2016 UCAT SUMMER STUDENT PROGRAM FINAL PRESENTATION

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@清華大學　16.8.31

2016 UCAT SUMMER STUDENT PROGRAM

Modeling the Magnetic Field Structure of Molecular Clouds through Dust Polarization

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Outline

- Class 0 protostar & magnetic field structure
- Polarization & Stokes parameter
- Modeling： python & CASA 
- Future work

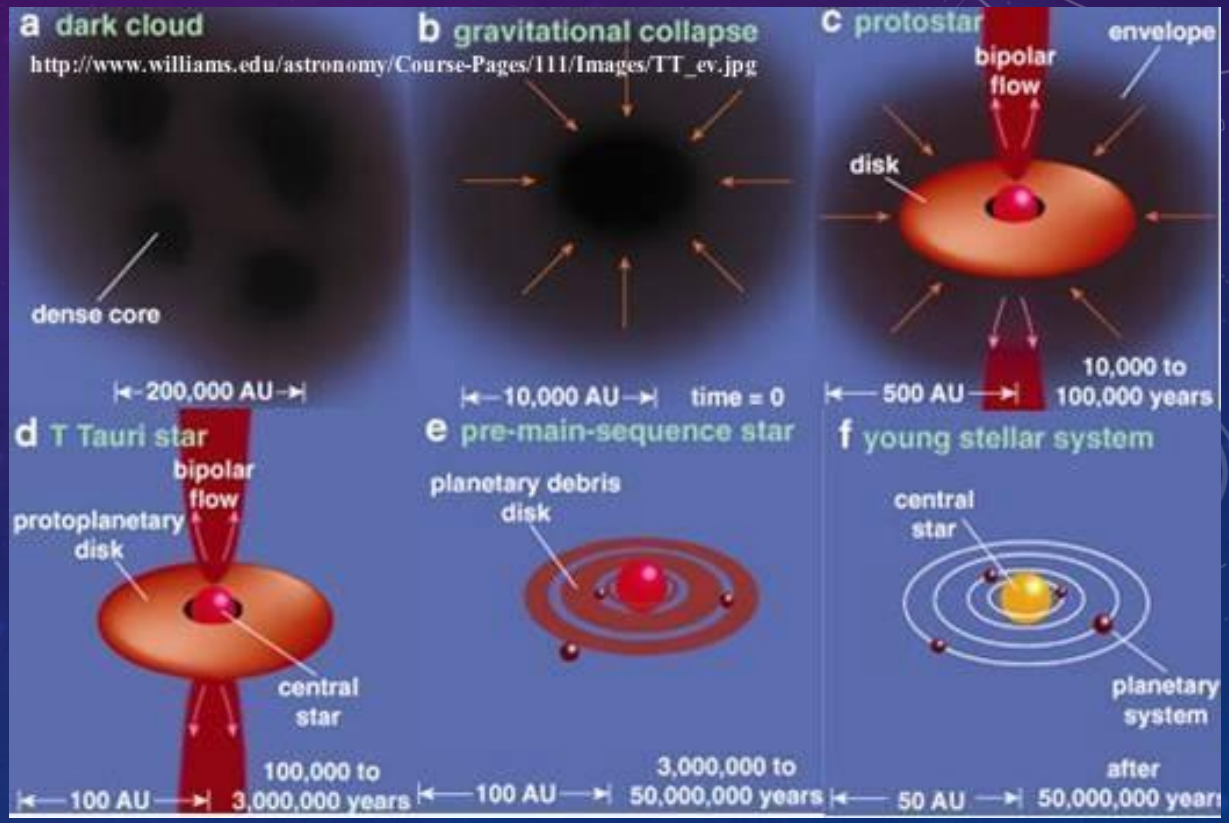
(no more L1527 & VLA1623 !)

CLASS 0 PROTOSTAR AND MAGNETIC FIELD STRUCTURE

NGC1333 ↗ (http://apod.nasa.gov/apod/ap140306.html)

STAR FORMATION

Class 0/I star



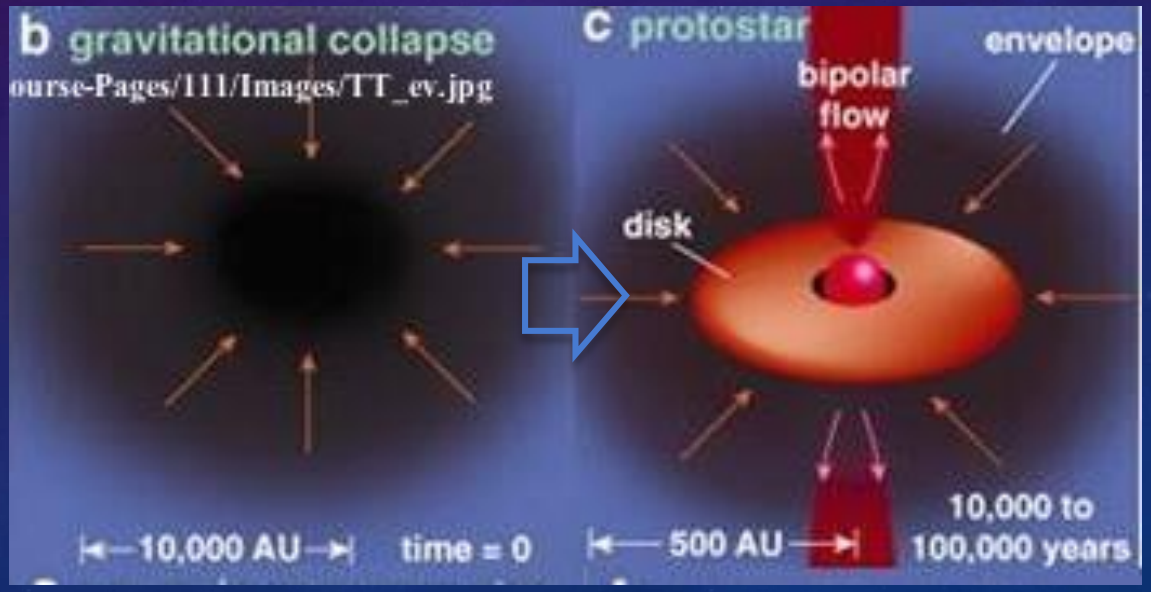
(https://astrobites.org/2012/07/20/first-gasps-of-star-formation-in-taurus/)

STAR FORMATION：

Two Models For Class 0 Protostar

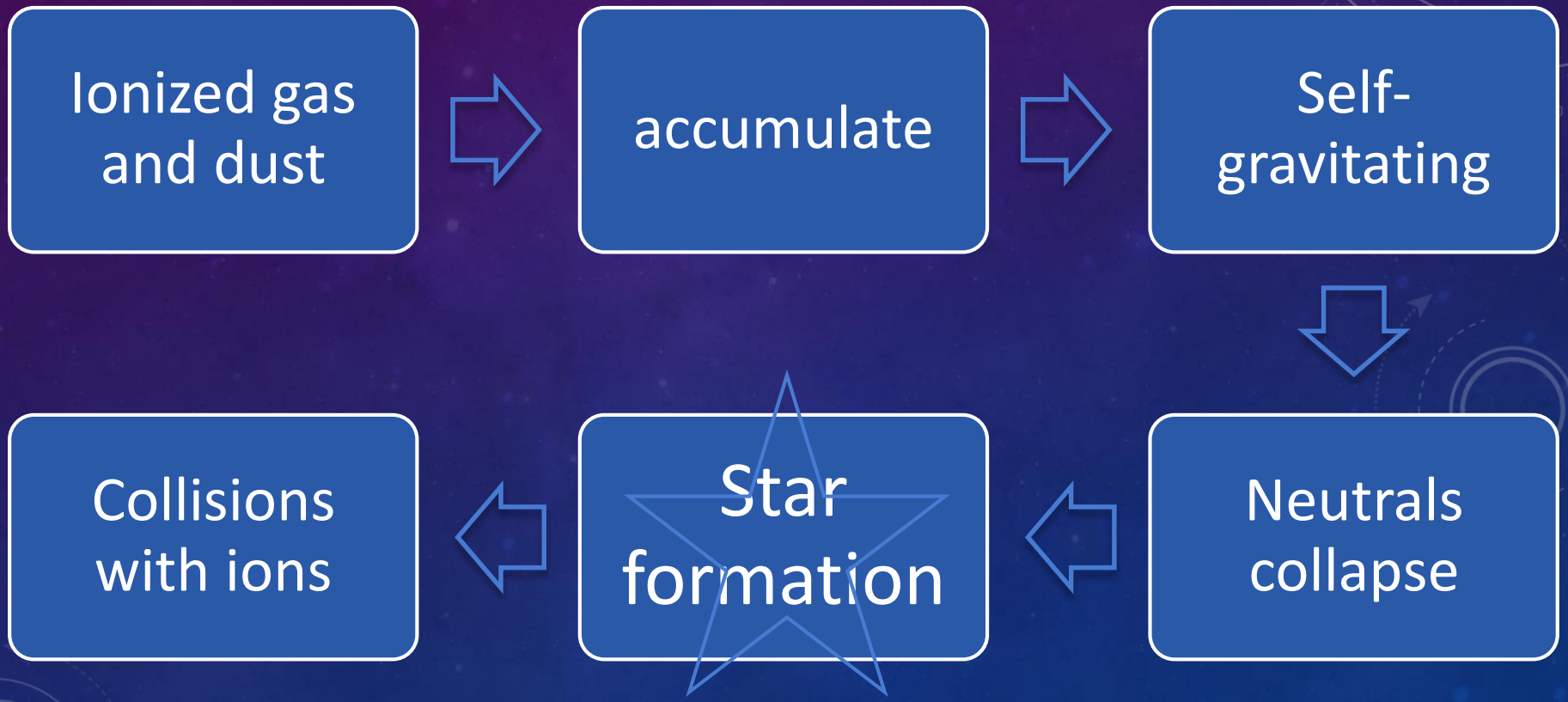
?

With magnetic field v.s. Without magnetic field

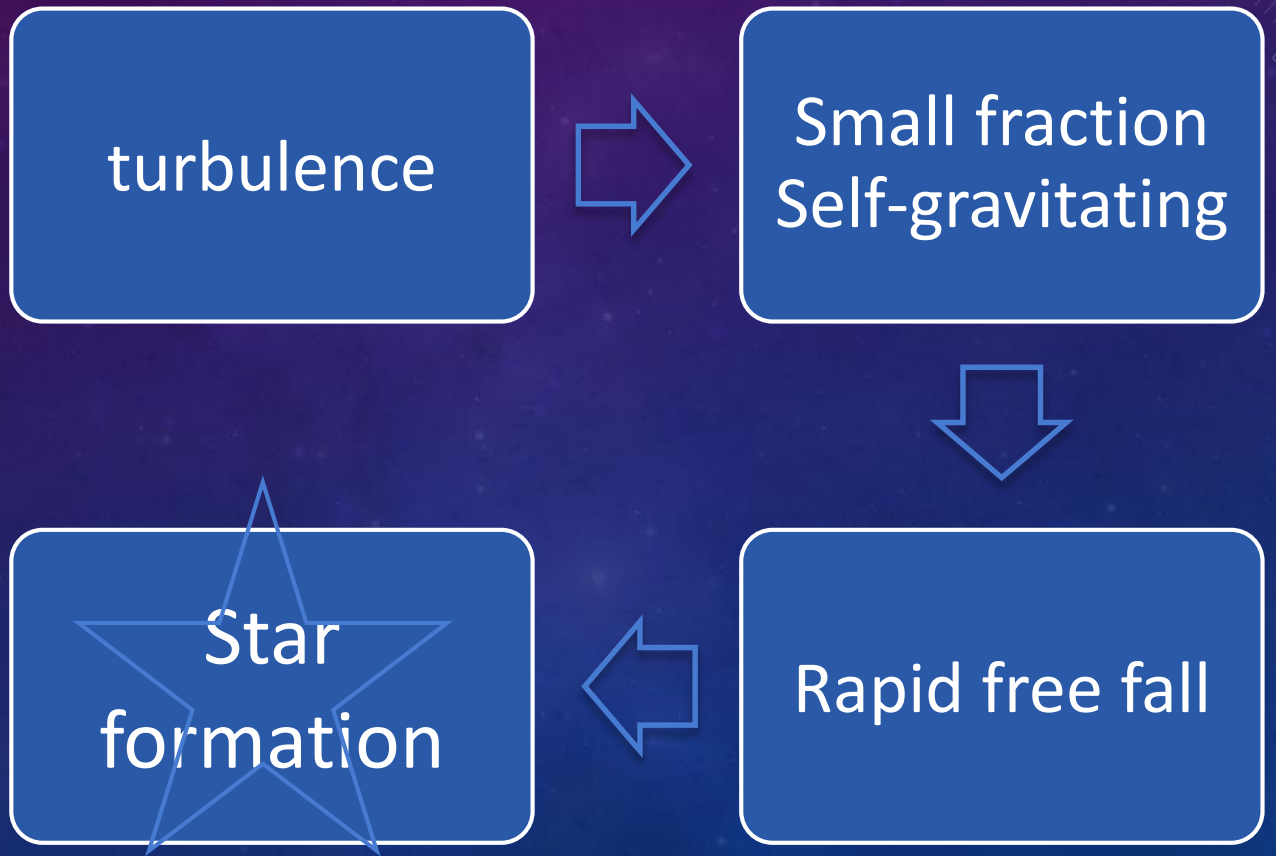


(https://astrobites.org/2012/07/20/first-gasps-of-star-formation-in-taurus/)

