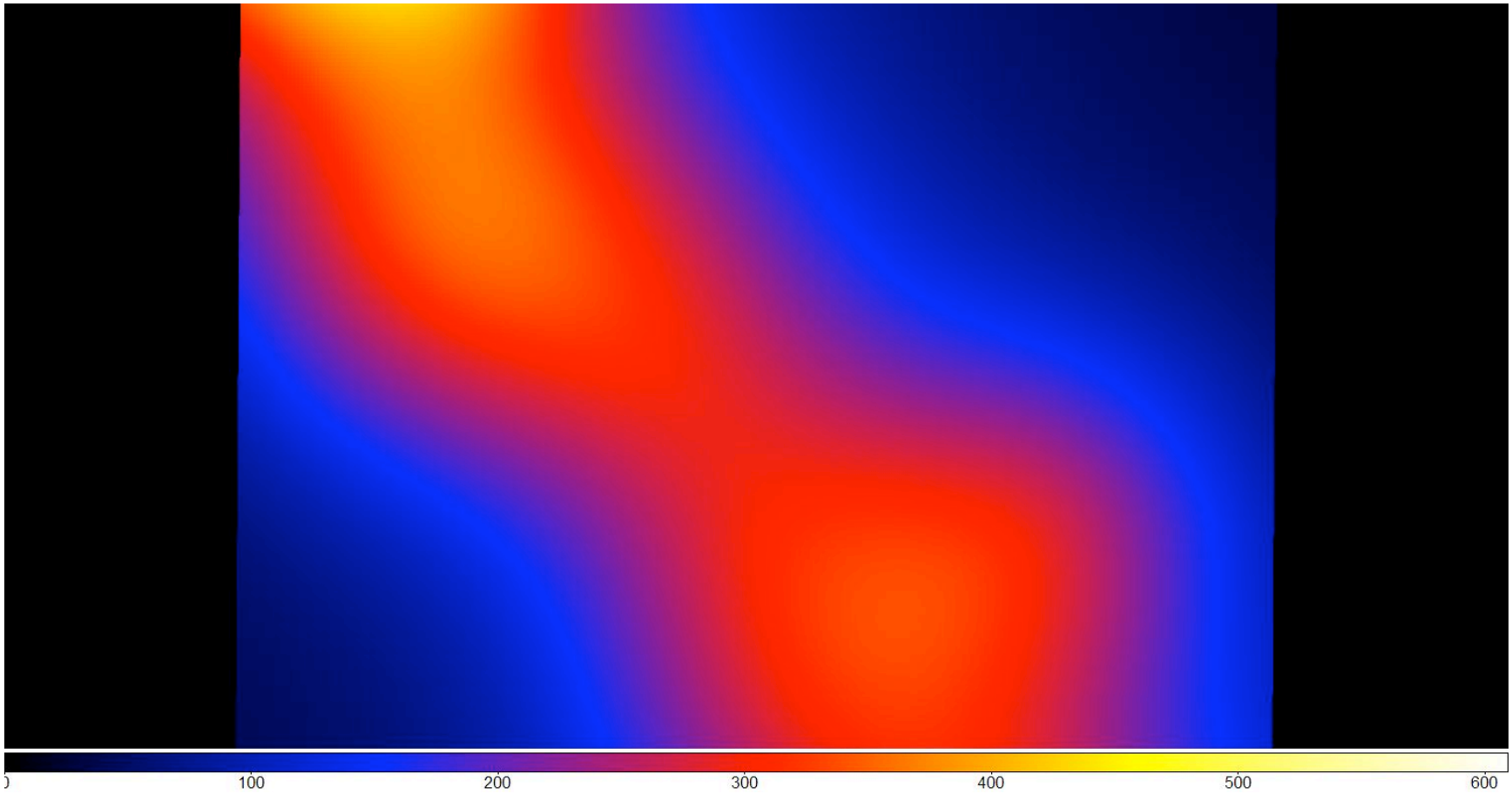
- LDB Platform
- >14 day flights

2009 – First Engr. Flight

2010-11 - First Science Flight: CII Survey

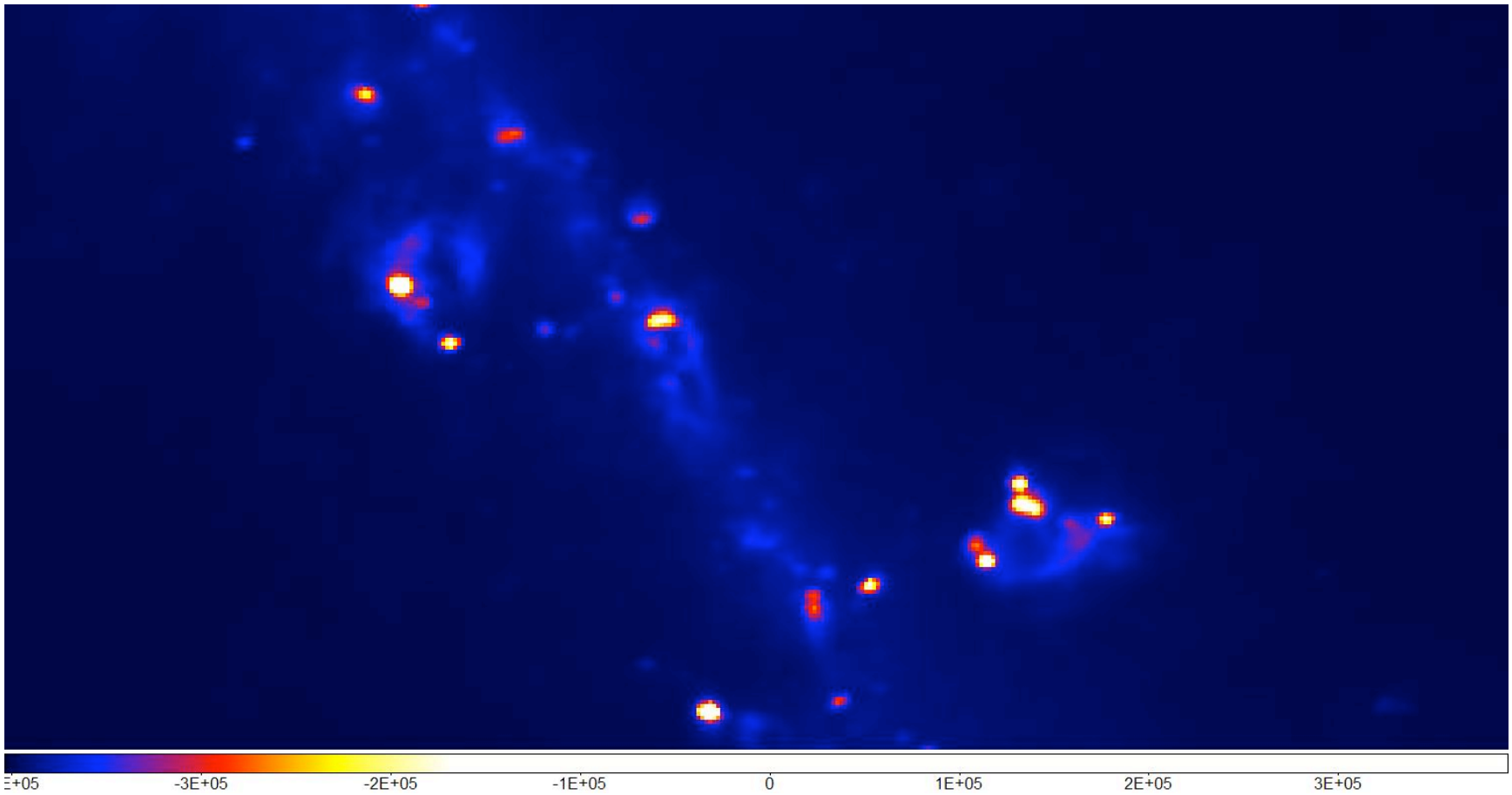

Fundamental Goals
1. Determine the life cycle of Galactic interstellar gas.
2. Study the creation and disruption of star forming clouds in the Galaxy.
3. Determine the parameters that affect the star formation rate in a galaxy.
4. Provide templates for star formation and stellar/ interstellar feedback in other galaxies.

