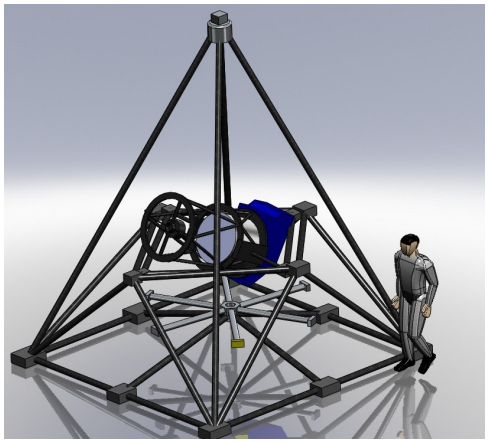
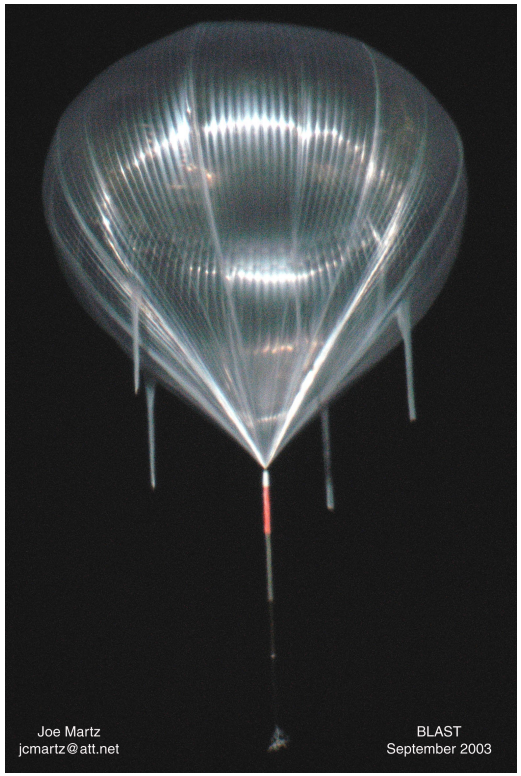
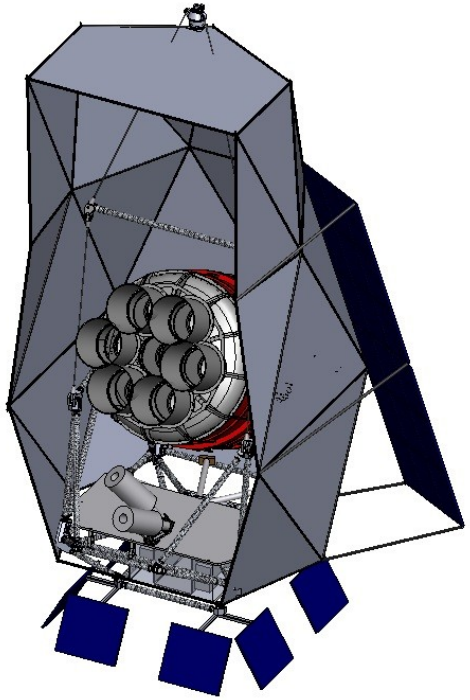
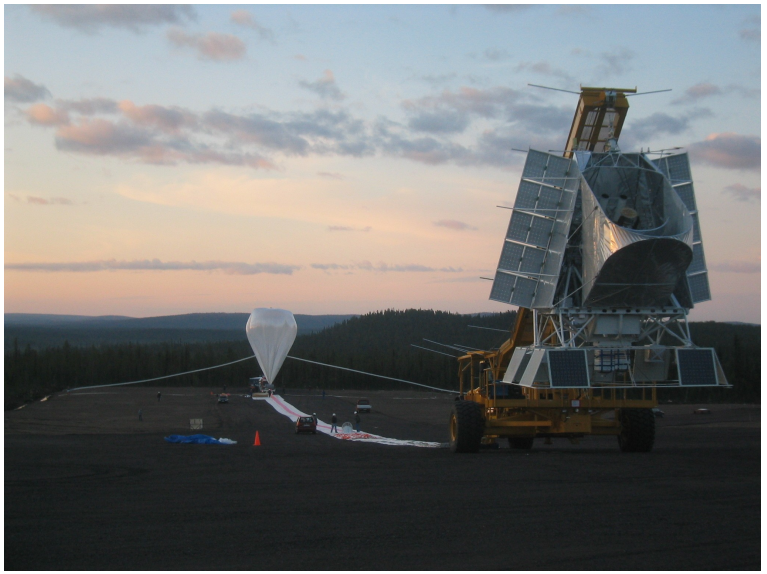
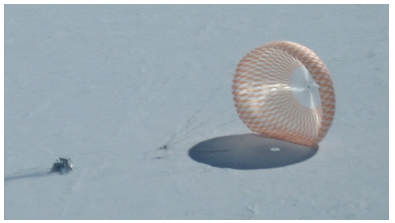
Astrophysics from the Stratosphere:





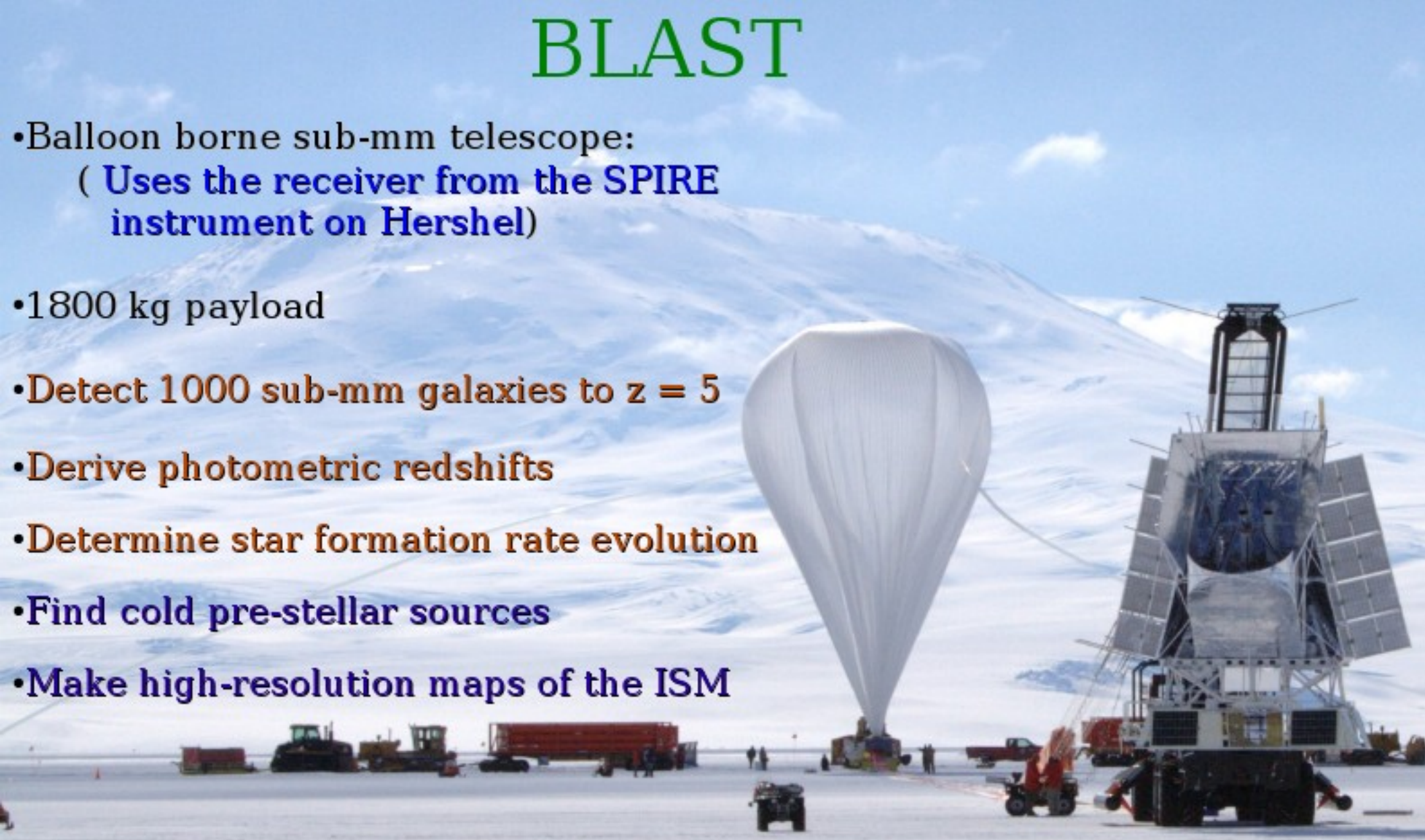






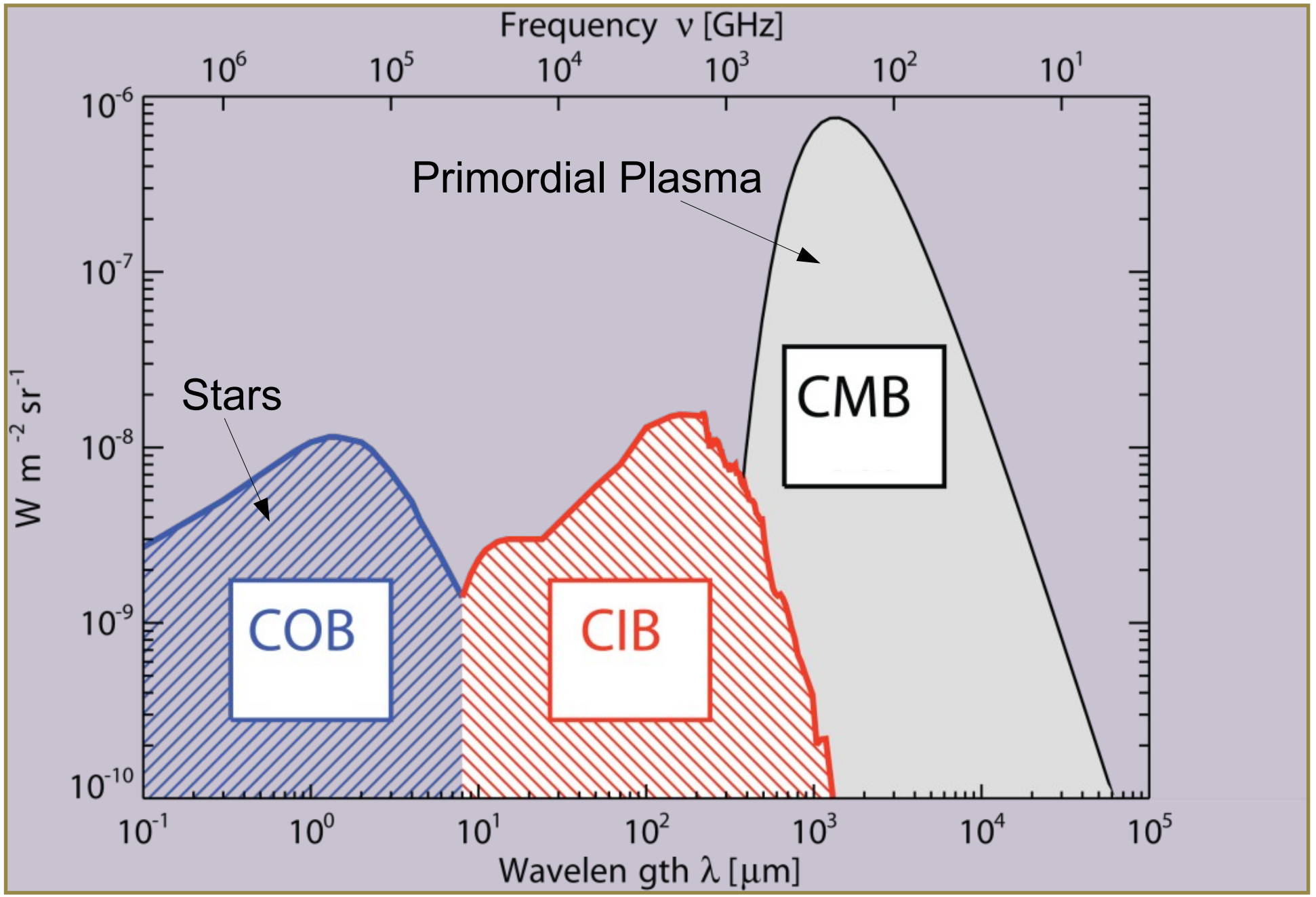
BLAST

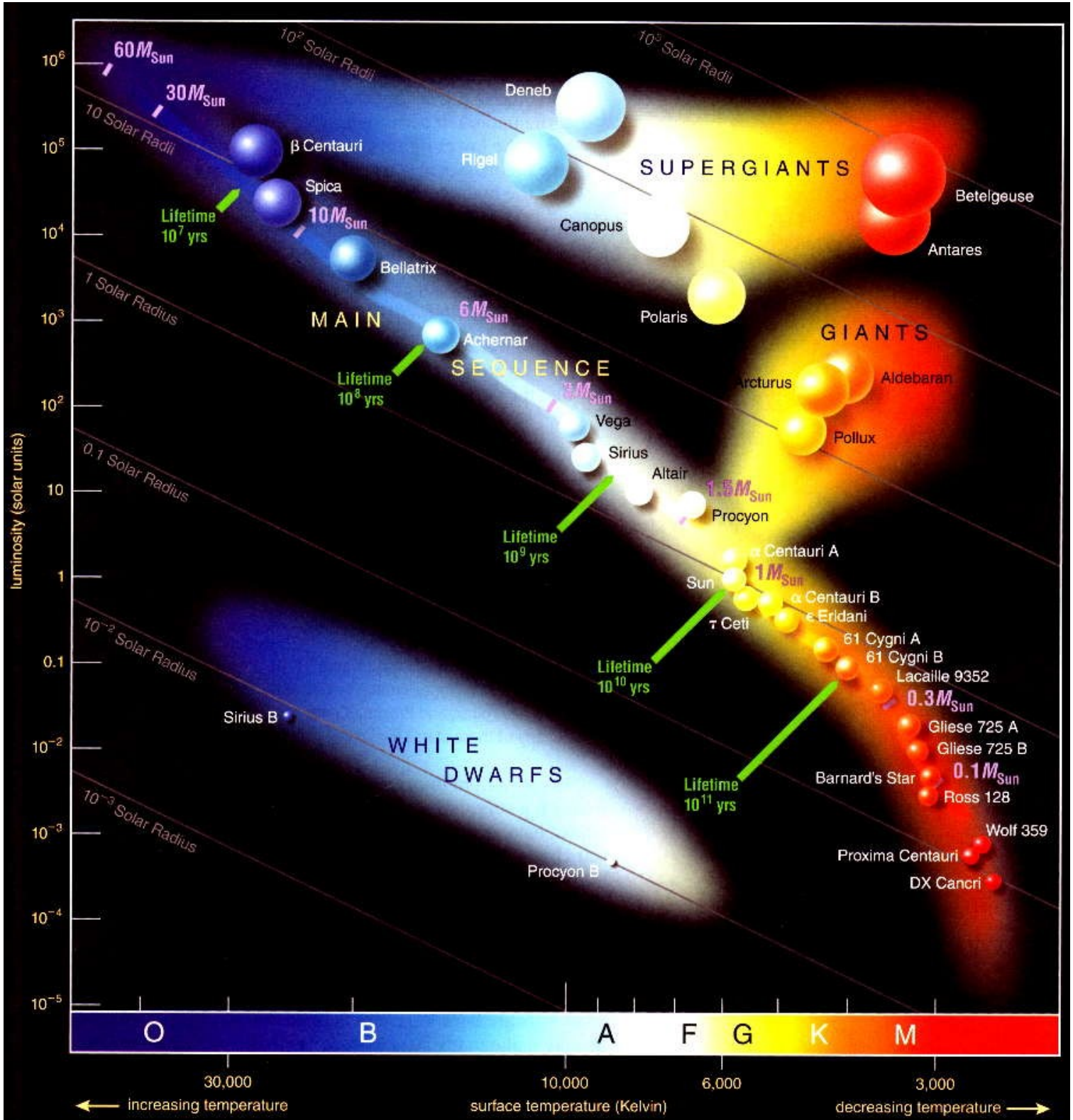
- Balloon borne sub-mm telescope:
  (**Uses the receiver from the SPIRE instrument on Hershel**)
- 1800 kg payload
- **Detect 1000 sub-mm galaxies to z = 5**
- **Derive photometric redshifts**
- **Determine star formation rate evolution**
- **Find cold pre-stellar sources**
- **Make high-resolution maps of the ISM**



University of Pennsylvania	University of Toronto
Brown University	UBC
University of Miami	Cardiff University
JPL	INOE (Mexico)

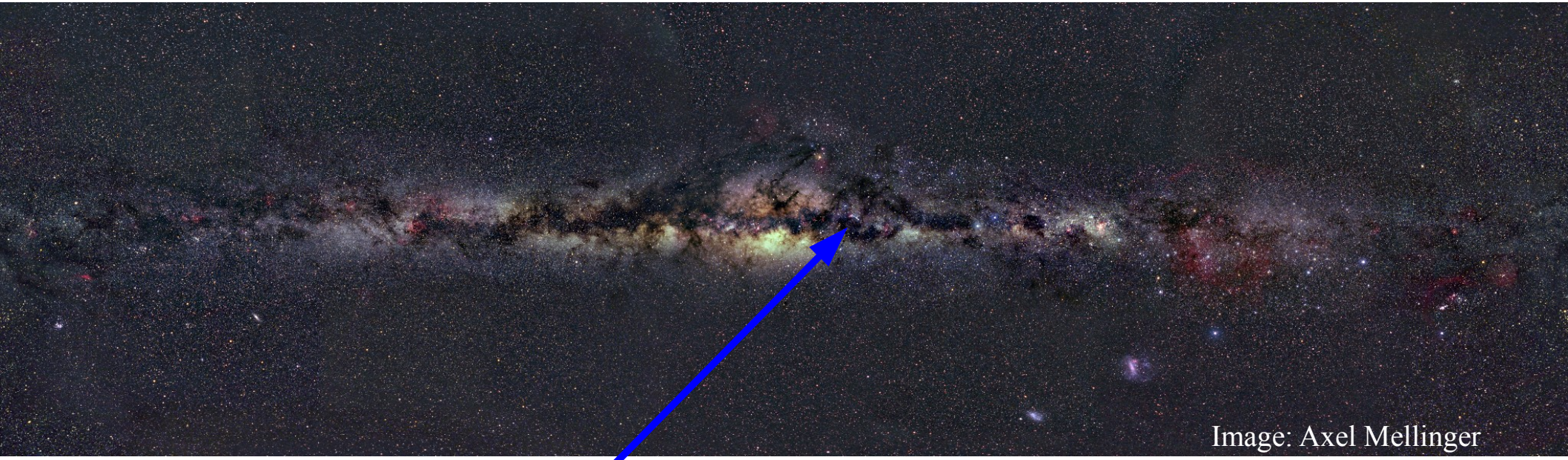
Cosmic Backgrounds




Luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
$60M_{Sun}$
$30M_{Sun}$
$10M_{Sun}$
$6M_{Sun}$
$3M_{Sun}$
$1.5M_{Sun}$
$1M_{Sun}$
$0.3M_{Sun}$
$0.1M_{Sun}$
10^2 Solar Radii
10^3 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
10^{-2} Solar Radius
10^{-3} Solar Radius
Lifetime 10^7 yrs
Lifetime 10^8 yrs
Lifetime 10^9 yrs
Lifetime 10^{10} yrs
Lifetime 10^{11} yrs
Deneb
Rigel
Canopus
Polaris
Betelgeuse
Antares
SUPERGIANTS
β Centauri
Spica
Bellatrix
MAIN
SEQUENCE
Achernar
Vega
Sirius
Altair
Procyon
Arcturus
Aldebaran
Pollux
GIANTS
α Centauri A
Sun
α Centauri B
ε Eridani
τ Ceti
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Sirius B
Procyon B
WHITE
DWARFS
O
B
A
F
G
K
M
30,000
10,000
6,000
3,000
increasing temperature
surface temperature (Kelvin)
decreasing temperature

The Milky Way Galaxy

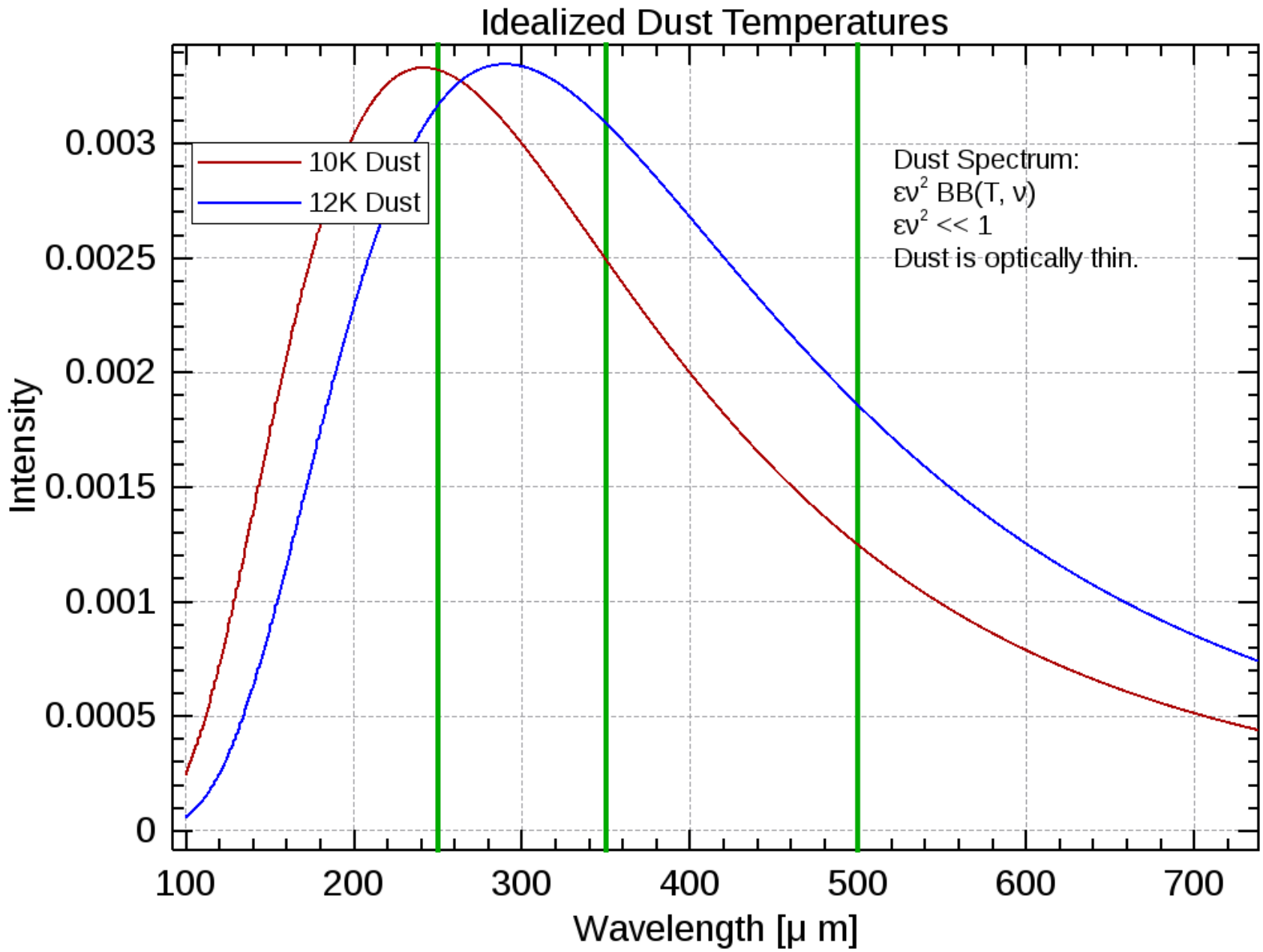
Our galaxy, viewed from the inside.



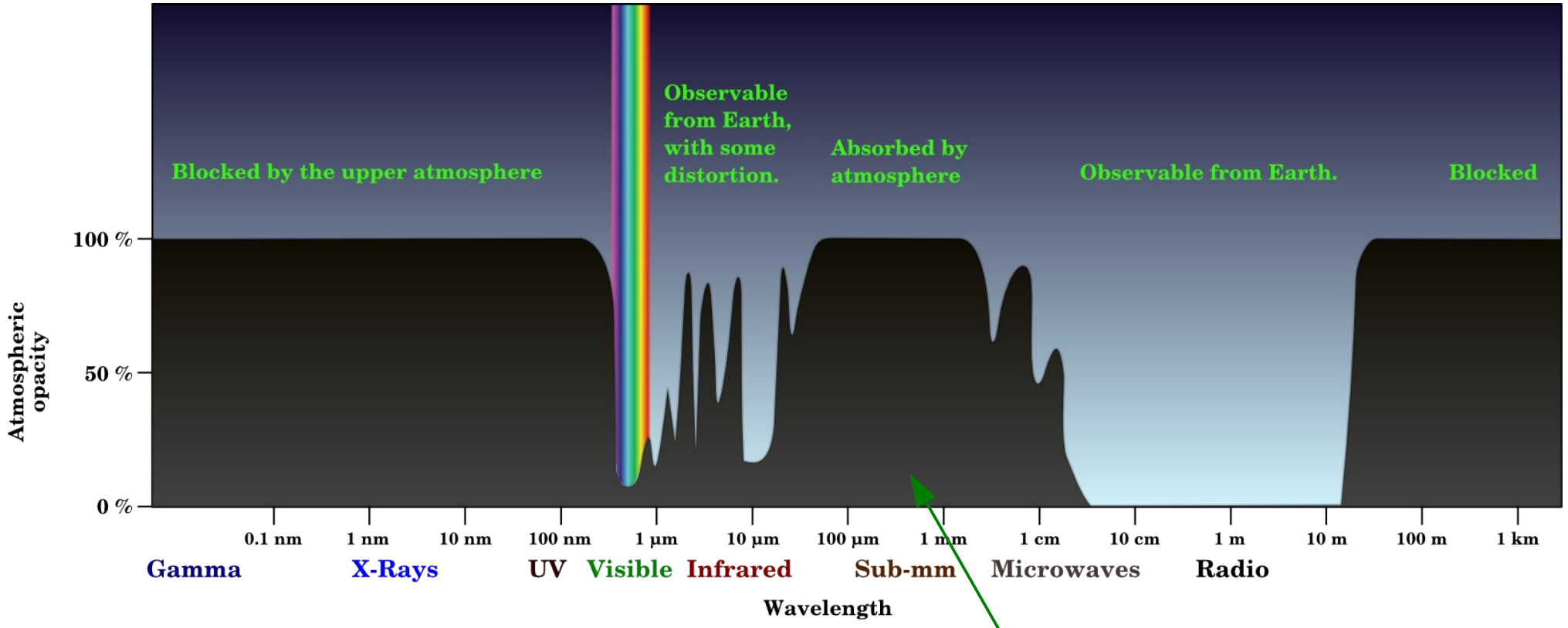
Dust Obscures Star Formation!

The Andromeda Galaxy

The nearest spiral galaxy


Idealized Dust Temperatures
10K Dust
12K Dust
Dust Spectrum:
εν² BB(T, ν)
εν² << 1
Dust is optically thin.
Intensity
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
100
200
300
400
500
600
700
Wavelength [μ m]

The atmosphere is only transparent at some wavelengths.