WITH MAGNETIC FIELD



WITHOUT MAGNETIC FIELD

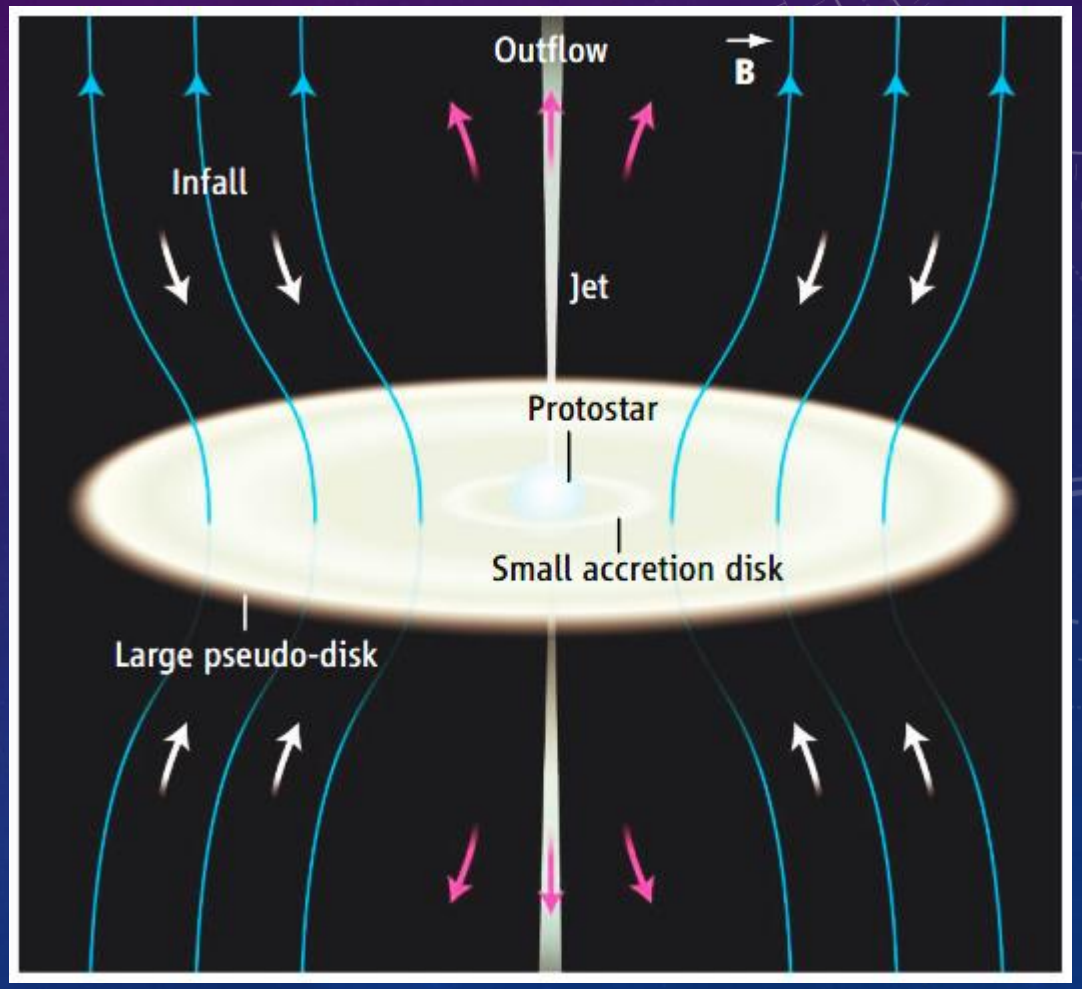


COMPARISON

	strong magnetic field	**weak magnetic field**
time scale	Longer	Shorter
Self-gravitation	whole	Small fraction
star formation rate	Consists with our Galaxy star formation rate (one solar mass per year)	

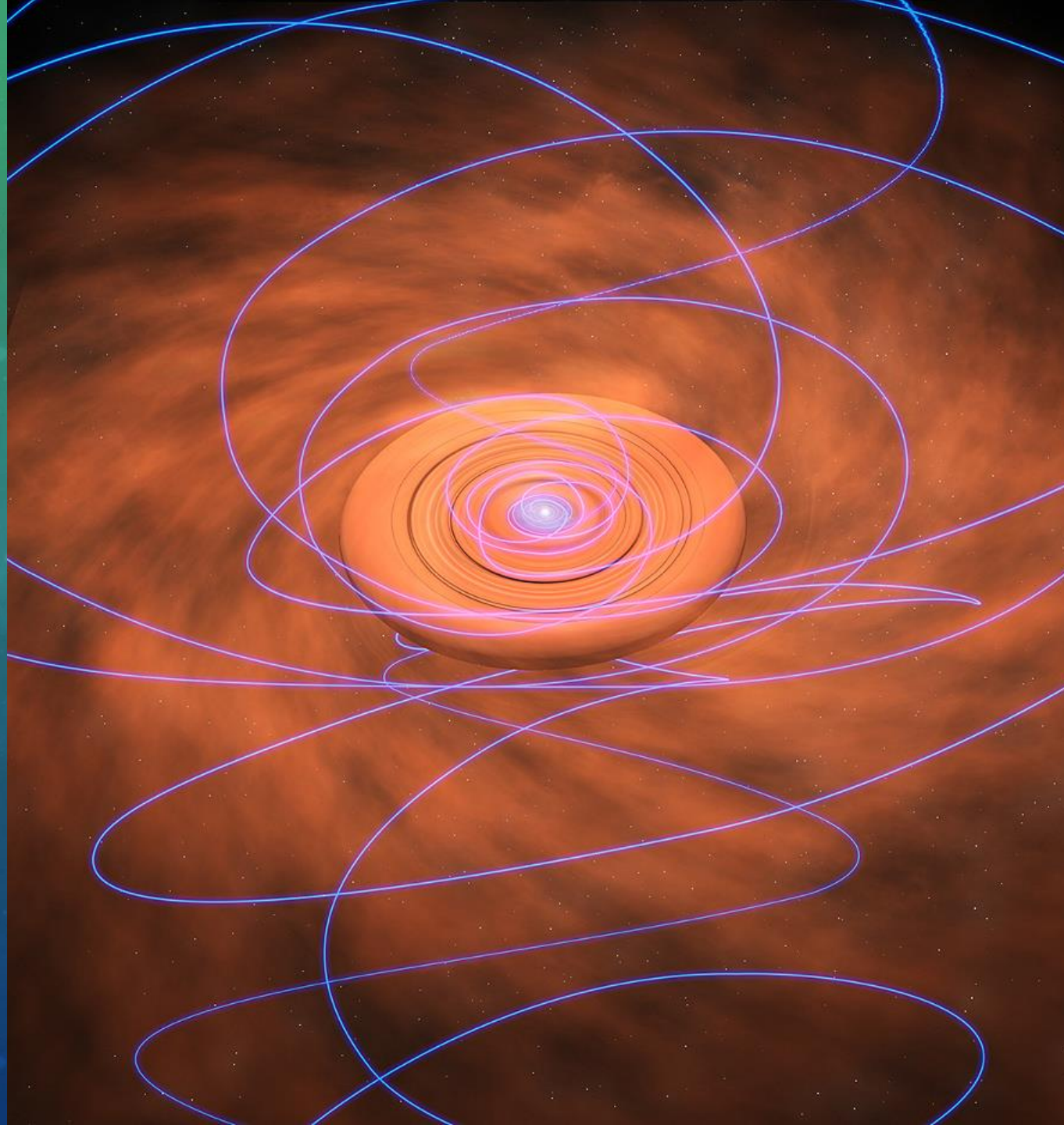
MAGNETIC FIELD STRUCTURE

- Parallel
- Disk
- Hourglass structures



SCIENCE VOL 313,
Richard M. Crutcher,
2006

POLARIZATION



(https://astronomynow.com/2015/12/25/twisted-magnetic-fields-give-new-insights-on-star-formation/)

POLARIZATION

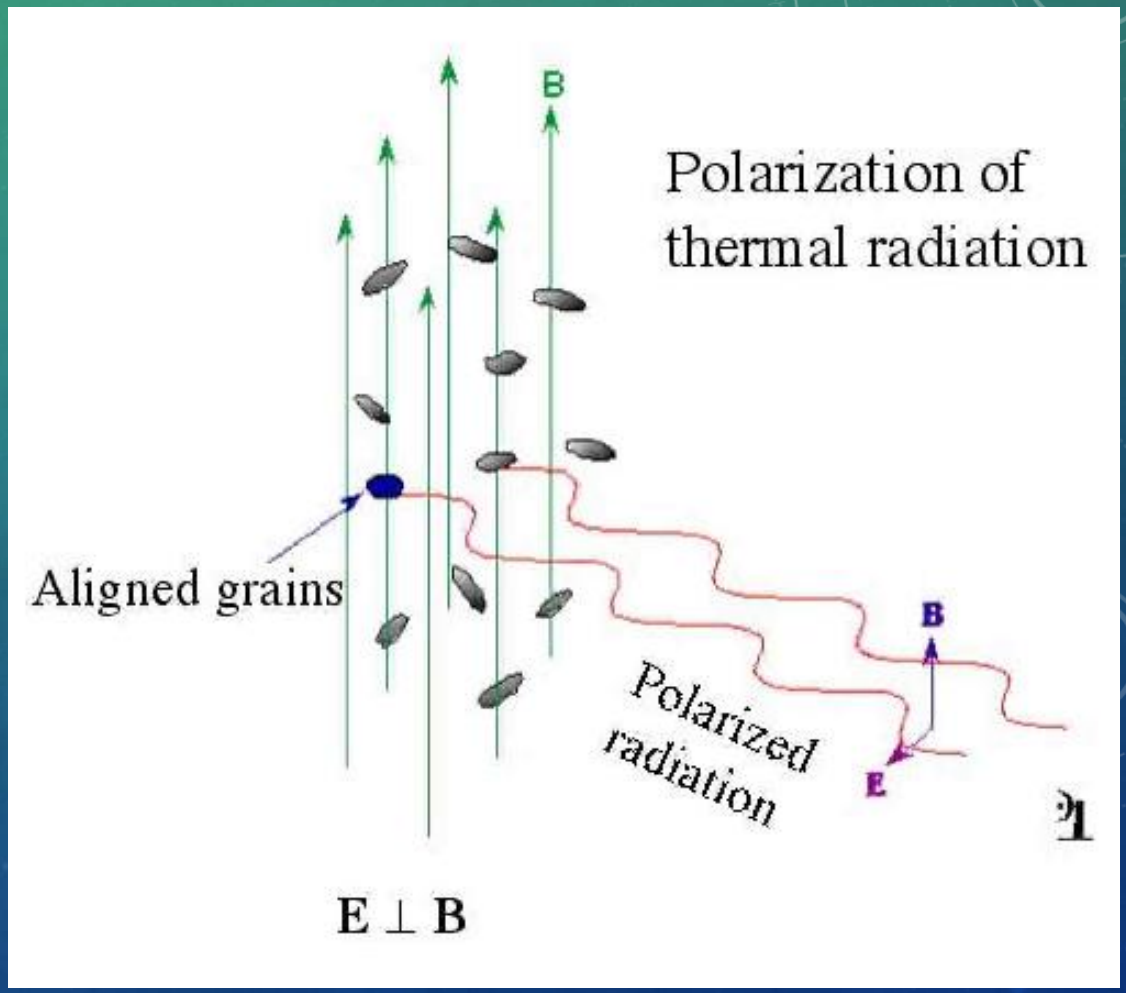
Molecular Line Polarization

- Zeeman effect: Goldreich-kylafis effect

Dust polarization

- Spinning about short axis,
  short axis aligned with the magnetic field
- Perpendicular：larger projection dimension
  parallel：smaller projection dimension

