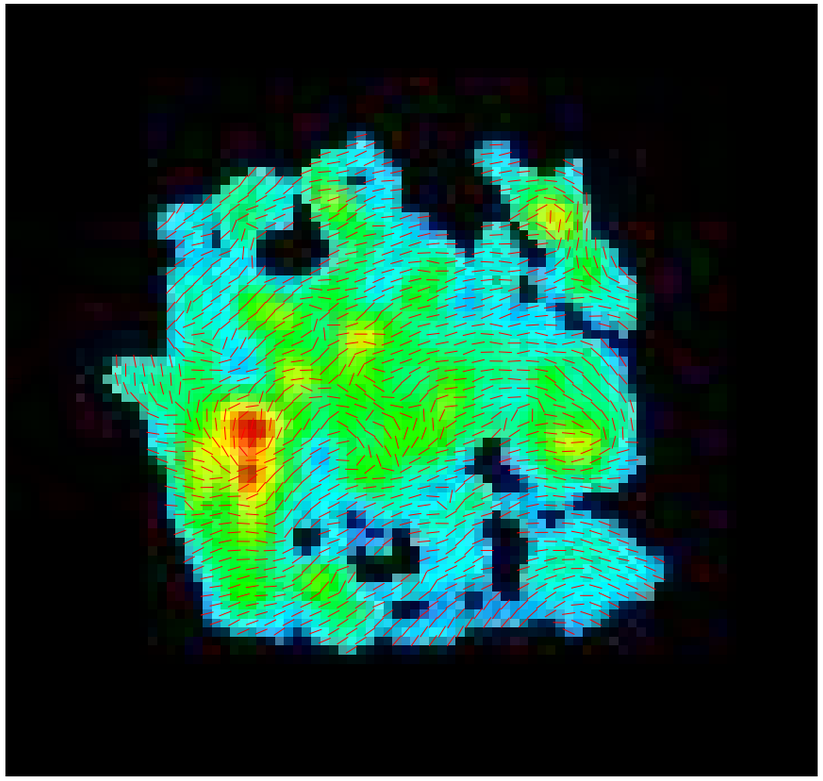
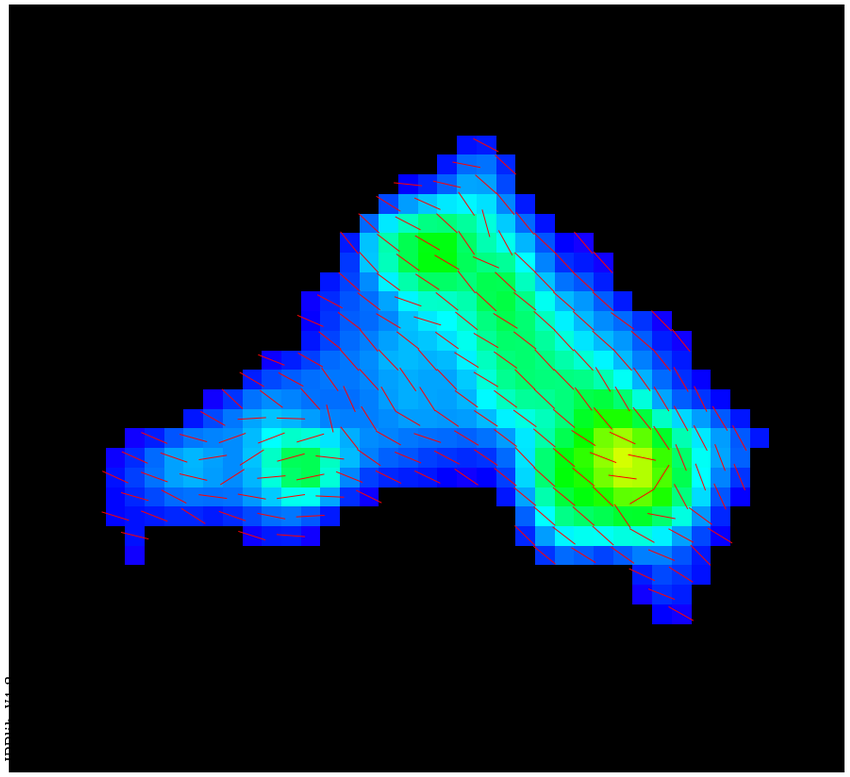
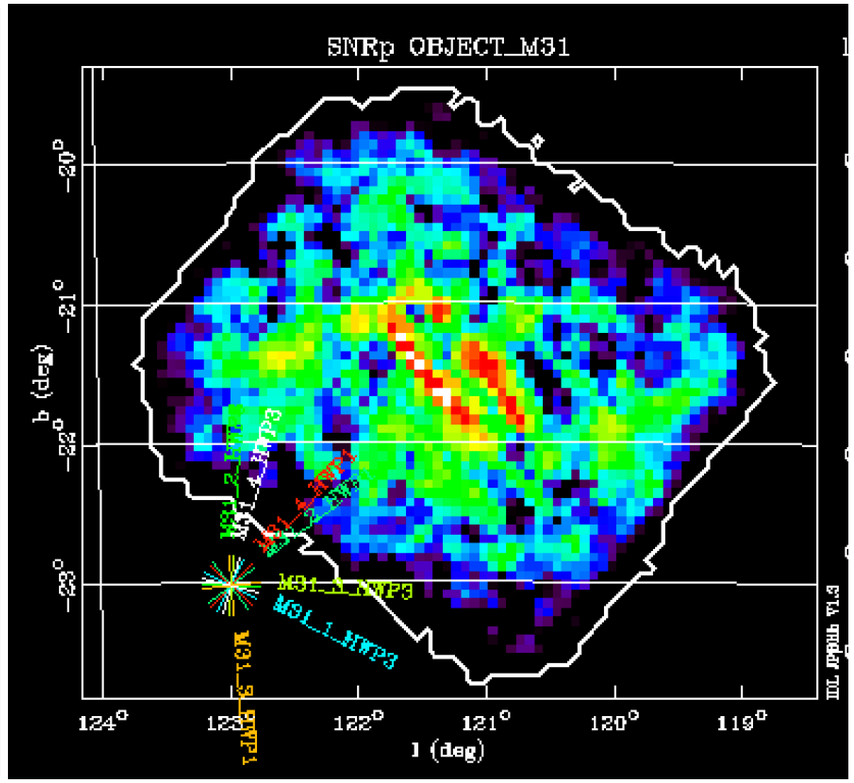


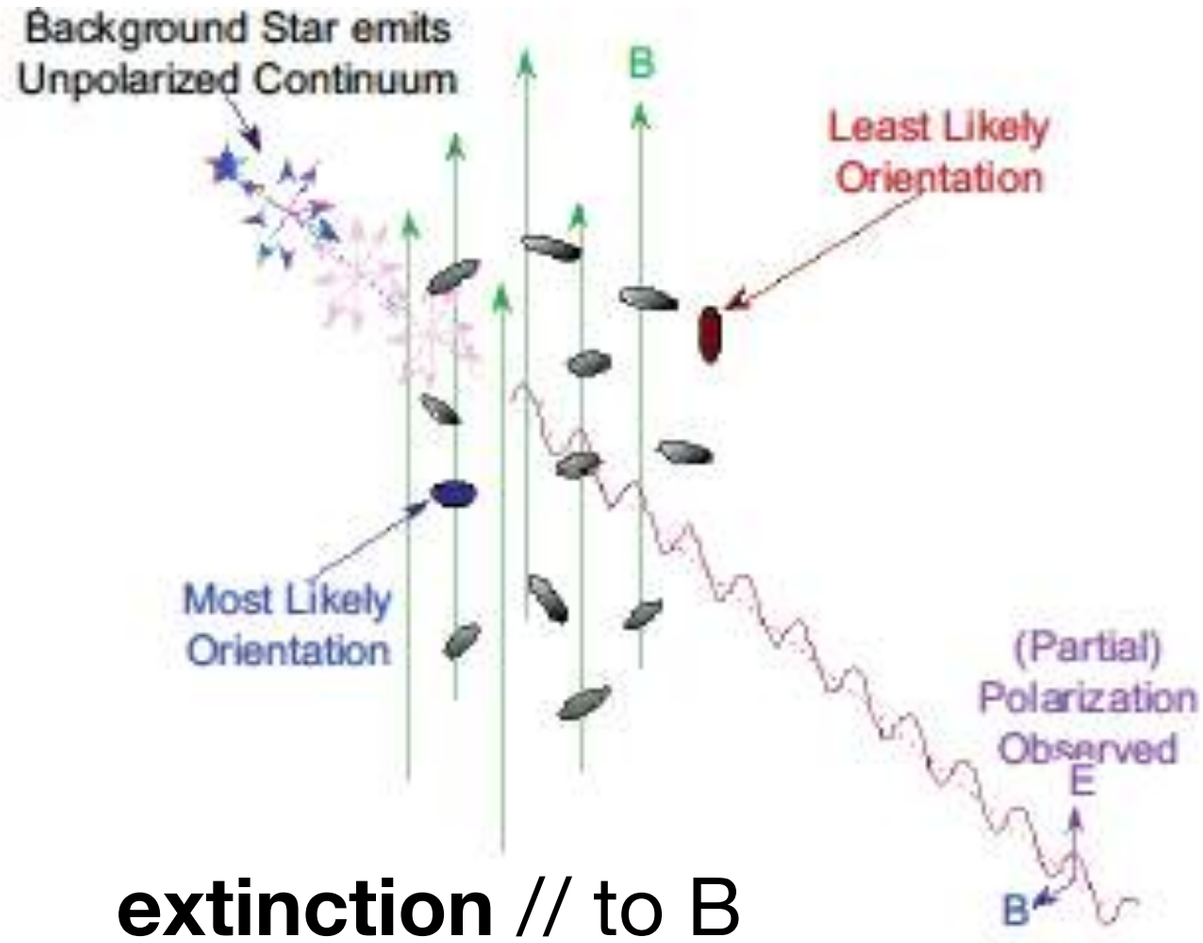




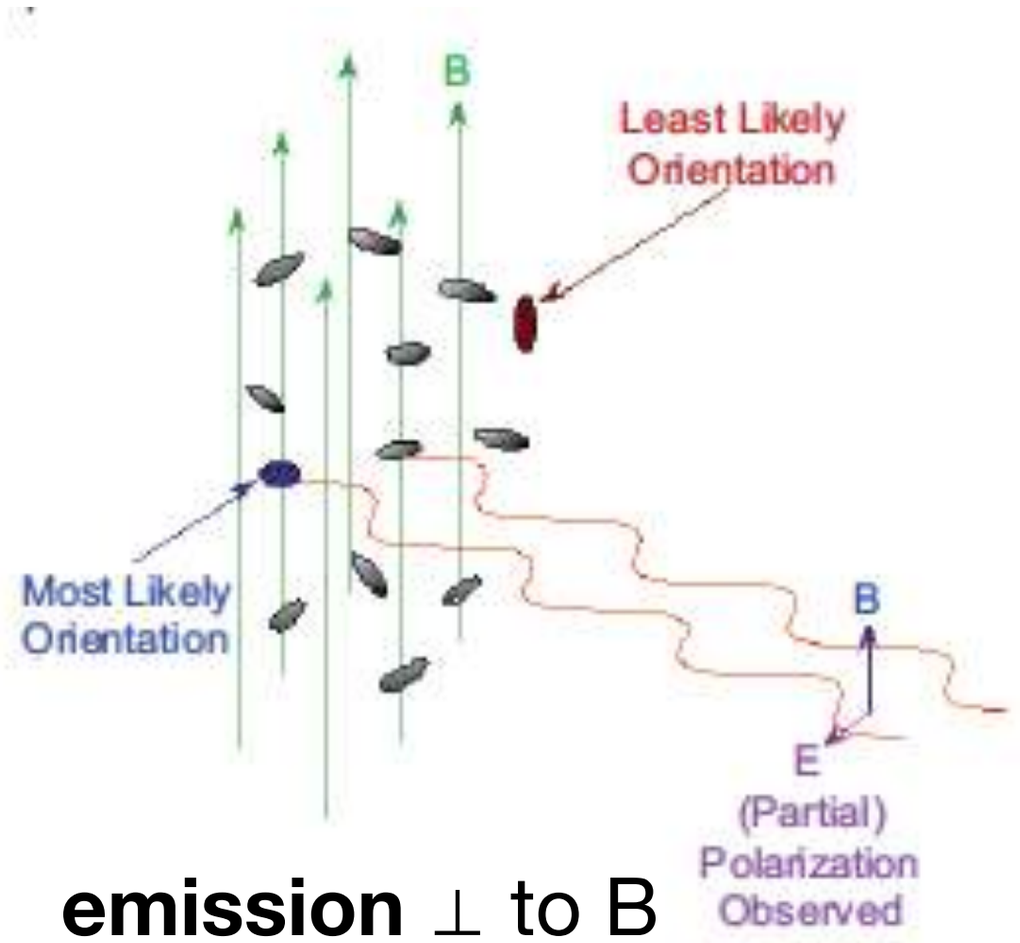
Polarised Dust Emission in the Magellanic Clouds

Annie Hughes, Jean-Philippe Bernard, Ludovic Montier, Dana Alina, Isabelle Ristorcelli, Ruka Misawa, Gabriel Foenard & the PILOT team

Dust Polarisation

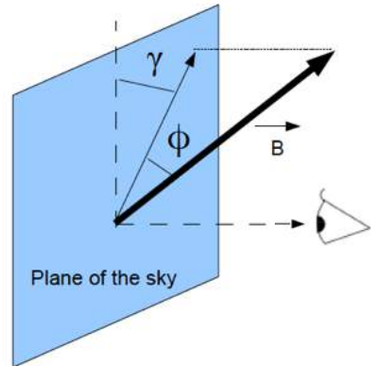


extinction // to B



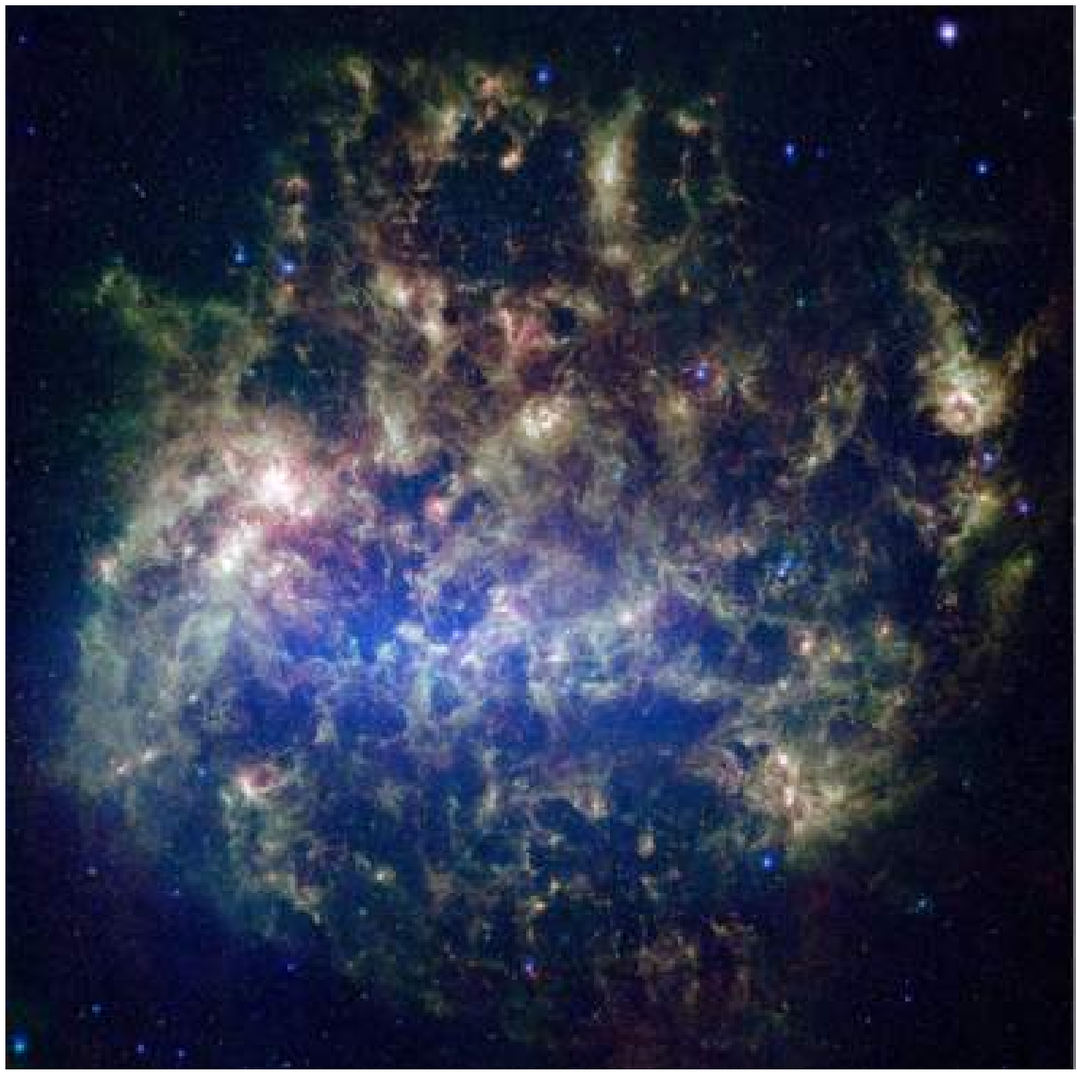
emission ⊥ to B

- Grains are elongated and rotating
- Grains align partially on B
- Cross section depends on grain size
- Trace B direction projected on the sky (like synchrotron)



$$P = \sqrt{(Q^2+U^2)} \propto \cos^2\phi$$

The Magellanic Clouds

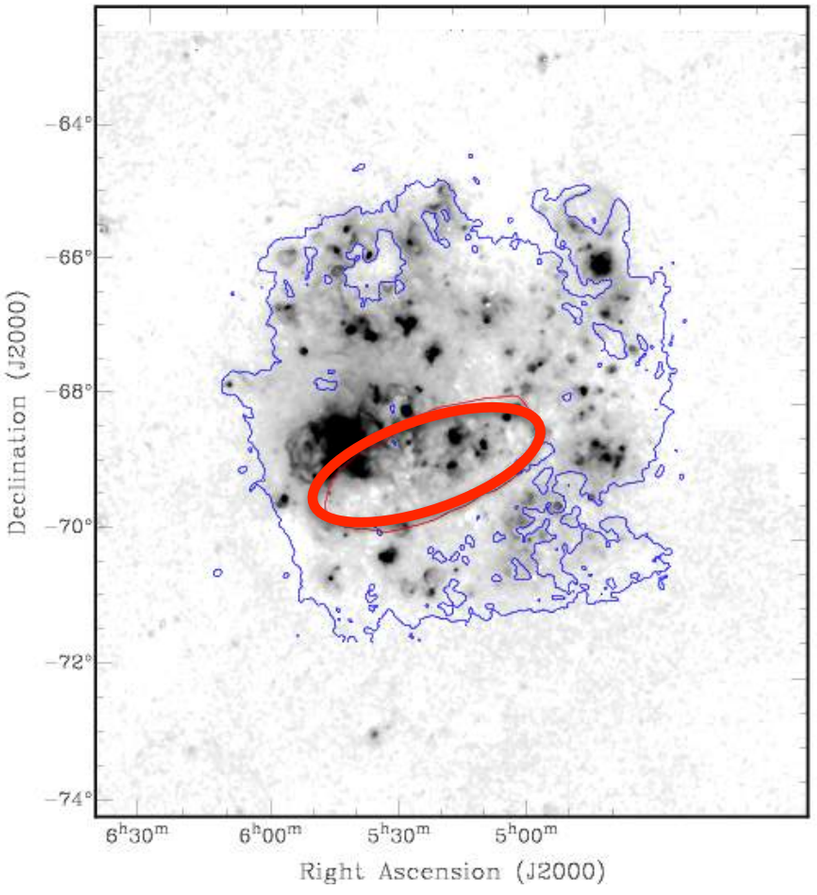


Fully mapped by the Spitzer SAGE and Herschel HERITAGE key programmes (Meixner ea 2006, 2013)

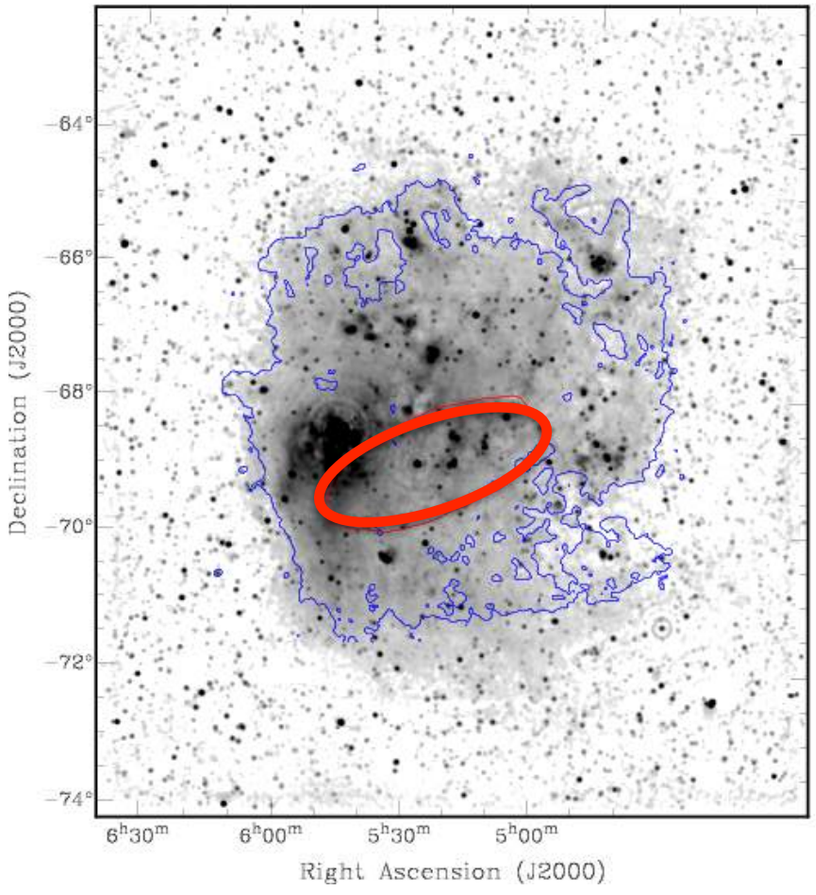
- Nearby: high resolution (~15pc) observations of dust, synchrotron and gas
- Low metallicity: LMC~1/2 and SMC ~1/6 solar, early Universe prototypes
- External vantage point: effect of galactic environment, known distance
- High galactic latitude: foreground contamination minimised

The Large Magellanic Cloud

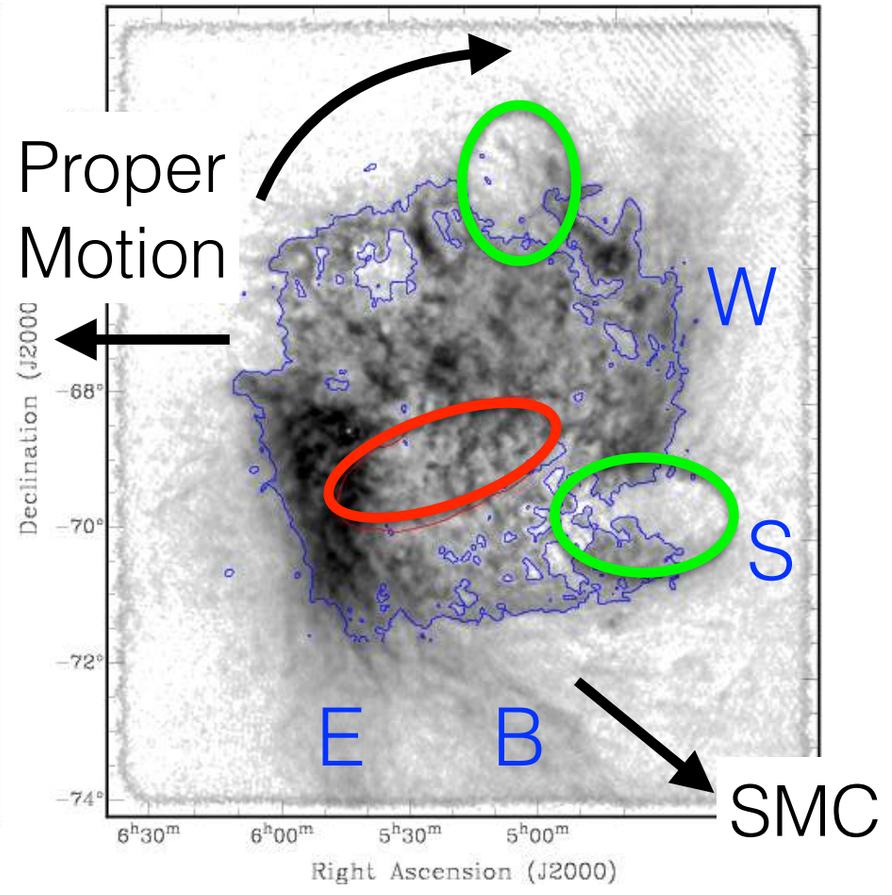
Star formation (Hα)