STO Vastly Improves Available Angular Resolution



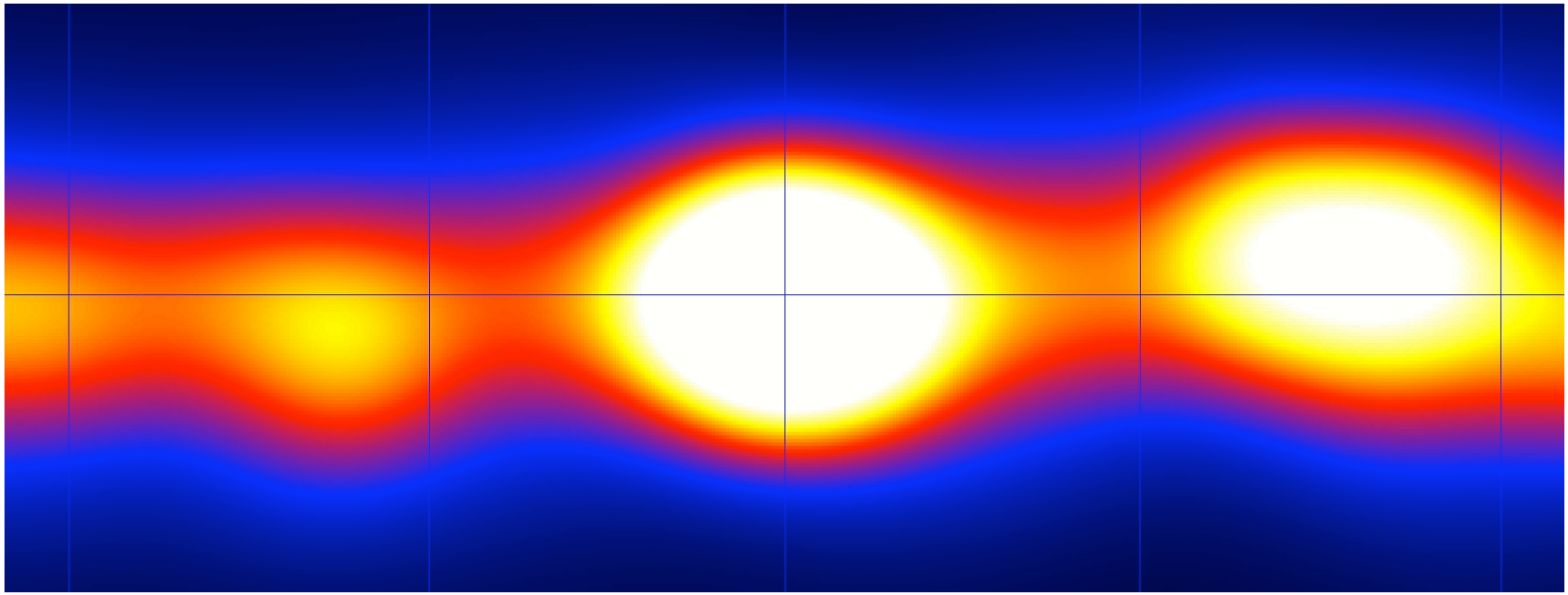
Galactic Plane Region Near **l** = 340 IRAS 60 μm Smoothed to 3°

STO Vastly Improves Available Angular Resolution



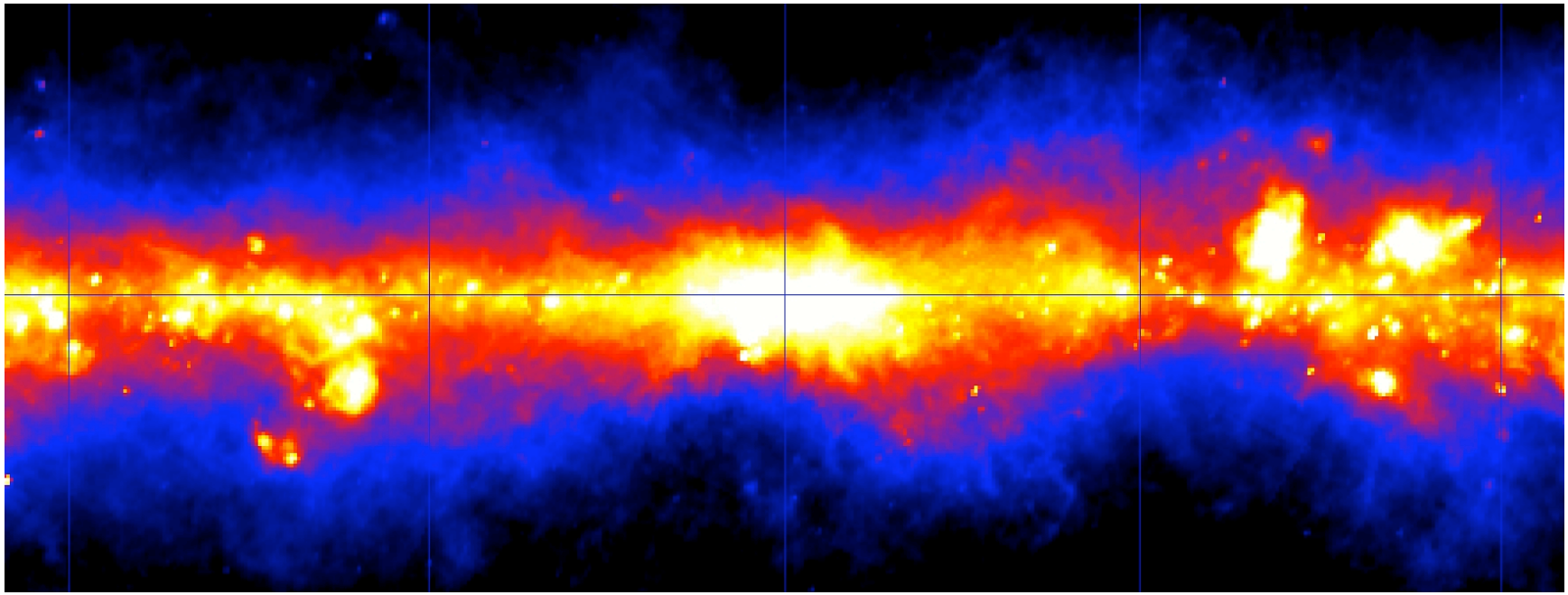
Galactic Plane Region Near $l = 340$ IRAS 60 μm 2' Resolution