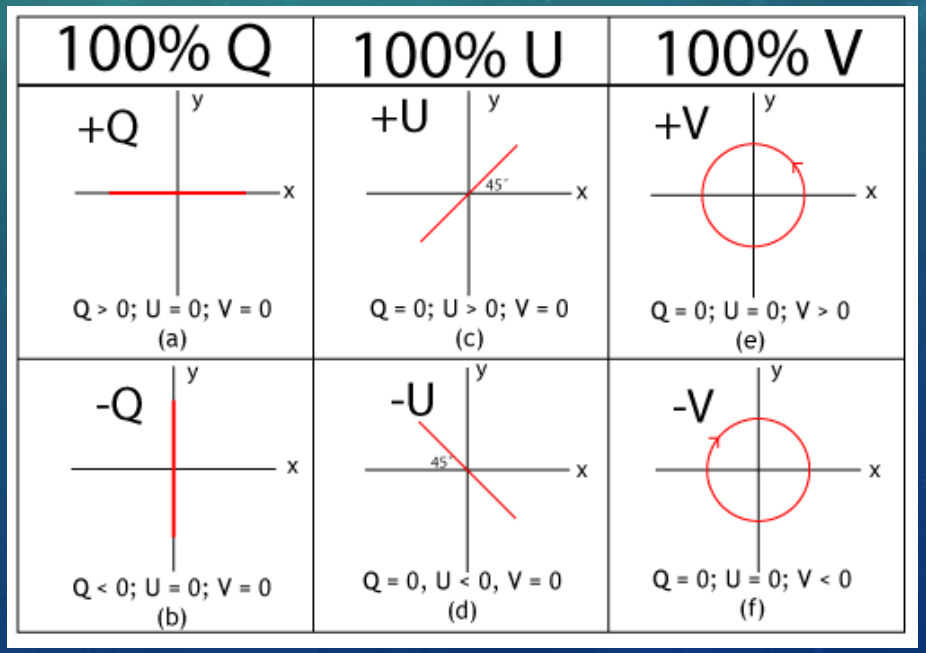
DUST POLARIZATION



(https://astrobites.org/2015/11/17/protostar-polarization-the-role-of-magnetic-fields-in-star-formation/)

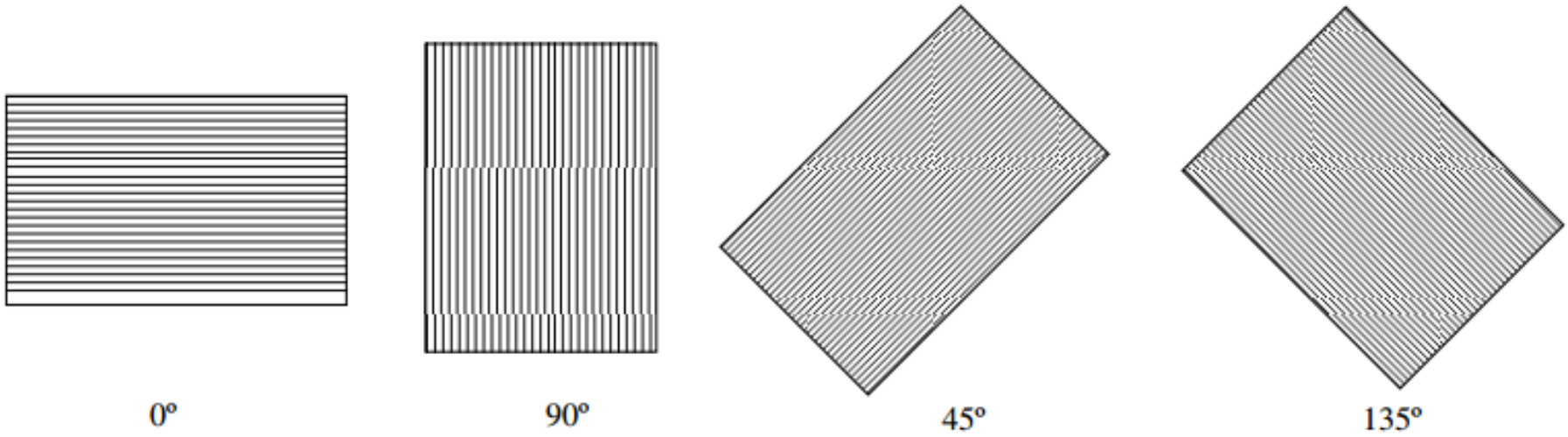
STOKES PARAMETER：I, Q, U, & V

- Stokes I ------ total intensity
- Stokes Q & U ------ linear polarization
- (Stokes V ------ circular polarization)



(https://en.wikipedia.org/wiki/Stokes_parameters)

STOKES PARAMETER：I, Q, U, & V

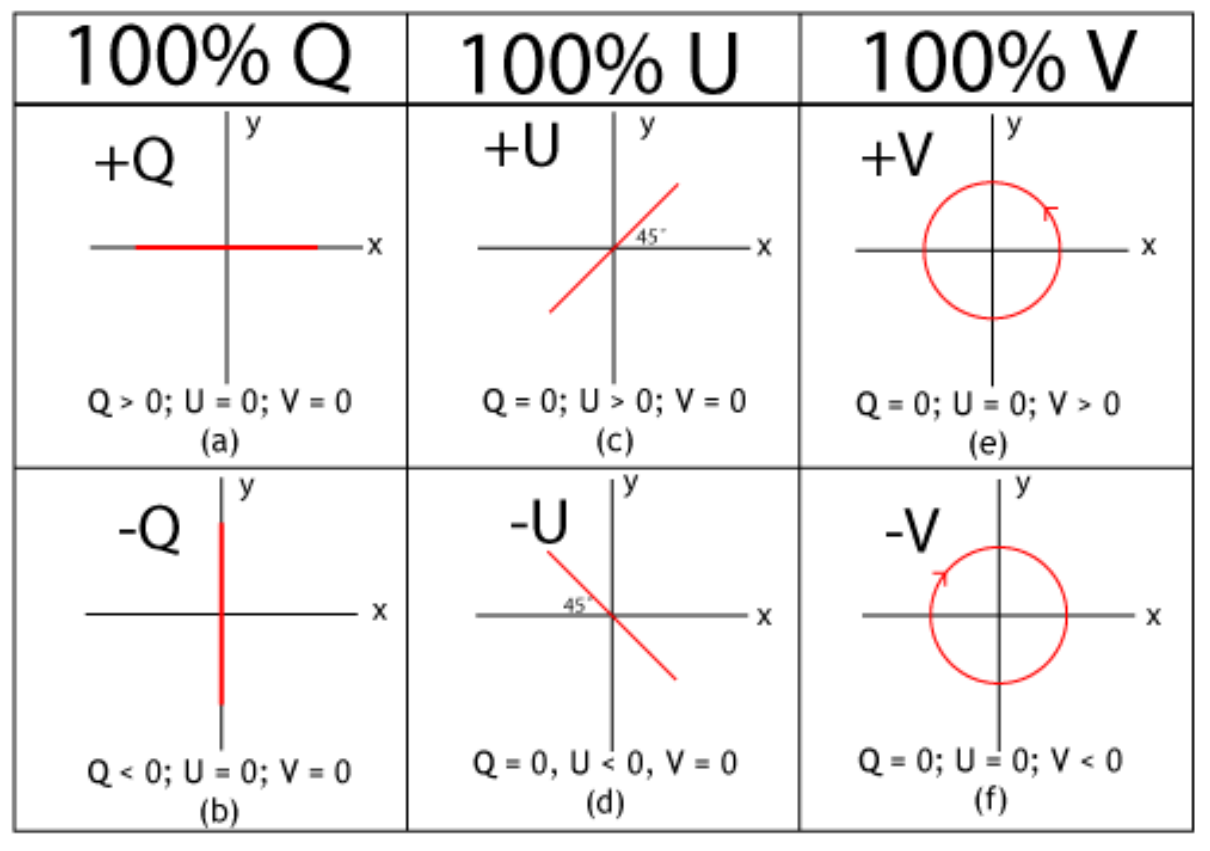


$$\mathbf{Q} = F_0 - F_{90}$$
$$\mathbf{U} = F_{45} - F_{135}$$

(http://astrowww.phys.uvic.ca/~tatum/physopt/physopt4.pdf)

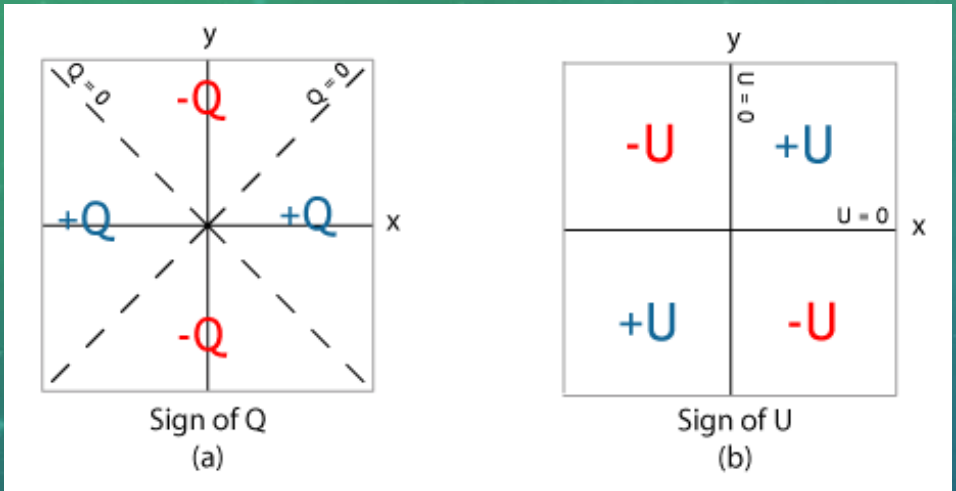
STOKES PARAMETER

$$\mathbf{Q} = F_0 - F_{90}$$
$$\mathbf{U} = F_{45} - F_{135}$$

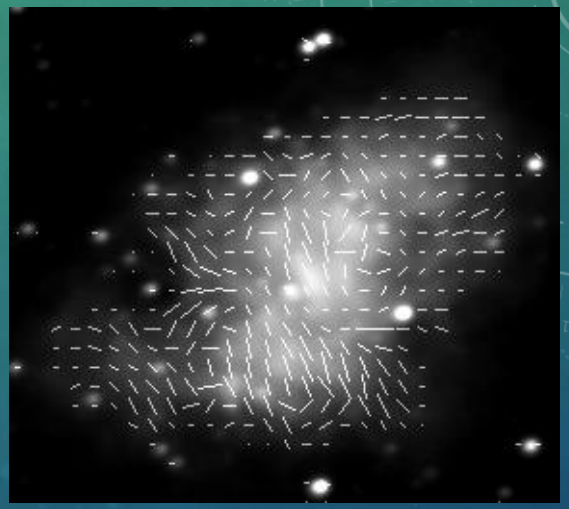


(https://en.wikipedia.org/wiki/Stokes_parameters)

STOKES PARAMETER



(https://en.wikipedia.org/wiki/Stokes_parameters)



