B-fields In STar forming Region Observations: BISTRO

Pol. Image Credit: POL-2 Commissioning Team

P.I.s: **Derek Ward-Thompson (UK)**, Di Li (China), **Ray S. Furuya (Japan)**,
Woojin Kwon (Korea), Ramprasad Rao (Taiwan), Pierre Bastien (Canada)

BISTRO: Overview

- **Aims to map polarized 850 micron emission towards Gould Belt star-forming regions**

- **Aims to map the high-column-density regions of: Ophiuchus, Orion A & B, Perseus, Serpens Main, Taurus L1495/B211, Auriga, IC5146**

- **Awarded 224 hours of Band 2 observing time**

- **The first science data were successfully taken last night!**

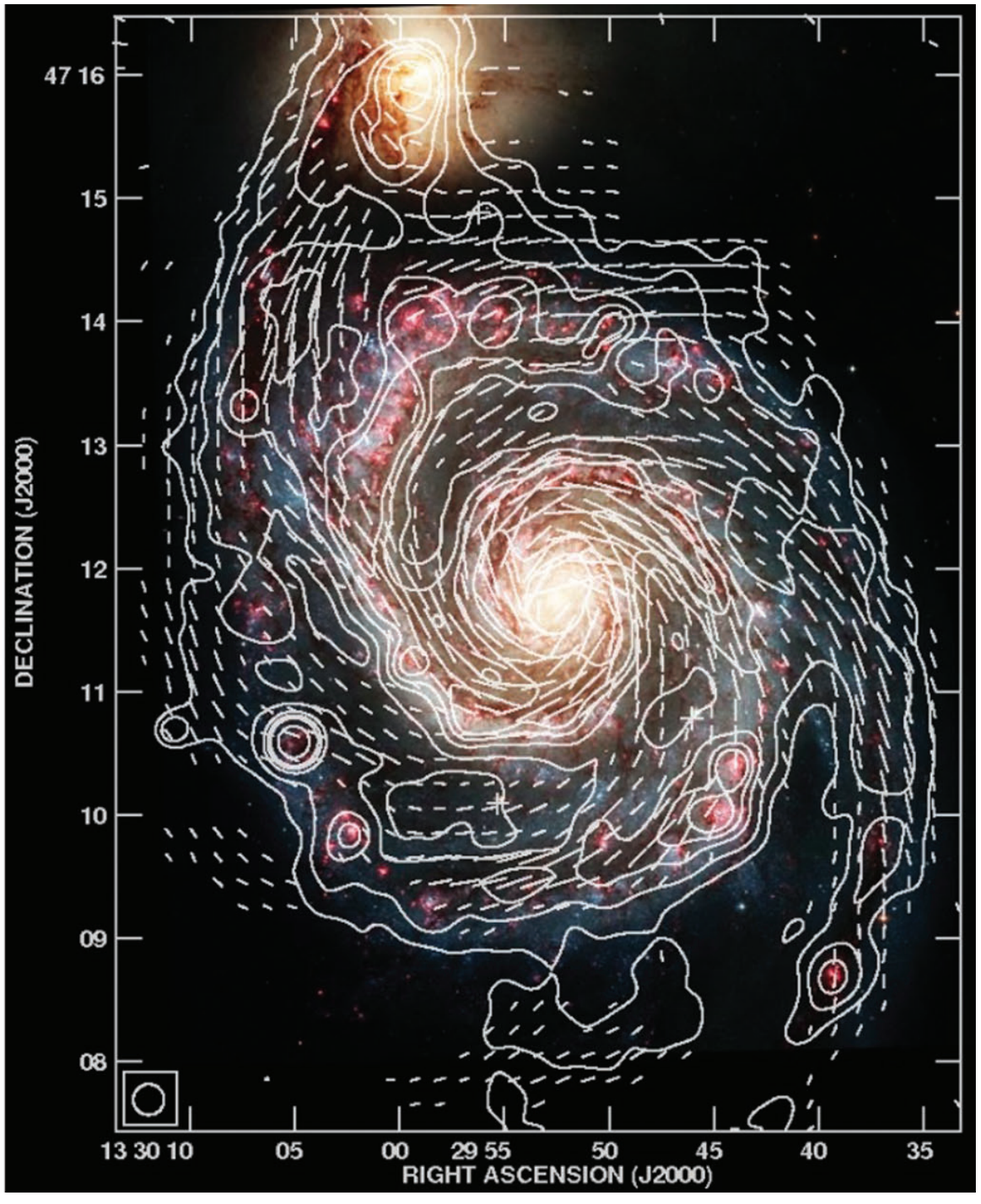
- **~100 survey members across 6 partner regions + EAO**

P.I.s: **Derek Ward-Thompson (UK)**, Di Li (China), **Ray S. Furuya (Japan)**, Woojin Kwon (Korea), Ramprasad Rao (Taiwan), Pierre Bastien (Canada)

Pol. Image Credit: POL-2 Commissioning Team

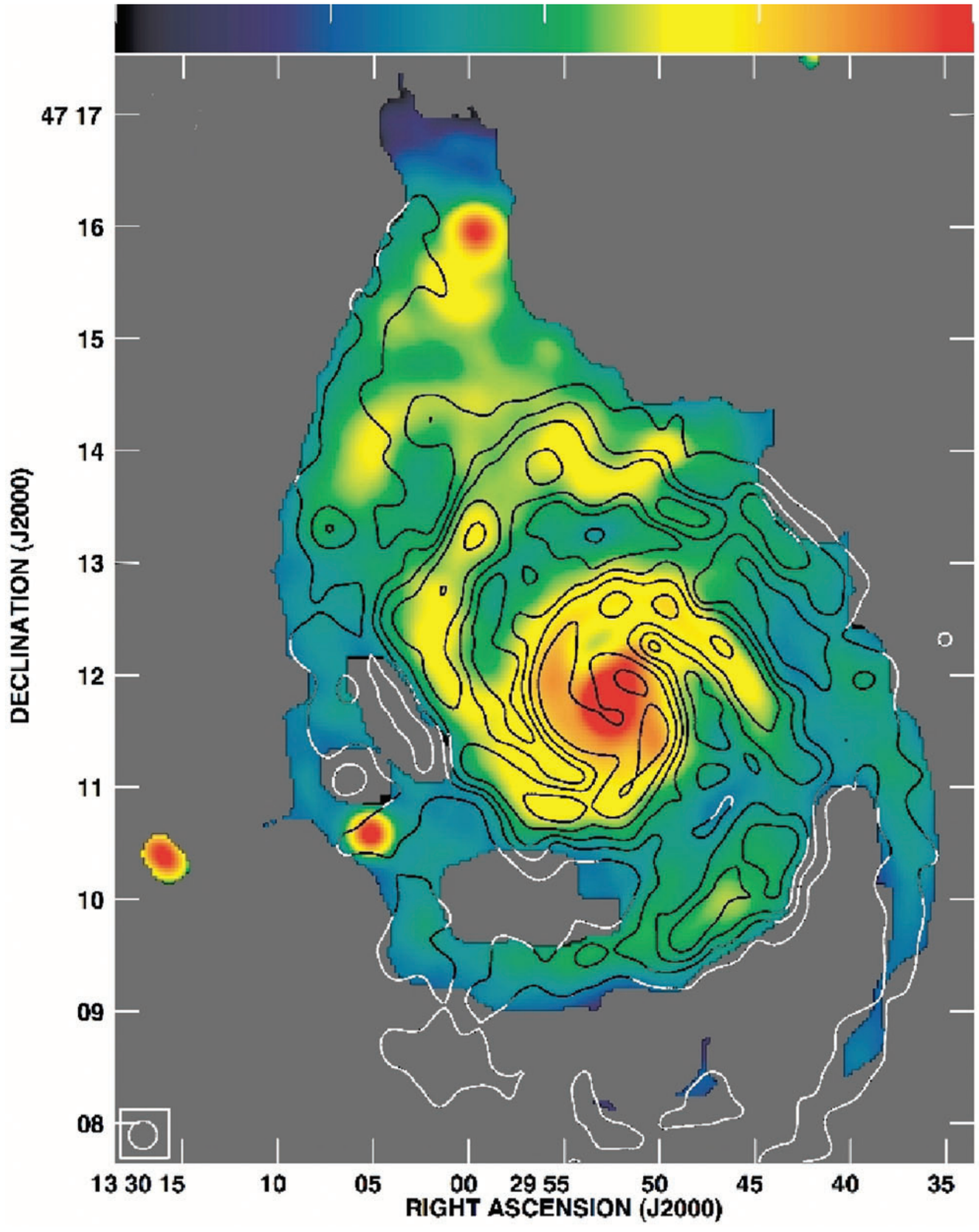
Importance of B-feilds in a Spiral G.

