Through The Looking Glass:

Faraday Conversion
in
Turbulent Blazar Jets

Nicholas MacDonald

Boston University

Talk Outline

A brief introduction to Faraday Conversion.

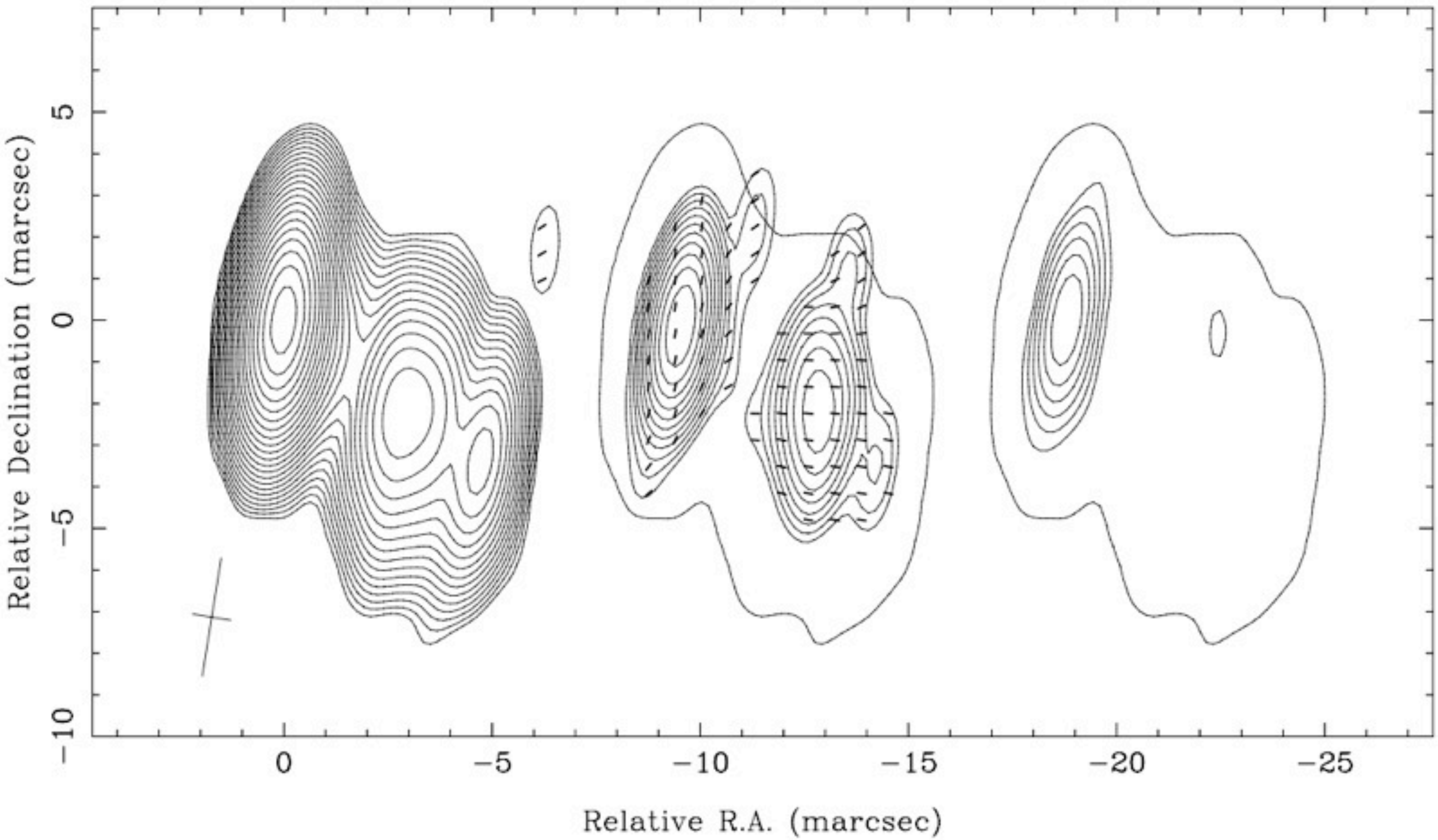
Can circular polarization be produced within a turbulent jet?

Malaga, Spain

June 2016

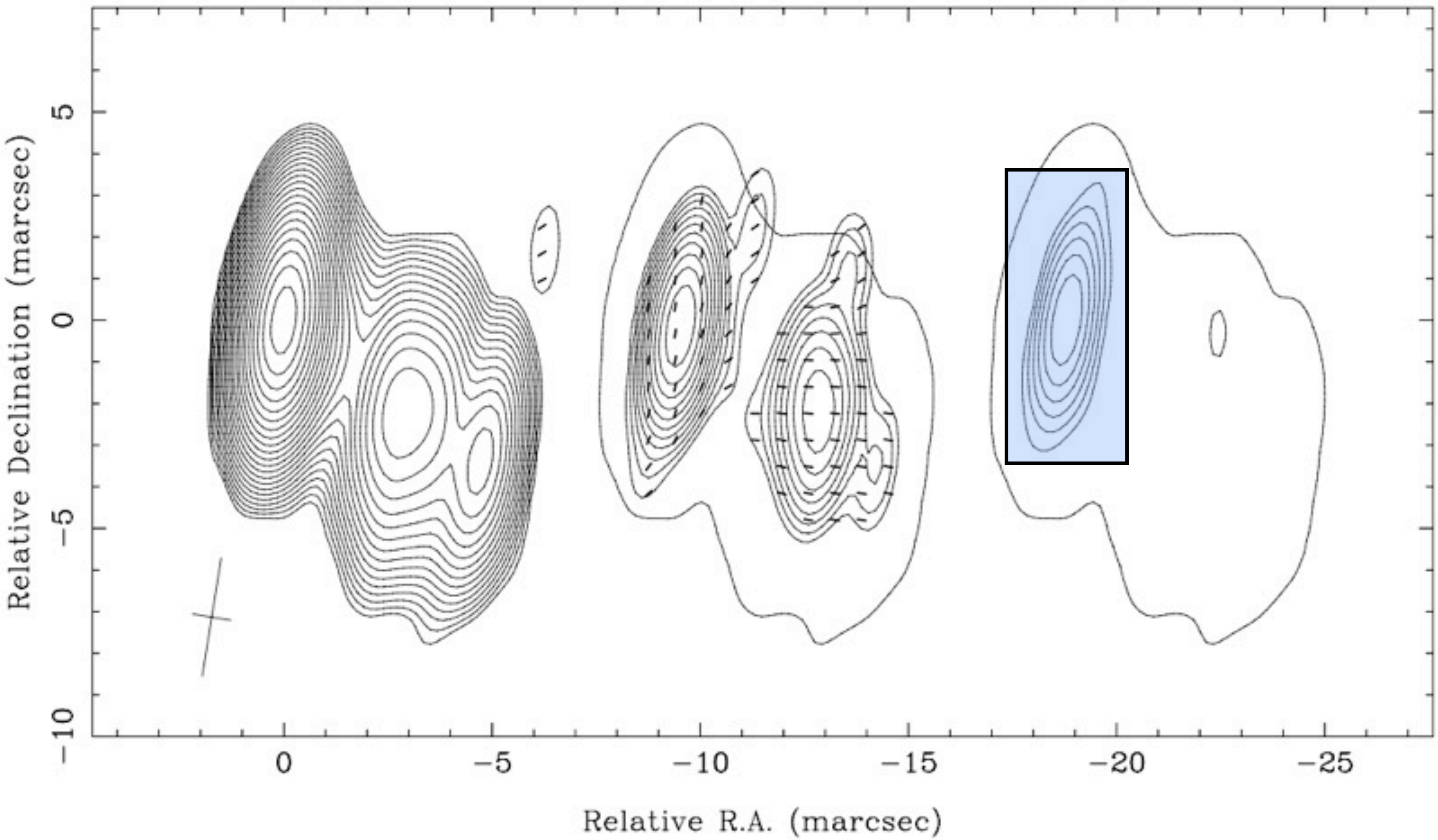
Birefringence

3C 279



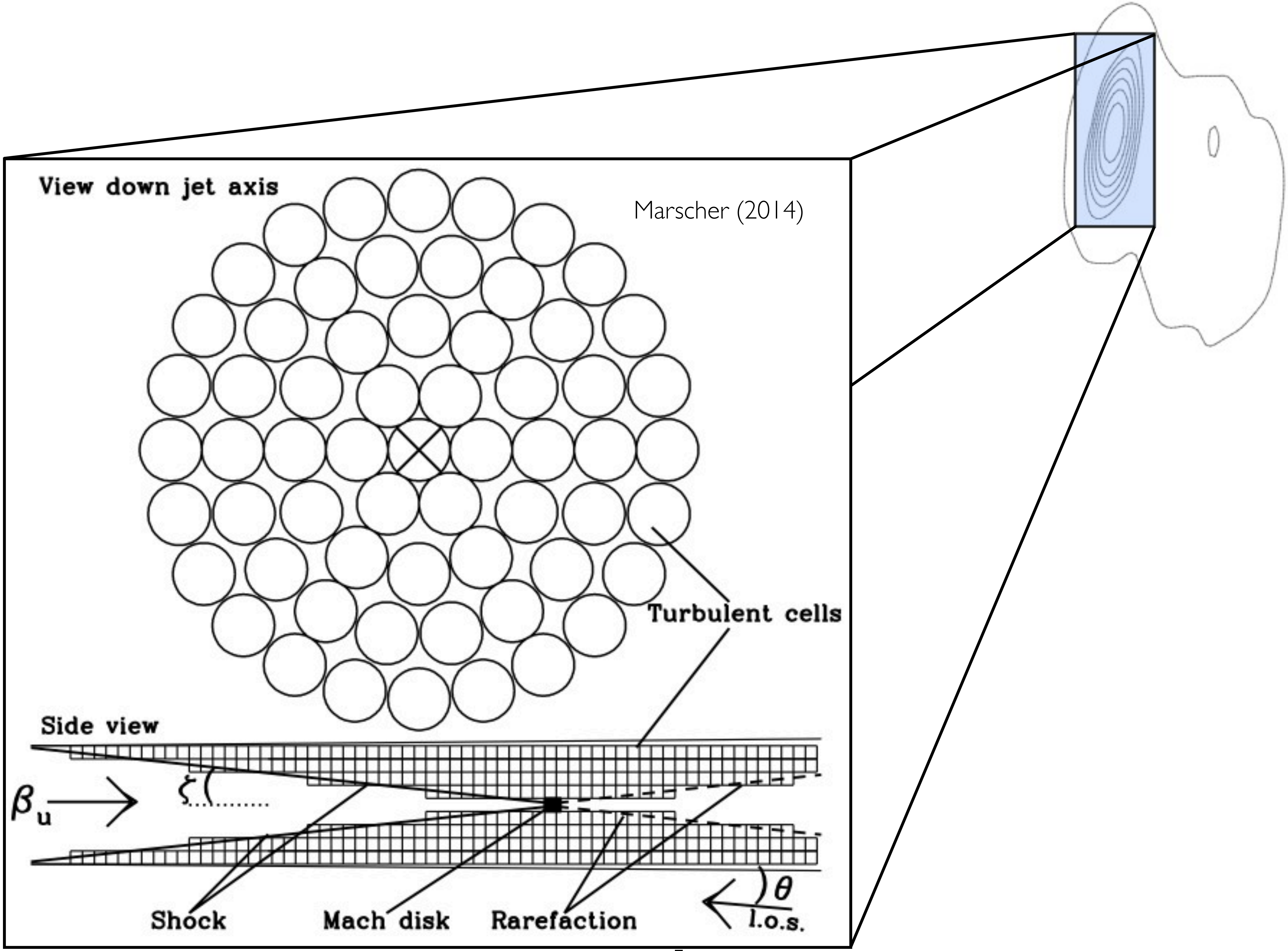
Homan et al. (2009)

3C 279



Homan et al. (2009)

The turbulent extreme multi-zone (TEMZ) code:



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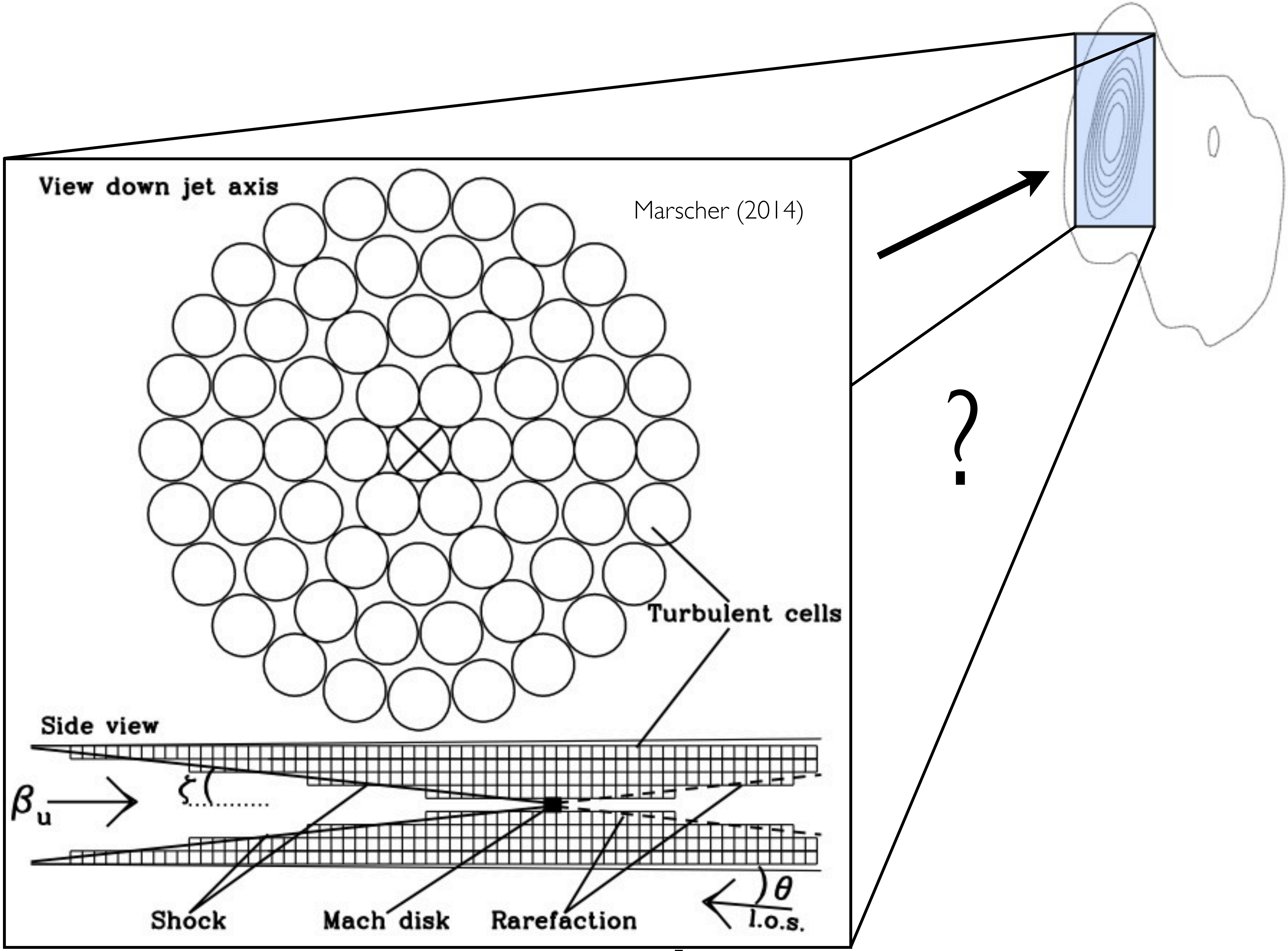