20cm Stokes I

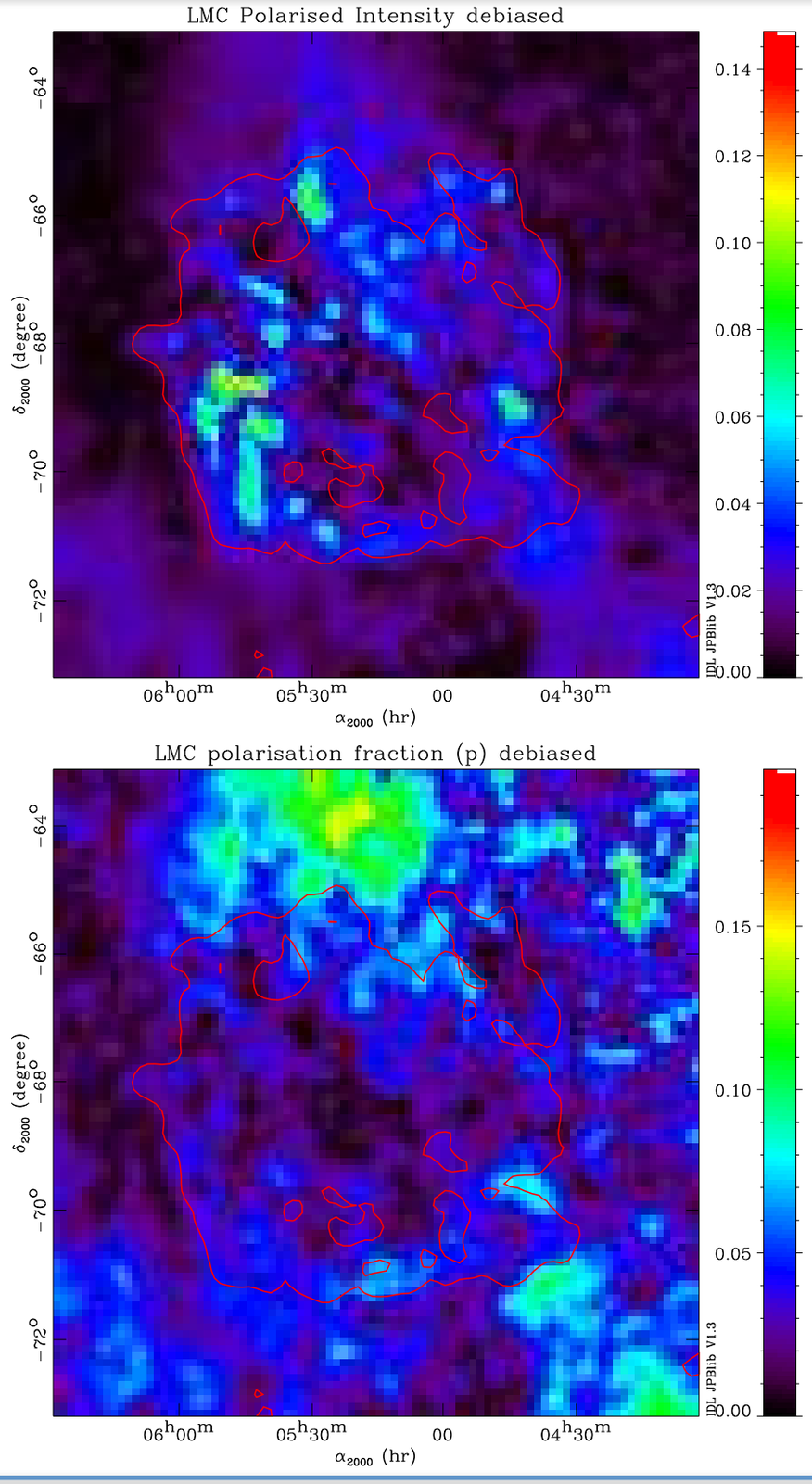


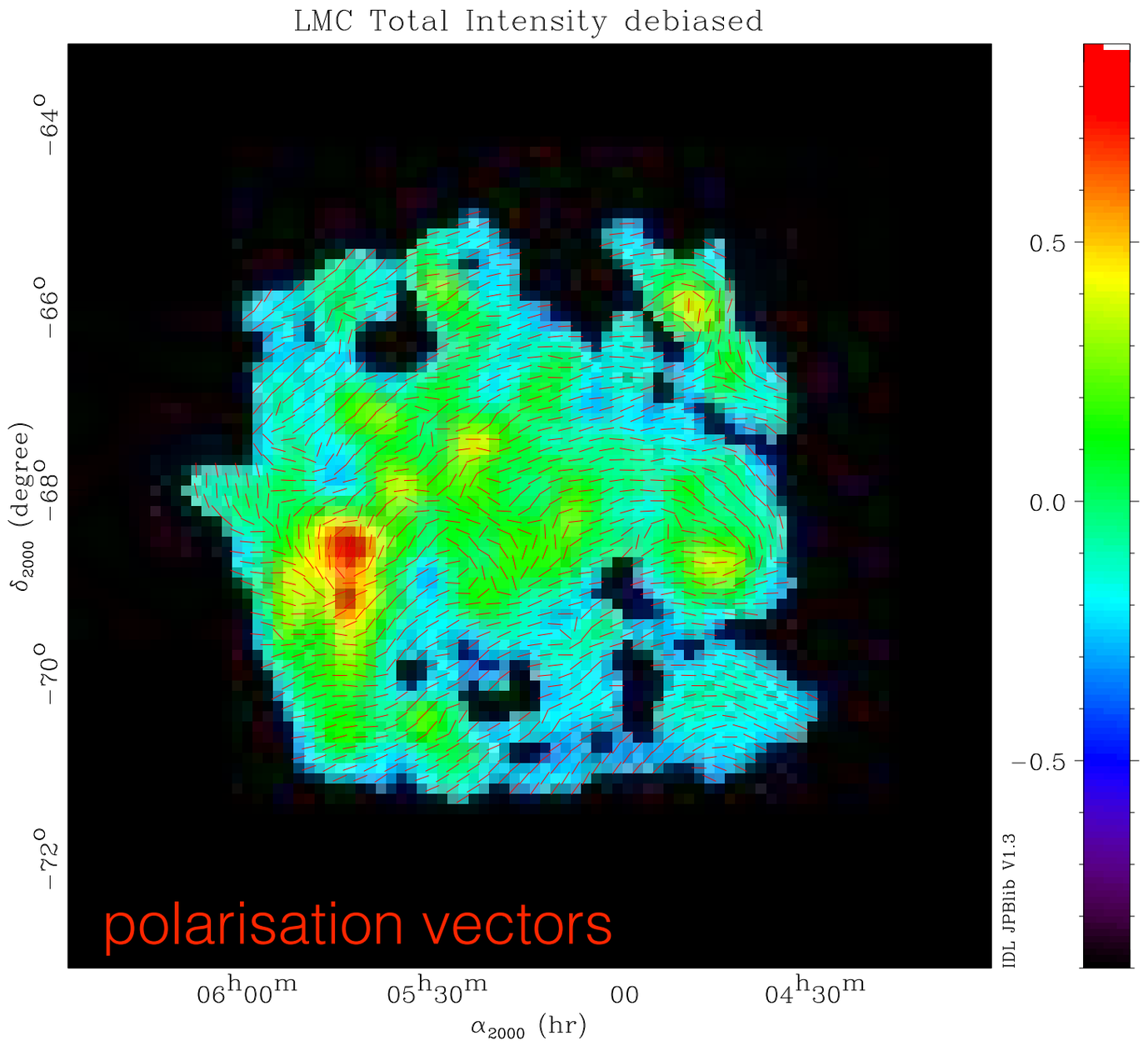
Atomic Gas



- synchrotron & HI disk are more extended than SF region (esp. in south)
- HI & RC similar morphology, inc. “holes”— rarely seen in external galaxies

353GHz Polarized Sky: LMC

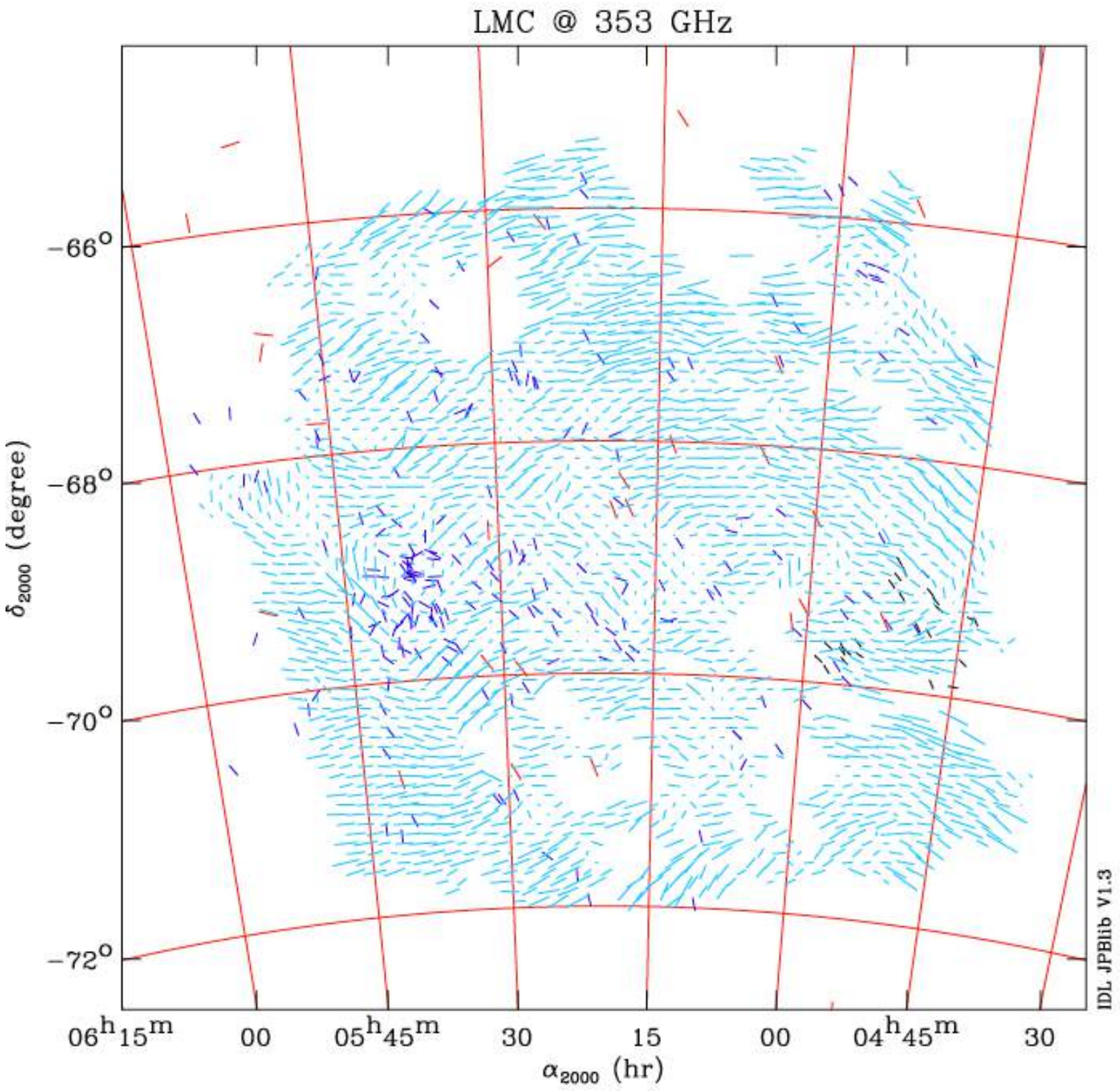




debiased DX9 Planck data (15’)

no foreground subtraction

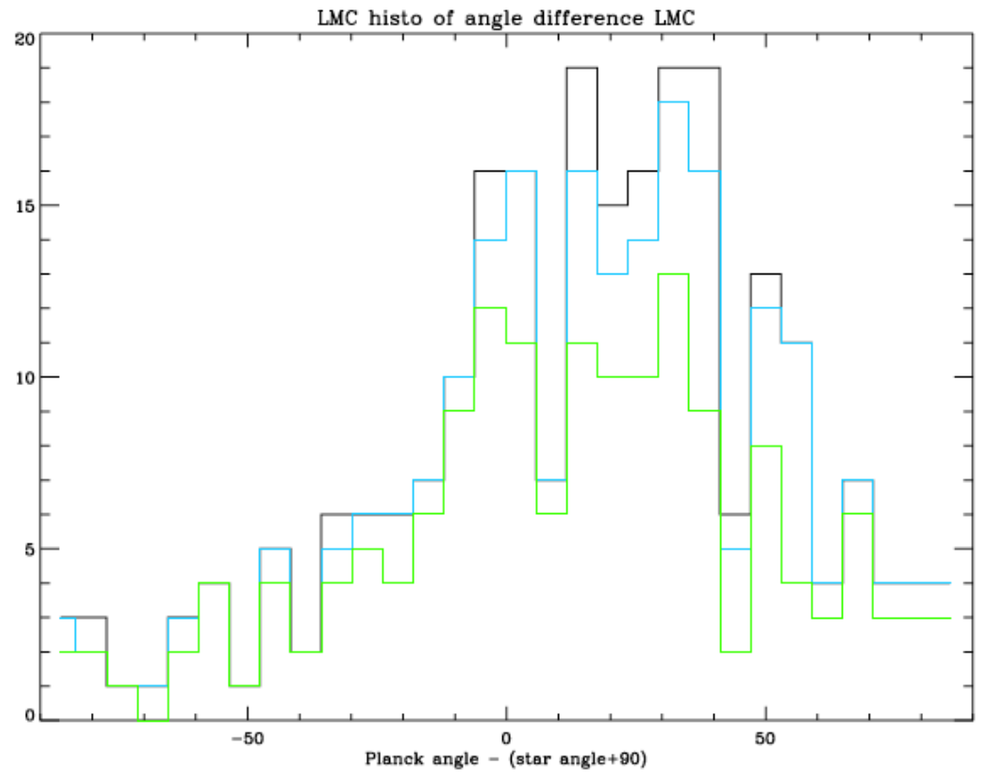
353GHz vs Visible: LMC



Blue: Planck 353GHz

Dark Blue: LMC stars

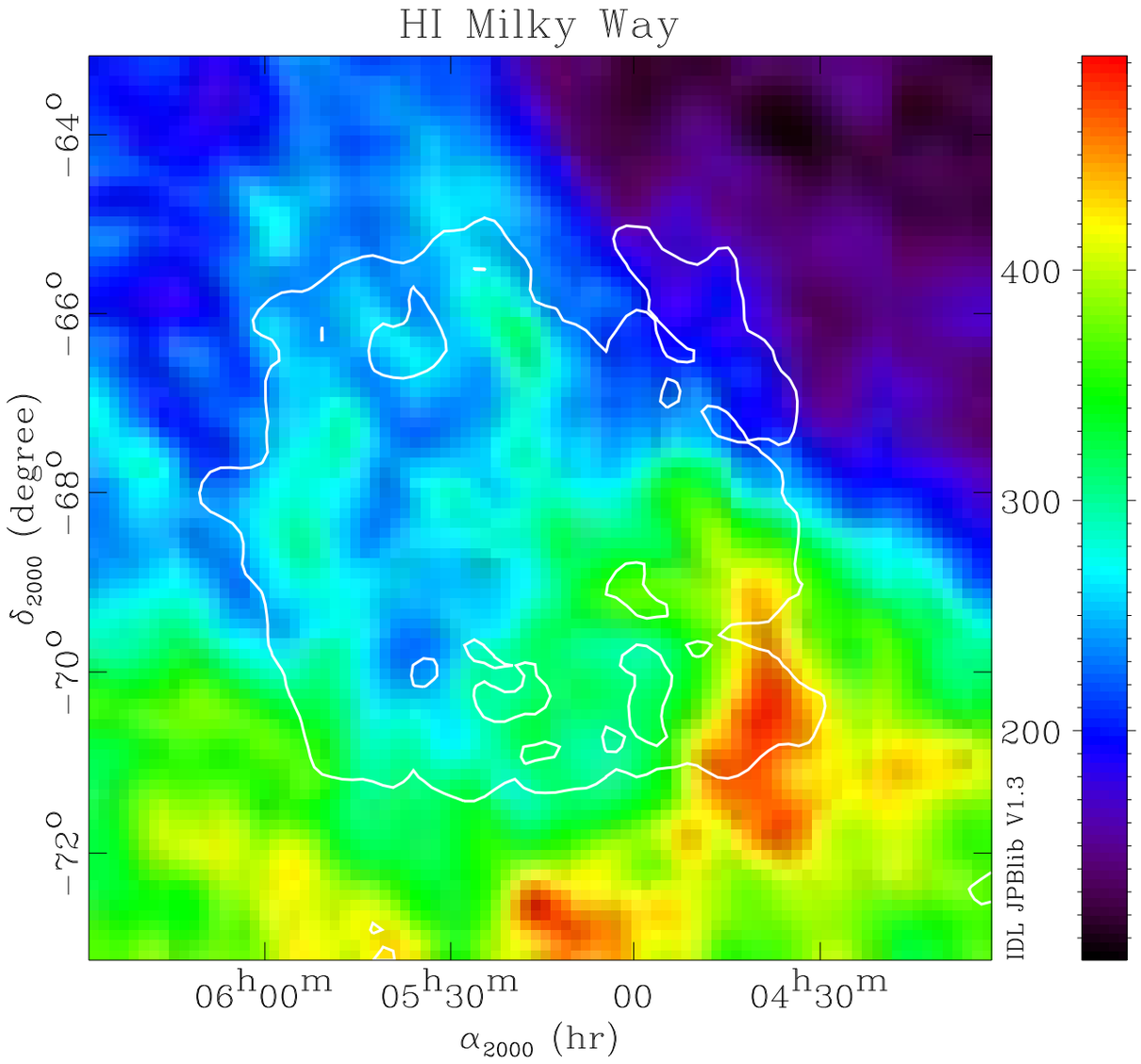
Red: MW stars

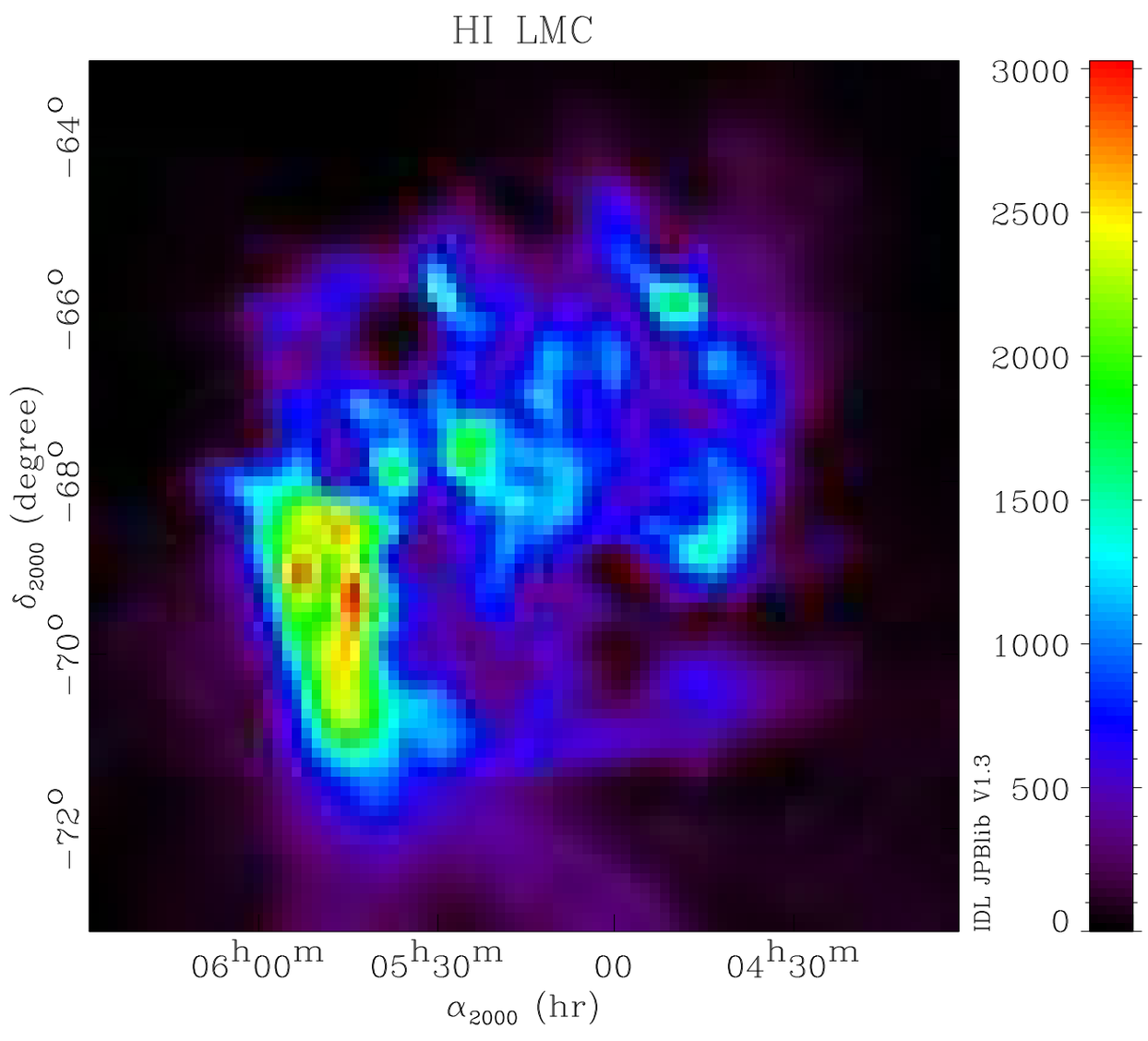


no foreground subtraction

Foreground Removal: p

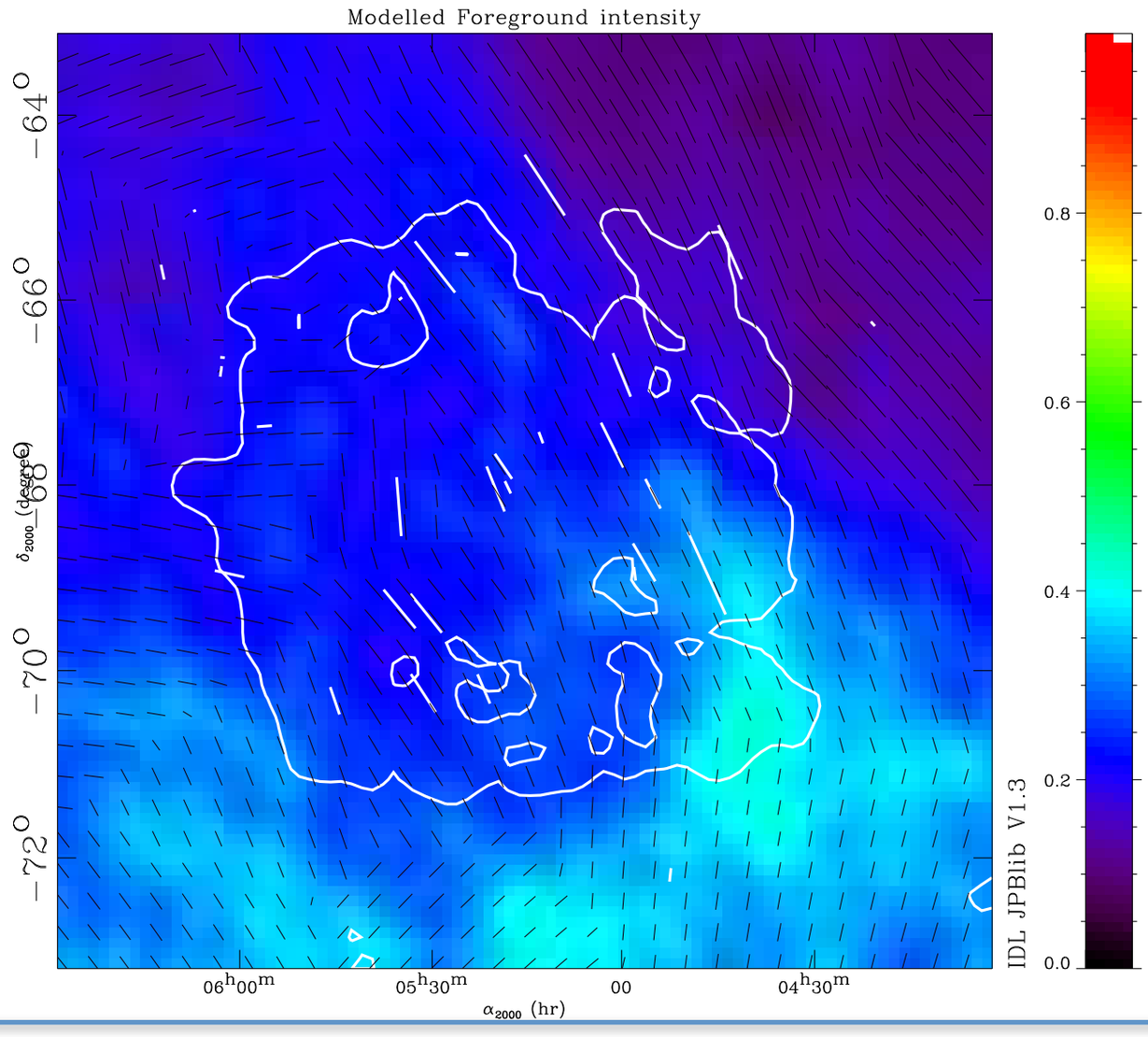
- l_{FG} from correlation with MW HI just outside LMC
- p_{FG} of foreground from correlation of P and I with MW HI just outside LMC (p_{FG} = 4.4%)

