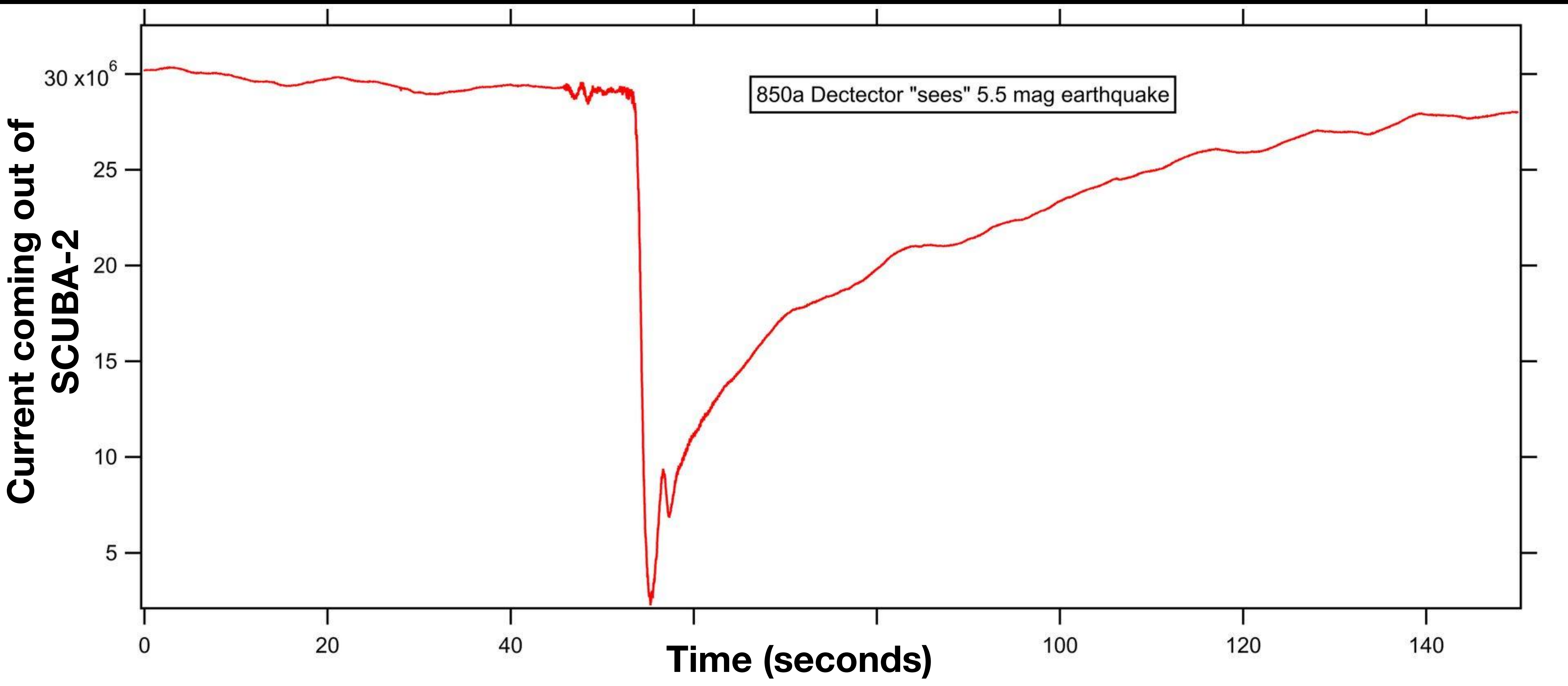
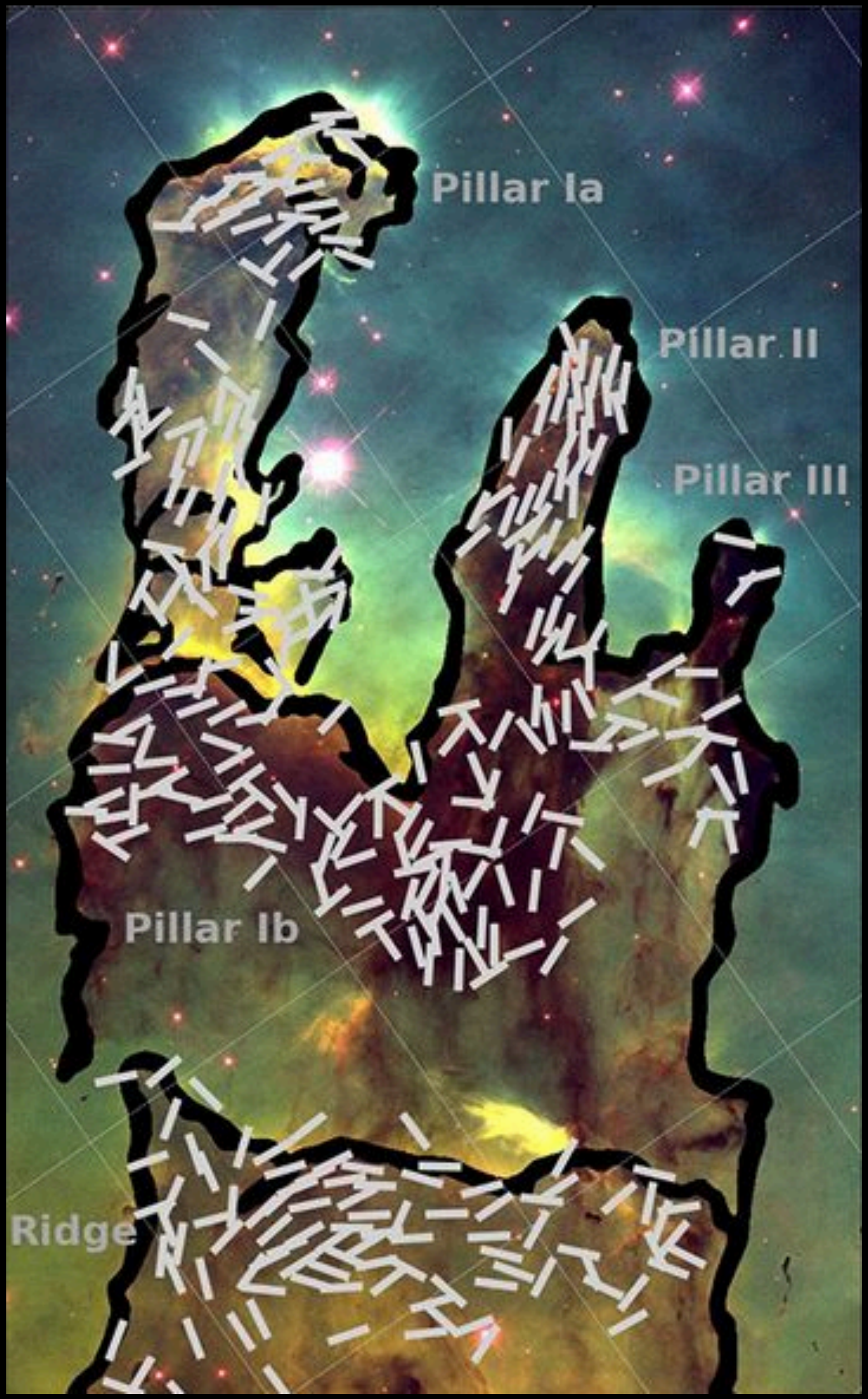
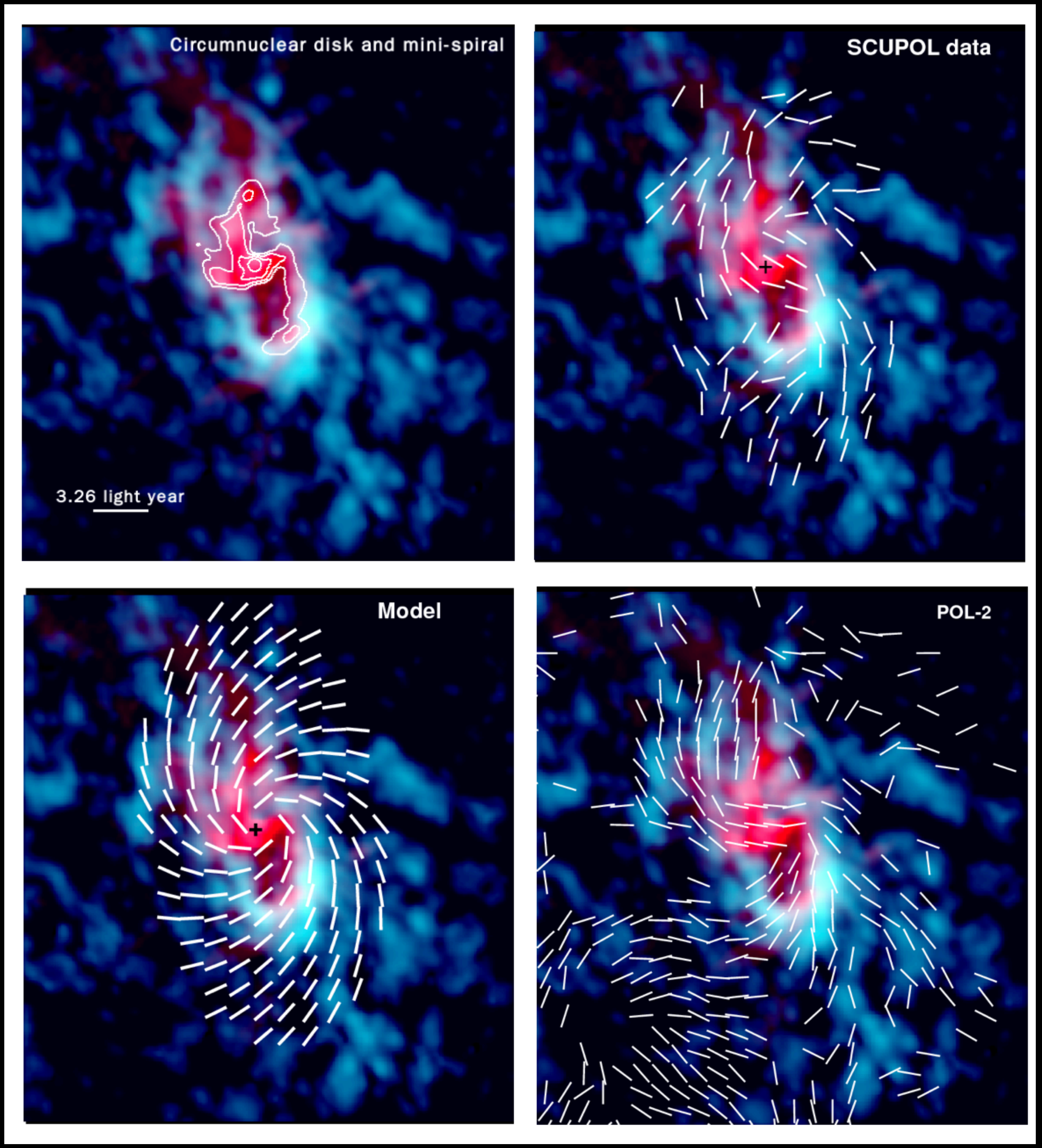