Magnetic fields and spiral arms in M51

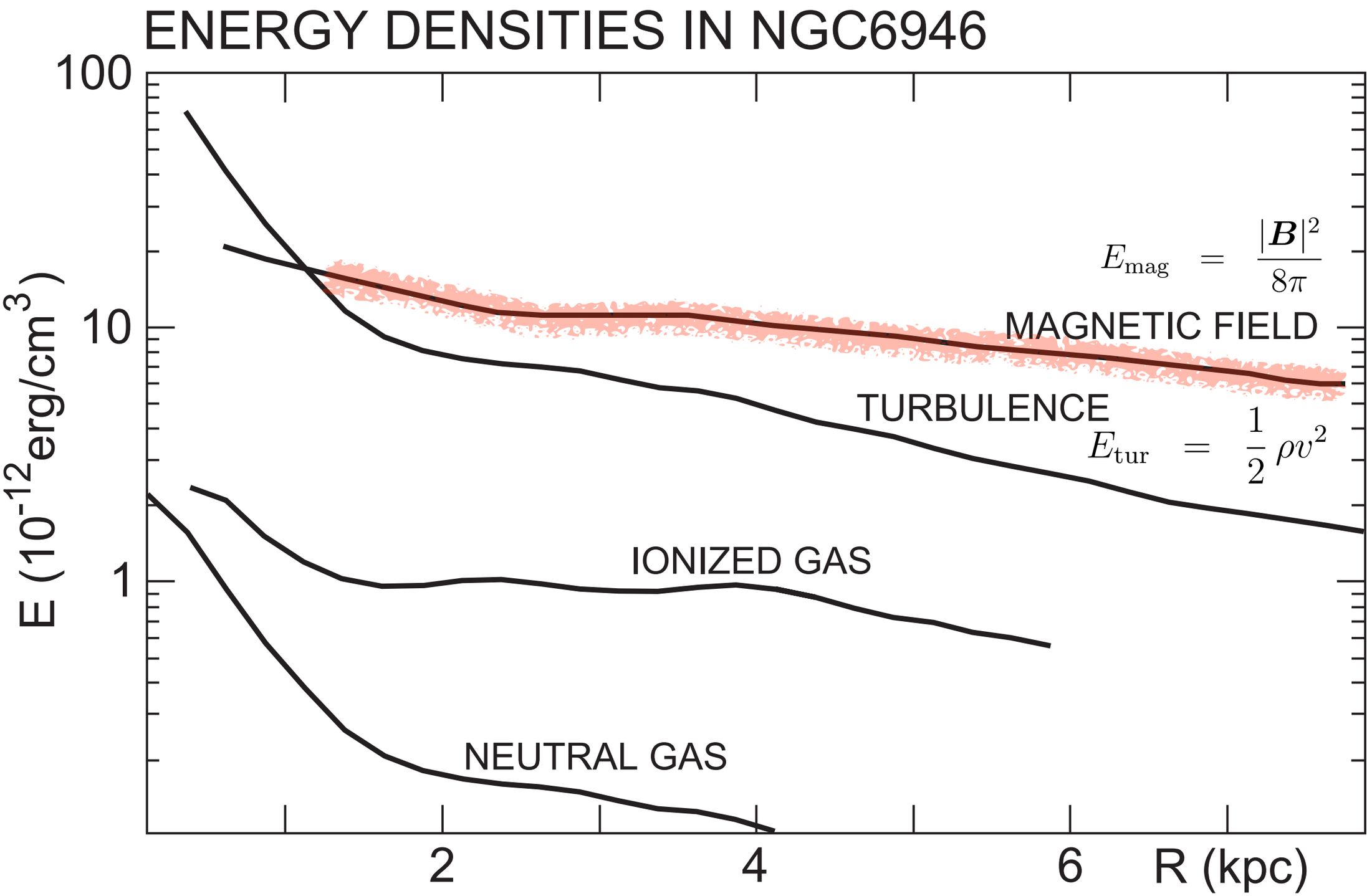


Fletcher et al. 2011

|B|-field strength in micro-Gauss



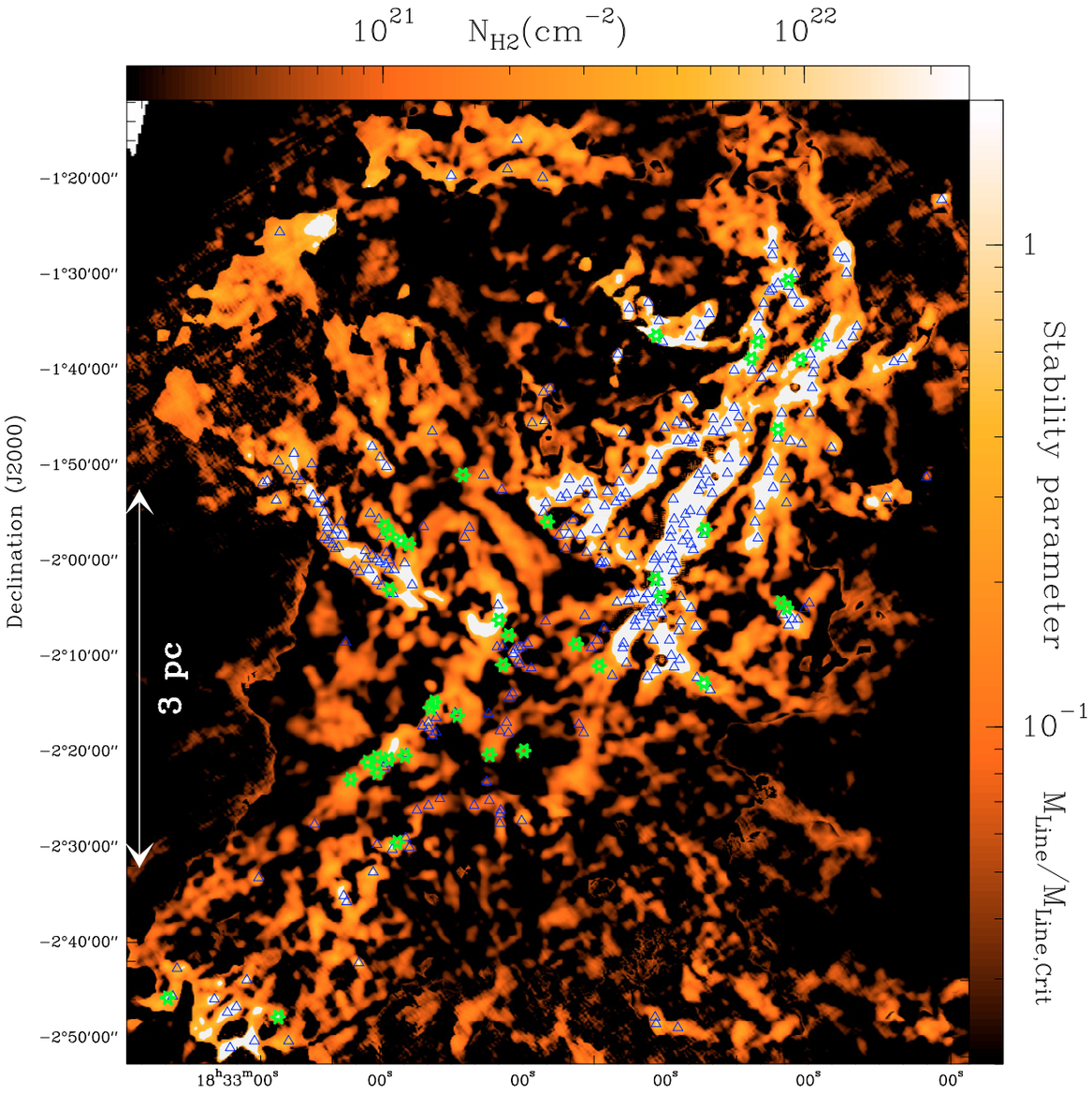
Importance of B-feilds in a Spiral G.