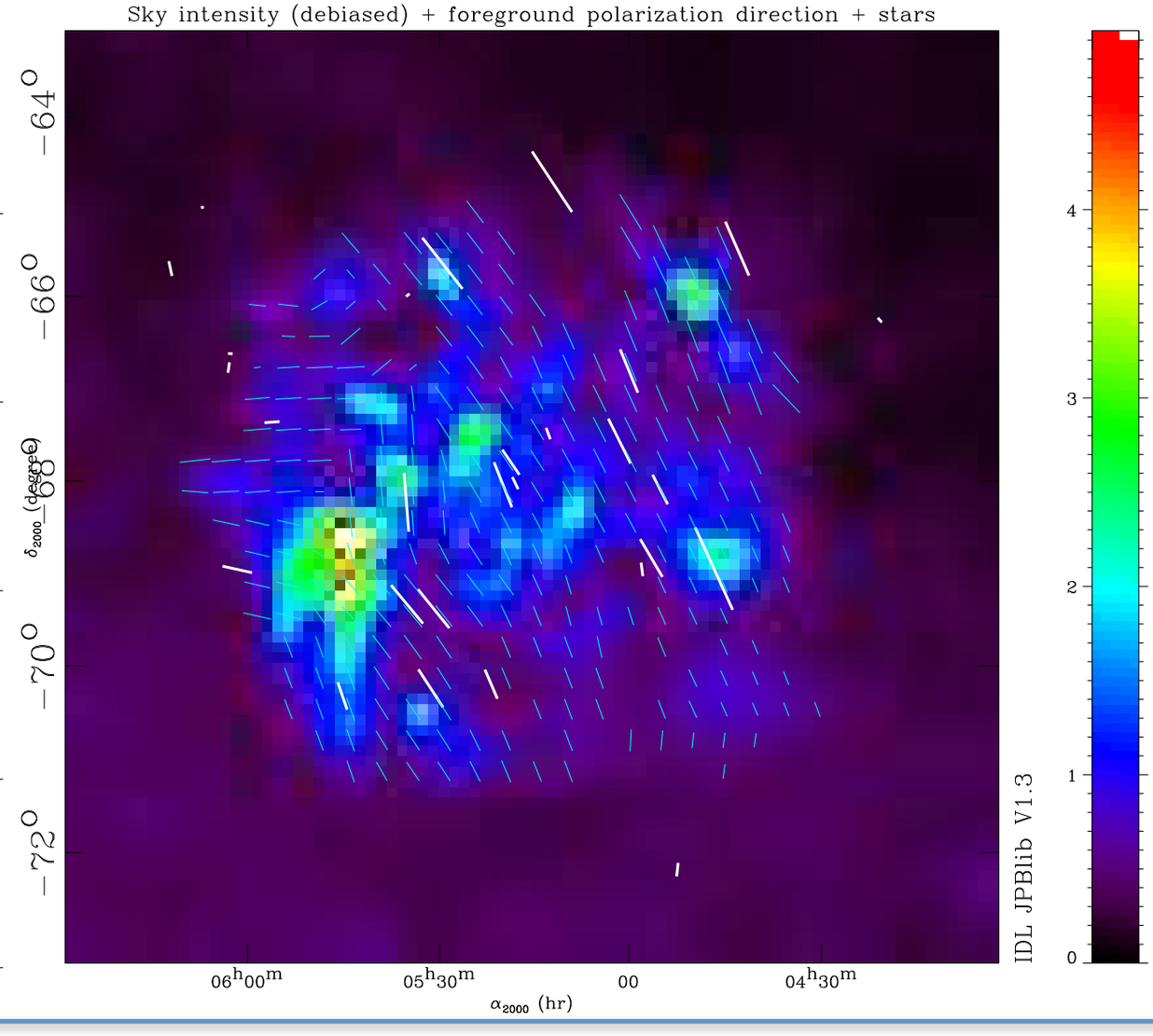




Foreground Removal: ψ

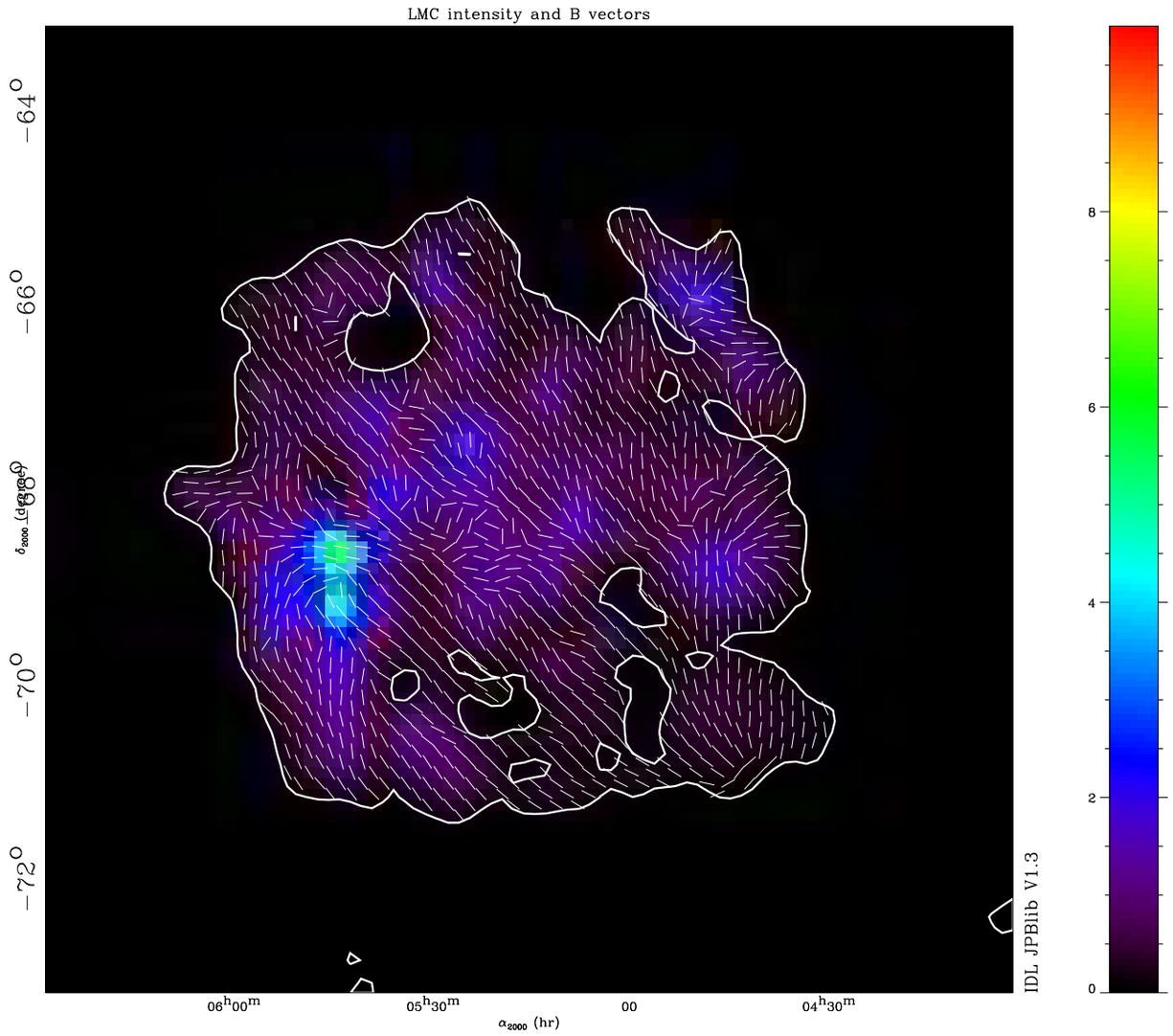
- ψ_{FG} of foreground polarization from foreground stars interpolated over LMC
- $Q_{FG} = p_{FG} * I_{FG} * \cos(2*\psi_{FG})$
- $U_{FG} = p_{FG} * I_{FG} * \sin(2*\psi_{FG})$



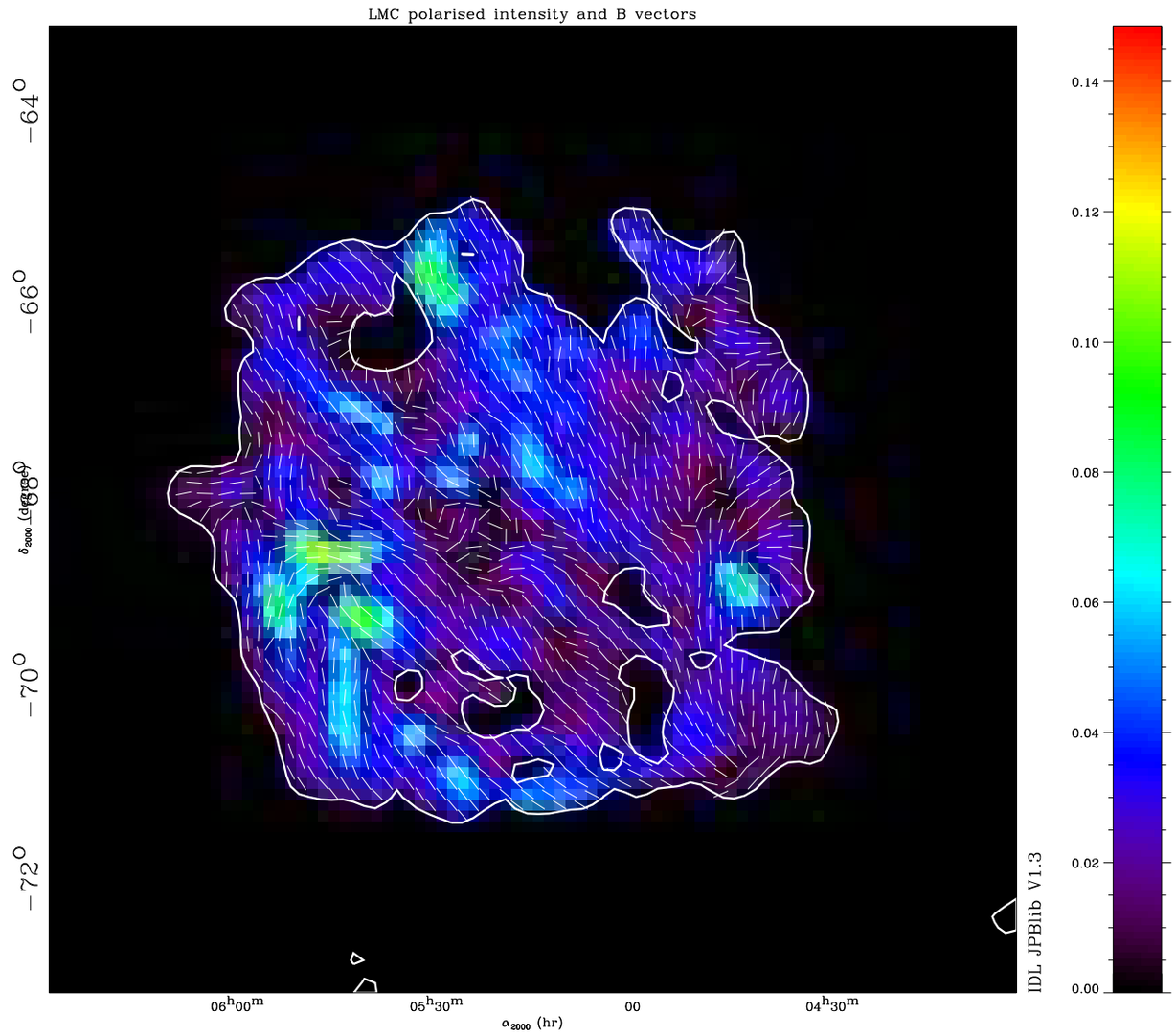


Foreground Subtracted: LMC

Total Intensity + B vectors

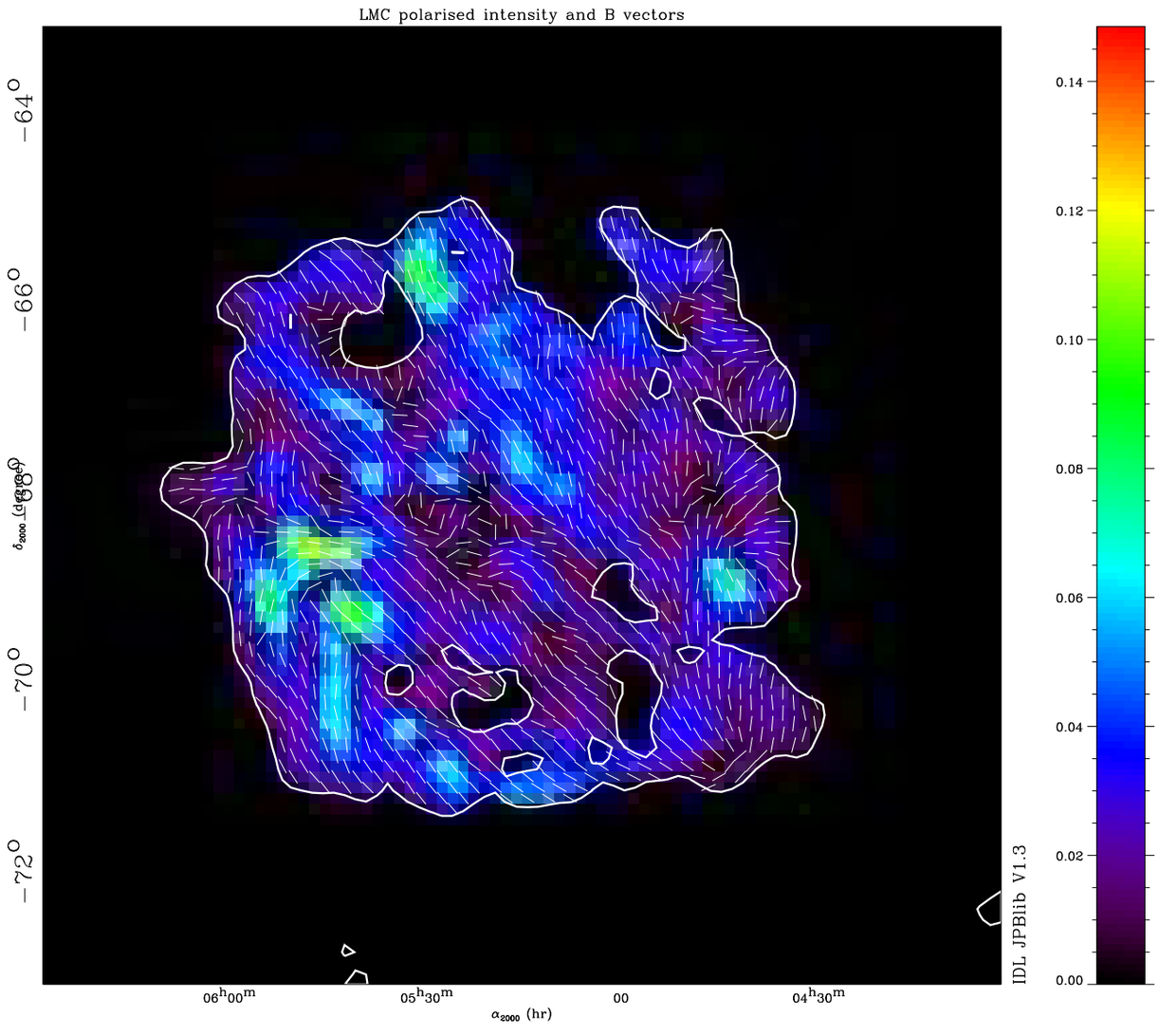


Polarised Intensity + B vectors



Dust v s Synchrotron: LMC

Polarised Intensity + B vectors



1.4GHz Polarised Intensity + intrinsic polarisation angles

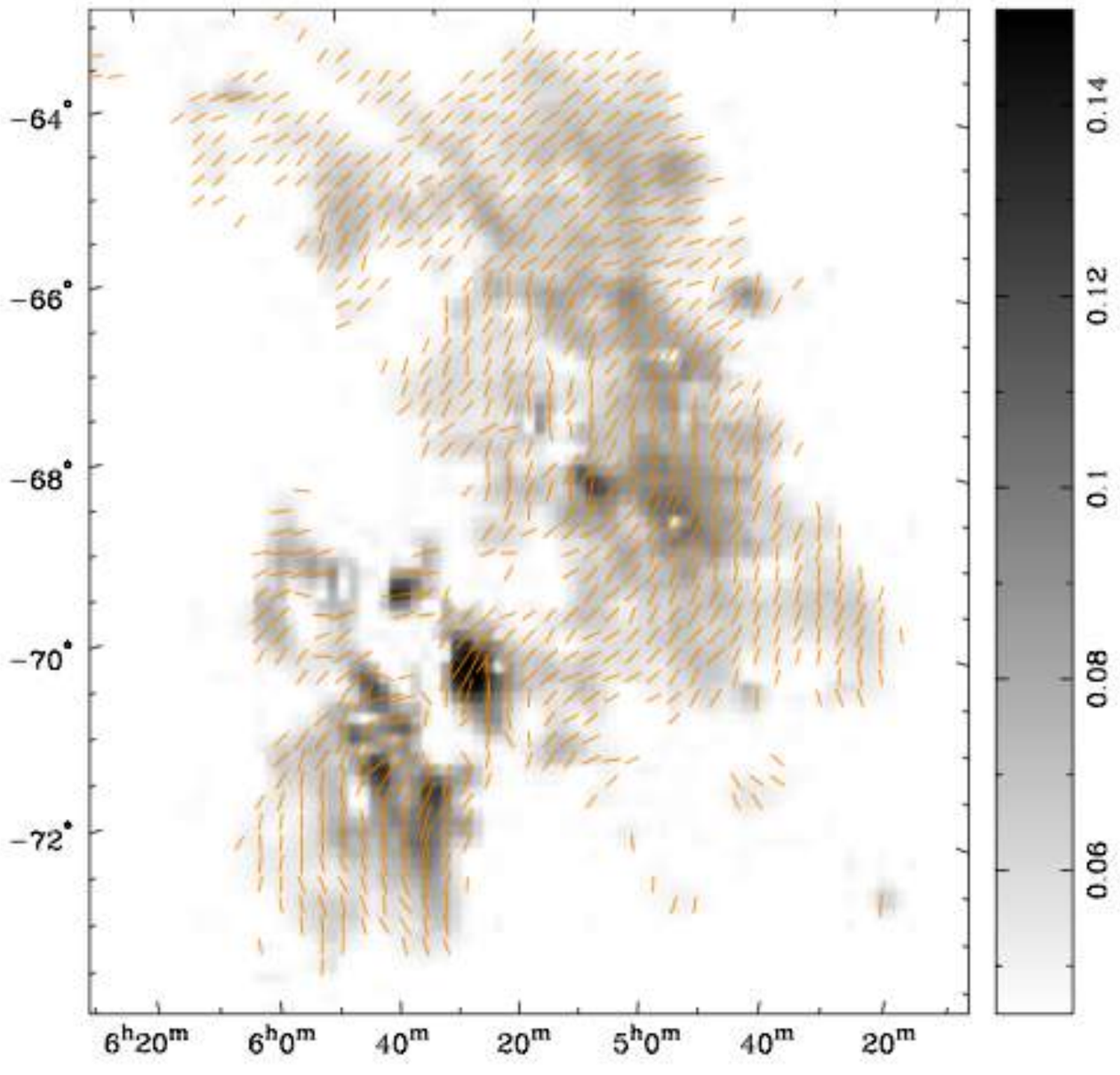
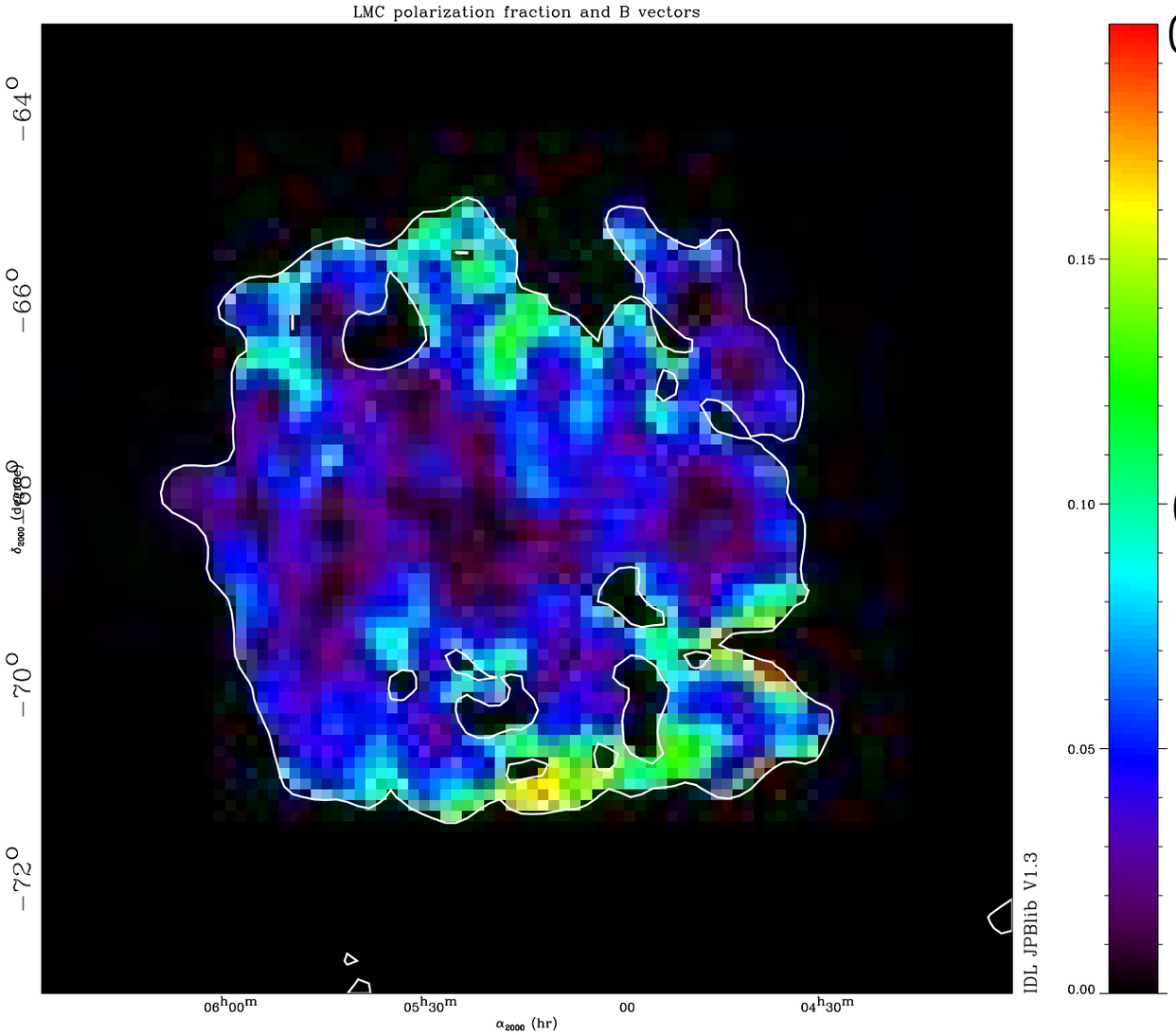


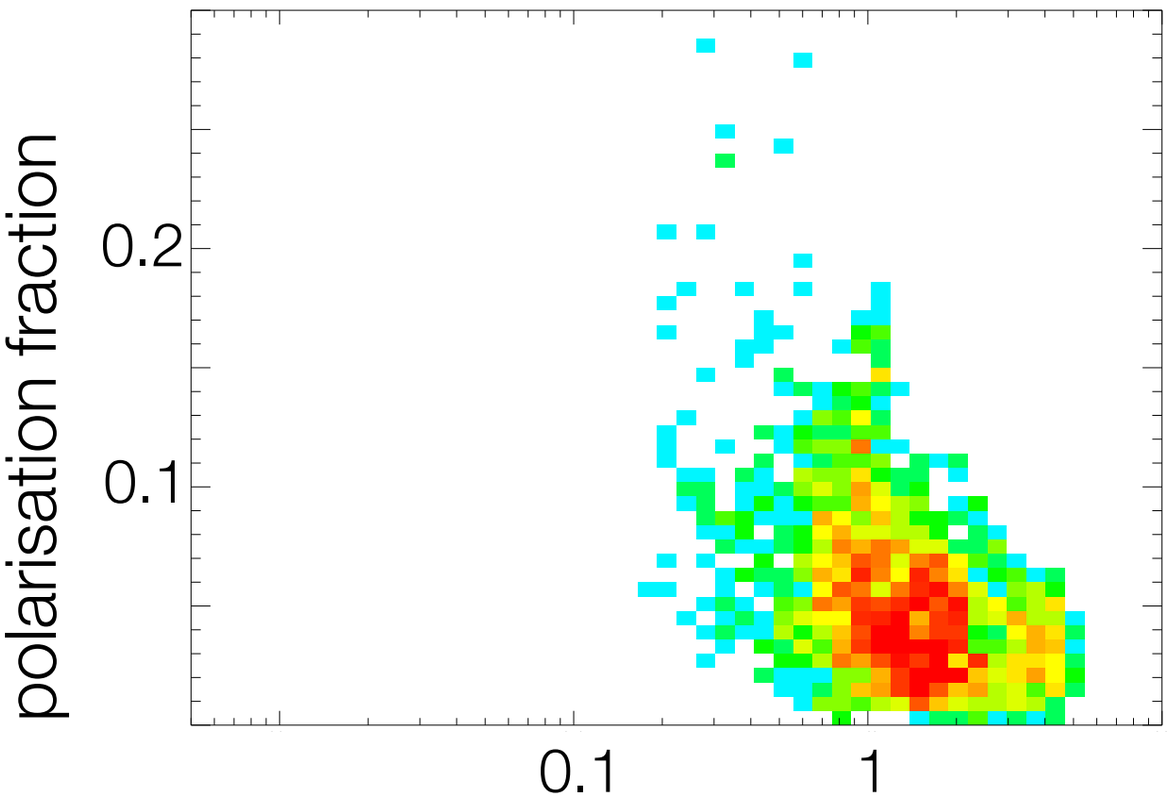
Figure 8, Mao et al (2013)

