BLAST-Pol: The Balloon-borne Large Aperture Submillimeter Telescope for Polarimetry

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BLAST-Pol Collaboration

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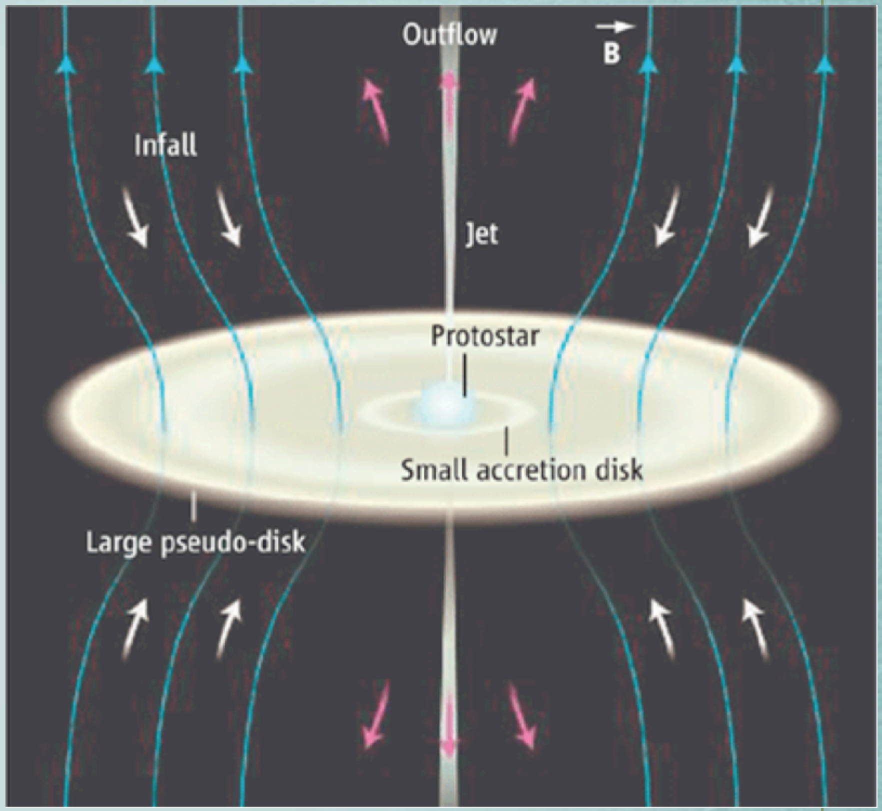
BLAST-Pol field crew

Moncelsi, Novak, Truch, Benton, Matthews, Pascale, Thomas, Devlin, Angile, Soler, Netterfield, Klein, Gandilo, Fissel

What influence do magnetic fields have on star formation?

•The star formation process is much slower than expected from free-fall gravitational collapse.

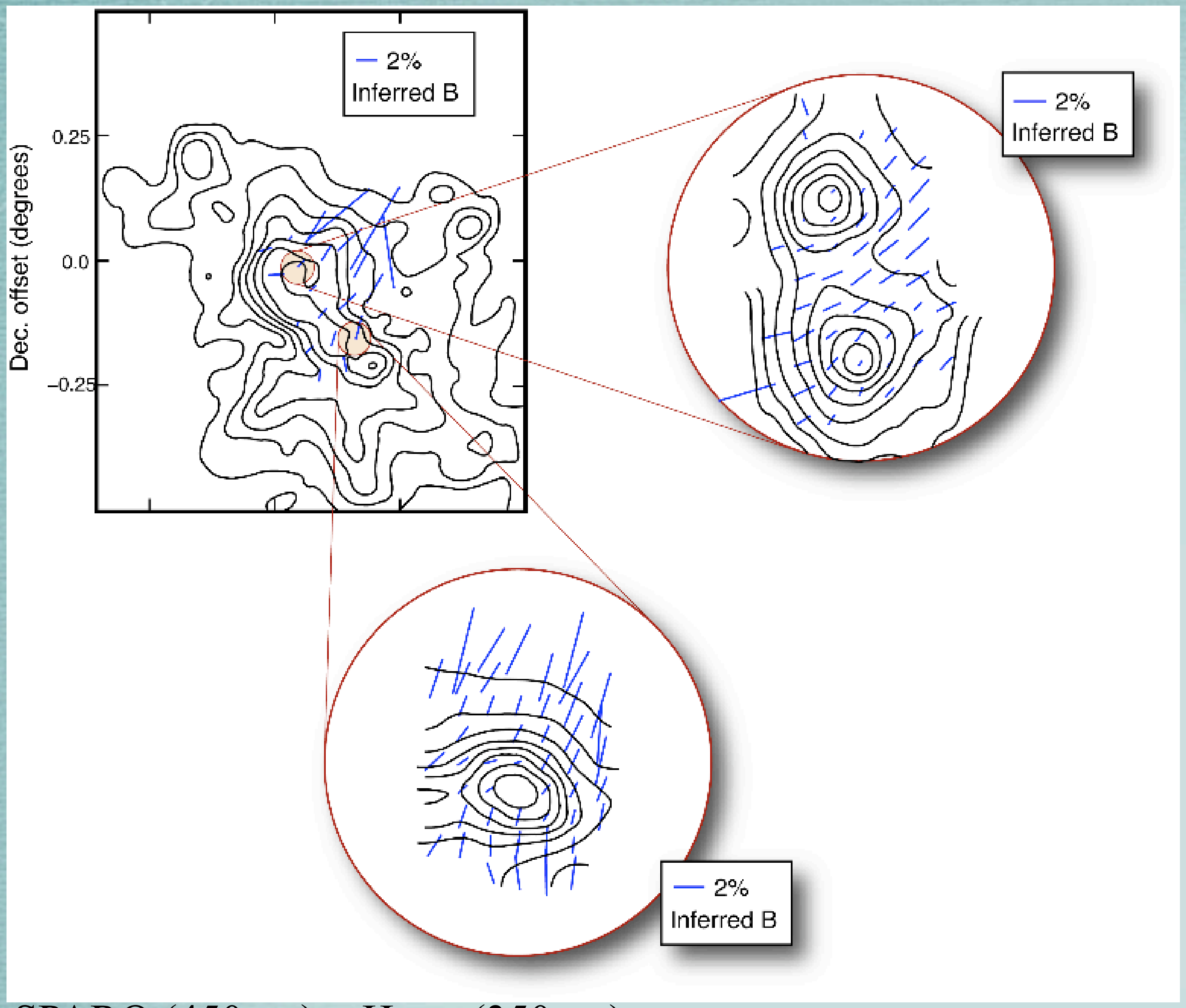
•Two mechanisms are proposed to regulate star formation:
1) mechanical support from strong *magnetic fields* (e.g. Shu et al. 1987, Mouschovias & Ciolek 1999)
2) supersonic *turbulence*
(e.g. Mac Low & Klessen 2004)



Crutcher (2006)

•Few ways to observe the magnetic field:
1) Zeeman molecular line observations, which directly measure magnetic field strengths
2) Polarimetry of starlight (optical/near-IR), or of thermal emission from dust (far-IR/submm)

Submm Polarimetry



SPARO (450μm) + Hertz (350μm)
on 100μm IRAS ISSA contours

Novak, Dotson, &Li (2009)

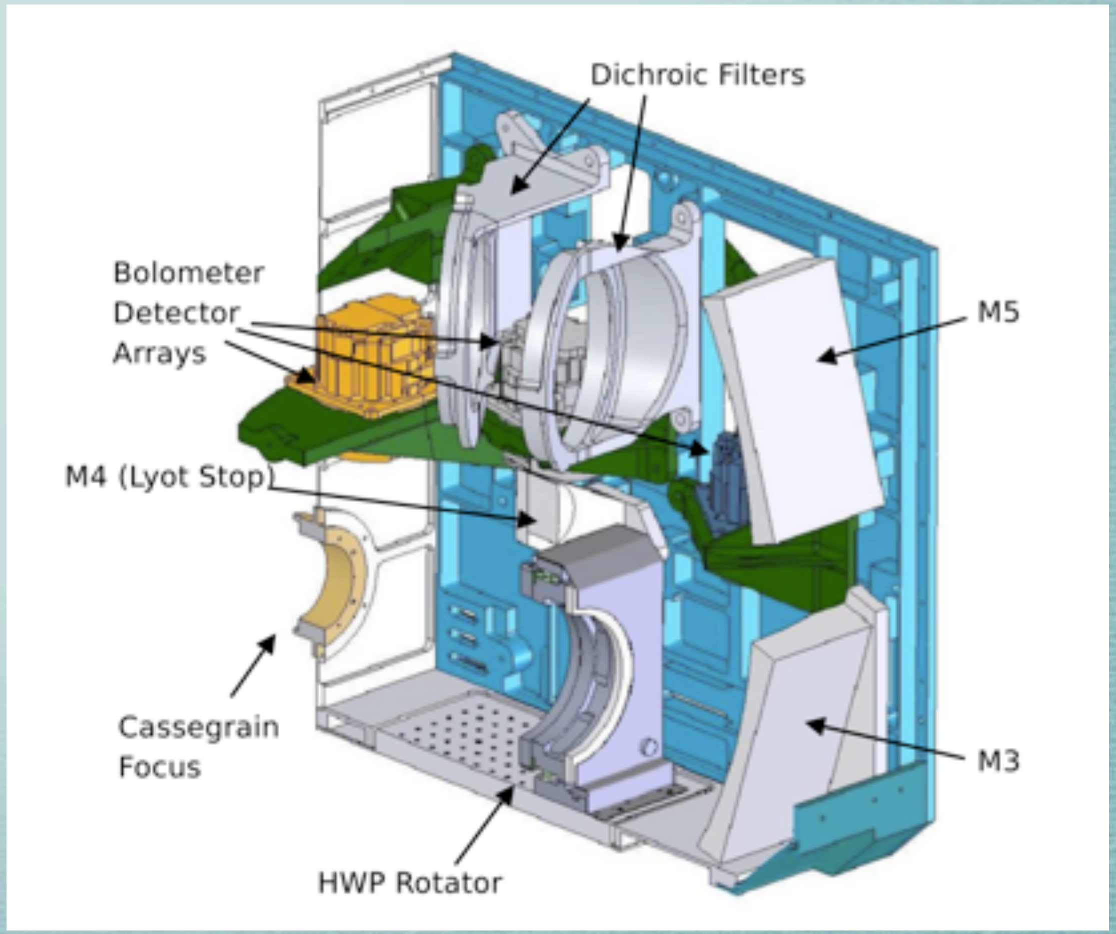
- Aspherical spinning dust grains align with long axis perpendicular to direction of magnetic field.

- Linearly polarized submm emission from molecular clouds traces out direction of magnetic field lines in the plane of the sky.

BLAST-Pol will provide thousands of polarization measurements per cloud for several clouds, over a wide range of dust column densities corresponding to $A_V \geq 4$.