850a Dectector "sees" 5.5 mag earthquake
Current coming out of SCUBA-2
30 x10^6
25
20
15
10
5
0
20
40
100
120
140
Time (seconds)

Magnetic Fields

At Submillimetre Wavelengths

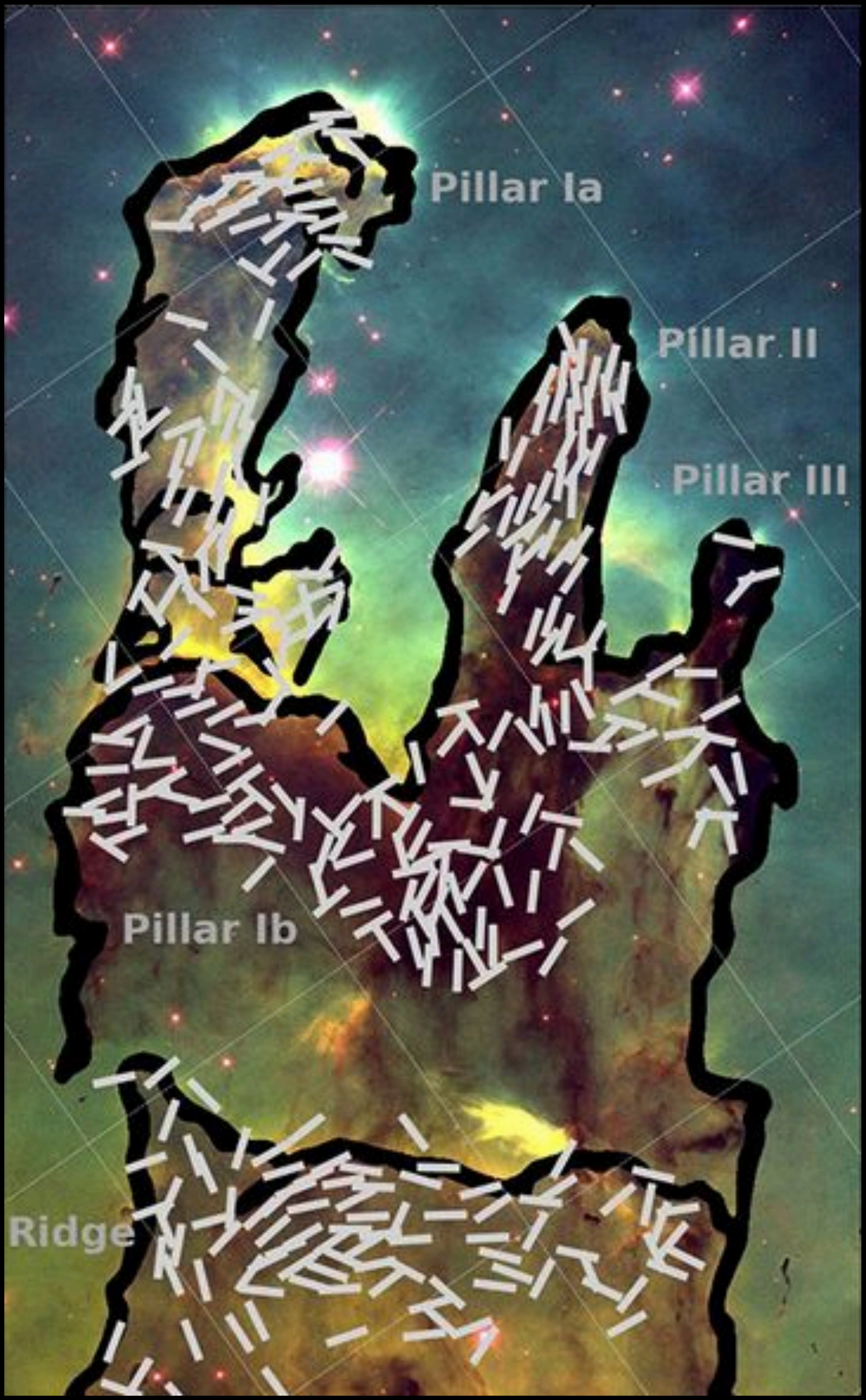




Dr. Steve Mairs (ASTR351L Spring 2019)