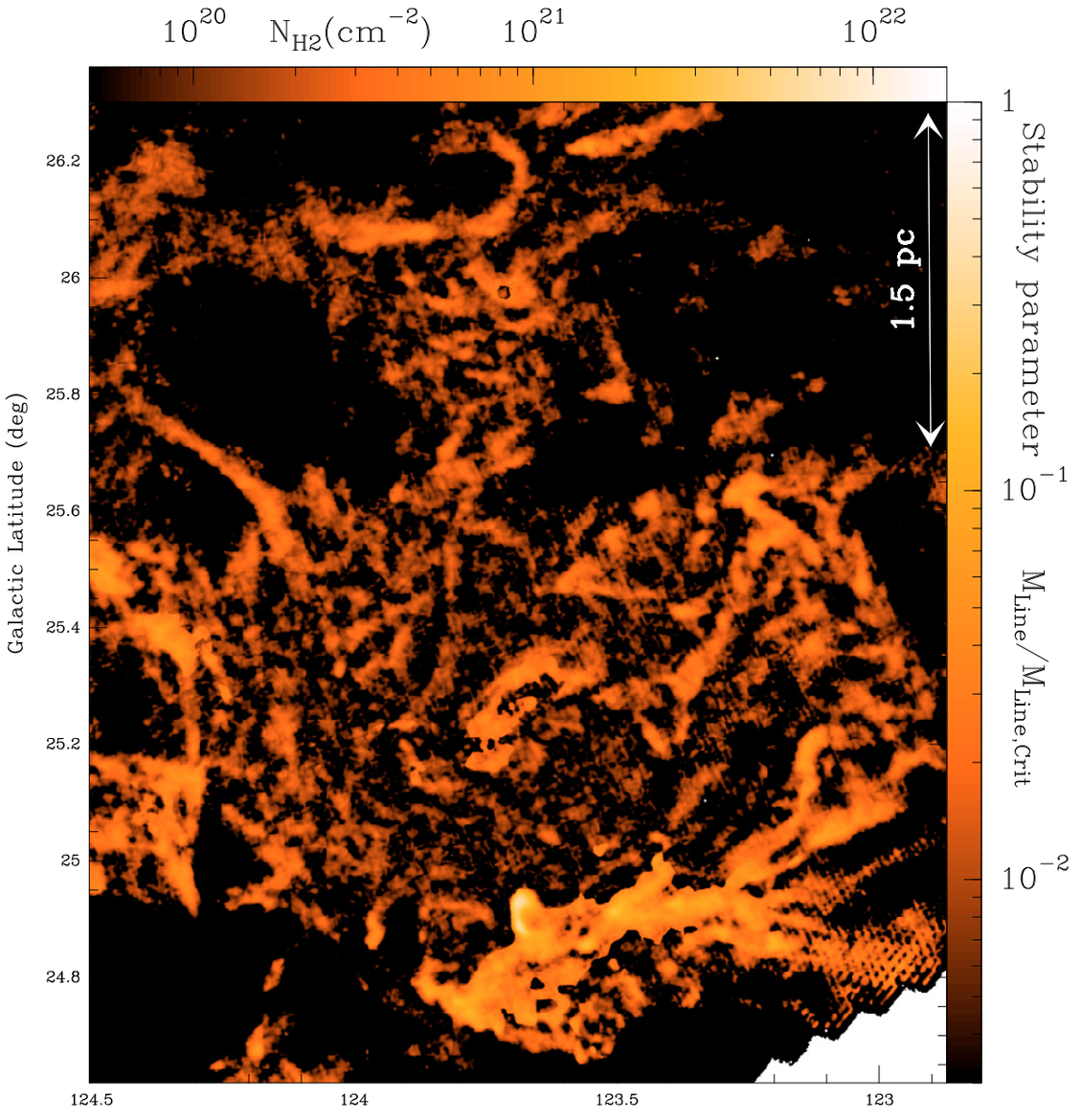


Beck, R., 2004

Filaments, Cores, and Protostars: Hierarchical Structure

Column density map derived from 70 – 500 μm maps taken with *Herschel*





Aquila Rift — Active SF

Polaris — Quiescence

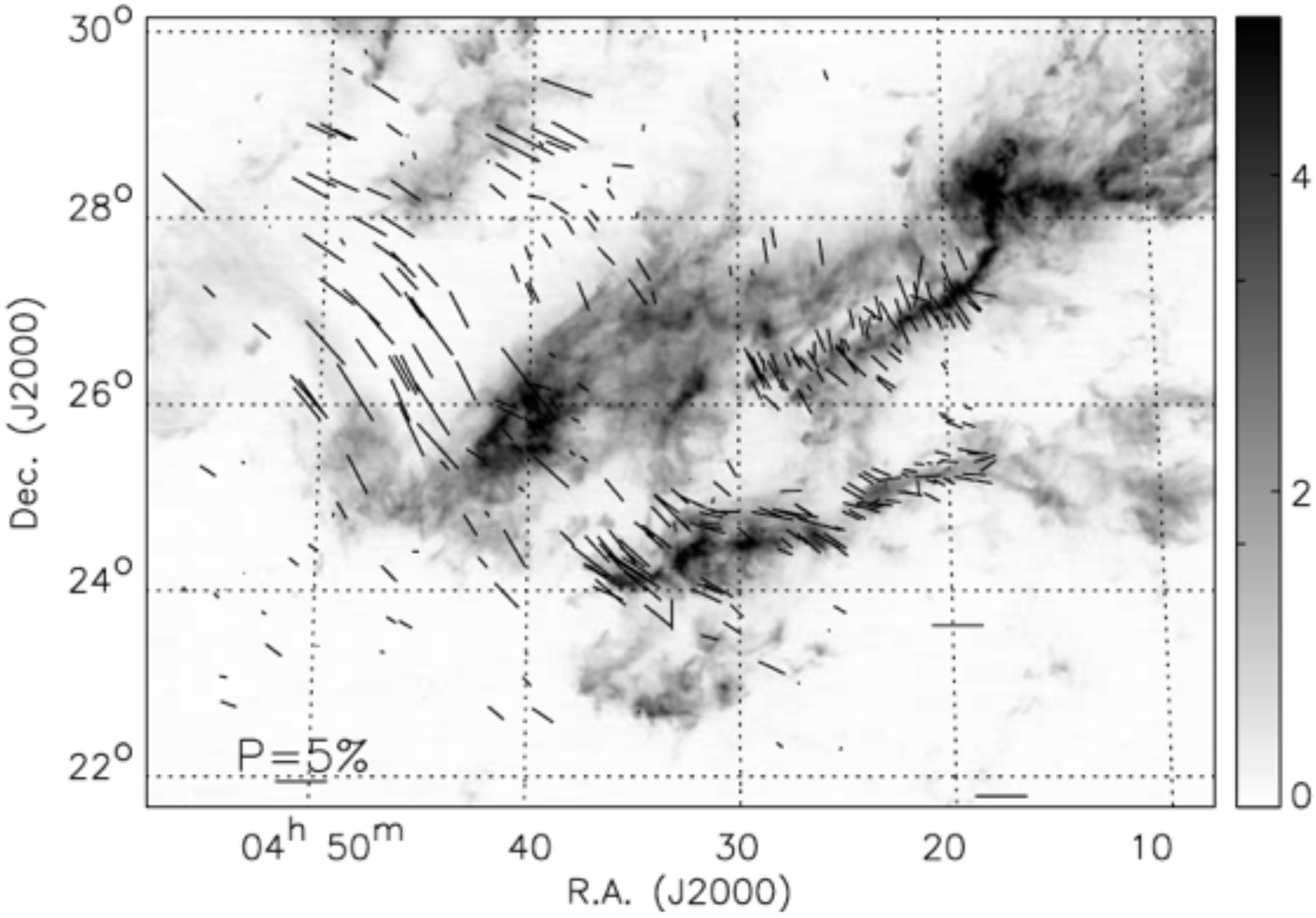