STO Vastly Improves Available Angular Resolution



Galactic Center Region IRAS 60 μm Smoothed to 7°

STO Vastly Improves Available Angular Resolution



Galactic Center Region IRAS 60 μm 3' Resolution

Scientific Merit and Impact

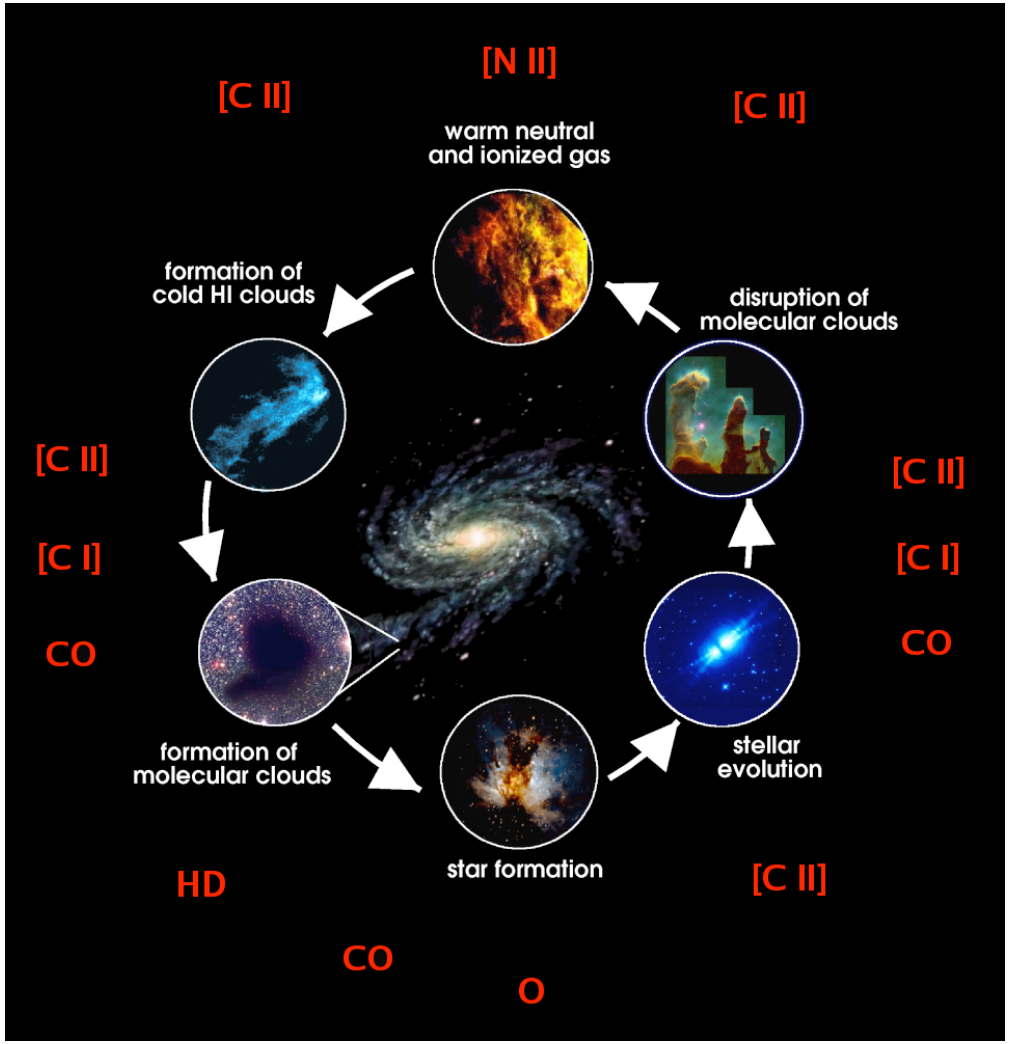
STO Surveys:

1. **GPS:** Galactic Plane Survey: $-20^o < l < -55^o$; $0 < b < 1^o$ in [C II] and [NII].
2. **DS**: Deep Survey of arm and interarm regions:

   $l \sim -50^o$ and -40^o ; -0.5 to -0.7^o in b

STO's potential for additional flights provides the ability to more fully map the Galaxy in the [C II] and [N II] lines and to change receivers to include other important interstellar lines such as [N II] 122 mm, [O I] 63 & 145 mm, and HD 112 mm. Surveys will sample the full dynamic range of dark clouds and star formation activity in the Galactic disk and bulge, allowing ***for the first time*** a complete picture of the Life Cycle of the ISM in the Milky Way.

Importance of [CII] & [NII]

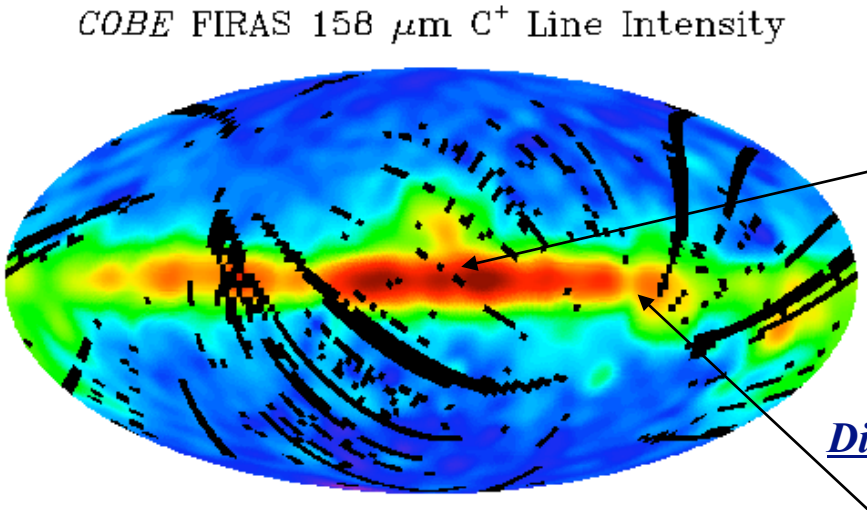


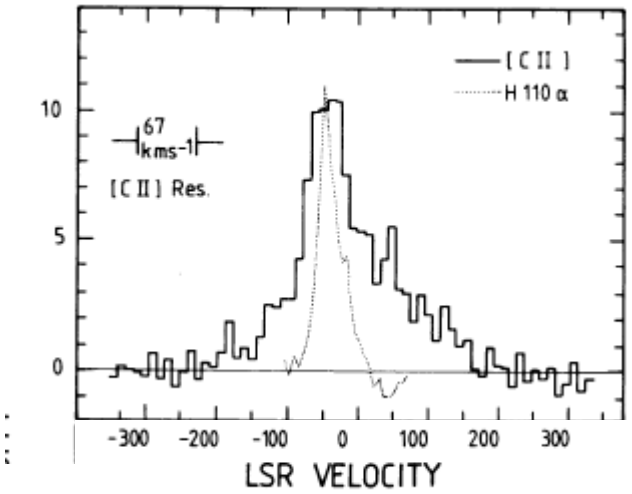
[CII] is the most powerful spectroscopic thread for probing the ionized/neutral components of the ISM.