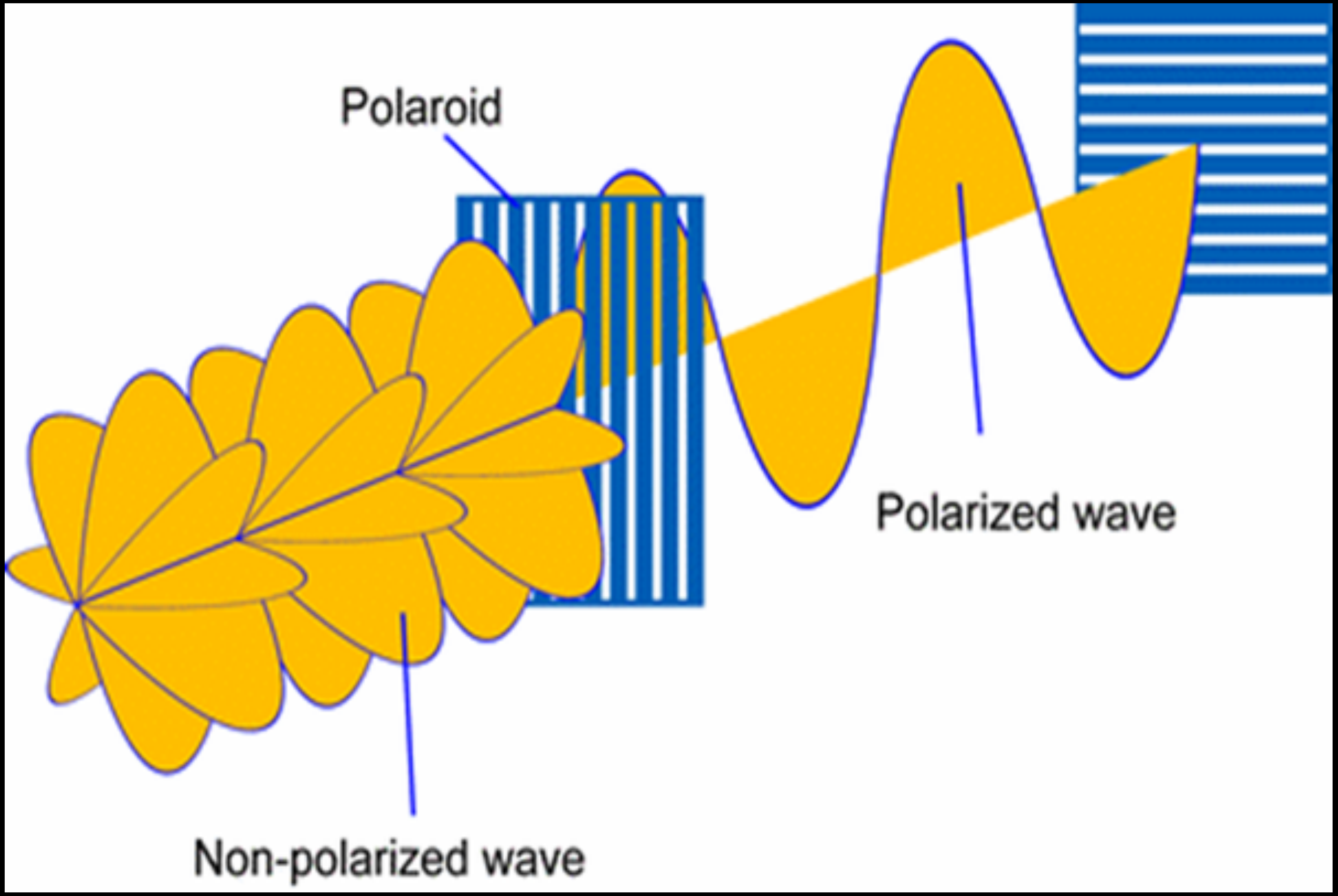
Overview

1. Stokes Parameters
2. POL-2 Primer
3. Magnetic Field Science
4. Jellyfish Nebula



Linear Polarisation: The angle of the Electric Field

The POL-2 Instrument at the JCMT is sensitive only to linear polarisation

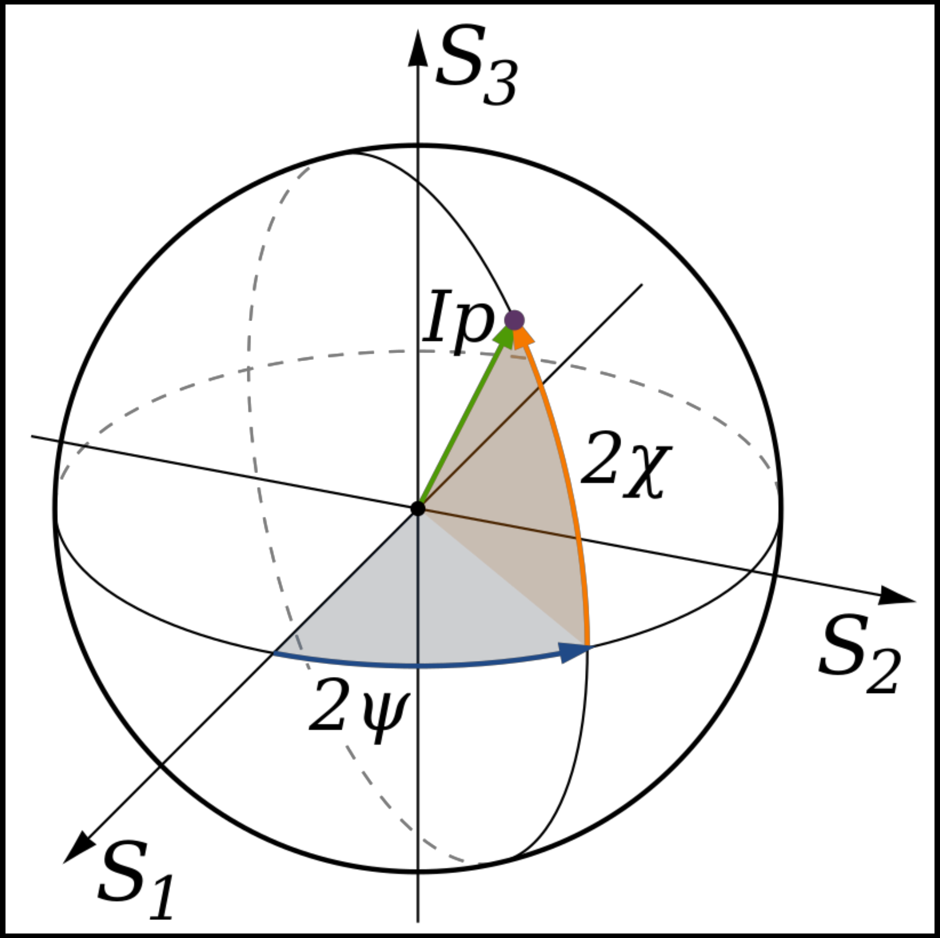


The light we receive is only partially polarised - so, from a given part of the sky there is a polarisation angle that has more light oriented in that direction than you would expect from completely unpolarised light.

The Poincaré Sphere and Stokes Parameters

Here's an opportunity for some math fun! Convince yourself this is true:

$$
\begin{aligned}
S_0 &= I \\
S_1 &= Ip\cos 2\psi \cos 2\chi \\
S_2 &= Ip\sin 2\psi \cos 2\chi \\
S_3 &= Ip\sin 2\chi
\end{aligned}
$$



We define the polarisation percentage as:

$$p = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0}$$

The Stokes Vector <I, Q, U, V>

$$\vec{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

The Stokes Vector

$$\vec{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

$\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$ Unpolarized

The Stokes Vector is a convenient way to describe the orientation of polarised light

$\begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix}$ Linearly polarized (horizontal)

$\begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix}$ Linearly polarized (vertical)