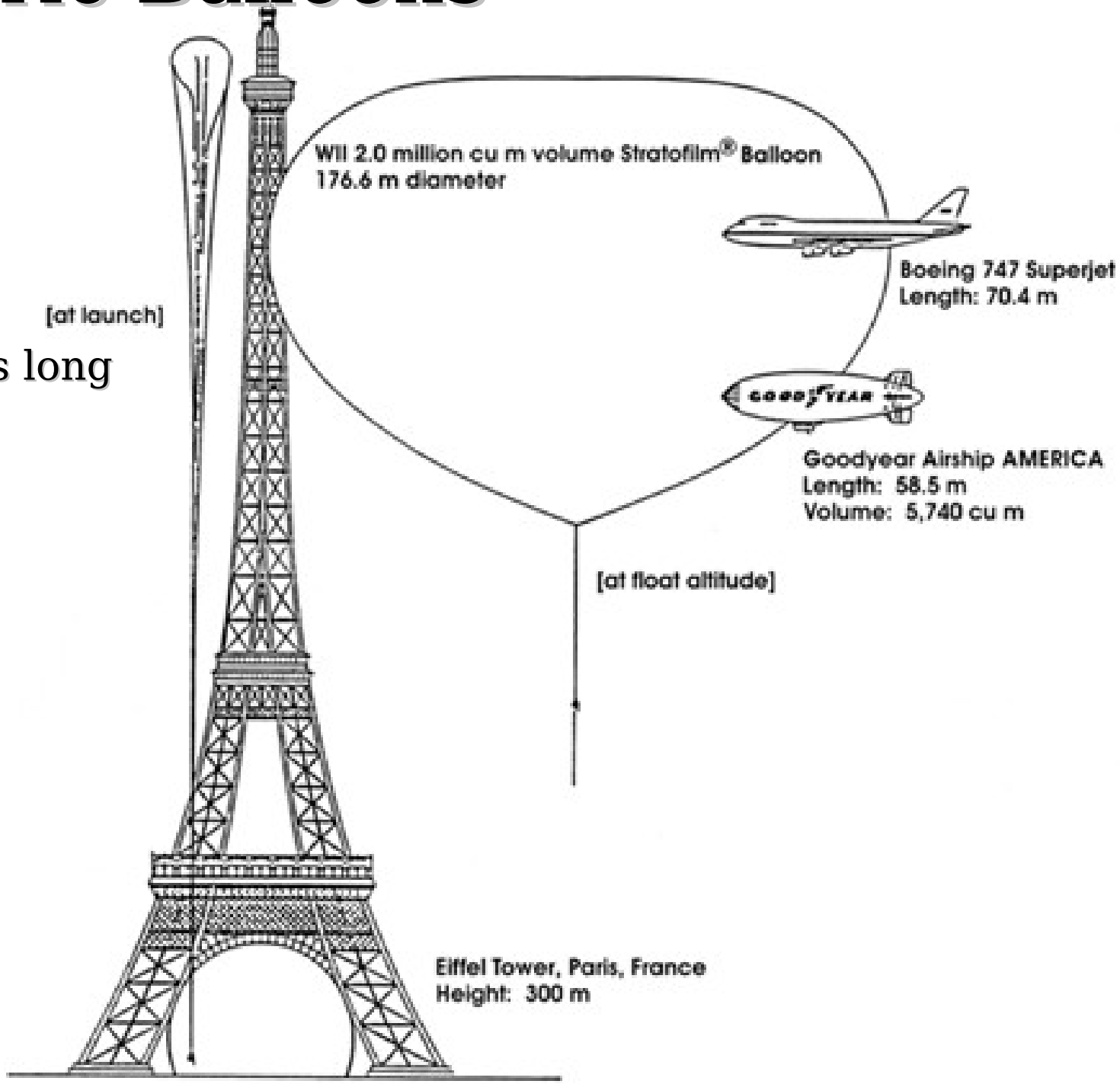
Star forming clouds glow with submm light.
So, we can't see them from the ground.

Stratospheric Balloons

40km altitude

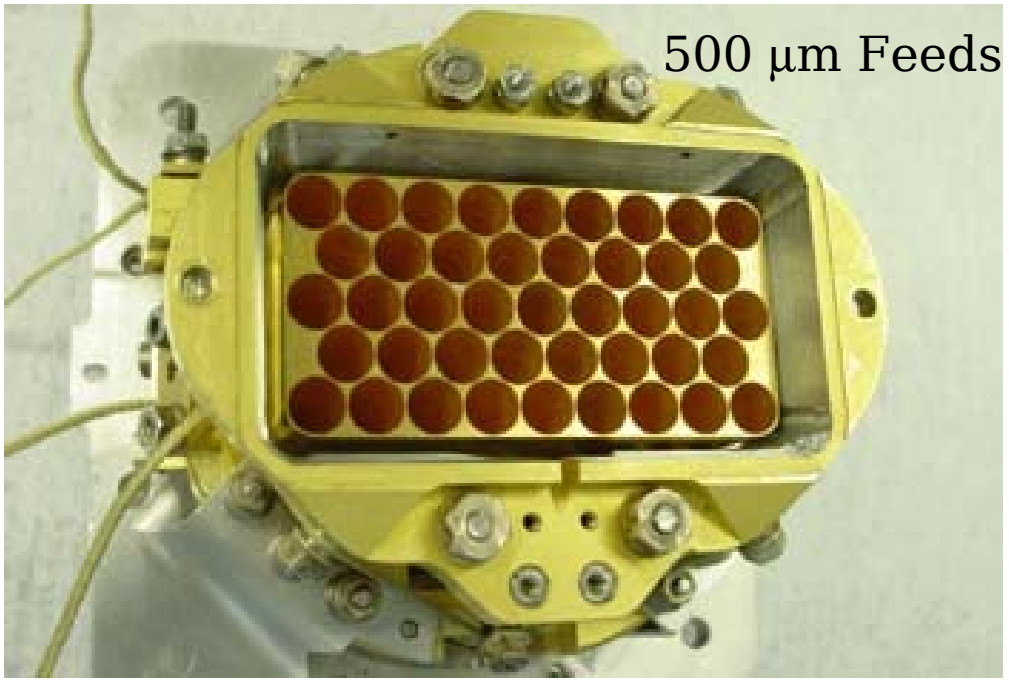
3000kg payloads

Flights up to 50 days long



Instrument

Cryostat:
250mK stage
2 week hold time



288 Bolometers, operating
at 250µ, 350µ and 500µ

2 meter primary mirror
Angular resolution of
30, 41 & 59 arcsec

Instrument: Gondola and Pointing system

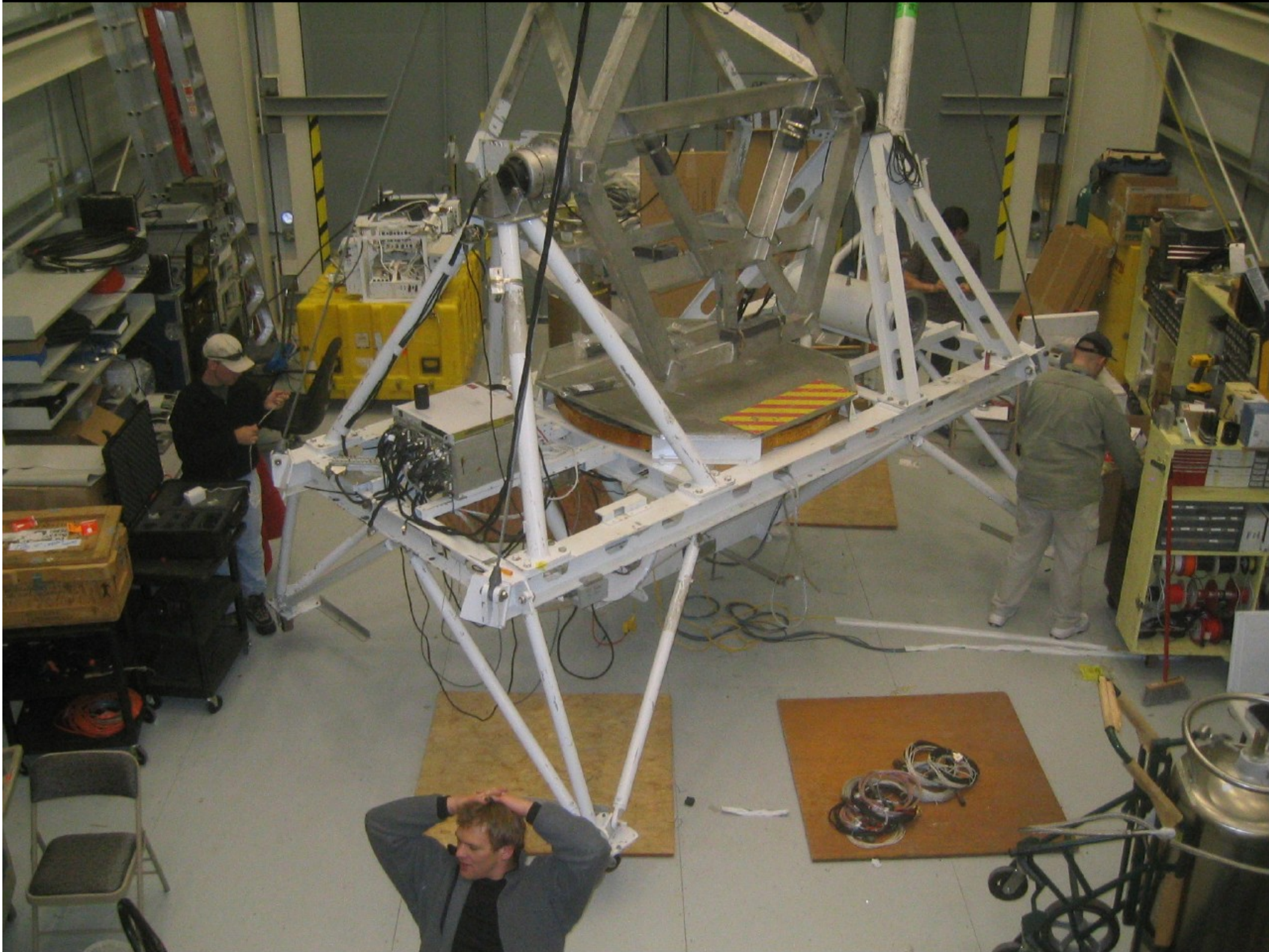
- Pointing control ~1'
- Post flight attitude determination ~4”
- Autonomous or commanded operation

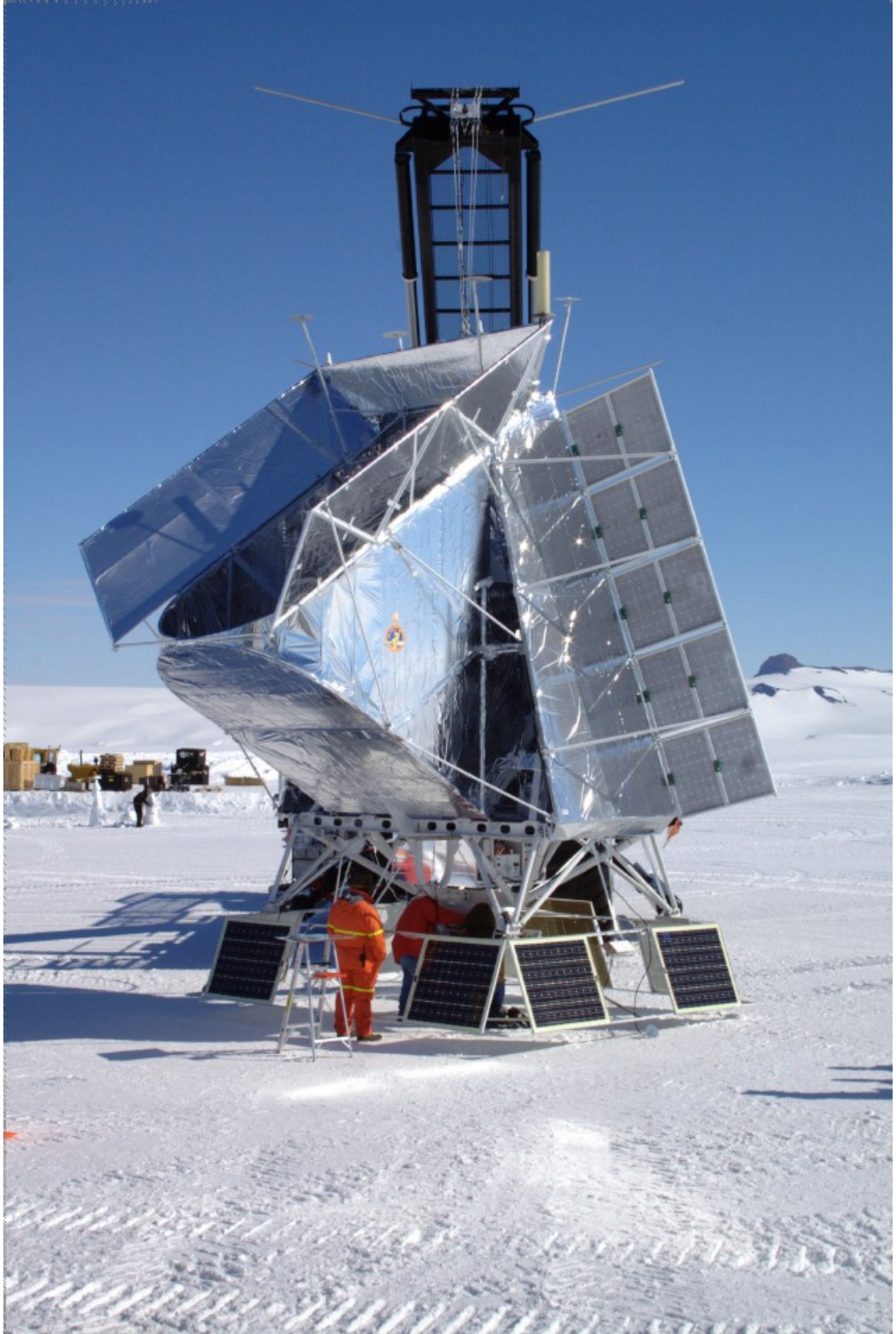
[Photo: Halpern]

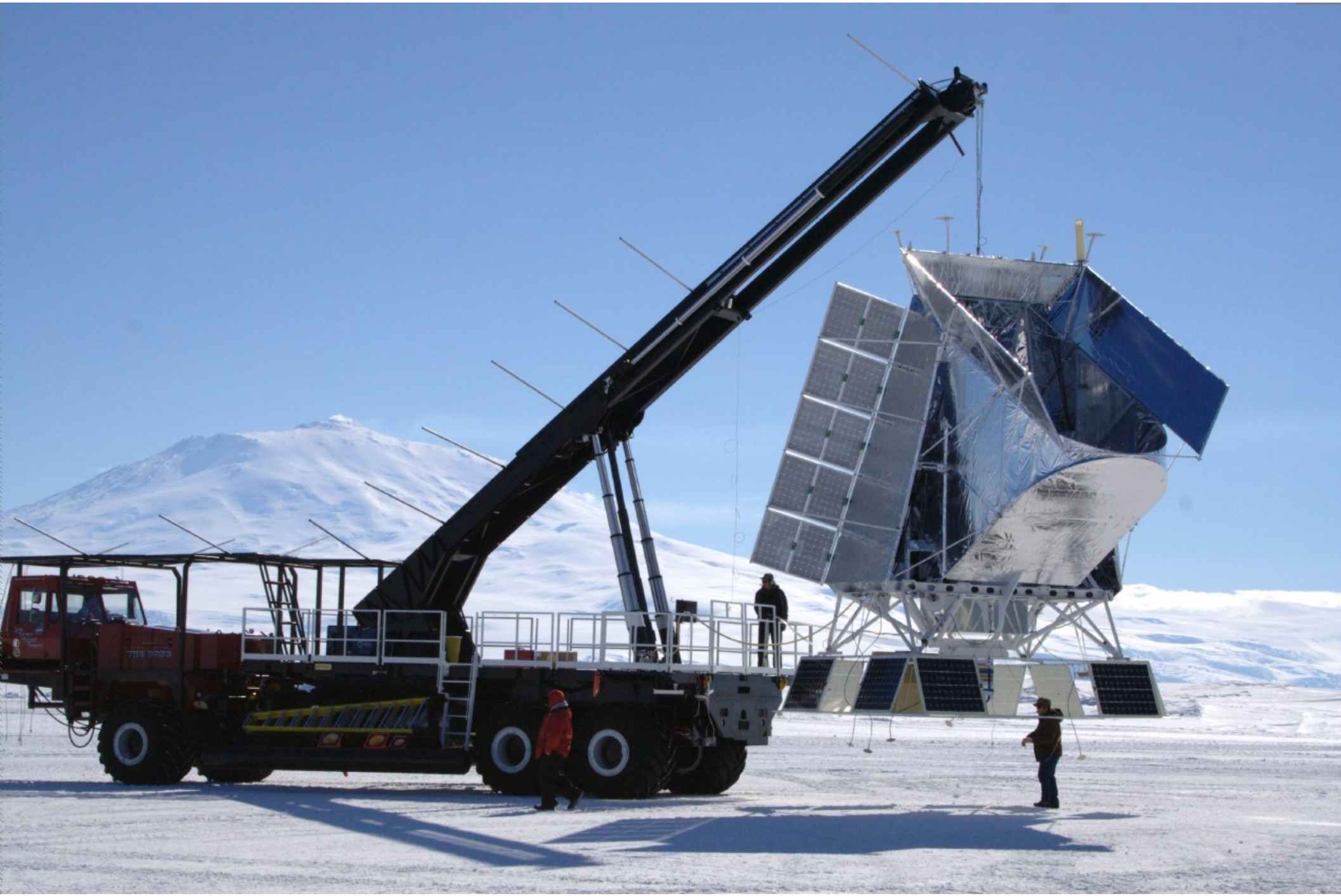
BLAST, 2006: Off to Antarctica!