[N II] observations provide sensitive/detailed maps of star formation rates in the Galaxy, and are used to separate the ionized and neutral components of [CII] emission.

[CII]/[NII] Emission is Widespread

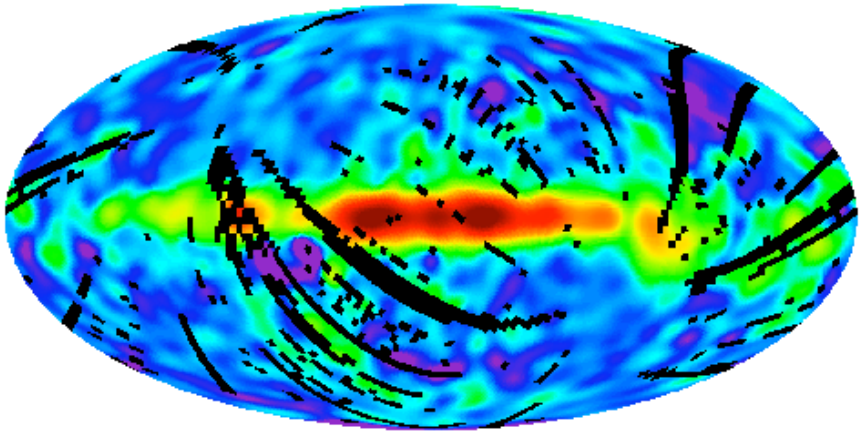
Bulge-KAO:

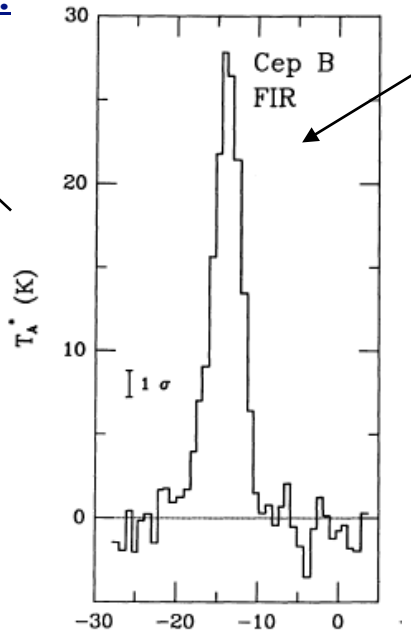




(Genzel, et al. 1990)

Disk-KAO:





High Velocity (Heterodyne) Resolution is essential!

STO maps ~10^5x angular ~10^3x velocity resolution of COBE.

(Borieko, et al. 1990)

Science Traceability: Baseline

Science Objectives	Science Measurement Requirements	Instrument Functional Requirements	Mission Functional Requirements (Top-level)
Measure mass of neutral and ionized clouds in Milky Way	**Mapping [CII] over 35^0 swath of the Galactic Plane, 0-1^0 height.**	**4 pixel, 1.9THz Receiver Heterodyne Receivers**	**~14 day mission lifetime**
Differentiate between ionized and neutral clouds	**Mapping [NII] over 35^0 swath of the Galactic Plane, 0-1^0 height.**	**4 pixel, 1.45THz Receiver Heterodyne Receivers**	**~14 day mission lifetime**
Spatially resolve interstellar clouds	**1 arc minute angular resolution**	**$\geq$65cm primary antenna**	**~15" pointing knowledge**
Velocity resolve interstellar clouds	**0.2 km/s velocity Resolution**	**Spectrometers with ~1MHz resolution**	**~30kps data rate**
Cover range of galactic radial velocities	**160-205 km/s velocity range**	**IF/Spectrometer Bandwidth per pixel ~1GHz**	**~30kps data rate**
Sensitive to Av ~ 0.4 clouds in Galactic Plane Survey	**Ability to detect T_B ~ 1 K**	**Trec (DSB) $\leq$ 2000 K Cryogenically cooled HEB receivers**	**^{4}He cryostat**

STO Systems Requirements (Antarctica):

System	Requirement		Proposal	Now (5/12/08)
Mission	Duration (Time at float)	Desired	> 14 days	> 14 days
		Minimum		10 days
	Altitude	Desired	> 120 kft	> 120 kft
		Minimum		100 kft
		Stability		± 20 kft
	Launch time		Any time of day	Any time of day
Telescope	Aperture		80 cm	80 cm
	F/ratio		f/7	f/12
	Back Focal Plane (from 1ary)			
	Secondary rms surface accuracy		< 4μm	< 4μm
	Minimum Field of View (FOV) for FULL field angle			10 arcmin
	Instantaneous FOV (IFOV)			1 arc min (PSF)
	Spot size at prime focus			
	Central pixel encirc. energy [%]			
	MTF	MTF		
		@ wavelength		
		@ spatial frequency		
	Spectral range		60 – 210 μm	60 – 210 μm
	Center of Gravity location			
	Weight (only telescope)		~ 210 lbs	
Receiver	Target Frequencies	CII	1.901 THz = 158 μm	1.901 THz = 158 μm
		NII	1.461 THz = 205 μm	1.461 THz = 205 μm
	Angular Resolution		~ 1'	~ 1'
	Type		4-pix HEB Mixer Arr.	4-pix HEB Mixer Arr.
	Noise		~ 1500K (DSB)	~ 1500K (DSB)
	Integration time			~ 1-2 sec/ spectrum
	Weight			40 lbs
	Power			190 W
Spectrometer	Type		8×1 GHz FFT analyz.	8×1 GHz FFT analyz
	Bandwidth		1 GHz (160-205 km/s)	1 GHz (160-205 km/s)
	Resolution		1 MHz (0.2 km/s)	1 MHz (0.2 km/s)
	Chopper throw		±0.4° @ ~ 1Hz	Flips beam into dewar
	Weight			20 lbs
	Power			110 W
Cryogenic Cooler	Type		^{4}He+60K cryocooler	
	Hold time		> 14 days	> 14 days
	Weight	wet		~ 330 lbs
		dry		~ 276 lbs
	Power			250 W (Sunpower GT)

System	Requirement		Proposal	Now (5/12/08)
Instrument Control Computer (ICC)	Computer	Quantity	1	1 or 2
		Type		ARM-based SBC
		Operating syst.		NetBSD or Linux
	Comms. with GCCC	Type		Ethernet
		Clock sync		± 1 sec or better
	Need Pressure vessel ?			TBD, probably 'yes'
	Location			mezzanine w/spectr.
	Weight + harness			5 lbs
	Power			< 5 watts
Gondola Command & Control Computers	Computer Quantity		2	2
	Autonomous Control Executive ACE	Type	ATX	
		Operating syst.	Linux	Linux
		Pressure vessl ?	YES	YES
		Location	Upper Mezzanine	Upper Mezzanine
		Talks with ICC	YES	YES
		Weight	70 lbs	70 lbs
		Power		
	MAX3	Type	ATX	
		Operating syst.	RT Linux	RT Linux
		Pressure vessl ?	YES	YES
		Location	Upper Mezzanine	Upper Mezzanine
		Talks with ICC	NO	YES
		Weight	75 lbs	75 lbs
		Power		
	Harness weight			~ 55 lbs
	CC&C Total Weight		~ 250 lbs	~ 200 lbs
	CC&C Total Power			
Data Storage	Developed by			U of Arizona
	Type			Solid state
	Controlled by computer			ICC
	Interface type			IDE to industrial CF
	Storage capacity			32-64 GB
	Need Pressure Vessel ?			TBD, probably 'yes'
	Location			ICC
	Easy recovery			YES
	Weight			ICC
	Power			ICC