Telescope

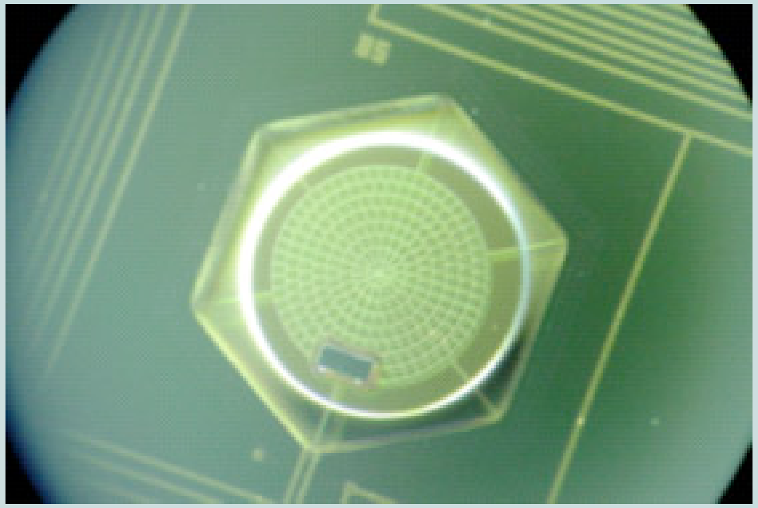
- Cassegrain telescope
- 1.8m parabolic primary
- 40cm adjustable secondary
- Offner-relay configuration
- Pointing reconstruction ~2″

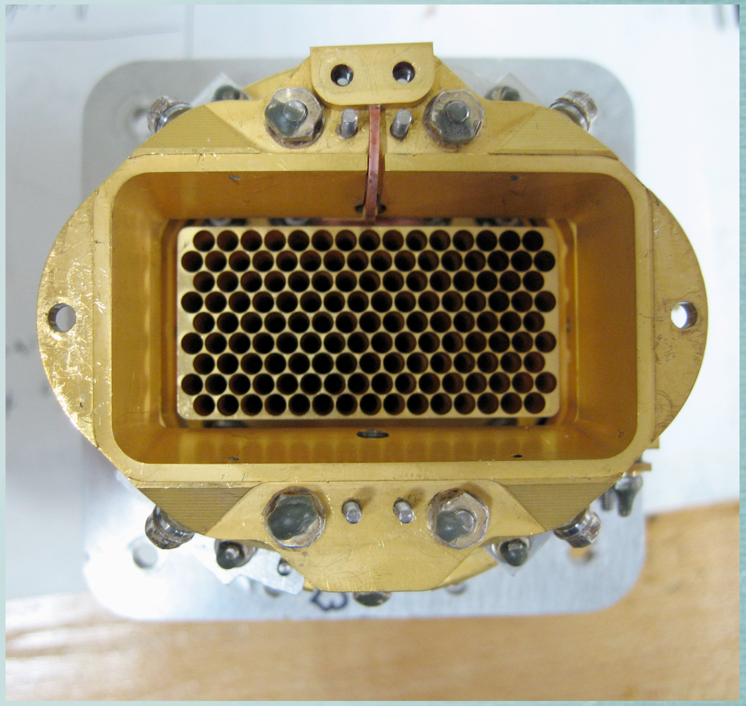


cold optics

Detectors

- Herschel SPIRE prototype silicon nitride micromesh bolometers
- Arrays at 250, 350 and 500μm
- Angular resolution ~1′

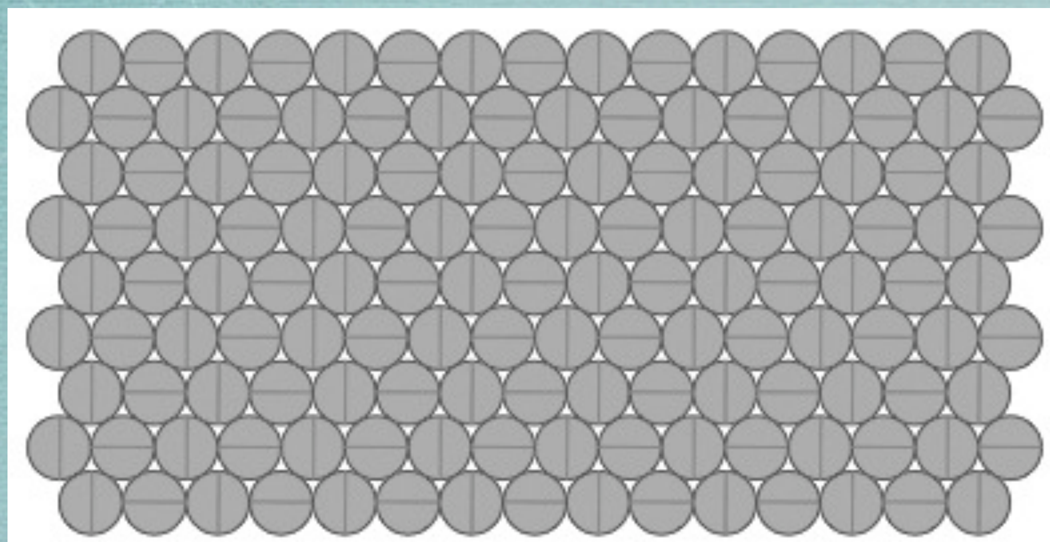




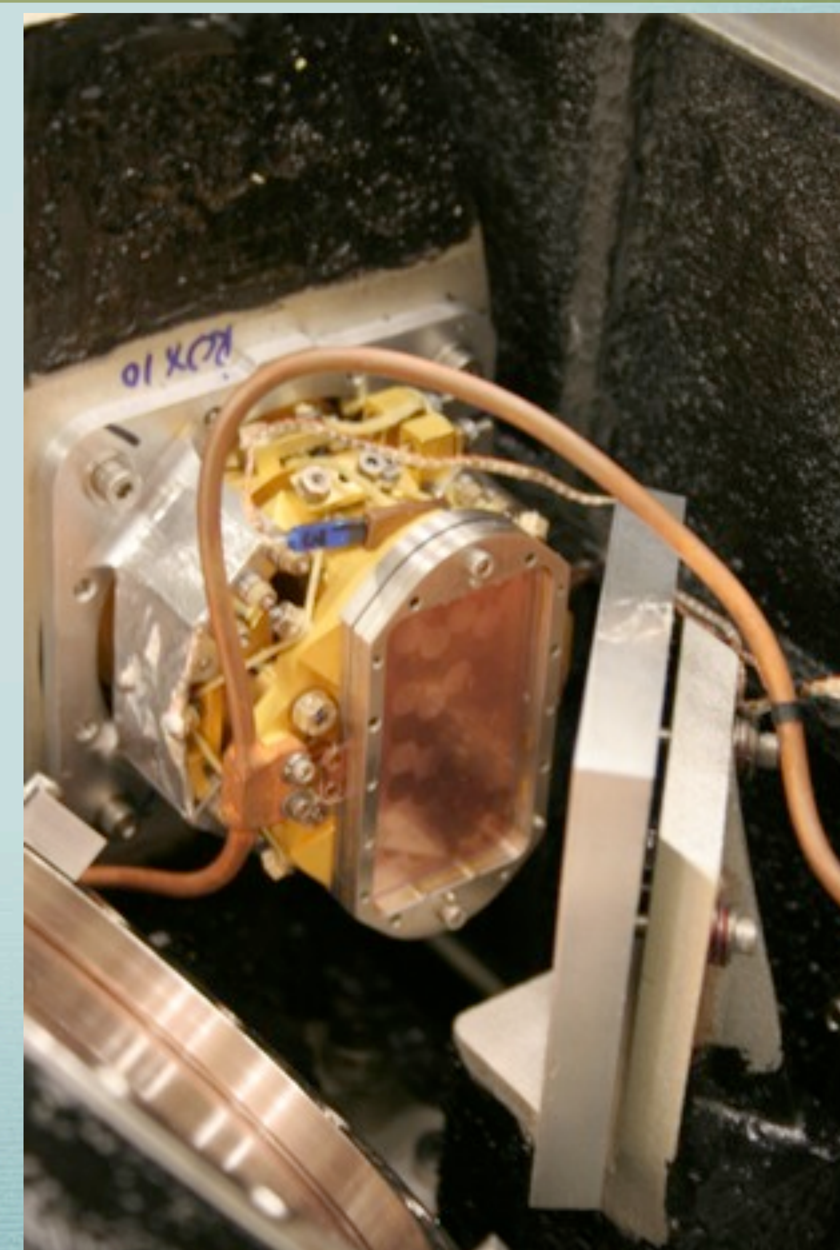
detectors maintained at 300mK by He/N cryostat with ~12-day hold time

wavelength (μm)	250	350	500
#detectors	149	88	43
NEFD (mJy $s^{1/2}$)	236	241	239
σ_{map} (mJy/beam)	11	8.6	6.6

Polarimetry



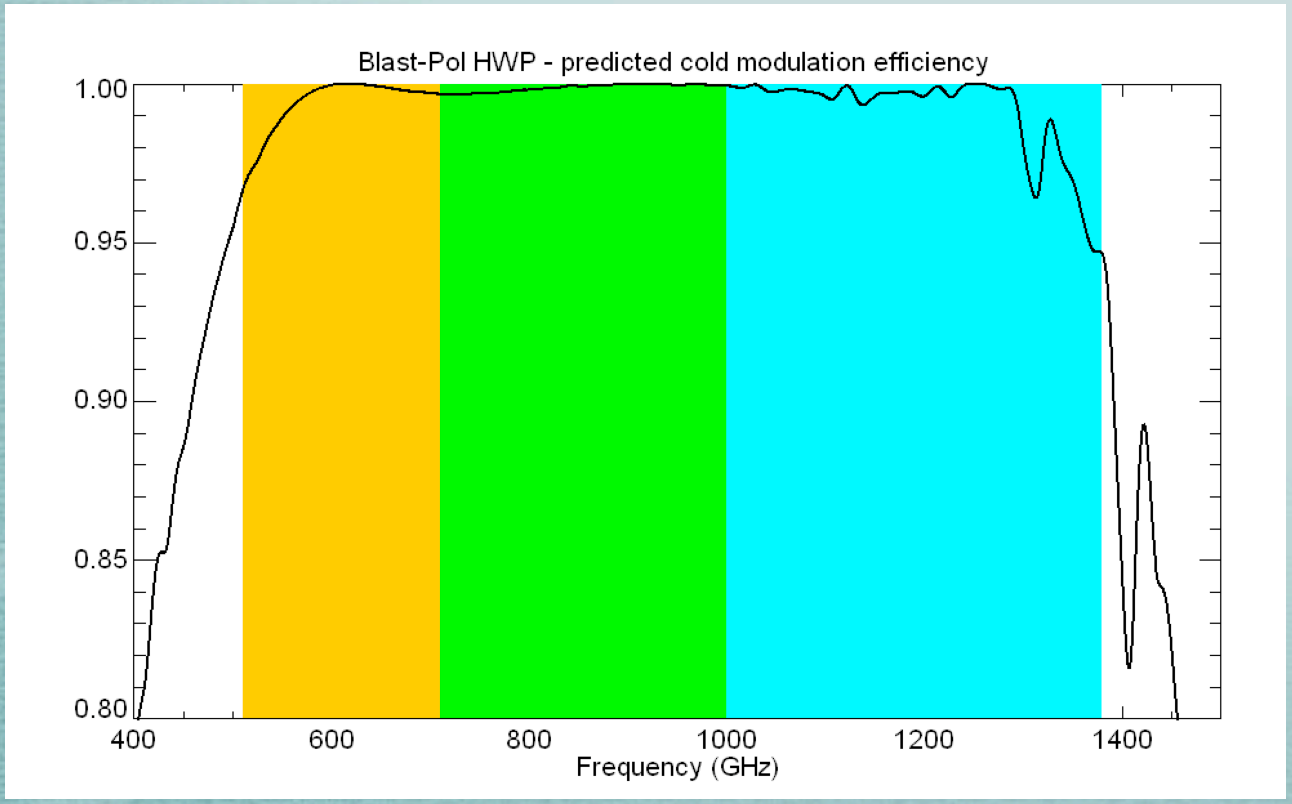
•Photo-lithographed polarized grid mounted in front of each array with alternating polarization angles