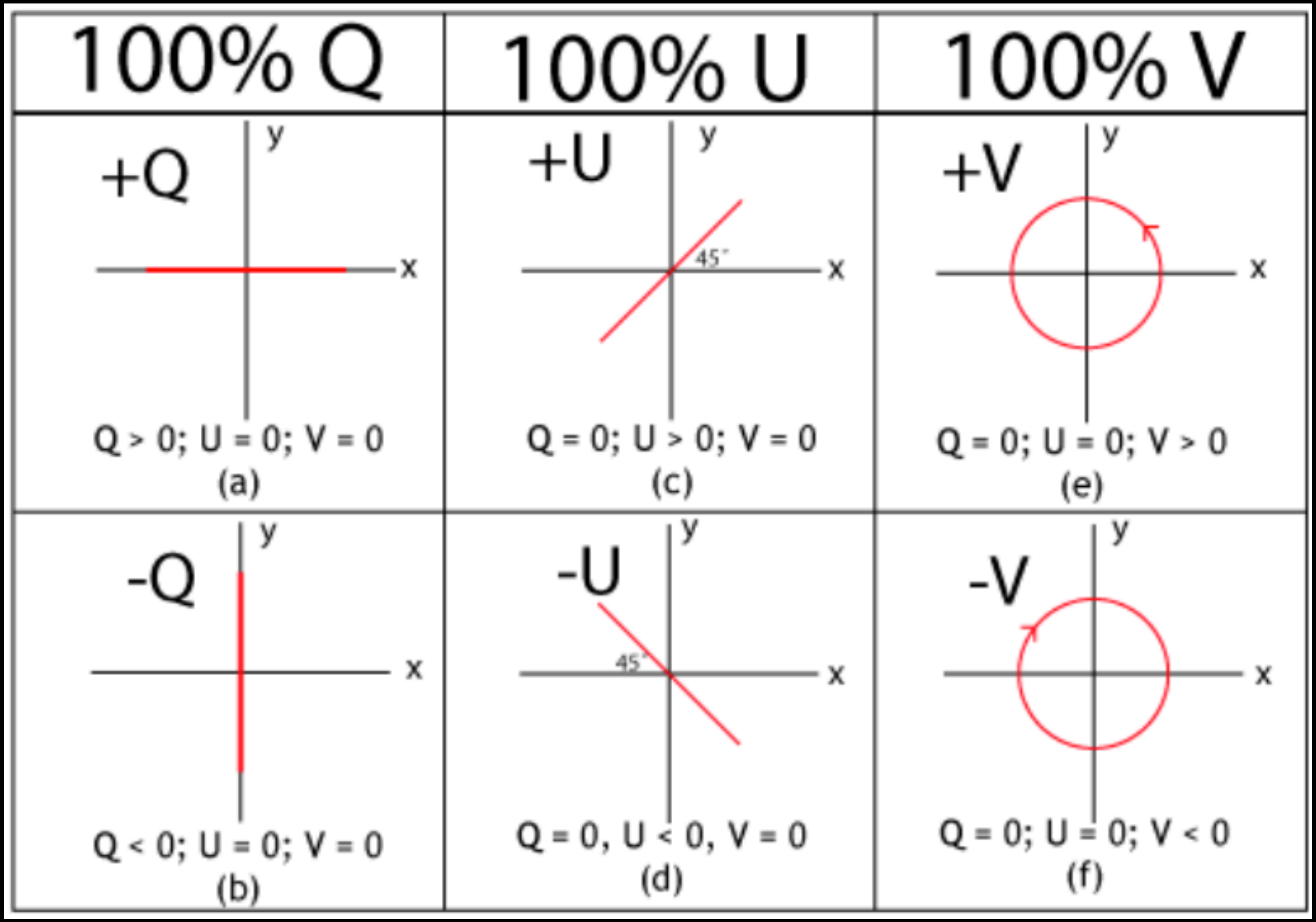
$\begin{pmatrix} 1 \\ 0 \\ 1 \\ 0 \end{pmatrix}$ Linearly polarized (+45°)

$\begin{pmatrix} 1 \\ 0 \\ -1 \\ 0 \end{pmatrix}$ Linearly polarized (–45°)

$\begin{pmatrix} 1 \\ 0 \\ 0 \\ 1 \end{pmatrix}$ Right-hand circularly polarized

$\begin{pmatrix} 1 \\ 0 \\ 0 \\ -1 \end{pmatrix}$ Left-hand circularly polarized

The Stokes Vector



JCMT: Linear Polarisation Only!

$$\vec{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

V is always 0!

So, for us, the equations get simpler!

Polarisation Percentage

$$p = \frac{\sqrt{Q^2 + U^2}}{I}$$

The amount of incoming radiation at the angle defined by Q and U

Polarisation Angle

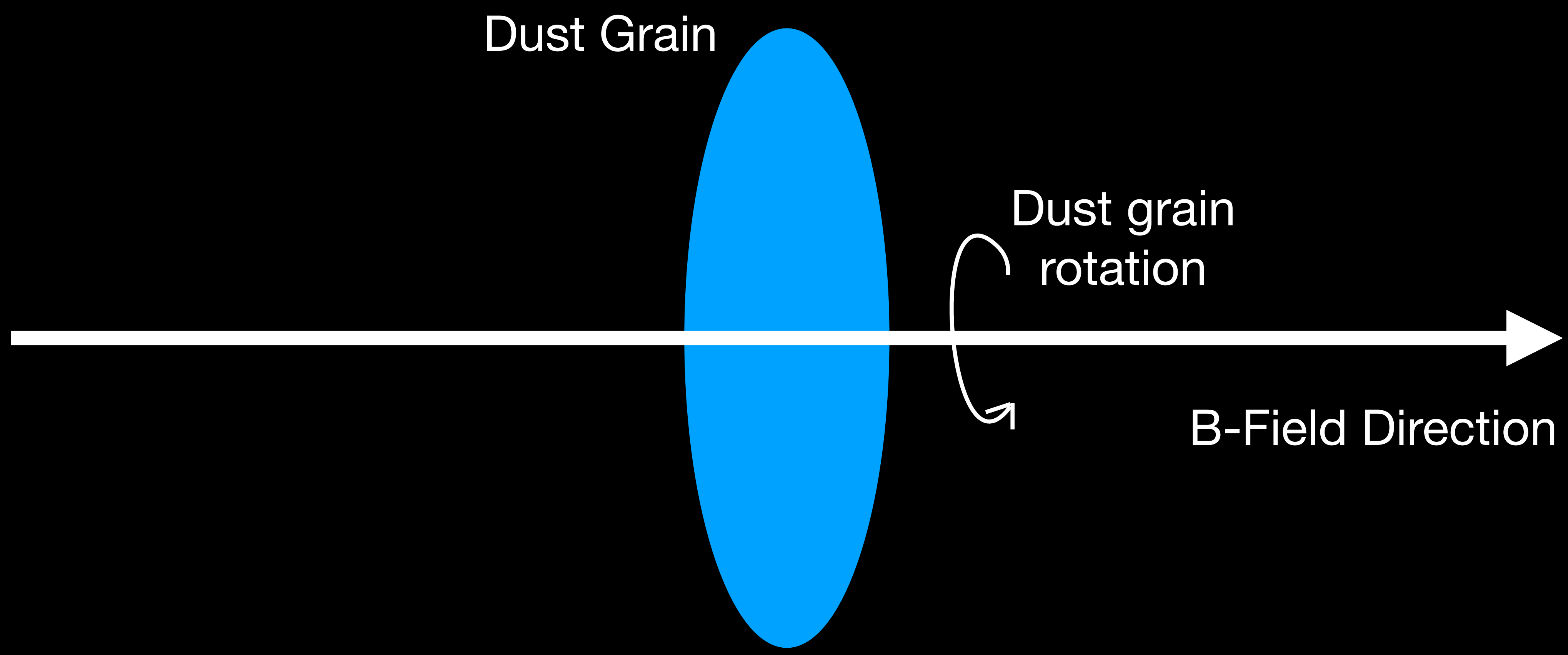
$$\mathrm{ANG} = \theta = \frac{1}{2}\arctan\frac{U}{Q}$$

The preferential angle the partially polarised light is landing on the detector

RAT (Radiative Alignment Theory)!