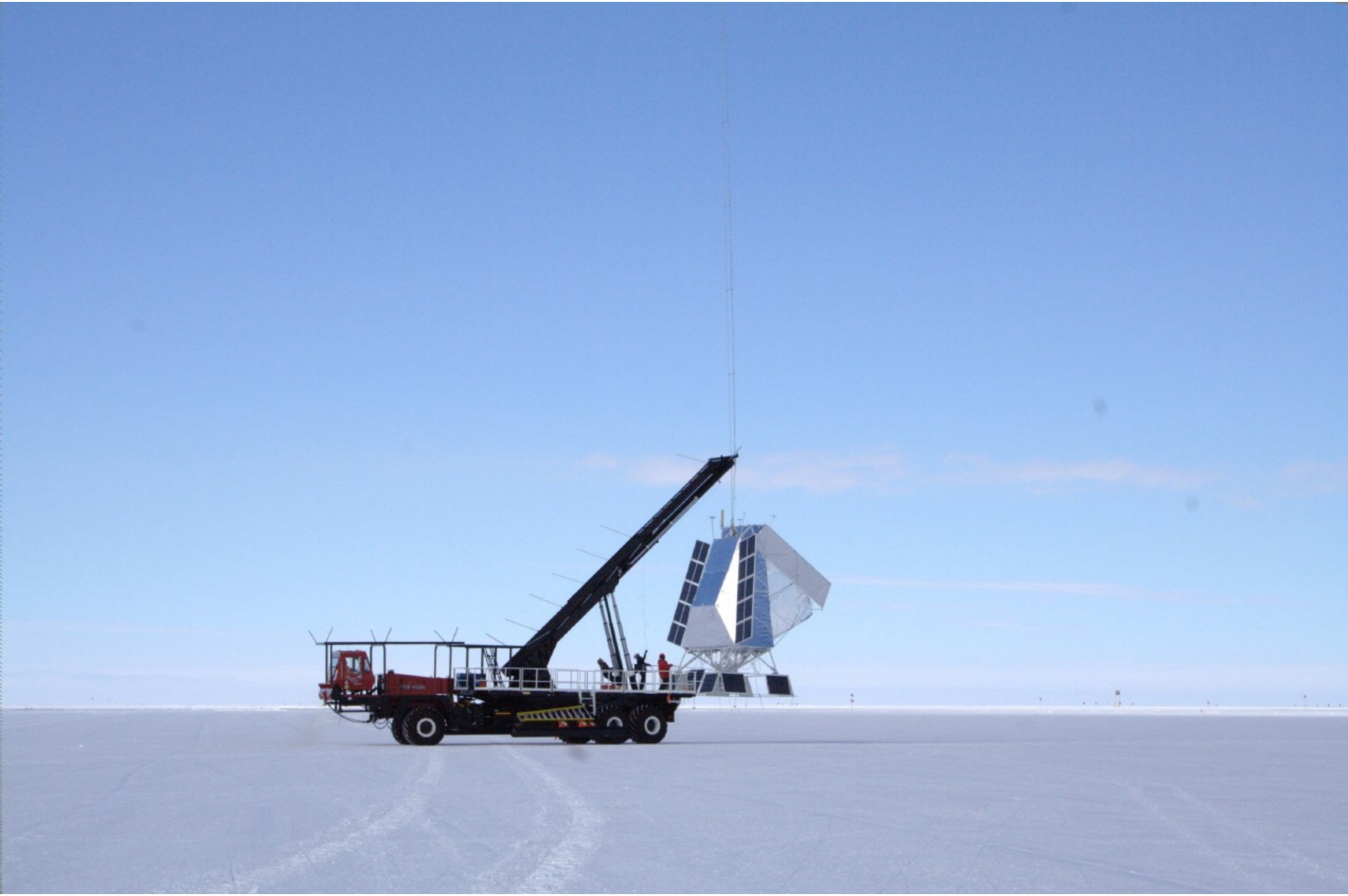

U.S. AIR FORCE
1106
62ND AW
446TH AW

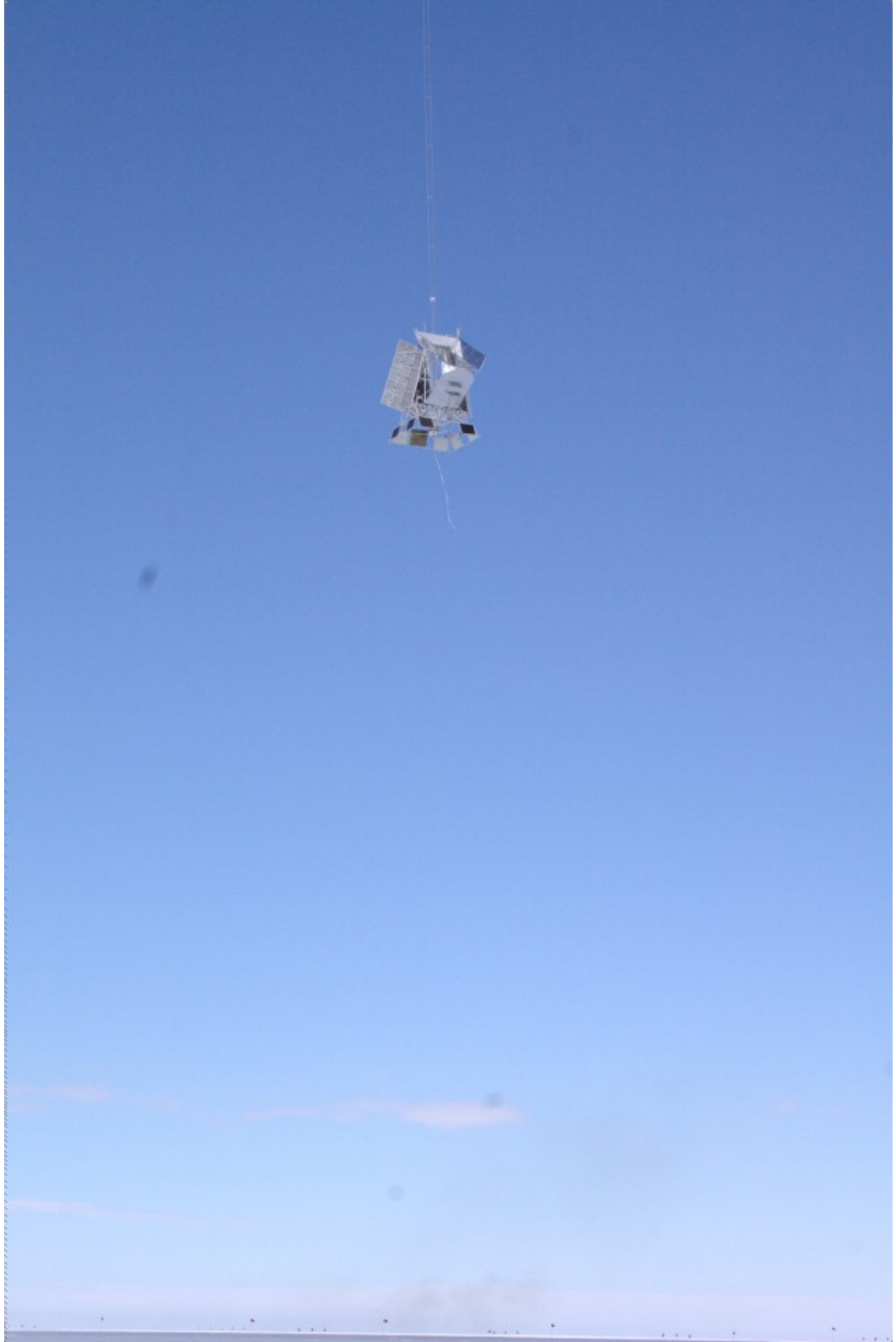

LDB

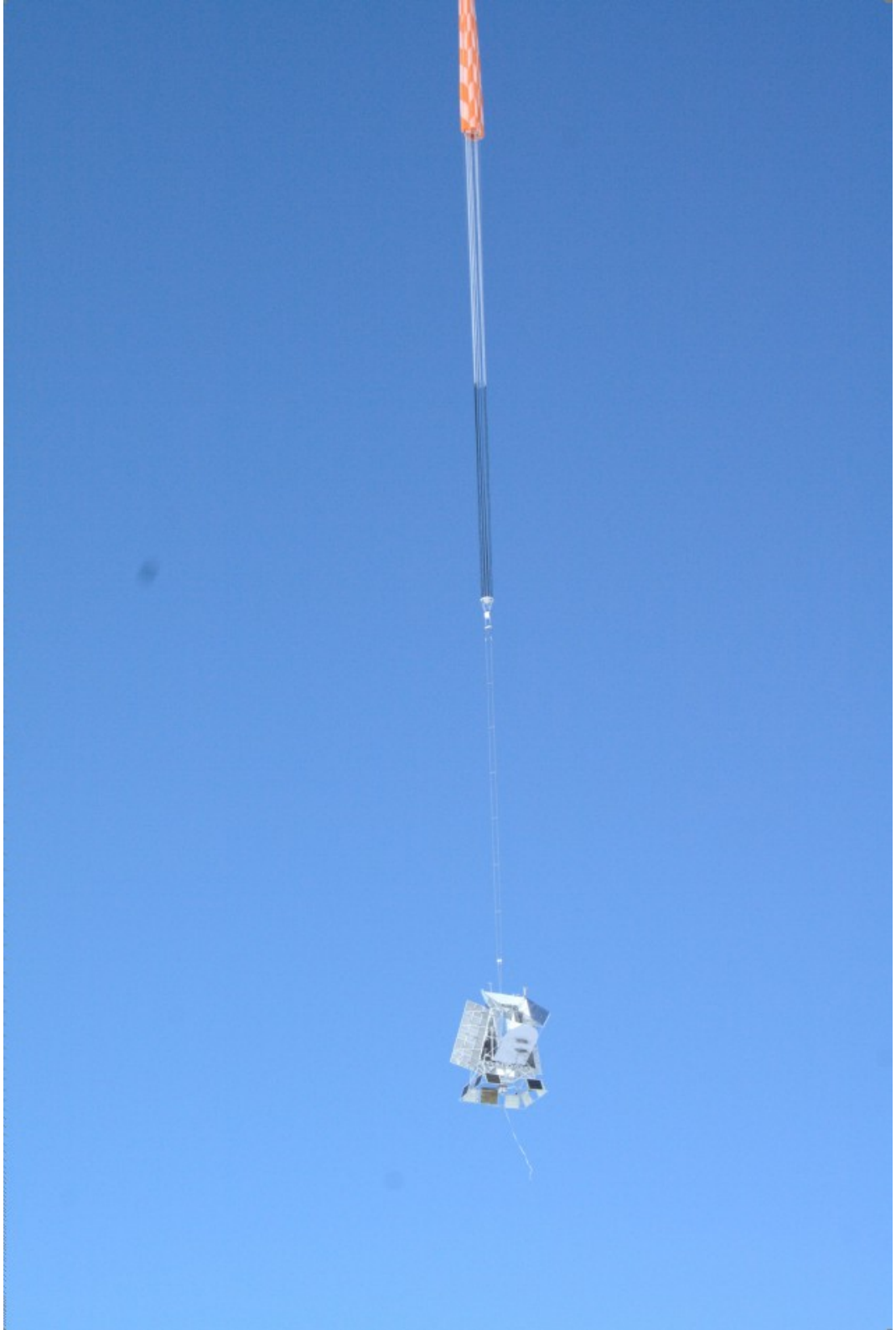


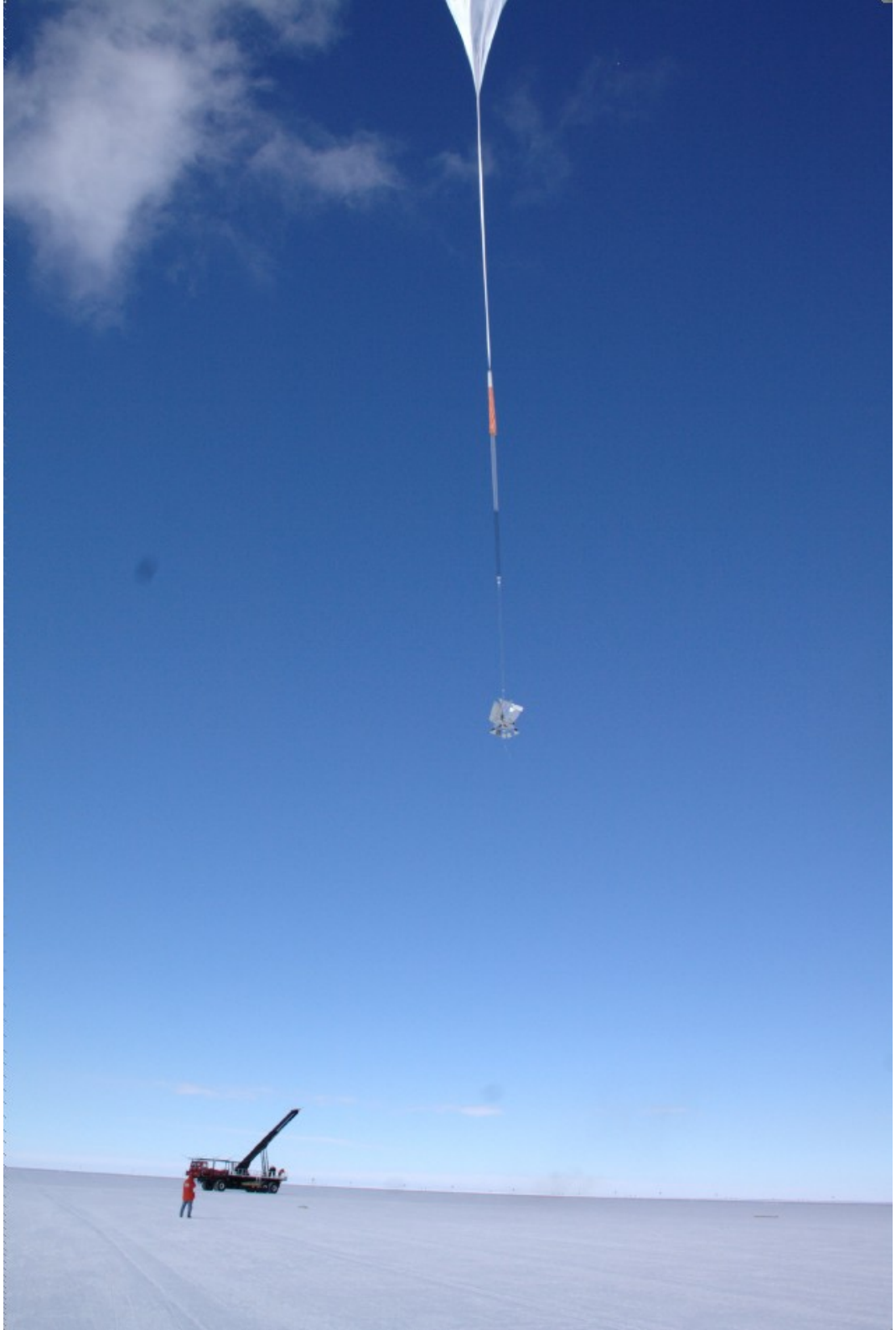




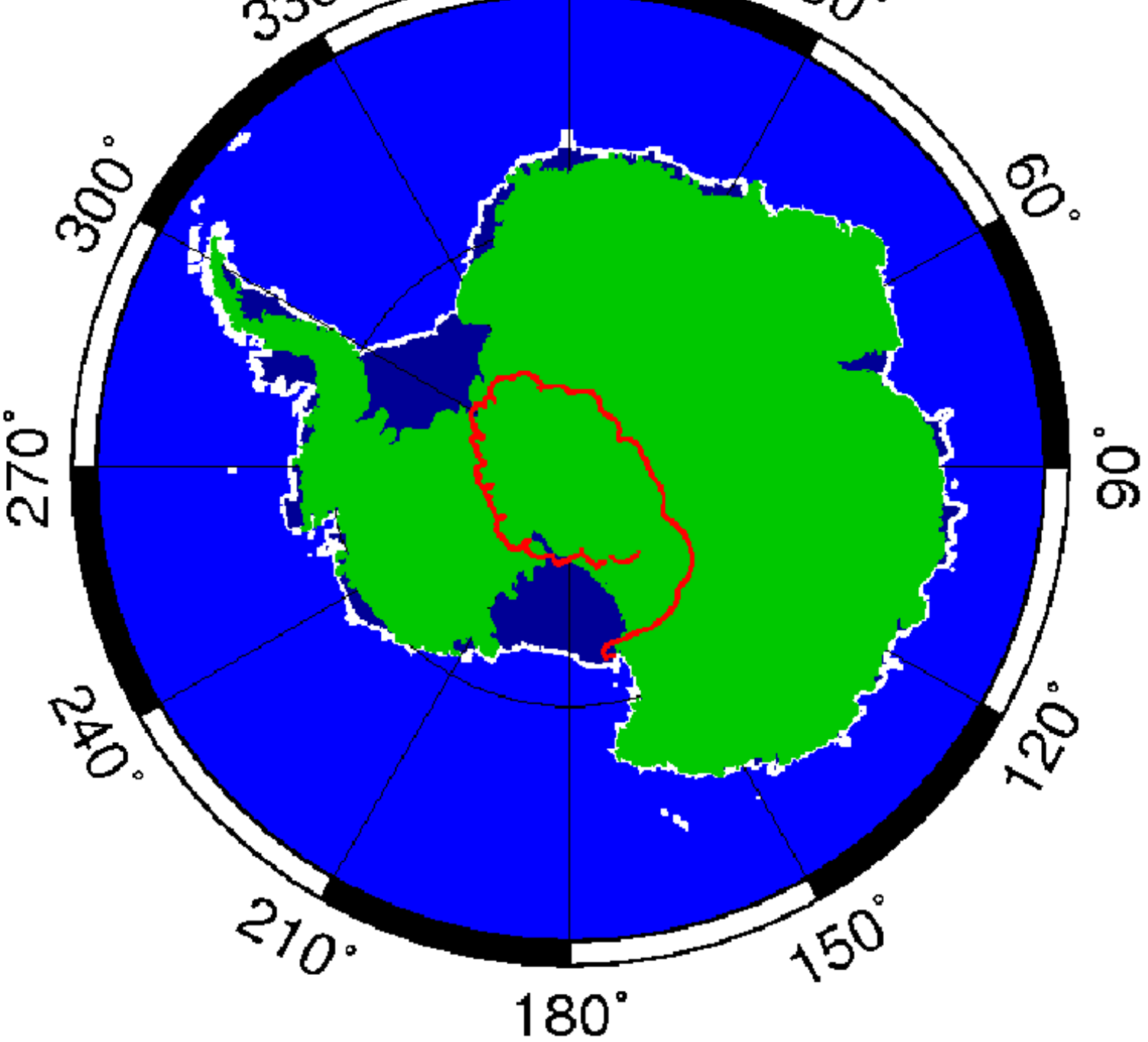




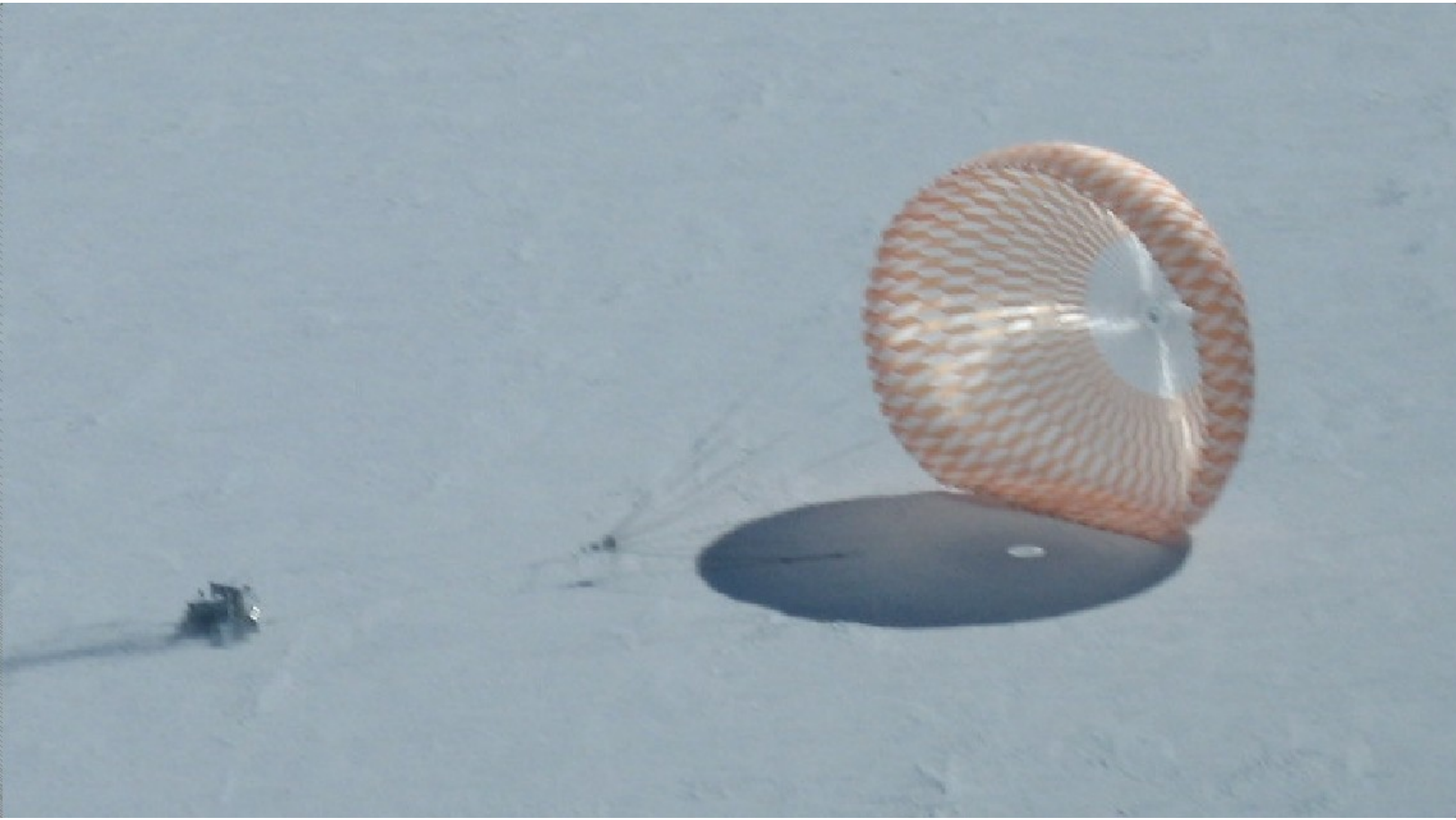




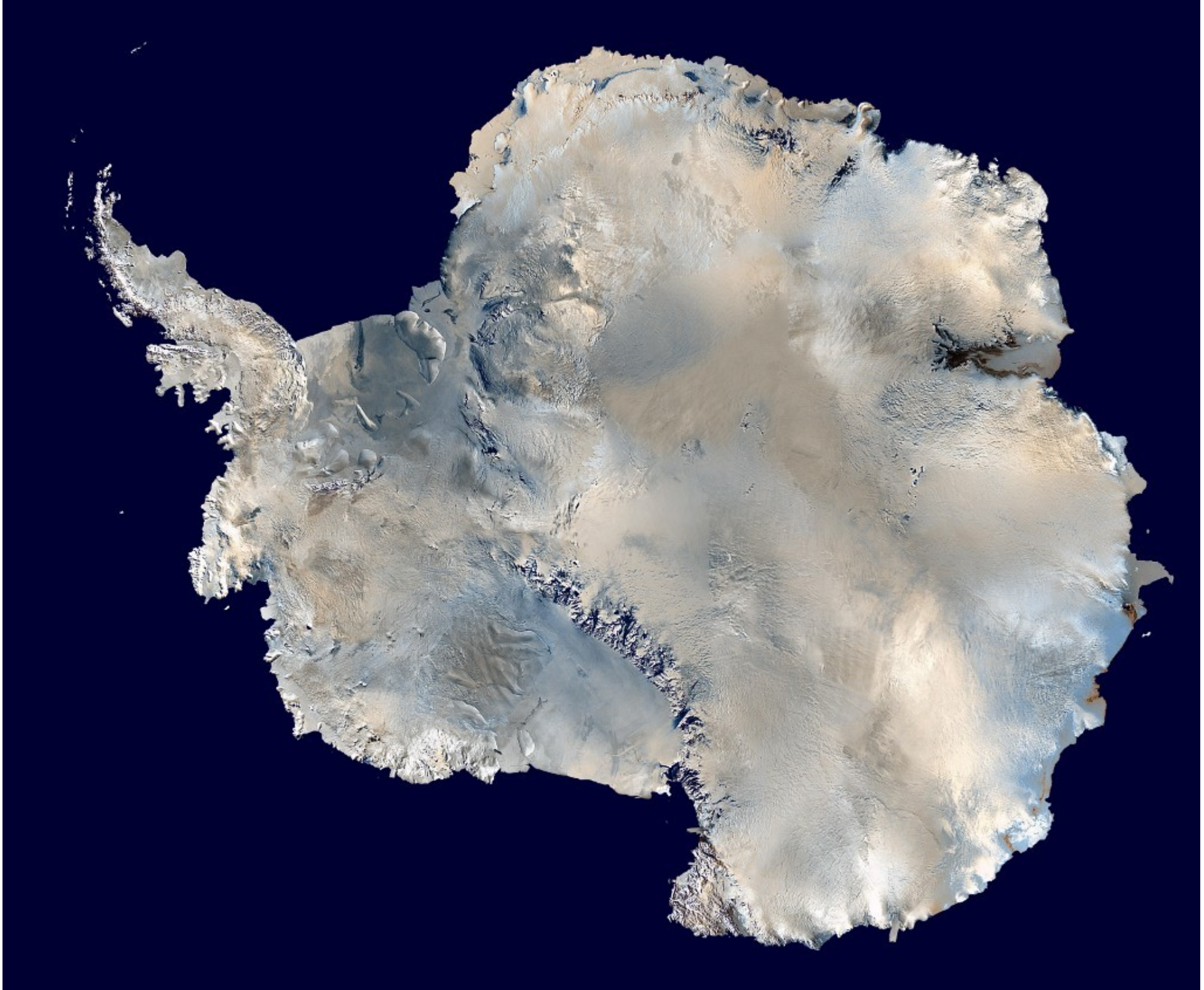

SMALL BUBBLE
Value Pack
SAVE 50%

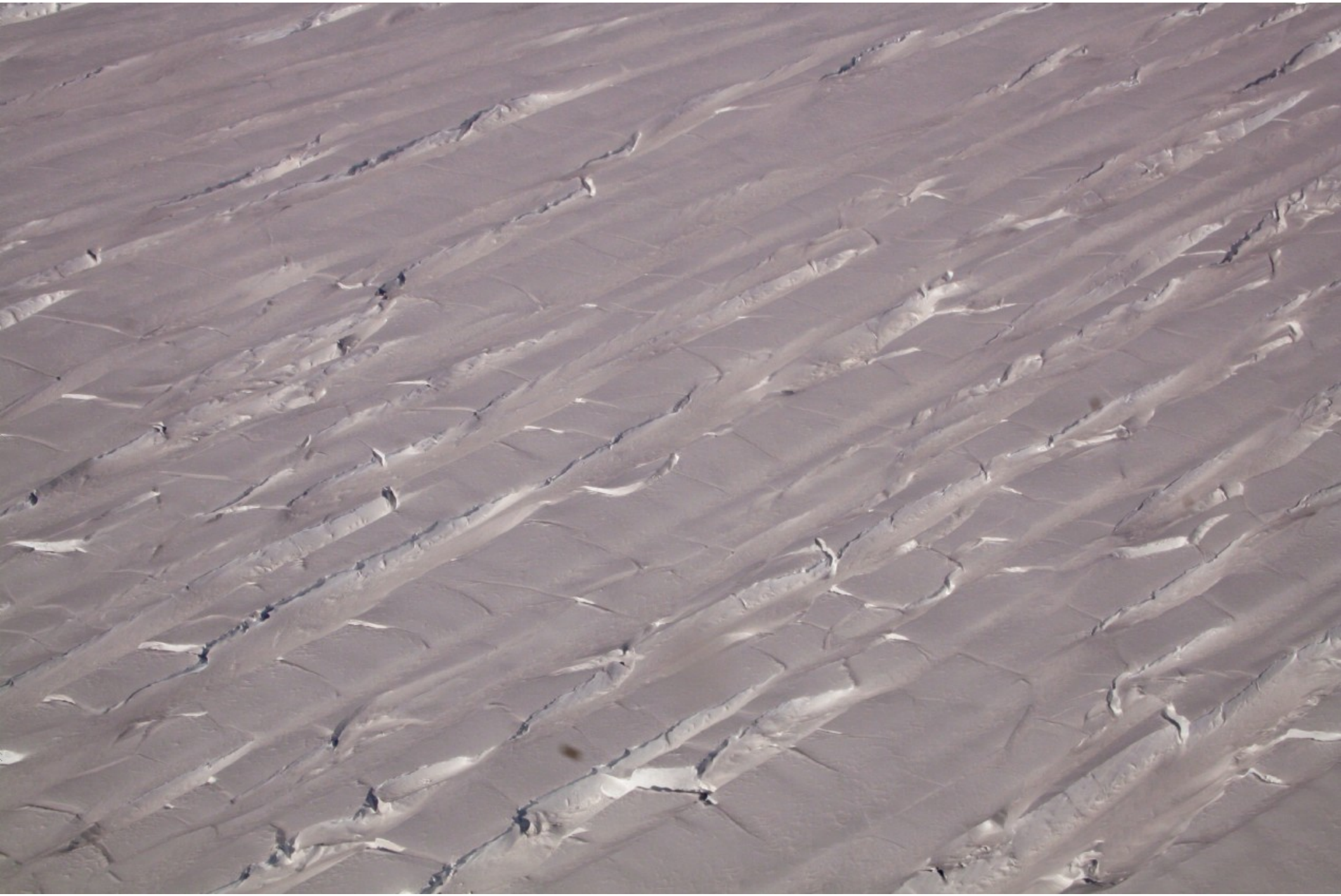


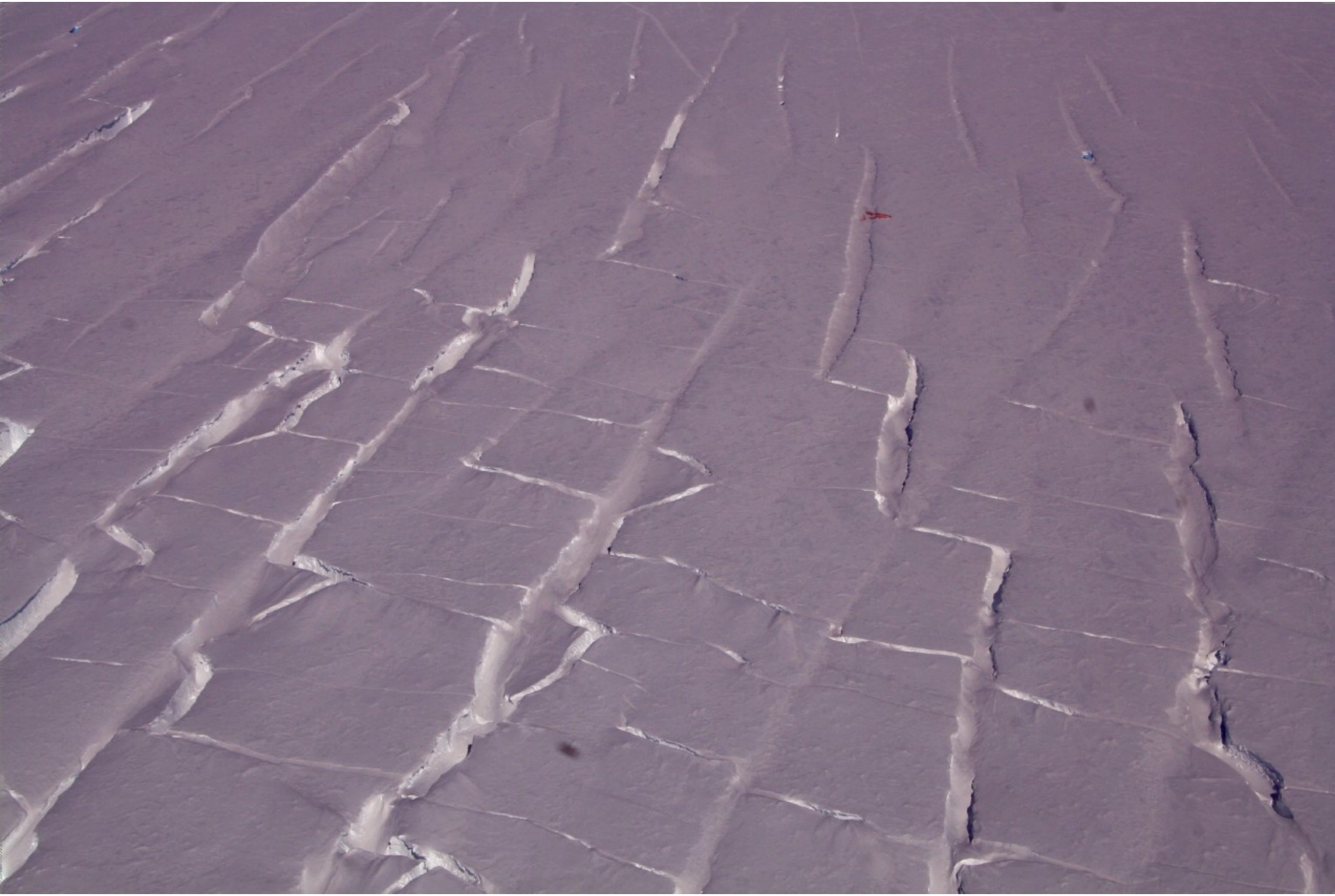
7_BLAST




Kenn Borek Air Ltd.
C-FMKB





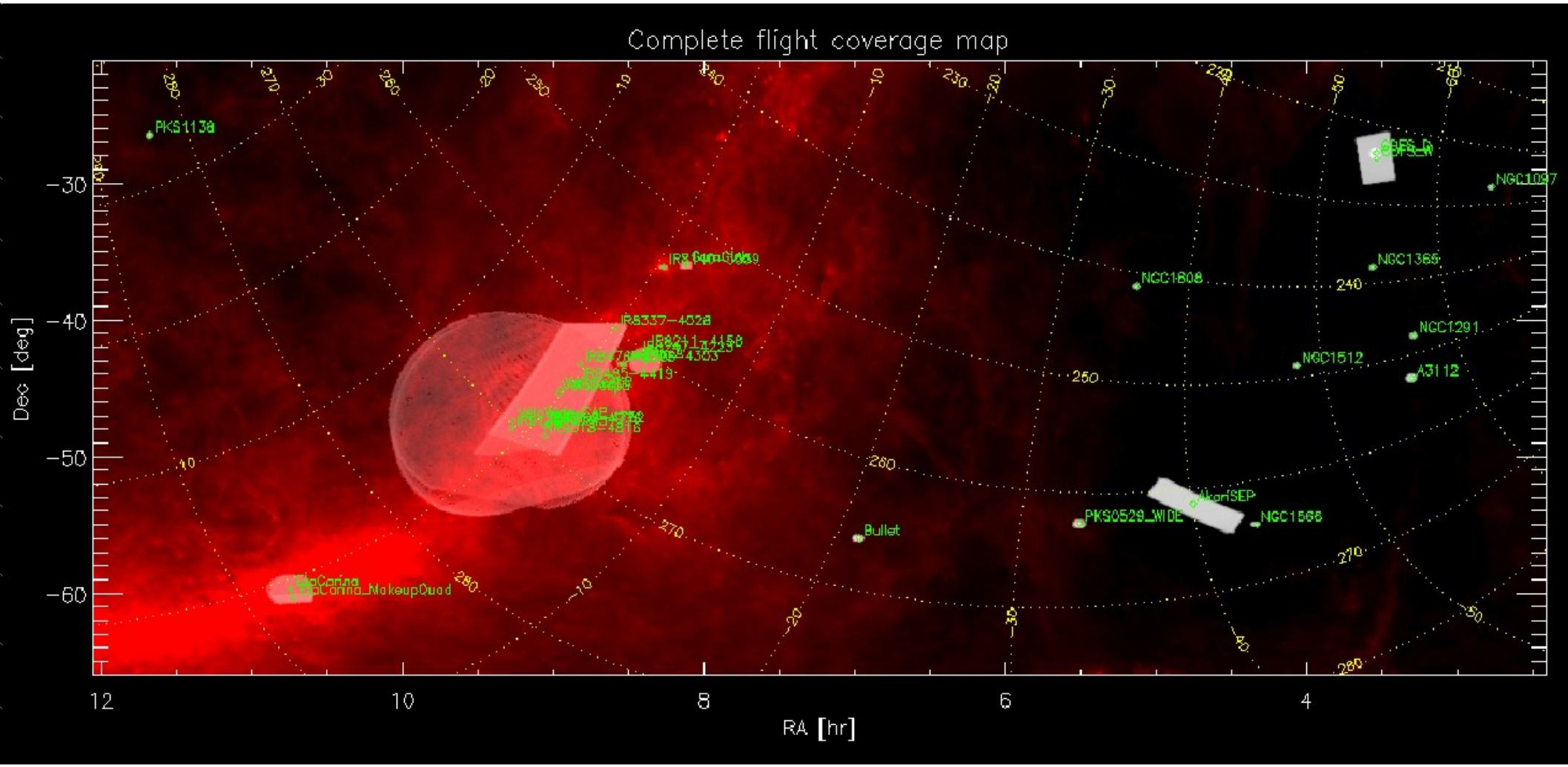


Extragalactic:

Chandra South Deep: 0.58 sq deg
Chandra South Wide: 9.88 sq deg
South Ecliptic Pole: 8.48 sq deg
And 10 other targets

Galactic:

Vela Deep: 48 sq deg.
Vela Wide: 198 sq deg
And 3 other targets



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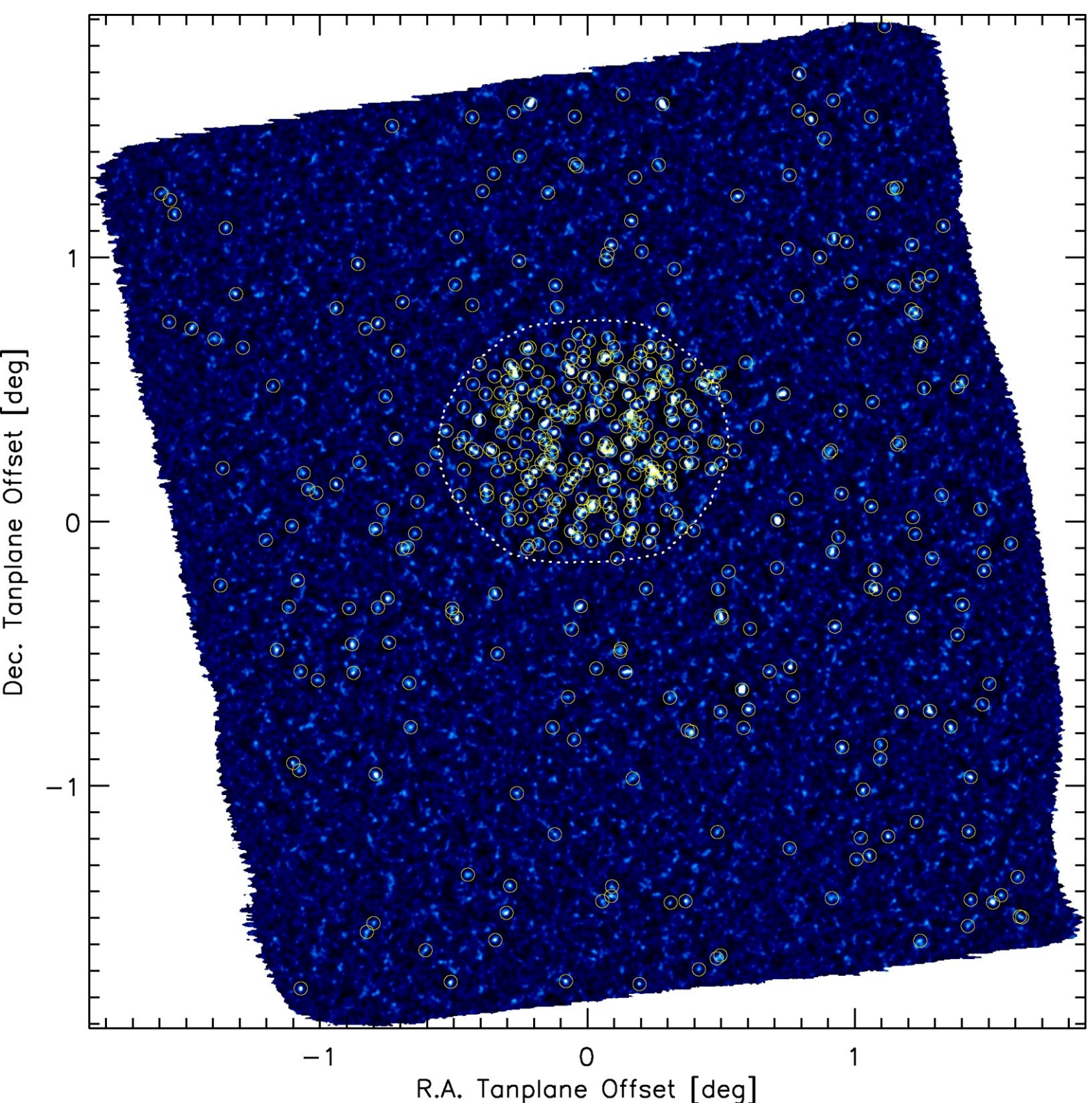
Truch, M. D. P., P. A. R. Ade, J. J. Bock, E. L. Chapin, M. J. Devlin, S. Dicker, M. Griffin, J. O. Gundersen, M. Halpern, P. C. Hargrave, D. H. Hughes, J. Klein, G. Marsden, P. G. Martin, P. Mauskopf, C. B. Netterfield, L. Olmi, E. Pascale, G. Patanchon, M. Rex, D. Scott, C. Semisch, C. Tucker, G. S. Tucker, M. P. Viero, and D. V. Wiebe, The Balloon-borne Large Aperture Submillimeter Telescope (BLAST) 2005: Calibration and Targeted Sources, 2008, The Astrophysical Journal, 681, 415

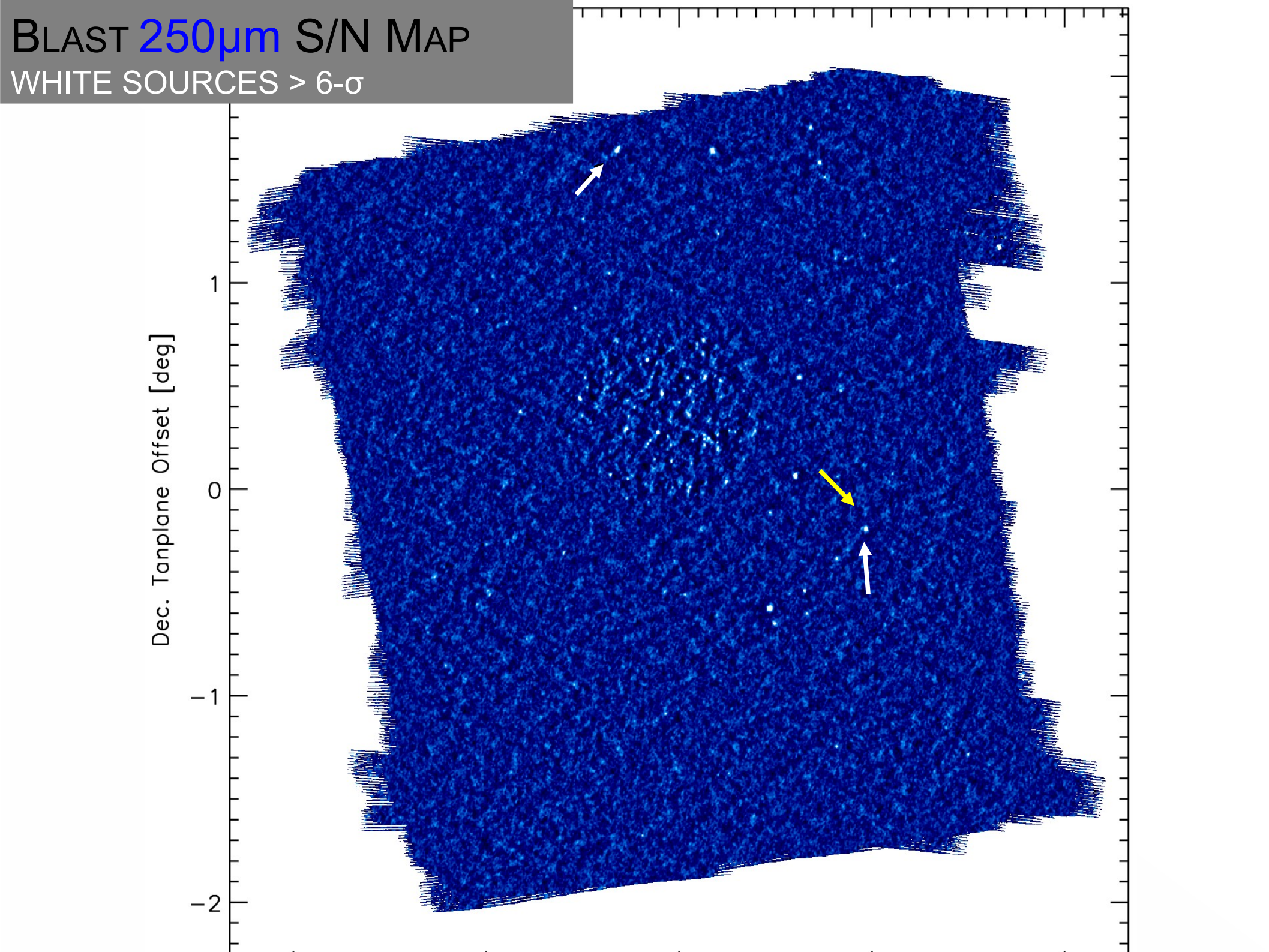
Pascale, E., P. A. R. Ade, J. J. Bock, E. L. Chapin, J. Chung, M. J. Devlin, S. Dicker, M. Griffin, J. O. Gundersen, M. Halpern, P. C. Hargrave, D. H. Hughes, J. Klein, C. J. MacTavish, G. Marsden, P. G. Martin, T. G. Martin, P. Mauskopf, C. B. Netterfield, L. Olmi, G. Patanchon, M. Rex, D. Scott, C. Semisch, N. Thomas, M. D. P. Truch, C. Tucker, G. S. Tucker, M. P. Viero, and D. V. Wiebe, The Balloon-borne Large Aperture Submillimeter Telescope: BLAST, 2008, The Astrophysical Journal, 681, 400



BLAST Deep and Wide Fields Combined S/N Map

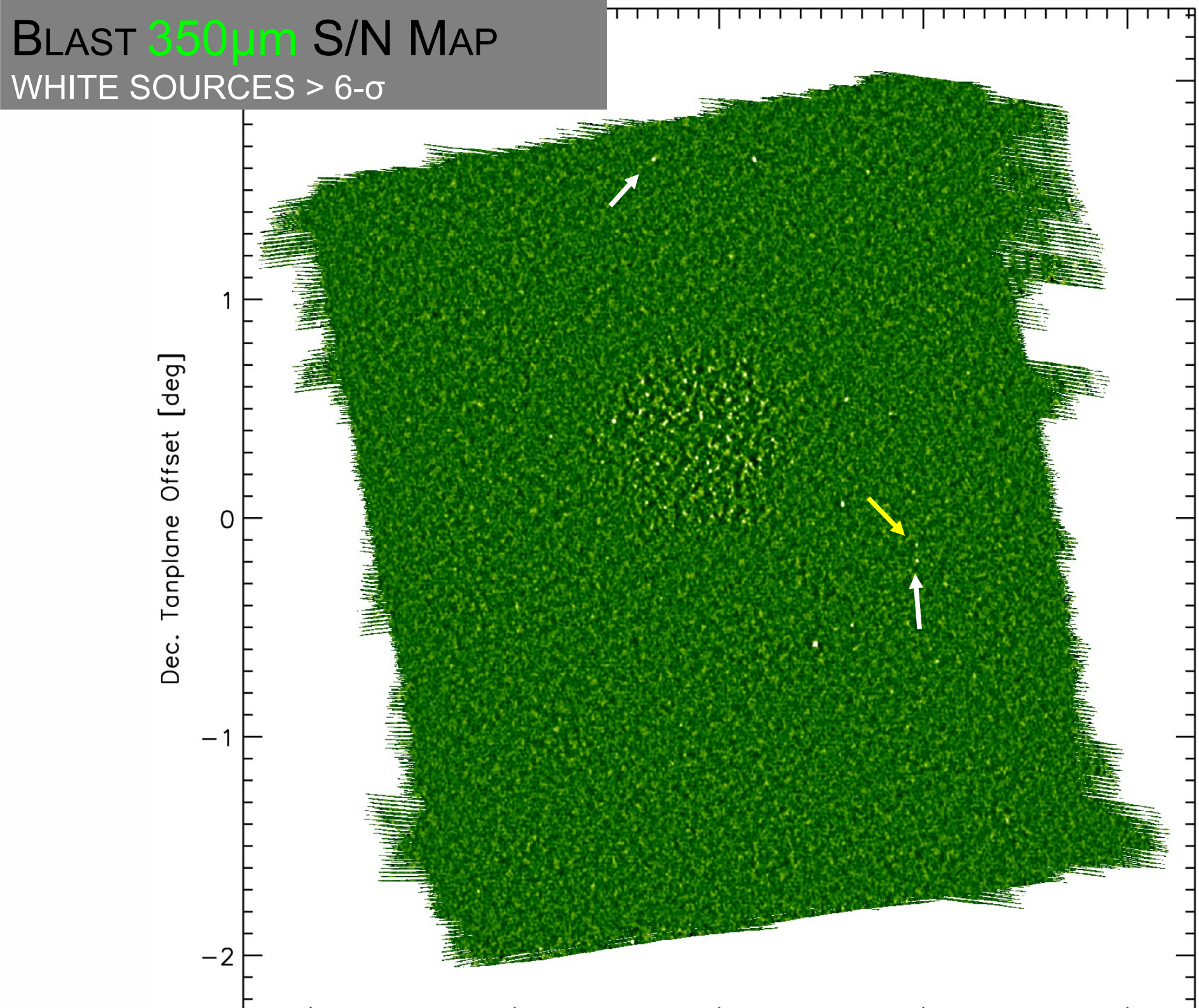
>500 sources
> 5σ!!!
+ many more at fainter cuts

0.8 sq. deg. DEEP
10 sq. deg. WIDE


BLAST 250μm S/N MAP
WHITE SOURCES > 6-σ
Dec. Tanplane Offset [deg]
1
0
−1
−2

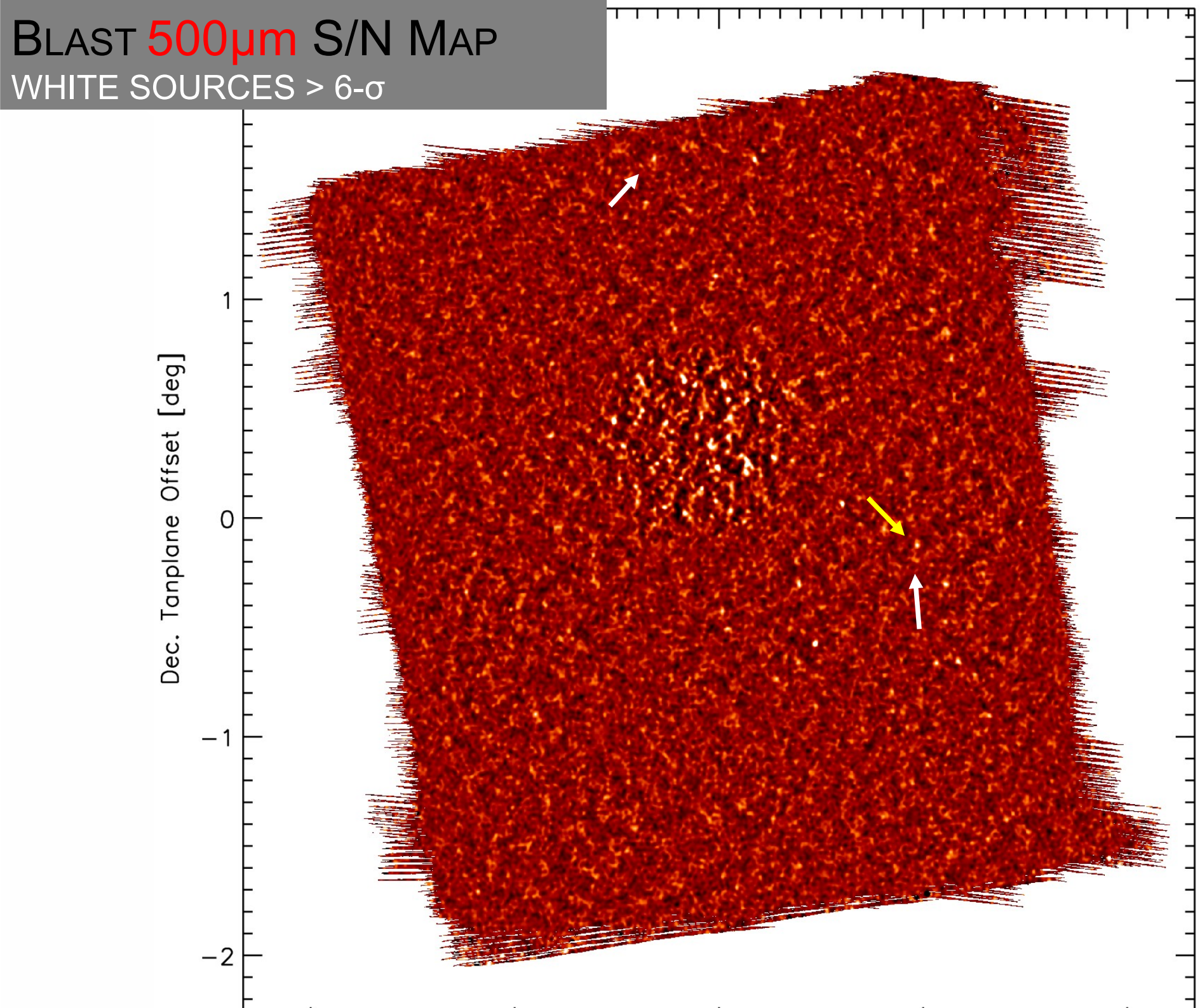
BLAST 350μm S/N MAP

WHITE SOURCES > 6-σ

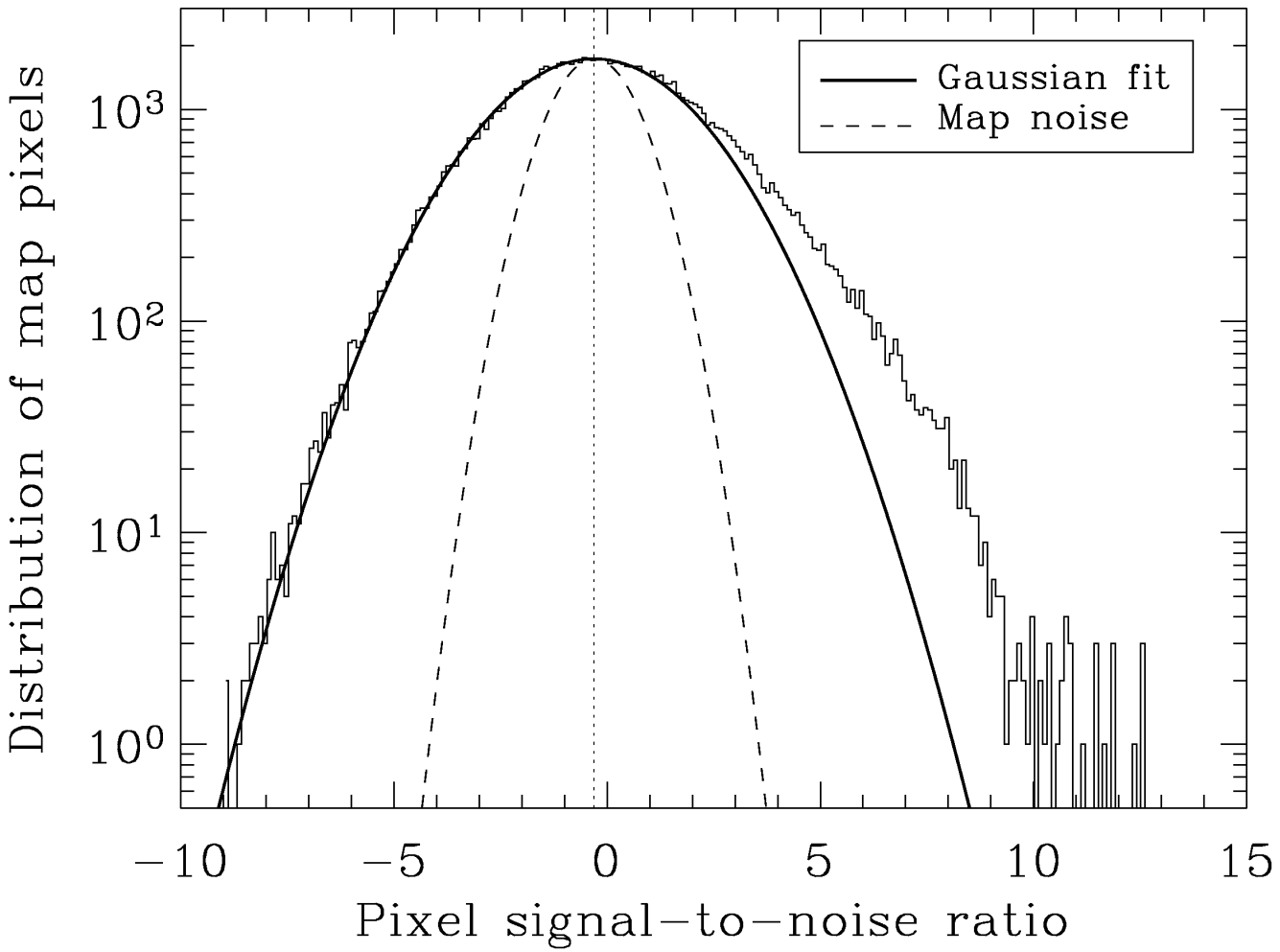


BLAST 500μm S/N MAP

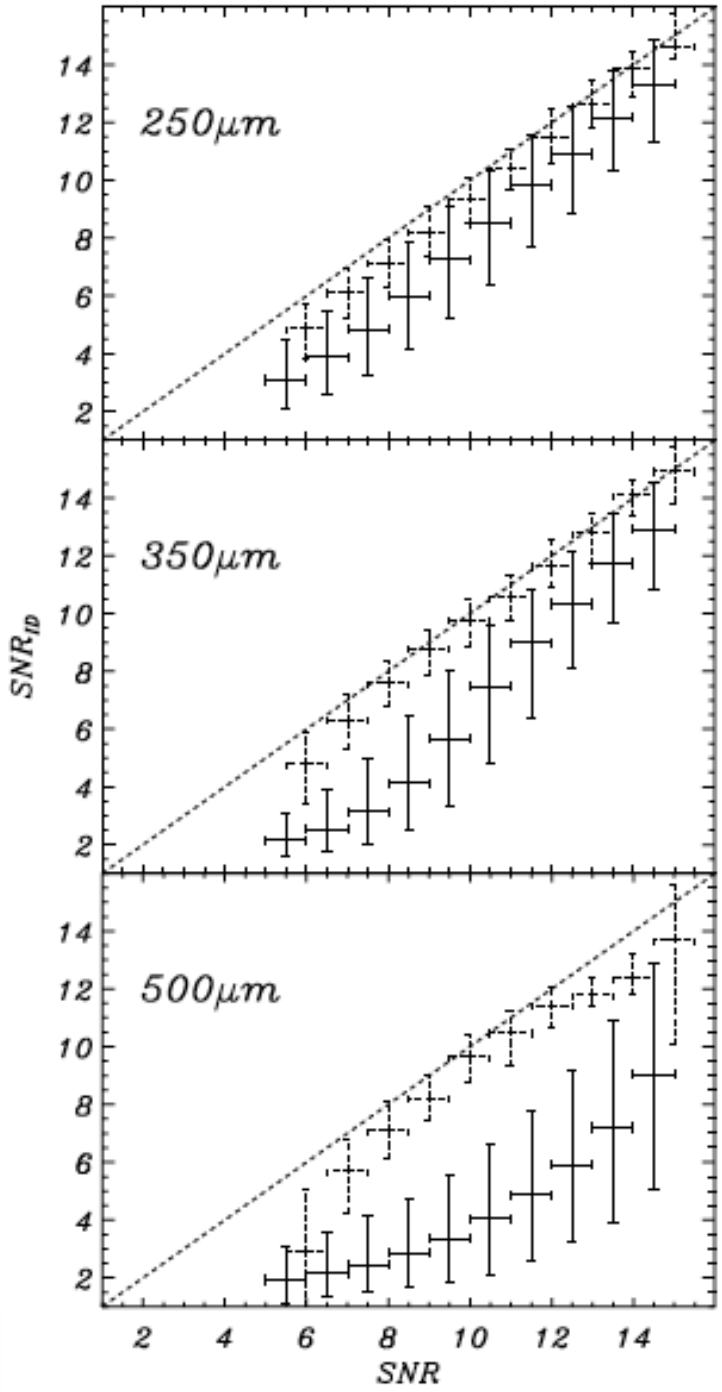
WHITE SOURCES > 6-σ



Confusion Dominated Maps...

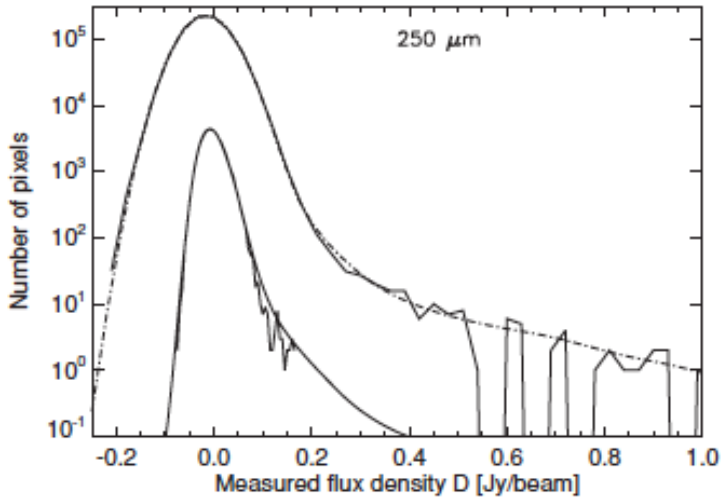


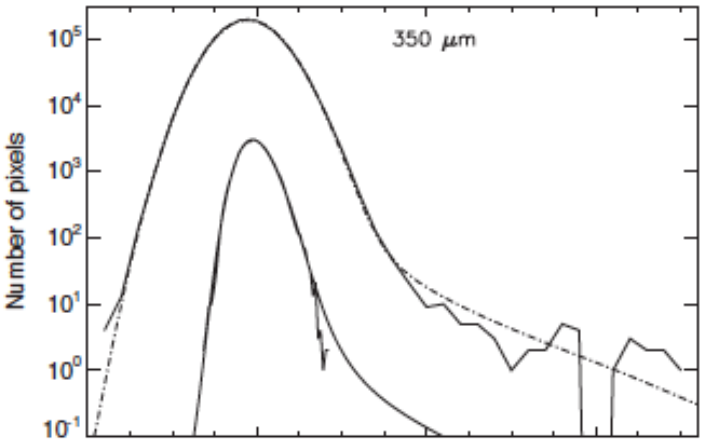
Marsden et al, 2009

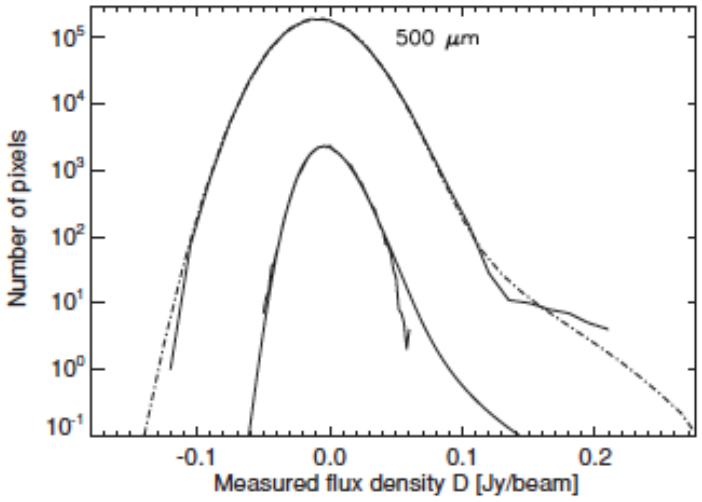


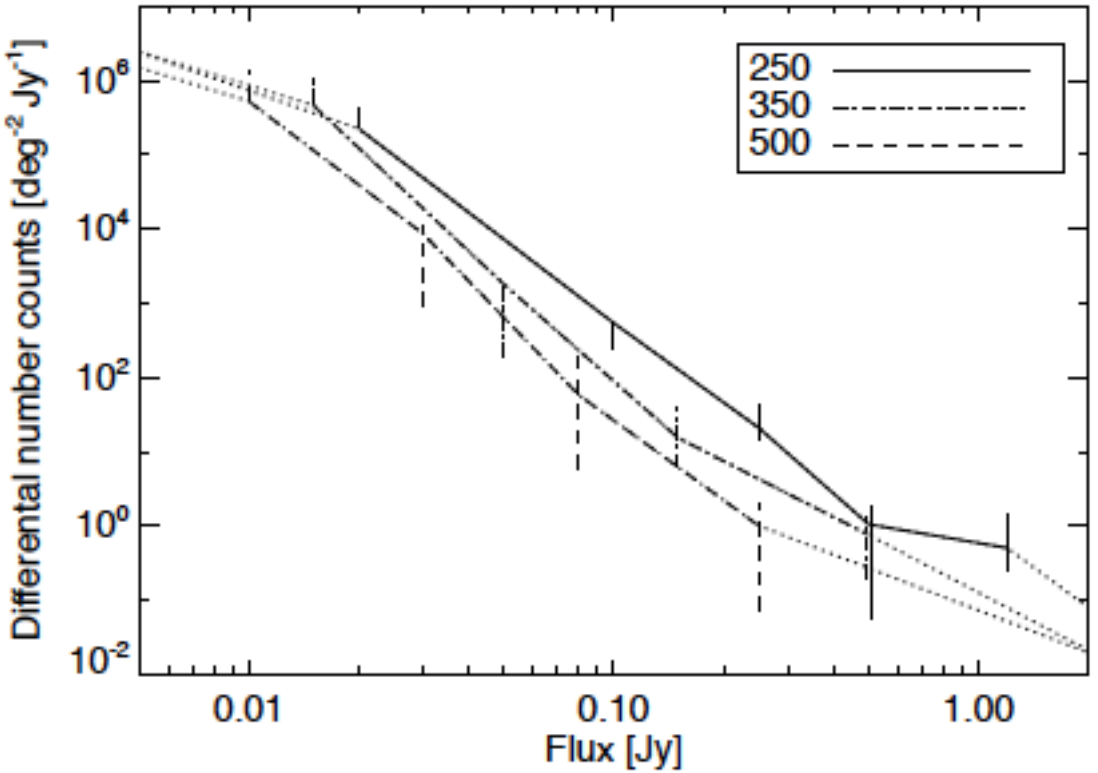
Moncelsi et al.