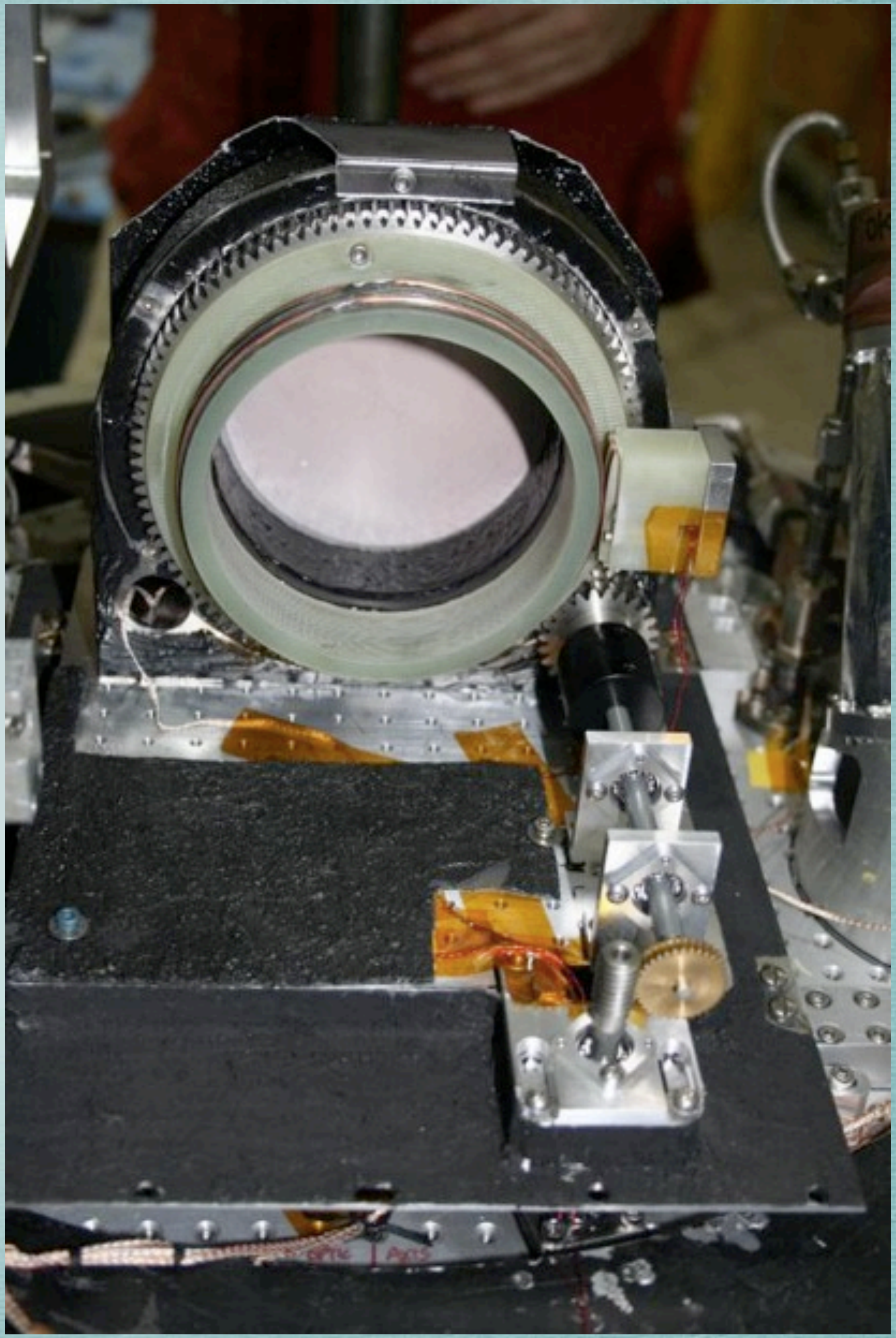


•Scan direction is approximately along row of detectors.
•Time to measure one Stokes parameter (Q or U) is <1s.

Polarimetry

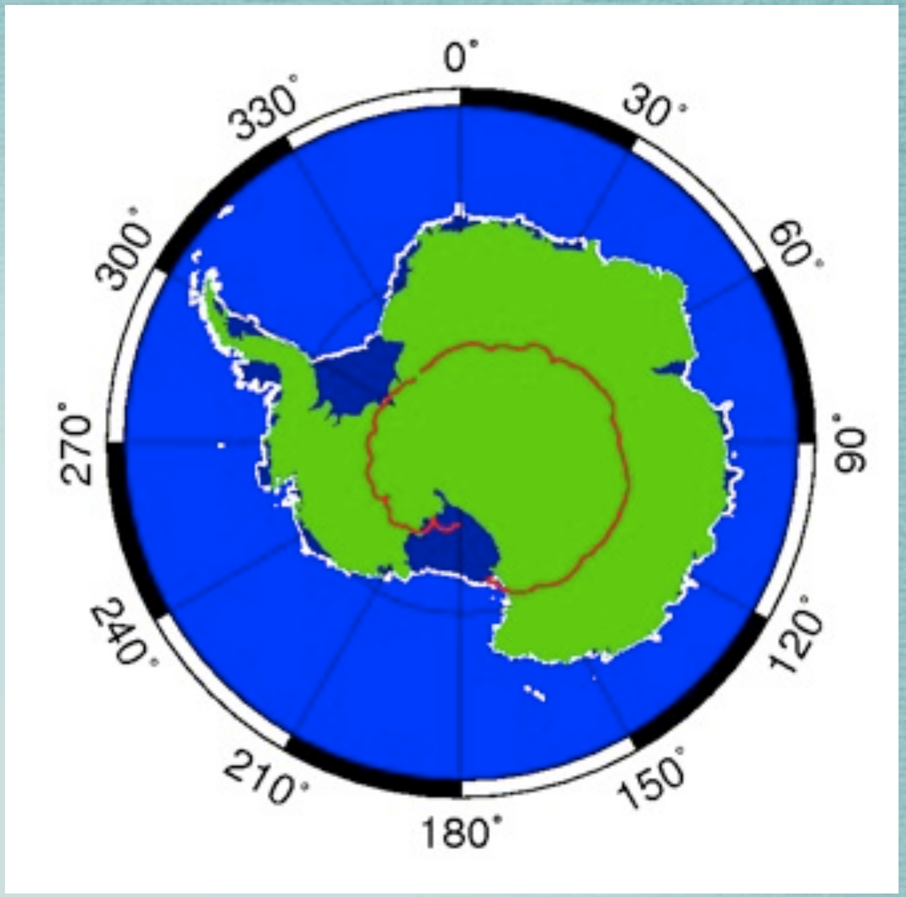
- •Achromatic sapphire half-wave plate mounted inside optics box
- •Stepped by 22.5° after every scan
- •Good modulation efficiency over three BLAST-Pol bands
- •Instrumental polarization <1%





BLAST-Pol Flight

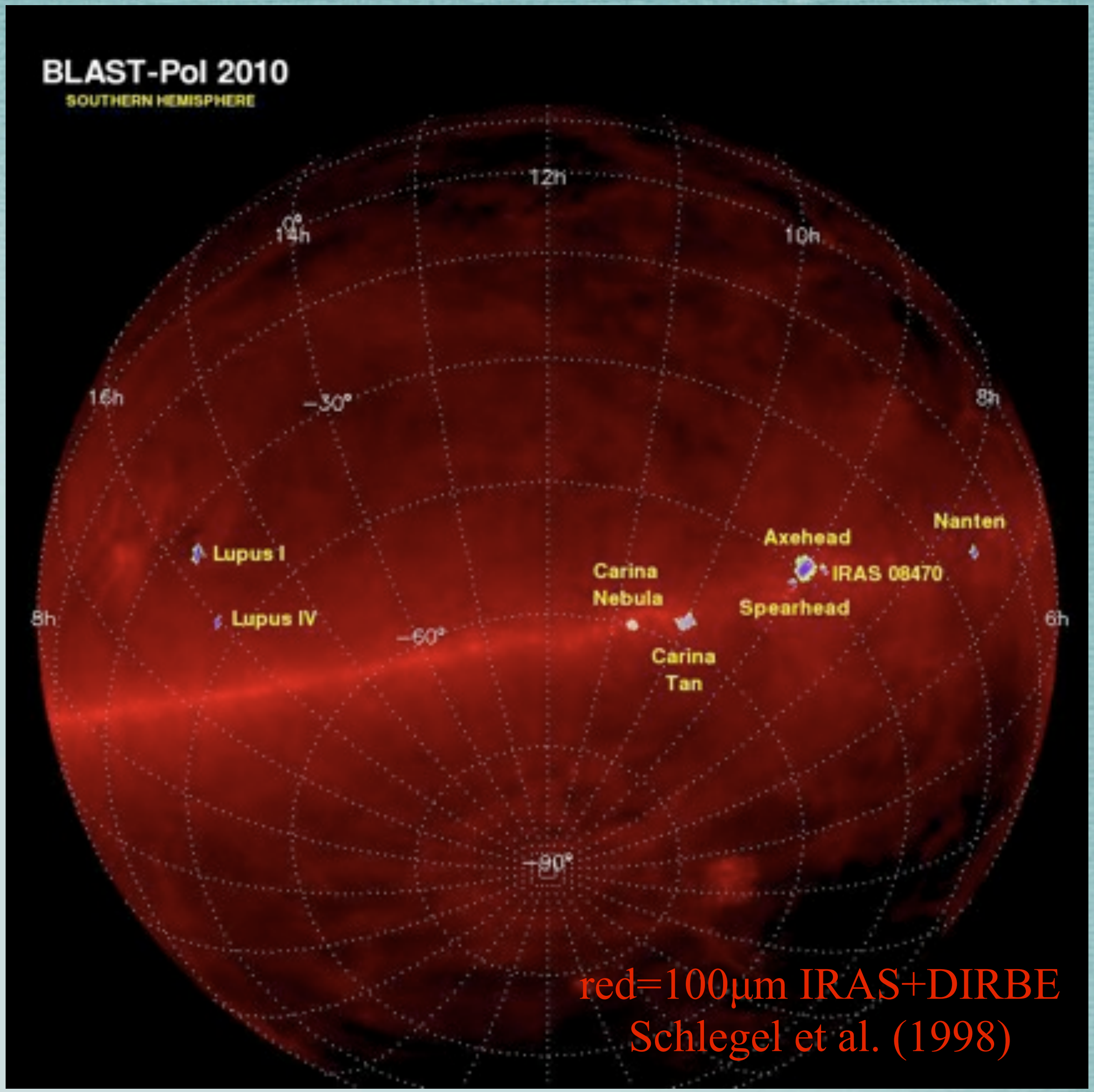
launched: Dec.27, 2010 from McMurdo Station, Antarctica