A surface density threshold for star formation? $M_L \sim \Sigma \times H$

where M_L critical line-mass, Σ denotes surface density, and H scale height.

Andre et al. 2010; see also Palla and Stahler 02, Goldsmith+08, MeMen'shchikov+08

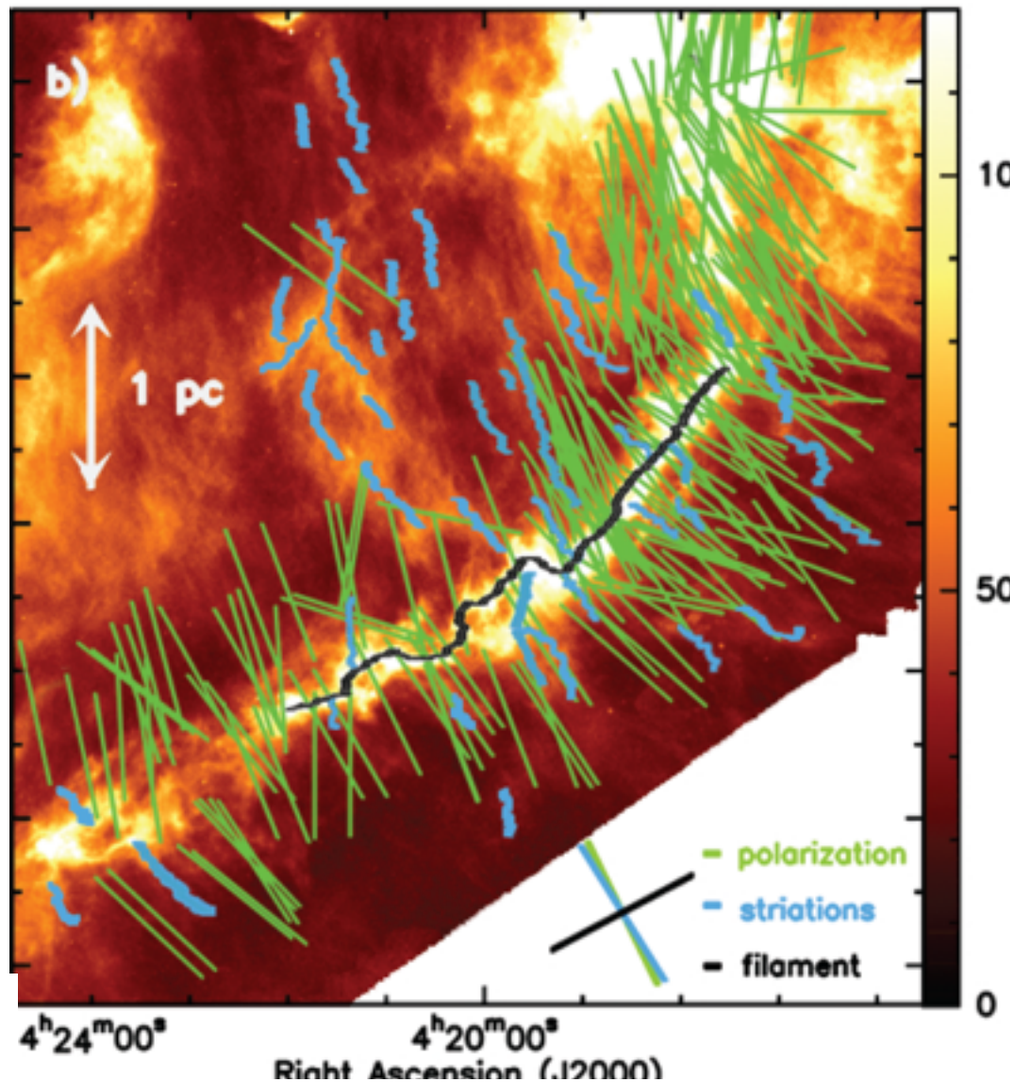
Filament evolution and Core Formation: Regulated by *B* field?