Determine number counts by fitting to map histograms... not by counting sources.







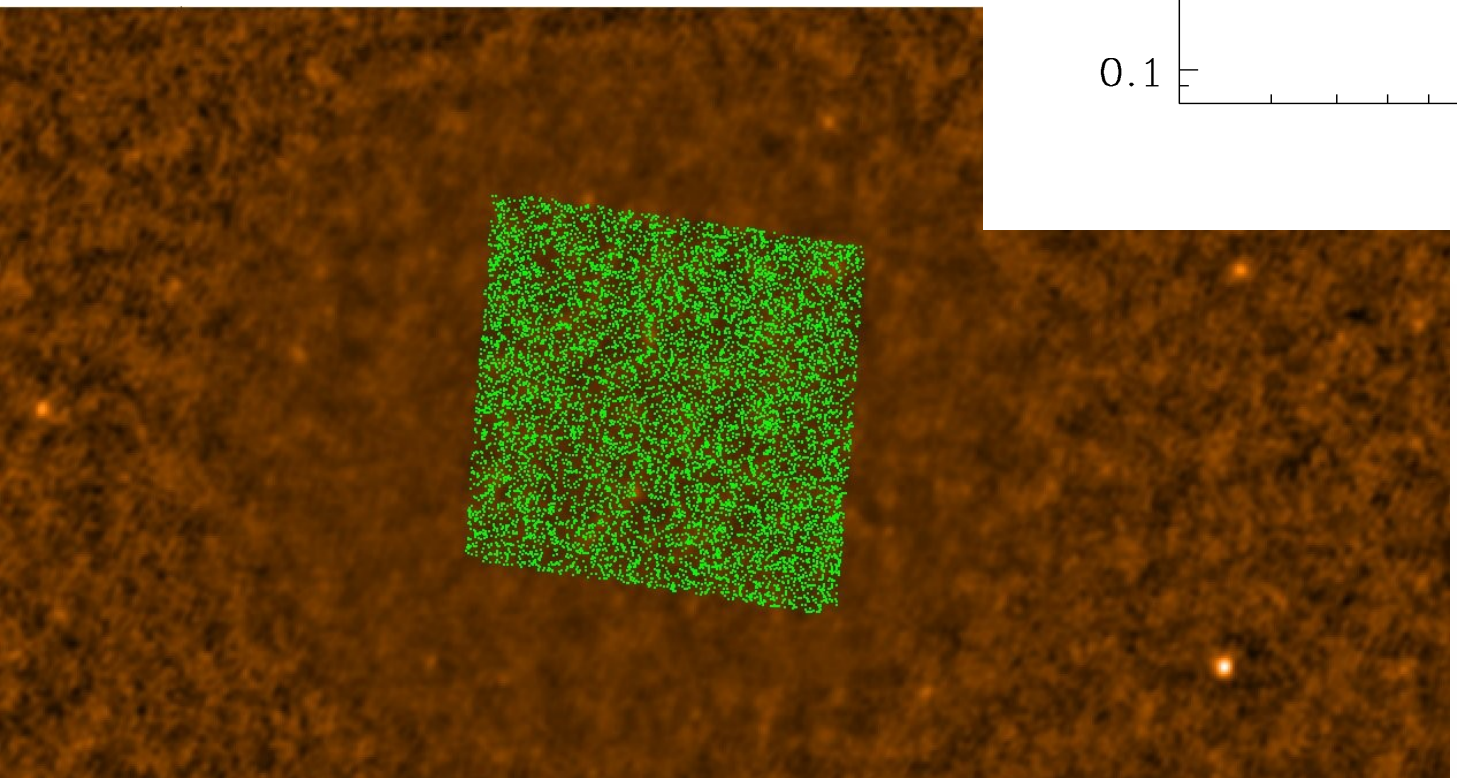


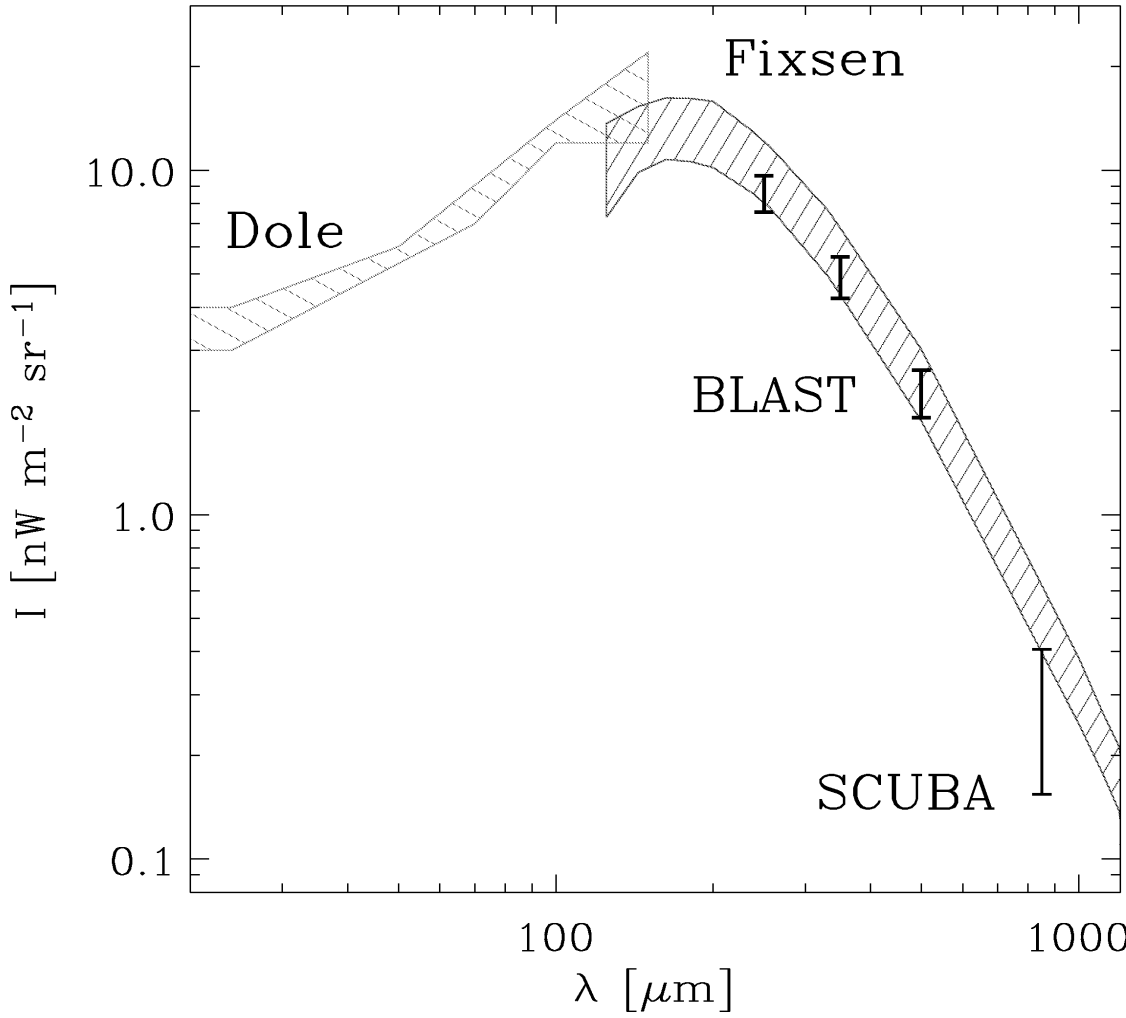
Patanchon et al.

Determining Galaxy Properties:

Correlate BLAST maps with FIDEL 24 micron Catalog (9118 Galaxies)

Determine average flux per Galaxy in each BLAST band



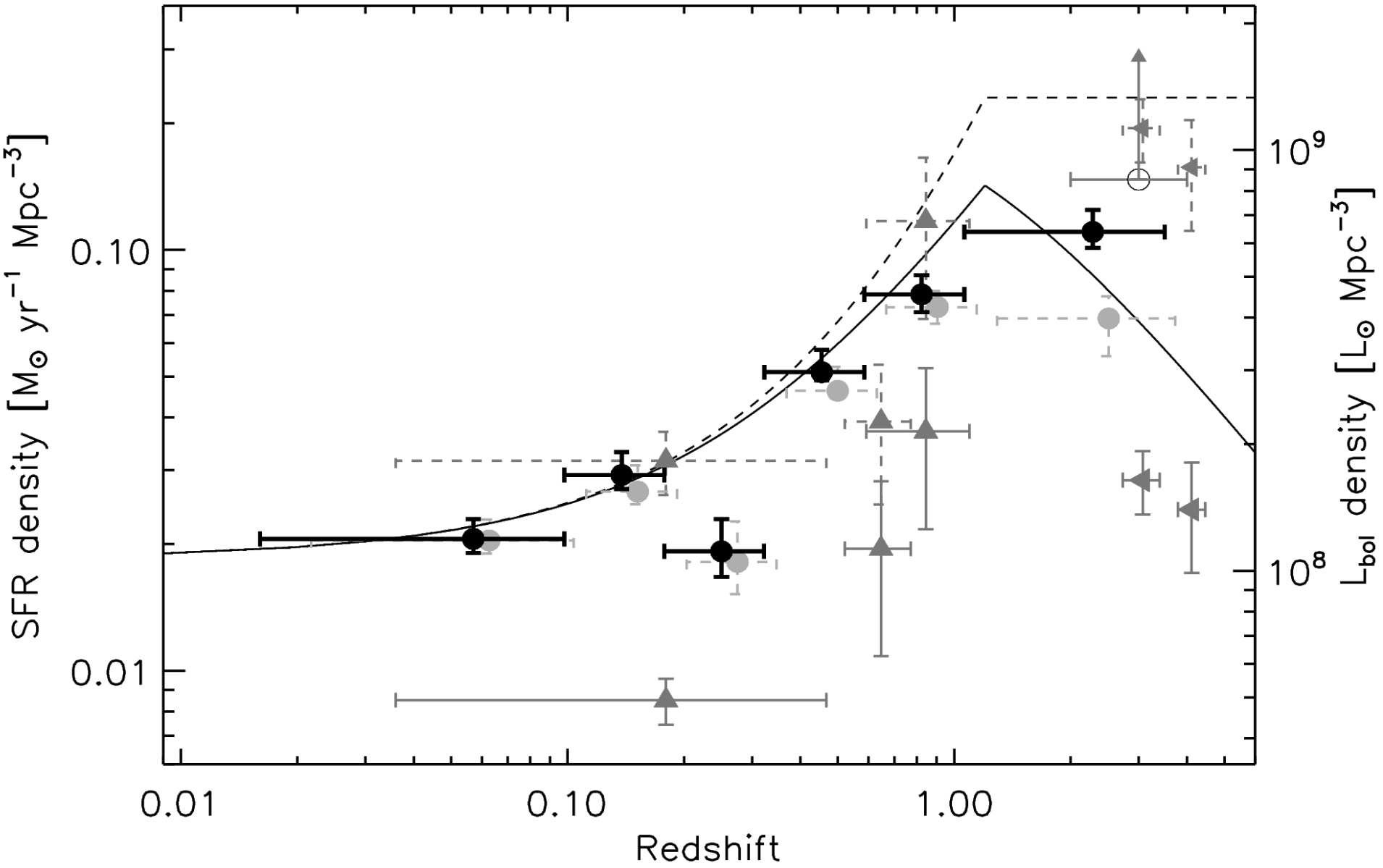


Cosmic Infrared Background is from these Galaxies...

Marsden et al.

Devlin et al.

Break into Redshift bins to find star formation history



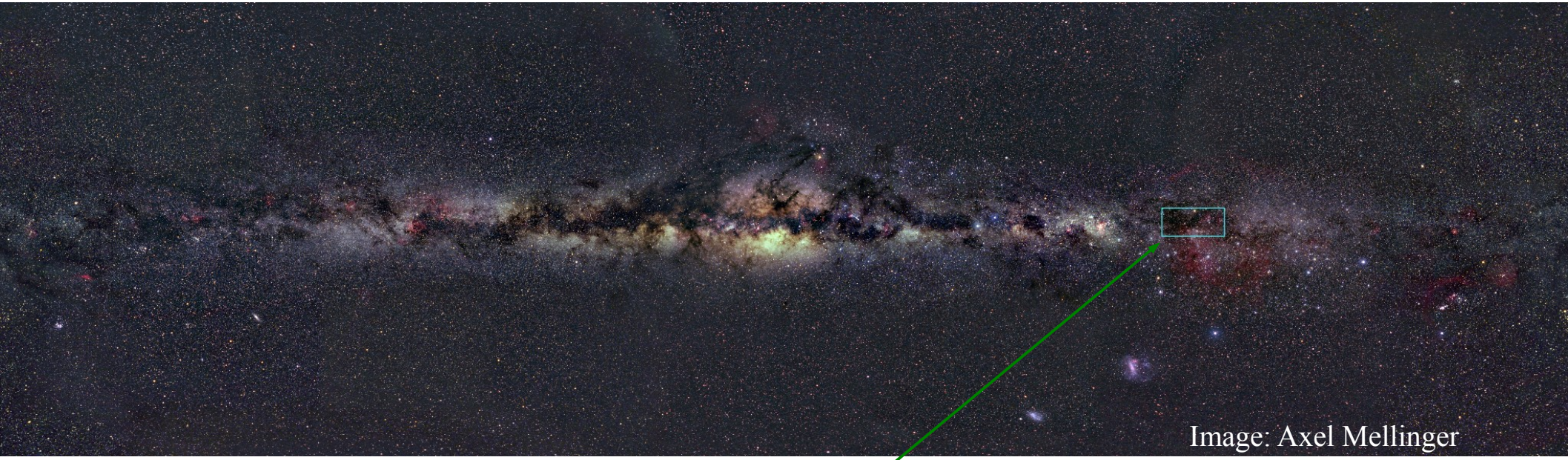
Pascale et al, 2009

The Milky Way Galaxy

Our galaxy, viewed from the inside.

The Milky Way Galaxy

Our galaxy, viewed from the inside.



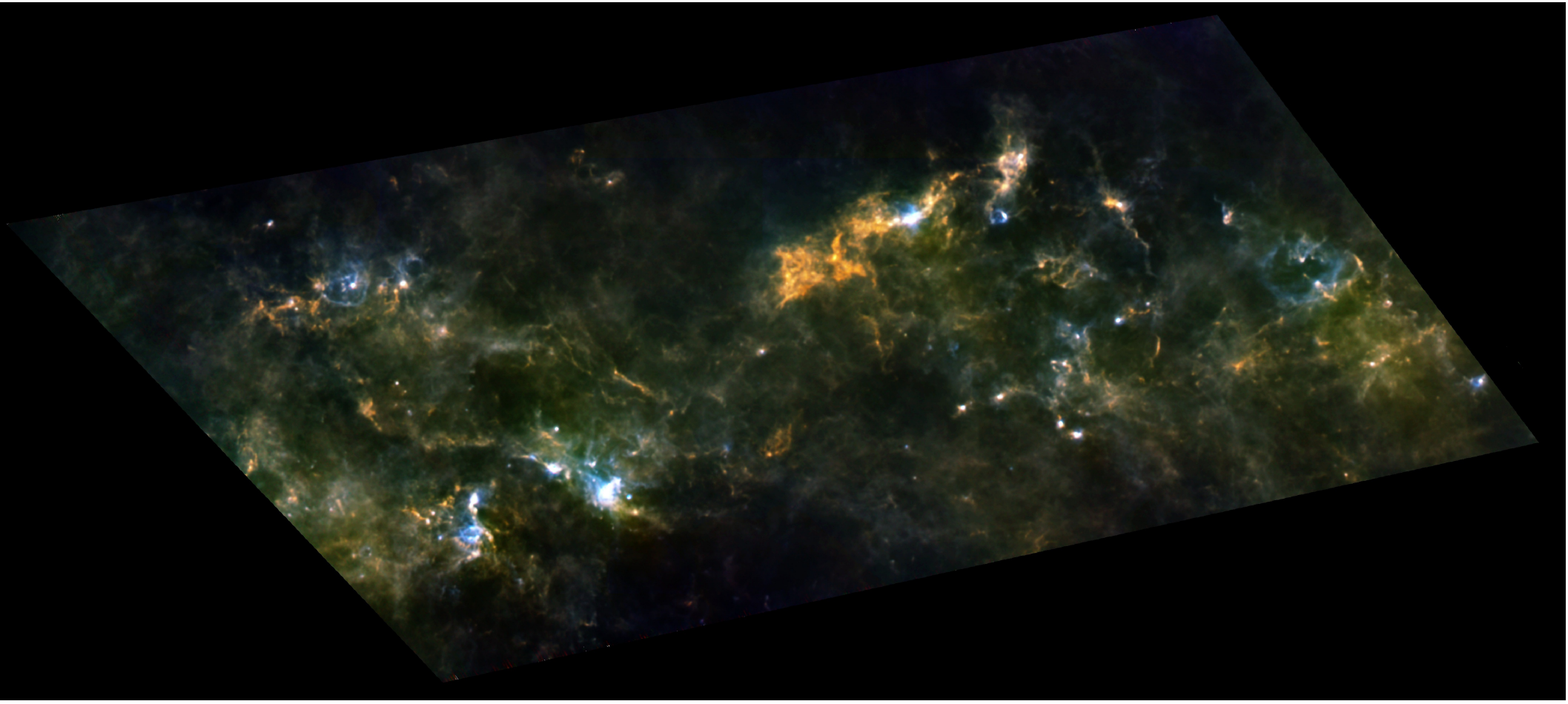
BLAST looked here, towards the Vela constellation.

The Milky Way Galaxy

Zoomed in towards Vela.

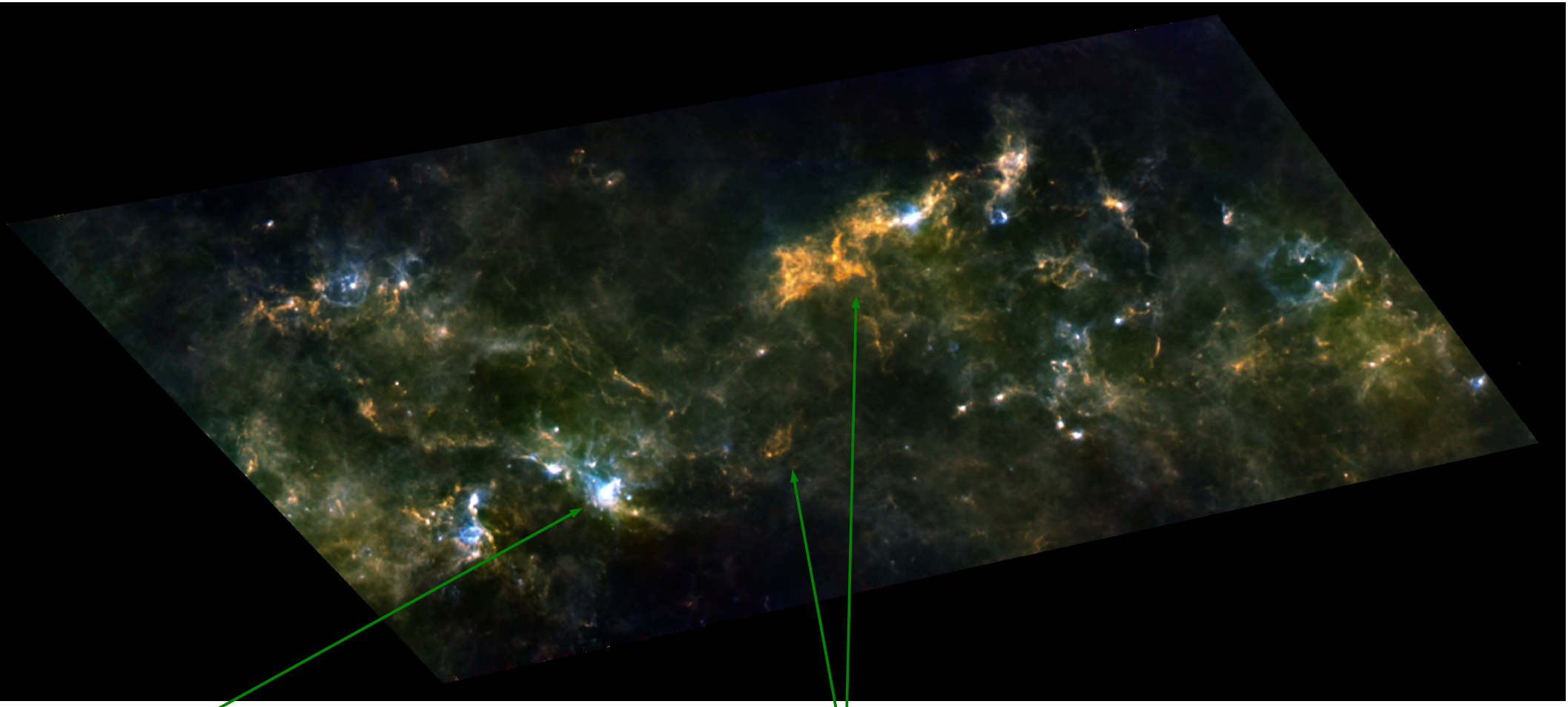
The Milky Way Galaxy

BLAST provides a new view of the Universe!



The Milky Way Galaxy

BLAST provides a new view of the Universe!



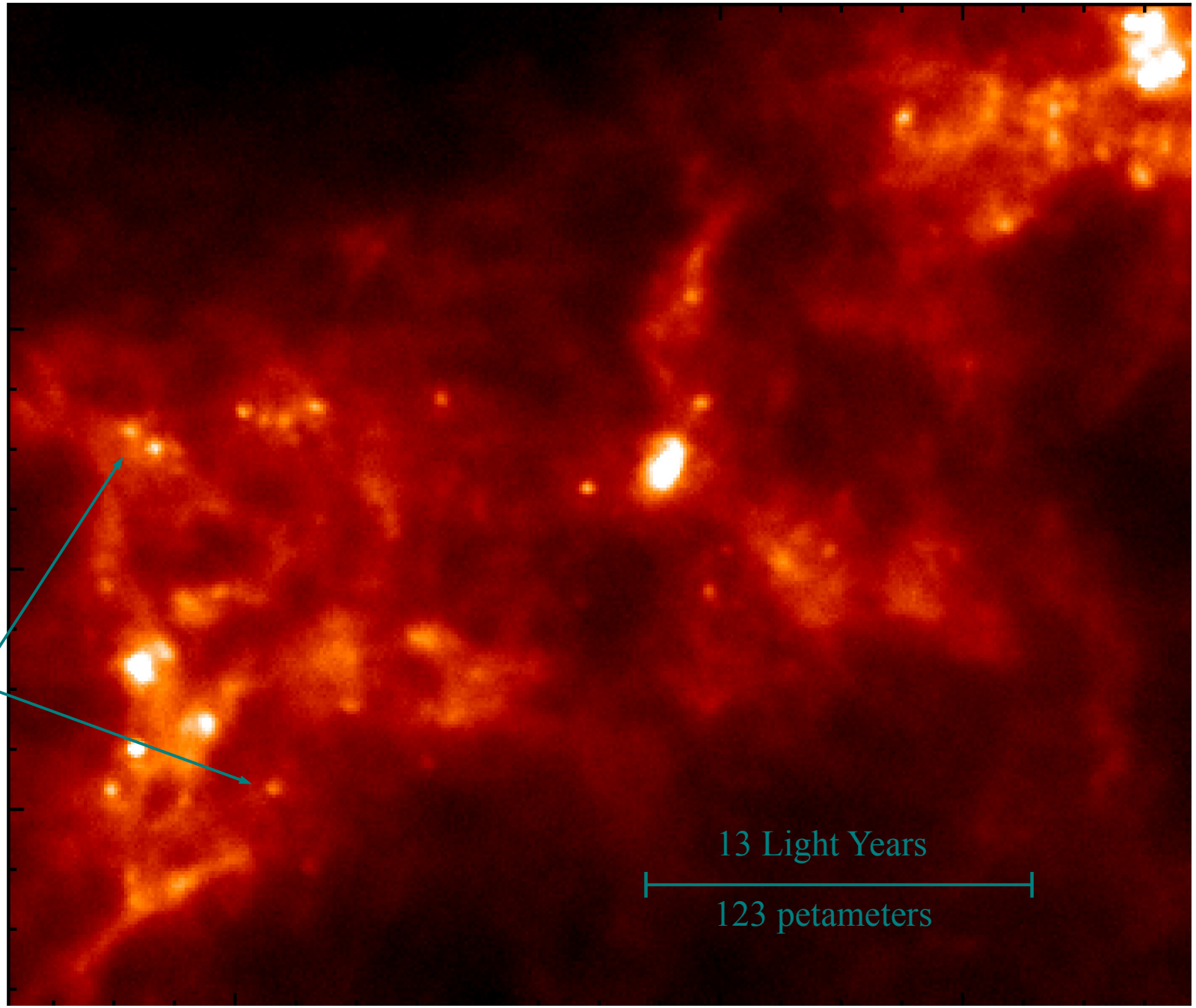
Blue: dust warmed by recent and current star formation

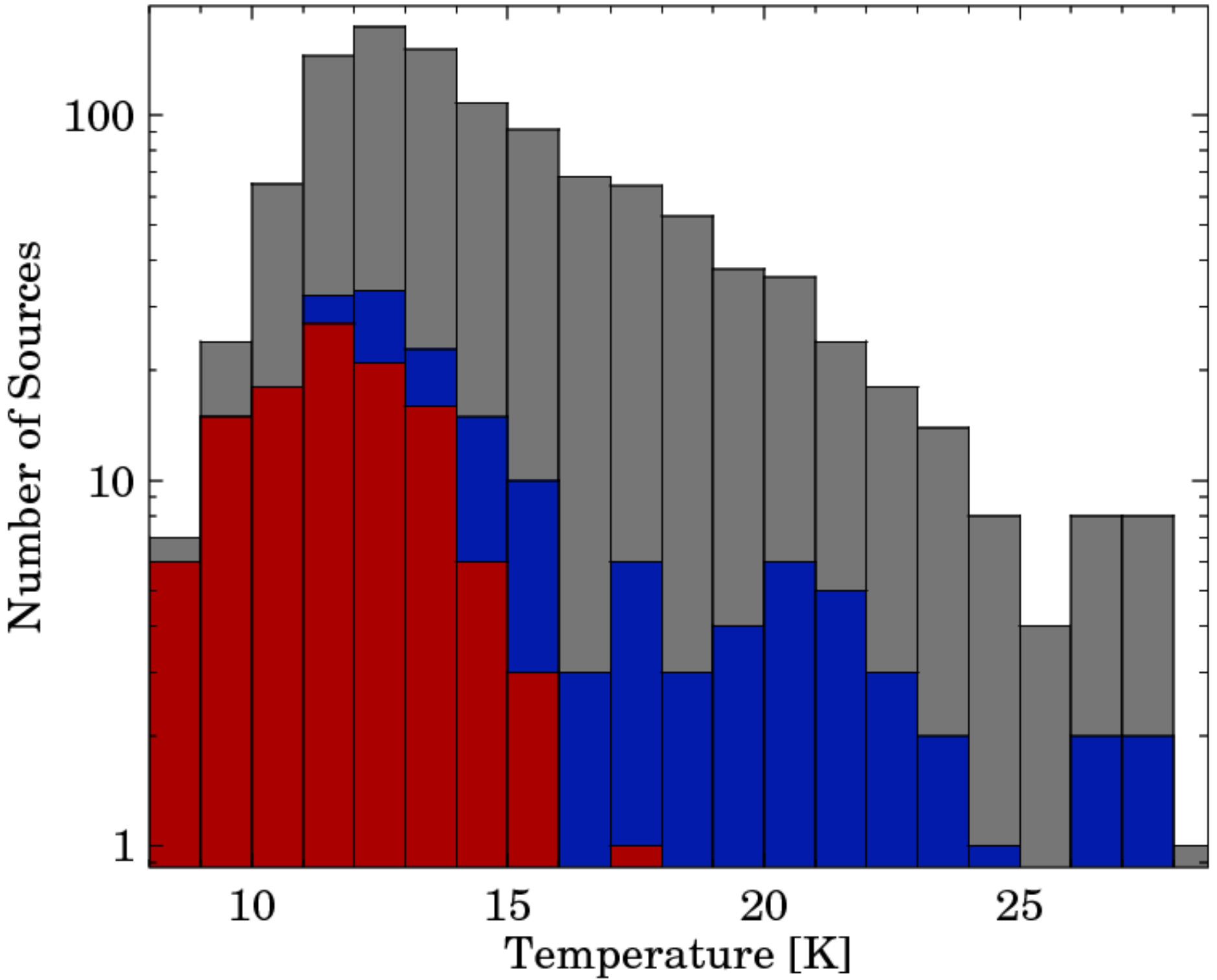
Orange: cold (10k) dust - Home of imminent star formation

Star Formation Towards Vela

Temperature:
12K (-261 C)

Distance:
2,200 Light Years
(21 exameters)




100
10
1
Number of Sources
10
15
20
25
Temperature [K]

Over this large region, ~2% of molecular gas is in cold cores (similar to other regions, but... this seems universal.)