(http://www.astrosurf.com/buil/us/polar/polar.htm)

polarized intensity

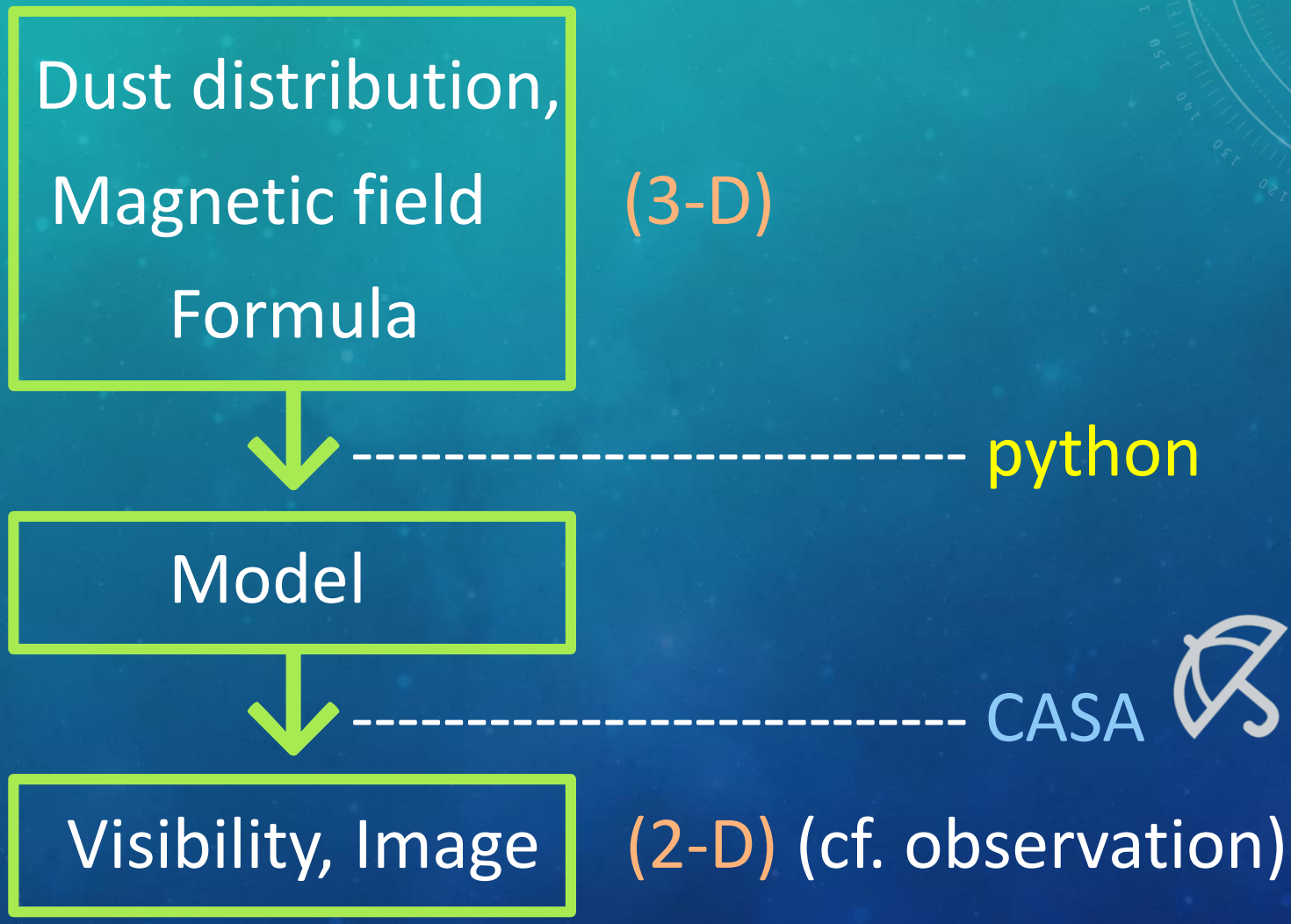
$$P = \sqrt{U^2 + Q^2}$$

position angle

$$\Theta = \frac{1}{2}\tan^{-1}\left(\frac{U}{Q}\right)$$

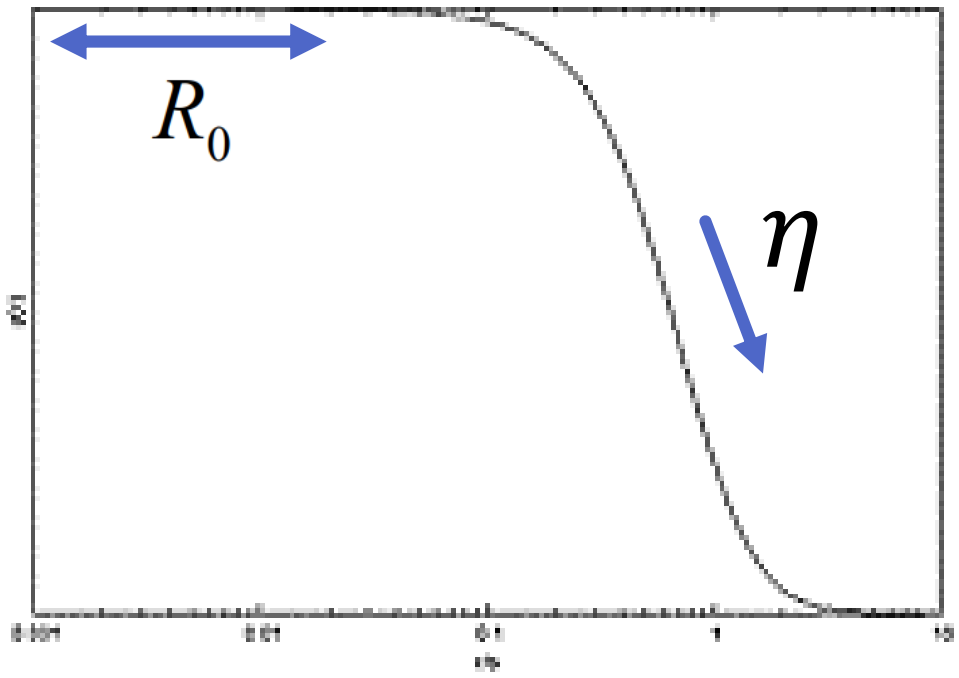
MODELING

MAGNETIC FIELD SIMULATION



Dust distribution,
Magnetic field
Formula

(3-D)



$$\rho(r, t=0) = \rho_0 \left[\frac{R_0}{\left(R_0^2 + r^2\right)^{1/2}} \right]^{\eta}$$