Polarisation Fraction: LMC

Polarisation Fraction



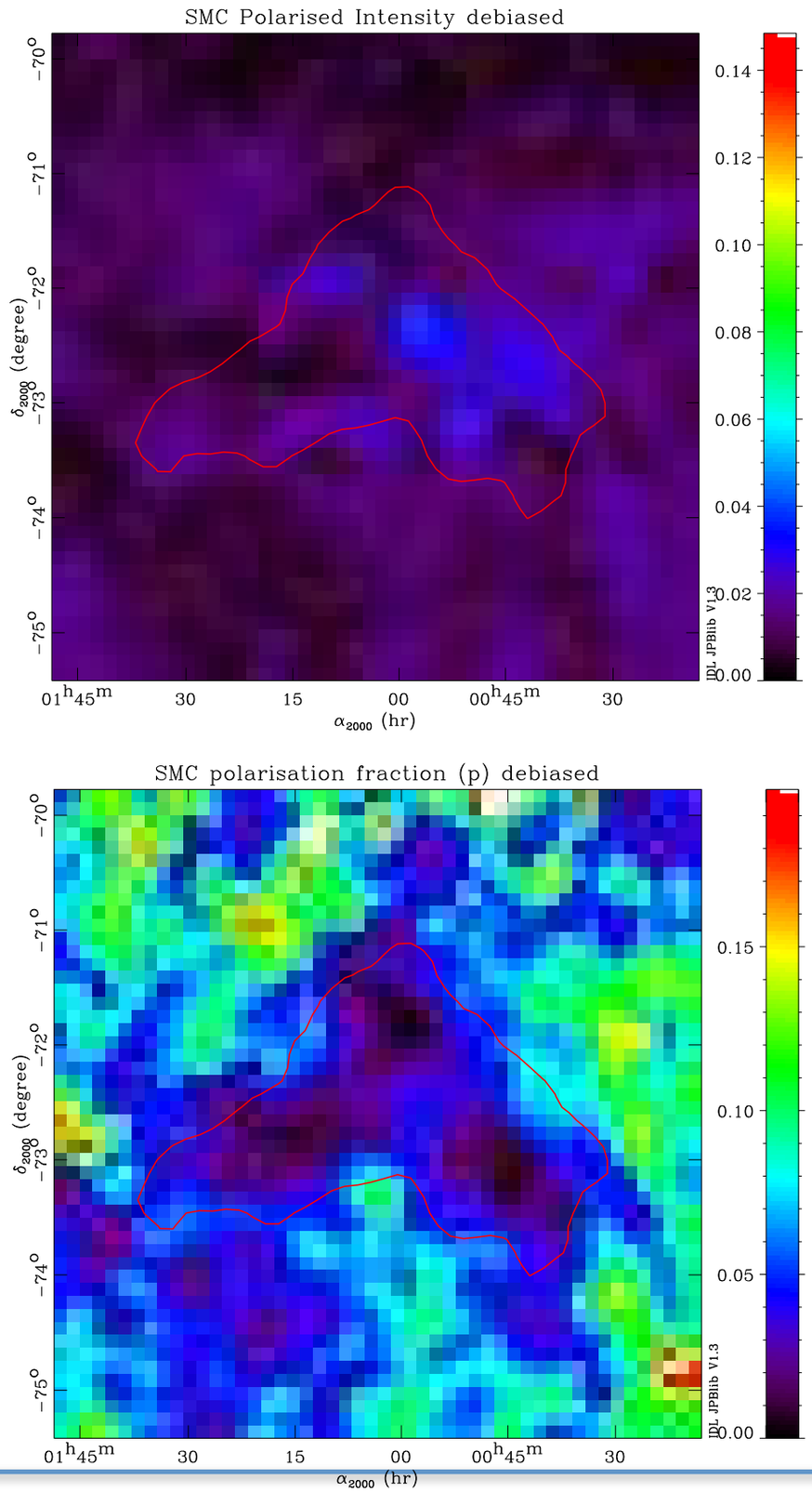
Polarisation Fraction vs N(H)

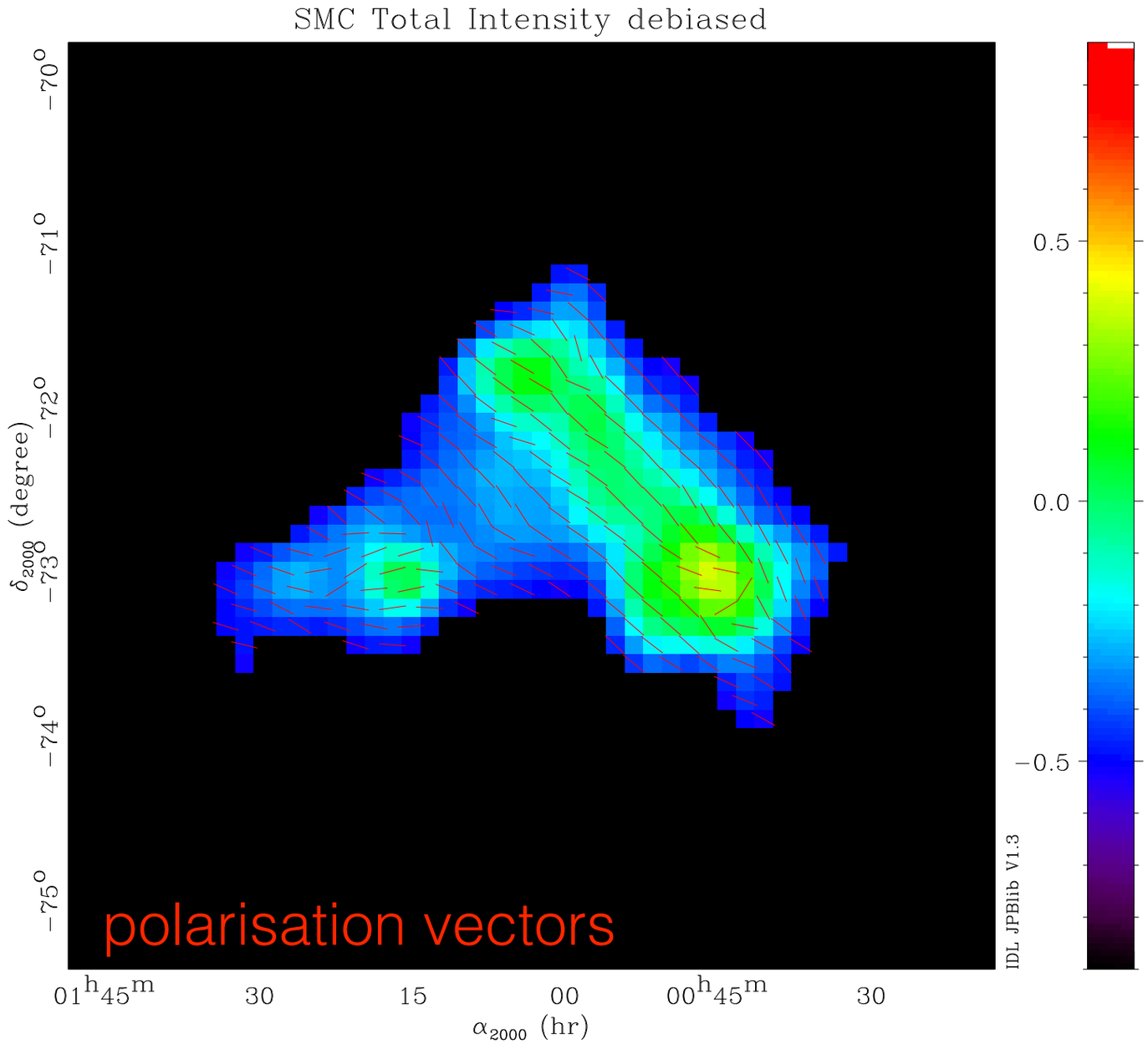


p decreases with N(H), similar to trend seen in MW

(Planck XIX, 2015)

353GHz Polarized Sky: SMC



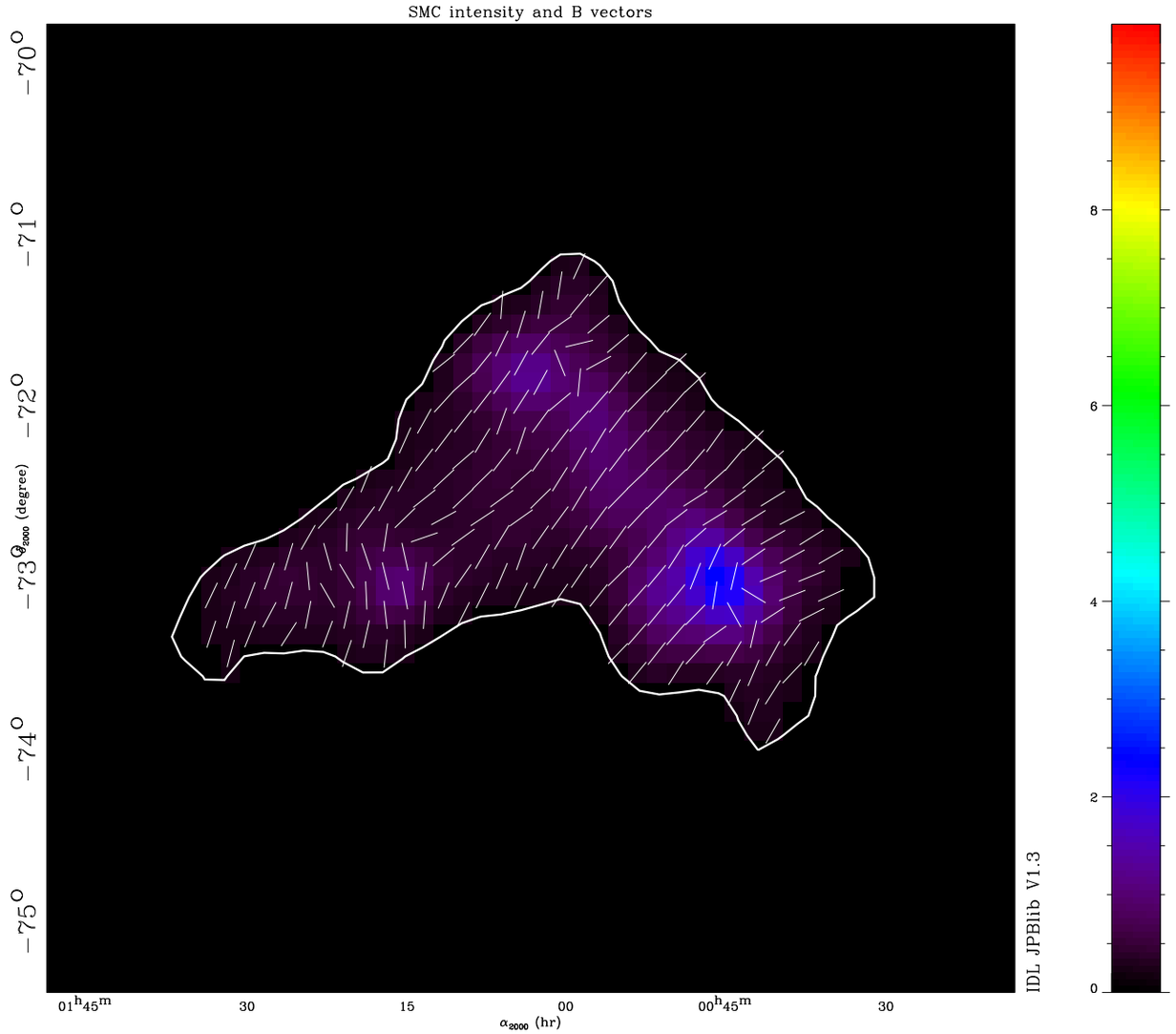


debiased DX9 Planck data (15’)

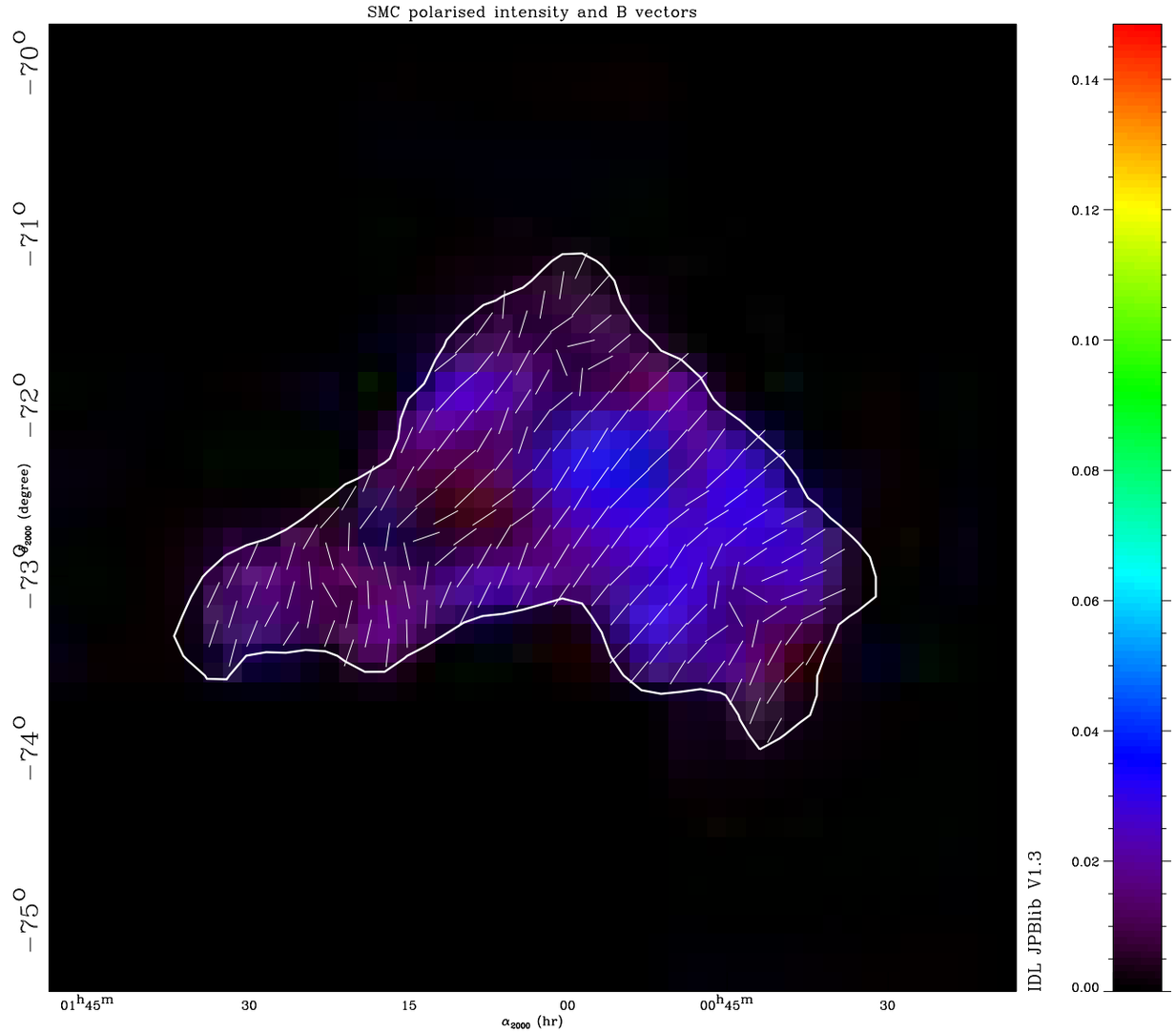
no foreground subtraction

Foreground Subtracted: SMC

Total Intensity + B vectors

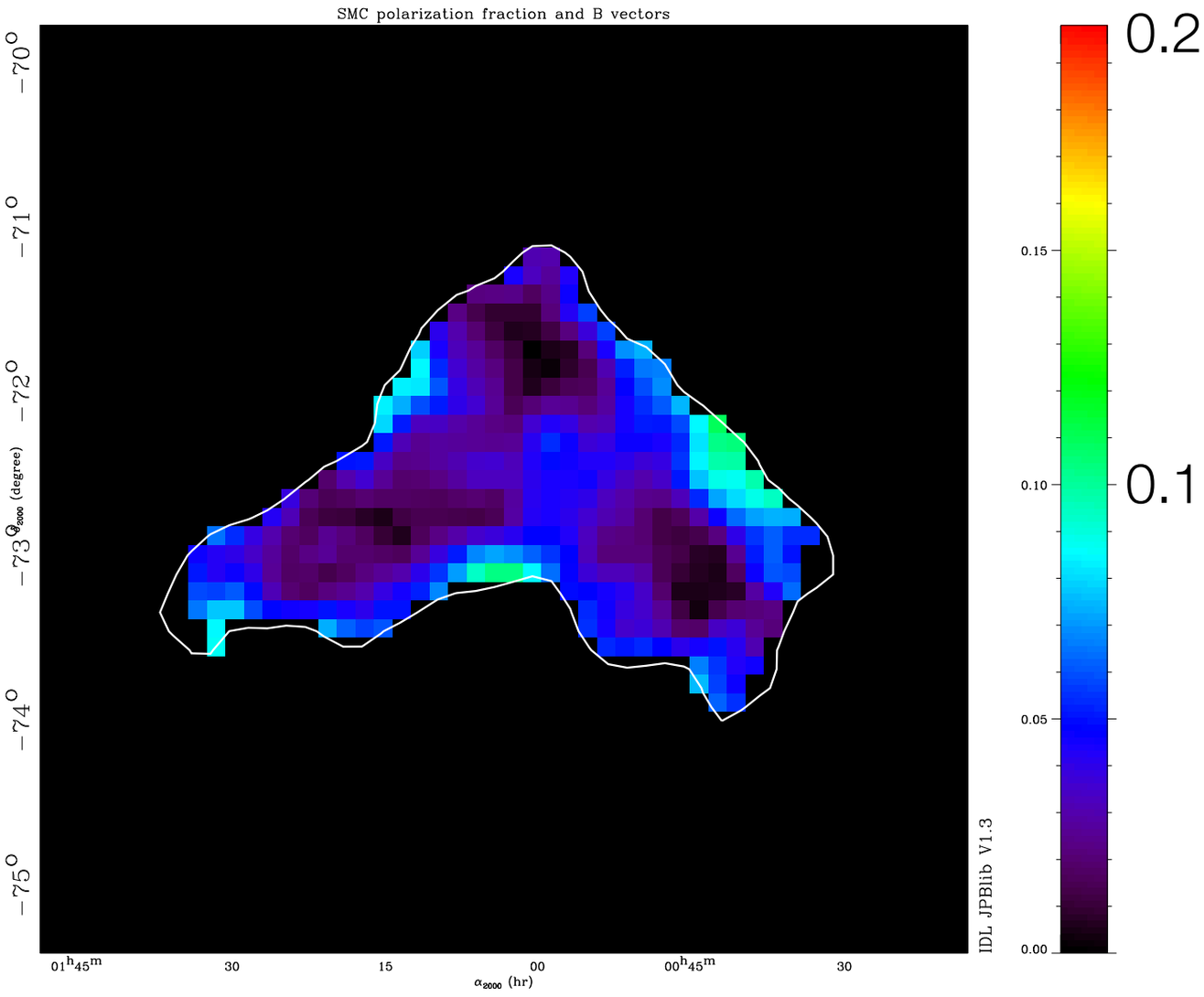


Polarised Intensity + B vectors

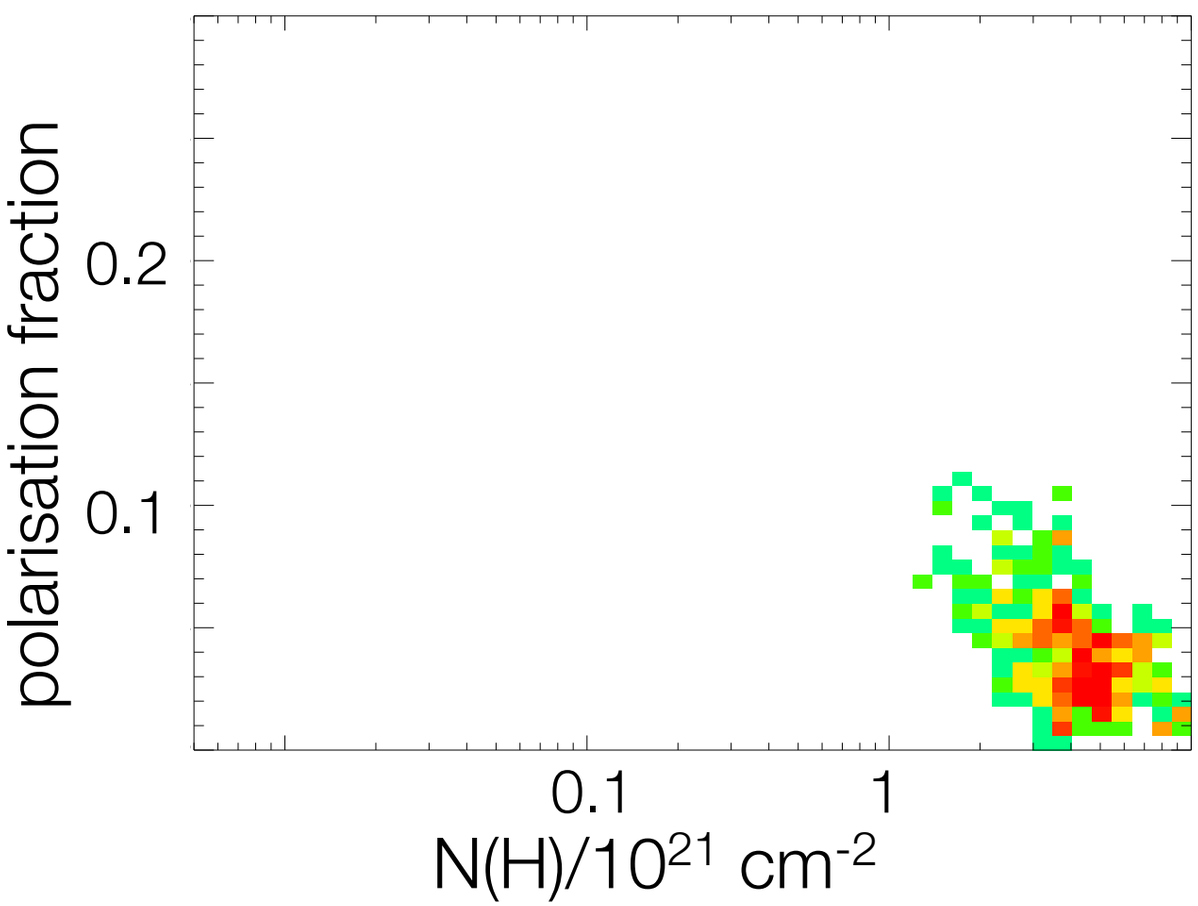


Polarisation Fraction: SMC

Polarisation Fraction



Polarisation Fraction vs N(H)



p decreases with N(H), similar to trend seen in MW & LMC

(Planck XIX, 2015)

Overview

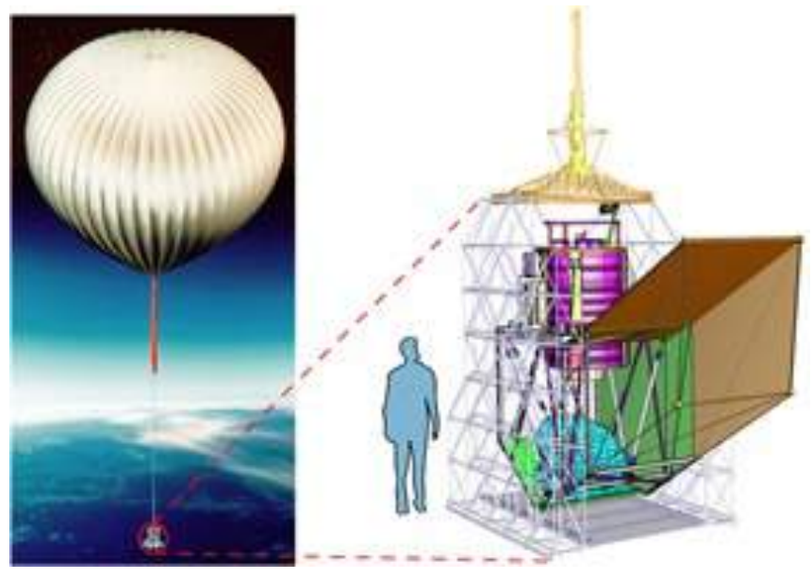
PILOT: Polarised Instrument to Observe the Tenuous ISM

Measures linear polarization of dust emission in the FIR/submm

λ=240μm, angular resolution: 1.4’, instantaneous FoV ~ 1° x 0.8°

Bolometer array with 2048 detectors

First flight on 20 September 2015 from Timmins. Two more flights foreseen (including southern hemisphere)