1977

1977

6

1977


THIS DAY IN STAR WARS
MAY 25, 1977
STAR WARS IS RELEASED IN THEATERS

The Astrophysical Journal, 214: 522–539, 1977 June 1

TRANSFER OF POLARIZED RADIATION IN SELF-ABSORBED SYNCHROTRON SOURCES. I. RESULTS FOR A HOMOGENEOUS SOURCE

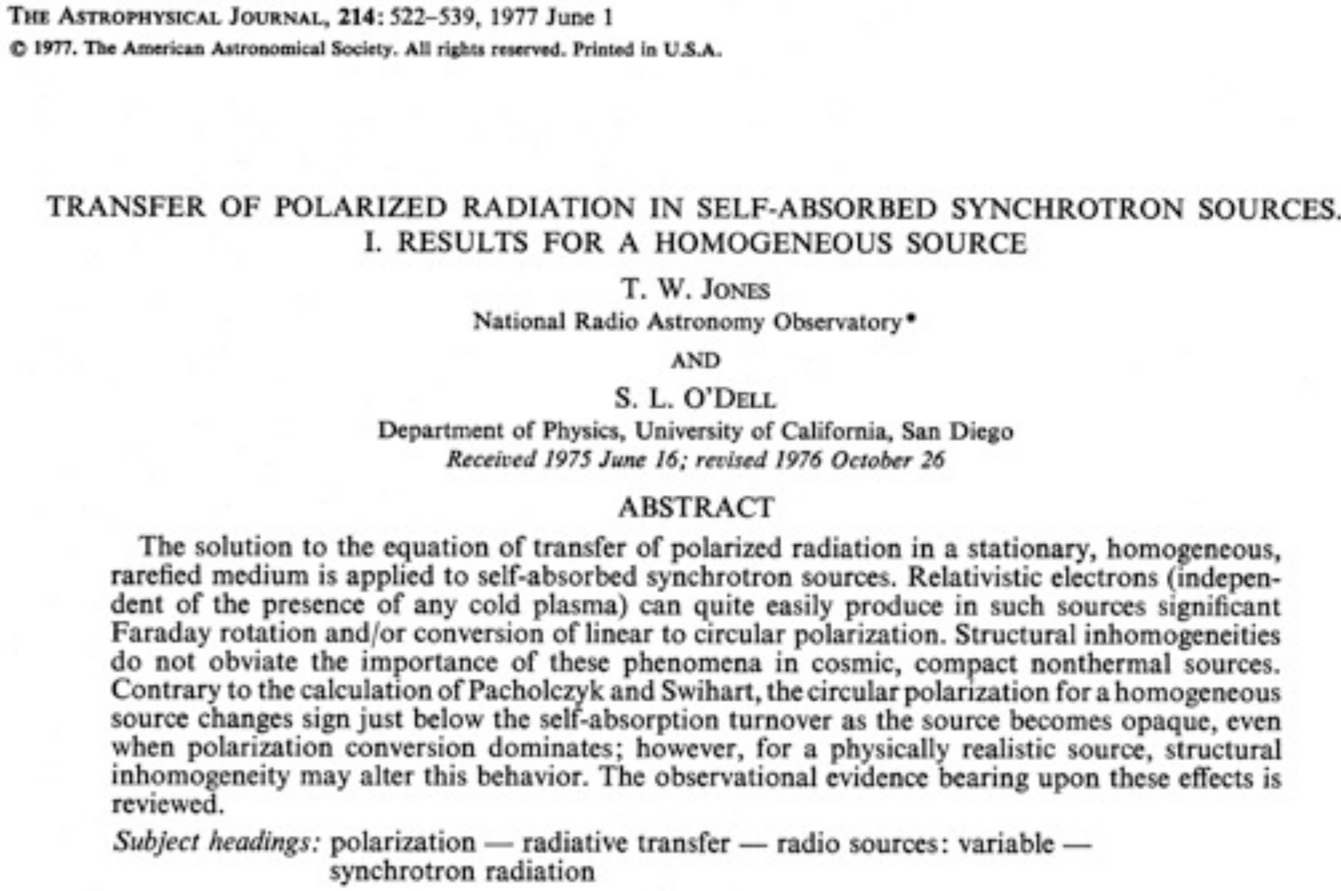
T. W. Jones
National Radio Astronomy Observatory*
AND
S. L. O'Dell
Department of Physics, University of California, San Diego
Received 1975 June 16; revised 1976 October 26

ABSTRACT

The solution to the equation of transfer of polarized radiation in a stationary, homogeneous, rarefied medium is applied to self-absorbed synchrotron sources. Relativistic electrons (independent of the presence of any cold plasma) can quite easily produce in such sources significant Faraday rotation and/or conversion of linear to circular polarization. Structural inhomogeneities do not obviate the importance of these phenomena in cosmic, compact nonthermal sources. Contrary to the calculation of Pacholczyk and Swihart, the circular polarization for a homogeneous source changes sign just below the self-absorption turnover as the source becomes opaque, even when polarization conversion dominates; however, for a physically realistic source, structural inhomogeneity may alter this behavior. The observational evidence bearing upon these effects is reviewed.

Subject headings: polarization — radiative transfer — radio sources: variable — synchrotron radiation

1977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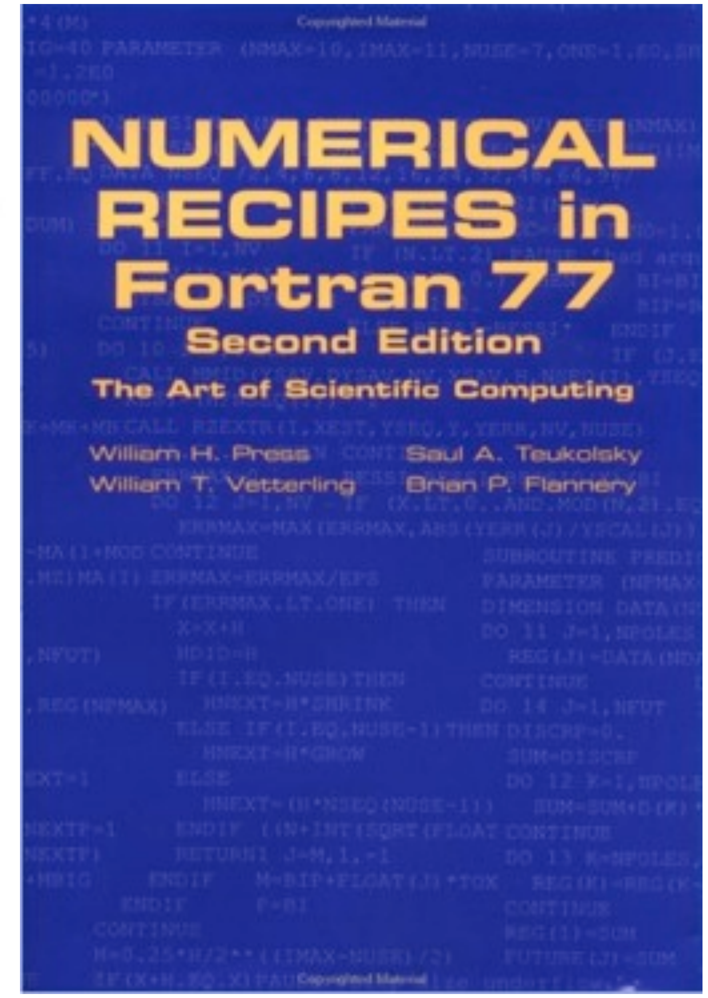

1977

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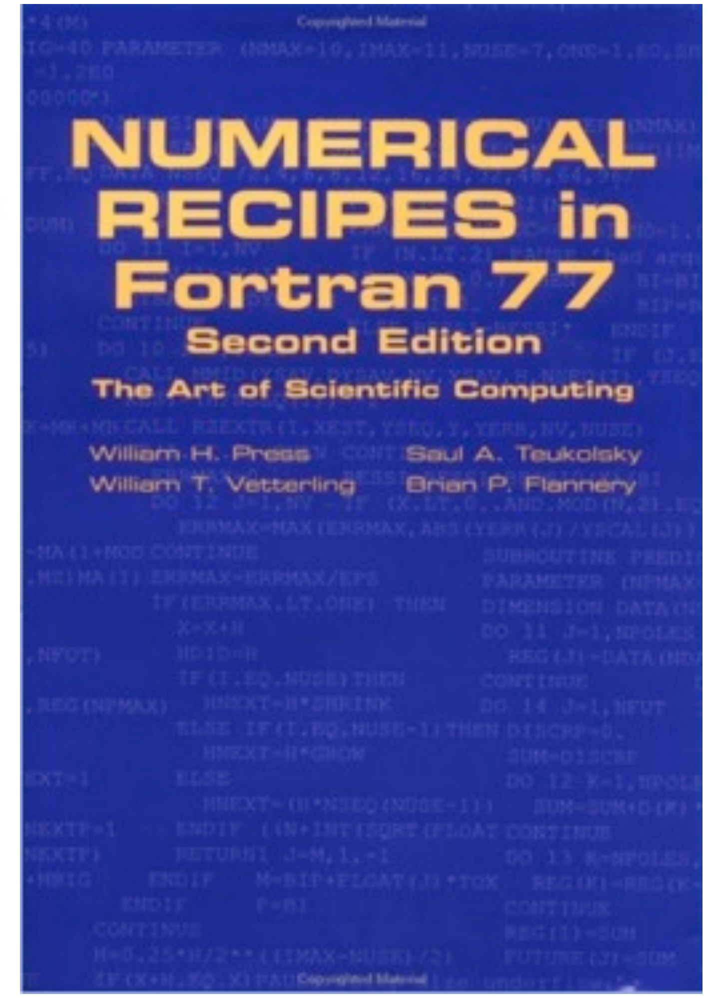

1977

Solving the Full Stokes Equations of Radiative Transfer

$$\begin{vmatrix} \left(\dfrac{d}{dl}+\kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\ \kappa_Q & \left(\dfrac{d}{dl}+\kappa_I\right) & {\kappa^*}_V & -{\kappa^*}_U \\ \kappa_U & -{\kappa^*}_V & \left(\dfrac{d}{dl}+\kappa_I\right) & {\kappa^*}_Q \\ \kappa_V & {\kappa^*}_U & -{\kappa^*}_Q & \left(\dfrac{d}{dl}+\kappa_I\right) \end{vmatrix} \begin{vmatrix} I_\nu \\ Q_\nu \\ U_\nu \\ V_\nu \end{vmatrix} = \begin{vmatrix} {\eta_\nu}^I \\ {\eta_\nu}^Q \\ {\eta_\nu}^U \\ {\eta_\nu}^V \end{vmatrix}$$

Jones & O'Dell (1977)

Stokes Parameters

$$
\begin{vmatrix}
\left(\frac{d}{dl} + \kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\
\kappa_Q & \left(\frac{d}{dl} + \kappa_I\right) & {\kappa^*}_V & -{\kappa^*}_U \\
\kappa_U & -{\kappa^*}_V & \left(\frac{d}{dl} + \kappa_I\right) & {\kappa^*}_Q \\
\kappa_V & {\kappa^*}_U & -{\kappa^*}_Q & \left(\frac{d}{dl} + \kappa_I\right)
\end{vmatrix}
\begin{vmatrix} I_\nu \\ Q_\nu \\ U_\nu \\ V_\nu \end{vmatrix}
=
\begin{vmatrix} {\eta_\nu}^I \\ {\eta_\nu}^Q \\ {\eta_\nu}^U \\ {\eta_\nu}^V \end{vmatrix}
$$

Jones & O'Dell (1977)

Emission Coefficients

$$\begin{vmatrix} \left(\frac{d}{dl}+\kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\ \kappa_Q & \left(\frac{d}{dl}+\kappa_I\right) & {\kappa^*}_V & -{\kappa^*}_U \\ \kappa_U & -{\kappa^*}_V & \left(\frac{d}{dl}+\kappa_I\right) & {\kappa^*}_Q \\ \kappa_V & {\kappa^*}_U & -{\kappa^*}_Q & \left(\frac{d}{dl}+\kappa_I\right) \end{vmatrix} \begin{vmatrix} I_\nu \\ Q_\nu \\ U_\nu \\ V_\nu \end{vmatrix} = \begin{vmatrix} {\eta_\nu}^I \\ {\eta_\nu}^Q \\ {\eta_\nu}^U \\ {\eta_\nu}^V \end{vmatrix}$$

Jones & O'Dell (1977)

Absorption Coefficients

$$\begin{vmatrix} \left(\frac{d}{dl}+\kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\ \kappa_Q & \left(\frac{d}{dl}+\kappa_I\right) & {\kappa^*}_V & -{\kappa^*}_U \\ \kappa_U & -{\kappa^*}_V & \left(\frac{d}{dl}+\kappa_I\right) & {\kappa^*}_Q \\ \kappa_V & {\kappa^*}_U & -{\kappa^*}_Q & \left(\frac{d}{dl}+\kappa_I\right) \end{vmatrix} \begin{vmatrix} I_\nu \\ Q_\nu \\ U_\nu \\ V_\nu \end{vmatrix} = \begin{vmatrix} {\eta_\nu}^I \\ {\eta_\nu}^Q \\ {\eta_\nu}^U \\ {\eta_\nu}^V \end{vmatrix}$$

Jones & O'Dell (1977)

$$
\begin{vmatrix}
\left(\frac{d}{dl}+\kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\
\kappa_Q & \left(\frac{d}{dl}+\kappa_I\right) & \boxed{{\kappa^*}_V} & -{\kappa^*}_U \\
\kappa_U & \boxed{-{\kappa^*}_V} & \left(\frac{d}{dl}+\kappa_I\right) & {\kappa^*}_Q \\
\kappa_V & {\kappa^*}_U & -{\kappa^*}_Q & \left(\frac{d}{dl}+\kappa_I\right)
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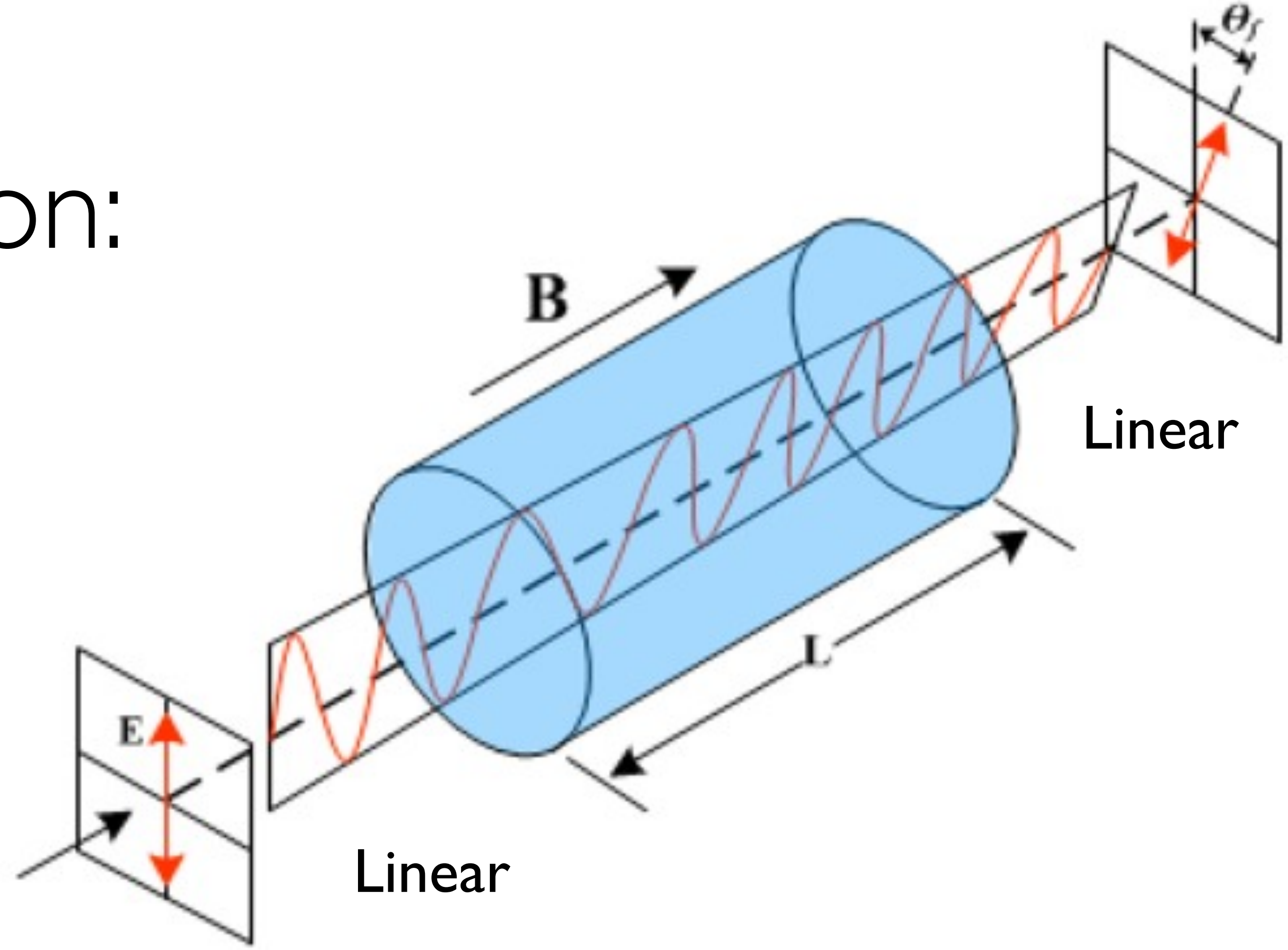
Jones & O'Dell (1977)

Faraday Rotation:



$$
\begin{vmatrix}
\left(\frac{d}{dl}+\kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\
\kappa_Q & \left(\frac{d}{dl}+\kappa_I\right) & \kappa^*{}_V & -\kappa^*{}_U \\
\kappa_U & -\kappa^*{}_V & \left(\frac{d}{dl}+\kappa_I\right) & \kappa^*{}_Q \\
\kappa_V & \kappa^*{}_U & -\kappa^*{}_Q & \left(\frac{d}{dl}+\kappa_I\right)
\end{vmatrix}
\begin{vmatrix}
I_\nu \\ Q_\nu \\ U_\nu \\ V_\nu
\end{vmatrix}
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Jones & O'Dell (1977)