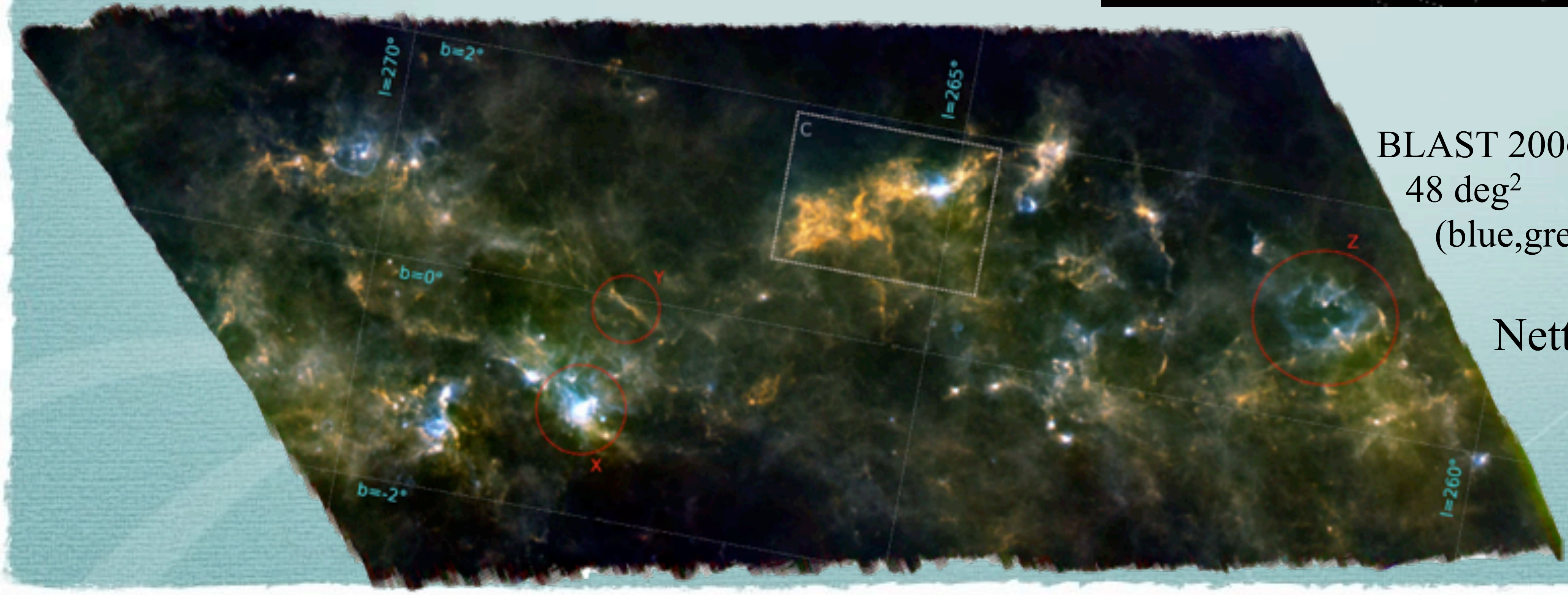
9.5 day flight at ~38km altitude, above 99.5% of the atmosphere
terminated: Jan.6th, 2011 on Ross Ice Shelf

BLAST-Pol Targets

Target Name	Area mapped (deg^2)	Observation Time (hrs)	Distance (kpc)
Lupus I	0.7	48	0.2
Lupus IV	0.2	13	0.2
Vela C	1.4	56	0.7
Vela Filament	0.2	8	0.7
Puppis 238.9-01.6	0.3	23	~1
GMC in Carina Tangent	1.0	13	~1.5
IRDC G321.934-0.052	0.5	5	>2?
IRDC G323.71-0.28	0.5	3	>2?



red=100μm IRAS+DIRBE
Schlegel et al. (1998)

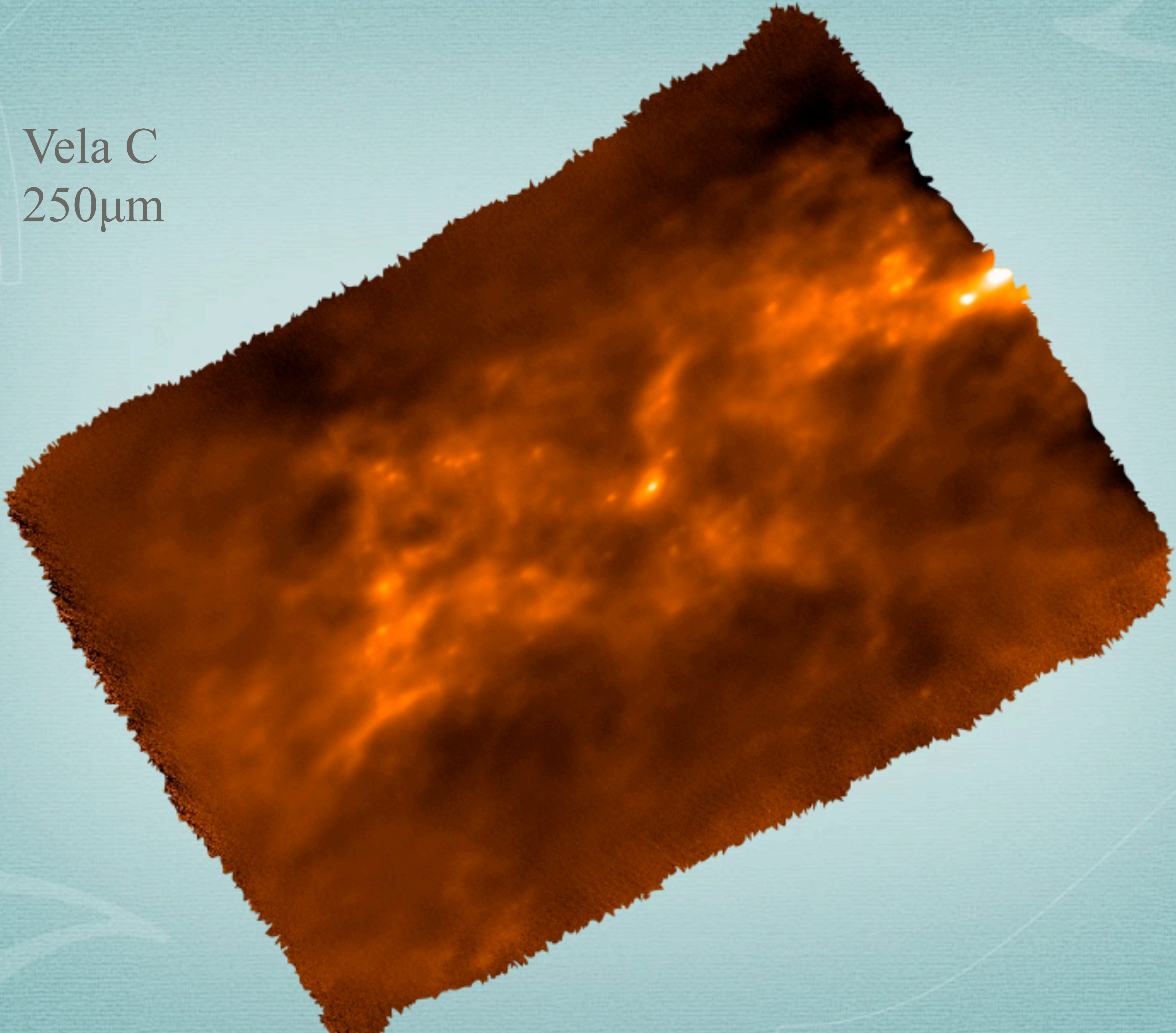


BLAST 2006 Vela map
48 deg^2
(blue,green,red) = (250, 350, 500μm)

Netterfield et al. (2009)