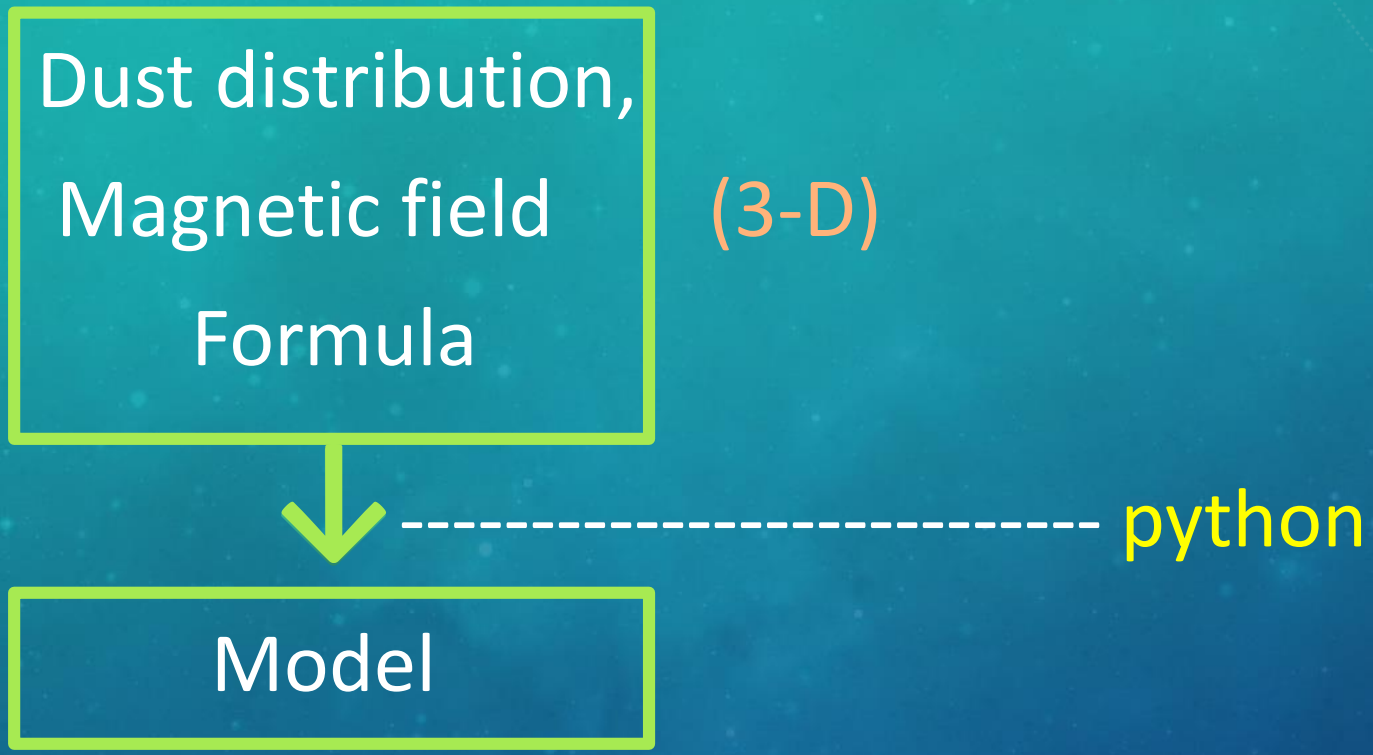
isothermal spherical Plummer-like model

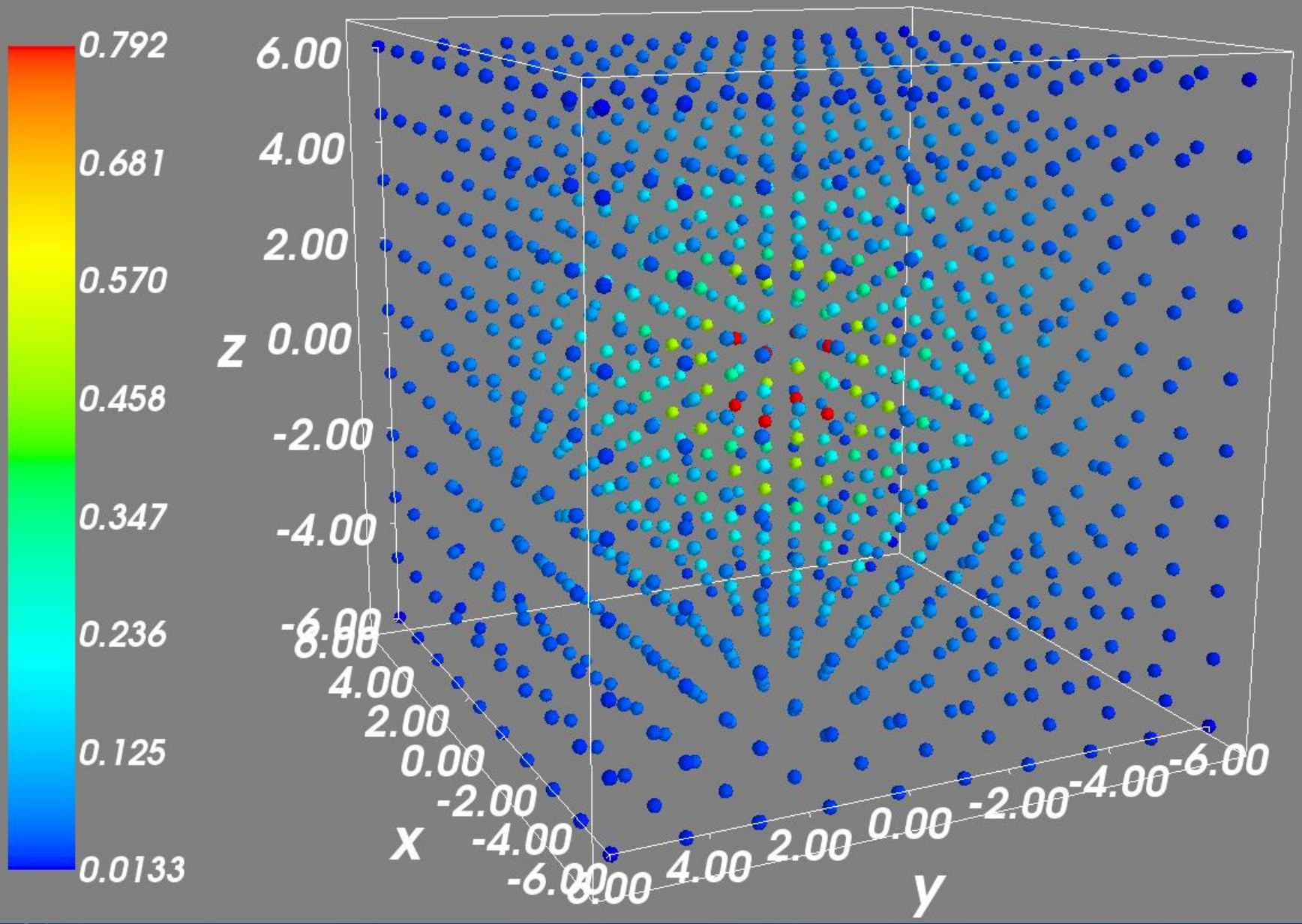
Two parameters：

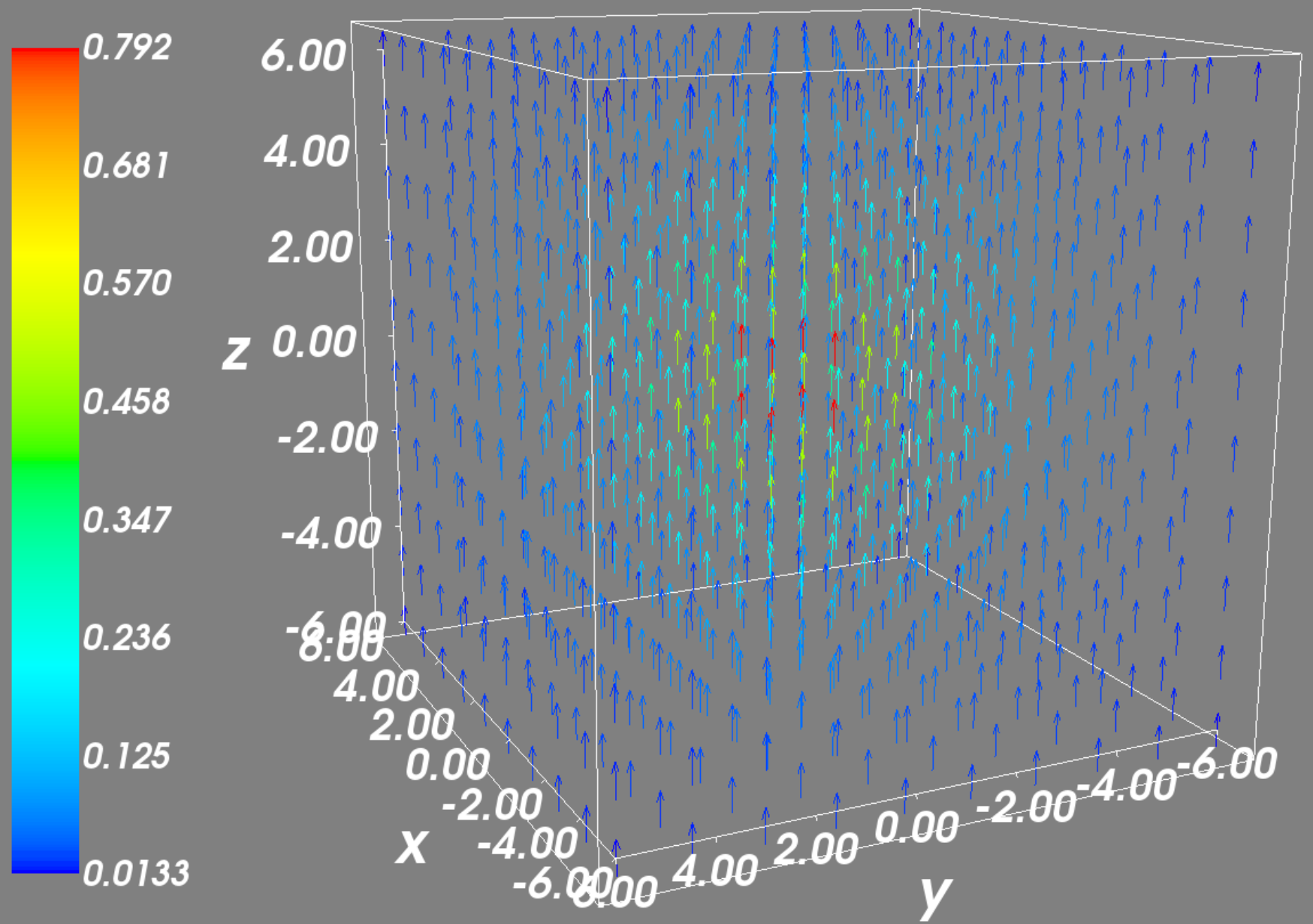
R_0

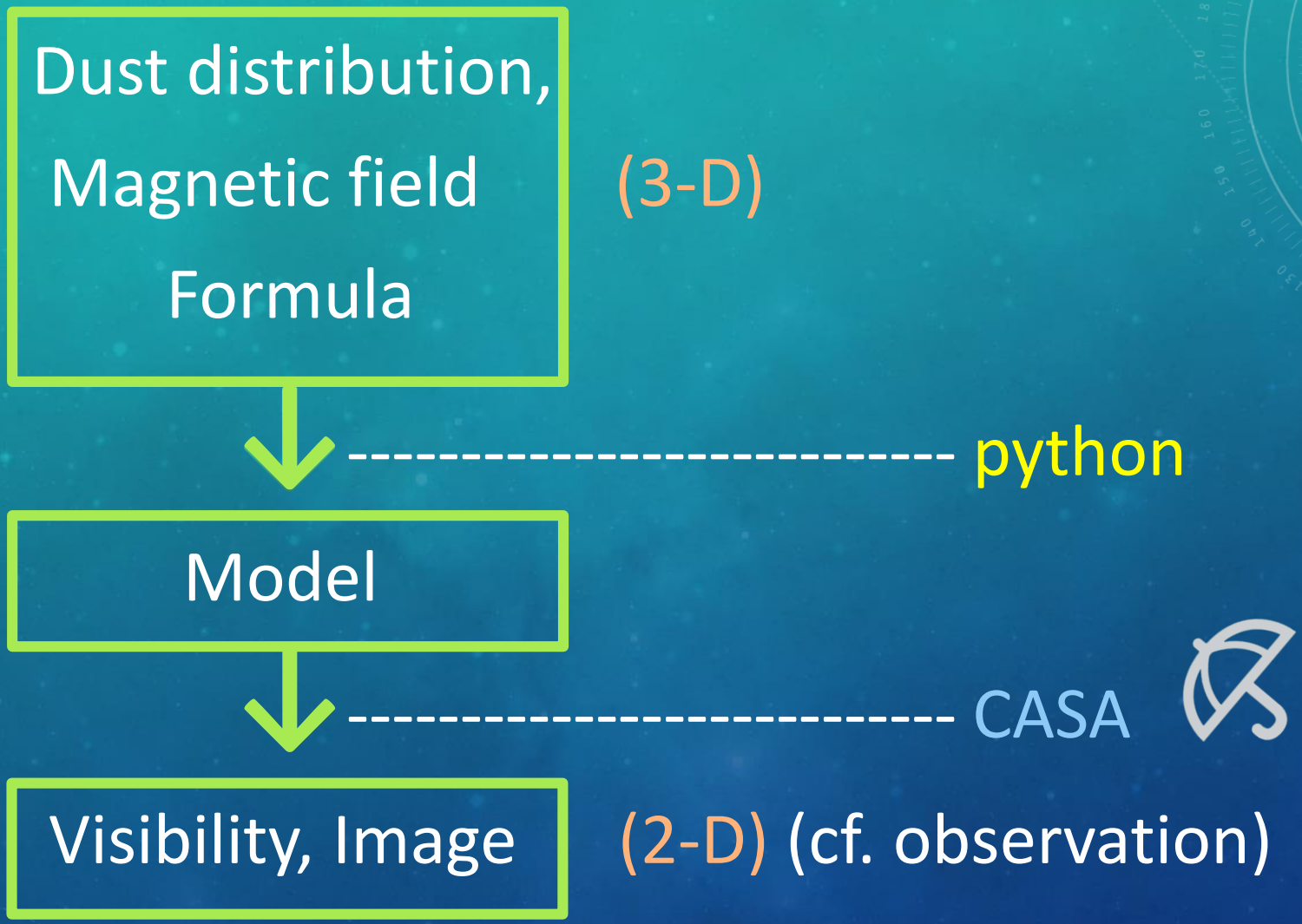
η (= 3.37)

(https://en.wikipedia.org/wiki/Plummer_model)

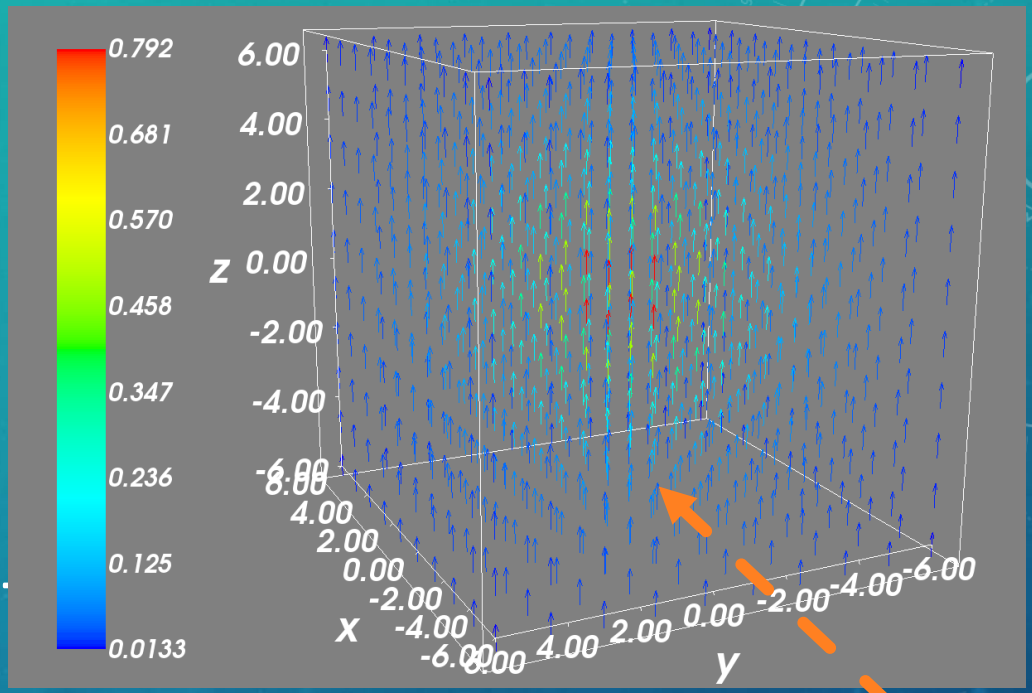

Dust distribution,
Magnetic field
Formula
(3-D)
python
Model


0.792
0.681
0.570
0.458
0.347
0.236
0.125
0.0133
z
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
x
8.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
y
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00


0.792
0.681
0.570
0.458
0.347
0.236
0.125
0.0133
z
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
x
8.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
y
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00


Dust distribution,
Magnetic field
Formula
(3-D)
python
Model
CASA
Visibility, Image
(2-D) (cf. observation)