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\begin{vmatrix}
\left(\frac{d}{dl} + \kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\
\kappa_Q & \left(\frac{d}{dl} + \kappa_I\right) & {\kappa^*}_V & -{\kappa^*}_U \\
\kappa_U & -{\kappa^*}_V & \left(\frac{d}{dl} + \kappa_I\right) & {\kappa^*}_Q \\
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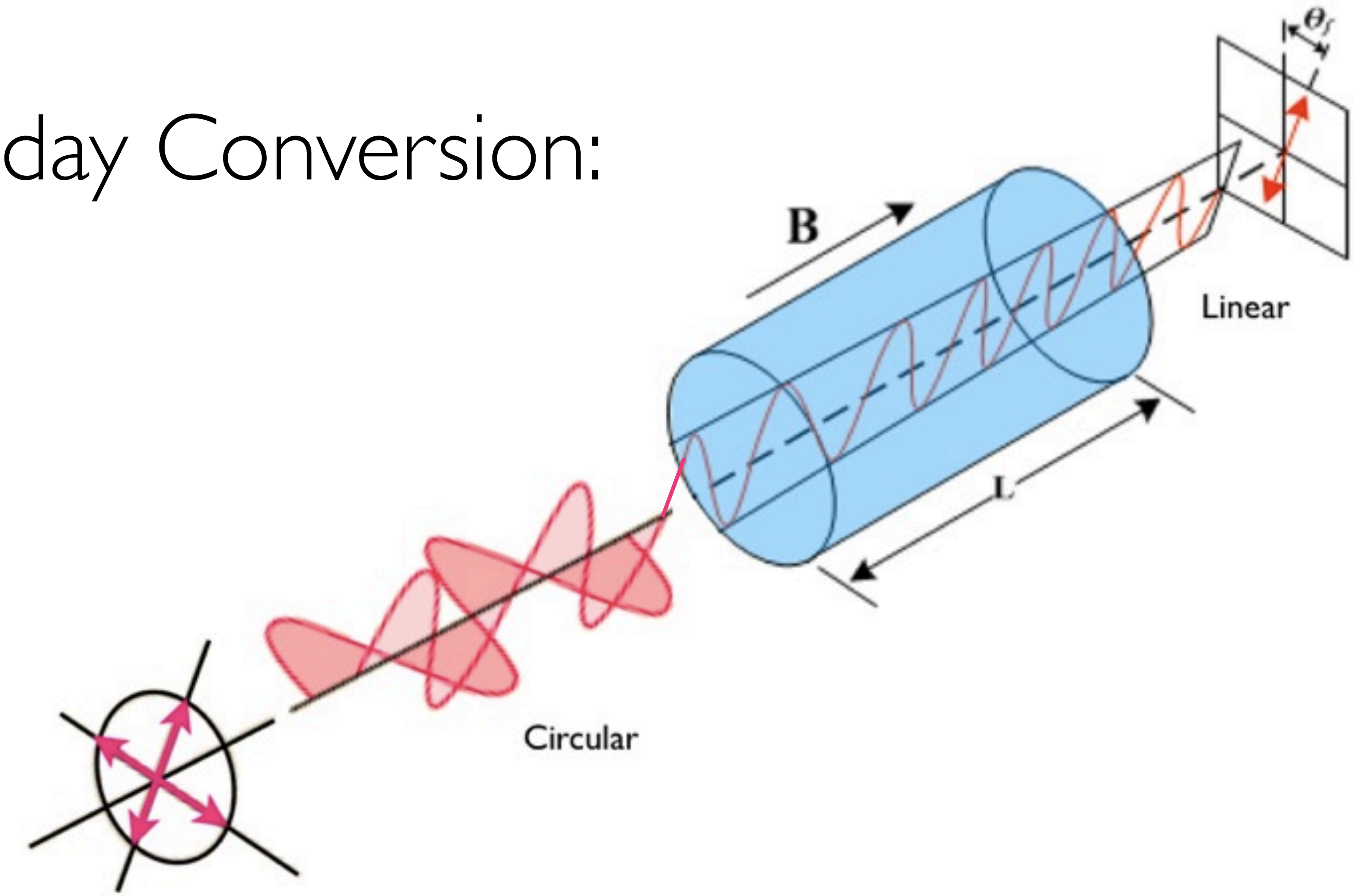
Jones & O'Dell (1977)

Faraday Conversion:



$$\begin{vmatrix} \left(\frac{d}{dl}+\kappa_I\right) & \kappa_Q & \kappa_U & \kappa_V \\ \kappa_Q & \left(\frac{d}{dl}+\kappa_I\right) & {\kappa^*}_V & -{\kappa^*}_U \\ \kappa_U & -{\kappa^*}_V & \left(\frac{d}{dl}+\kappa_I\right) & {\kappa^*}_Q \\ \kappa_V & {\kappa^*}_U & -{\kappa^*}_Q & \left(\frac{d}{dl}+\kappa_I\right) \end{vmatrix} \begin{vmatrix} I_\nu \\ Q_\nu \\ U_\nu \\ V_\nu \end{vmatrix} = \begin{vmatrix} {\eta_\nu}^I \\ {\eta_\nu}^Q \\ {\eta_\nu}^U \\ {\eta_\nu}^V \end{vmatrix}$$

Jones & O'Dell (1977)

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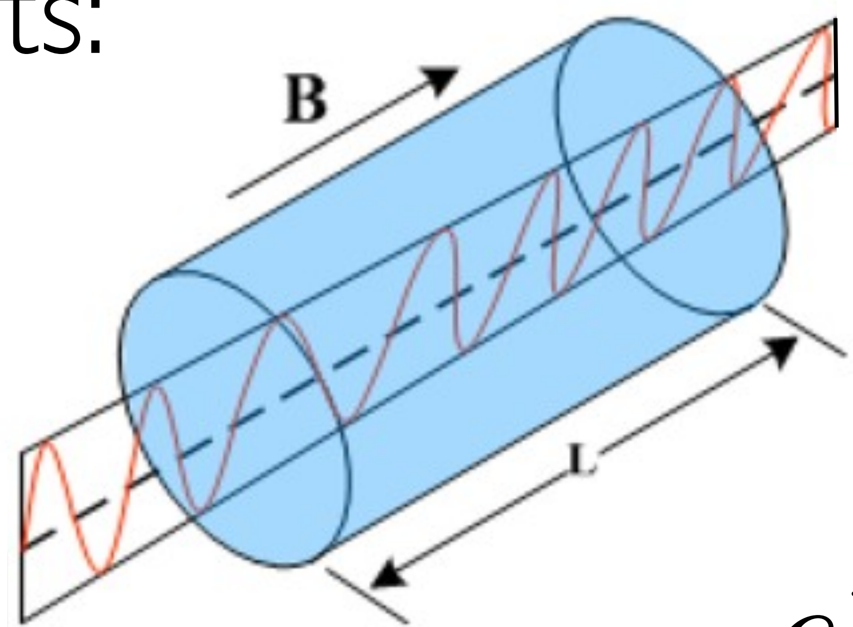
Jones & O'Dell (1977)

Optical Depth Effects:



$$e^{-\tau}$$

The Full Stokes Equations for Radiative Transfer of Polarized Emission:

$$\begin{vmatrix} I_\nu \\ \\ Q_\nu \\ \\ U_\nu \\ \\ V_\nu \end{vmatrix} = \begin{vmatrix} {I_\nu}^\infty \\ \\ {Q_\nu}^\infty \\ \\ {U_\nu}^\infty \\ \\ {V_\nu}^\infty \end{vmatrix} + e^{-\tau} \left\{ \begin{matrix} \text{A lot of math!} \\ (\ B,\ \theta,\ L,\ \nu,\ n_o,\ \alpha,\ \gamma_{\min}\ ) \end{matrix} \right\} \begin{vmatrix} {I_\nu}^0 - {I_\nu}^\infty \\ \\ {Q_\nu}^0 - {Q_\nu}^\infty \\ \\ {U_\nu}^0 - {U_\nu}^\infty \\ \\ {V_\nu}^0 - {V_\nu}^\infty \end{vmatrix}$$

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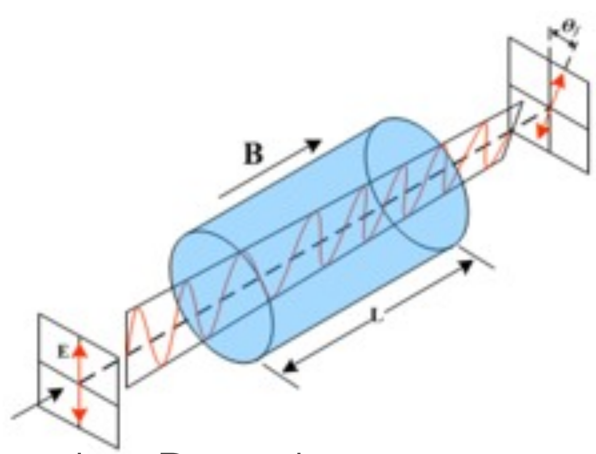
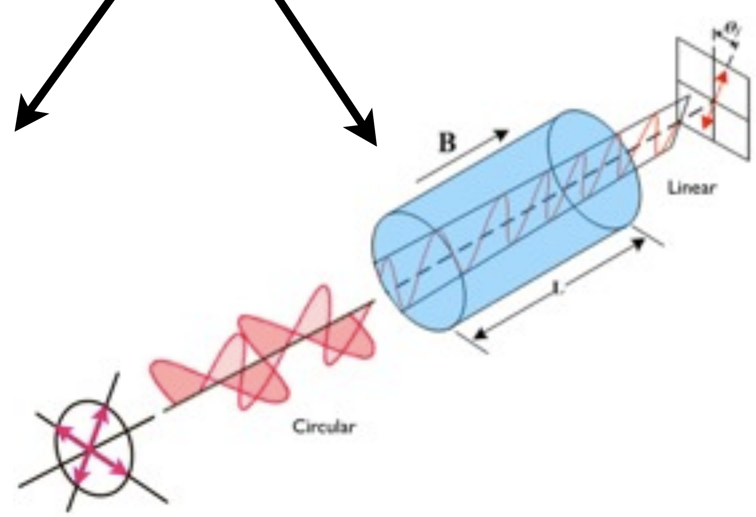


Faraday Rotation



Faraday Conversion

Jones & O'Dell (1977)

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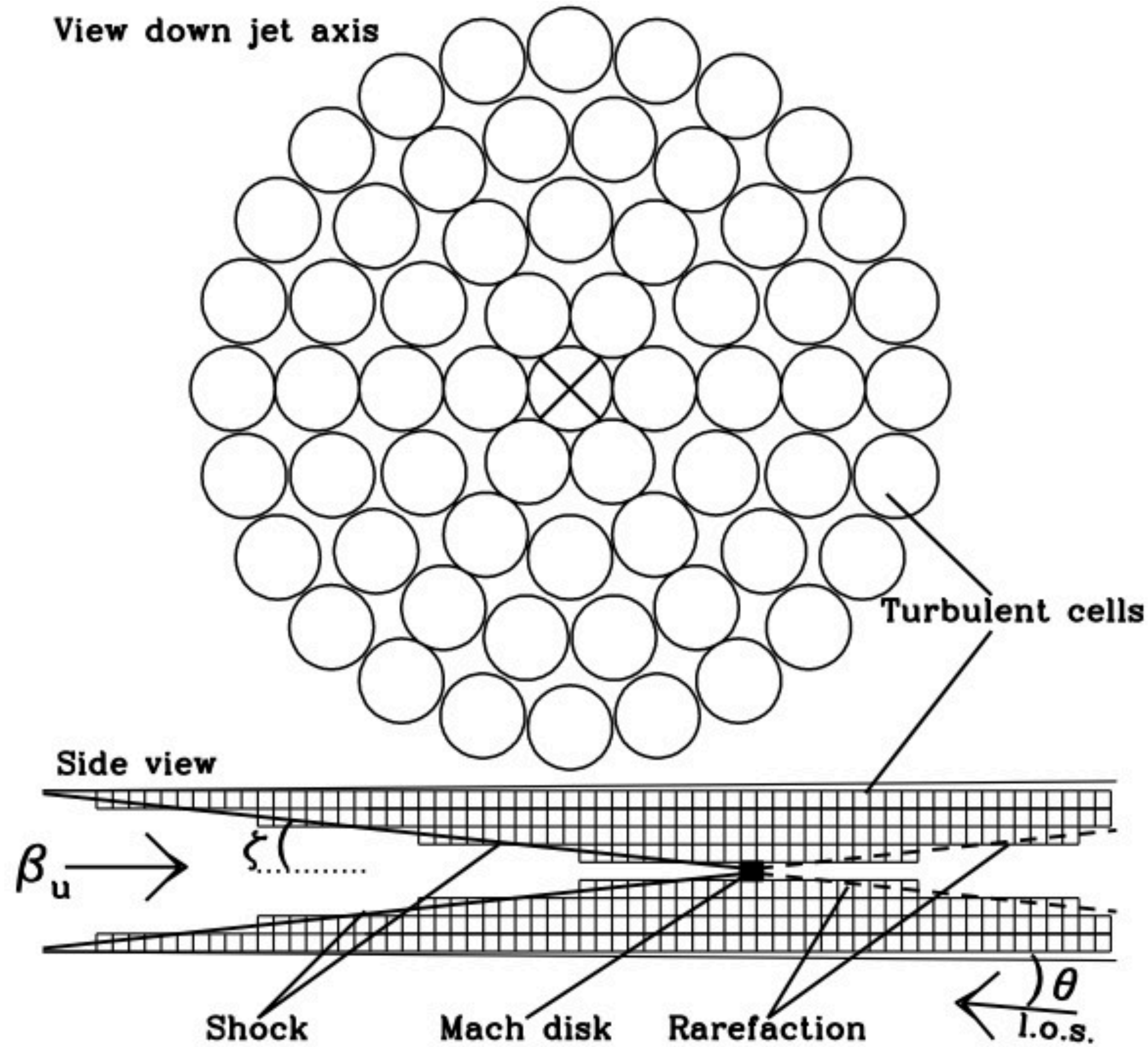

Marscher (2014)

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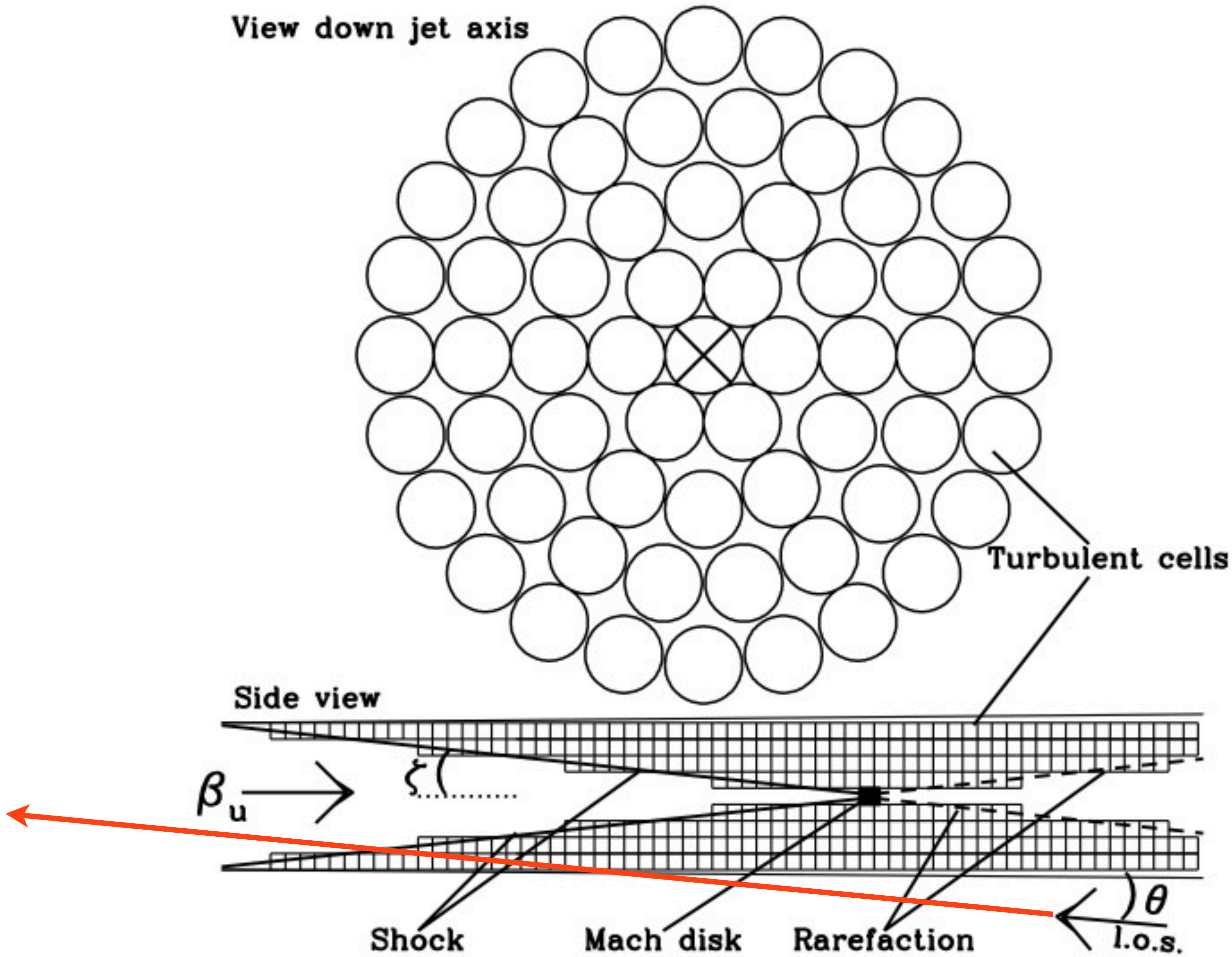
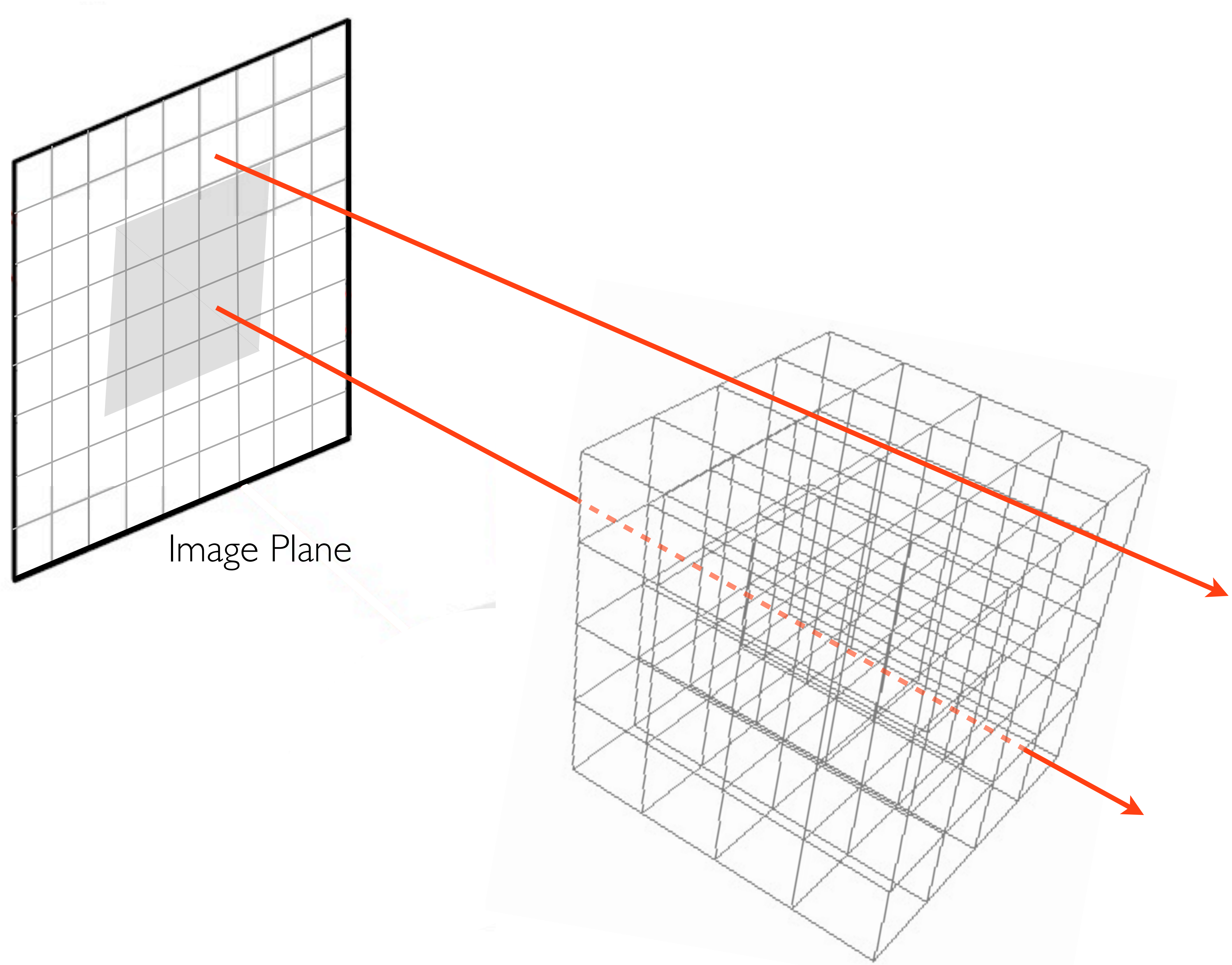