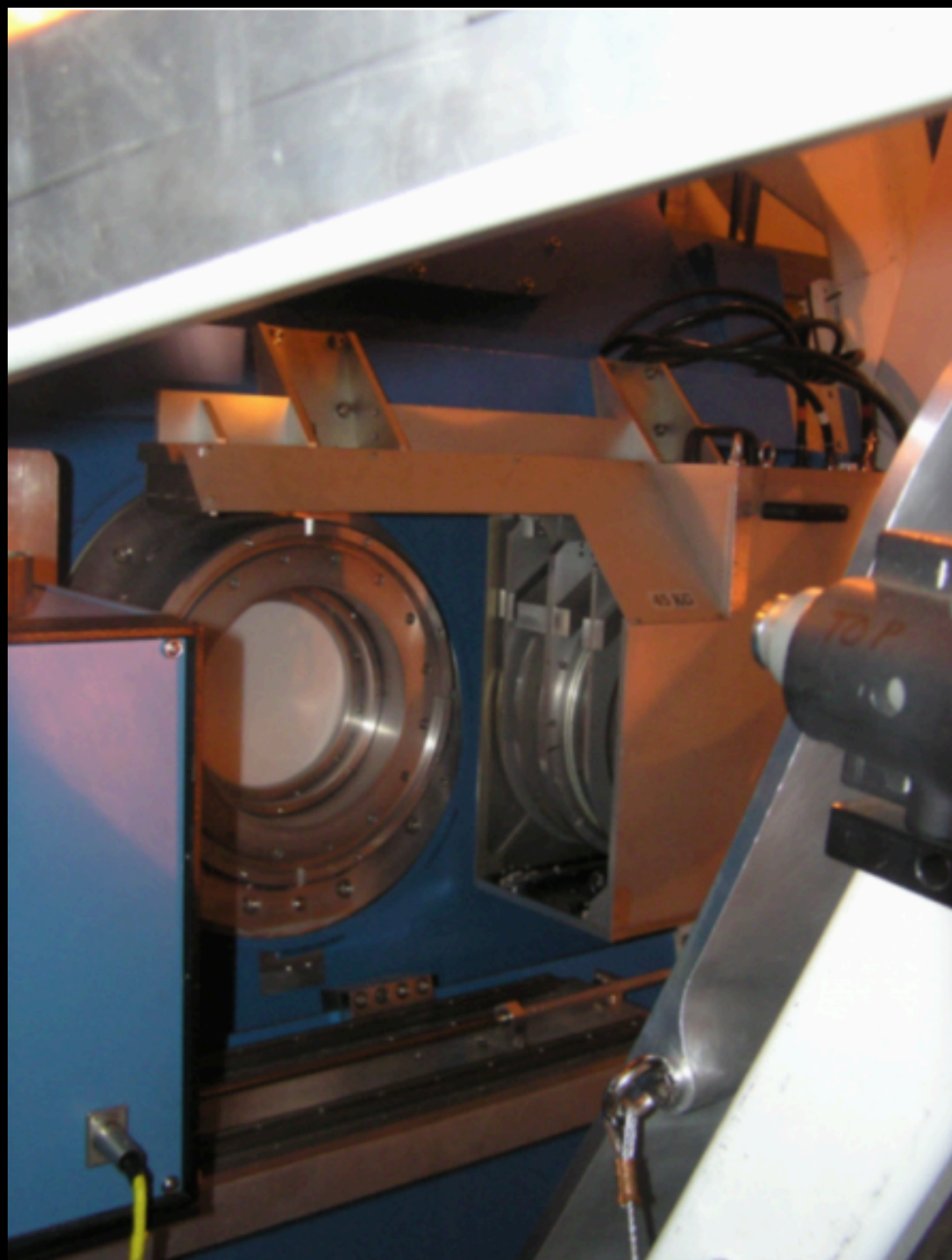
The Radiative Alignment Theory of Dust Grains says:

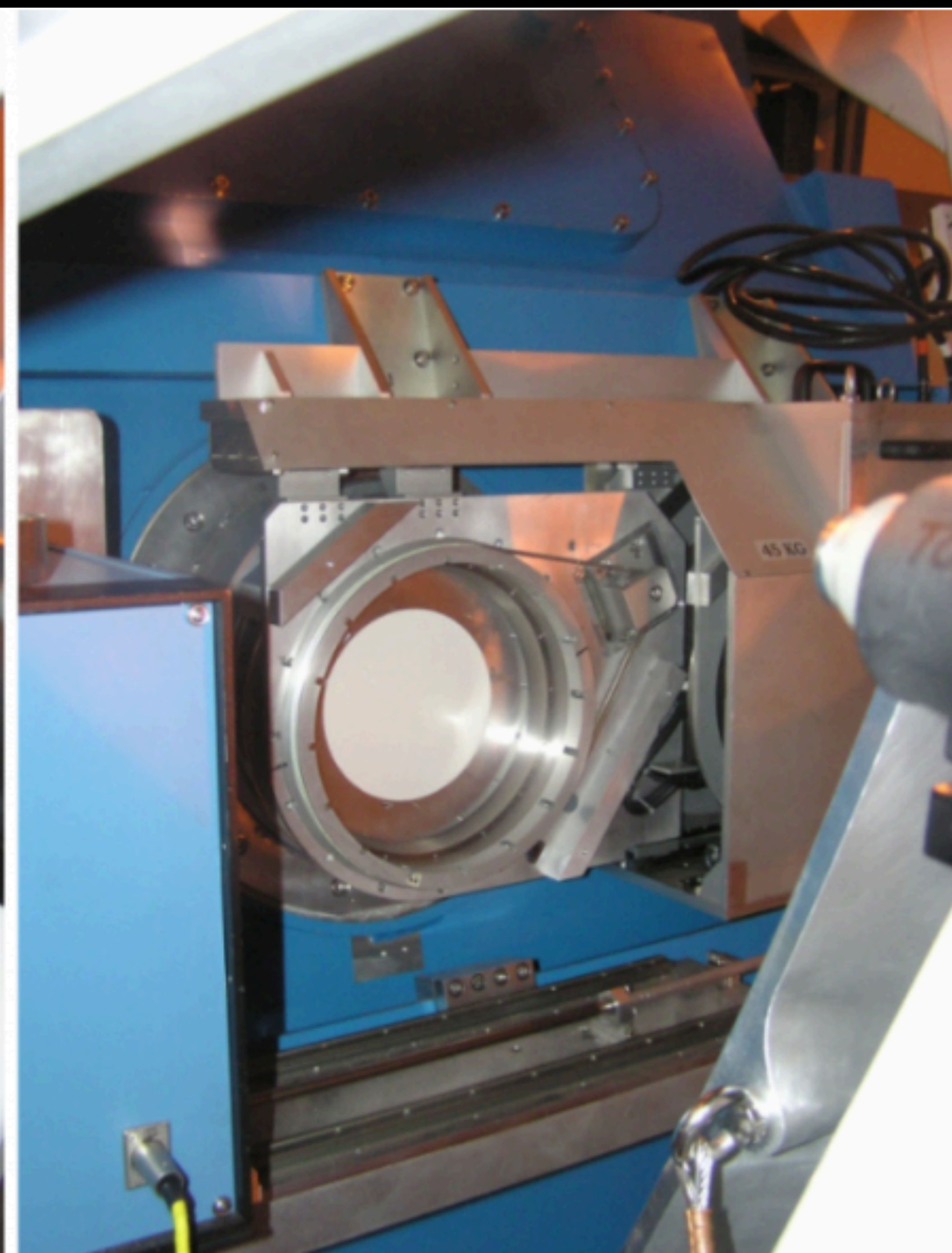
The long axis of dust grains tend towards an alignment perpendicular to B-field lines



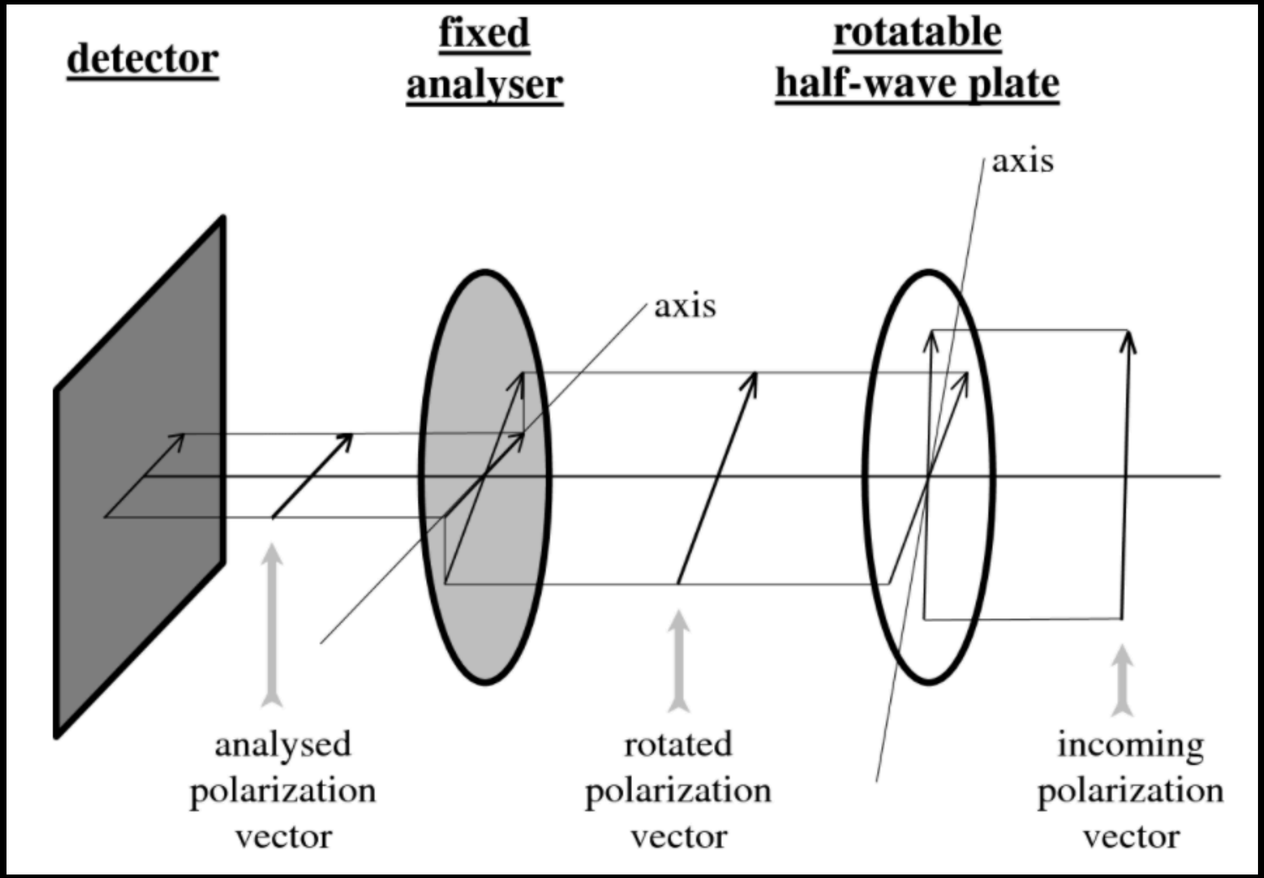
The polarisation from the light we receive is defined by the dust grain orientation!