Dust distribution,
Magnetic field
Formula



Model

CASA

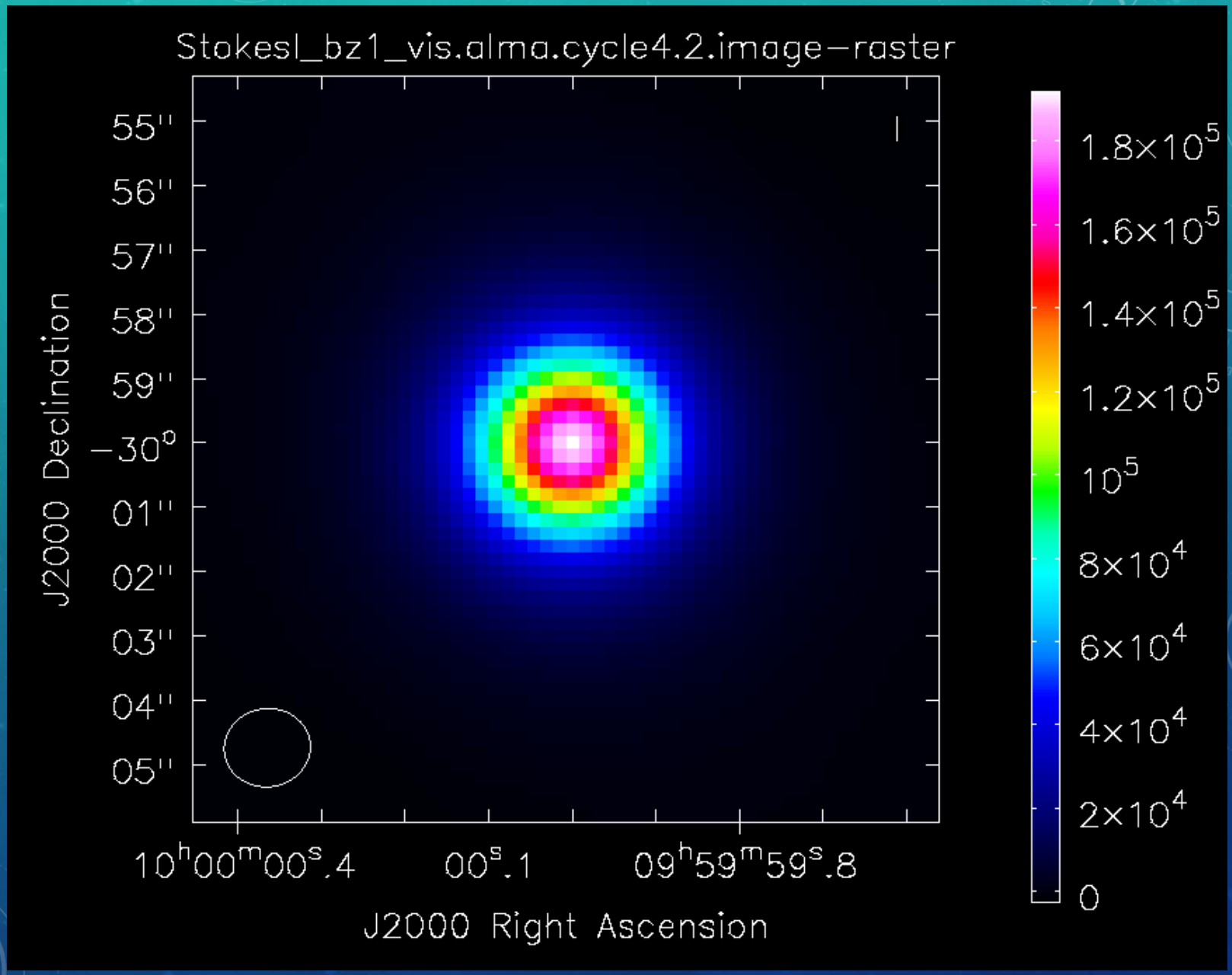
Visibility, Image (2-D) (cf. observation)

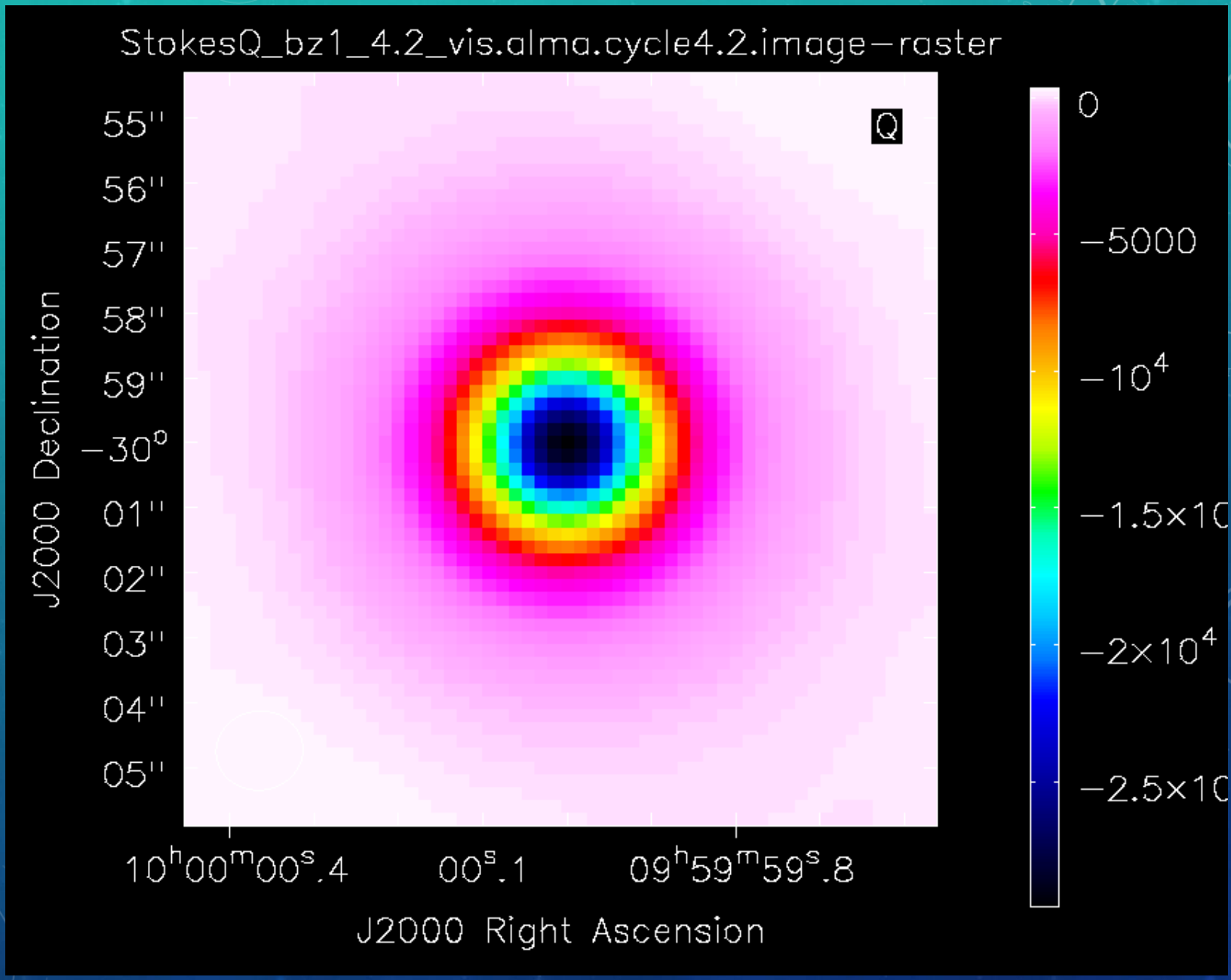
CASA useful instructions：

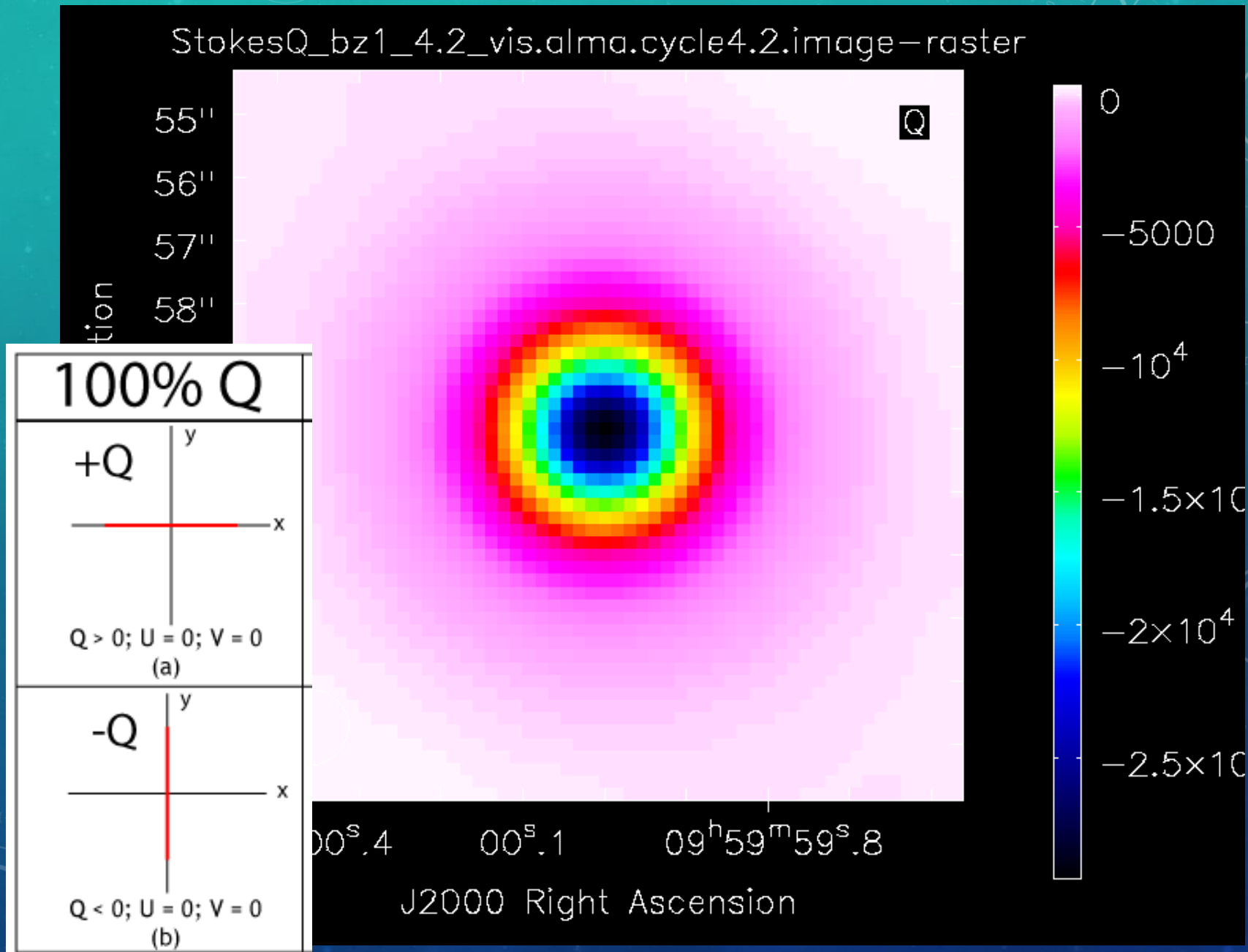
Simobserve()---turns arrays into visibilities

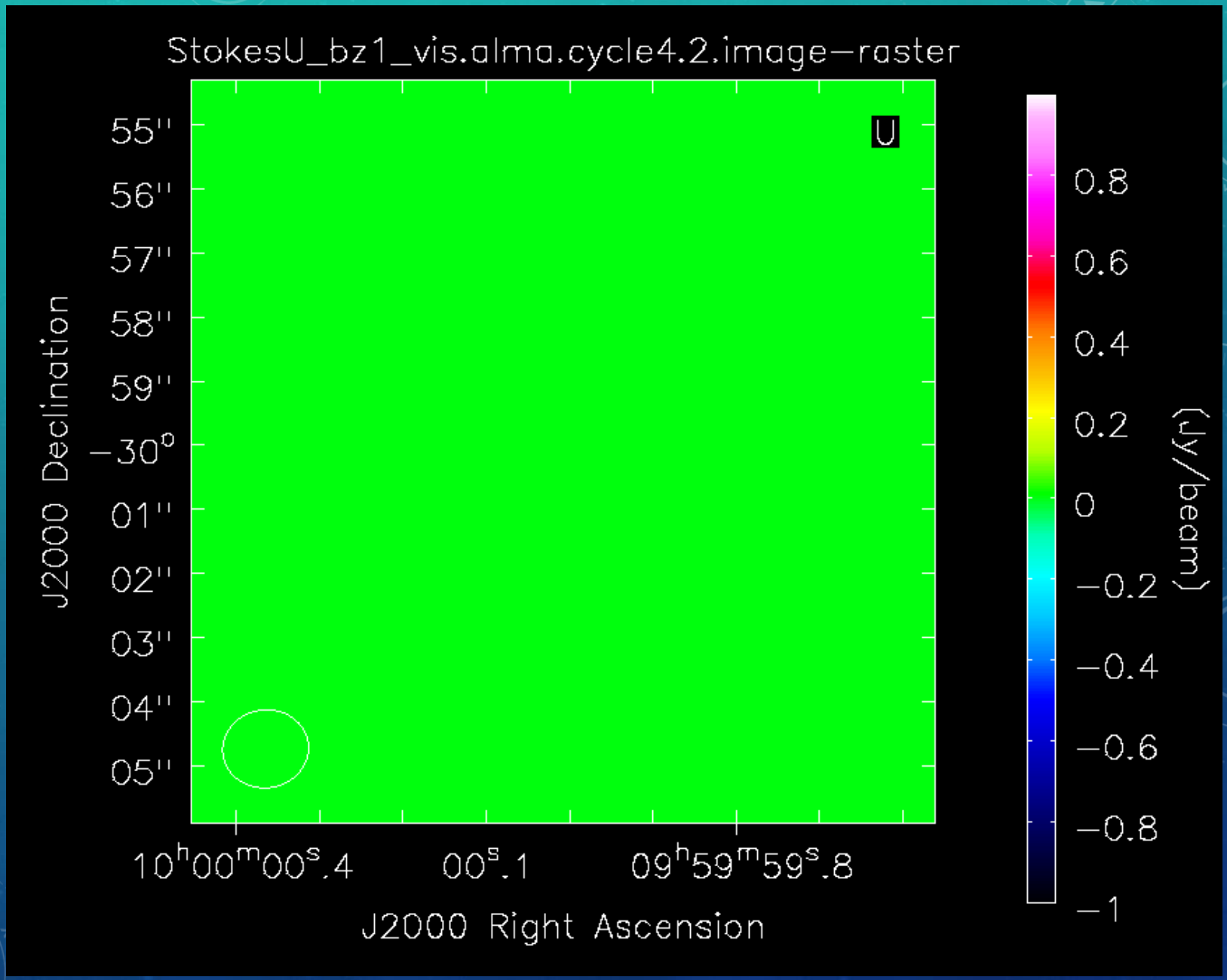
Simanalyze()---creates images from visibilities, “clean” image