Marscher (2014)

Ray Tracing Algorithm:



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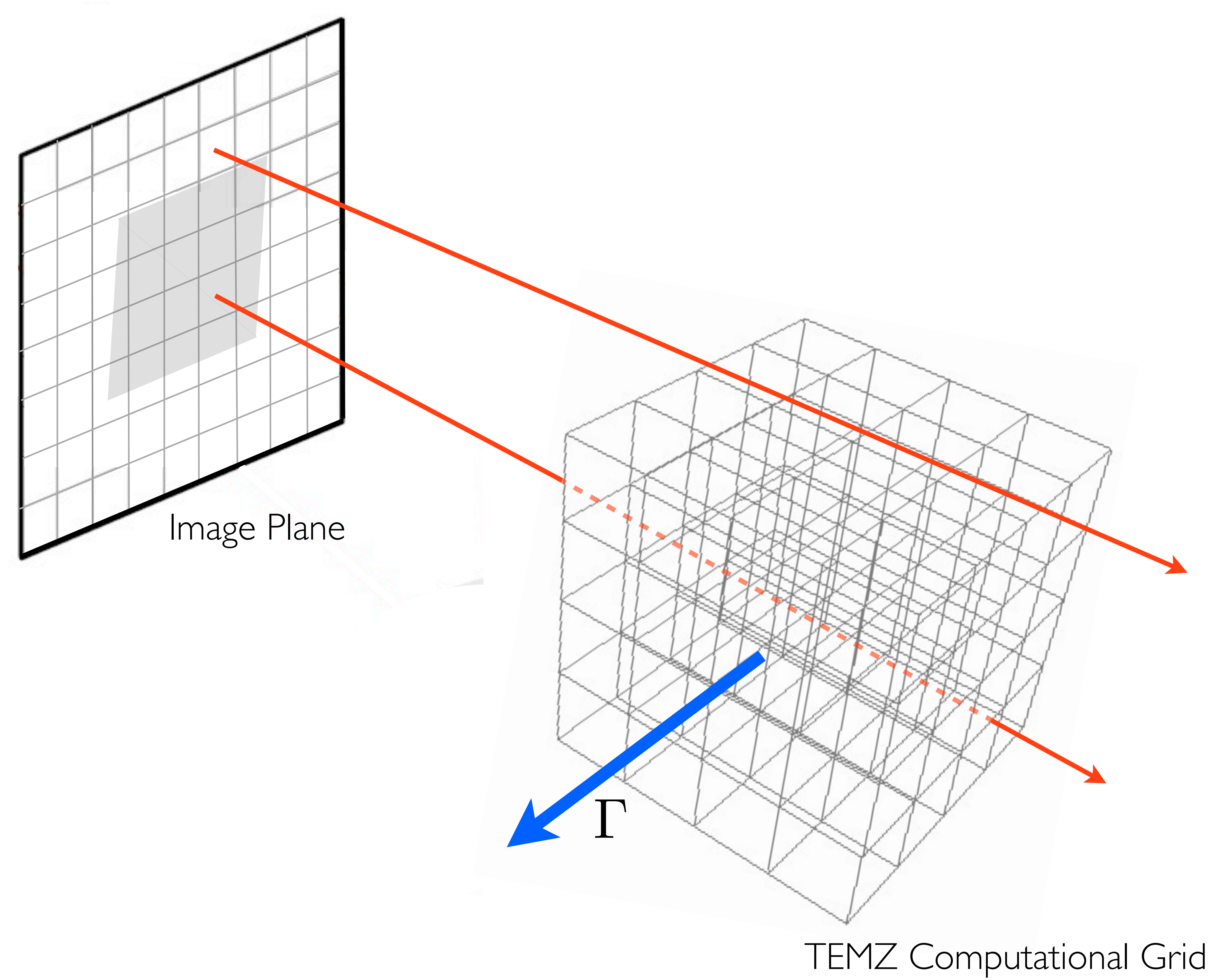

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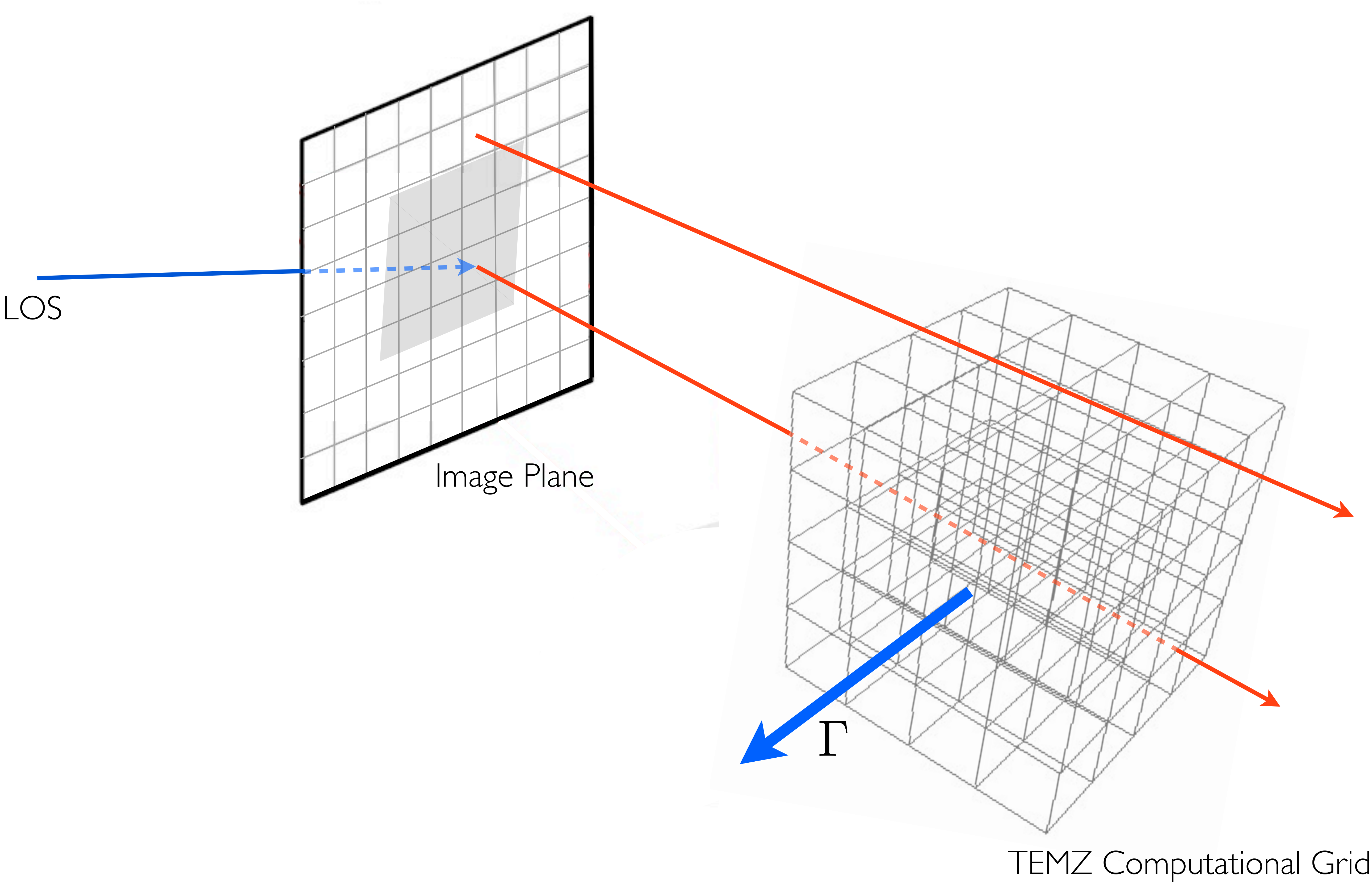

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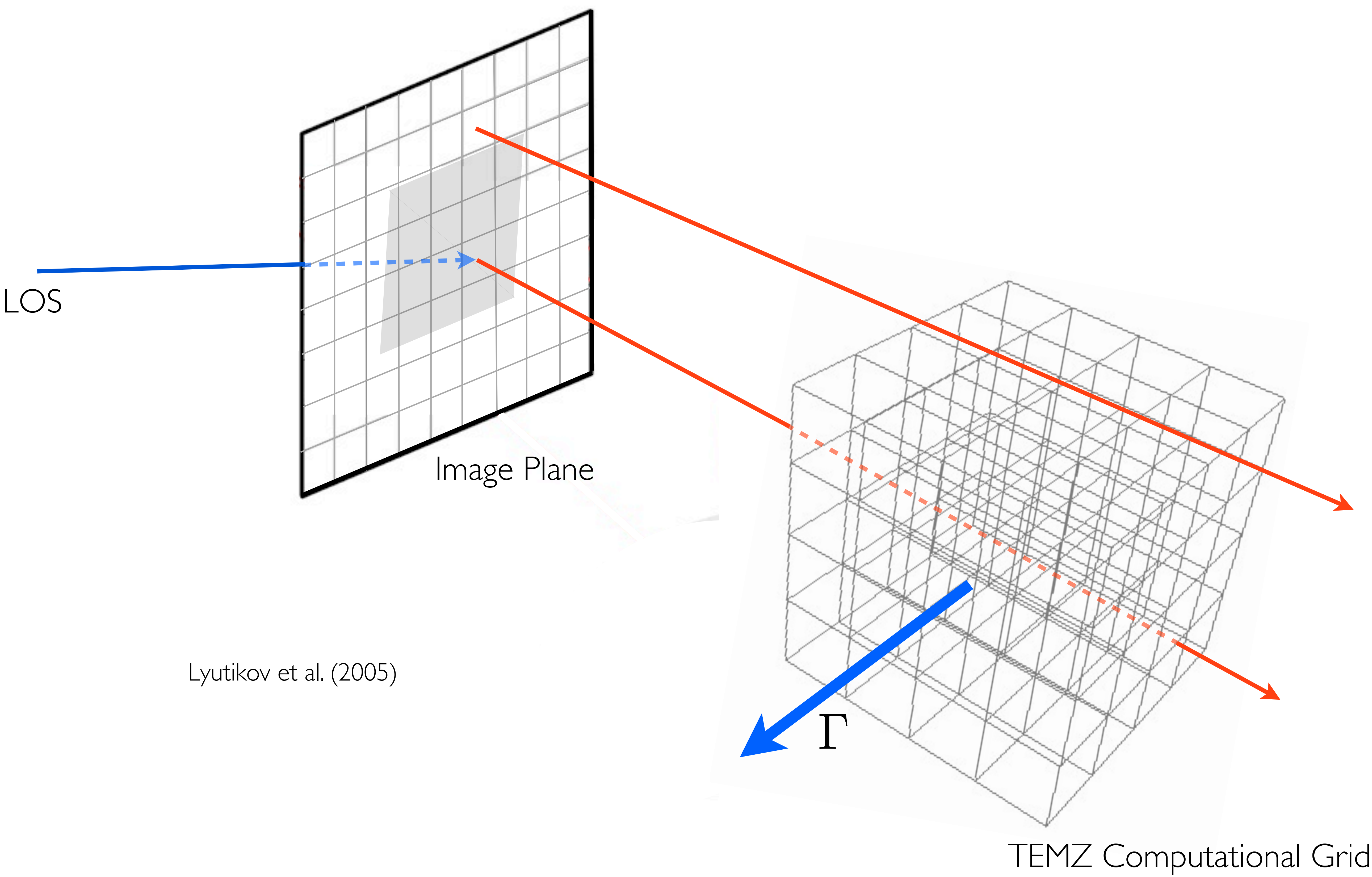
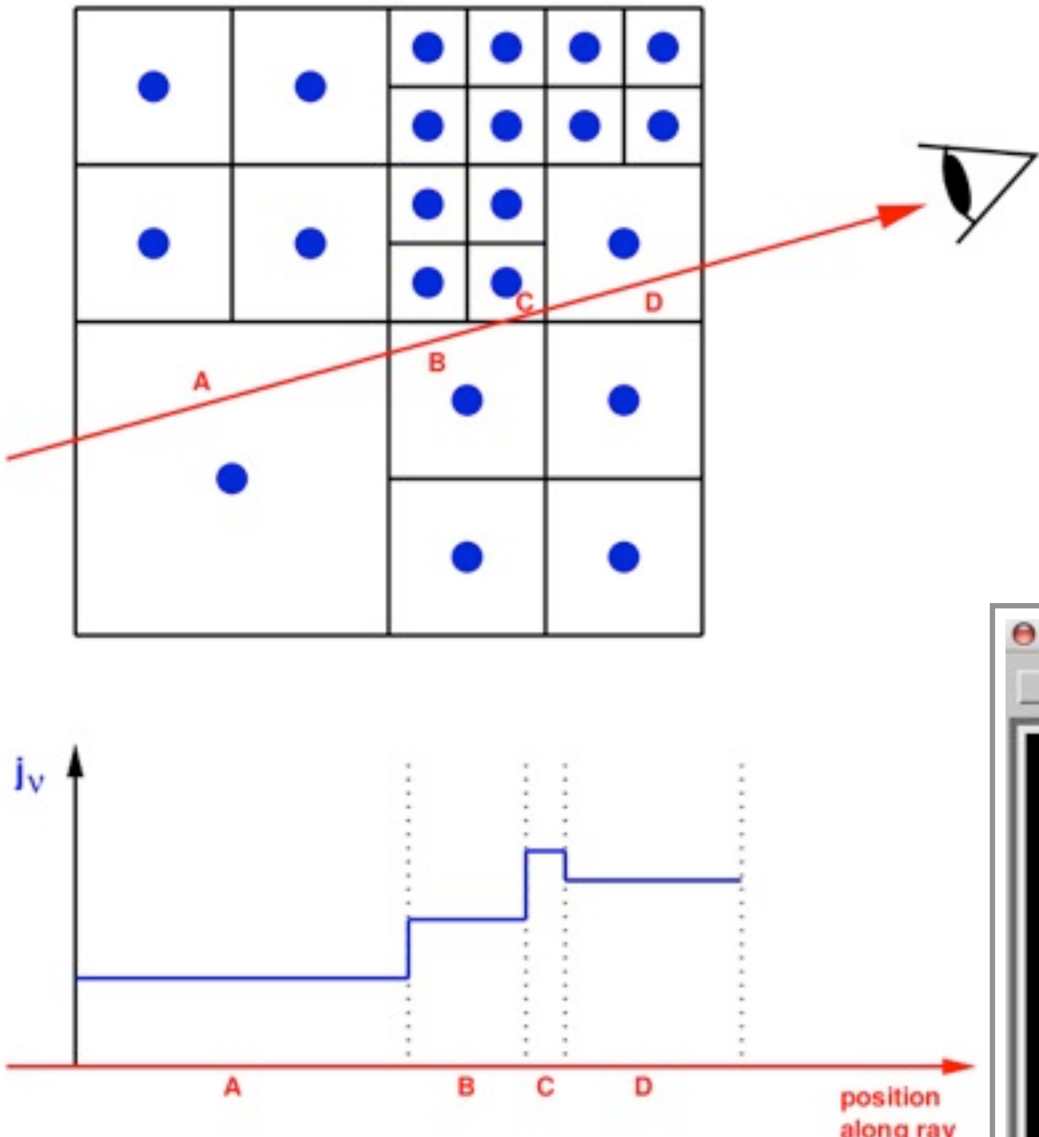
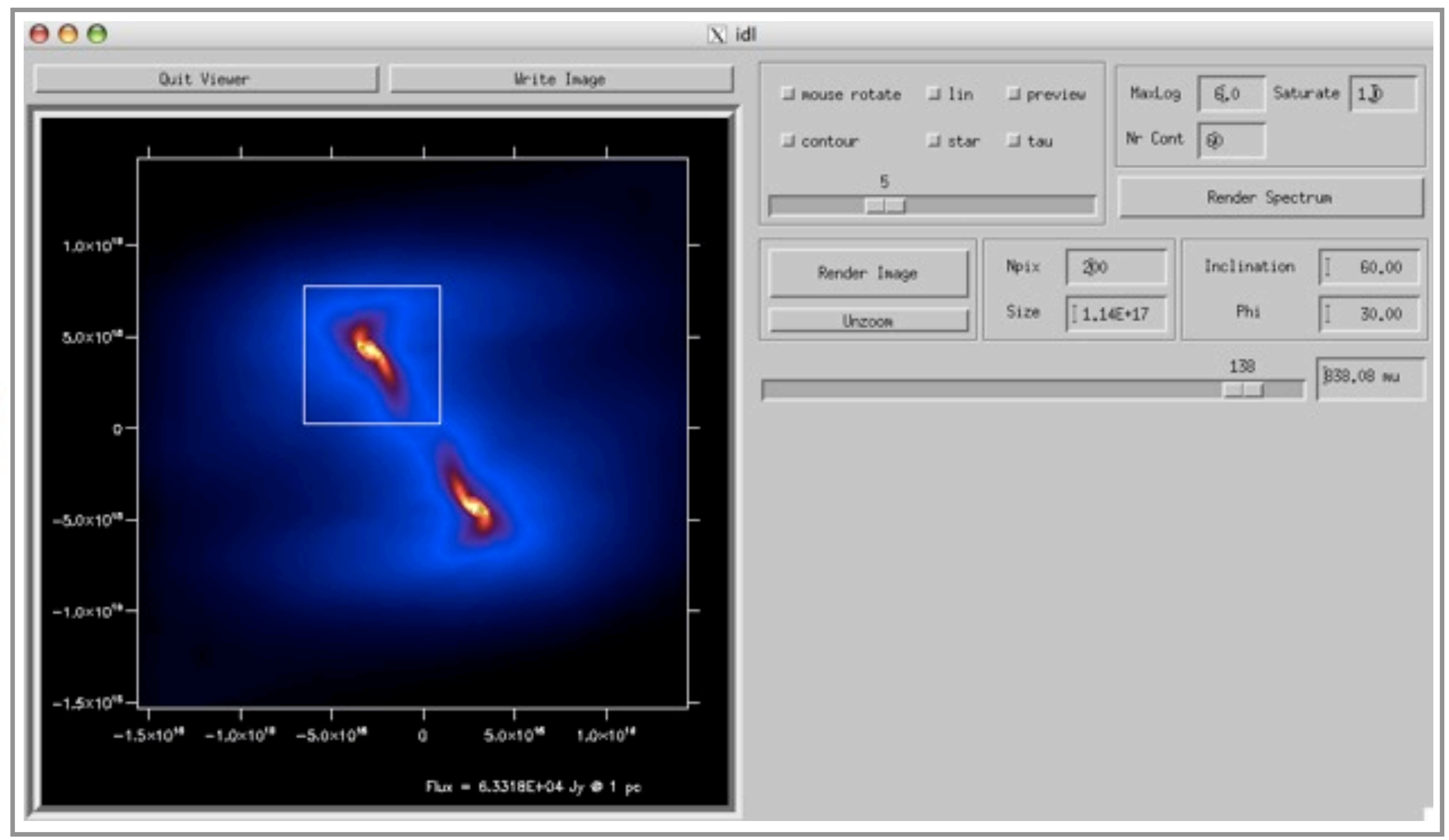