Given Milky way star formation rate and total molecular gas, estimate a time scale:

$$T = 4 \text{ million years}$$

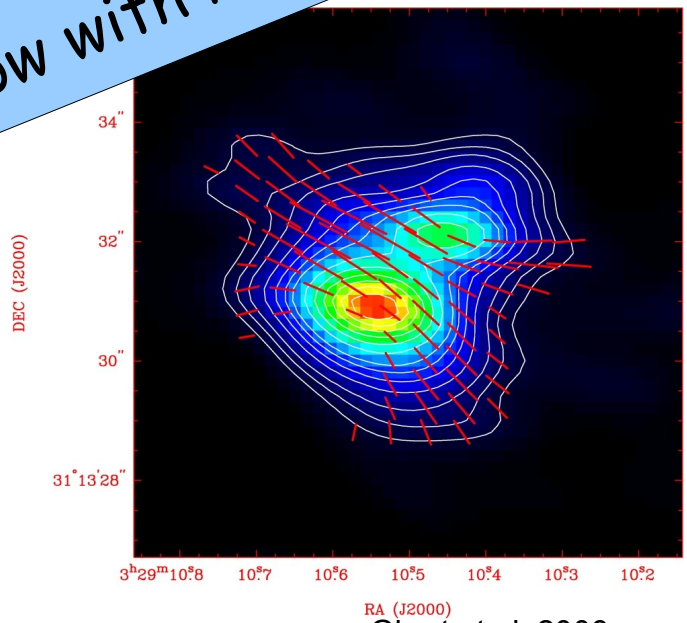
This is 10 times the free fall time.

BLASTpol: BLAST reborn

- Dust is polarized by alignment of dust grains
- Alignment of dust grains shows direction of magnetic fields
- Look for correlation with morphology

- Successful flight December, 2010
- Analysis ongoing

Now with Polarization!



Girart et al. 2006

[Image: Steve Benton]

The Universe

The Universe is Expanding

Here be Dragons

The Universe is now Transparent

Gas

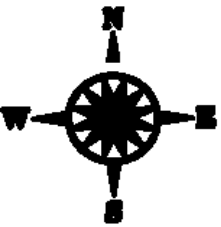
Look Back to when
it wasn't

Plasma

Surface of
Last Scattering
(z~1100)

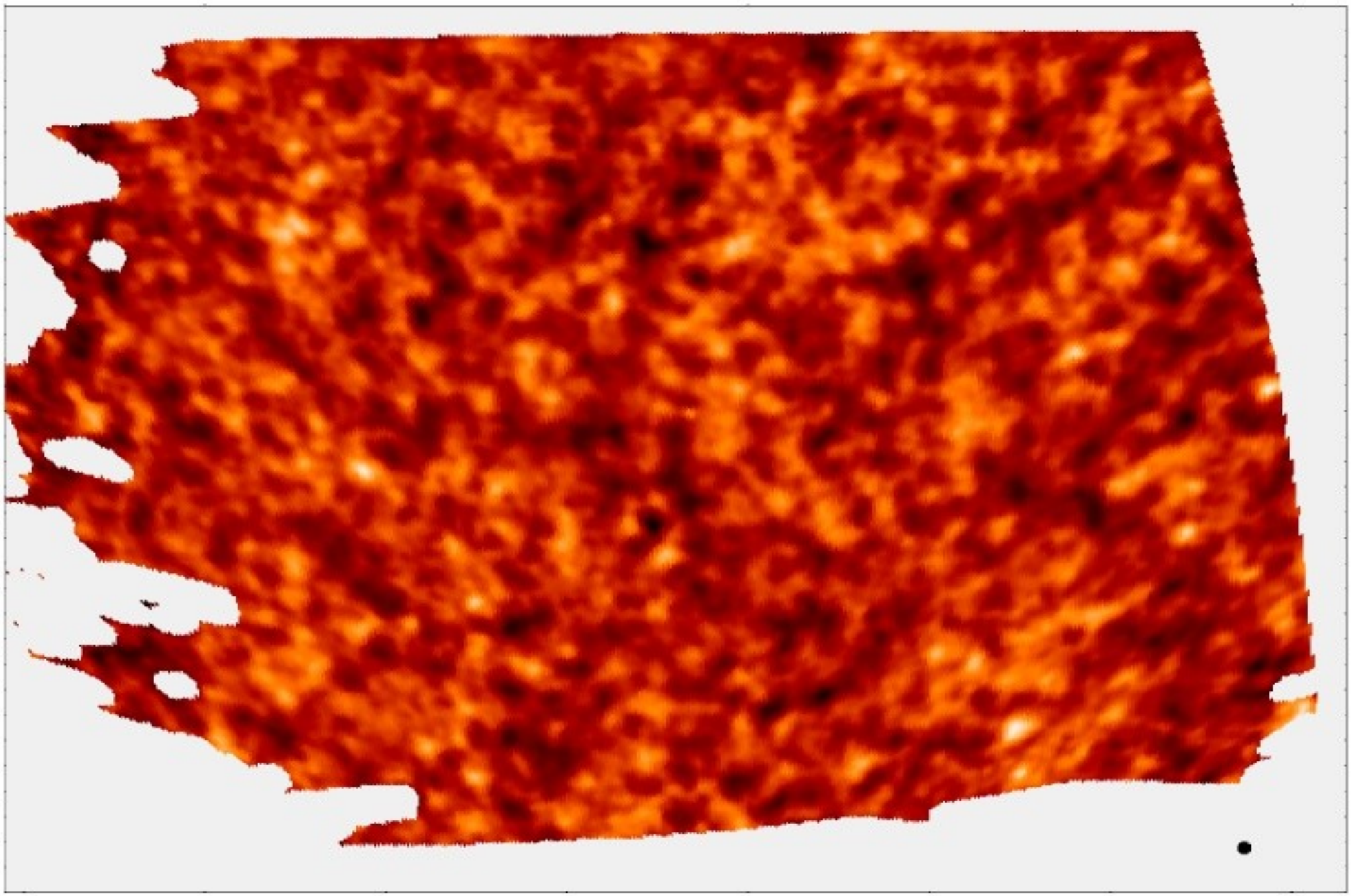
See what things were like
in the year

14,000,000 BC



BOOMERANG

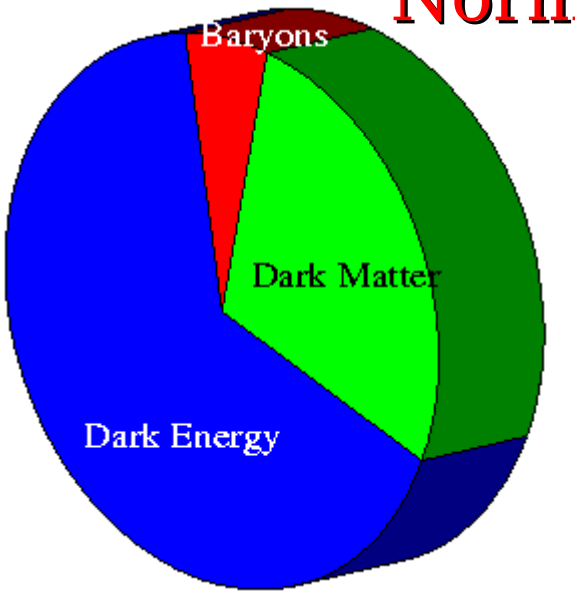
[Image: Phil Mauskopf]


−300 μK
300 μK
−300
−200
−100
0
100
200
300

Some Conclusions:

What is the Universe made of?

Normal Matter



Dark Matter

????

What is the Geometry of the Universe?

Euclidian (Flat)

What is the age of the Universe?

13.7 Billion Years

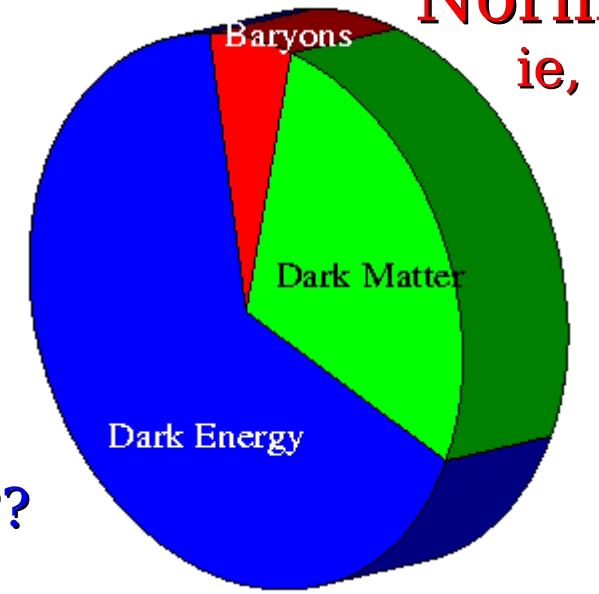
* Includes contributions from other astrophysical data (supernovea, or Ho, or LSS...)
* Confirmed by other CMB observations (DASI, MAXIMA, VSA, CBI, ACBAR, WMAP...)

Some Conclusions:

What is the Universe made of?

Normal Matter

ie, Stars, dust, cheeseburgers



Dark Matter

ie, neutrinos, Star Trek particles

????

ie, ????

What is the Geometry of the Universe?

Euclidian (Flat)

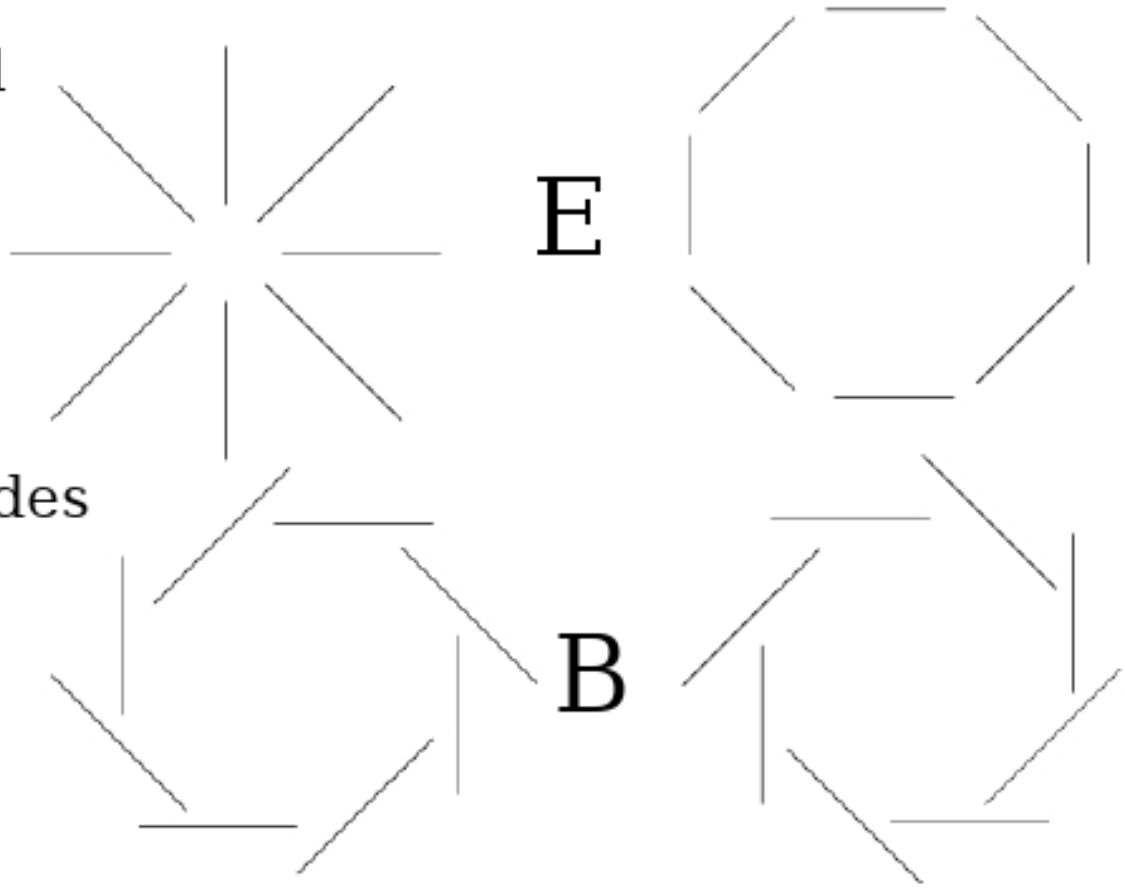
What is the age of the Universe?

13.7 Billion Years

* Includes contributions from other astrophysical data (supernovea, or Ho, or LSS...)
* Confirmed by other CMB observations (DASI, MAXIMA, VSA, CBI, ACBAR, WMAP...)

Polarization: E modes and B modes

E Modes:
- Gradient of the polarization
- Produced by both scalar and tensor modes
- Have been detected



B Modes:
- Curl of the polarization
- Produced only by tensor modes

...or gravitational lensing

...or foregrounds

...or systematics

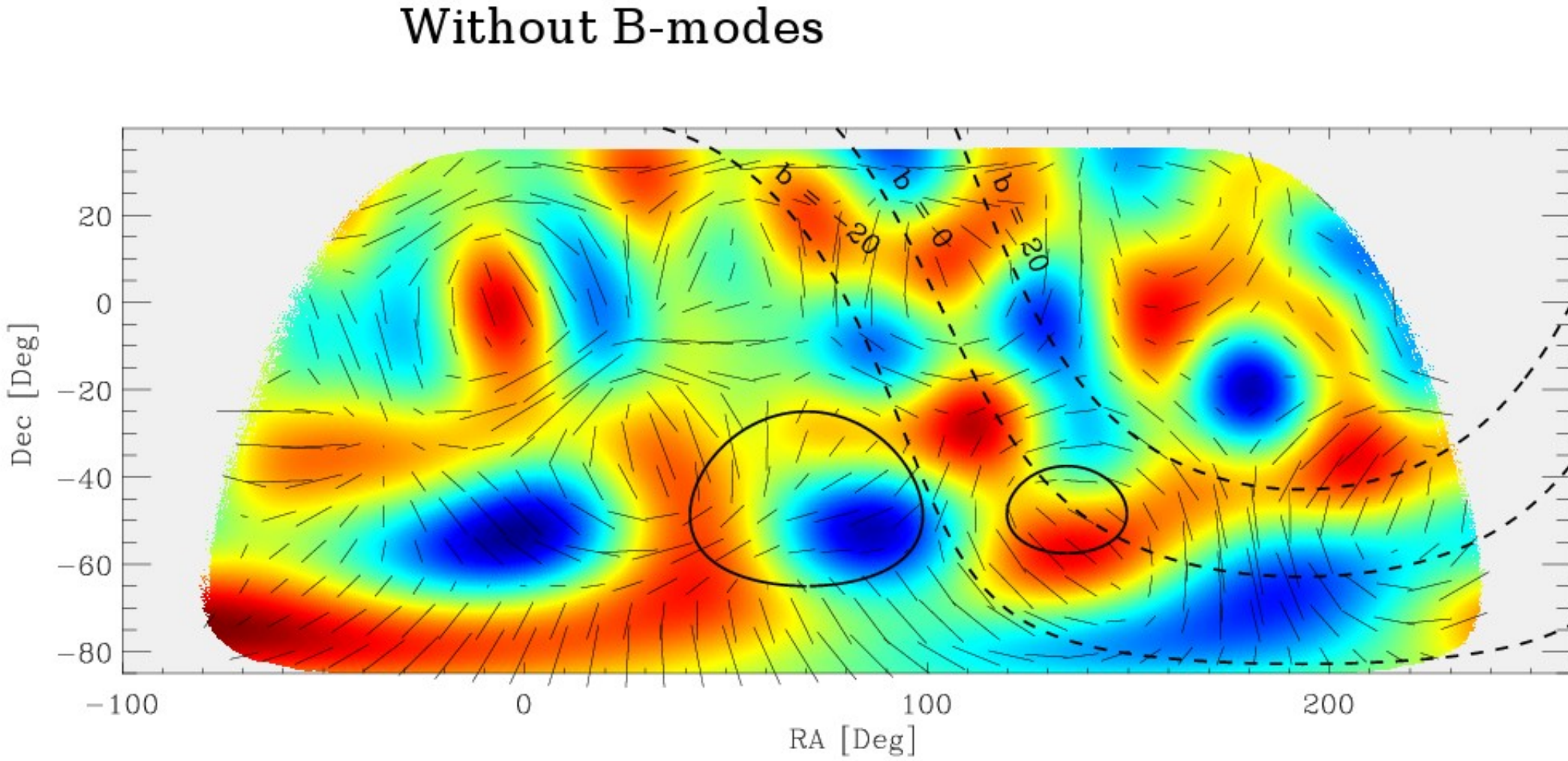
- Expected from inflation
- Have not been detected

A detection of primordial sourced B modes would provide important evidence for, and determine the energy scale of

Inflation

The amplitude is unknown!

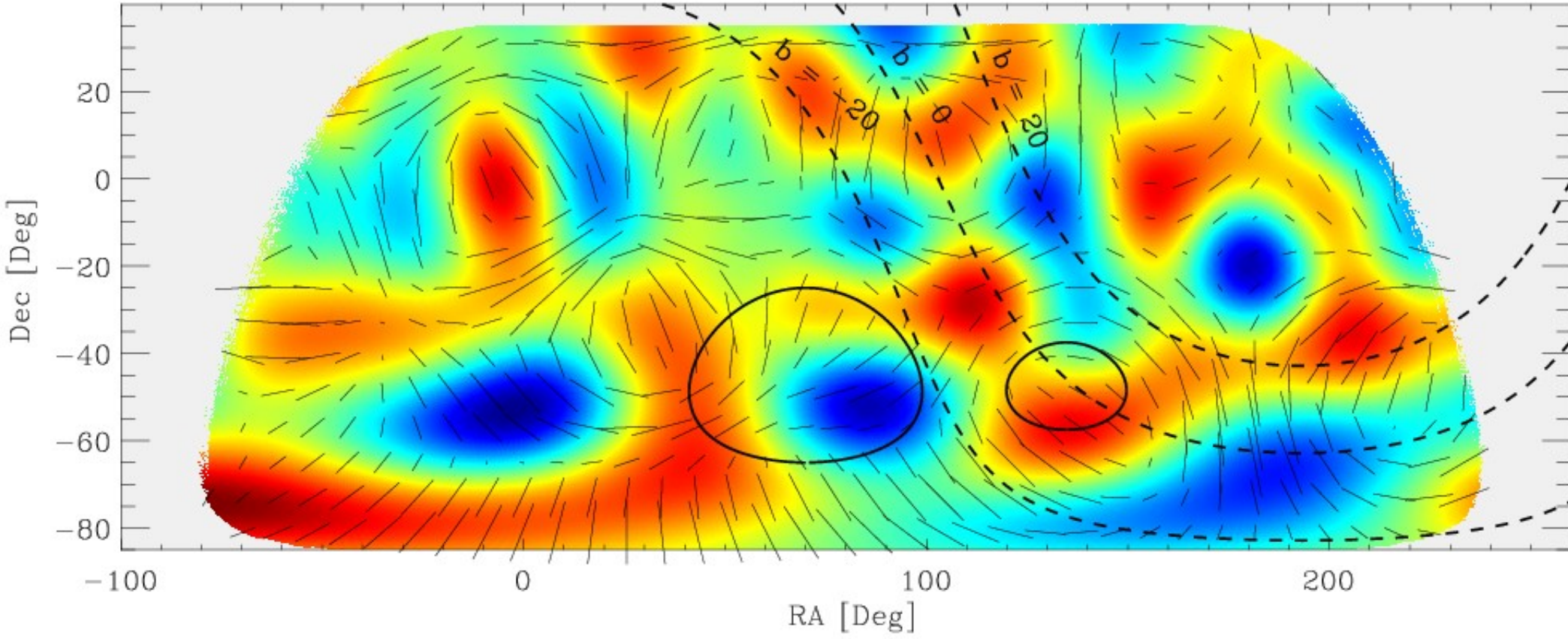
Simulated Spider Polarization Map



[Carlo Contaldi]

Simulated Spider Polarization Map

With B-modes, r=0.1



Goal: to detect r >= 0.01

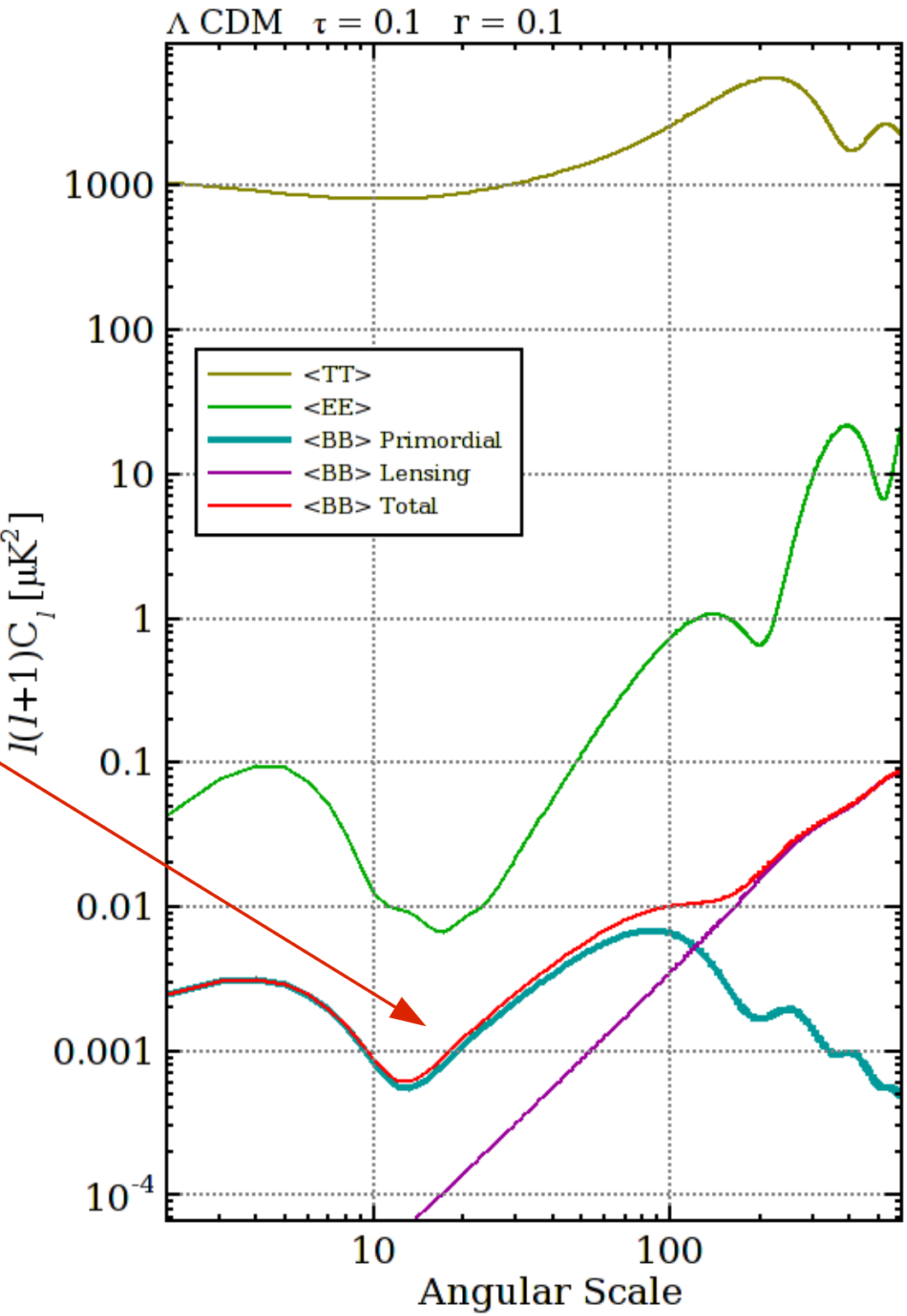
[Carlo Contaldi]

Challenges

Signal is very small

Need unprecedented sensitivity

-Large arrays of detectors.
-Long integration times.
-Minimize atmospheric Contribution (space)



Challenges

<TT> greater than <BB>

Must minimize

I-QU Mixing

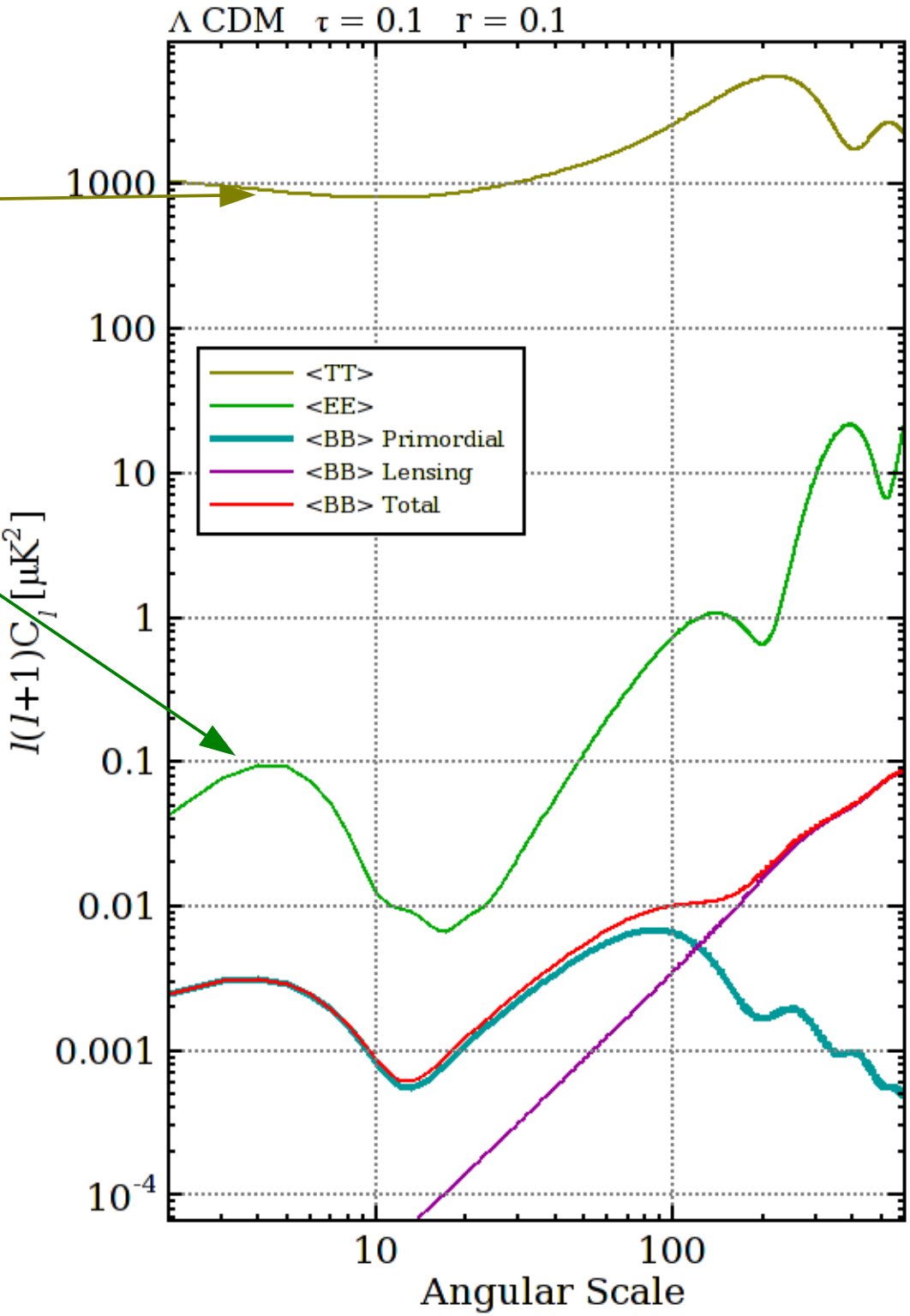
<EE> greater than <BB>

Must minimize

E-B Mixing

Requires unparalleled control of systematics!