Overall Taurus: Molecular line



Goldsmith et al. 2008

B213 in Taurus: Dust Cont.

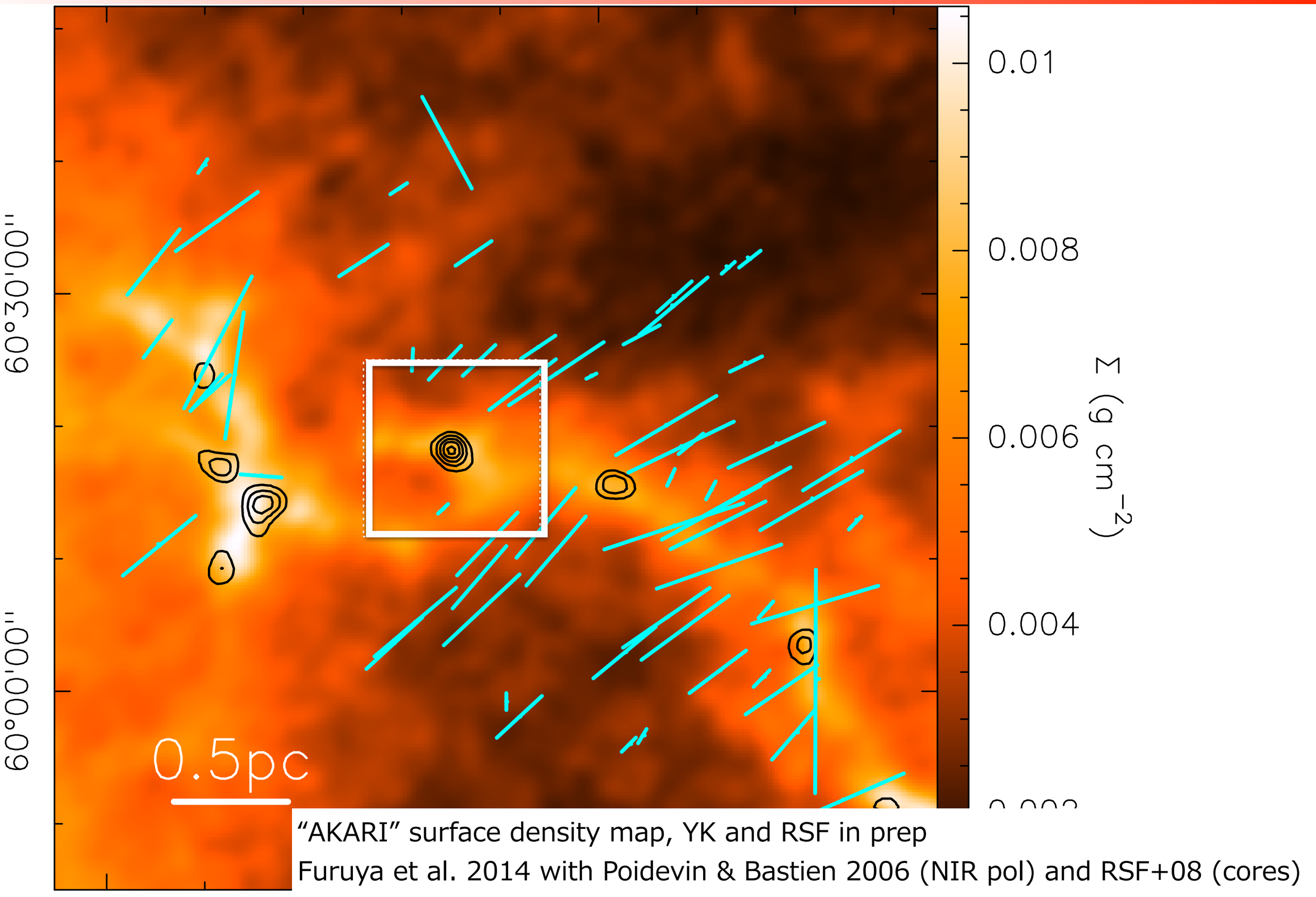


Palmeirim et al. 2013

Super critical filament ⊥ Magnetic field

Subcritical filament ∥ Magnetic field

Need to explore B-feilds in high-density gas



"AKARI" surface density map, YK and RSF in prep

Furuya et al. 2014 with Poidevin & Bastien 2006 (NIR pol) and RSF+08 (cores)

POL-2 + SCUBA-2: Unique tool

- ***Only*** open-instruments in the northern sky
- Tracing pol. structure in ***high-density*** gas of $n(H_2)\sim10^{3\text{-}5}$ cm^{-3} , while Opt/NIR pol. does $\sim10^{1\text{-}3}$ cm^{-3}
- 14” beam @850 um:
  - ***Links arcmin-scale*** by e.g., Planck ***with (sub)arcsec-scale*** by ALMA, SMA, NOEMA
  - Corresponding to ~1700AU@120 pc — ***Core-scale down to envelope-scale***
  - Comparable with the Nobeyama 45m beam@3mm

BISTRO: Scientific Goals

(1) To obtain maps of polarization position angle and fractional polarization in a statistically meaningful sample of cores

多数の分子雲コアでの偏波マップ

(2) To characterize the evidence for and relevance of the field and turbulence (in conjunction with previous and follow-up HARP-B/FOREST observations) in cores and their surrounding environments

偏波マップと磁場や乱流との関連性

(3) To test the predictions of low-mass star formation theories (filament, cores, outflow, field geometry), and grain alignment theories

小質量星形成やダスト整列の理論を検証

(4) To generate a large sample of objects that are suitable for follow-up with other instruments, such as ALMA, SMA, Zeeman measurements at Nobeyama 45m