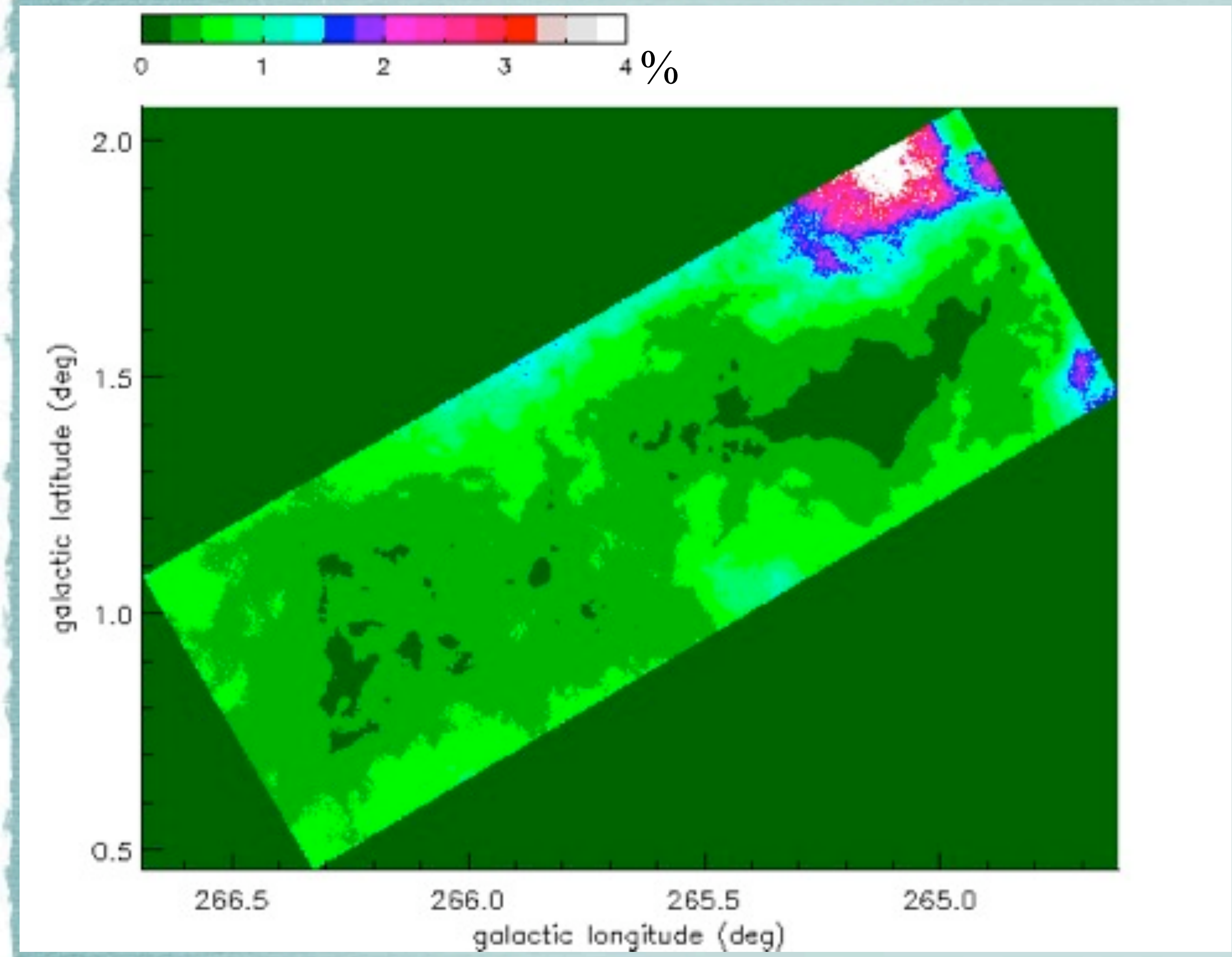
Preliminary Intensity Map

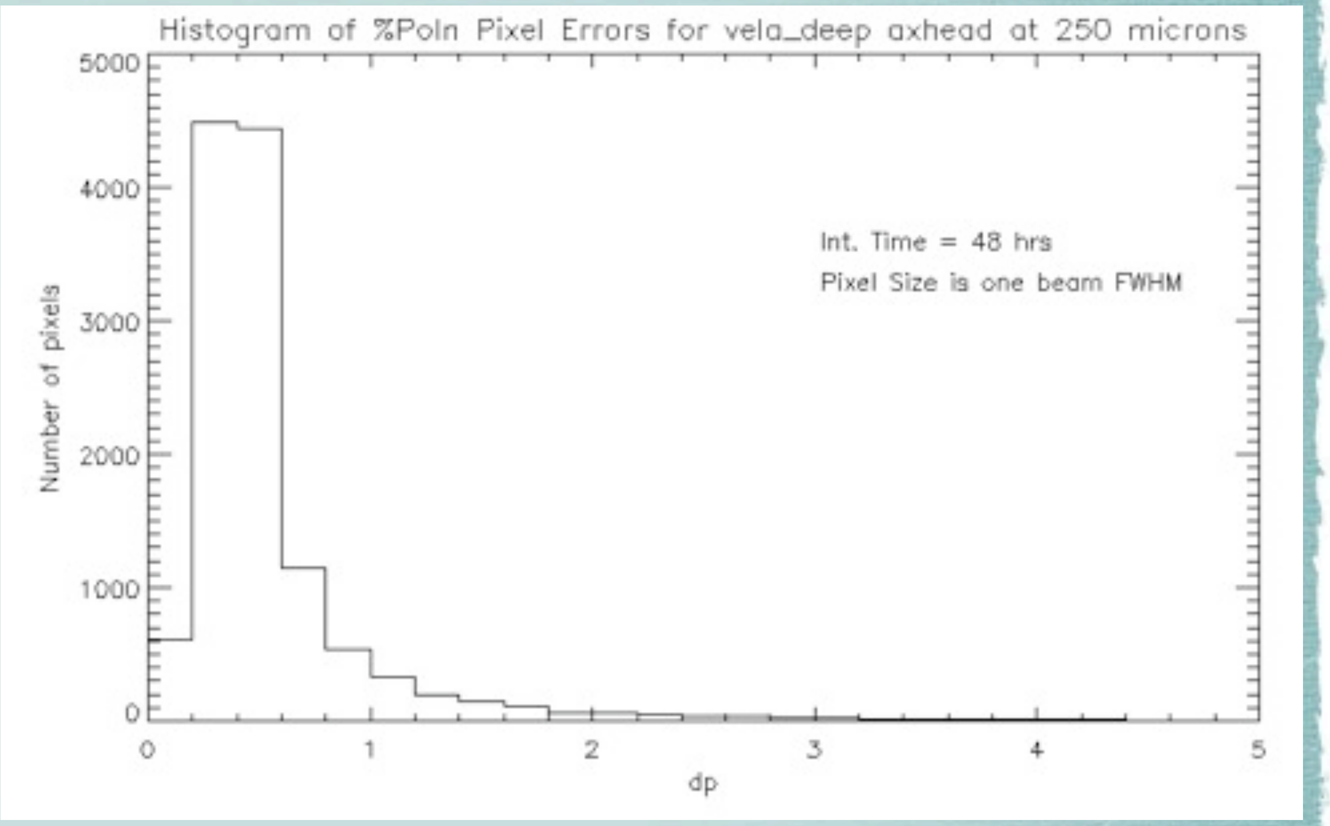
Vela C
250μm



Predicted σ_p

250μm

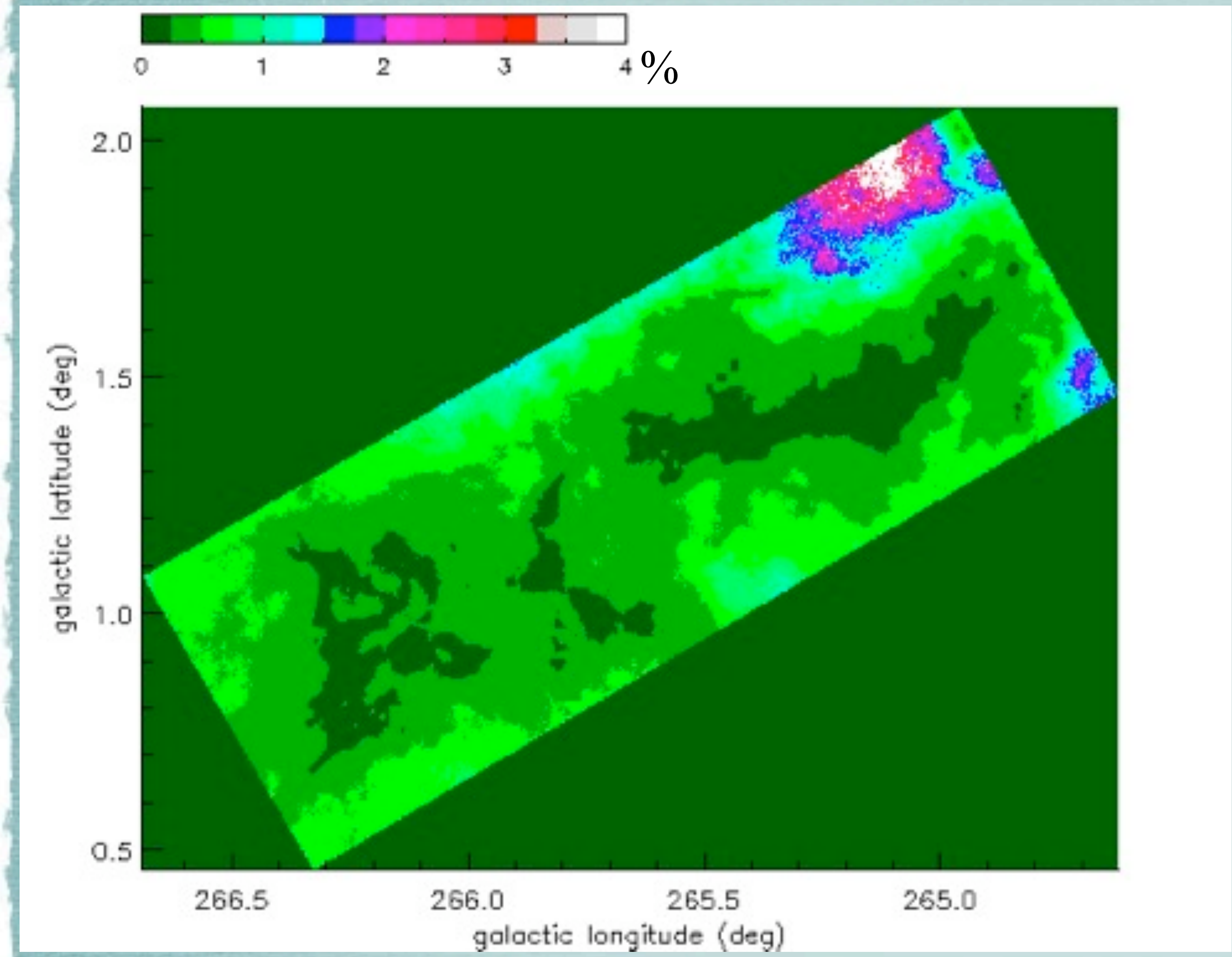


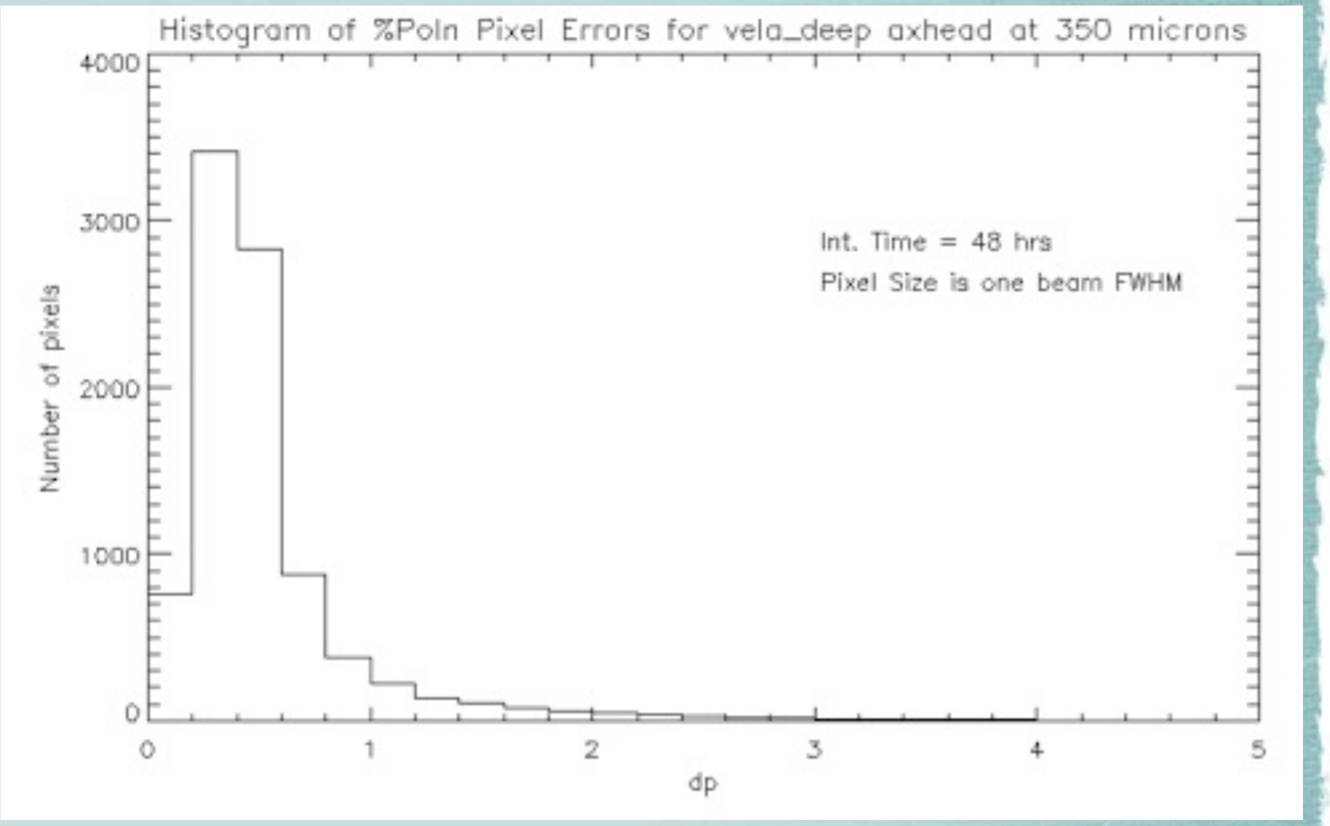


48 hrs, 1.4 sq.deg. map of Vela C

Predicted σ_p

350μm

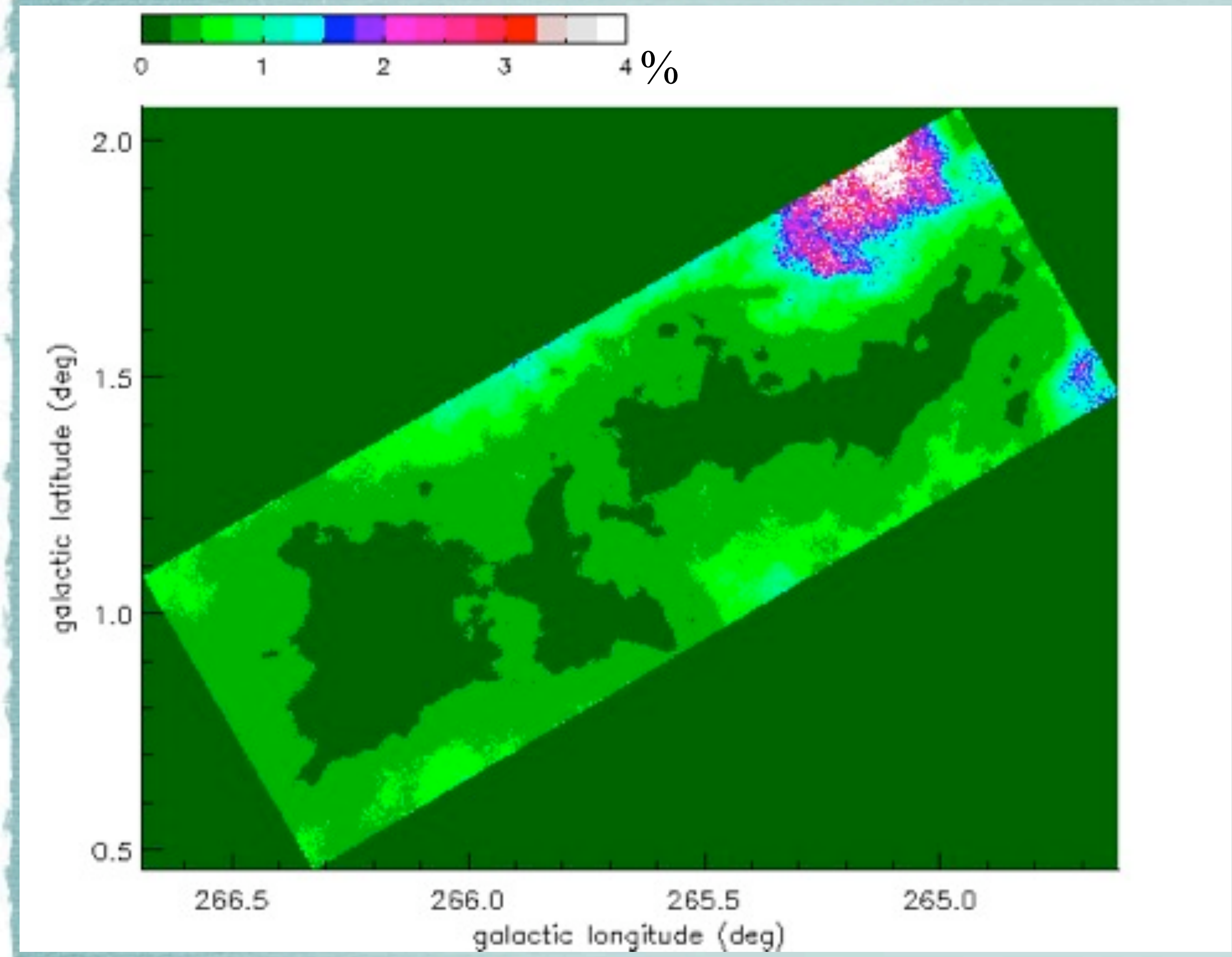