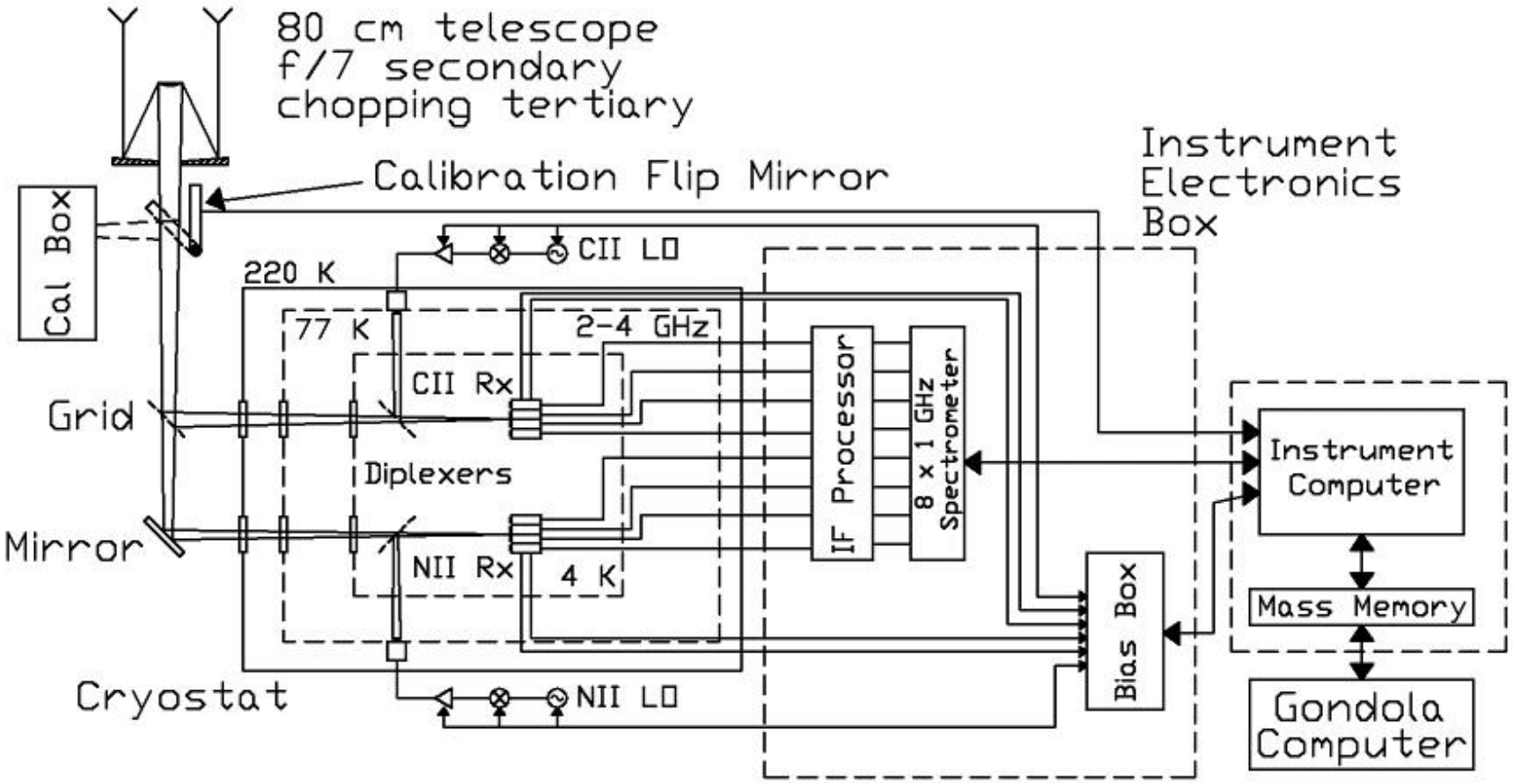
System	Requirement			Proposal	Now (5/12/08)
Pointing System	Range		Azimuth	360° > 60° away from Sun	360° > 45° away from Sun
			Elevation	0 to 54°	0 to 54°
	Acquisition accuracy			< 40 "	< 20 " at beginning of scan
	Pointing stability			< 30 " for 2 sec inter	< 20 " for 2 sec interval
			Pulse		
			DC		
	Knowledge			< 15 "	< 15 " relative to beginning of scan
	Scan drift rate				15"/sec in any arbitrary direction on the sky
	Scan length		Min Size		2deg across gal. plane
			Min Duration		10 minutes
	Weight (Star track + IMU)			~ 60 lbs	
	Power		Peak		
			Average		
Power System	Power Requirement		Instrument	400 W	555 W
			Gondola	430 W	400 W
			Total	**830 W**	**955 W**
	Design			1400 W	1600 W = 600 cells
	Panels orientation			Front @ +45° azim. Variable ± 20° (?)	Front @ +45° azim. Adjustable ± 5°
	# batteries (Odyssey)			4	4
	Battery stack capacity			130 Ah	130 Ah
	Bus voltage			24 V	24 V
	Weight	Batteries (4)		120 lbs	120 lbs
		Solar Arrays		~ 100 lbs	
		Charge c. + harness		~ 30 lbs	~ 30 lbs
		Total		~ 250 lbs	
Gondola	Size	Frame Footprint (H x W x D)		~ 4.5m x 1.5m x 1.7m	~ 4.5m x 1.5m x 1.7m
		W with Arrays		~ 5.7 m	~ 5.7 m
	Weight	Frame		1800 lbs	
		CCC + harness		250 lbs	200 lbs
		Pointing System		60 lbs	
		Power System		250 lbs	
		Telescope		210 lbs	
		Instru-ment	Receiver	200 lbs	40 lbs
			Spectrom.		20 lbs
			Cryostat		330 lbs
			Computer		5 lbs
		Balance booms			
		CSBF		570 lbs	570 lbs
		Total		**3440 lbs**	