他の望遠鏡での研究へ

POL-2: the Instrument

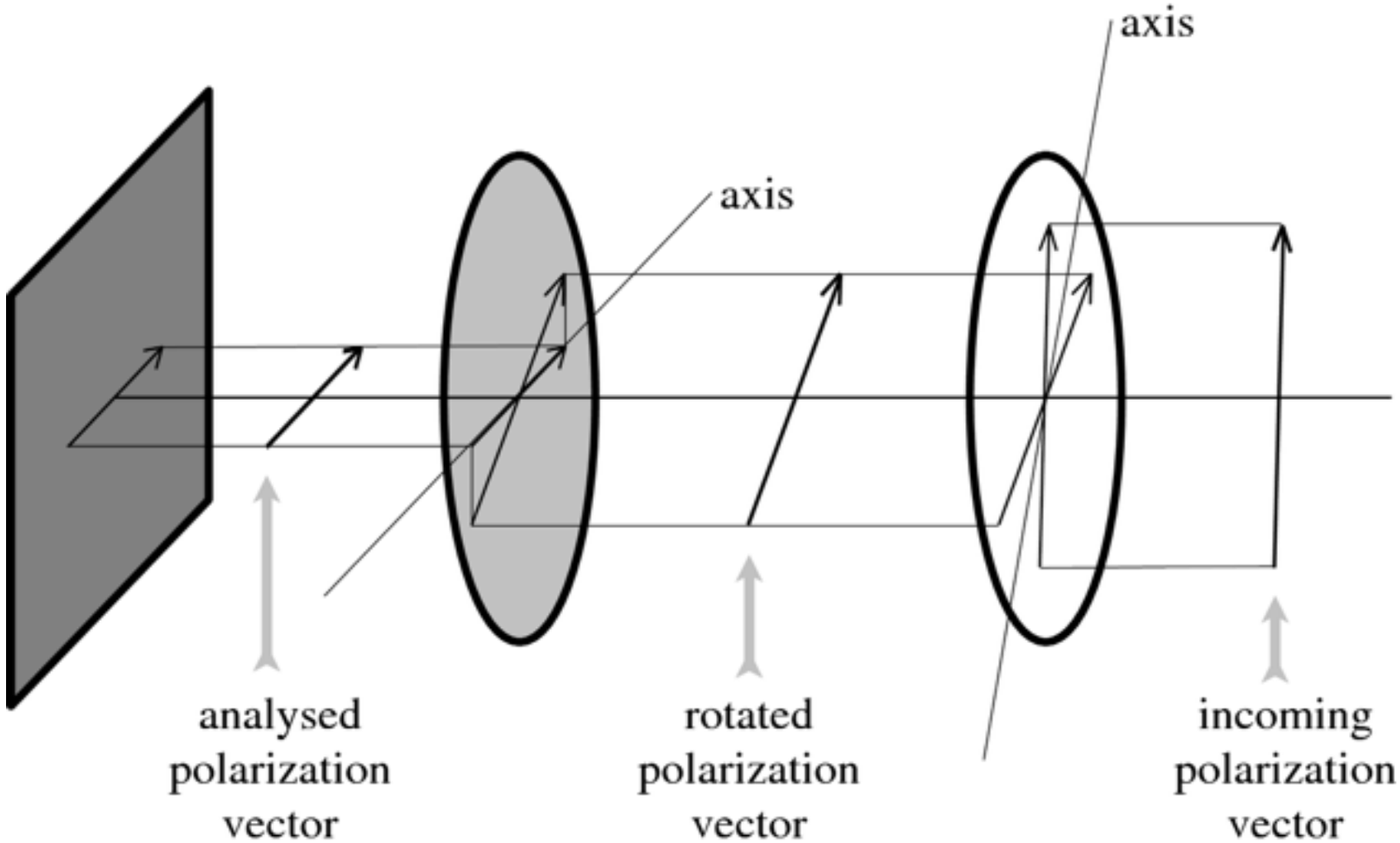
Credit: POL-2 User Manual

Half-wave plate
(2Hz rotation)

Fixed analysers

A single-beam imaging polarimeter

Measures linear polarisation (Stokes Q & U)



Credit: POLPACK documentation/SUN 233

POL-2: Current Status

- Final stages of commissioning → "Science run" : the first data were taken last night!

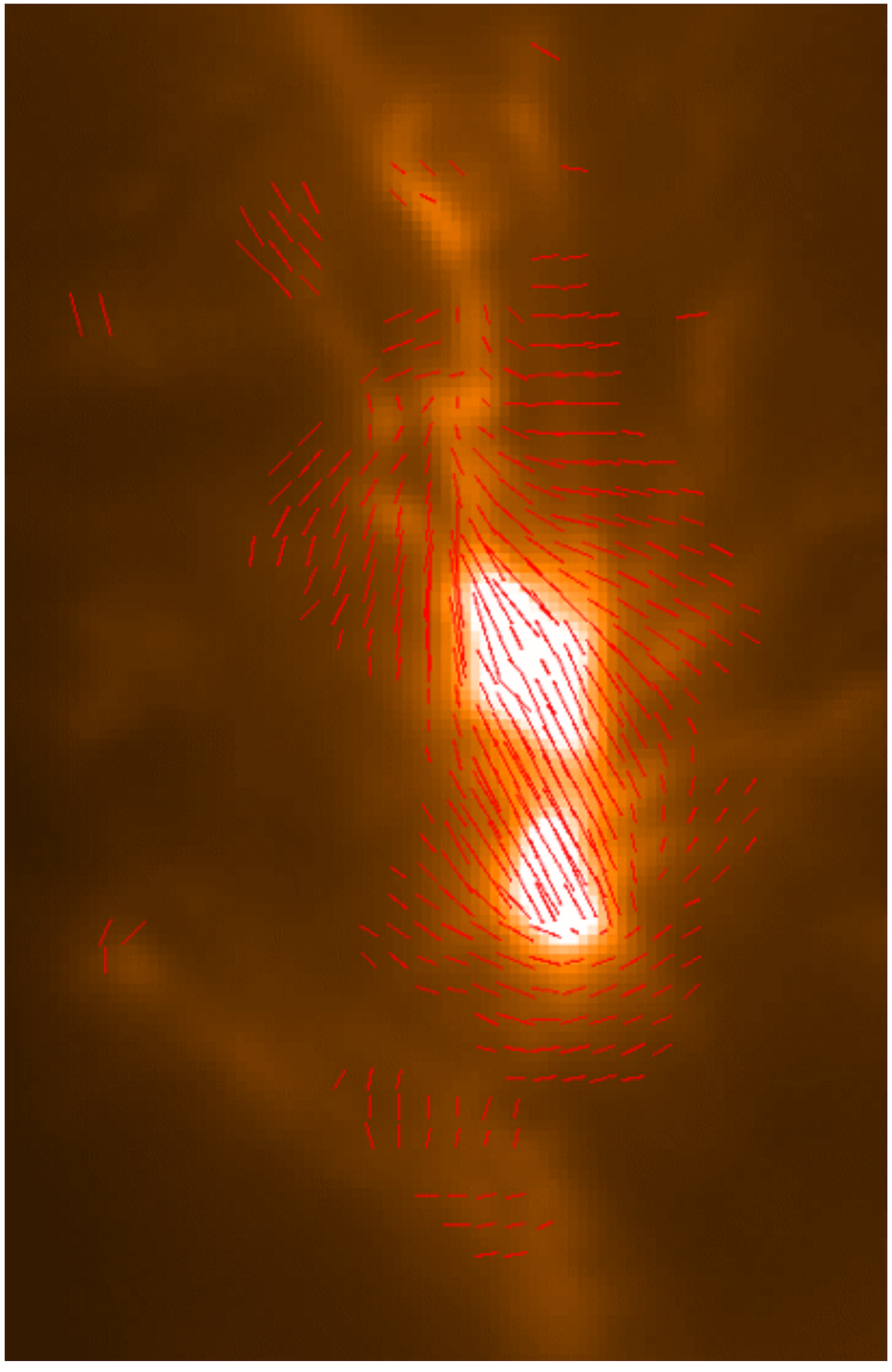
- Basic instrumental polarization (IP) well-established: 1.3%, parallel to elevation axis, at 850μm