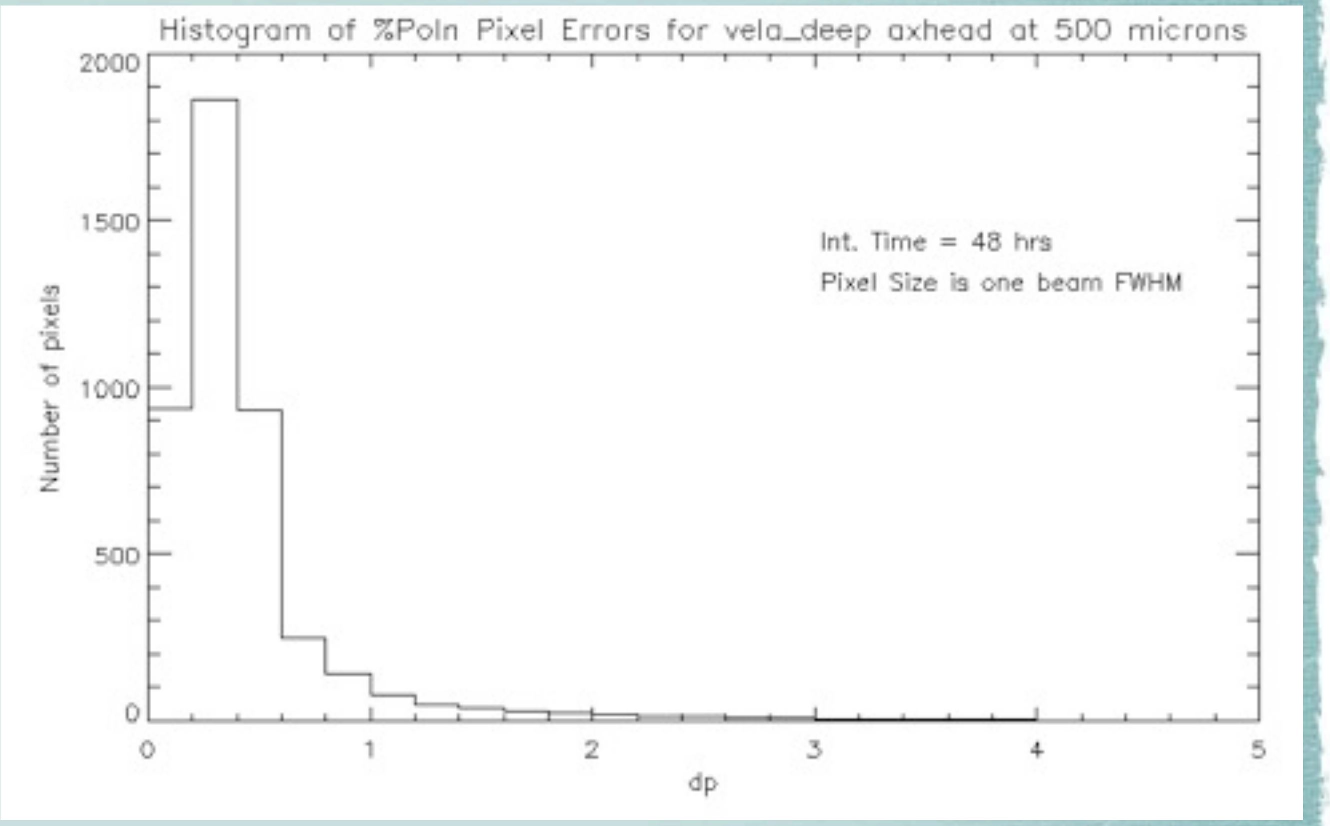


48 hrs, 1.4 sq.deg. map of Vela C

Predicted σ_p

500μm





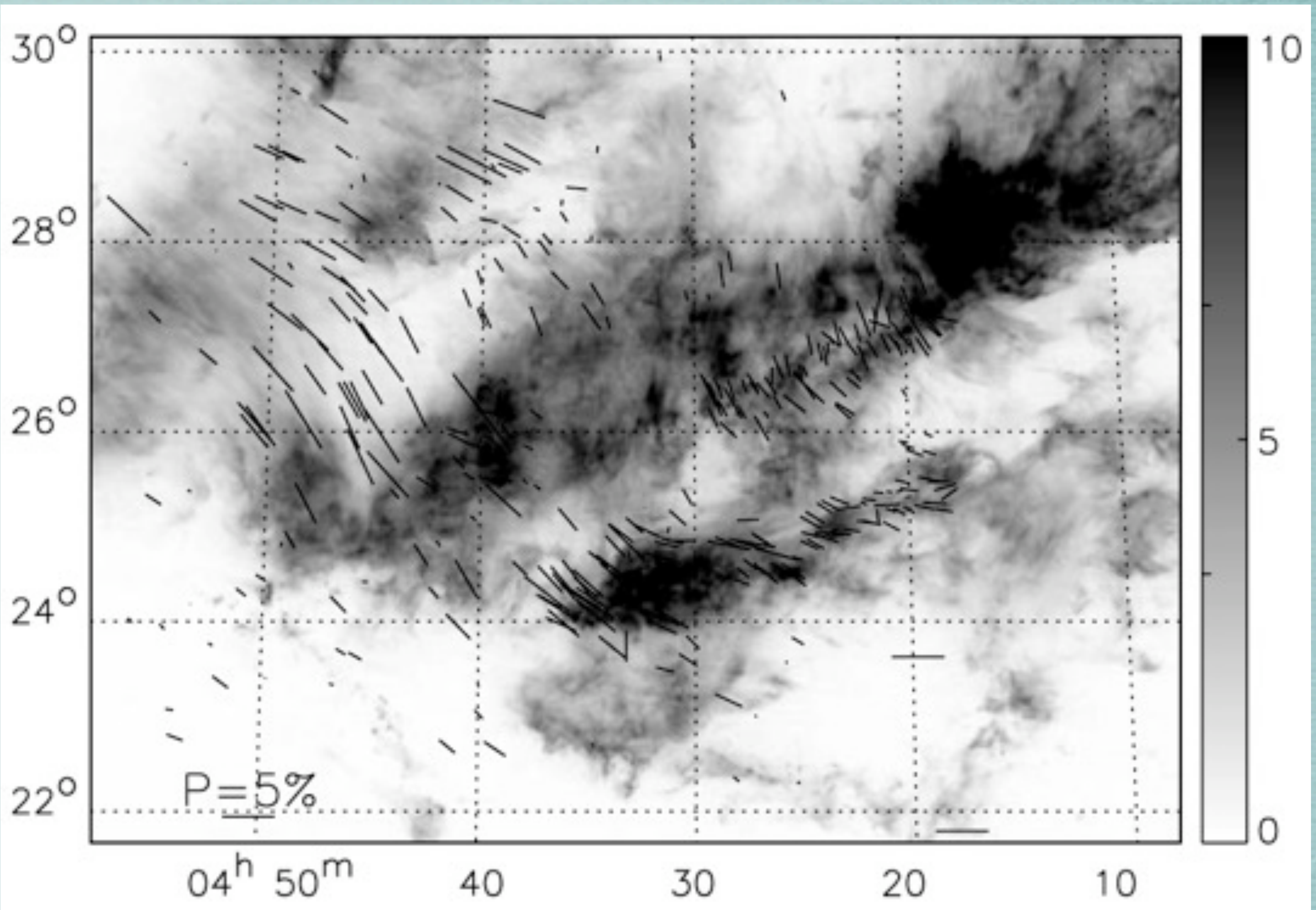
48 hrs, 1.4 sq.deg. map of Vela C

Magnetic field morphology

•BLAST-Pol will trace the magnetic fields from cores and high density filaments into lower density environments, at 1′ resolution

Goldsmith et al. (2008)