Ballooning & Gondola

May 8, 2011

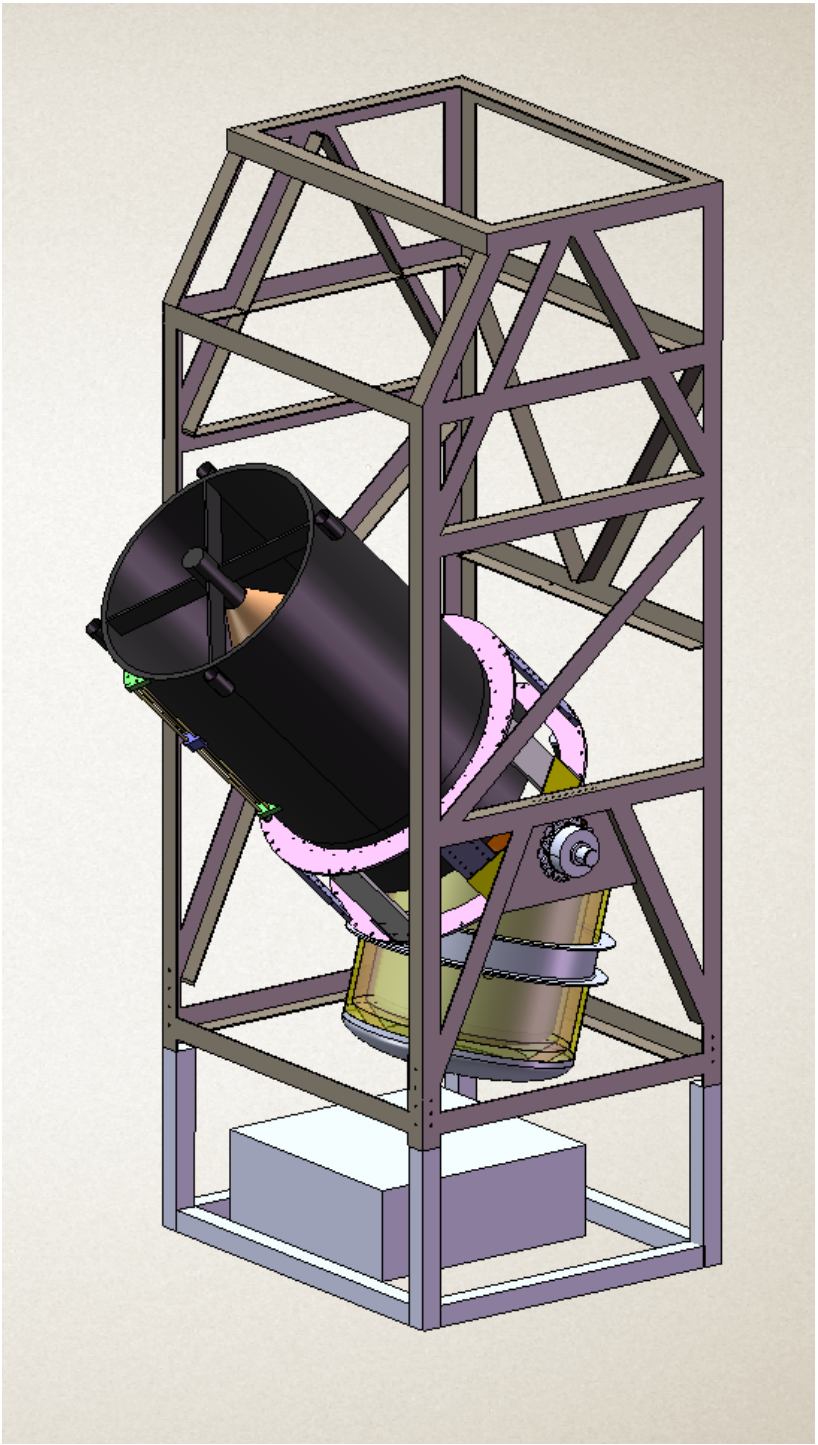
STO Instrument Concept

On-Axis Telescope



STO Optics and Cryogenics

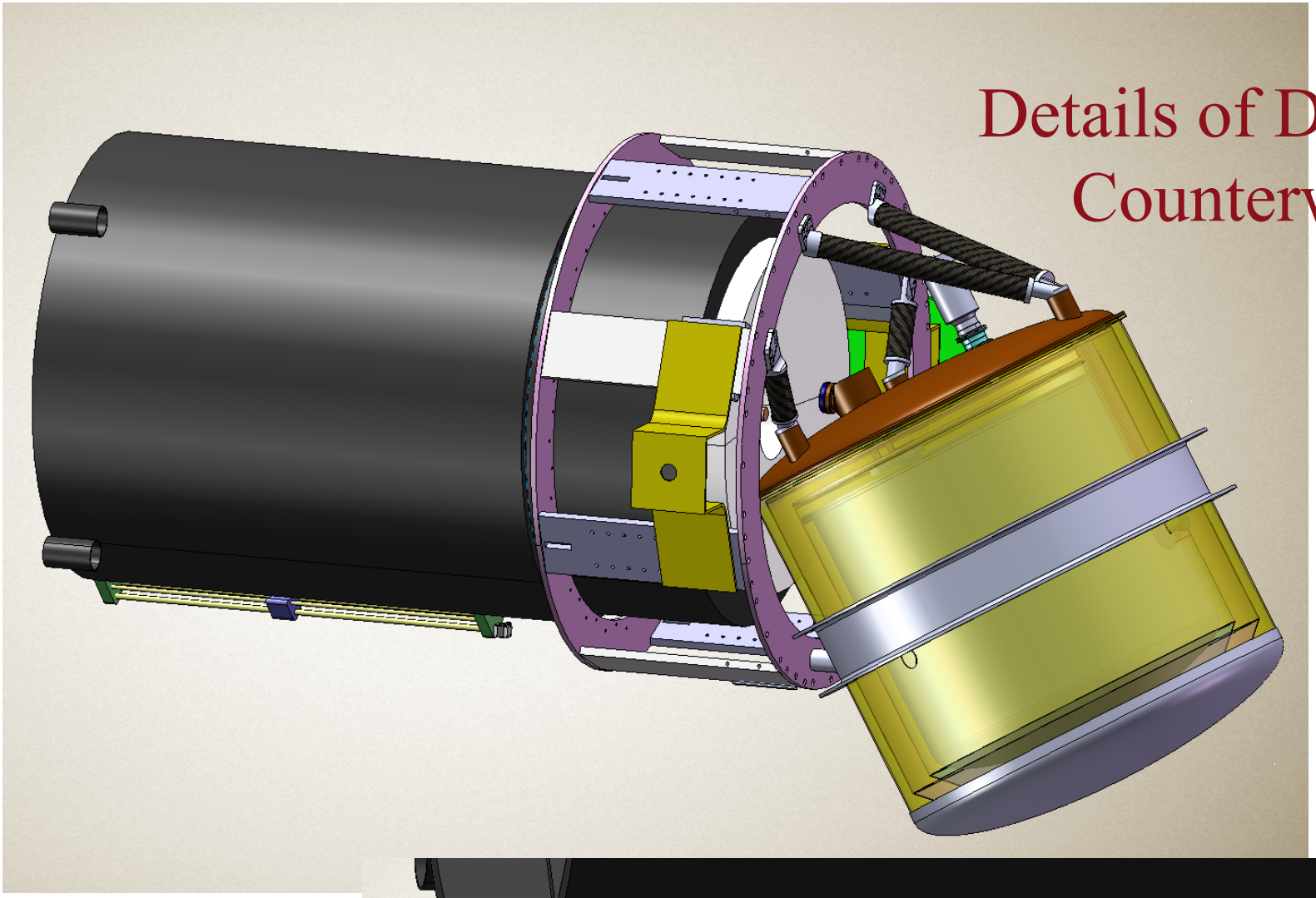
May 8, 2011

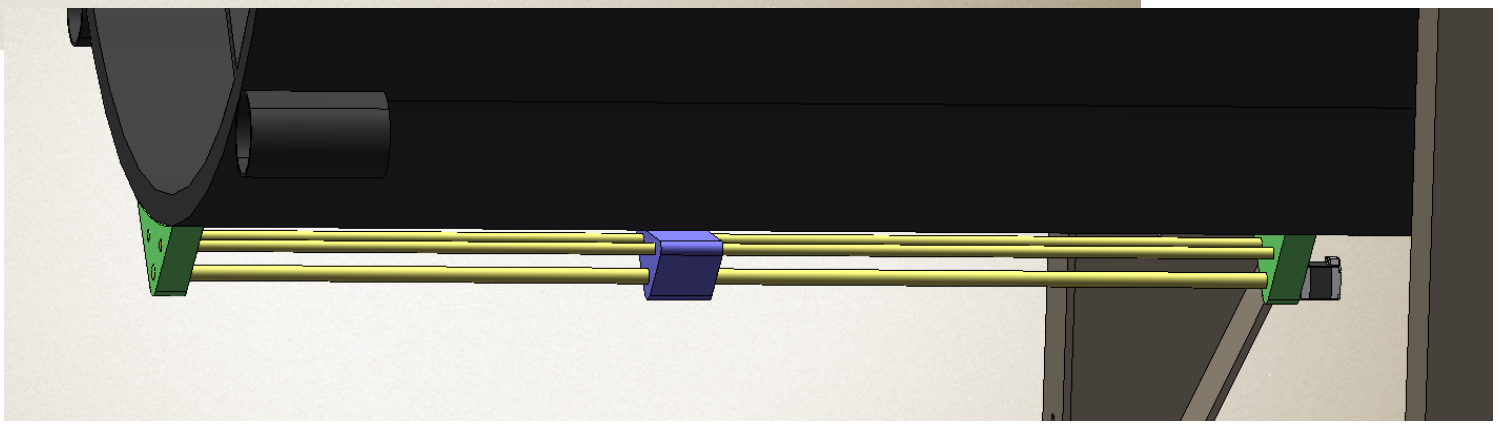


STO Antarctic Flight Cryogenics

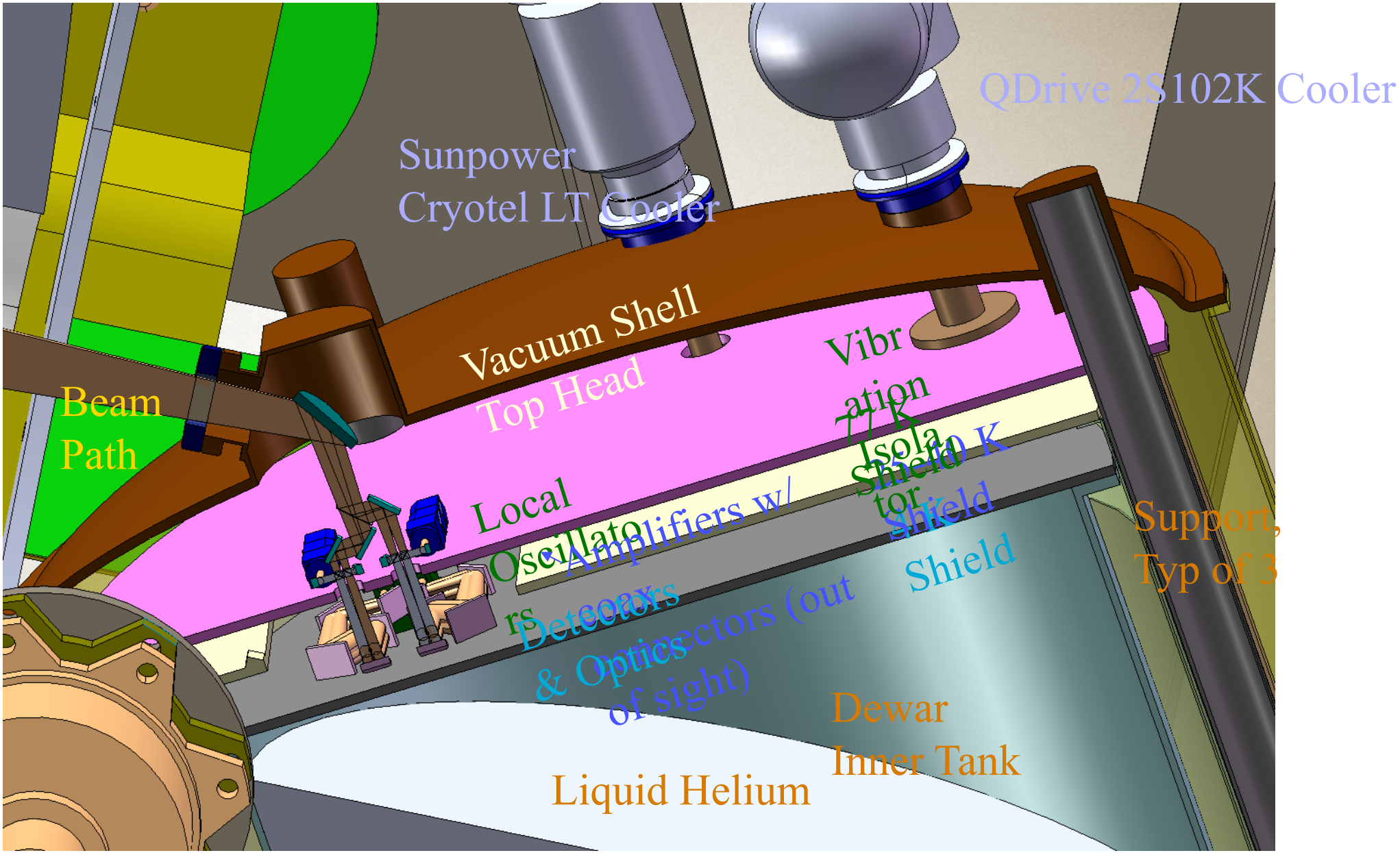
Weight List	(kg)
Inner Tank Top Plate	2.73
Inner Tank Body	10.05
Inner Shield Top Plate	2.27
Inner Shield	3.64
Outer Shield Top Plate	3.18
Outer Shield	4.55
Outer Shell Top Head	8.64
Outer Shell Bottom Head	7.27
Outer Shell Cylinder	16.36
Inner Supports	3.41
Outer Support Structure	9.50
Plumbing, Wiring, MLI	1.96
Misc. + Fasteners	6.82
Liquid Helium	15.91
Total:	96.29
plus 15% contingency:	14.44
Working Total:	110.73