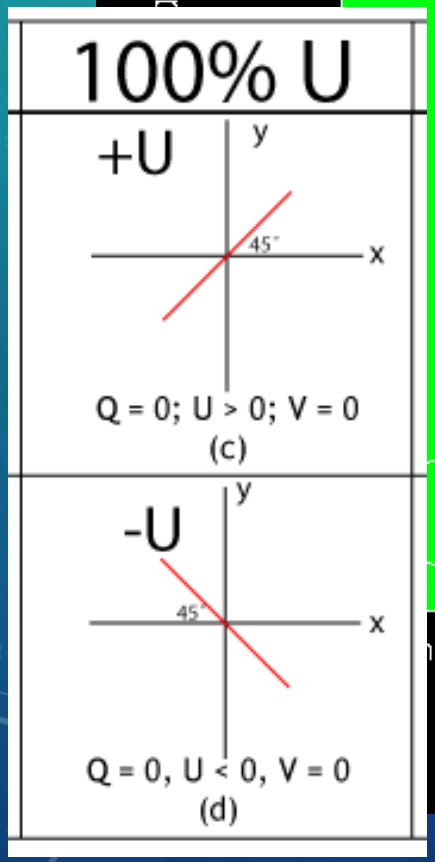
Antennas：
Cycle 4,
confriguration2


Stokesl_bz1_vis.alma.cycle4.2.image-raster
55''
56''
57''
58''
59''
−30°
01''
02''
03''
04''
05''
J2000 Declination
10h00m00s.4
00s.1
09h59m59s.8
J2000 Right Ascension
1.8×10^5
1.6×10^5
1.4×10^5
1.2×10^5
10^5
8×10^4
6×10^4
4×10^4
2×10^4
0


StokesQ_bz1_4.2_vis.alma.cycle4.2.image−raster
Q
55''
56''
57''
58''
59''
−30°
01''
02''
03''
04''
05''
J2000 Declination
10h00m00s.4
00s.1
09h59m59s.8
J2000 Right Ascension
0
−5000
−10^4
−1.5×10
−2×10^4
−2.5×10


StokesQ_bz1_4.2_vis.alma.cycle4.2.image-raster
55''
56''
57''
58''
Q
0
−5000
−10^4
−1.5×10
−2×10^4
−2.5×10
00s.4
00s.1
09h59m59s.8
J2000 Right Ascension
100% Q
+Q
y
x
Q > 0; U = 0; V = 0
(a)
-Q
y
x
Q < 0; U = 0; V = 0
(b)


StokesU_bz1_vis.alma.cycle4.2.image-raster
U
55''
56''
57''
58''
59''
−30°
01''
02''
03''
04''
05''
J2000 Declination
10h00m00s.4
00s.1
09h59m59s.8
J2000 Right Ascension
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
(Jy/beam)



StokesU_bz1_vis.alma.cycle4.2.image—raster

U

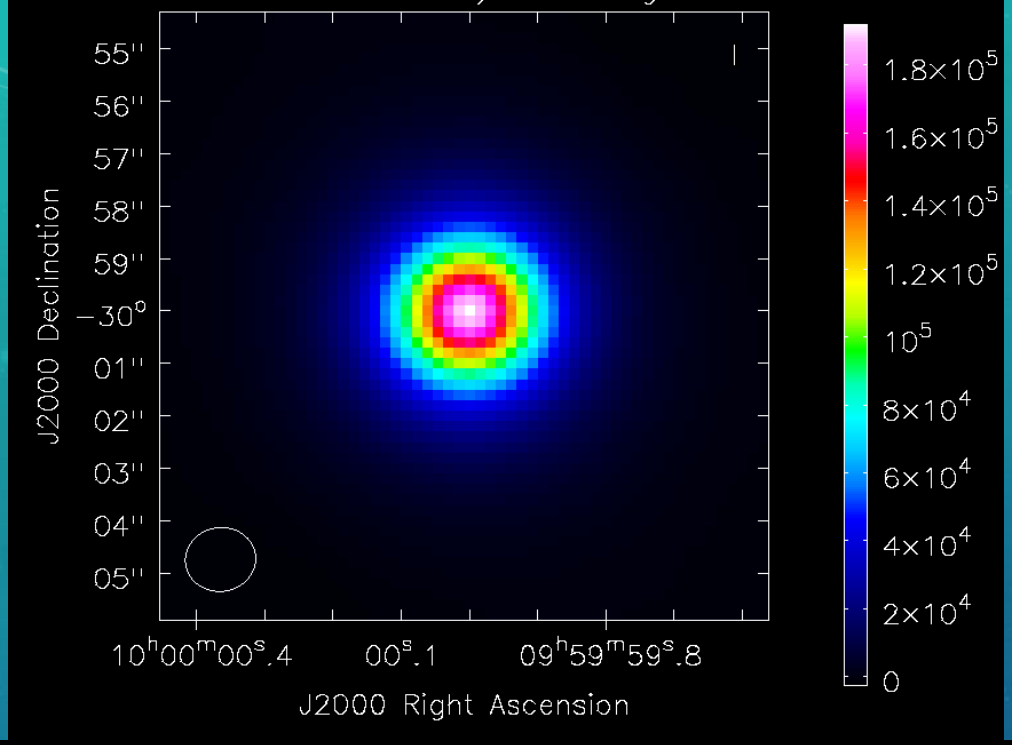
55''
56''
57''
58''

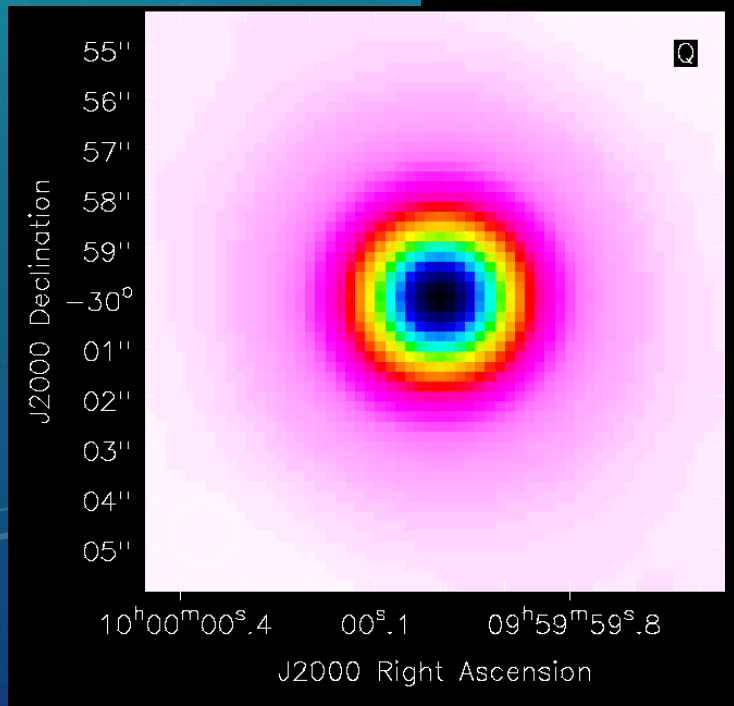
00s.4 00s.1 09h59m59s.8

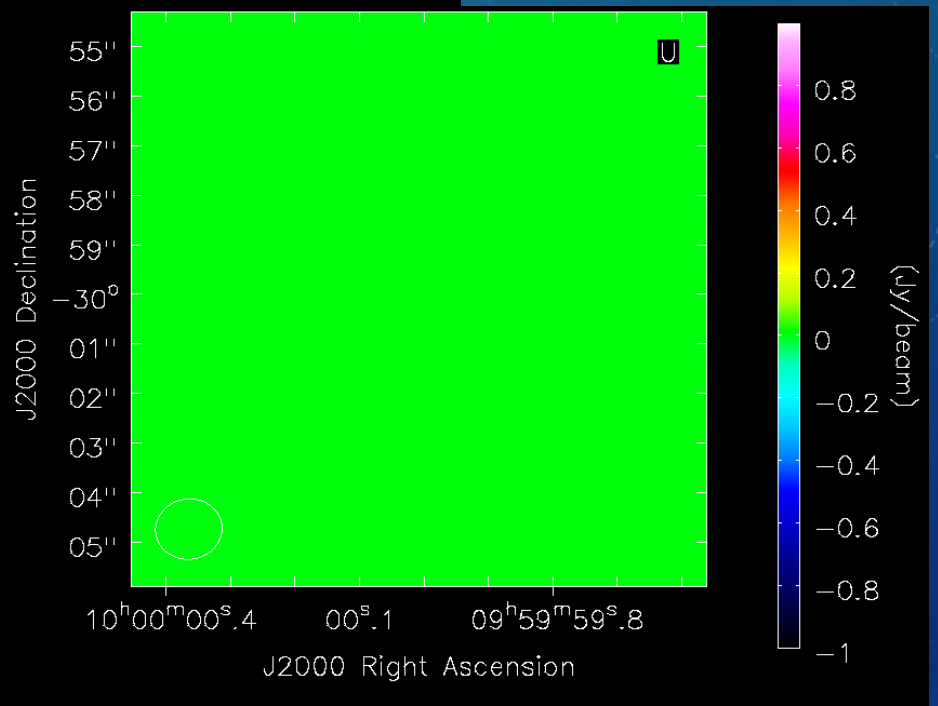
J2000 Right Ascension

0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1

(Jy/beam)


I
J2000 Declination
55''
56''
57''
58''
59''
−30°
01''
02''
03''
04''
05''
10h00m00s.4
00s.1
09h59m59s.8
J2000 Right Ascension
1.8×10^5
1.6×10^5
1.4×10^5
1.2×10^5
10^5
8×10^4
6×10^4
4×10^4
2×10^4
0


Q
J2000 Declination
55''
56''
57''
58''
59''
−30°
01''
02''
03''
04''
05''
10h00m00s.4
00s.1
09h59m59s.8
J2000 Right Ascension
0
−5000
−10^4
−1.5×10
−2×10^4
−2.5×10


U
J2000 Declination
55''
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10h00m00s.4
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J2000 Right Ascension
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
(Jy/beam)