- Details of instrumental polarization model being investigated:
  - Dependence on elevation
  - Variation across the focal plane

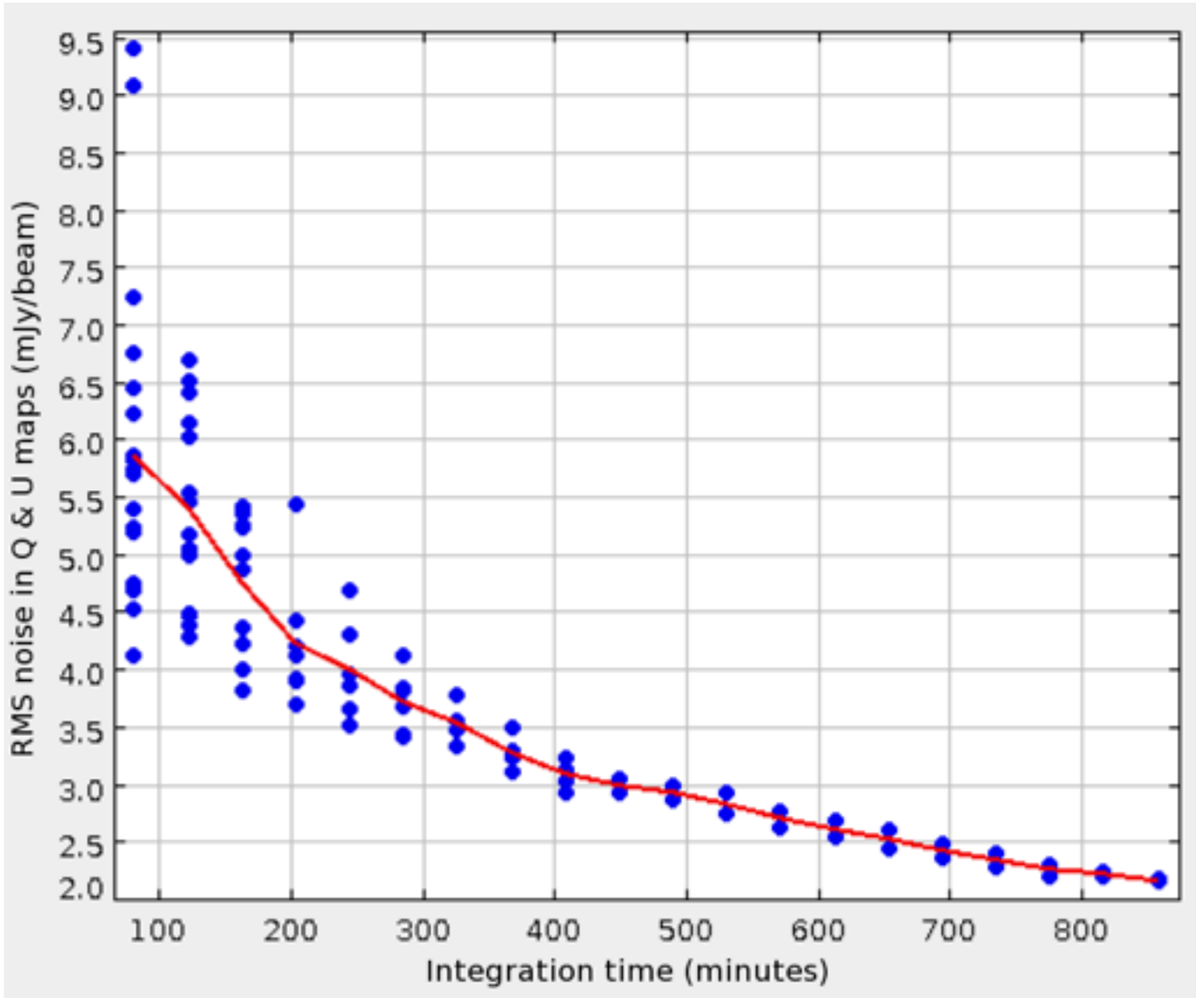
- Revised flux conversion factors: ×1.35 at 850μm; ×1.96 at 450μm