Lyutikov et al. (2005)

The RADMC-3D Code:

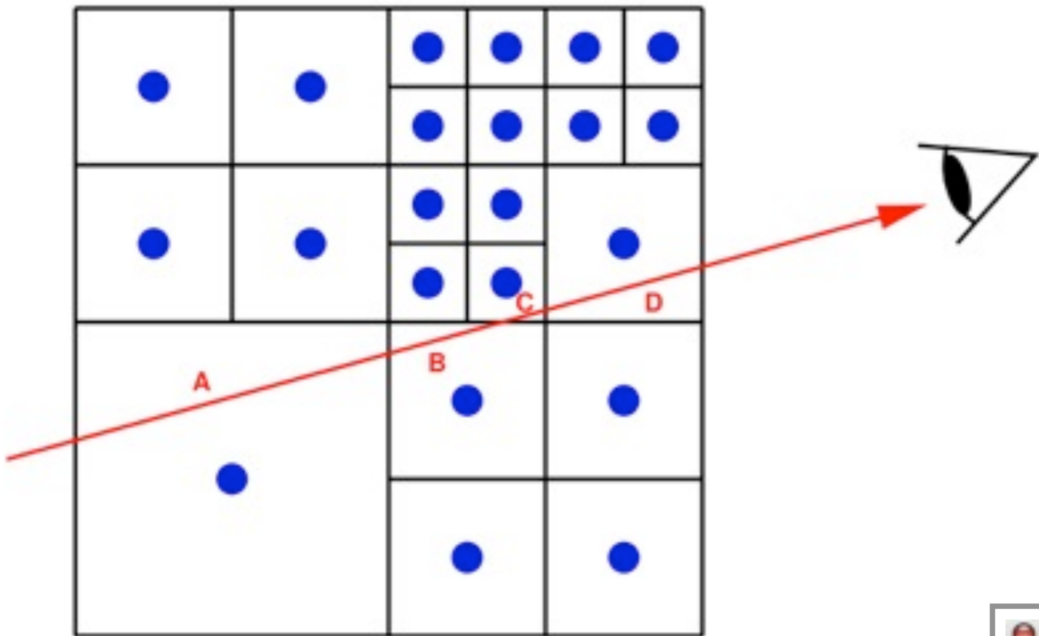


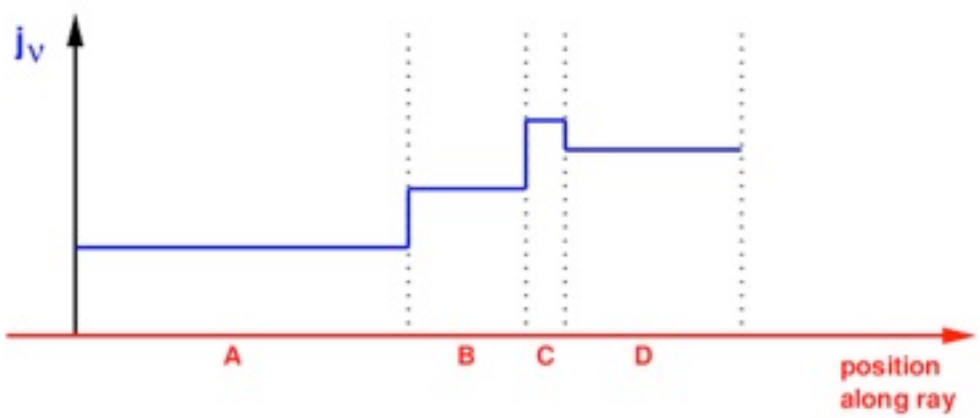


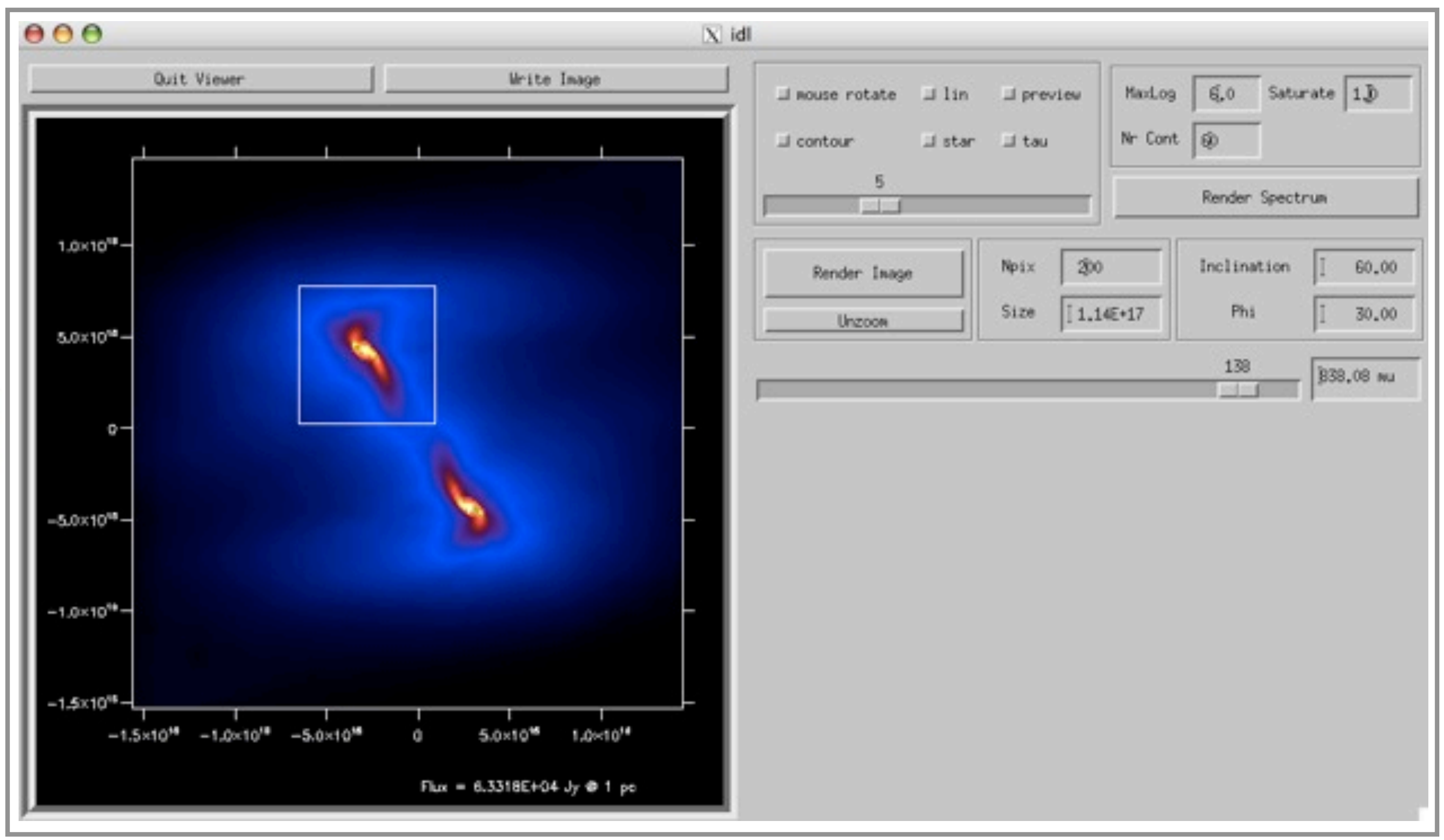
Dullemond (2015)

The RADMC-3D Code:

MAX-PLANCK-GESELLSCHAFT





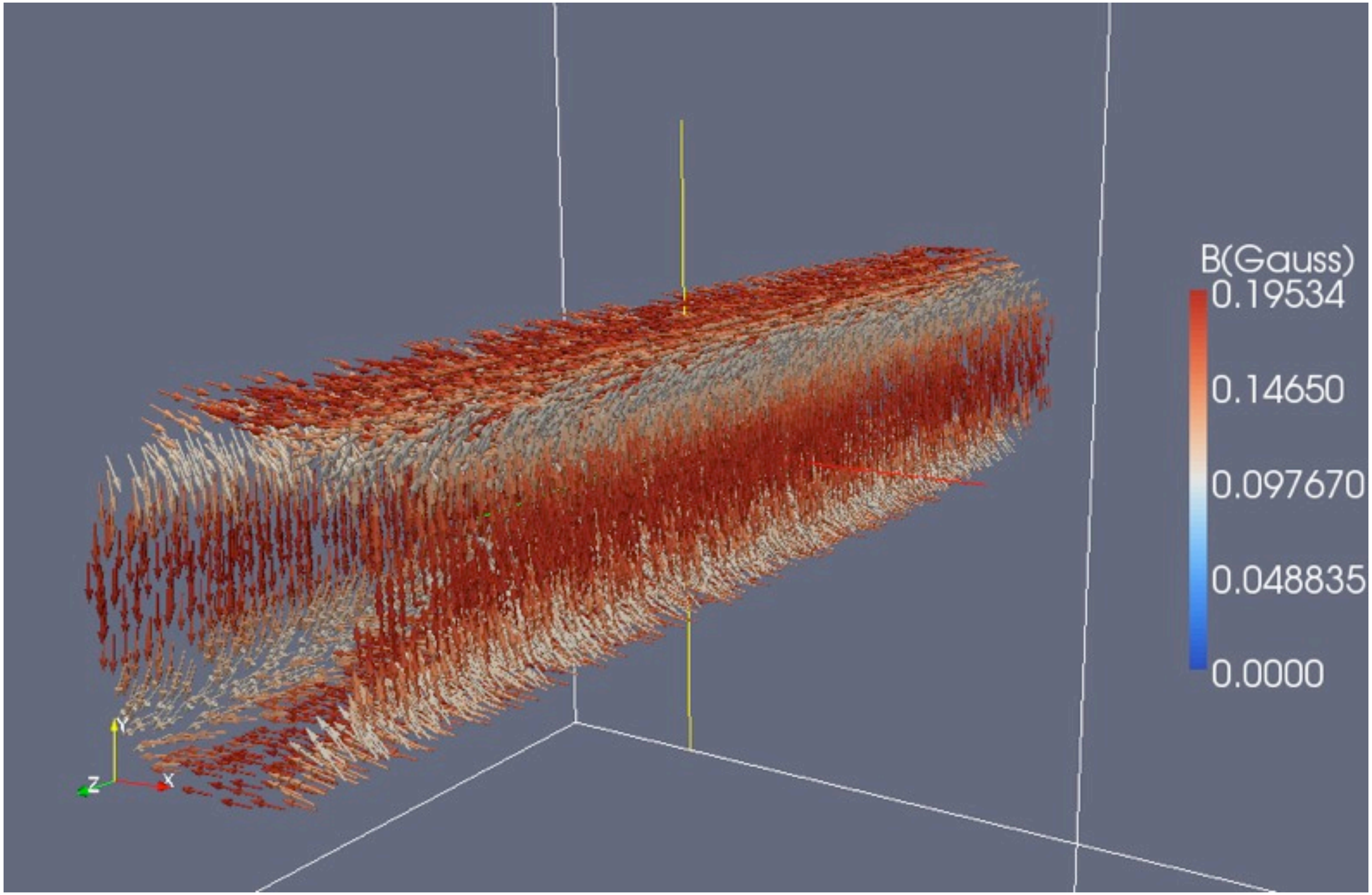


radmc3dPy

Attila Juhasz

Dullemond (2015)

TEMZ Model (Order):



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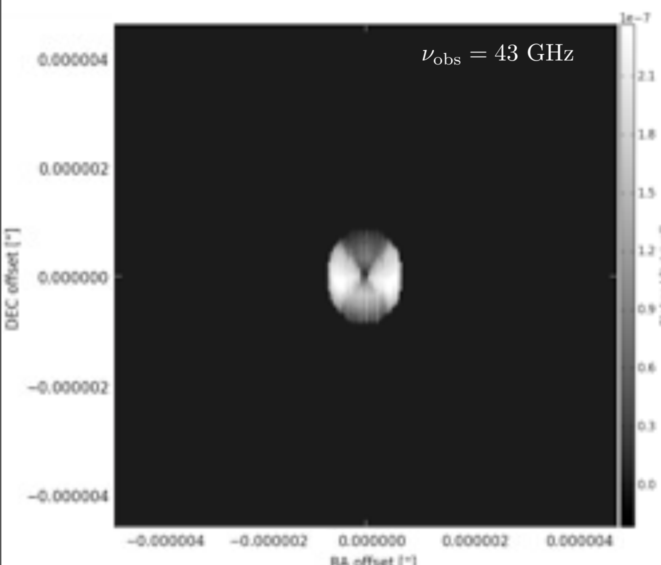
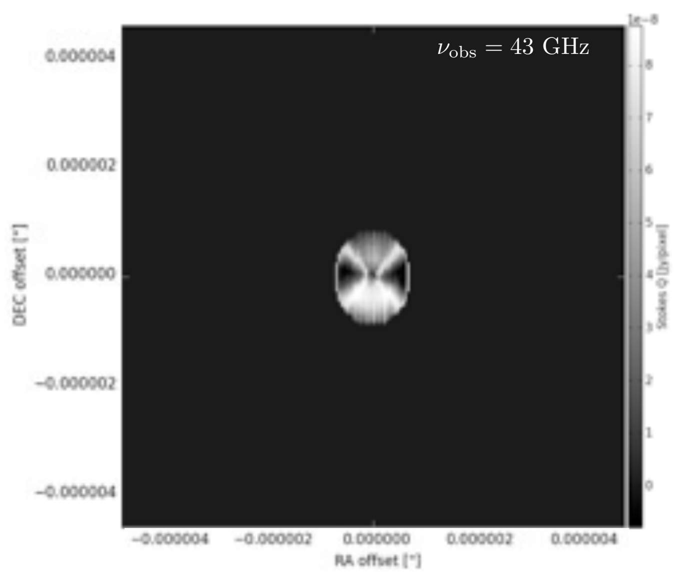
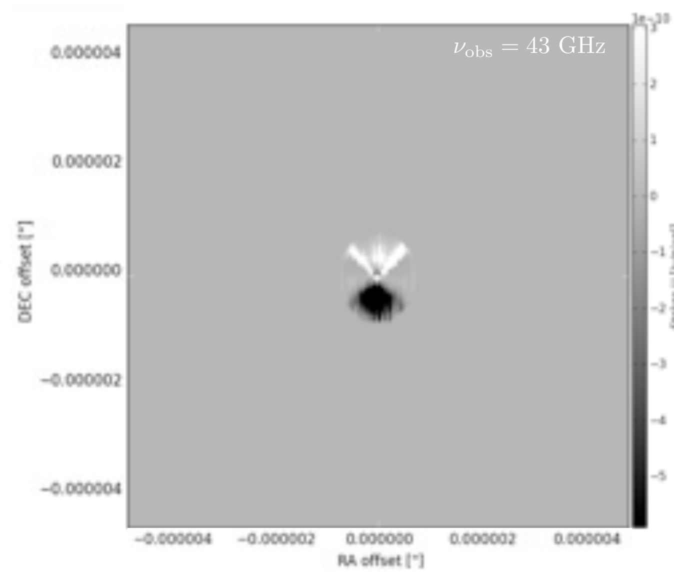