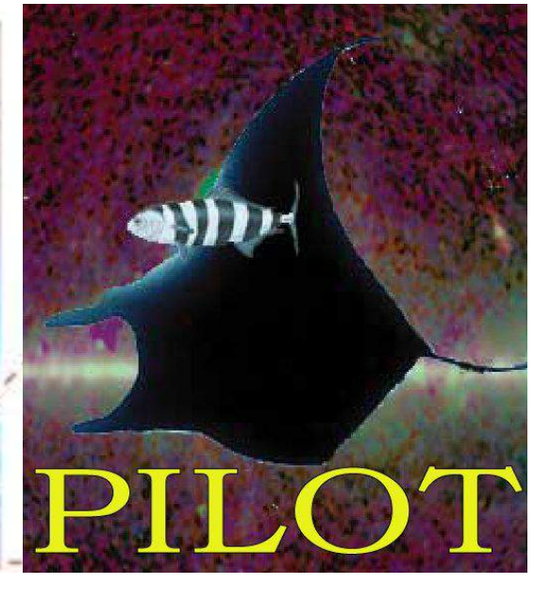


Science Objectives

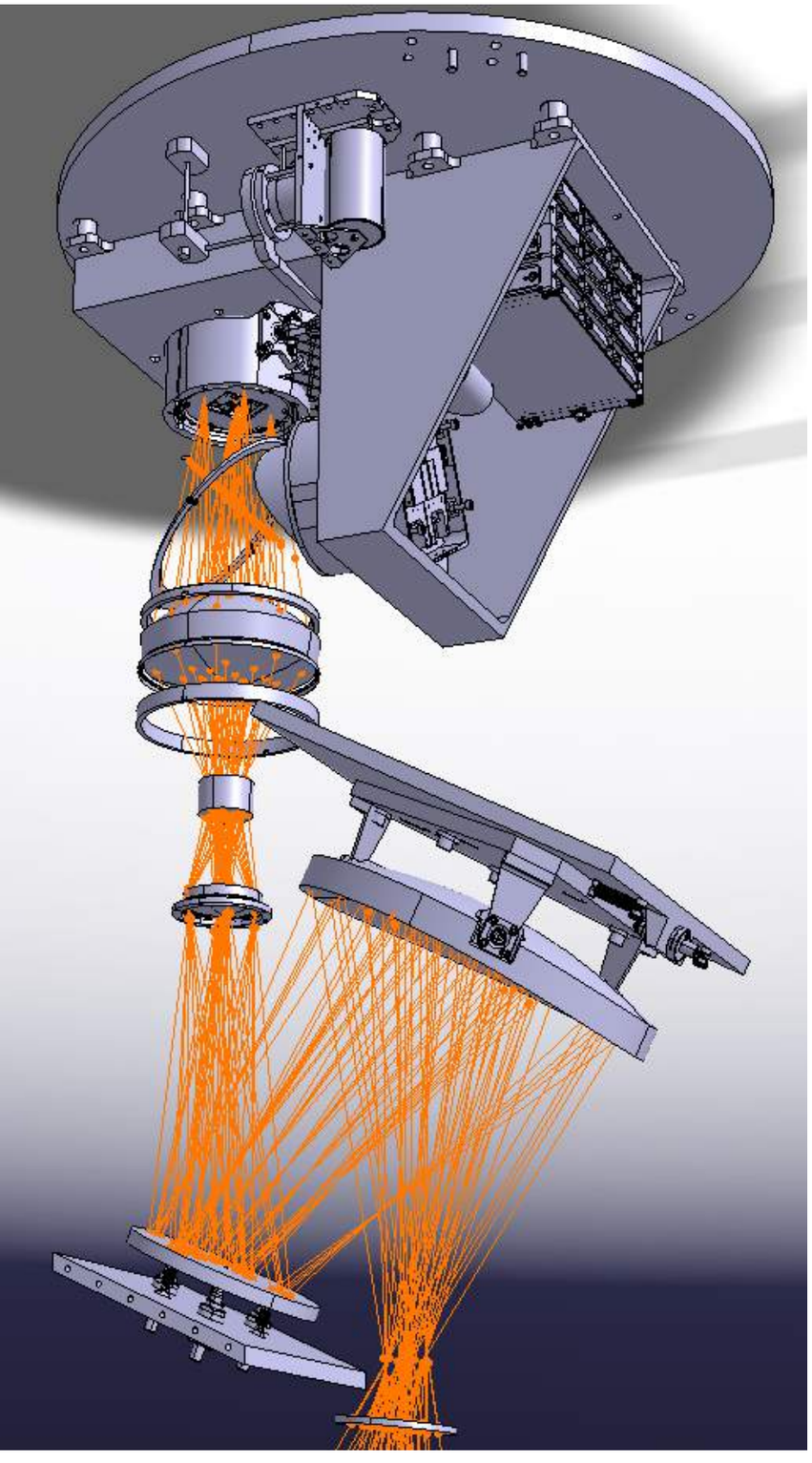
Key Science Objectives:

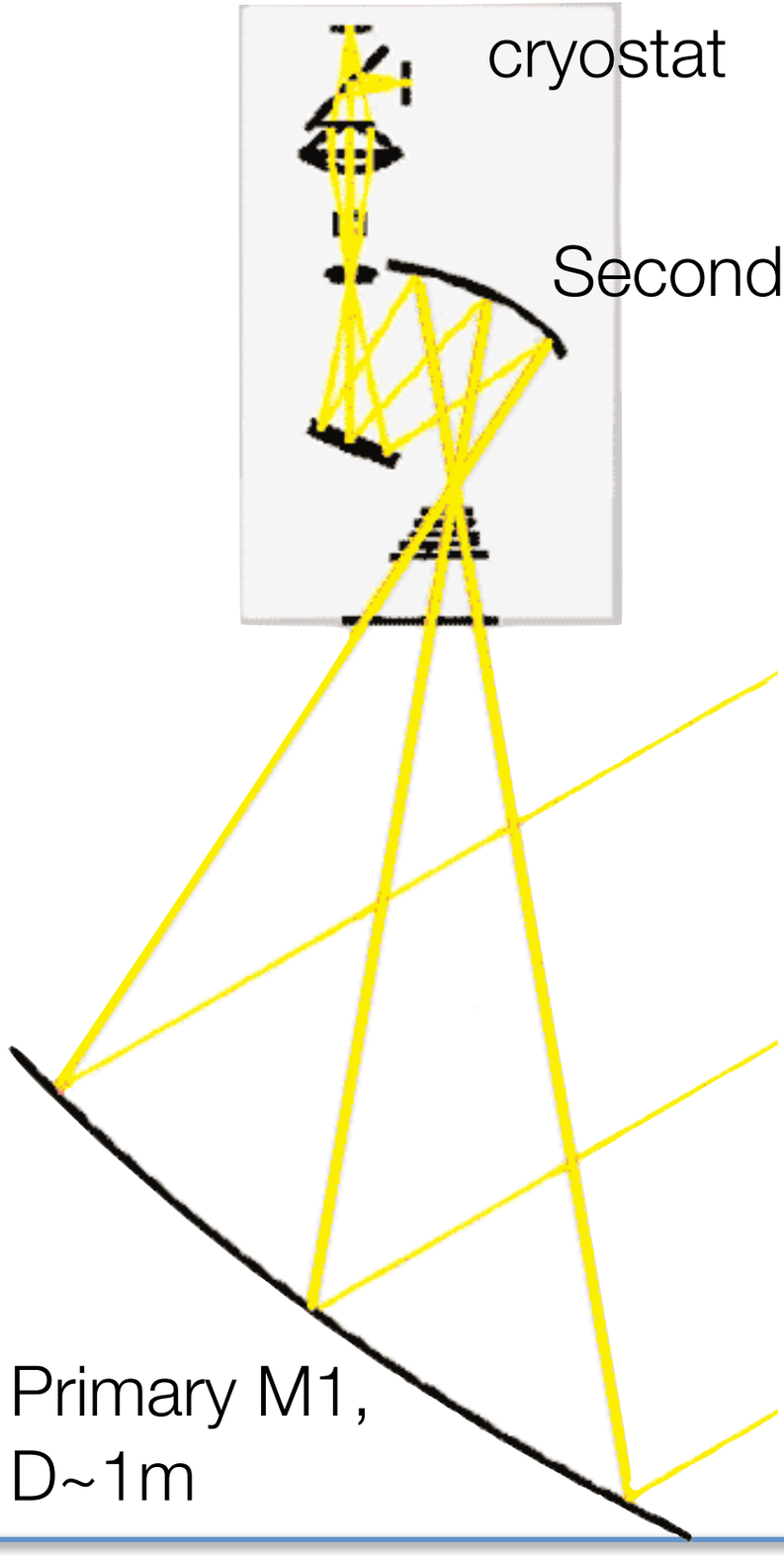
- the structure of the magnetic field from diffuse to dense ISM
- geometric and magnetic properties of dust grains
- understand polarized foreground
- complement Planck observations at $\lambda<850$ μm, with better accuracy and higher angular resolution

Observations: Galactic plane ($|b|<20°$), molecular clouds, nearby cold cores, external galaxies, diffuse ISM, deep fields



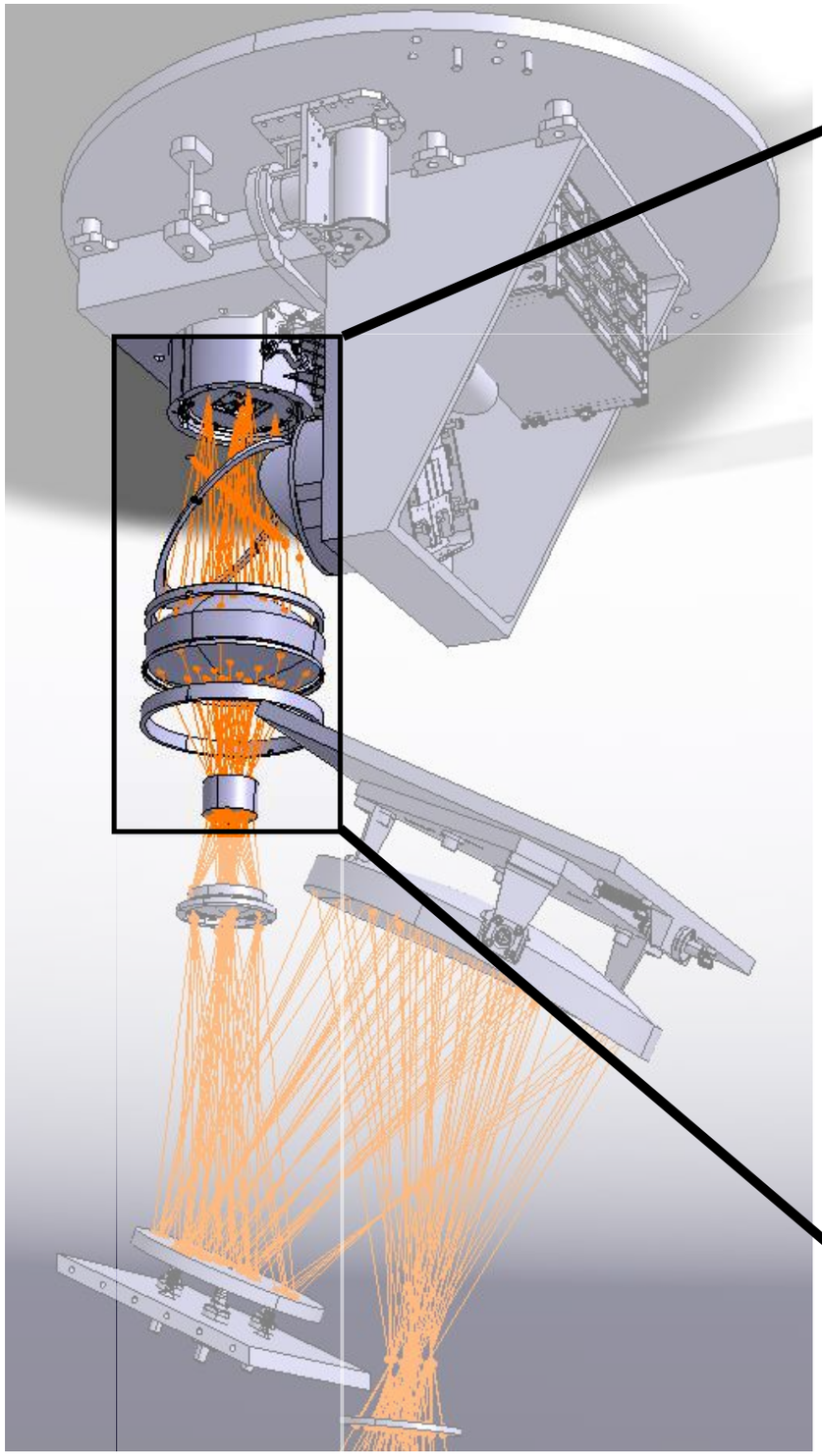
Optics

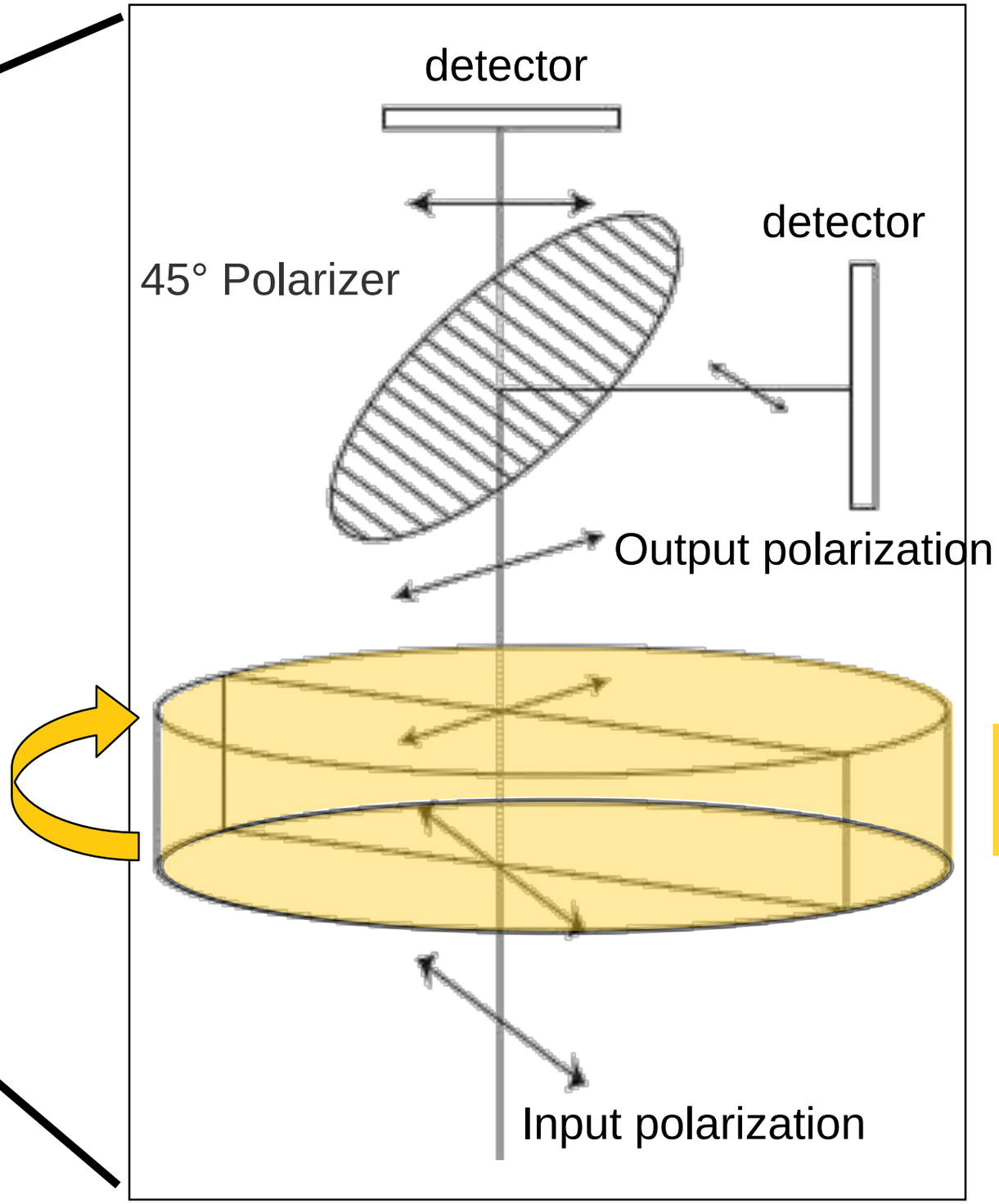




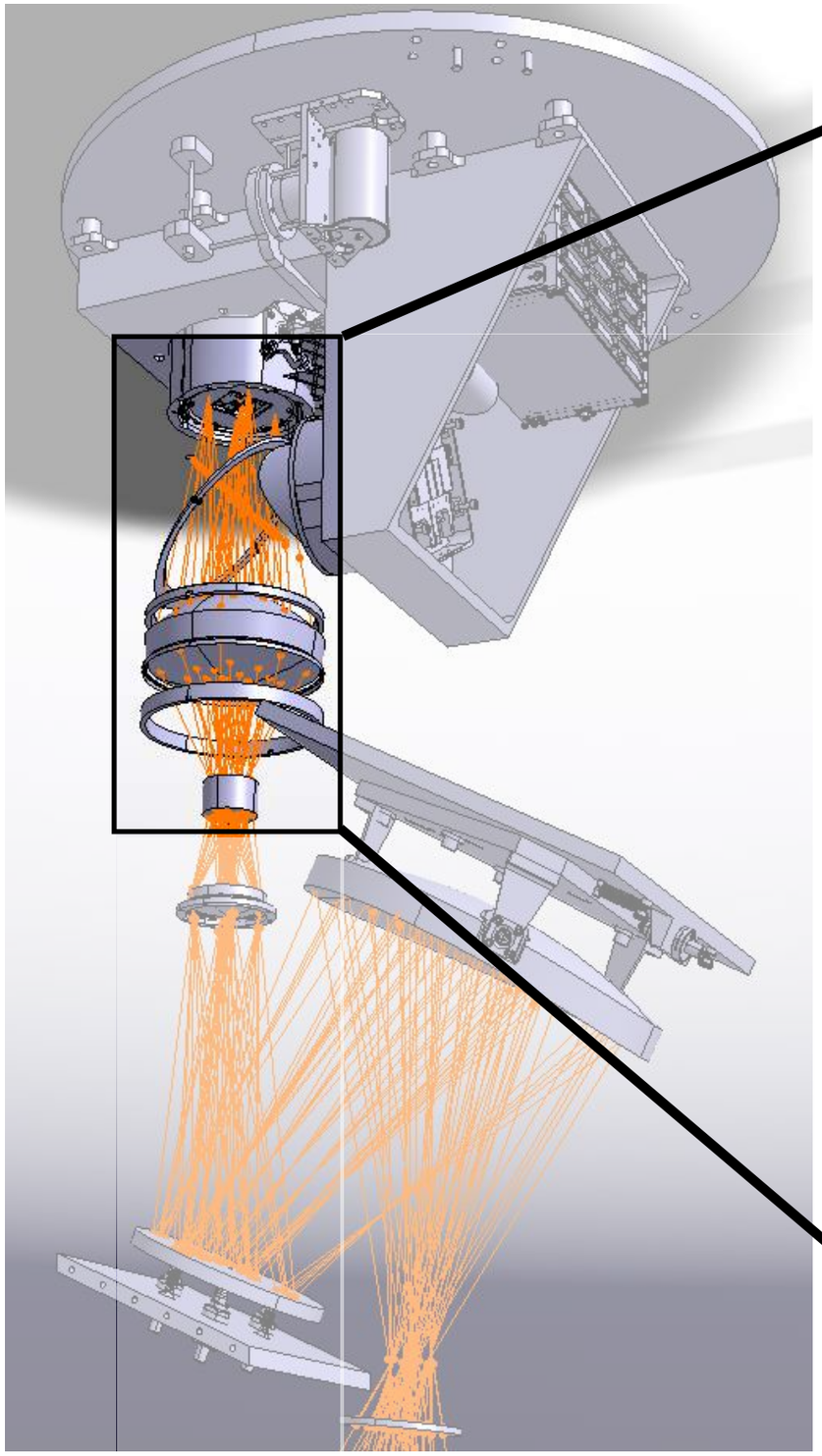
- Equivalent Focal length: 1800 mm, F/2.5
- Image quality diffraction limited
- Distortion : < 5%
- Polarization rotation : < 5°
- Tolerance :
  translation M1 = ±0.3 mm
  rotation M1 = ±0.06°