-Calibration
-Pointing
-Beam determination
-Bandpass determination
-Stability

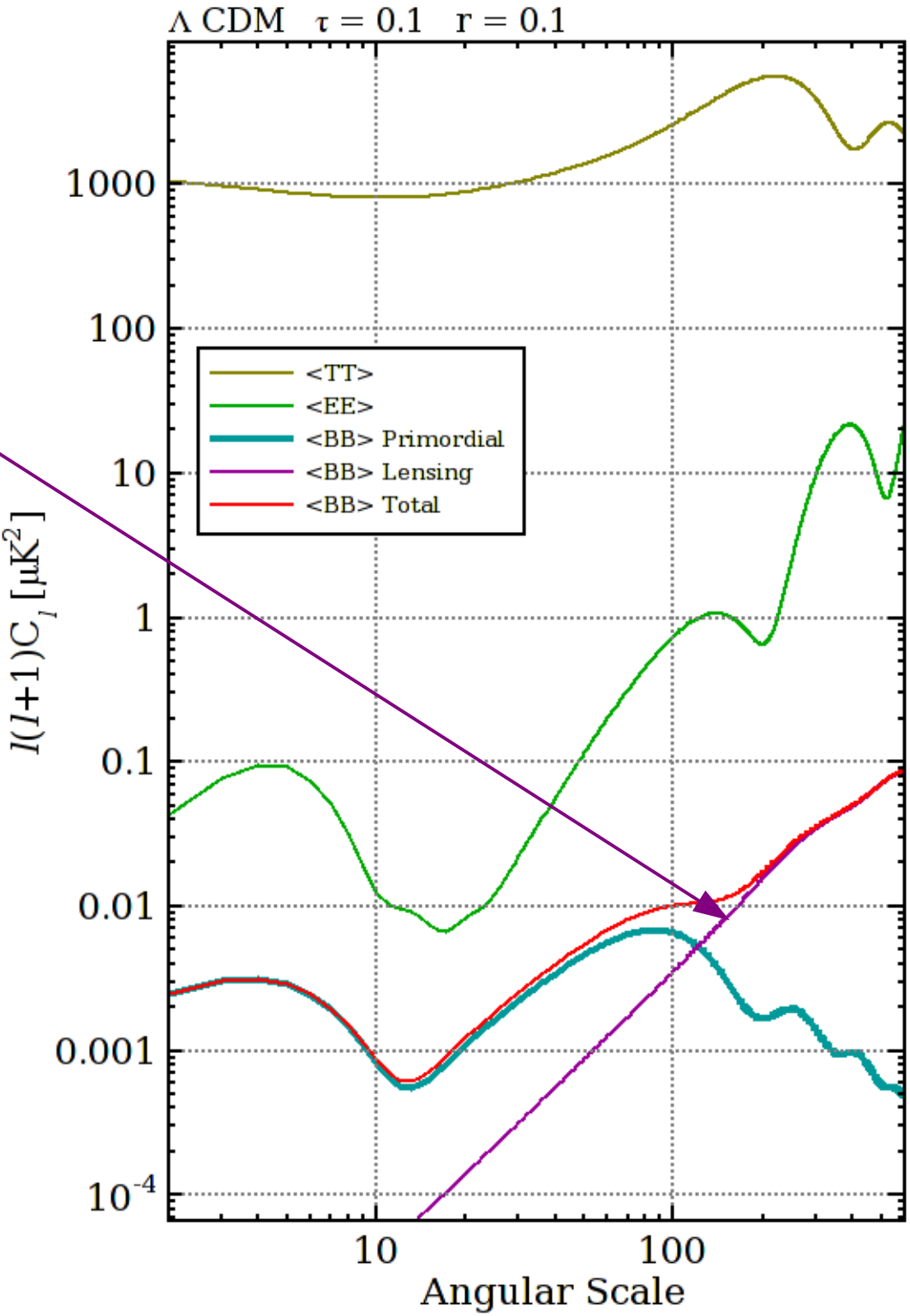


Challenges

Avoid Lensing <BB>

For r>0.05
- It may be sufficient to observe medium scales

For r < 0.05,
- -observe whole sky?
- -remove lensing <BB>



More Challenges

Polarized Synchrotron radiation dominates at low frequencies

It must be removed

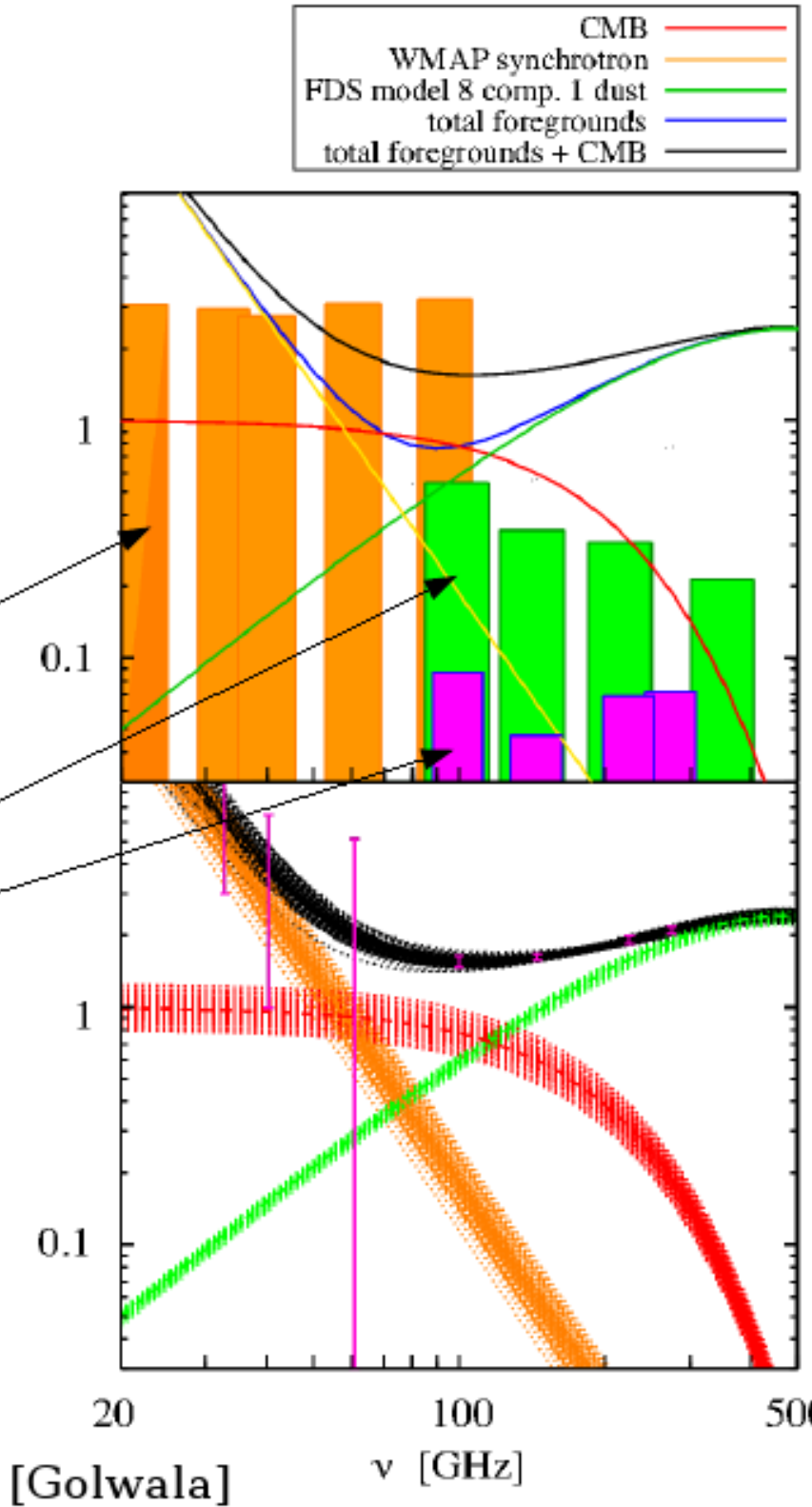
Polarized dust emission dominates at high frequencies

It must be removed

WMAP 8 year sensitivity

Planck HFI sensitivity

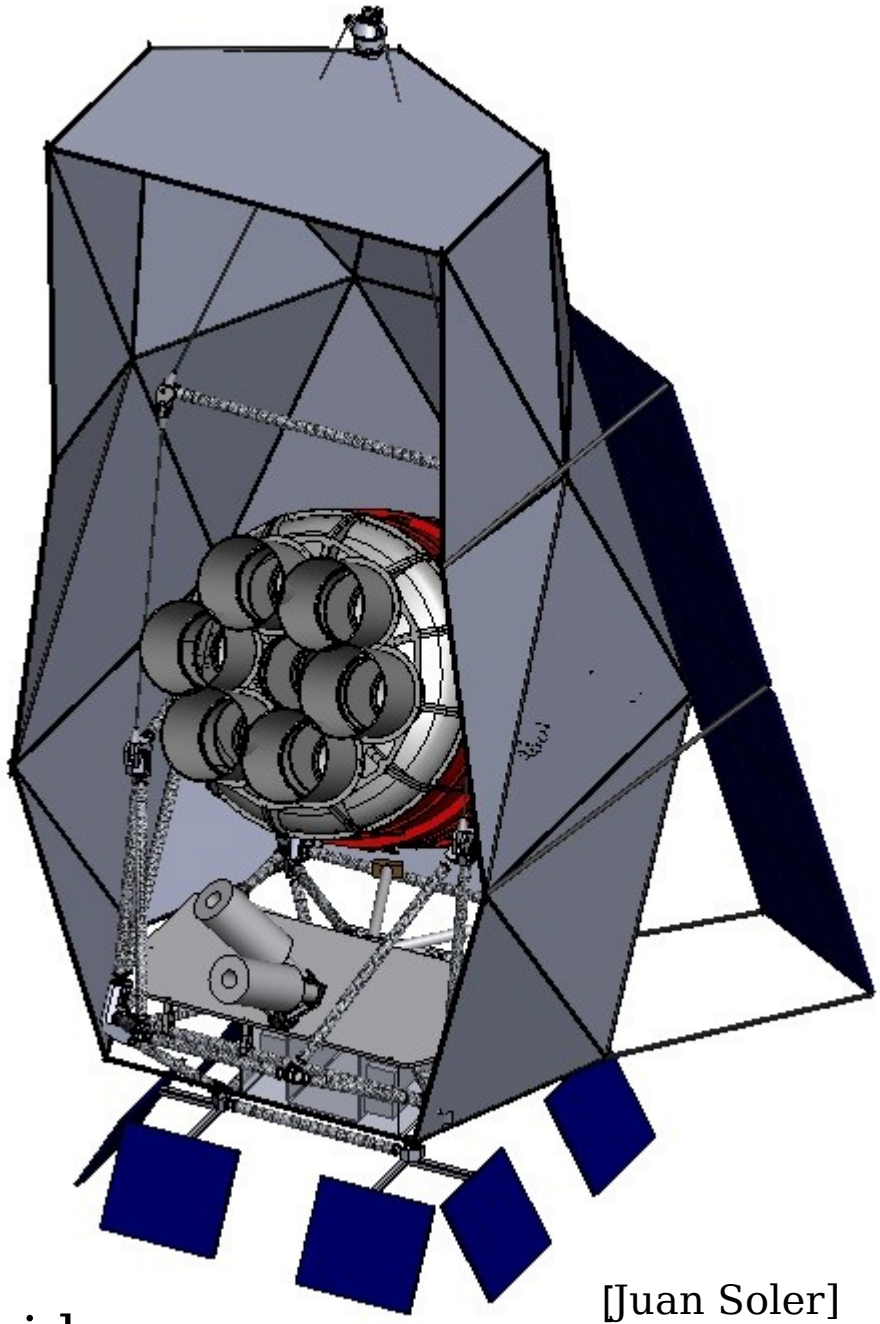
Spider Sensitivity (8% sky)



The choice of a clean patch of the sky can considerably reduce the problem.

Spider

- Balloon Borne mm polarimeter
- Will map 8% of sky
- Noise and frequency coverage adequate for r~0.03 detection
- Polarization modulation with stepped waveplate
- First flight in 2012

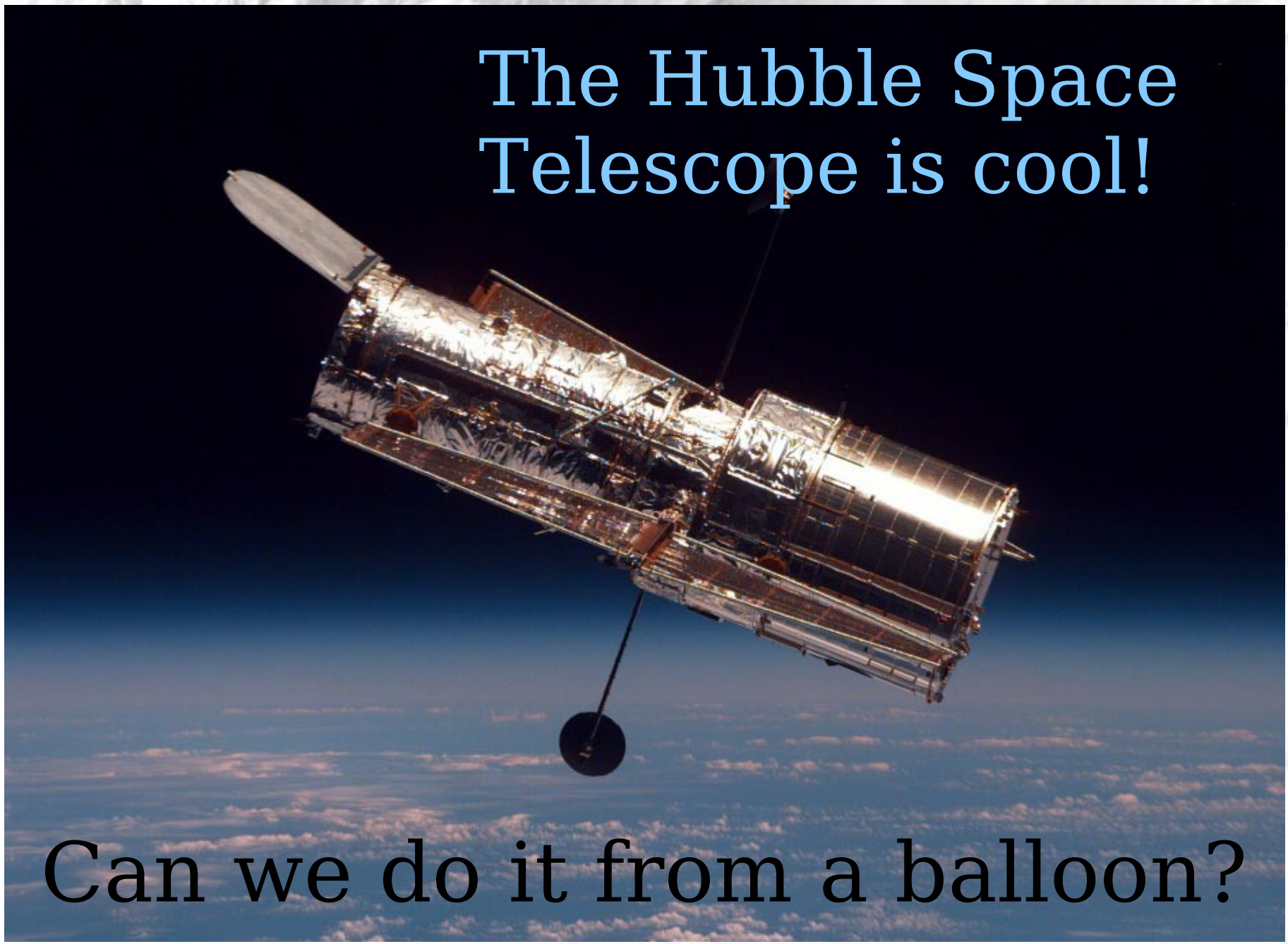


[Juan Soler]

Princeton, CWRU, CalTech, JPL, NIST,
Toronto, UBC, Imperial, Cardiff, Cambridge

Astronomy needs to be cool. . . .

So what's next for ballooning?

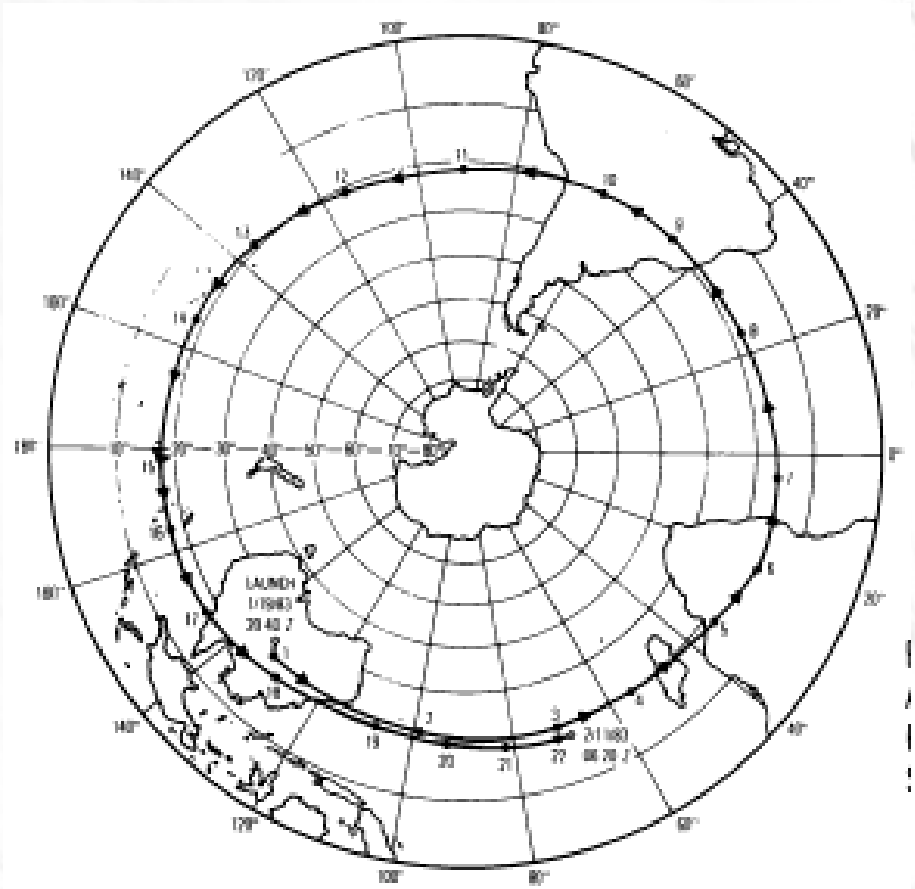

The Hubble Space Telescope is cool!
Can we do it from a balloon?

Flight Opportunities

Mid-latitude zero-pressure

22 days demonstrated
Day Night Cycles
+ Daily solar power
+Dark Sky at night

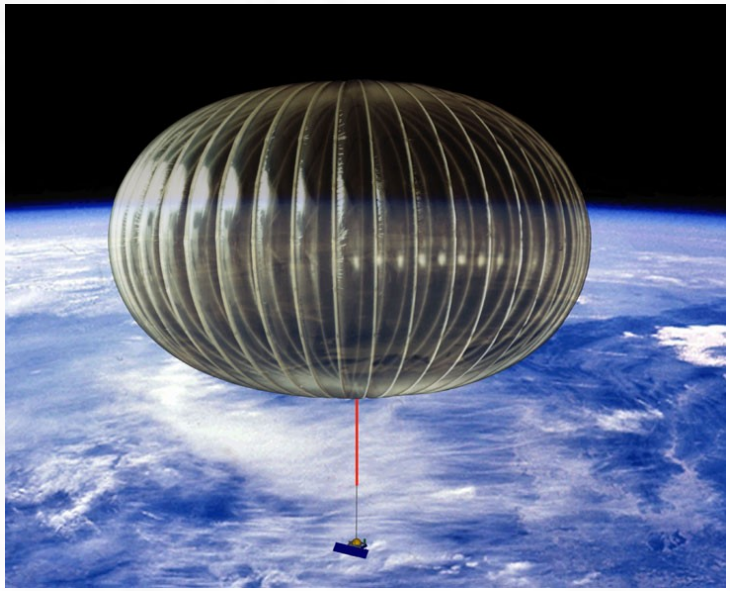
- 70 C Ambient ΔT
- Could be lost at sea
- Altitudes drop to 80kft.



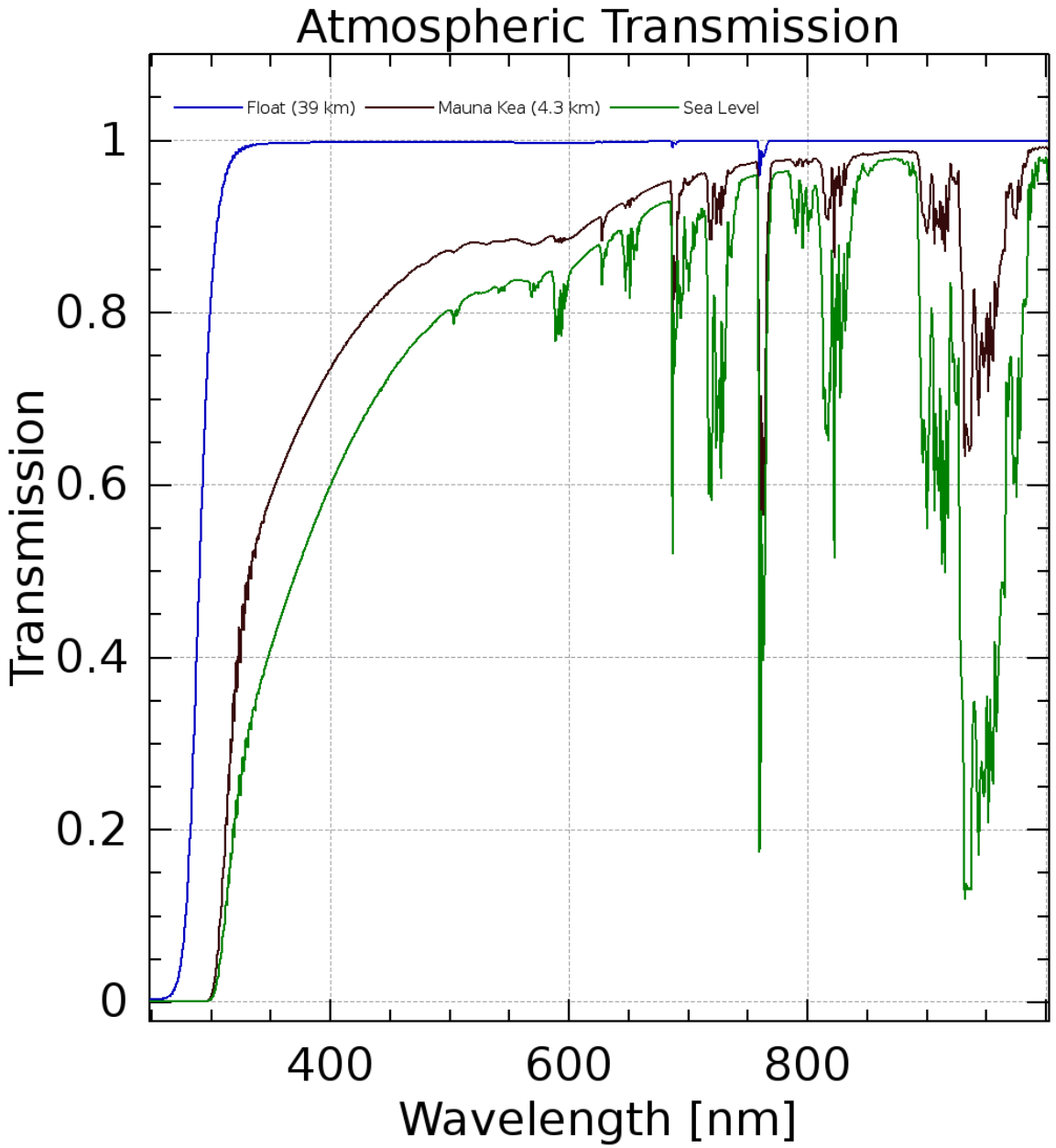
Flight Opportunities
Mid-latitude Super-pressure

100 day goal, Day Night Cycles
+Daily solar power
+Dark Sky at night
+Altitude stability