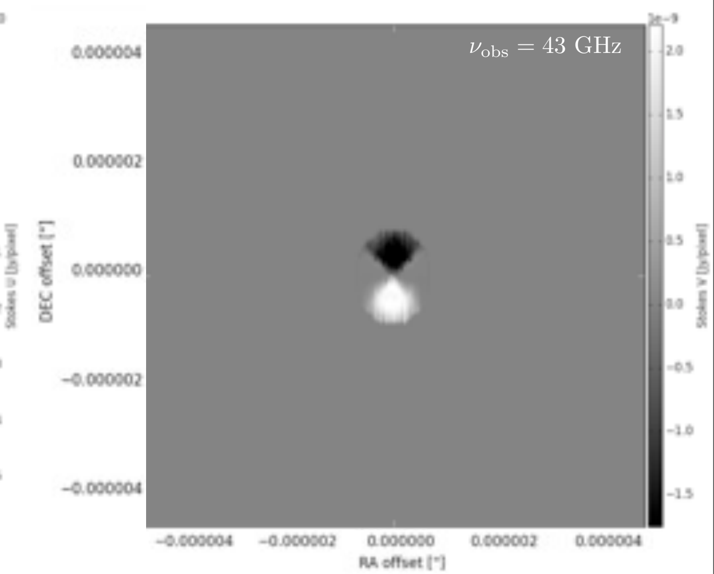
I_ν



Q_ν

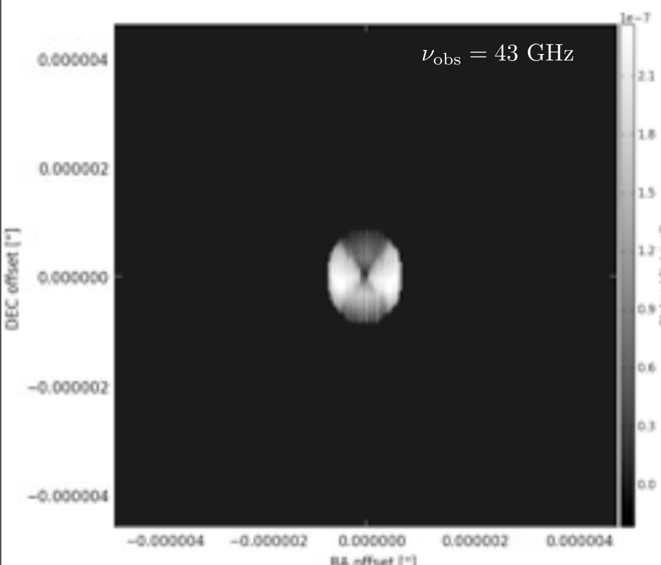


U_ν

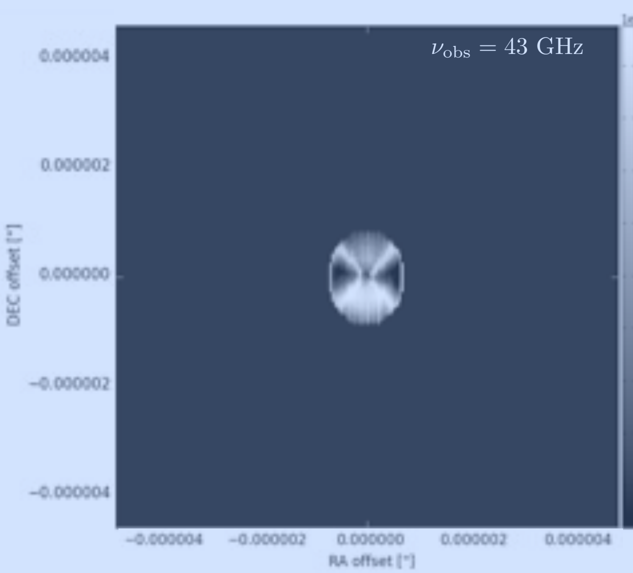


V_ν

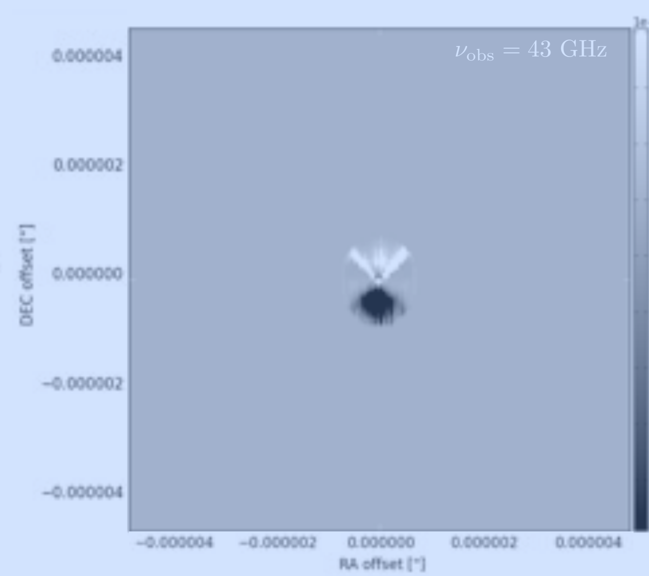
TEMZ Model (Order):



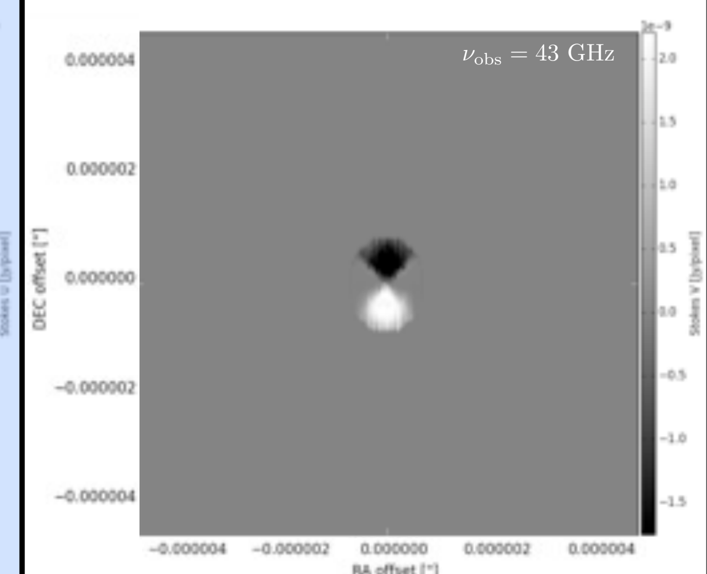
I_ν



Q_ν

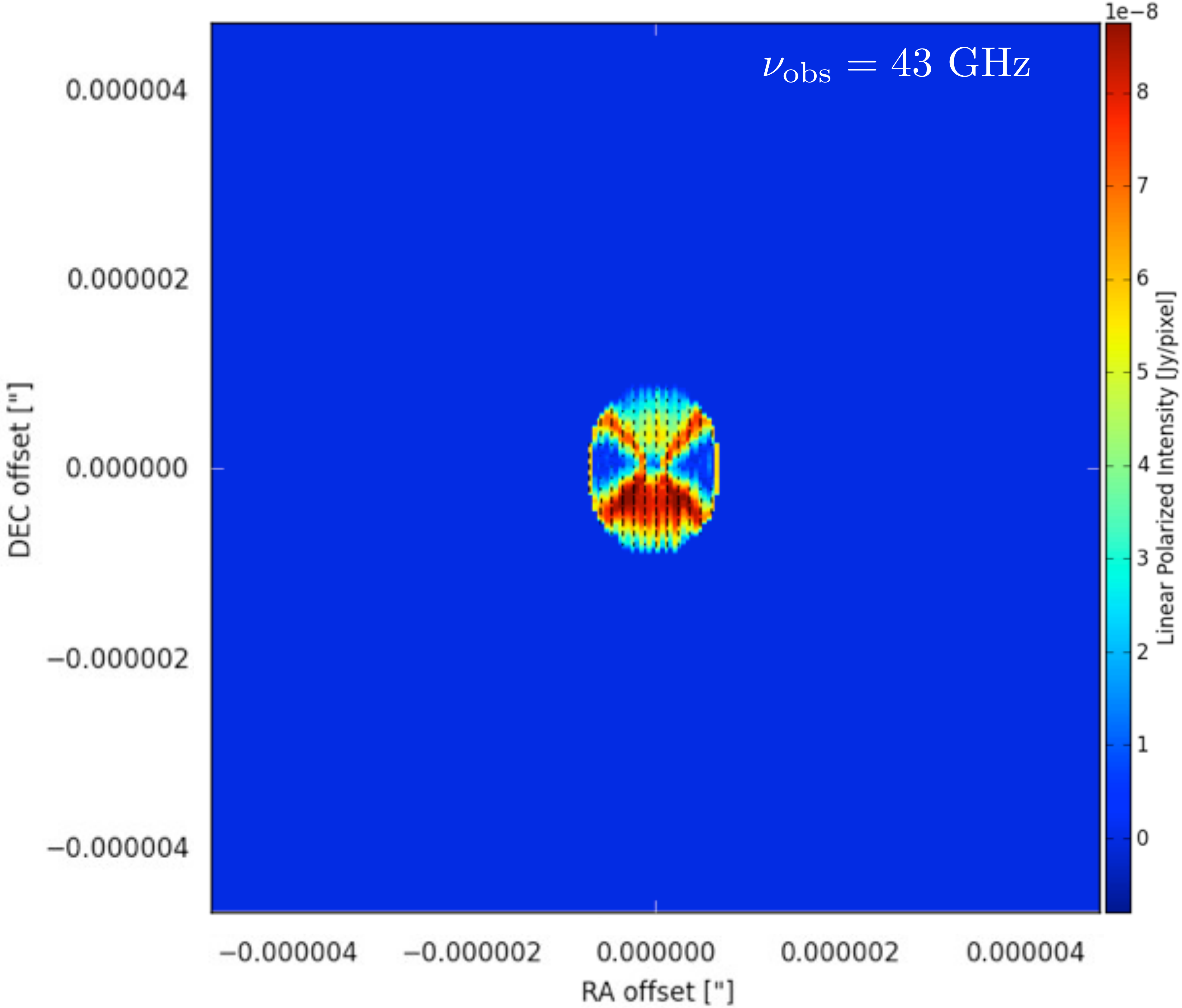


U_ν



V_ν

TEMZ Model (Order):



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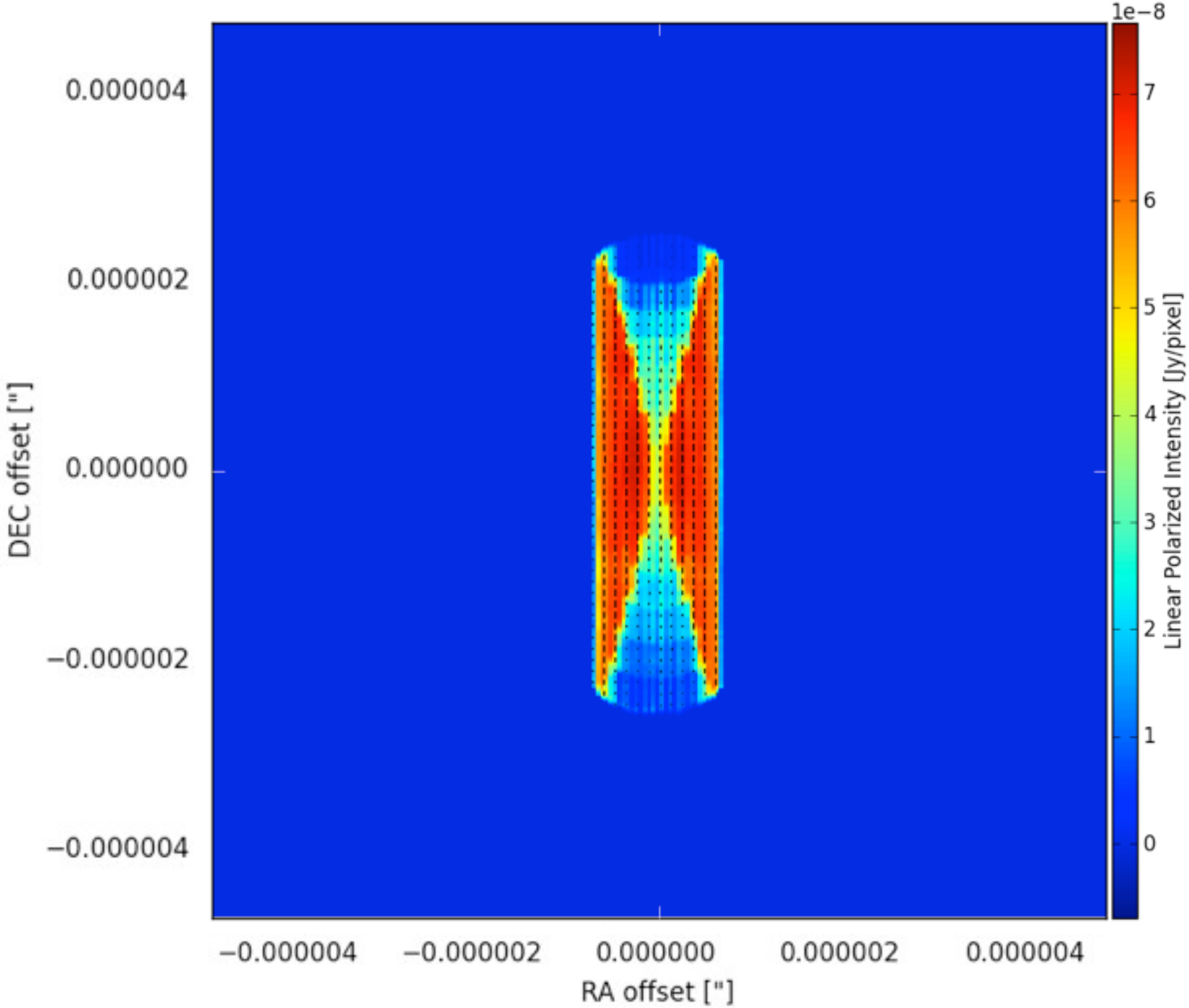

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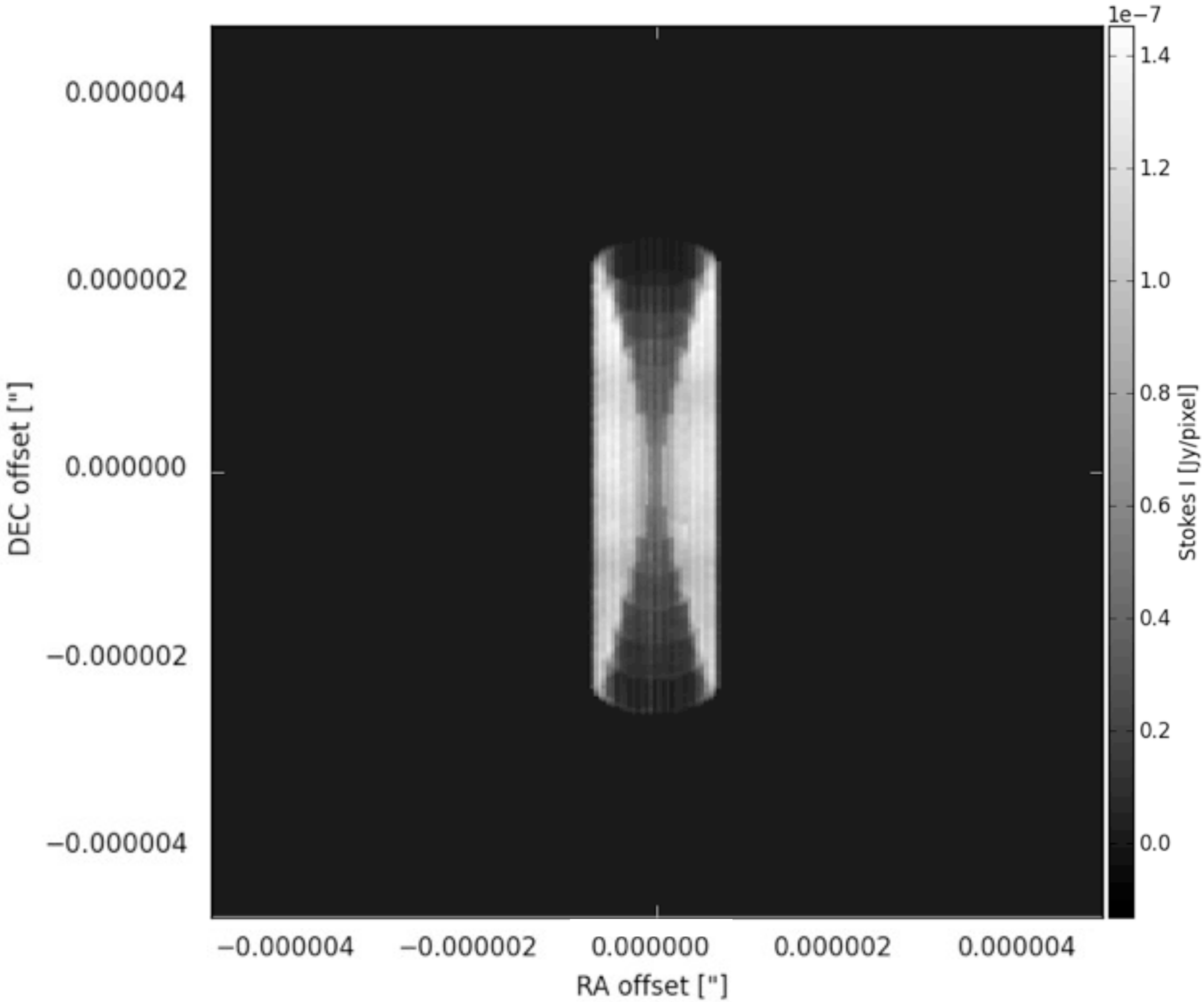