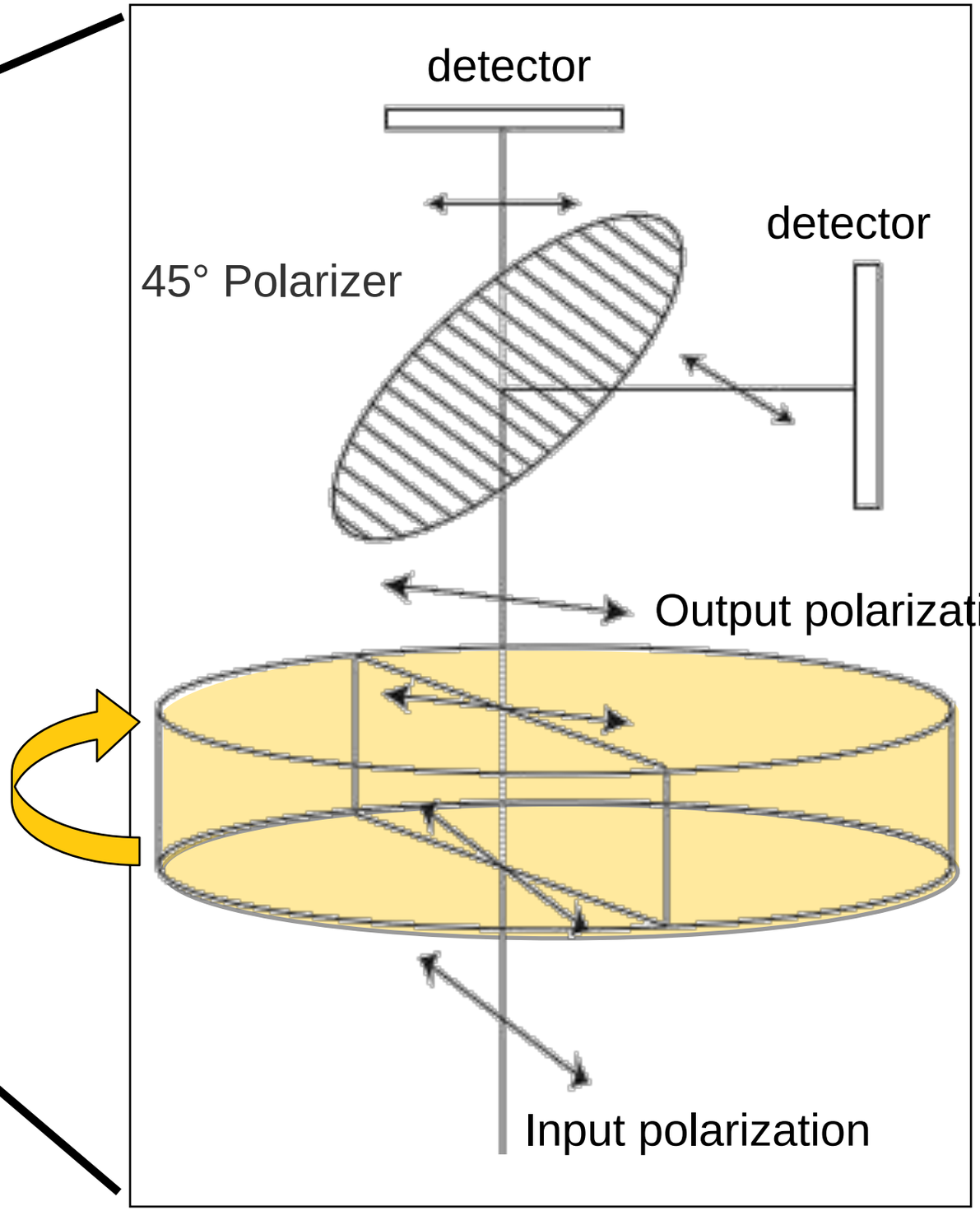
Polarisation Measurement





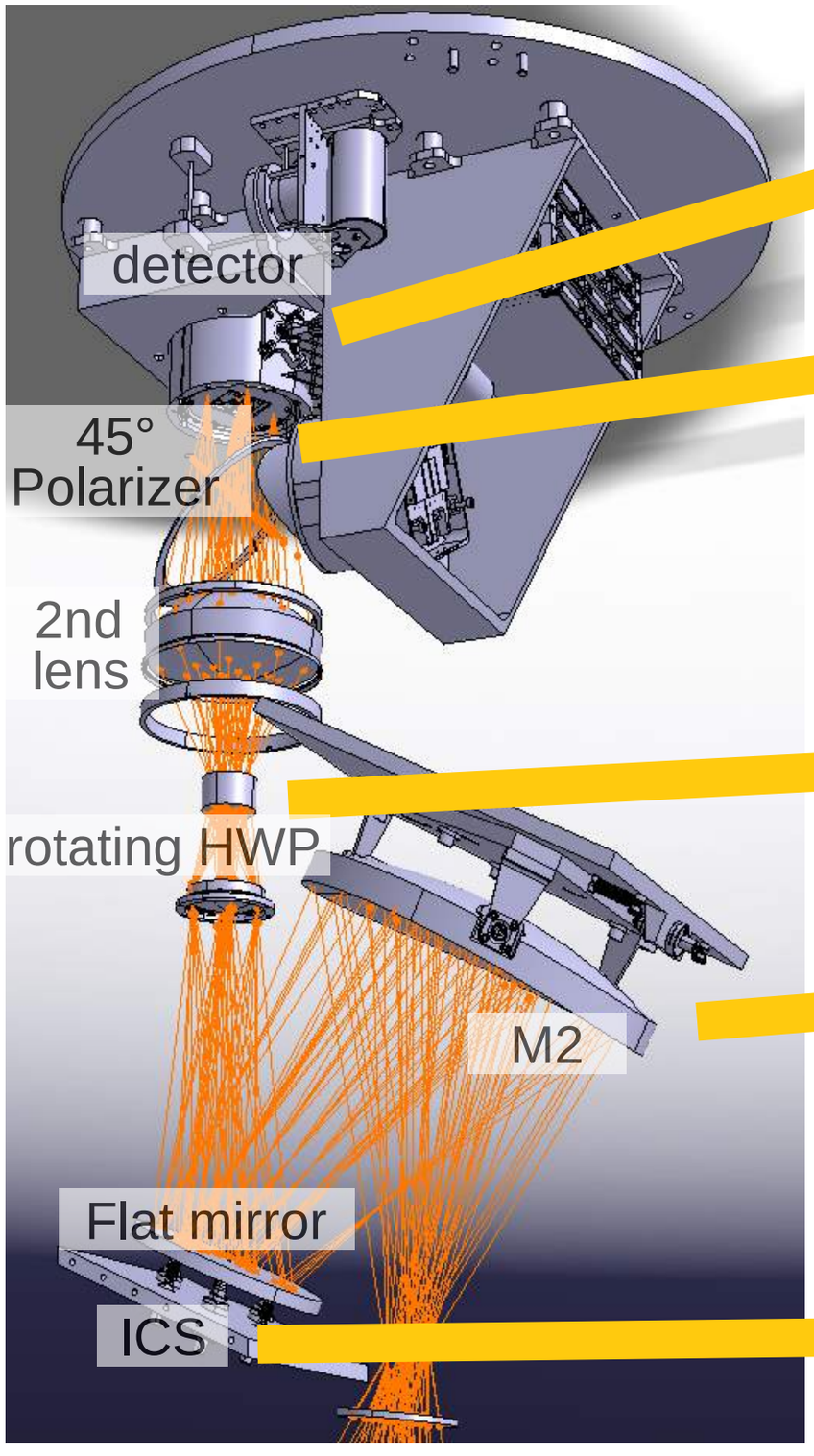
Polarisation Measurement

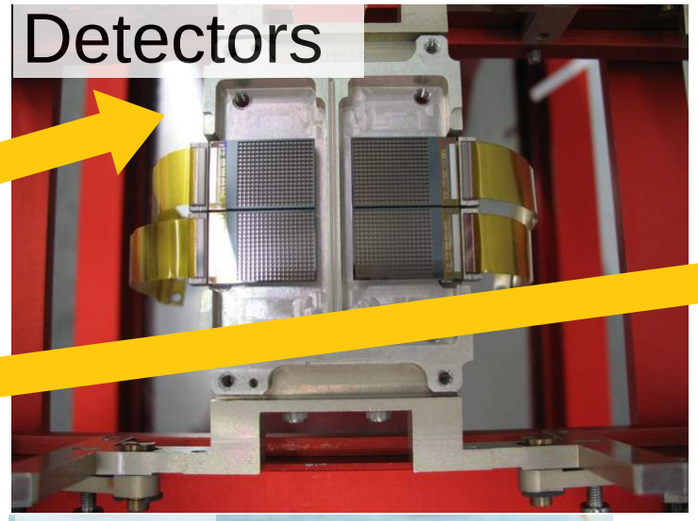


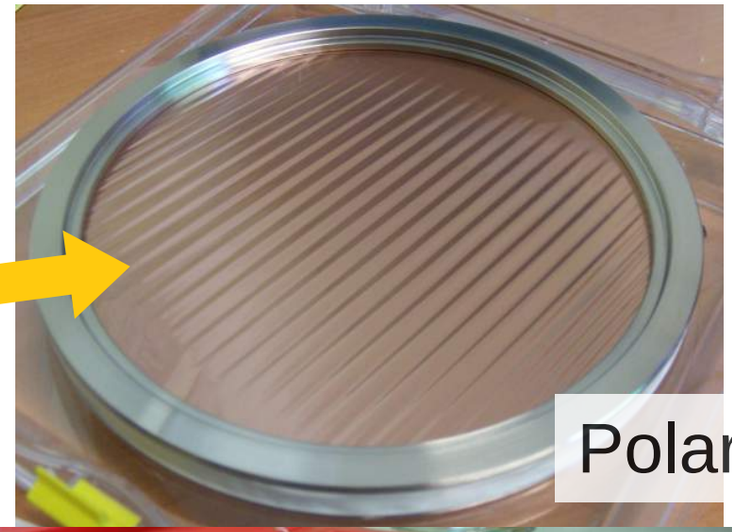


Half-Wave Plate

Main Components

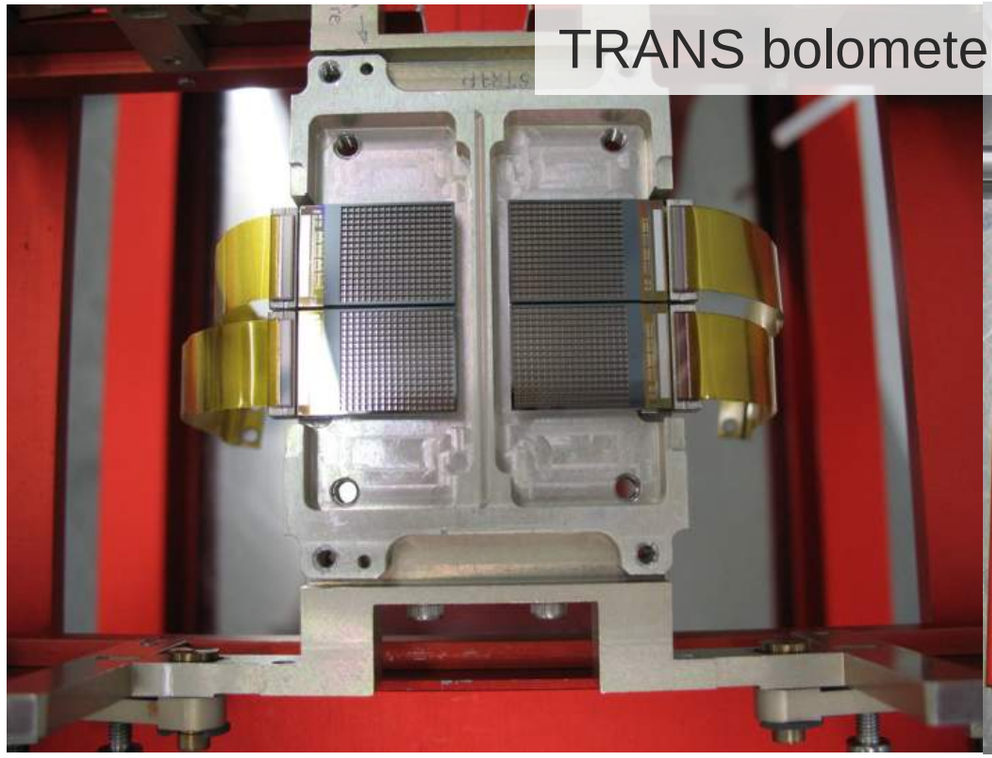




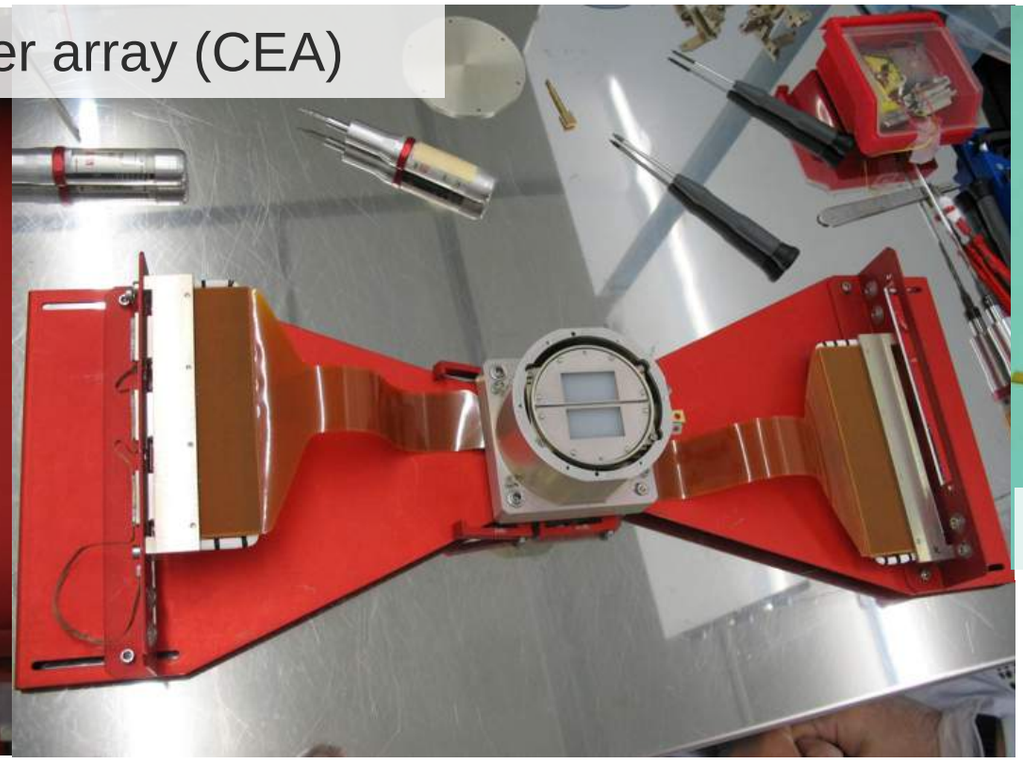


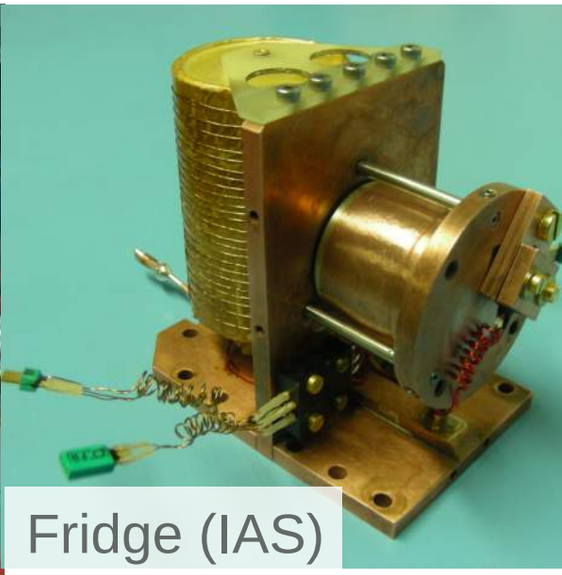
ICS: Internal Calibration Source
(calibrate the response of the detectors)

Detectors



TRANS bolometer array (CEA)

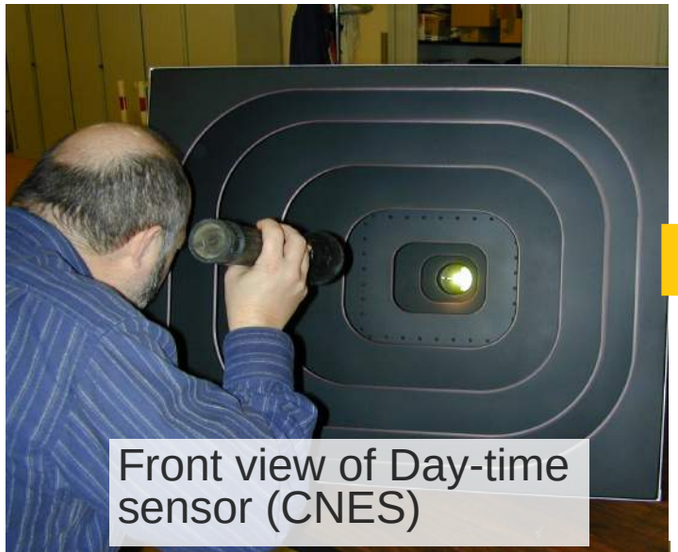




Fridge (IAS)

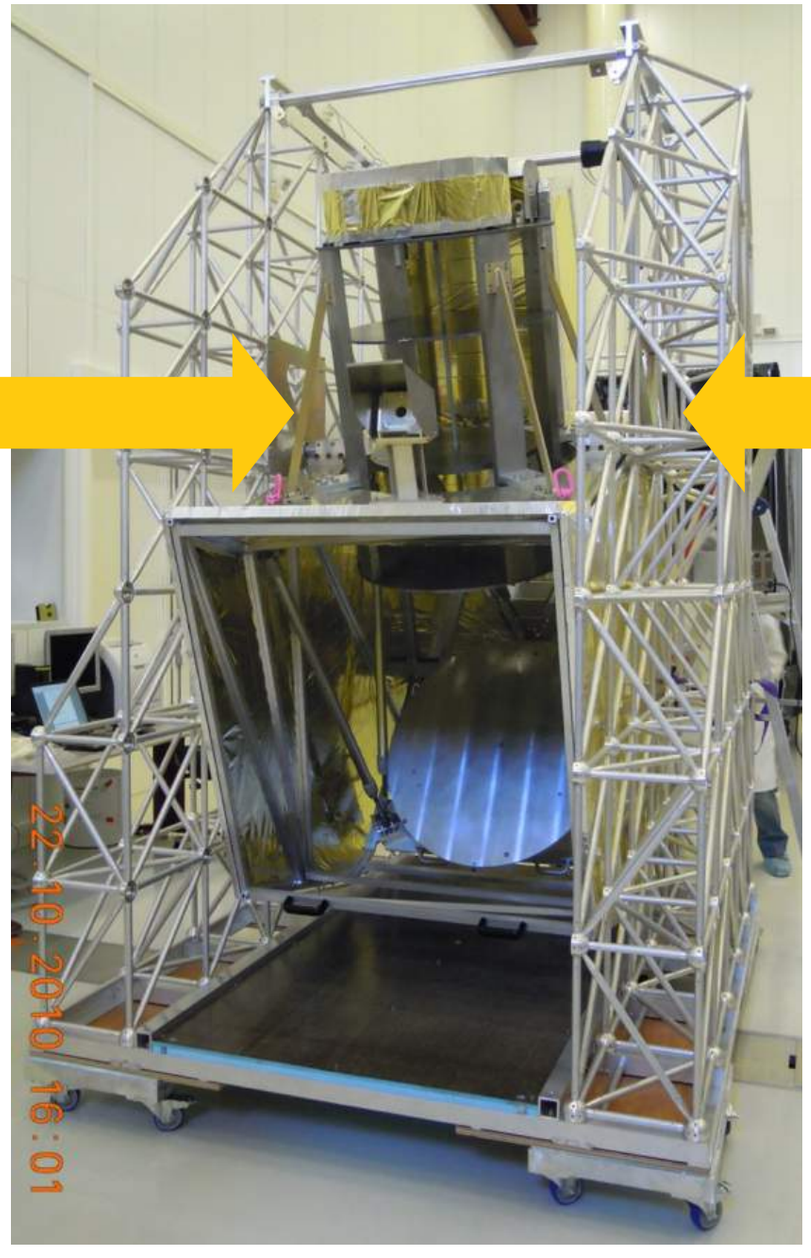
- Bolometer arrays developed by CEA/LETI
- Same technology as used on Herschel PACS
- Multiplexed bolometer arrays with a total of 2048 detectors
- Detectors cooled down to 0.3 K through closed-cycle He3 fridge
- NEP ~ 2×10^{-16} W/Hz$^{1/2}$

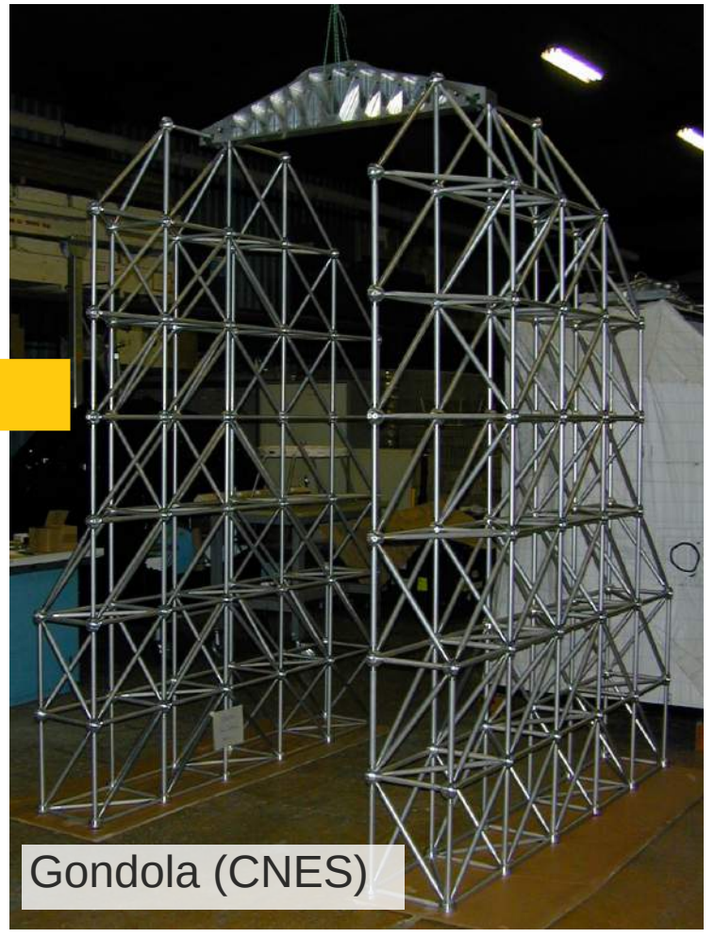
Estadius



Front view of Day-time sensor (CNES)

Side view of Day-time sensor (CNES)

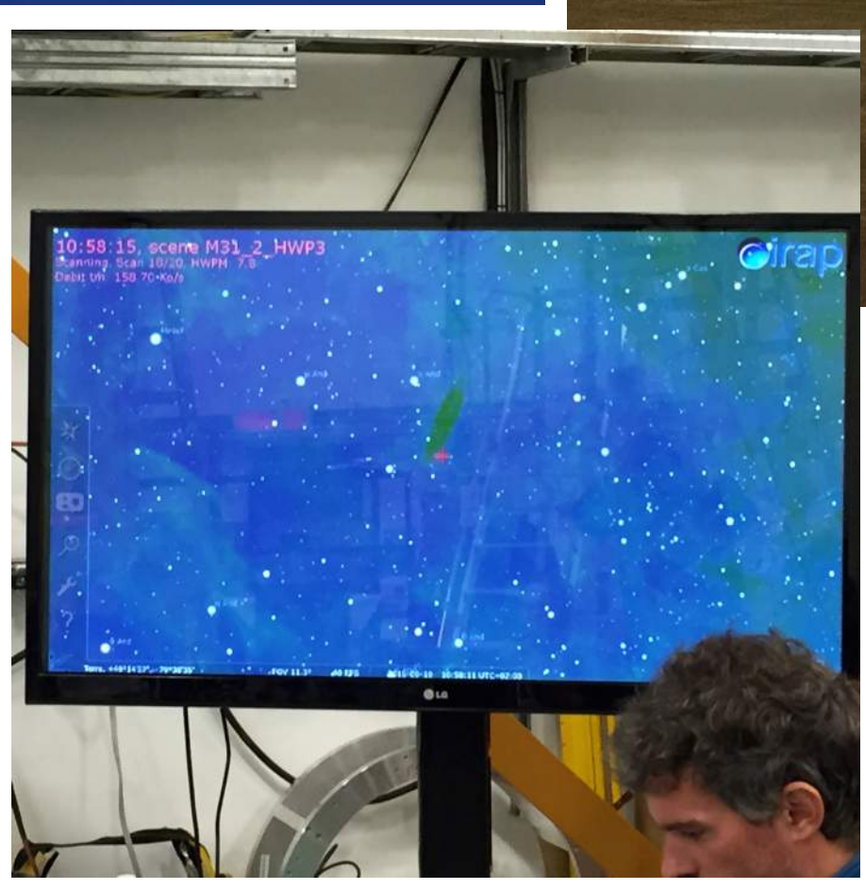




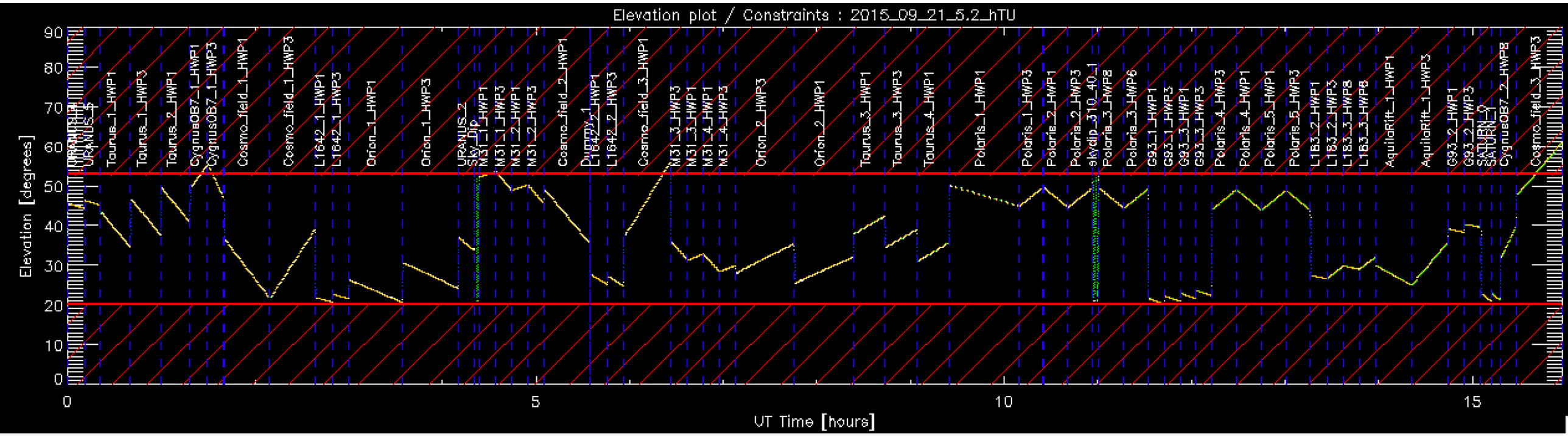
Gondola (CNES)

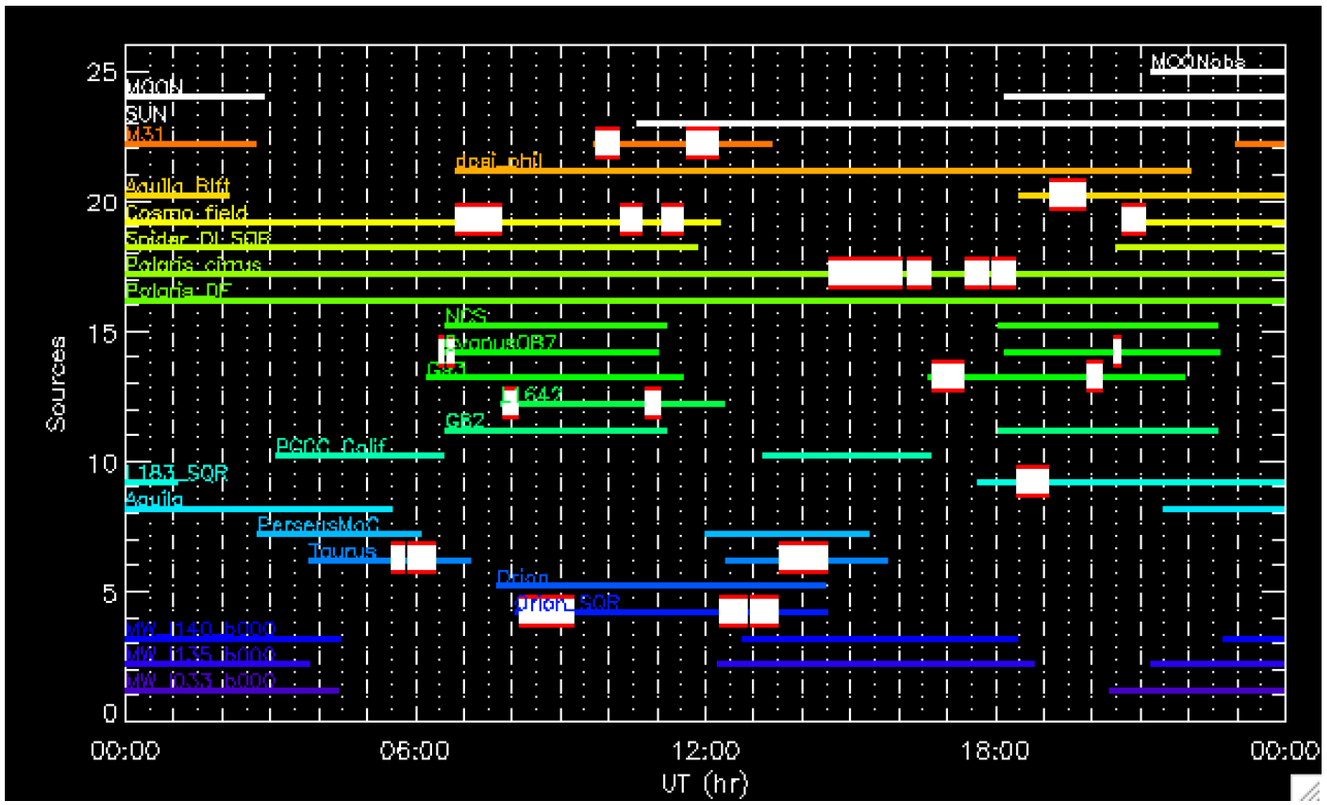
The day-time stellar sensor (Estadius) provides 5” accuracy while scanning up to 1°/sec