-70 C Ambient DT
-2000lb mass budget



The Atmosphere

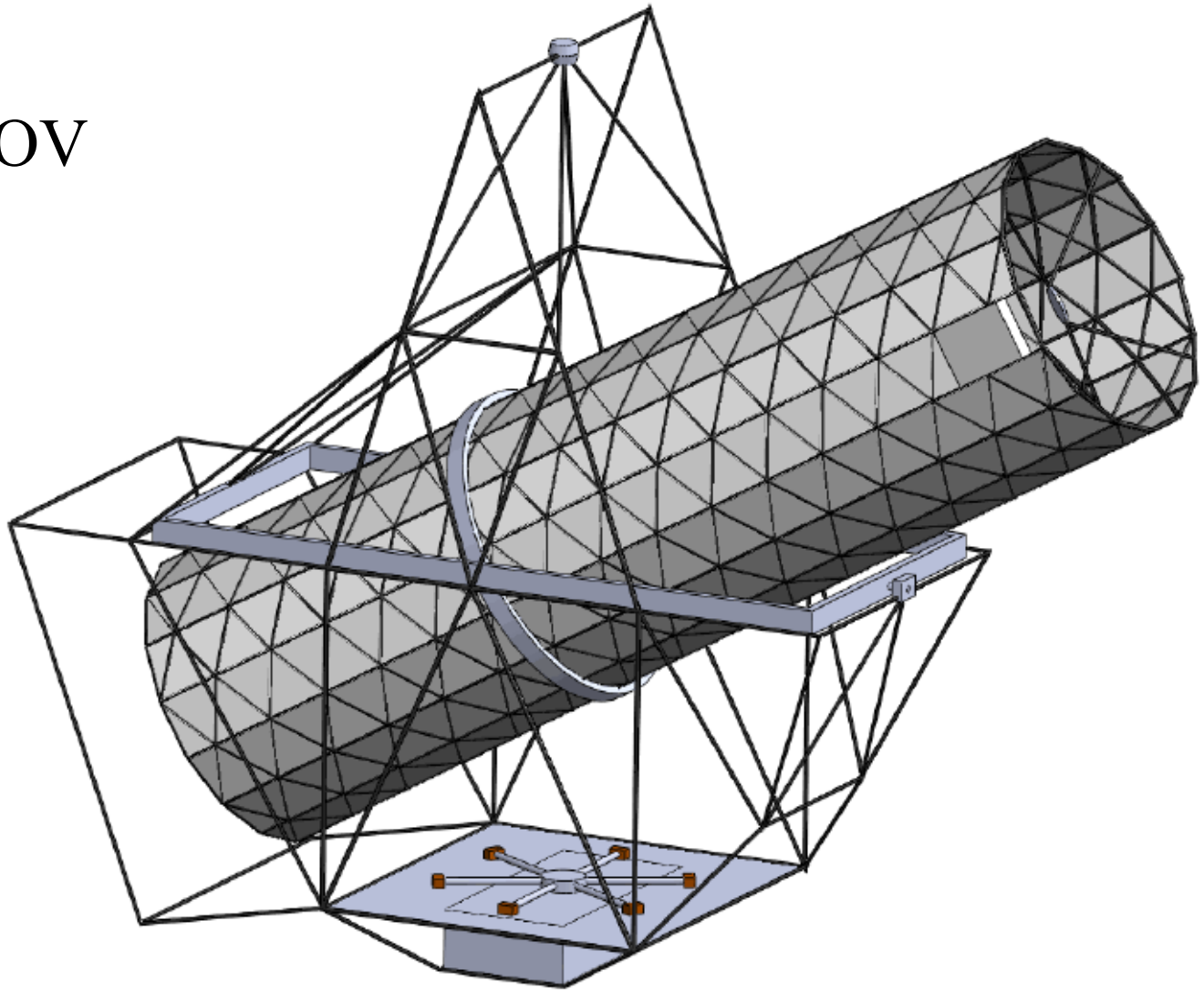


- Transmission: Essentially in space
- Emission: Essentially on the ground
- Seeing: several meter turbulent cell size means diffraction limited seeing

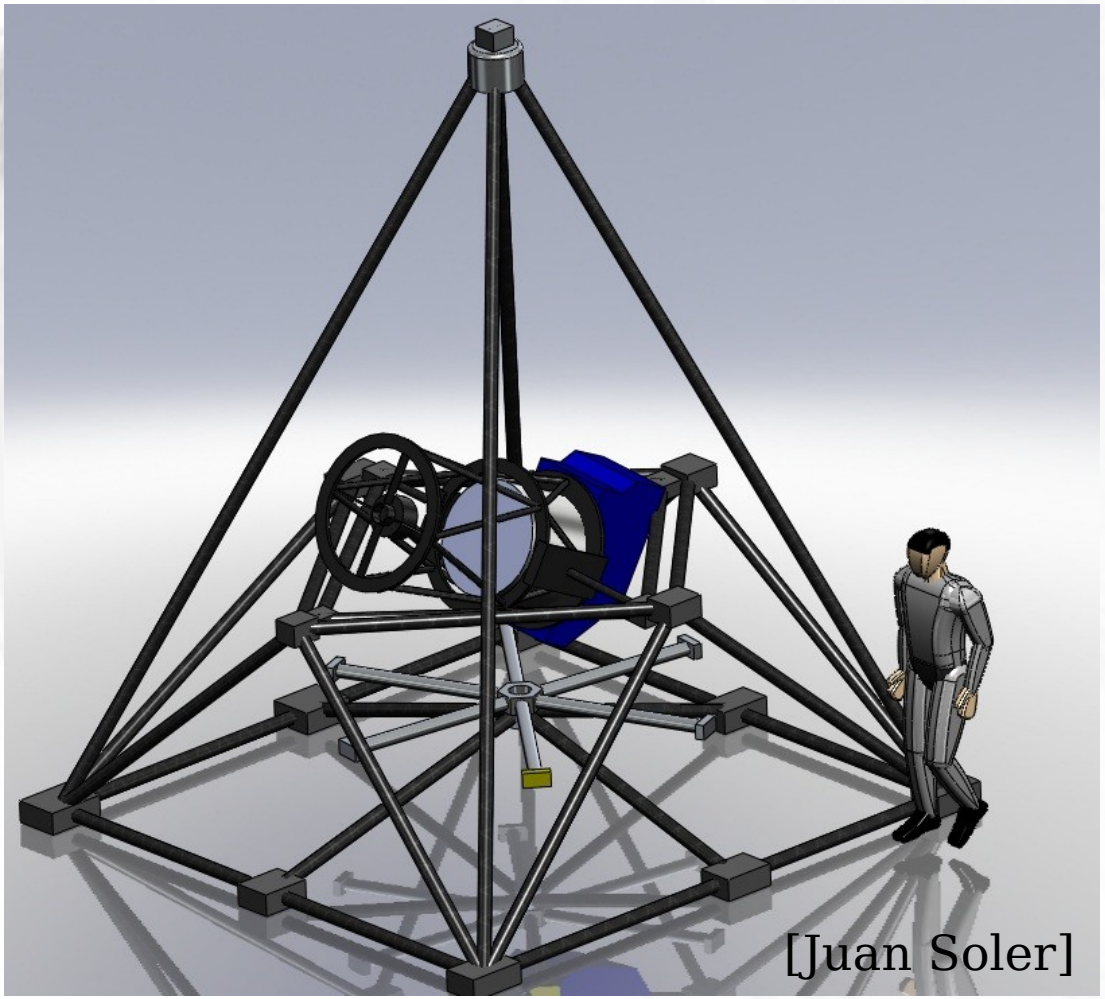
A Balloon Born Wide Field Imager

- 1.5m telescope
- 0.8 square deg FOV
- 0.1” resolution
- 1 GPix Camera
- Optical bands

- 380x the FOV of HST WFC3
- High-resolution wide surveys eg, lensing



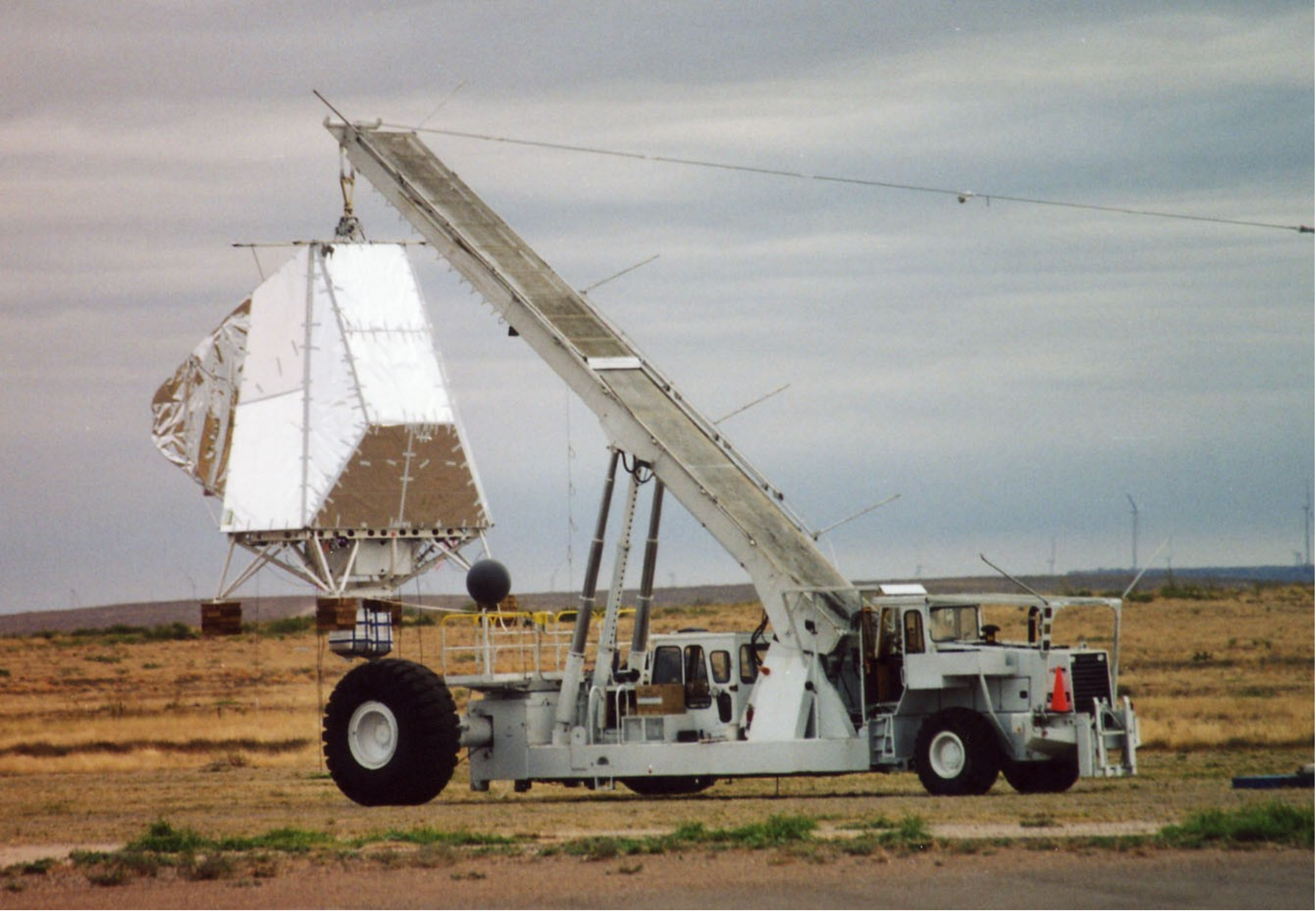
Prototype Balloon Optical Telescope

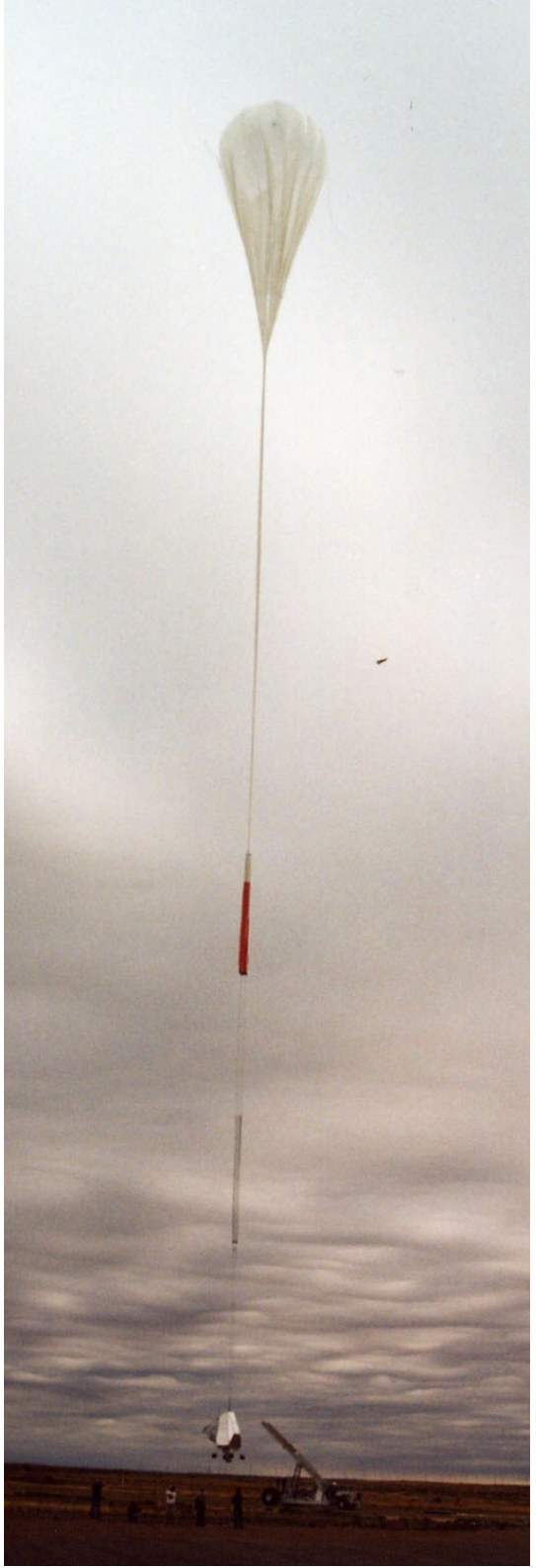


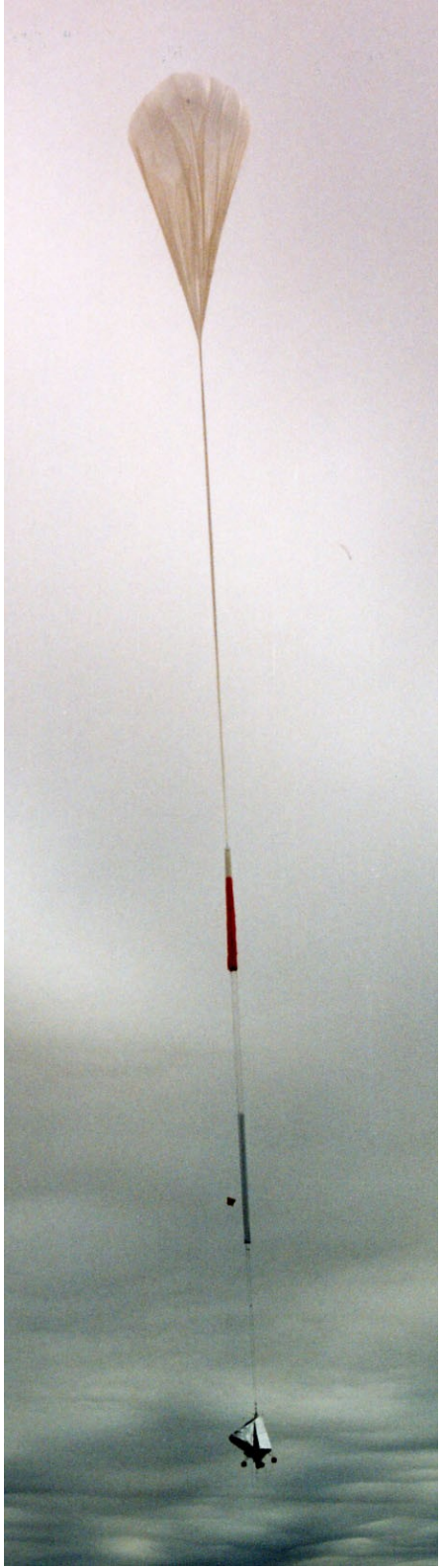
- 24” Optical Telescope
- Near UV/Vis Camera
- 'Borrow' parts from BLASTpol
- Test pointing
- Take cool pictures
- 0.2” imaging

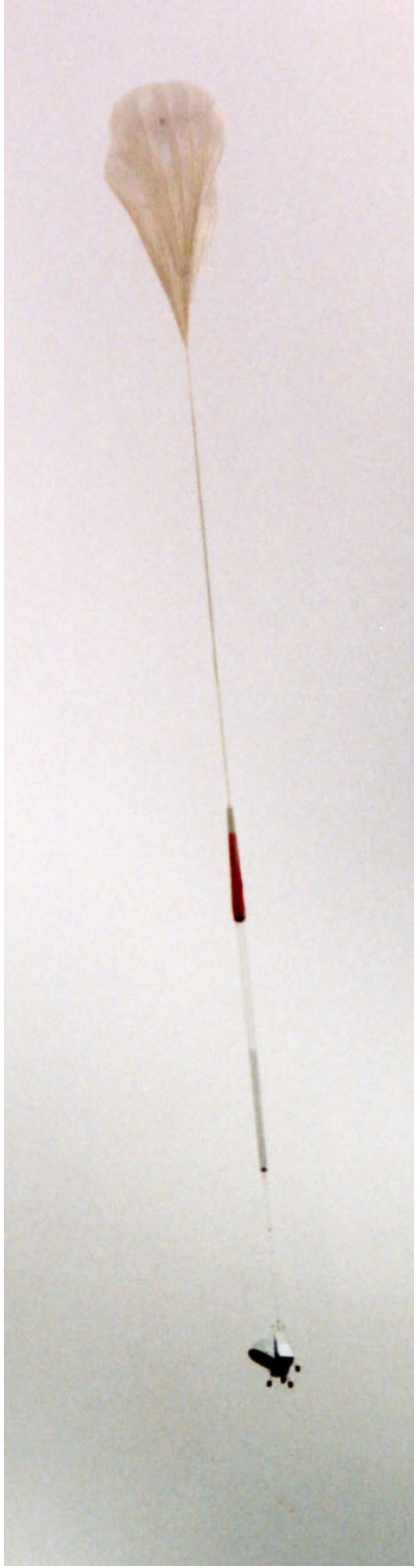
Only Hubble will have higher resolution!

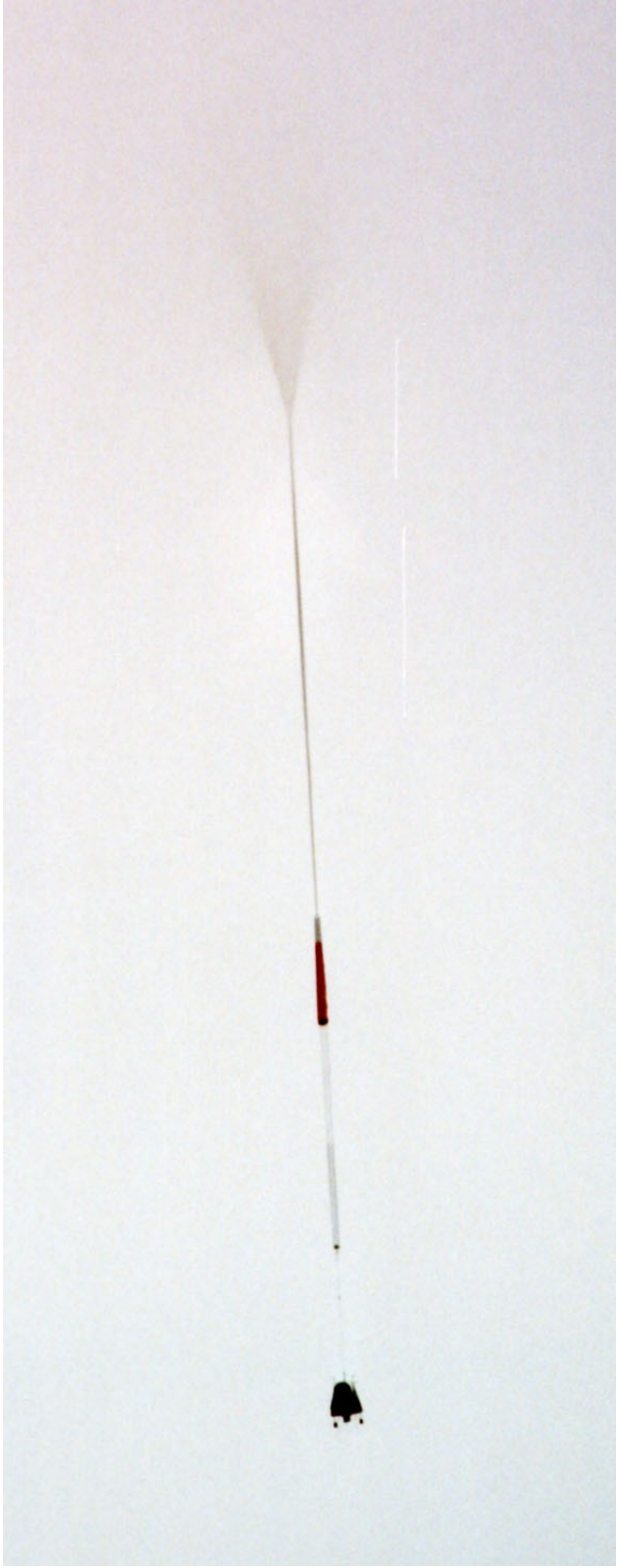
BLAST Test Flight (Ft. Sumner, September, 2003)

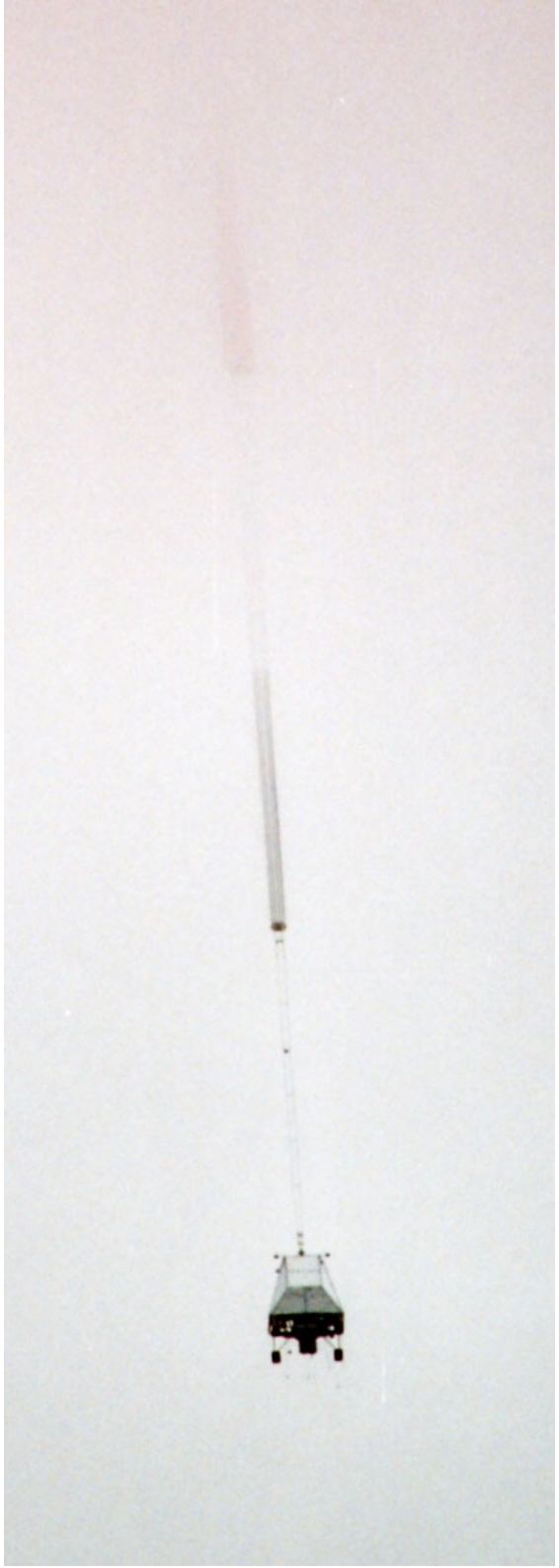


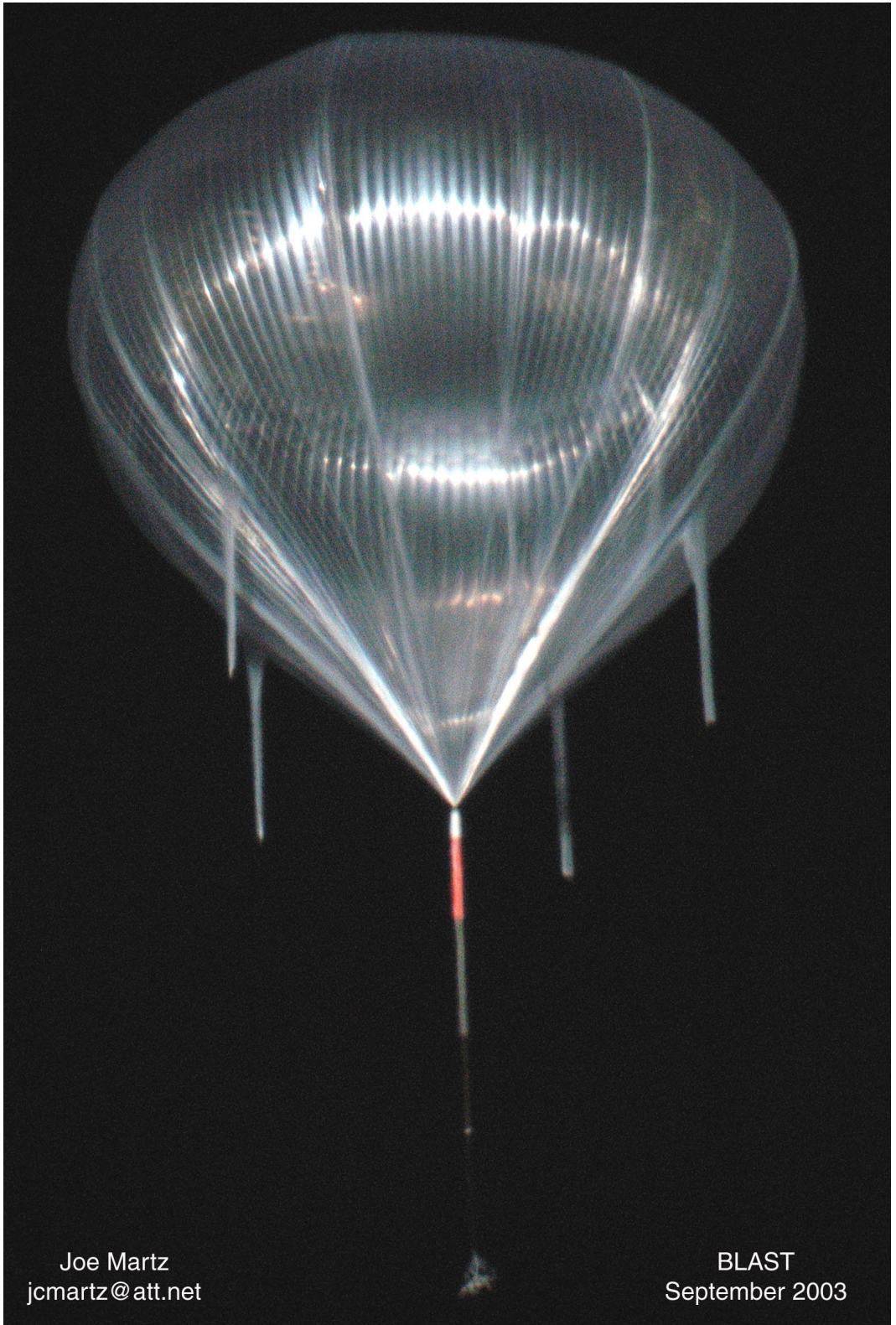











Joe Martz
jcmartz@att.net
BLAST
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