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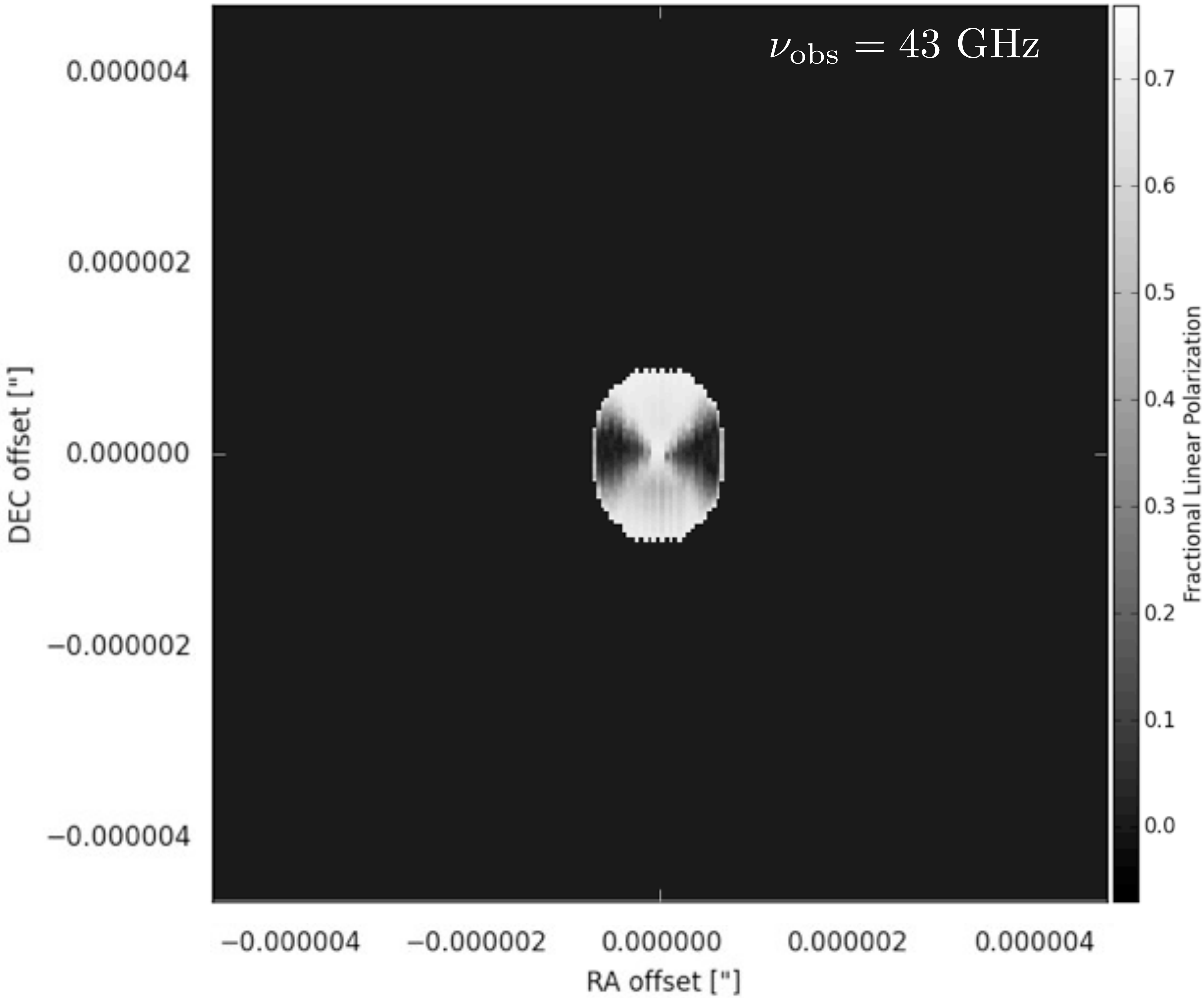

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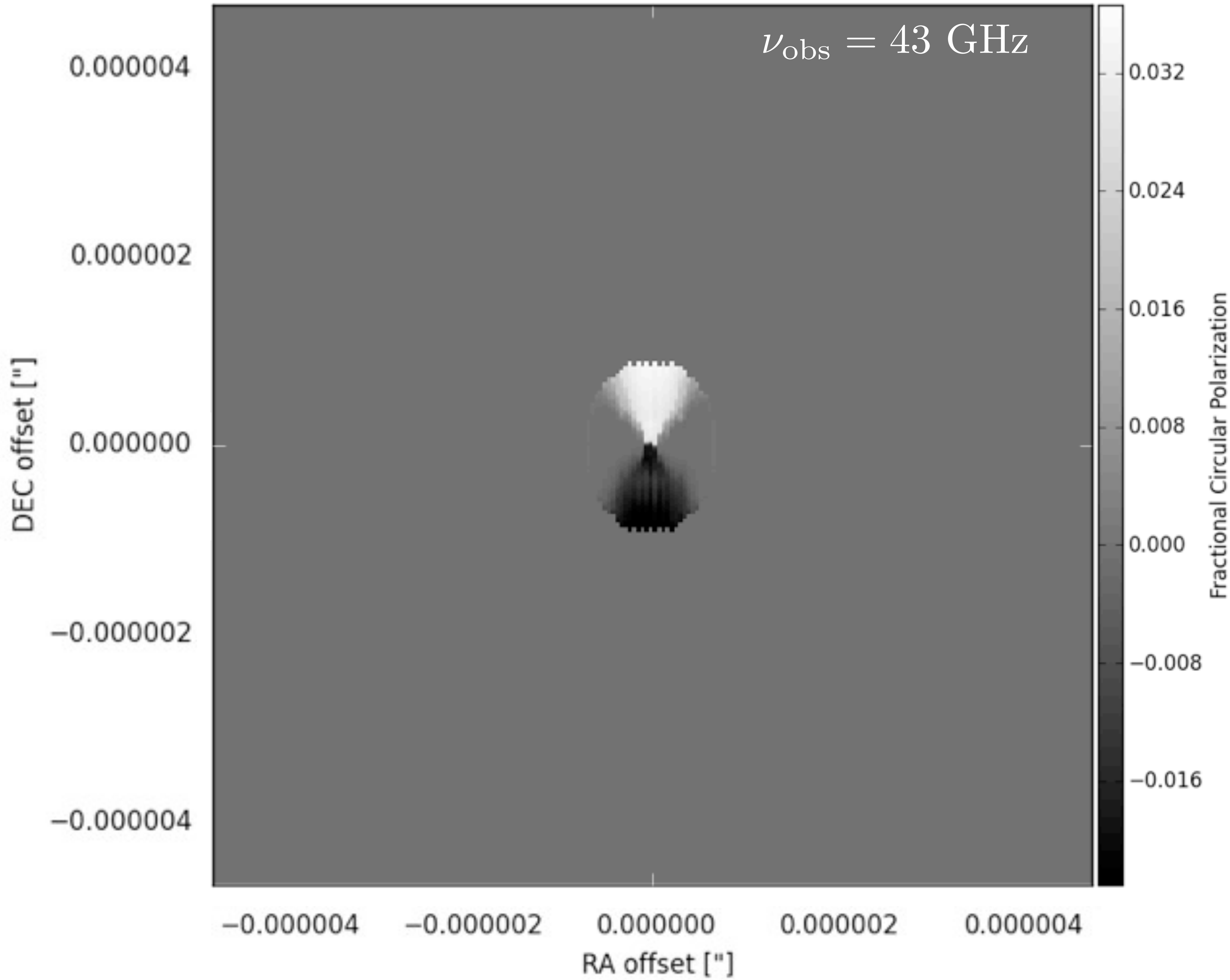

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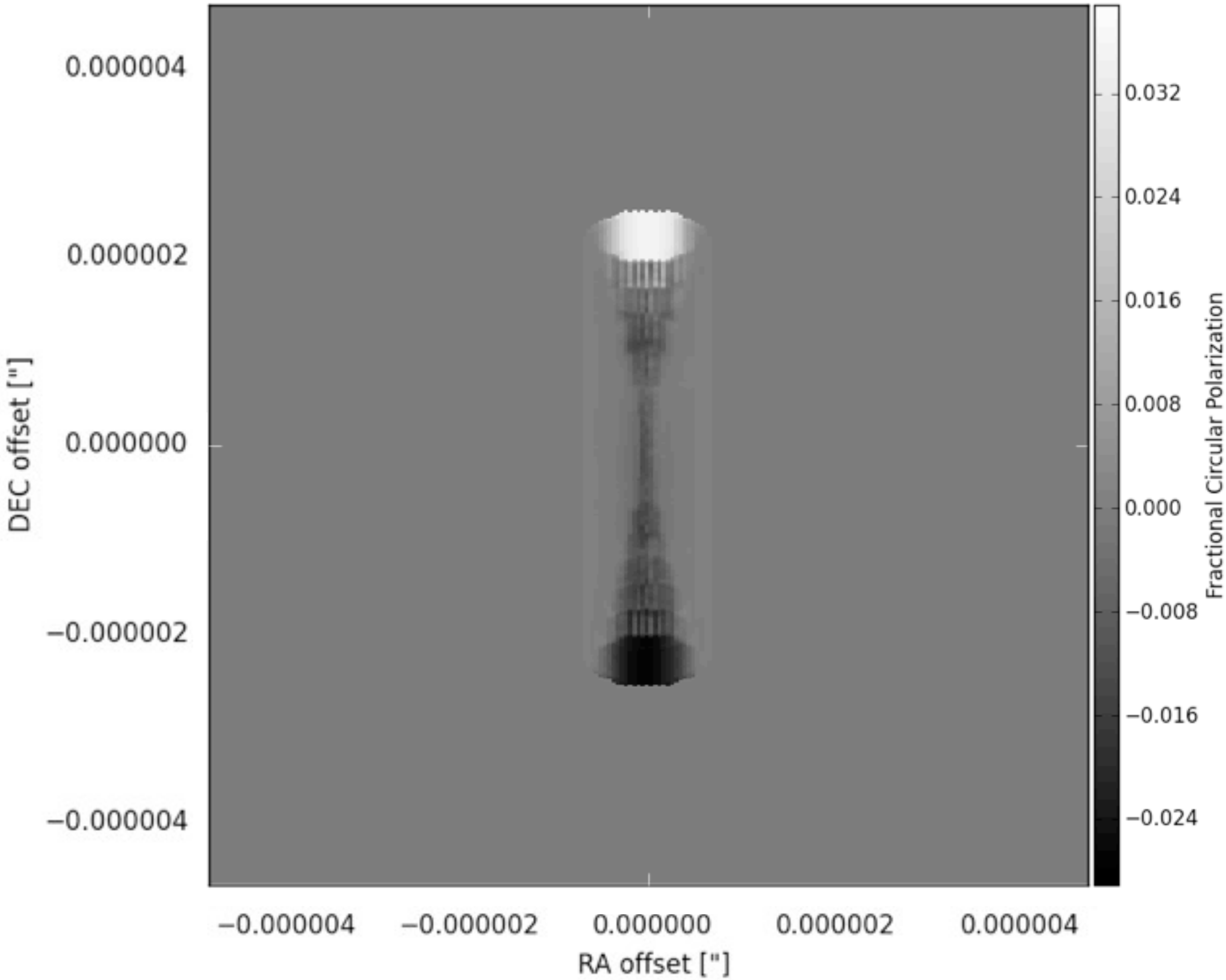

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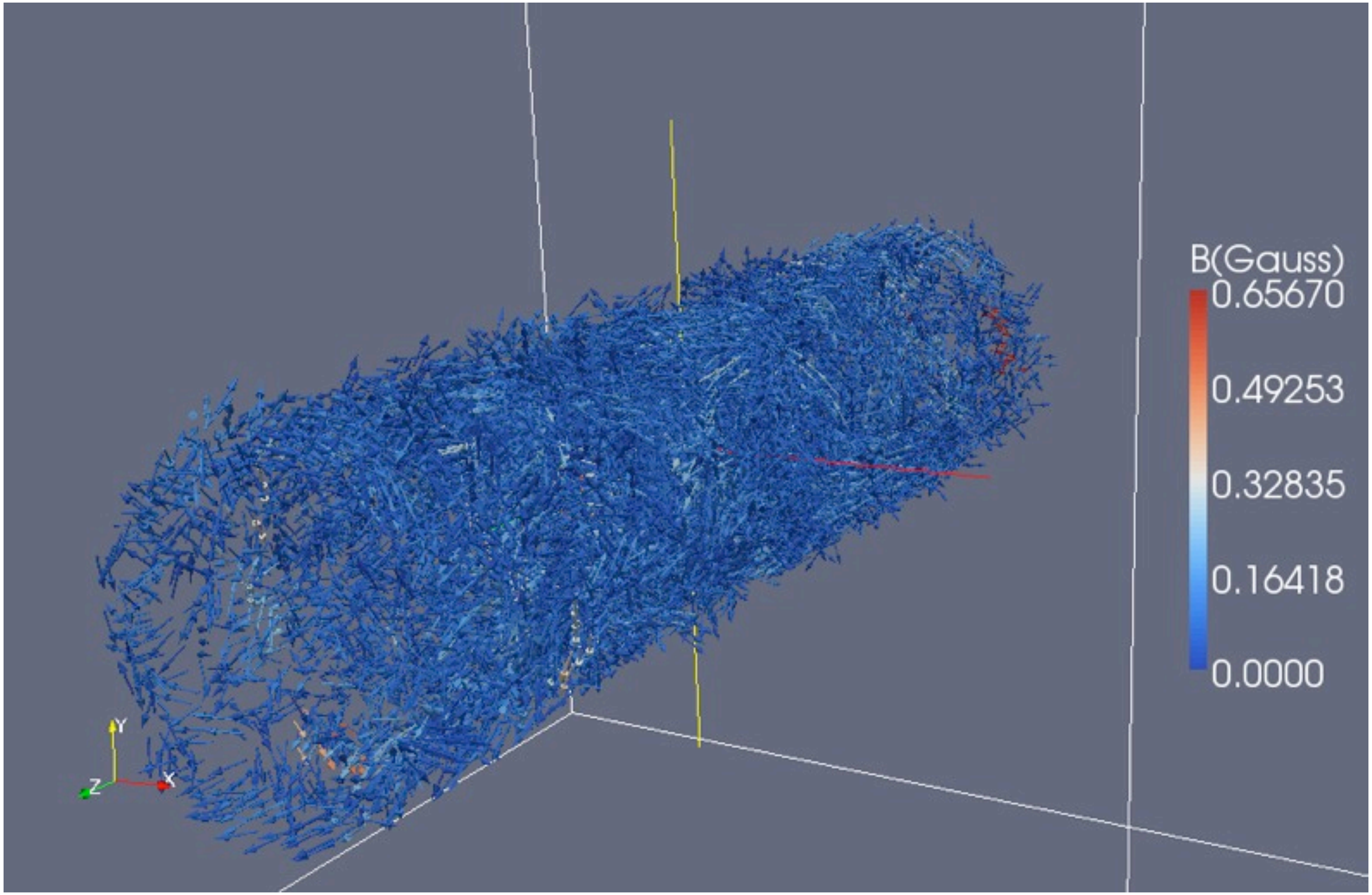