POL-2





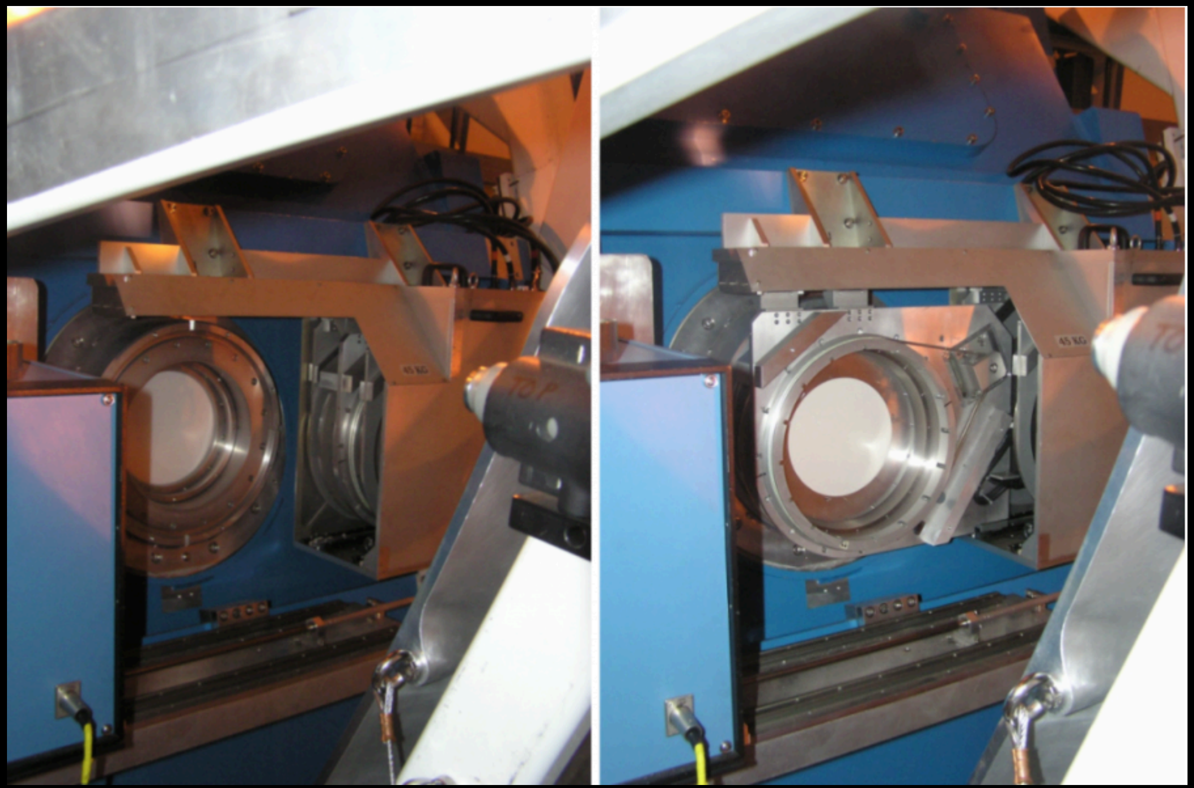
POL-2: Polarimeter



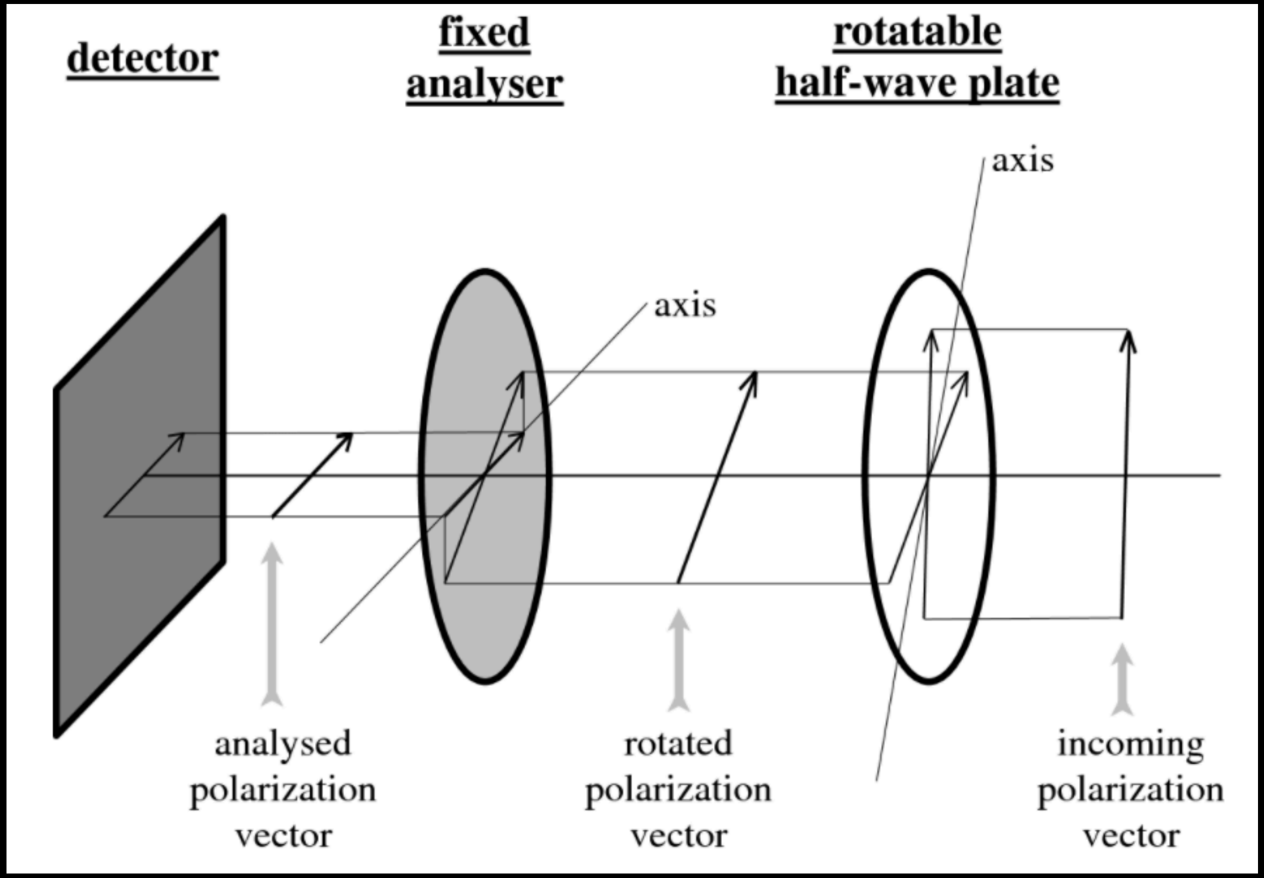
POL-2 works
in conjunction with SCUBA-2
it is not, itself, a detector

It has 2 Main components:

1. A Rotatable Wave Plate
2. An Analyser



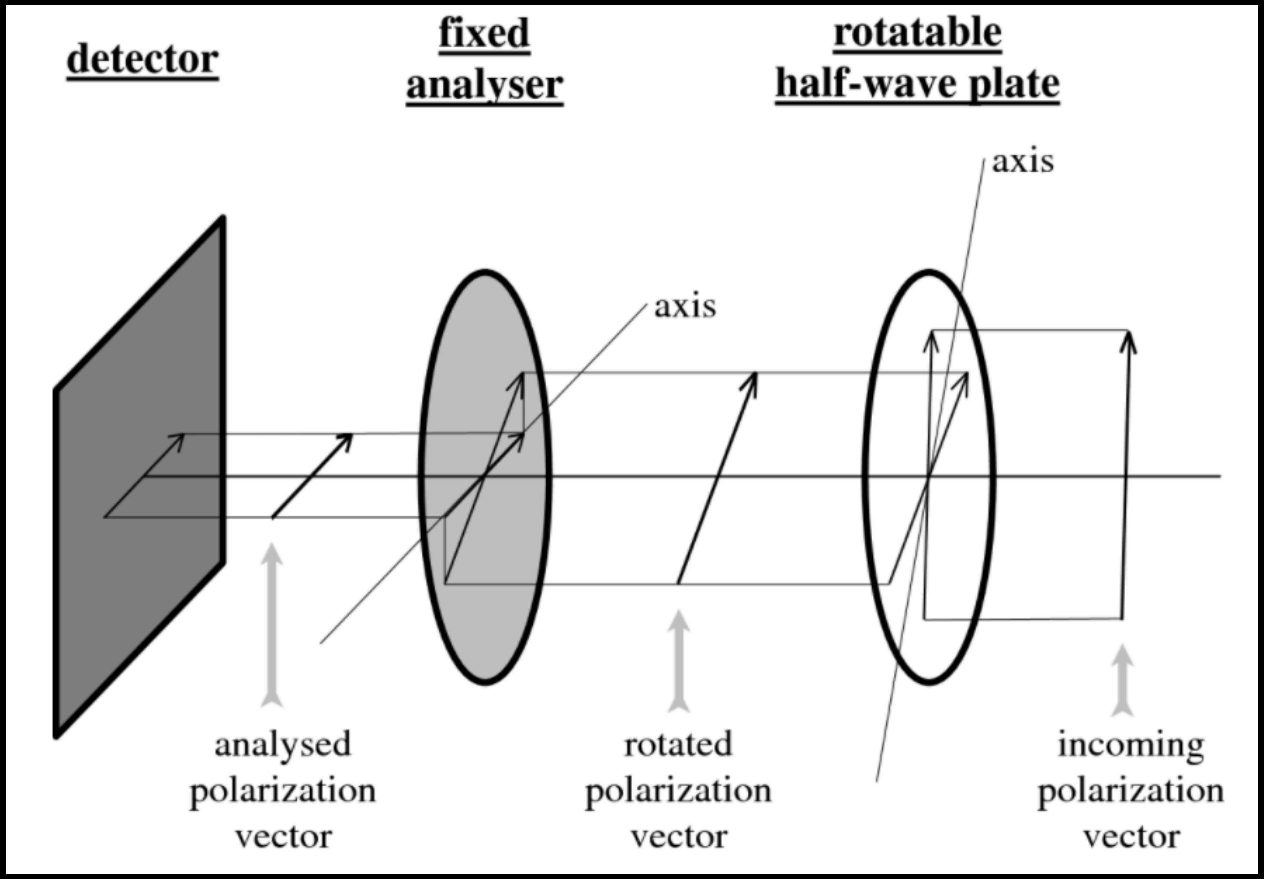
POL-2: Polarimeter



The analyser selects out light coming from a specific polarisation angle and sends that image to the detector

In order to measure the intensity at multiple polarisation angles, the rotatable plate is introduced to change the orientation of the polarised light before it is sent to the analyser

POL-2: Polarimeter



By making multiple measurements of the light at different polarisation angles, we can find the maximum and minimum intensity

This is how we derive the polarisation percentage of the light we receive from space and measure its specific, preferred, angle

Magnetic Field Strength

Davis-Chandrasekhar-Fermi (DCF) method
combines POL-2, SCUBA-2, and HARP data to calculate
the B-Field strength

$$B_{\rm pos} = Q' \sqrt{4\pi\rho}\,\frac{\sigma_v}{\sigma_\theta} \approx 9.3\,\sqrt{n({\rm H_2})}\,\frac{\Delta v}{\langle\sigma_\theta\rangle}\ \mu{\rm G}$$