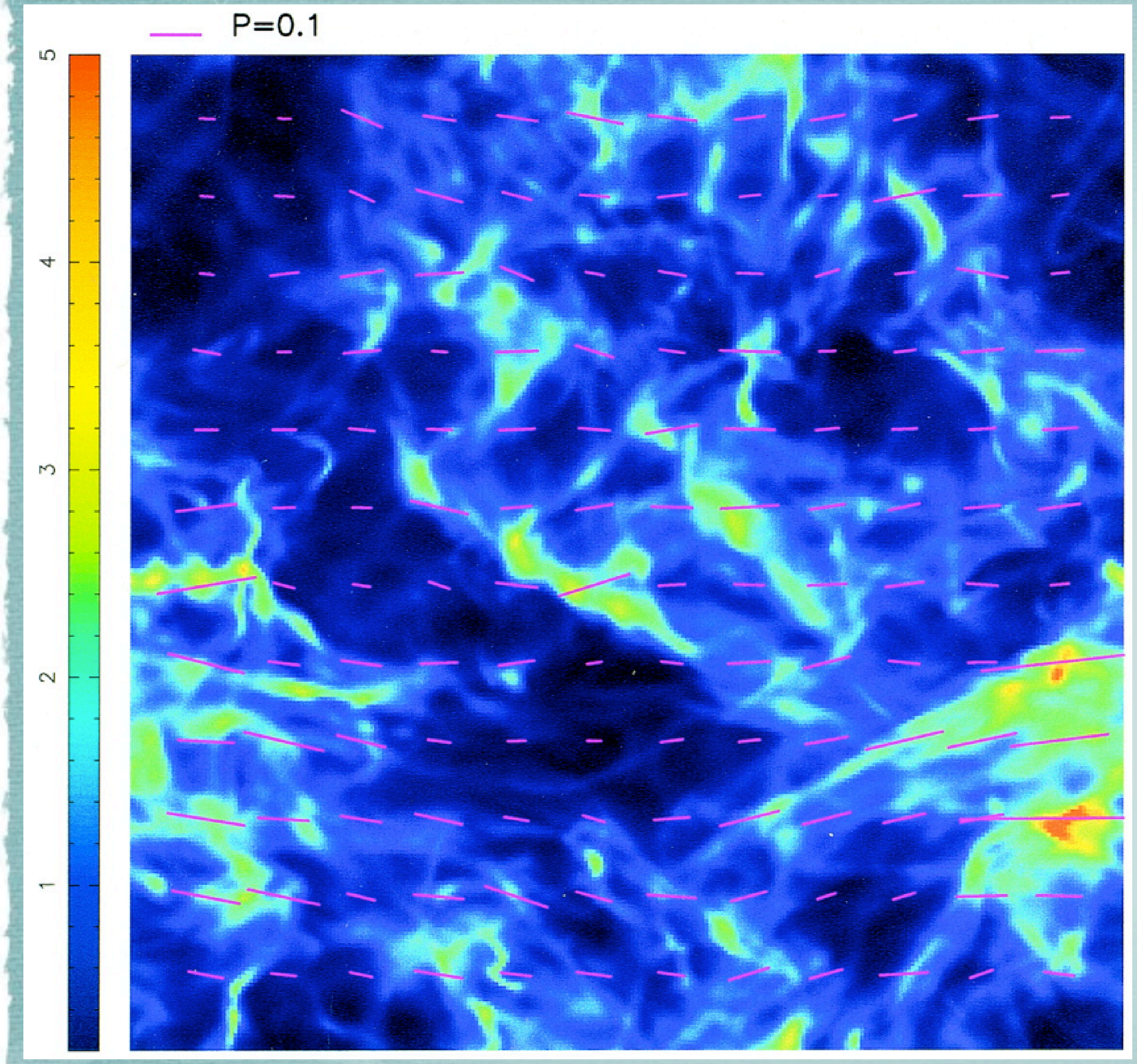
Taurus molecular cloud magnetic field line direction from optical polarimetry superimposed on ^{12}CO antenna temperature



•Do the *mean magnetic field directions* of clouds correlate with

- elongated cloud structure (filament-like)?
- orientation of Galactic plane?
- cloud rotation axis?
- orientation of magnetic field in surrounding diffuse ISM?

Magnetic field strength



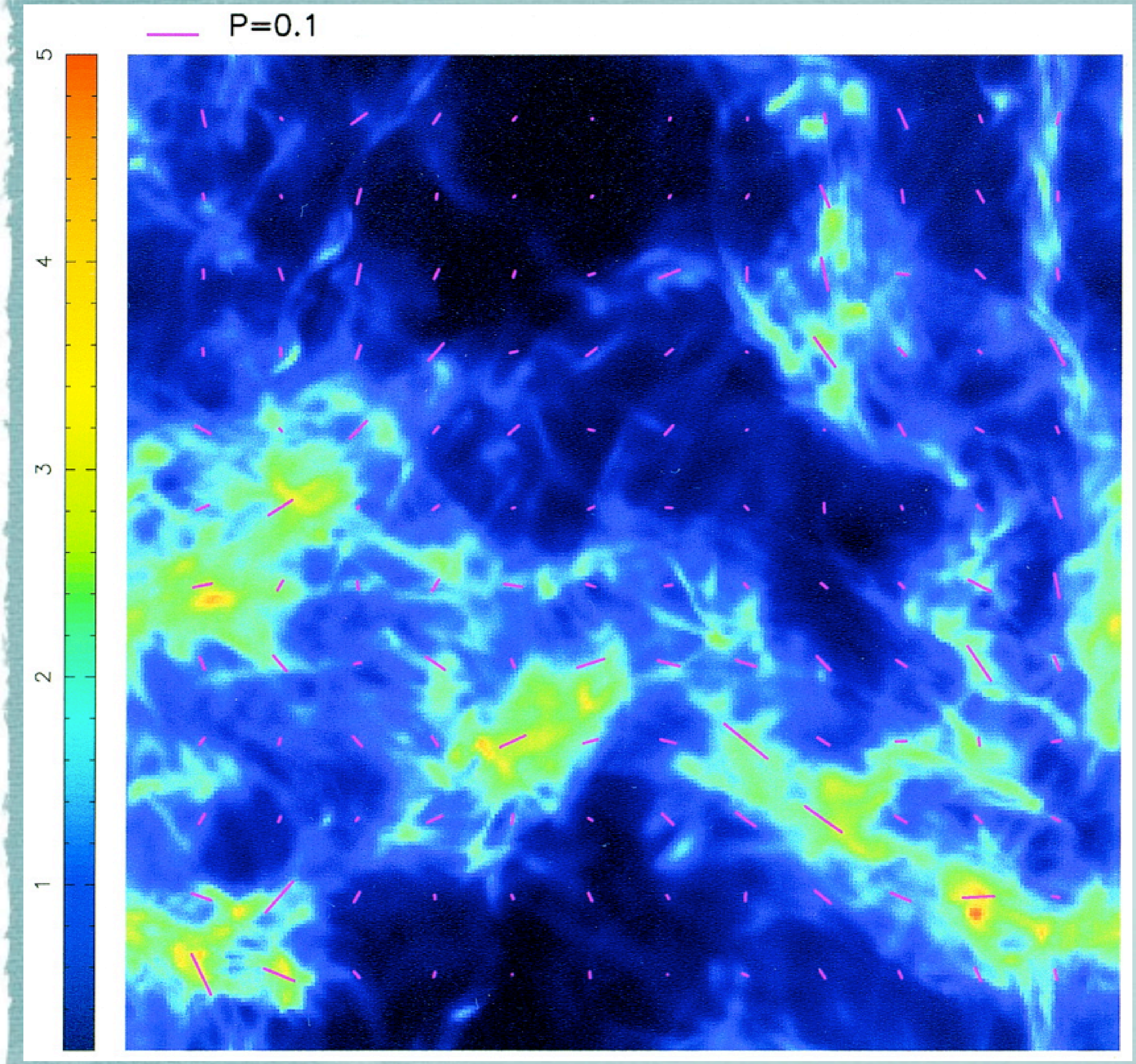
smooth, self-gravitating, iso-thermal gas with initial uniform B-field

Ostriker, Stone & Gammie (2001)

- What is the *overall degree of order* in cloud magnetic fields, and how does this vary from cloud to cloud? (eg.Li,Novak et al. 2006)
- σ_ϕ can be used to estimate the component of the B-field in the plane of the sky (Chandrasekhar & Fermi 1951)
- stronger B-field will resist getting tangled by turbulent motions

strong B-field
σ_ϕ=9.6°

Magnetic field strength



smooth, self-gravitating, iso-thermal gas with initial uniform B-field

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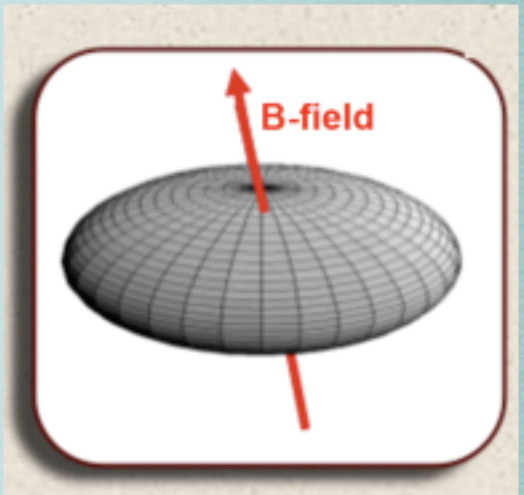
- σ_ϕ can be used to estimate the component of the B-field in the plane of the sky (Chandrasekhar & Fermi 1951)
- stronger B-field will resist getting tangled by turbulent motions

weak B-field
σ_ϕ=45.3°

Magnetic fields surrounding cores

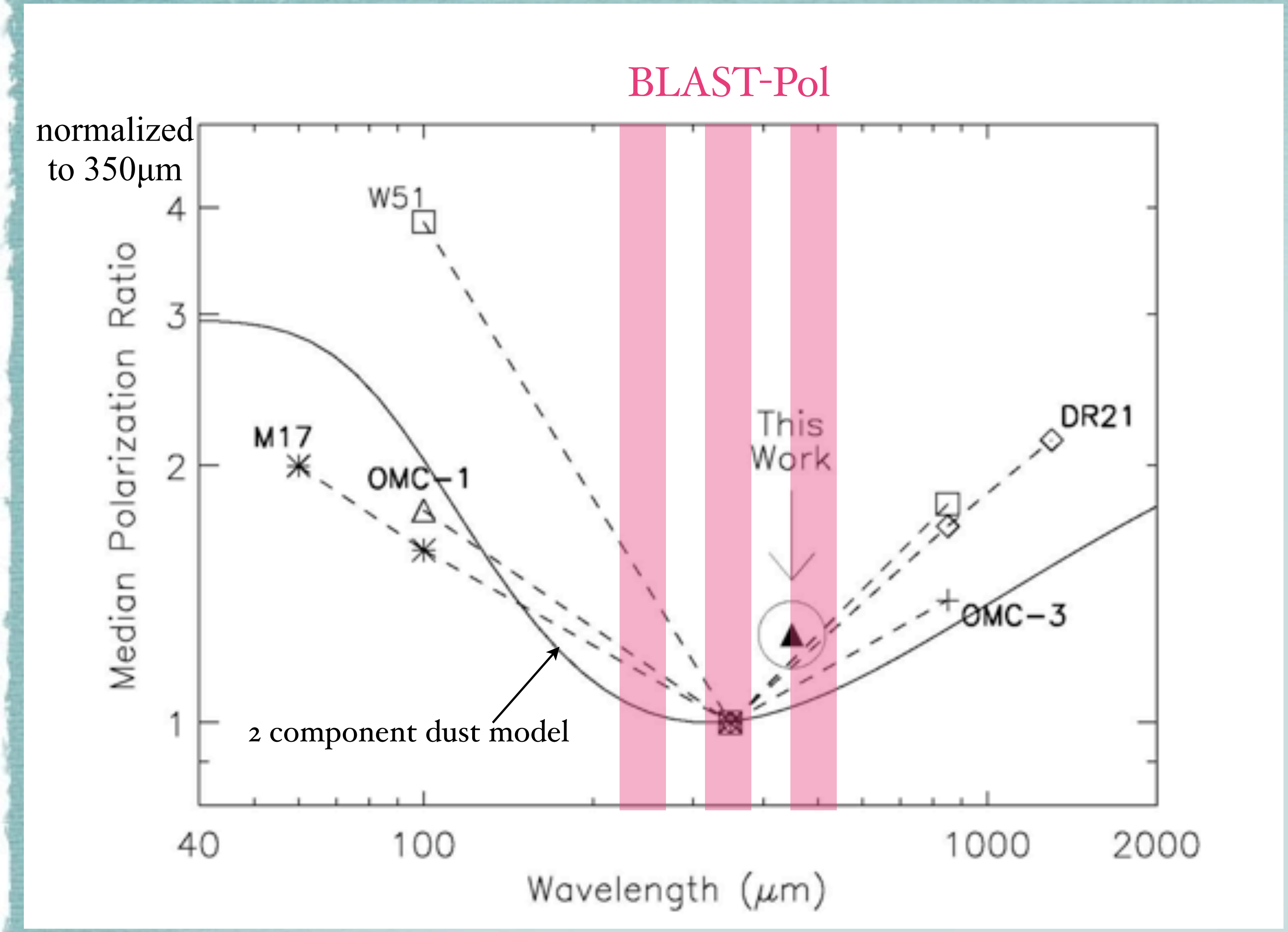
•Models invoking magnetic control predict that cores should be *oblate* with *minor axes parallel* to the B-field direction