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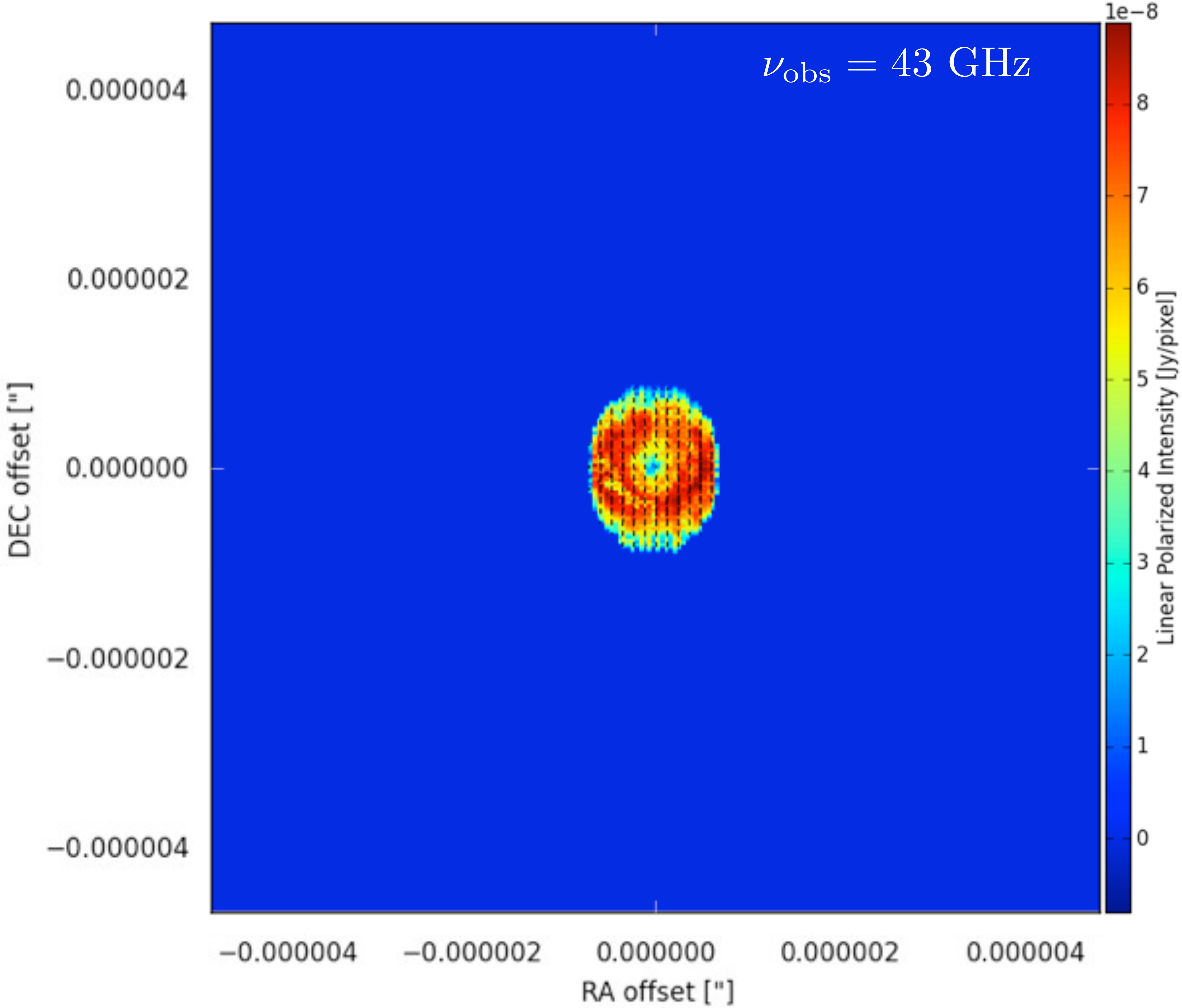

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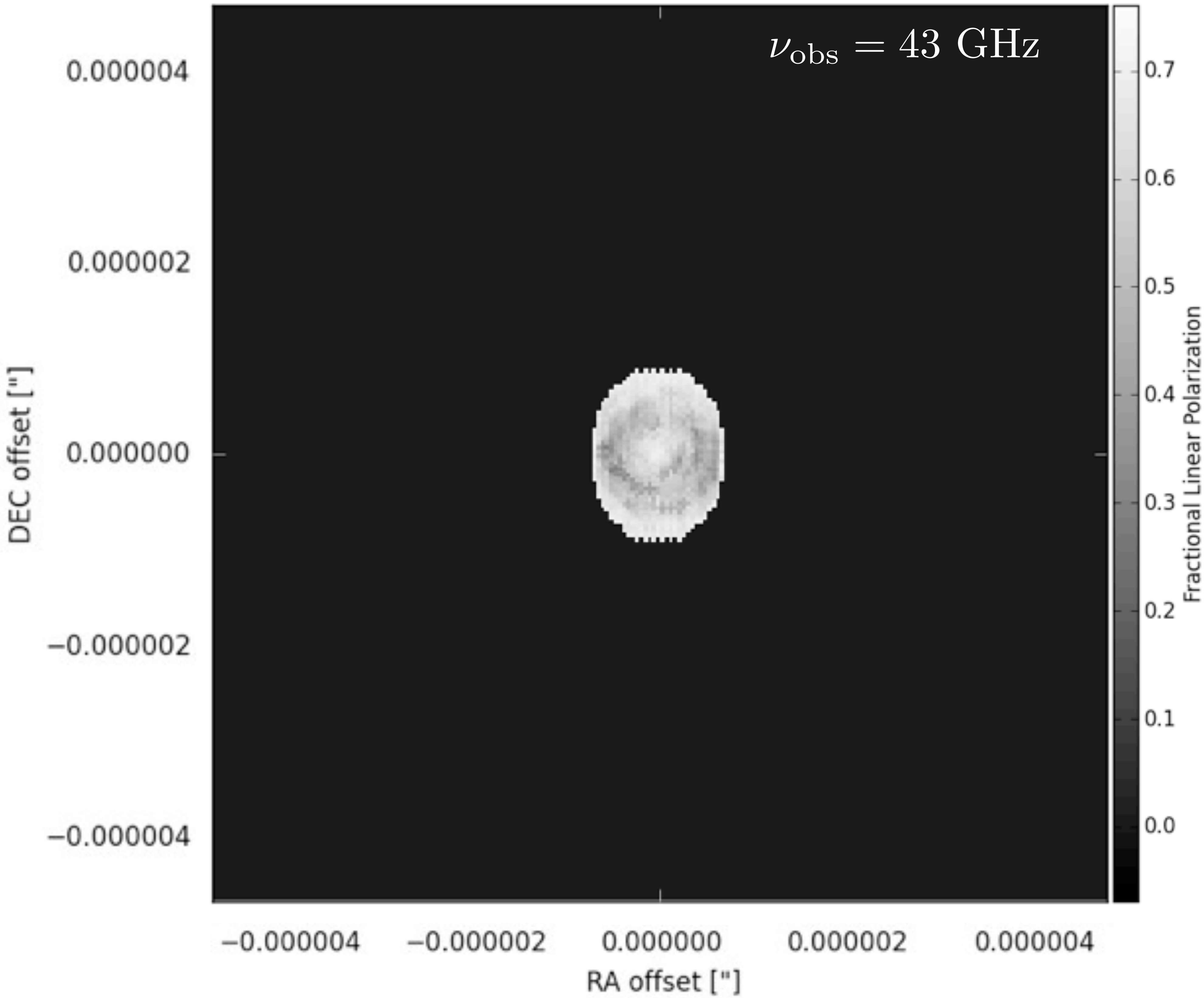

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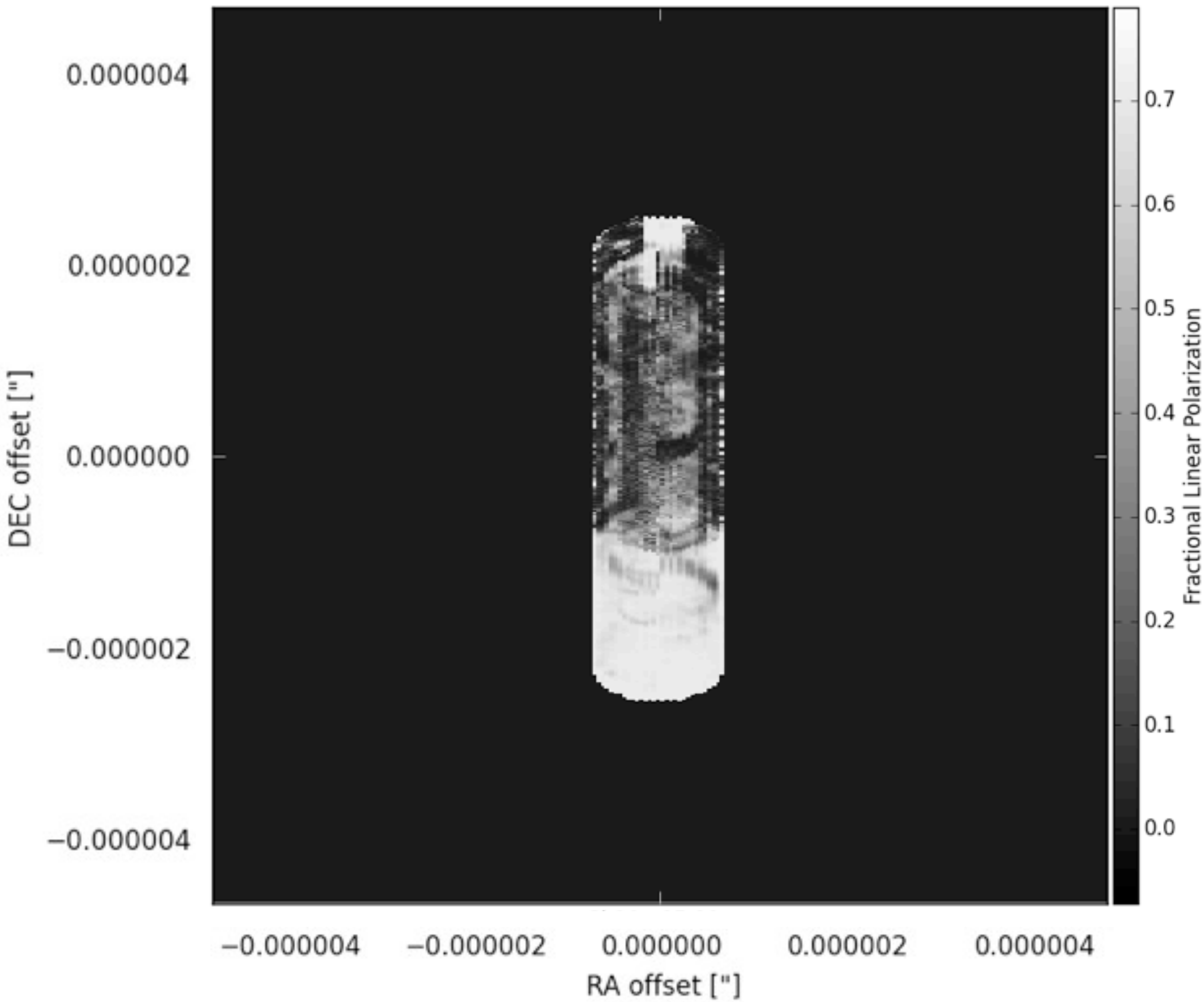

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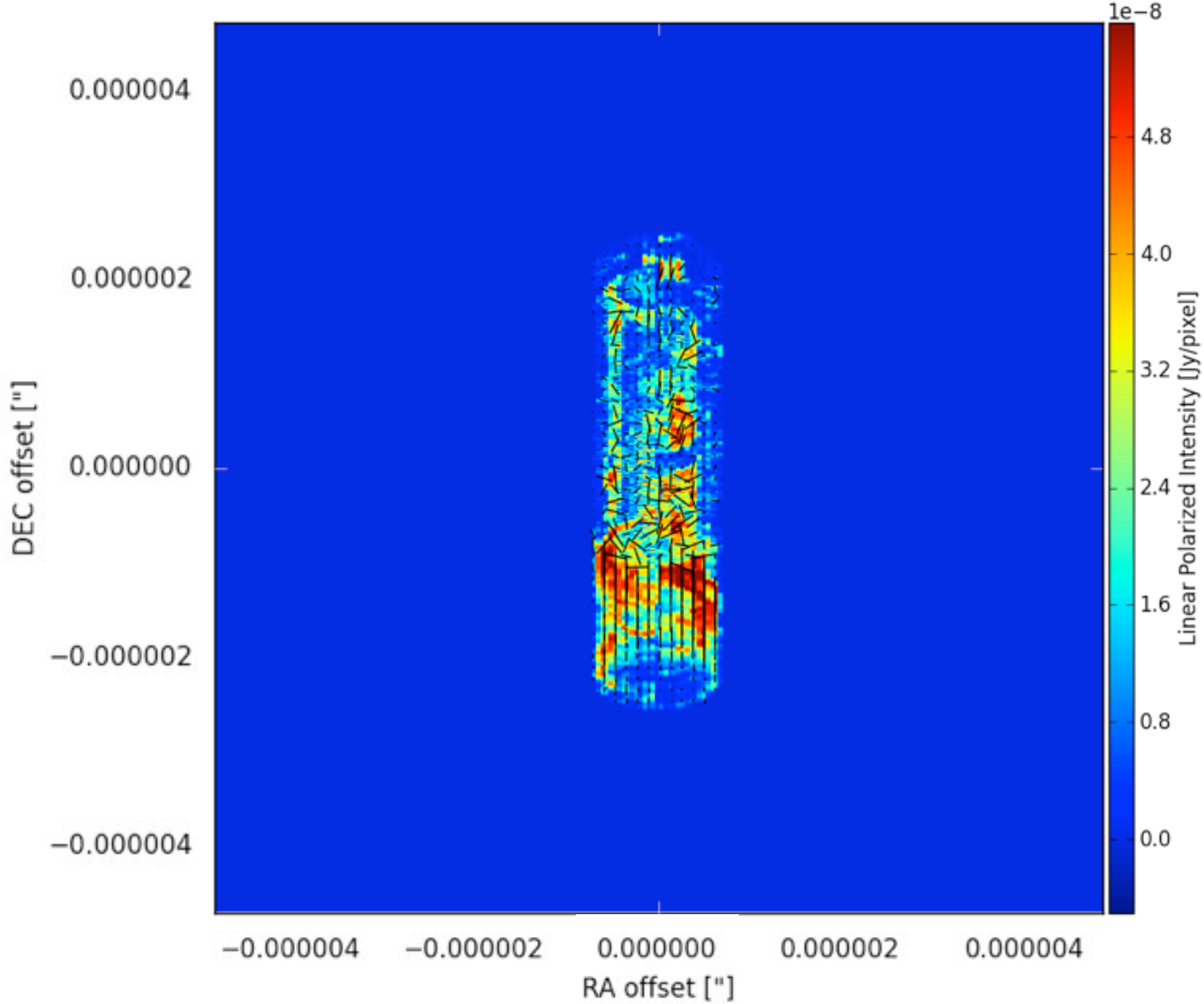

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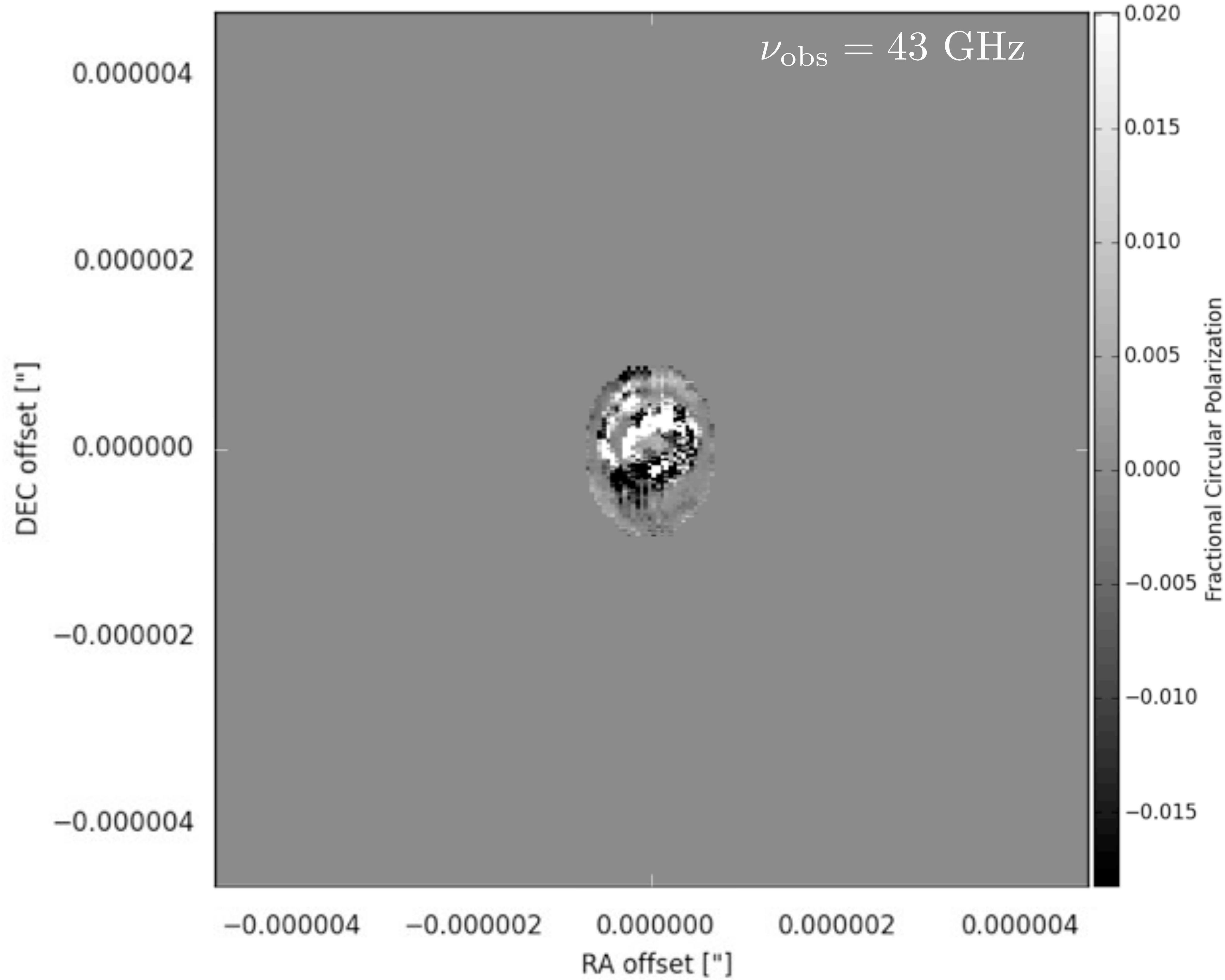

Can circular polarization be produced within a turbulent jet?


Questions?