First Flight



Actual Flight Plan



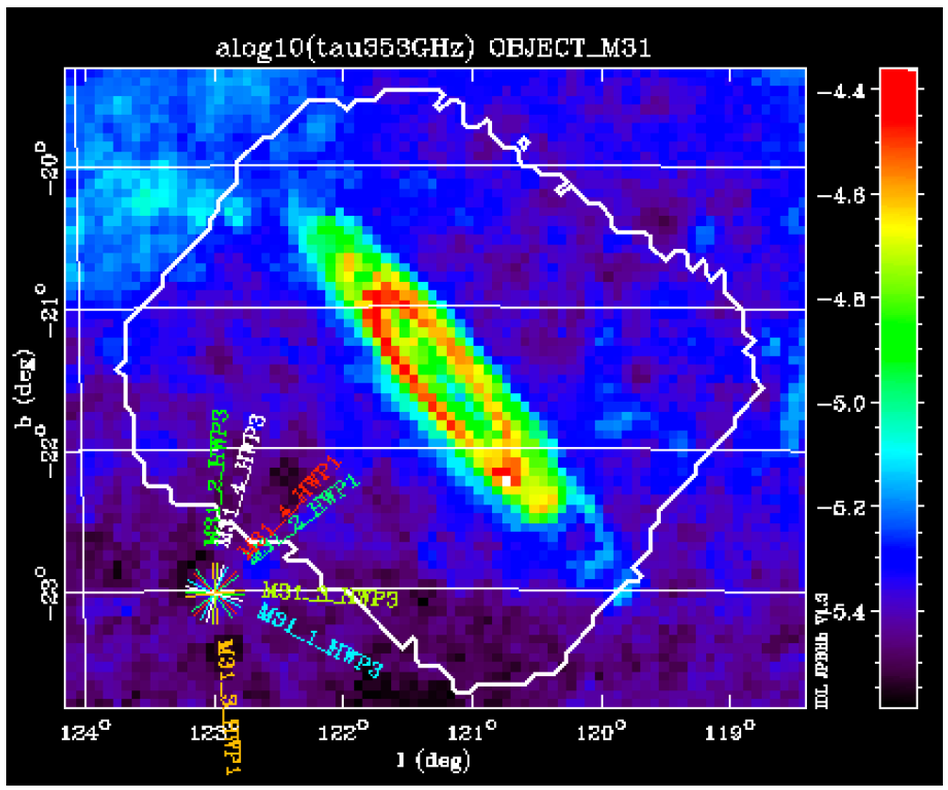


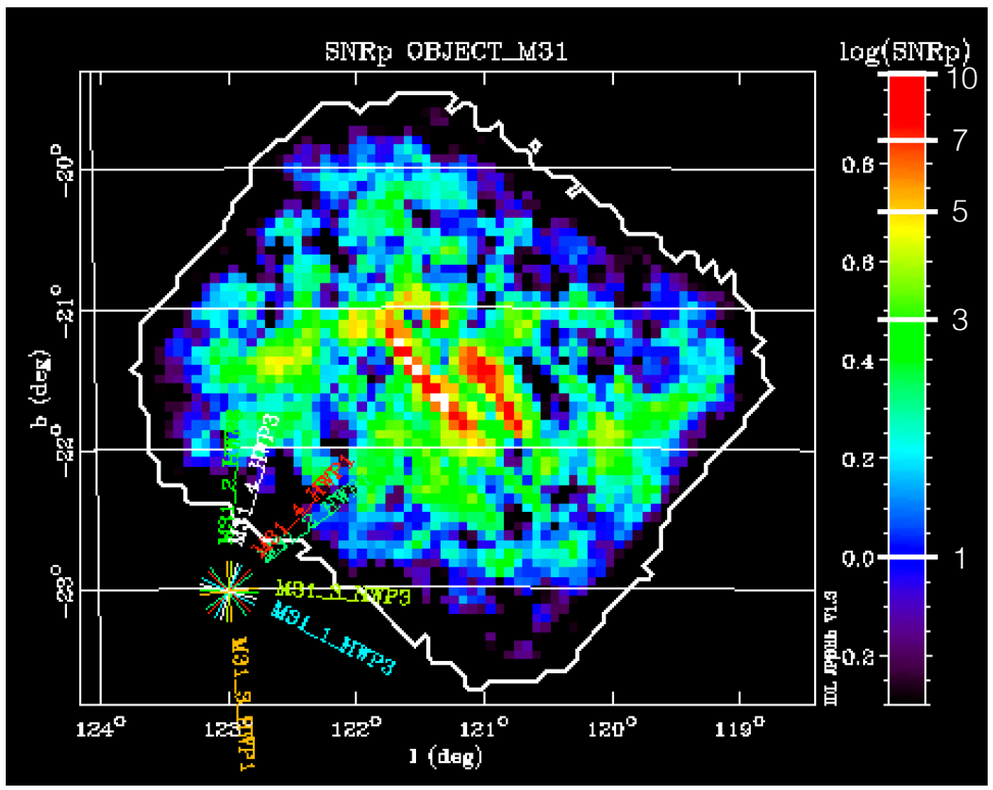
A balancing act between:

- science objectives
- calibration needs
- source visibility
- experiment constraints

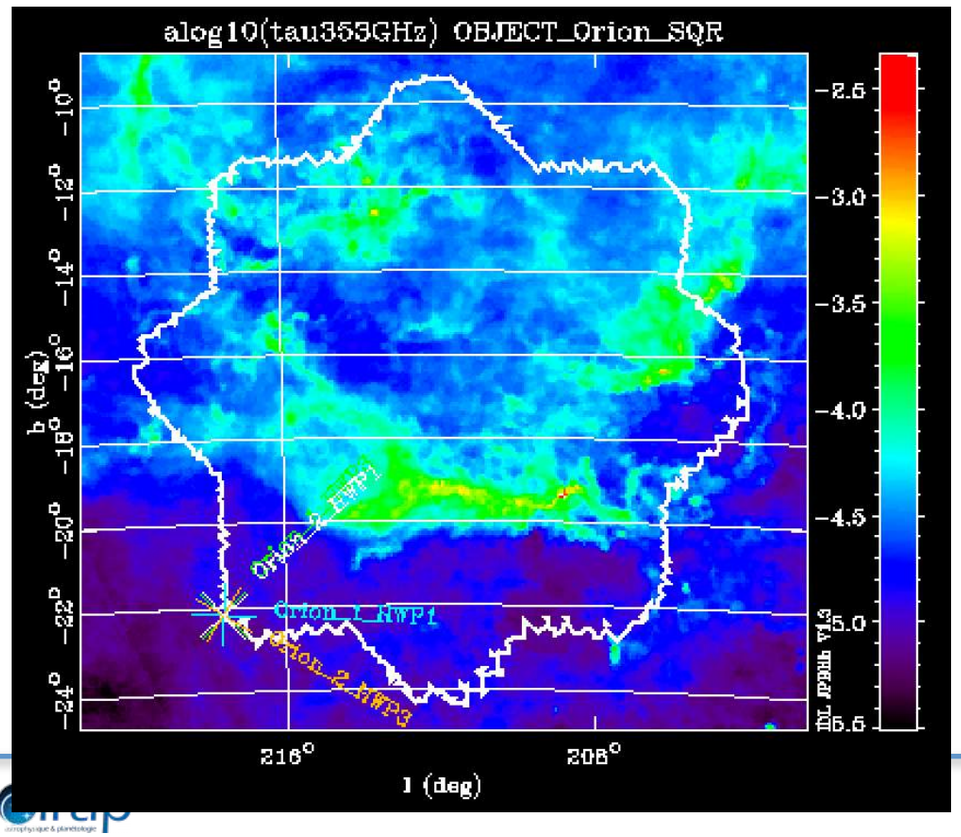
Flight Plan: M31, Orion

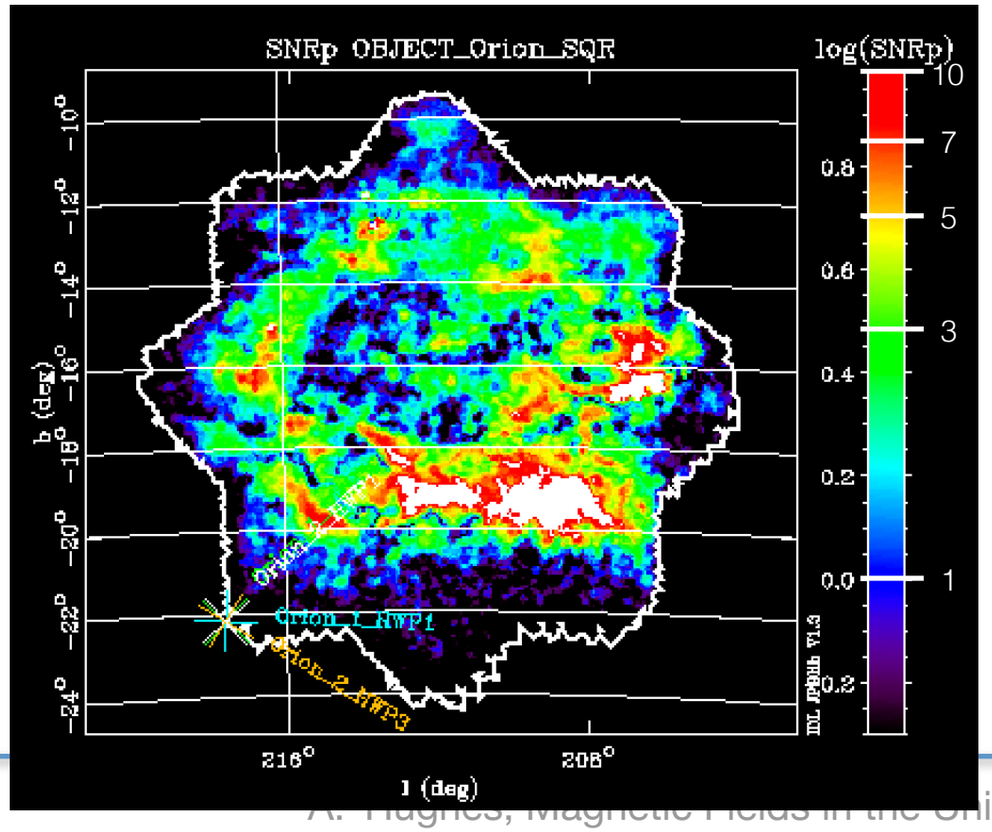
M31





Orion MC

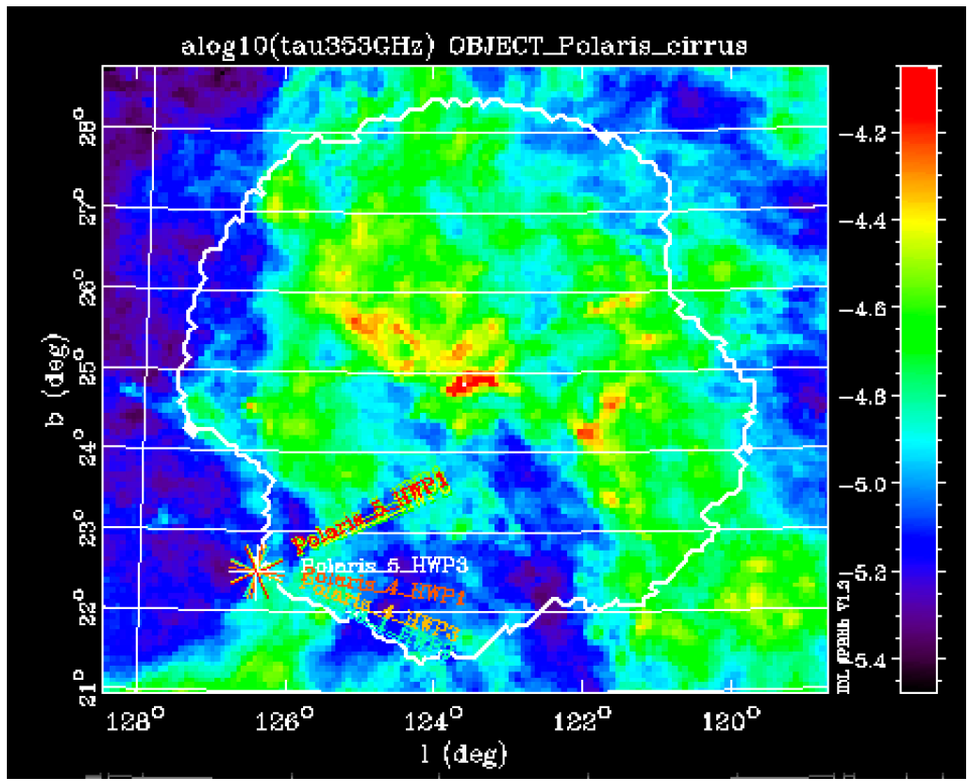


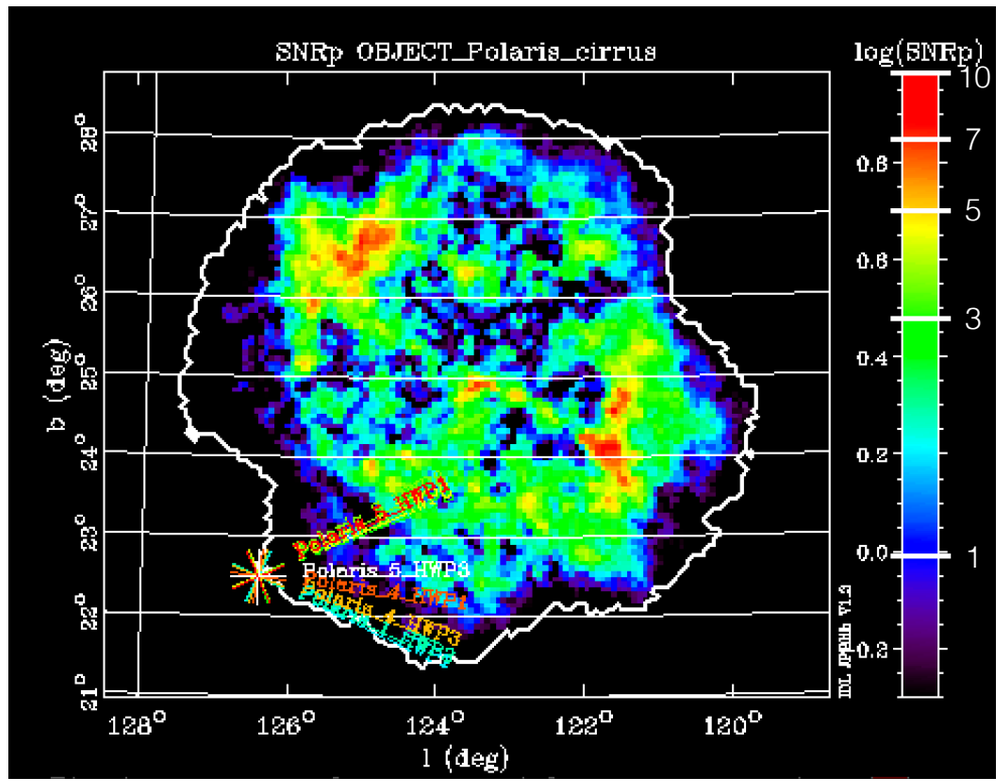


SNRp (5’)