- Tiling of observations to map larger regions currently under investigation

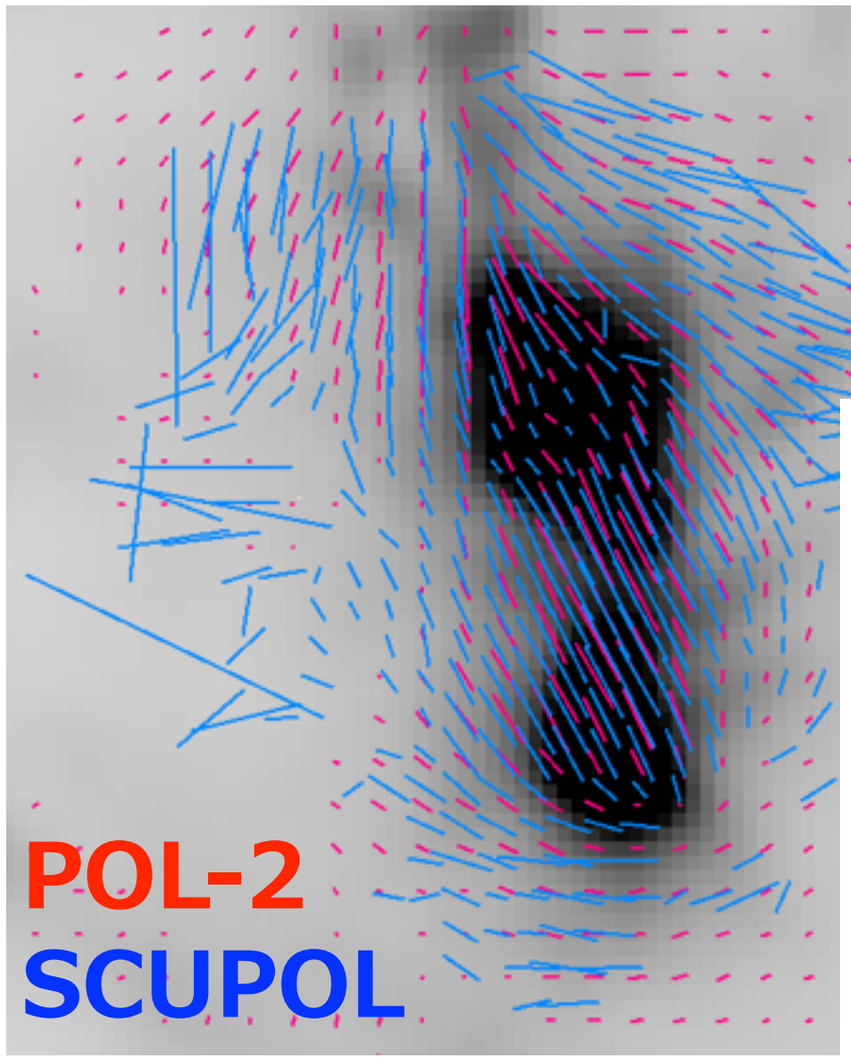
POL-2: Performance



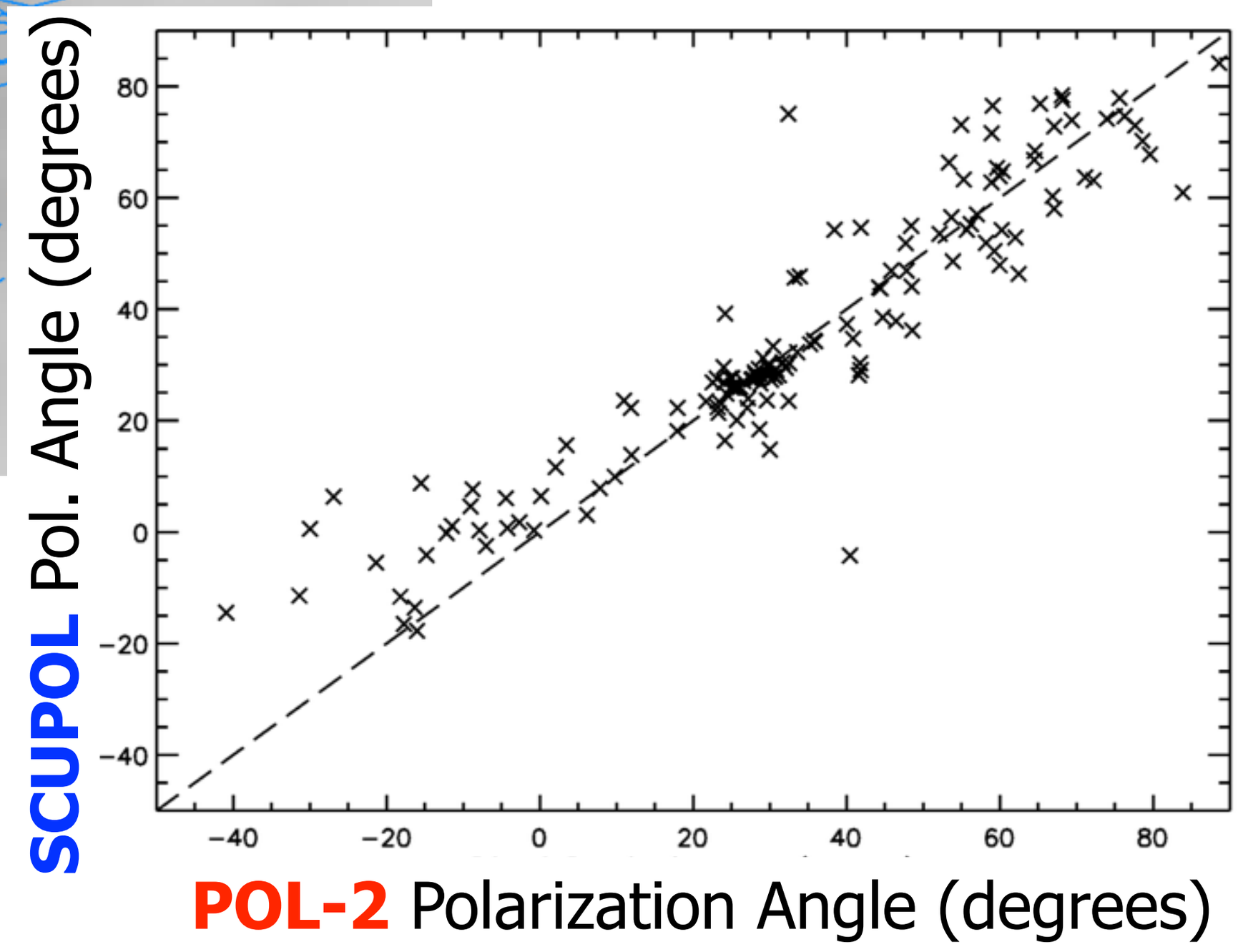
Credit: POL-2 Commissioning Team



POL-2: Comparison with SCUPOL



Credit: POL-2 Commissioning Team



BISTRO: Project Status and Plan

Finalized "Single Field" at BISTRO survey:

- A "field" is 3-arcmin radius with a DAISY scan mode
- σ~2 mJy/14" beam with PFoV= 12" using 850 um filter @tau_{225}~0.07 (weather band#2)
- Completed by 14 hrs observing time

- Awarded time 224 hrs / 14 hrs per field = 16 fields can be observed

- ~100 members in consortium / 16 fields ~ 6.25 members per field

- Japan, Korea and UK ~ 20 members each → 3 fields per country
- Canada, China and Taiwan ~ 12 members each → 2 fields each

BISTRO: Project Status and Plan

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Ophiuchus : 3 fields in L1688 and L1689

Auriga : 1 field

Taurus : 2 fields in the B211/213 filament, 1 field in L1495

Perseus : 2 fields in NGC1333, 1 fields in B1

Serpens : 2 fields in Serpens Main

Orion : 1 field in Ori-A (commssioning field), 1 in Ori-B

IC5146 : 1 field

- Management team (six PIs, Observatory, POL-2 team) meets once per month via Skype. PIs liaise with their own communities.

BISTRO: Publication Plans

- Started to write **"consortium" paper** towards the "commissioning field" Orion A by Derek Ward-Thompson with Commissioning Team

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- **First-generation publications**: 16 papers by mid-2017
  - Will <u>focus on presentation of POL-2 data</u>
  - Will be written by 6 "geographic regions" towards the 16 assigned "astronomical regions"
  - All members will appear in all first-generation publications

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- **Second-generation publications**: >8 papers, after mid-2017
  - Will <u>statistically</u> discuss scientific topics <u>across SF-regions</u>
  - Wii be written by one or more "geographic regions"

Team BISTRO-J

- Team BISTRO-J:

  held **ALMA Workshop** "B-fields in SF-regions and ISMs" on March 30 & 31: 37 participants including 24 non-BISTRO members

  pursues scientific discussion towards the 1st generation papers

BISTRO: Summary

- ”B-field In Star forming Region Observations” started!

- We expect to observe many molecular clouds to an unprecedented depth in polarized emission at 850 micron (<2 mJy/14” beam).

- This will enable determination of magnetic field direction and strength in dense star-forming gas.

- POL-2 is a completely unique instrument, and we intend to make the most of it to answer some of the most pressing questions in star formation.

- 19 members in “Team BISTRO Japan” are intensively working on DR, dust alignment mechanism, numeral simulations, and we are ***challenging crowd-funding*** for trips to JCMT