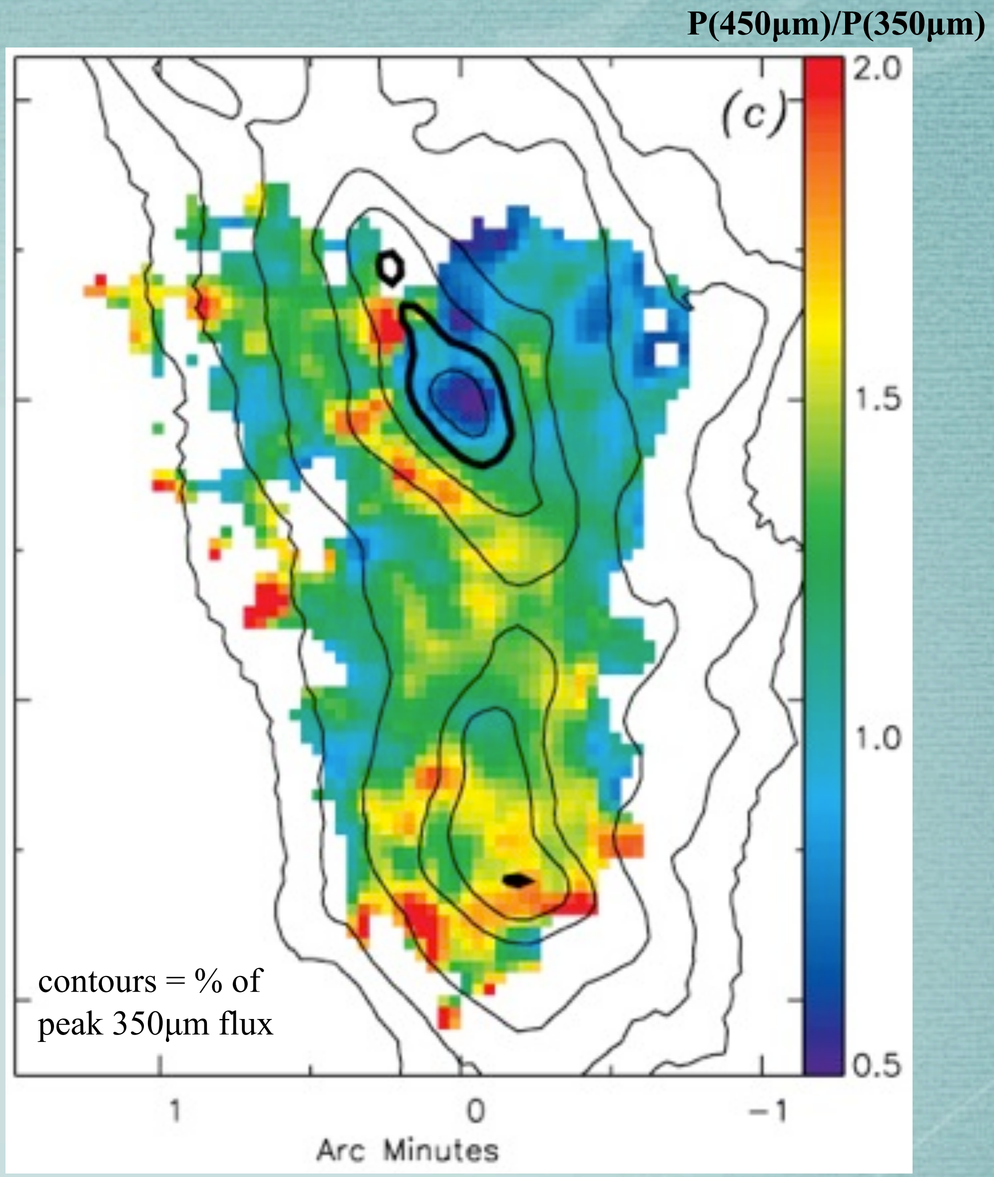
-e.g., Tassis et al. (2009) studied 24 clouds at 20″ resolution, and found the data was well fit by clouds with oblate shapes with small deviation (θ~24°) of magnetic field orientation to minor axis



•Are bipolar outflows preferentially parallel to core B-fields?

Polarization Spectrum

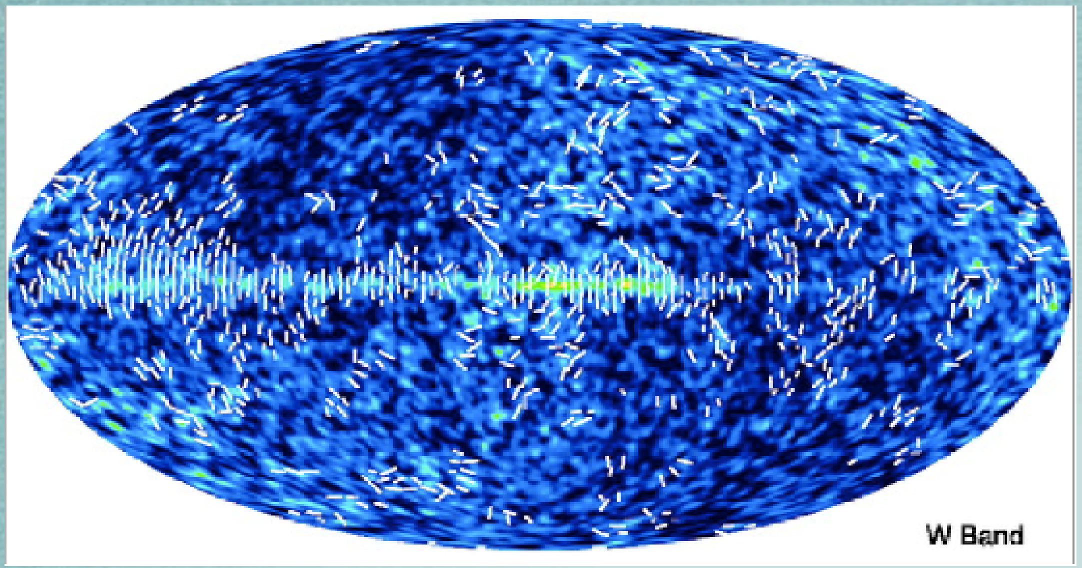




Vaillancourt et al. (2008)

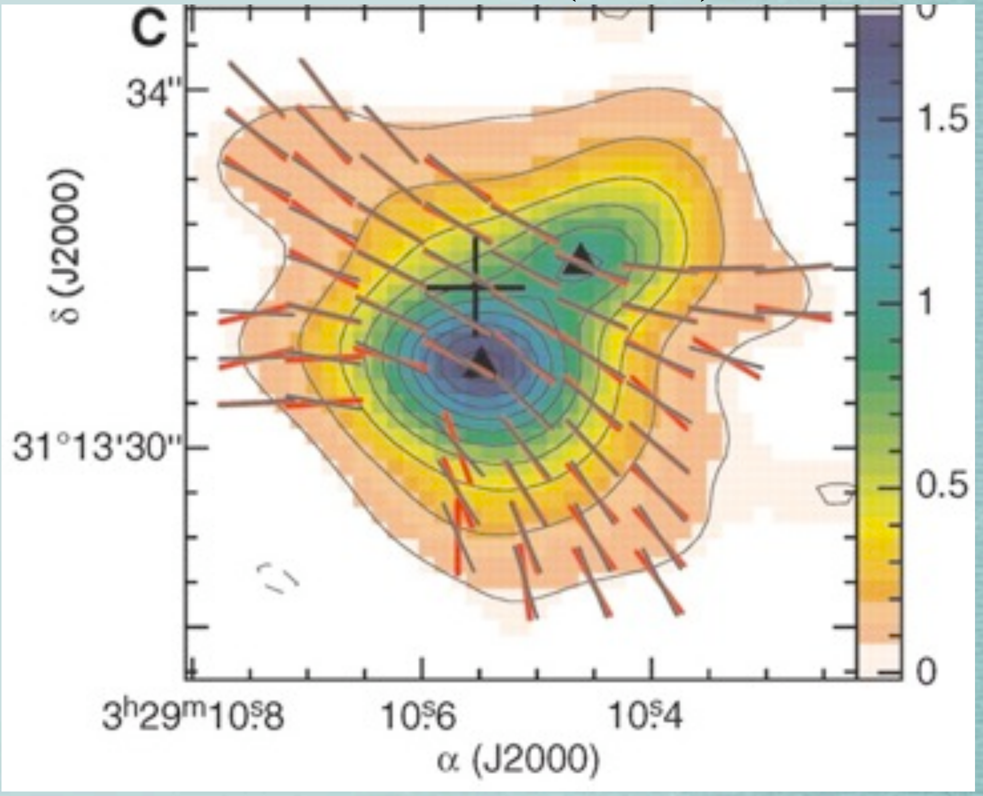
- The polarization spectrum can be used to place constraints on models of the grain alignment mechanism and its efficiency
- BLAST-Pol can better characterize the shape of the spectrum and see how it changes across different physical environments

WMAP 3mm polarization map
Page et al. (2007)



Planck will provide coarse resolution (5′) polarimetry across the whole sky

SMA polarimetry of a dusty infall envelope
Girart et al. (2006)



ALMA will provide sub-arcsecond resolution polarimetry, capable of tracing magnetic fields within cores and disks, but will not be sensitive to cloud-scale fields

BLAST-Pol is unique because it is sensitive to large scale magnetic fields and also has the resolution necessary to trace the fields into cores and dense filaments

Summary

- Submm polarimetry provides an opportunity to examine the role of magnetic fields in regulating star formation

- With its high resolution, large field of view, and high sensitivities, BLAST-Pol fills the gap between low-resolution, full sky Planck, and high-resolution, small field of view ALMA

- BLAST-Pol’s 9.5-day flight in Dec.2010-Jan.2011 mapped 8 star-forming regions

- Polarization maps coming soon...