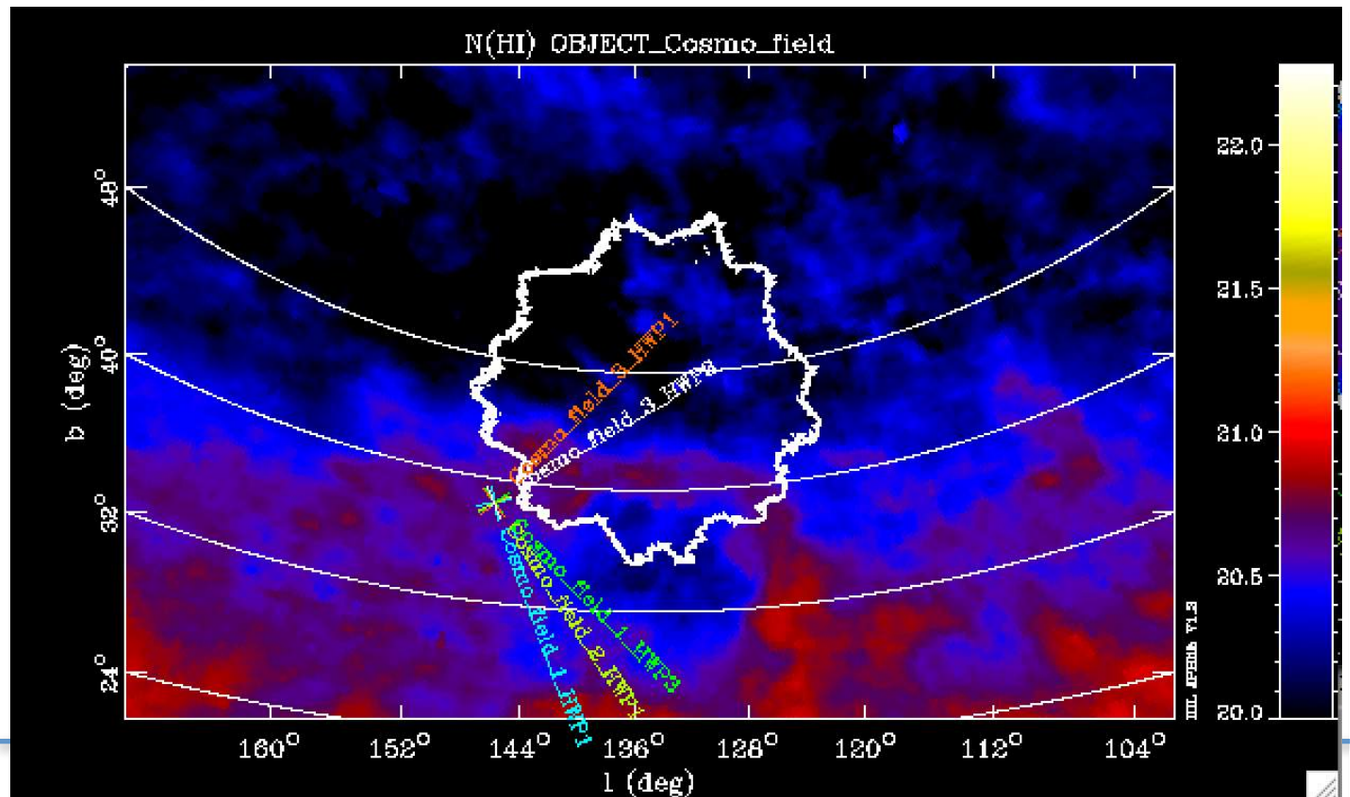
Flight Plan: Diffuse ISM, DF

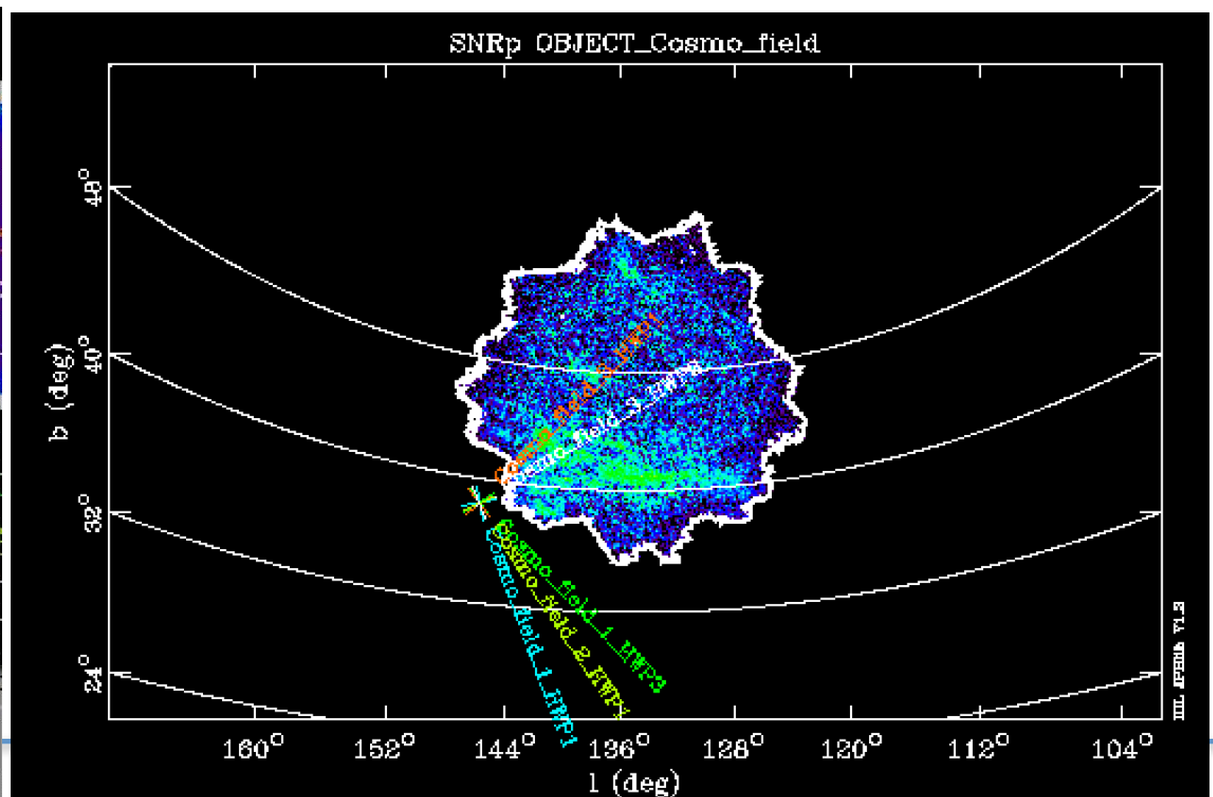
Polaris



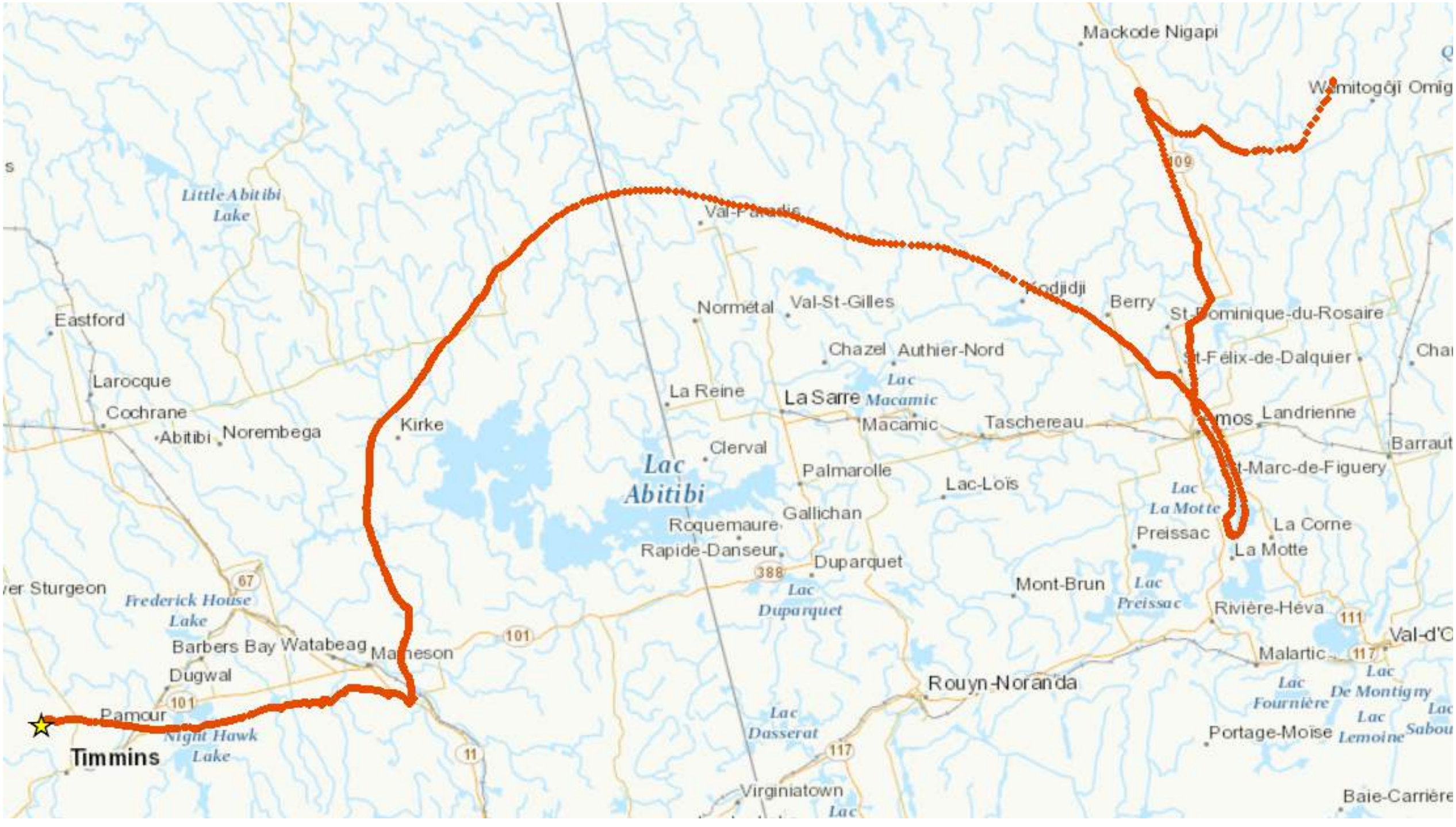


Deep Field

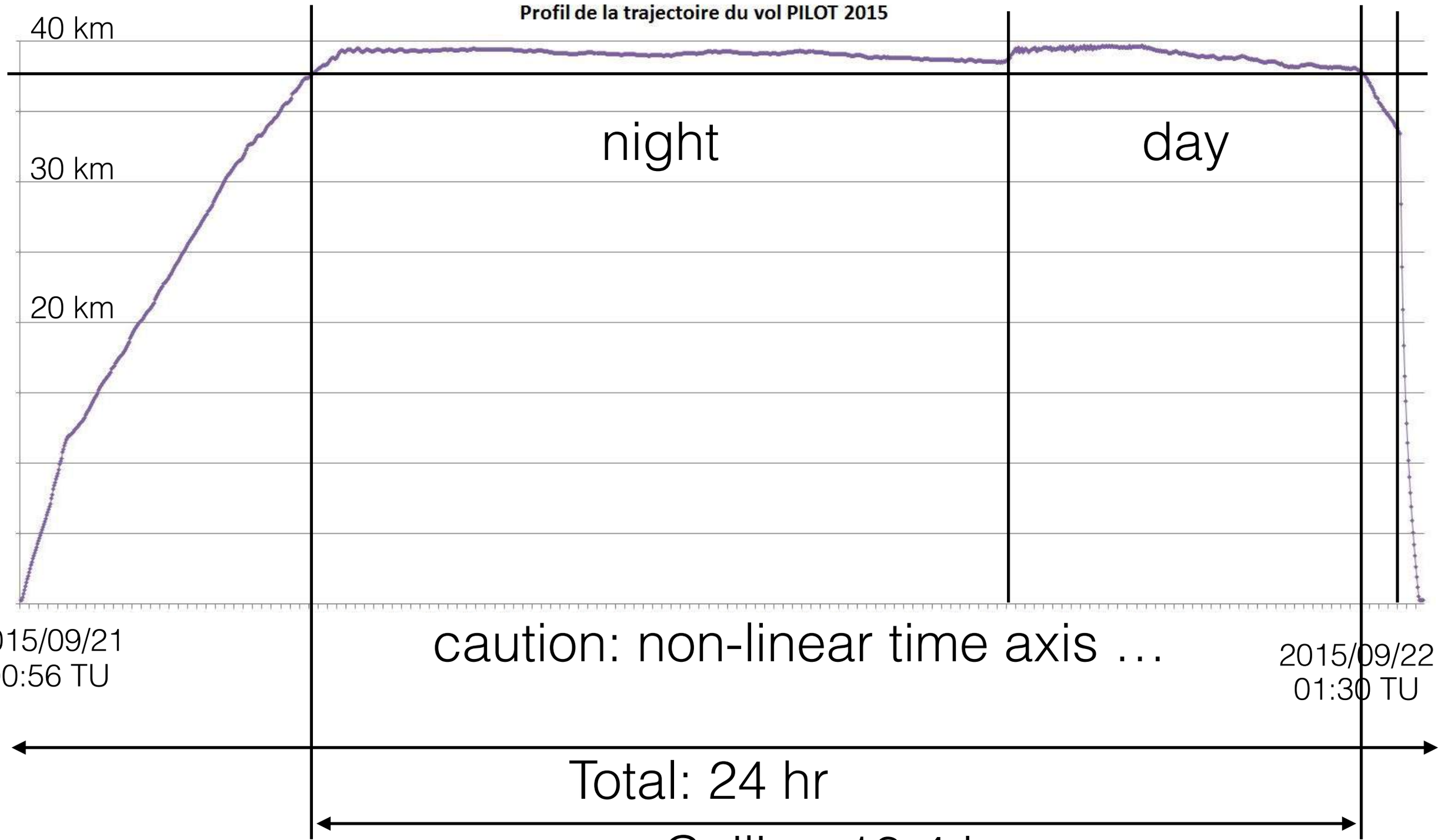




Timmins Flight Trajectory



Timmins Flight Trajectory



Science Observations

Sources	Nb scènes	t obs	Map size	Deg^2/h scène	Deg^2 / h intégré
Taurus	6	117 mn	12° x 8 °	331	55
Orion	4	145.3 mn	10° x 10 °	191	47.8
Aquila Rift	2	46 mn	8° x 8°	188	94
Cygnus OB7	2	21 mn	7° x 7°	333	166.5
L1642	4	44 mn	2° x 2 °	38	9.5
G93	6	61 mn	2° x 2 °	38	6.3
L183	4	41 mn	2° x 2 °	38	9.5
M31	8	84 mn	3° x 3 °	49	6.1
Polaris	10	160 mn	5° x 5 °	123	12.3
Cosmo field	3.5	116 mn	16° x 16 °	562	160
Uranus	3	31 mn	3° x 2 °	57	19
Saturne	2	12 mn	2° x 2 °	68	34
SkyDip	2	10 mn			

molecular clouds

YSOs & cold cores

diffuse ISM

Timmins Flight: Summary

Total flight time= 24 h

Total time at ceiling= 18.4 h

Ceiling altitude= 39 km (3 hpa)

Scientific data= 14.8 h (80 % of ceiling)

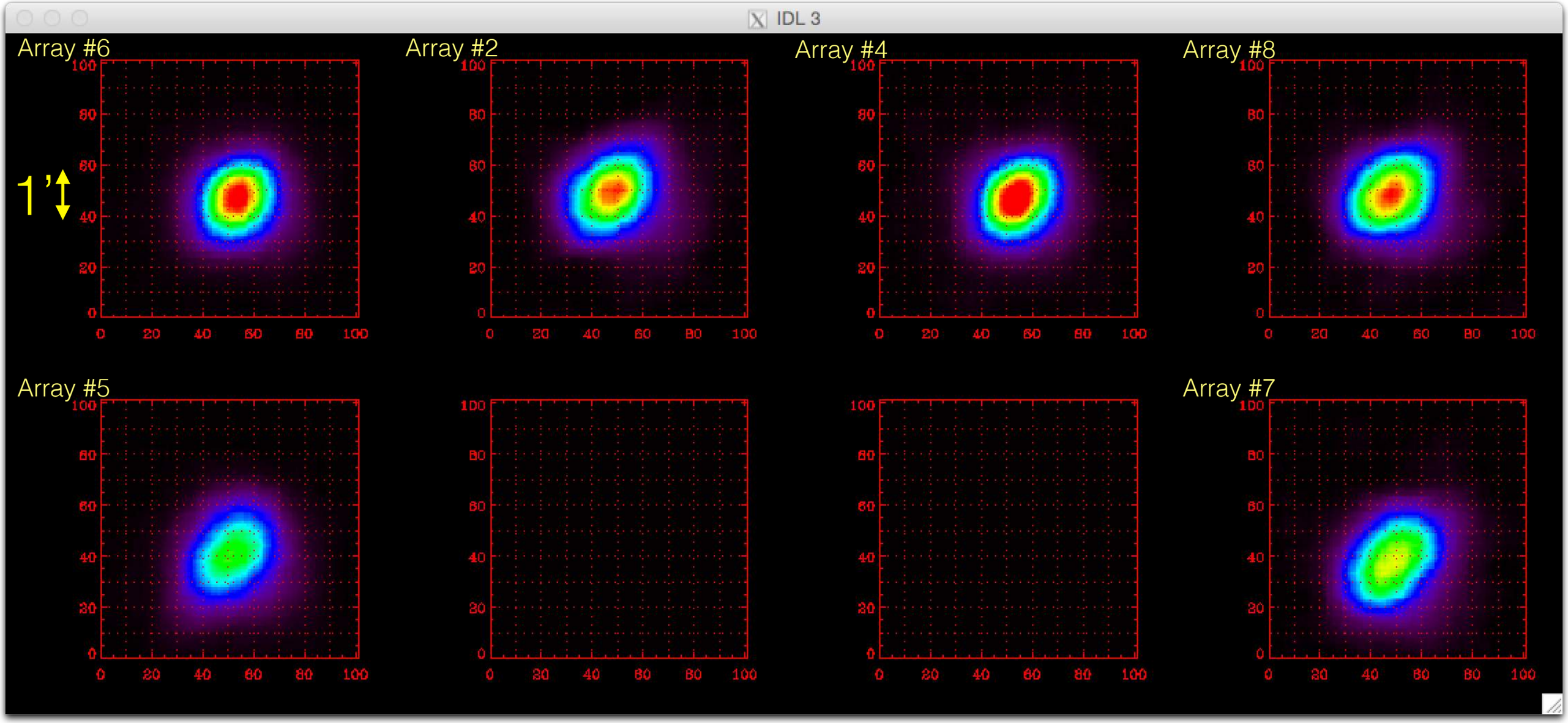
Detectors setting, Fridge recycling, slews = 3.6 h (20 %)

In-flight instrument performance:

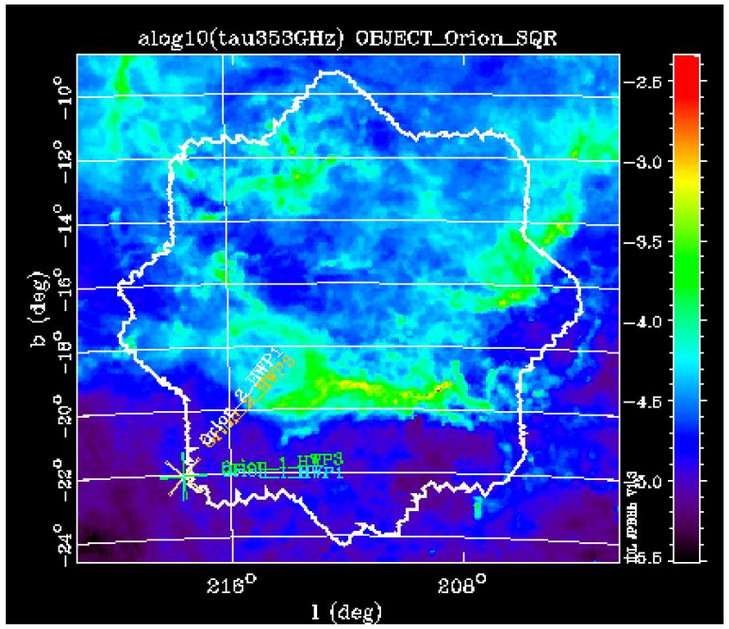
- Focal plane at 320 mK (as expected)
- 6 out of 8 arrays operational (as expected)
- Detector noise at expected levels (a few 10^{-16} W/Hz$^{1/2}$)
- Instrument PSF consistent with expectations
- Pointing accuracy (Estadius) nominal

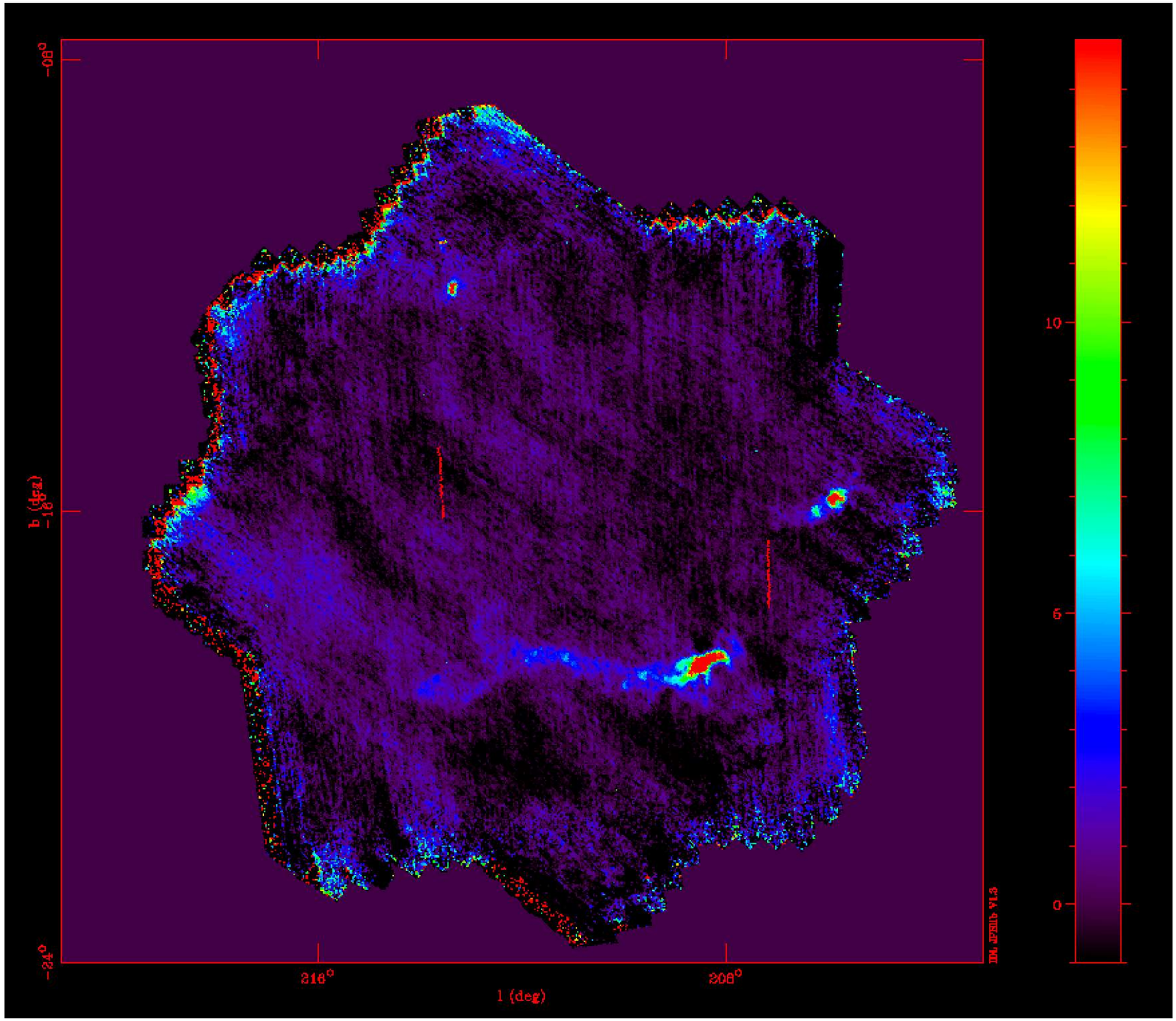
Inflight Performance: PSF

preliminary PSF on Saturn on individual arrays



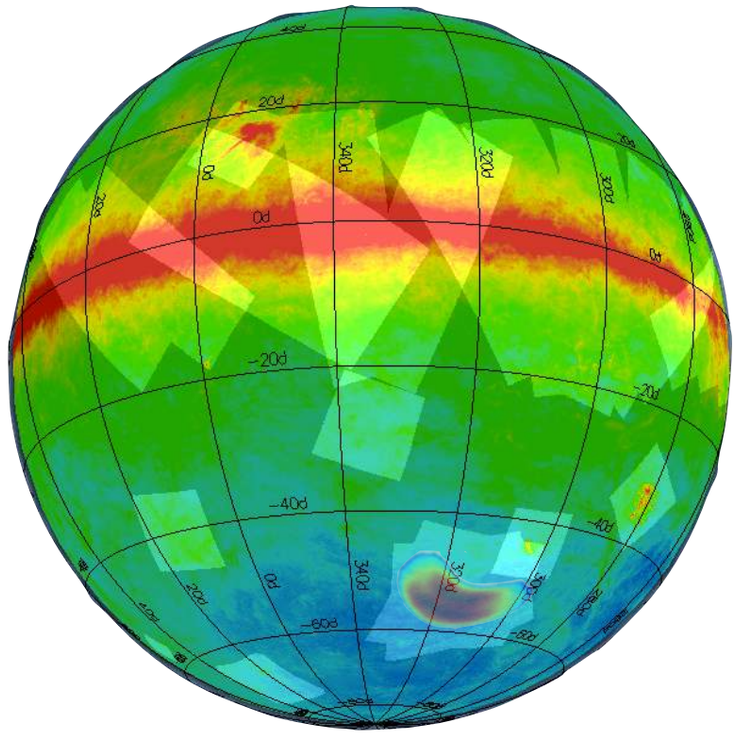
First Look: Orion

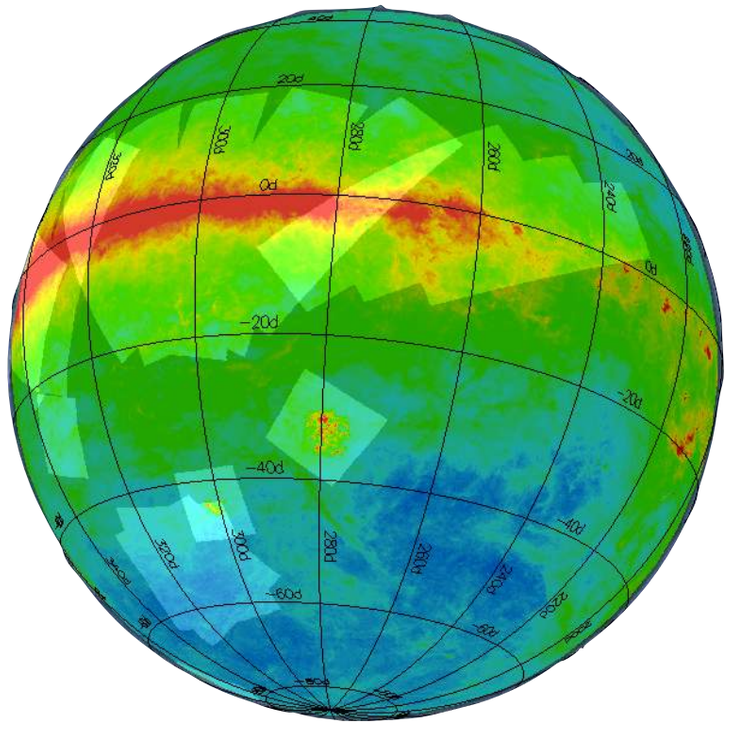




Australia 2017

- Fixing connectors to arrays 1 & 3
- Enlarging bandpass: potentially increase sensitivity by a factor of 3
- BICEP2, LMC & SMC, Galactic Plane, including Galactic Centre

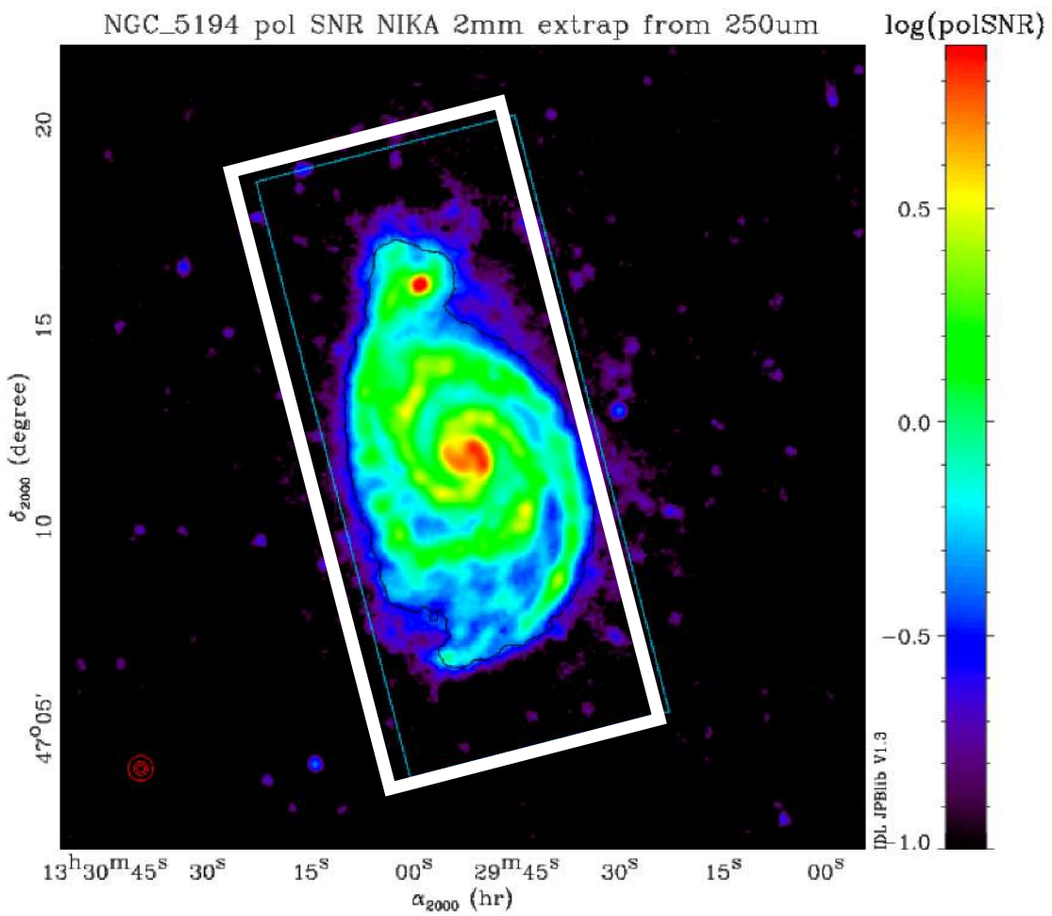


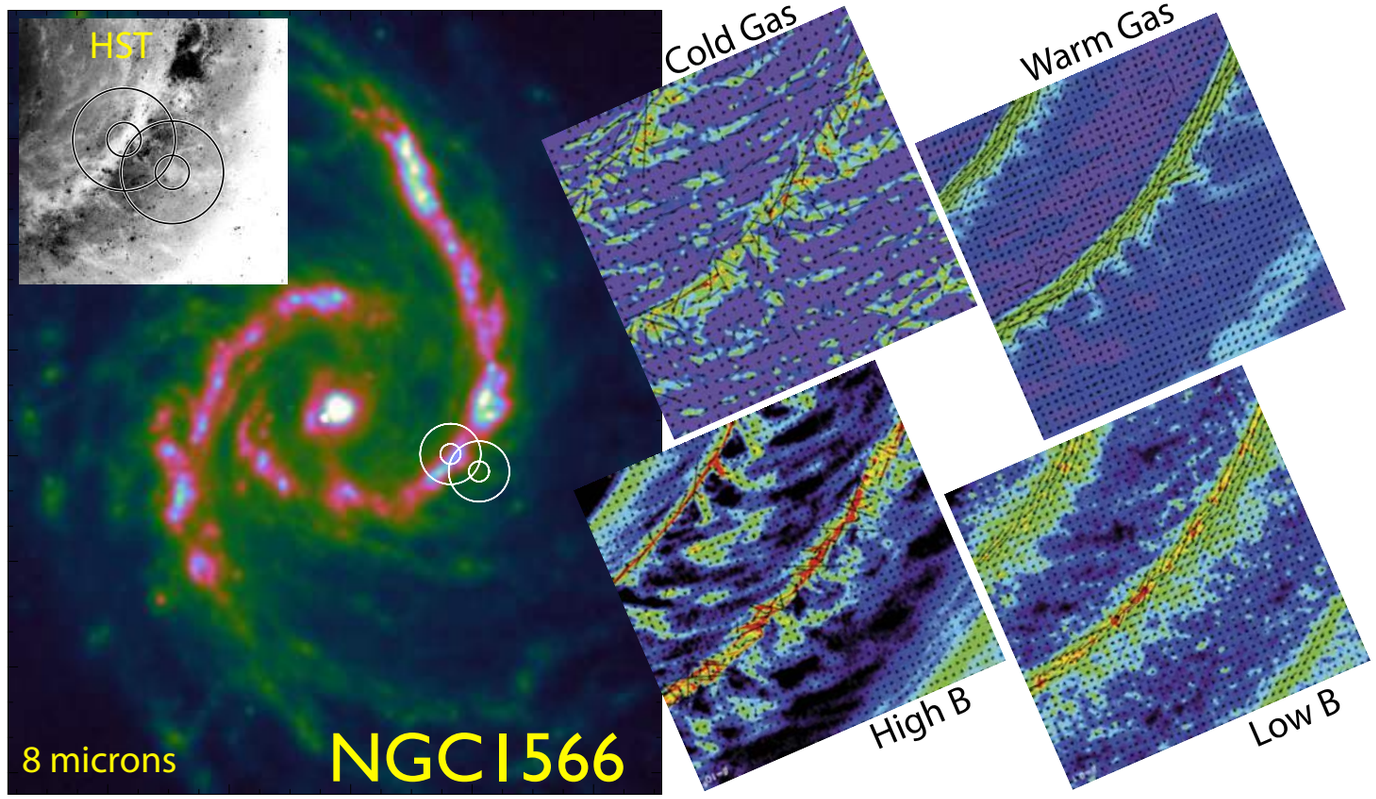


Other Opportunities

NIKA2 on IRAM 30m

Polarisation at 1 & 2 mm
KIDS detectors
Resolution: 12”, 23”
FoV: 6.5 x 6.5 arcmin
e.g. 8hr, M51, 36” at 2mm





ALMA Cycle 3:

2 pointings (arm+spur in NGC1566)
350 GHz continuum (B7)
Scales: 1.4” to 5.7” (60 to 250pc)
Time: 7.5 hrs (12m only)