Details of Dewar and Counterweight





Details of Cryostat / Dewar Design



Omnisys AB FPGA-Based Spectrometer

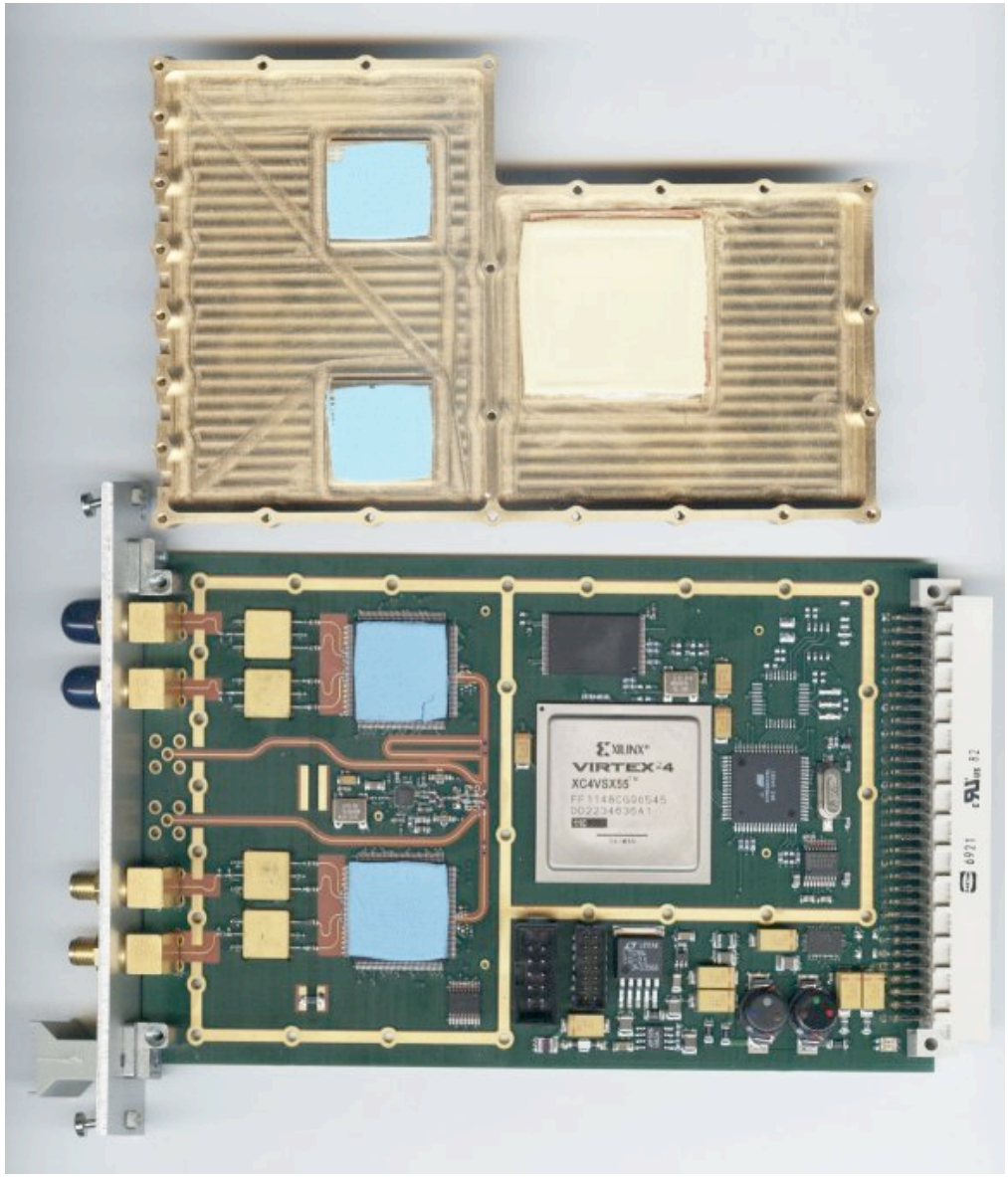
•Uses two interleaved 8 bit samplers to digitize the incoming IFs from the receiver.

•A large FPGA (Xilinx Virtex 4) performs a real time FFT on the data and integrates.

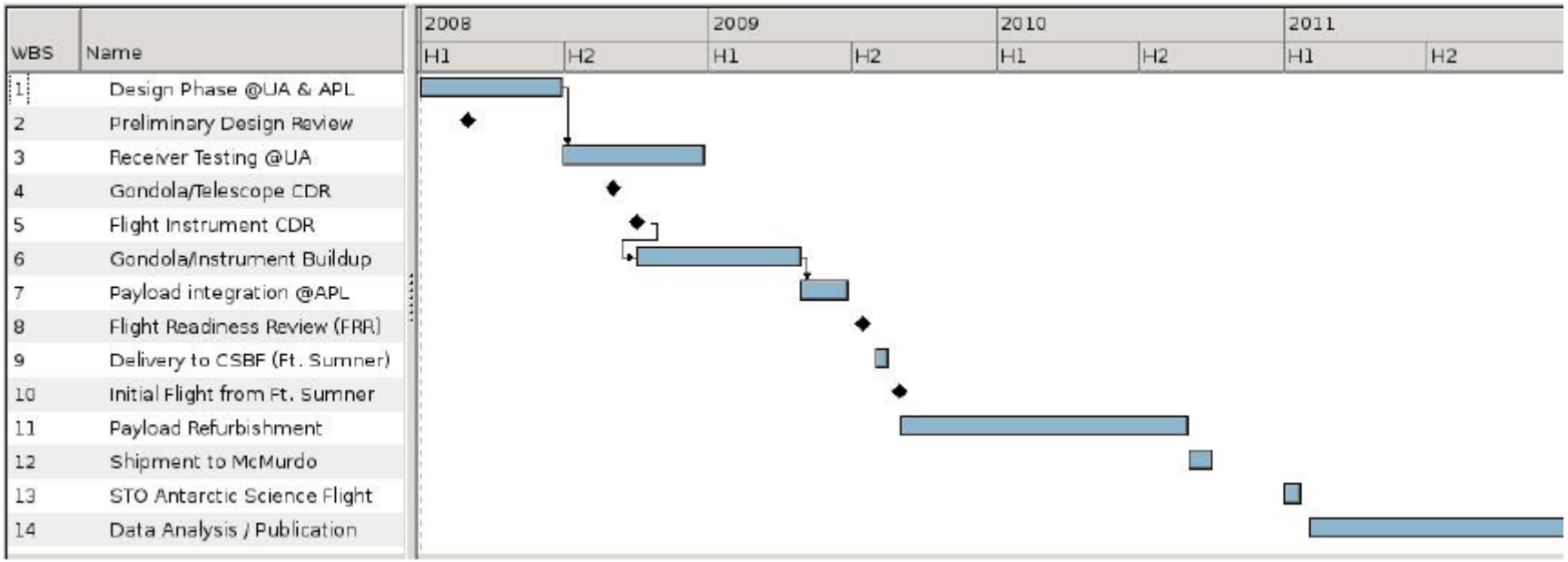
•One board processes 4 500 MHz bandwidth signals, with 2048 channels per spectrum (resolution of 250 kHz)

•8 board spectrometer system delivered! (16 GHz total BW, 32768 channels, 1 19” 3U rack)

•IF processor combines two 250 MHz BW IF channels into one spectrometer input



Schedule



WBS	Name
1	Design Phase @UA & APL
2	Preliminary Design Review
3	Receiver Testing @UA
4	Gondola/Telescope CDR
5	Flight Instrument CDR
6	Gondola/Instrument Buildup
7	Payload integration @APL
8	Flight Readiness Review (FRR)
9	Delivery to CSBF (Ft. Sumner)
10	Initial Flight from Ft. Sumner
11	Payload Refurbishment
12	Shipment to McMurdo
13	STO Antarctic Science Flight
14	Data Analysis / Publication