SCUBA-2

HARP

POL-2

Crutcher et al. 2004, ApJ 600:279

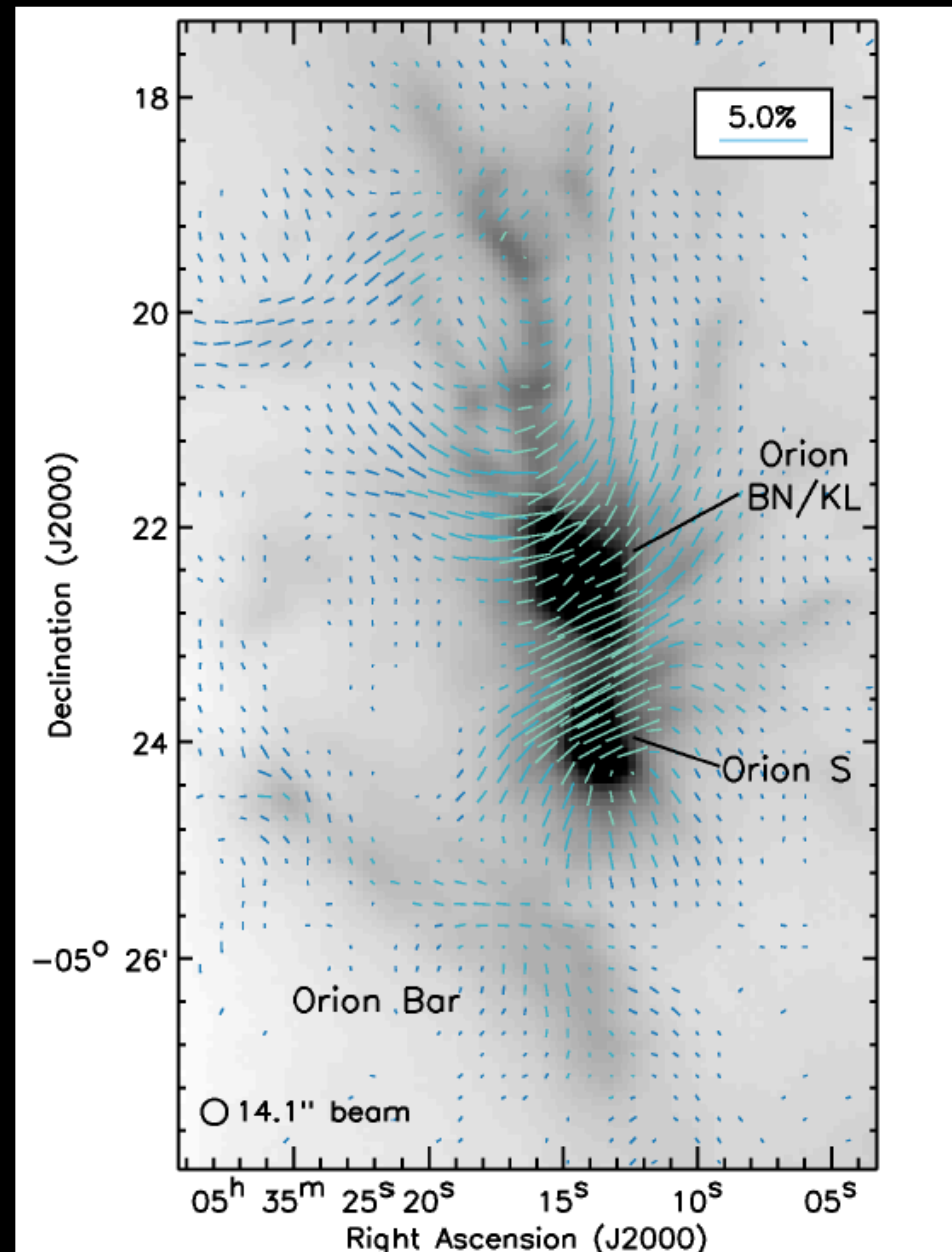
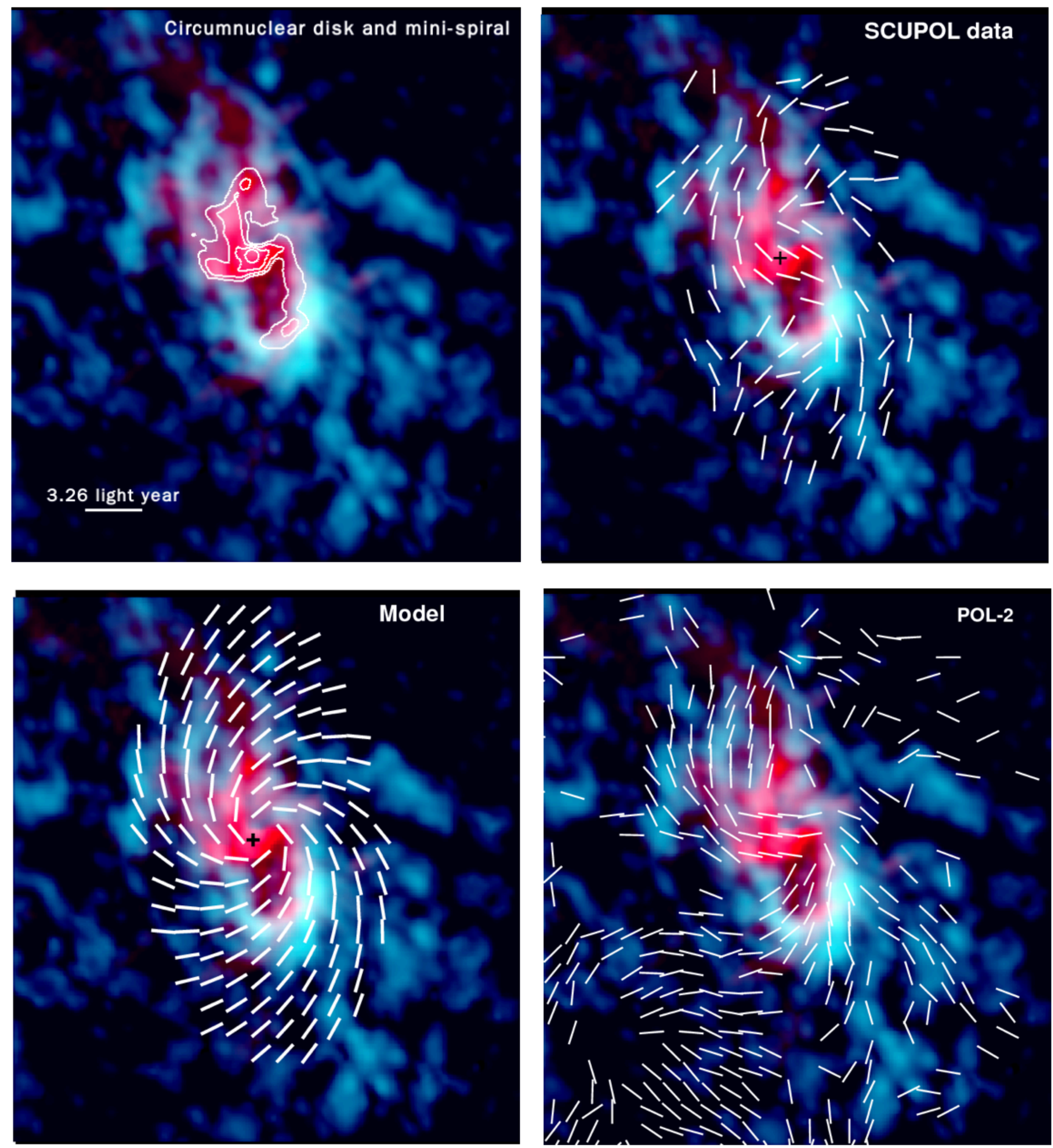


Figure: Pattle et al. 2017, ApJ 846:122

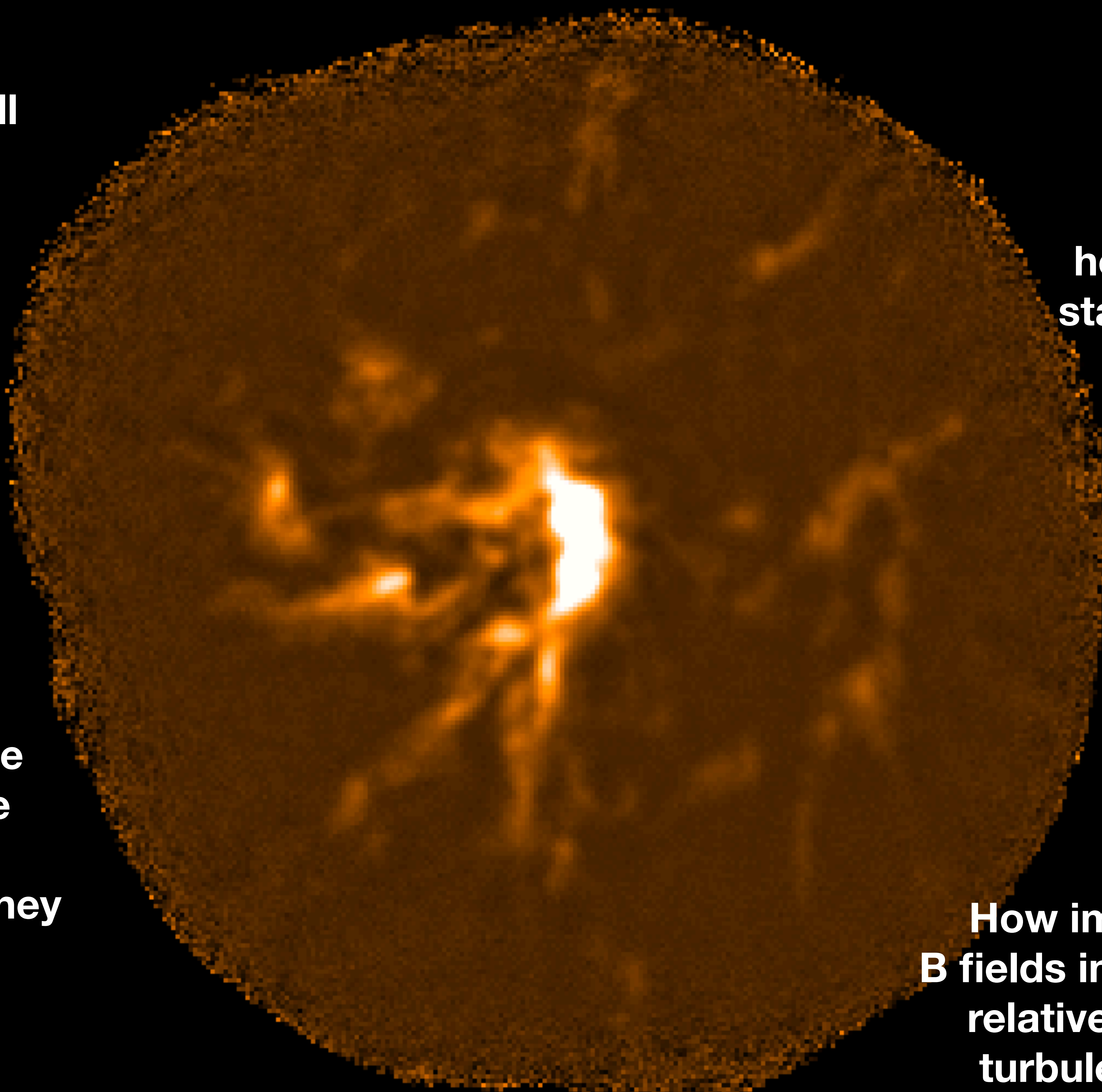
Tracing Magnetic Fields in Space!



The Jellyfish Nebula

What is the overall magnetic field structure?

Do B fields help or hinder star formation?



What are the roles of the filaments and how do they form?

How important are B fields in the dynamics relative to thermal/ turbulent energy?

The Jellyfish Nebula

We will be plotting magnetic field vectors and analysing the strength of the field