CASA useful instructions：

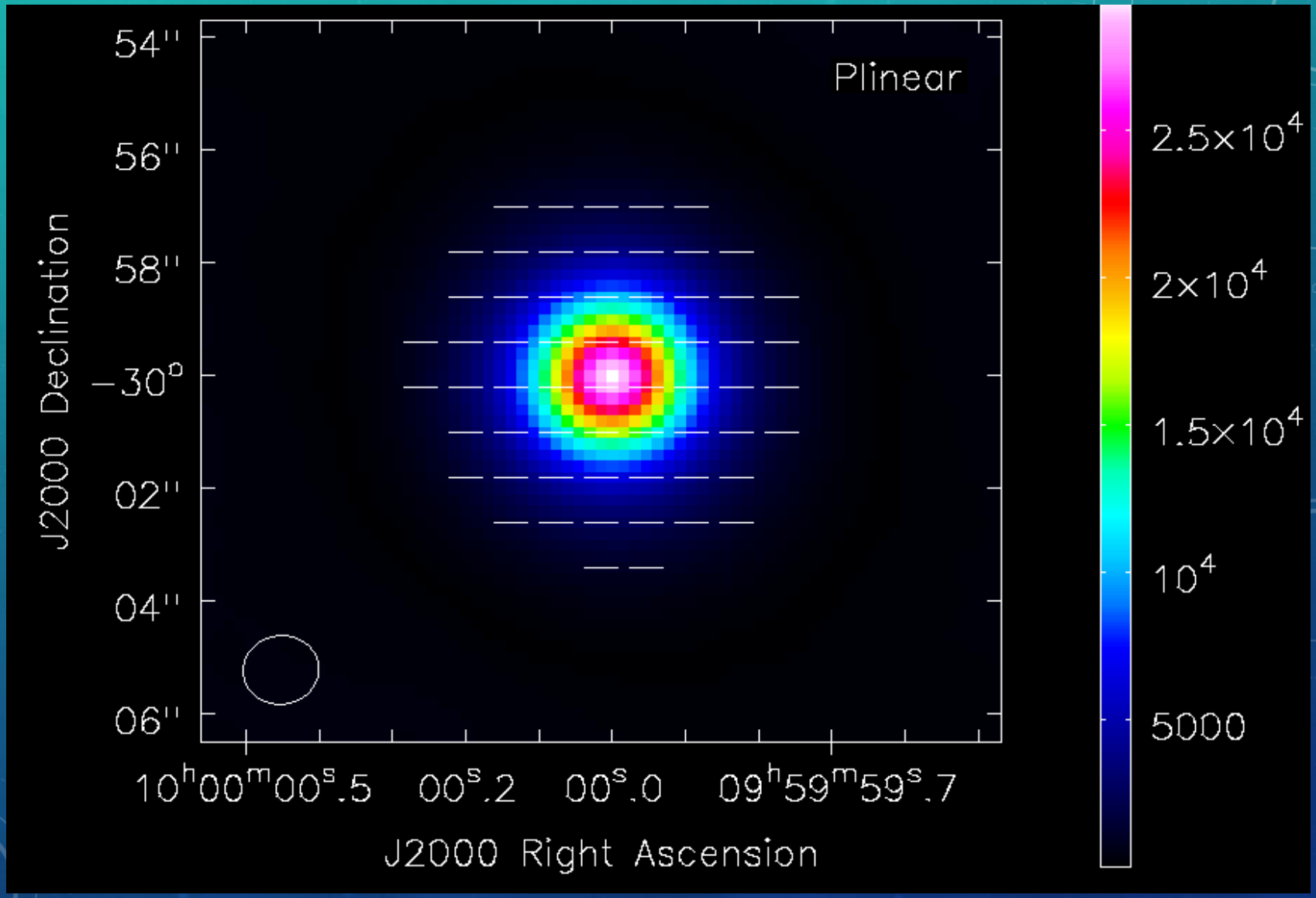
Simobserve()---turns arrays into visibilities

Simanalyze()---creates images from visibilities, "clean" image

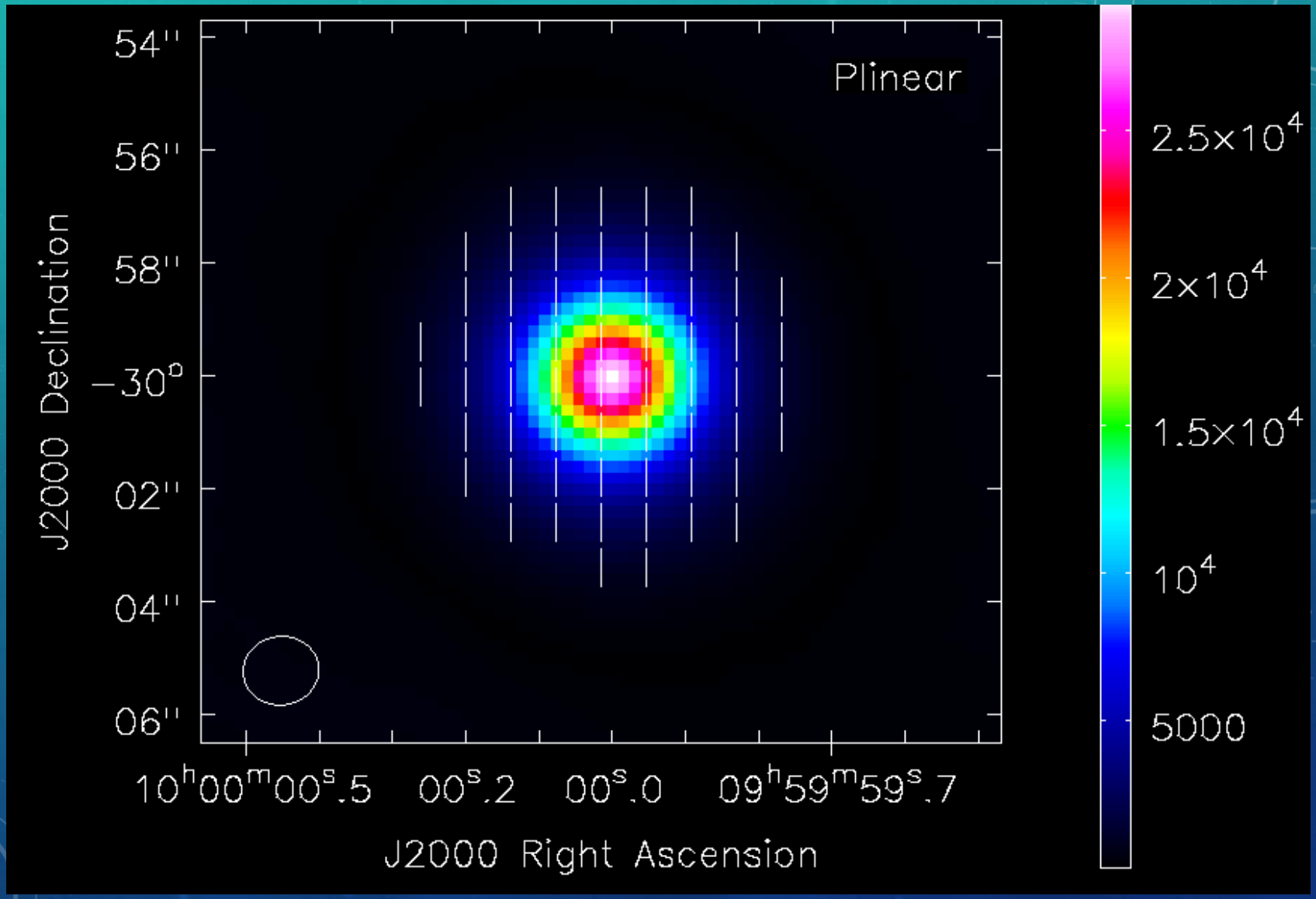
Immath()---calculates polarization map

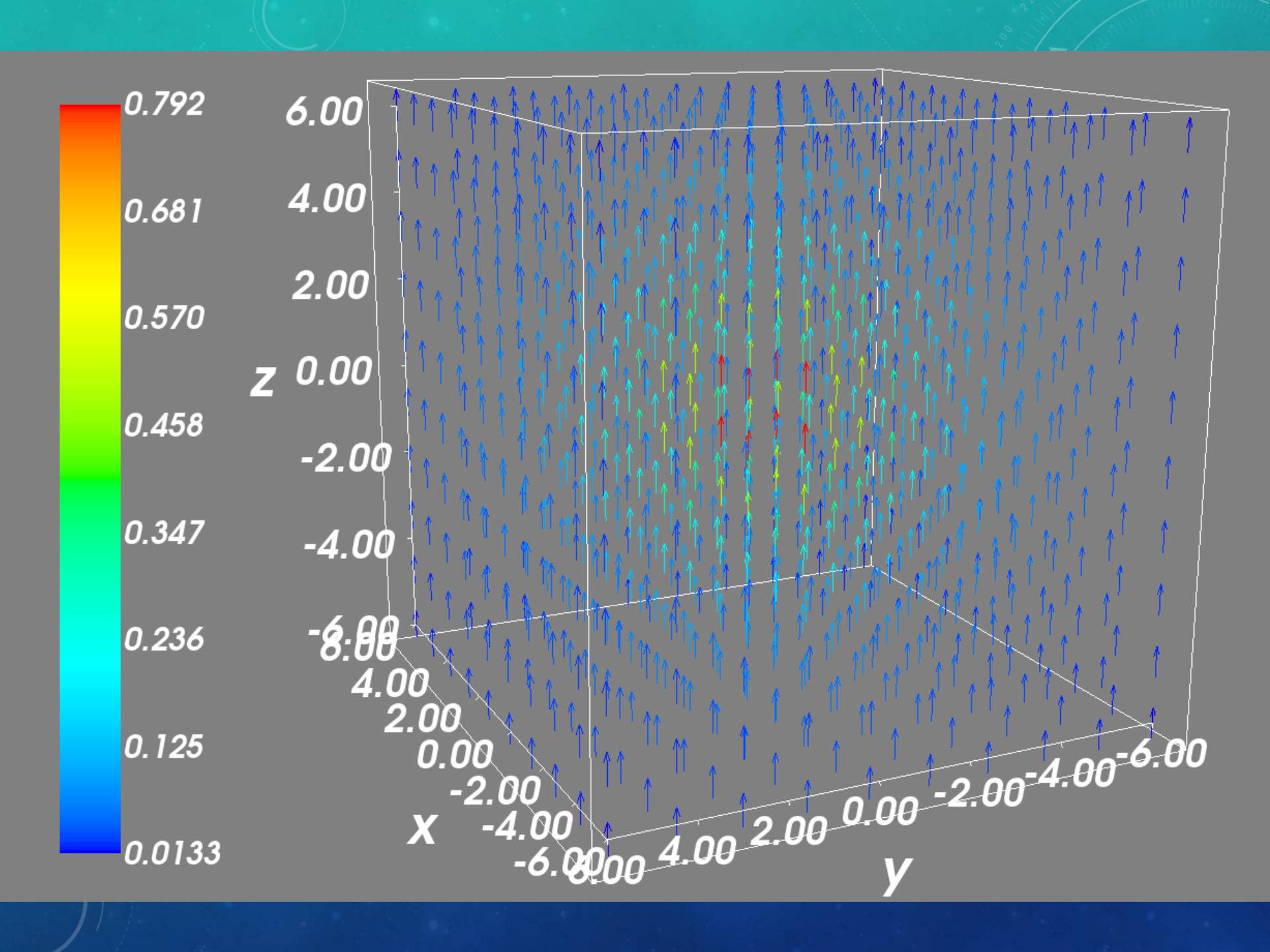
$$P = \sqrt{U^2 + Q^2} \quad \Theta = \frac{1}{2}\tan^{-1}\left(\frac{U}{Q}\right)$$

POLARIZATION MAP (electric vector position angle)



POLARIZATION MAP (magnetic field)




0.792
0.681
0.570
0.458
0.347
0.236
0.125
0.0133
z
6.00
4.00
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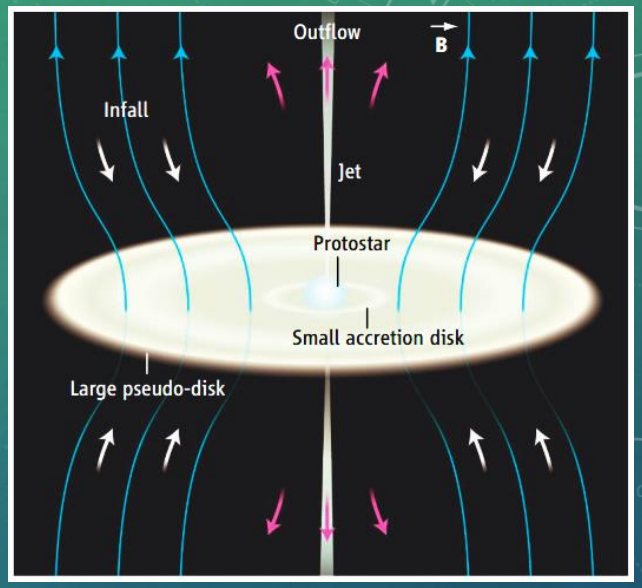
0.00
-2.00
-4.00
-6.00
x
8.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
y
8.00
4.00
2.00
0.00
-2.00
-4.00
-6.00

FUTURE WORK

(http://www.almaobservatory.org/en/visuals/images/?g2_itemid=10)

FUTURE WORK



(Richard M. Crutcher, 2006)

- Other models
  -density distribution
  -magnetic field
- Compare with observation from ALMA
- Units?
- Other factors causing Polarization?

  (ex: scattering)

THANK YOU!!