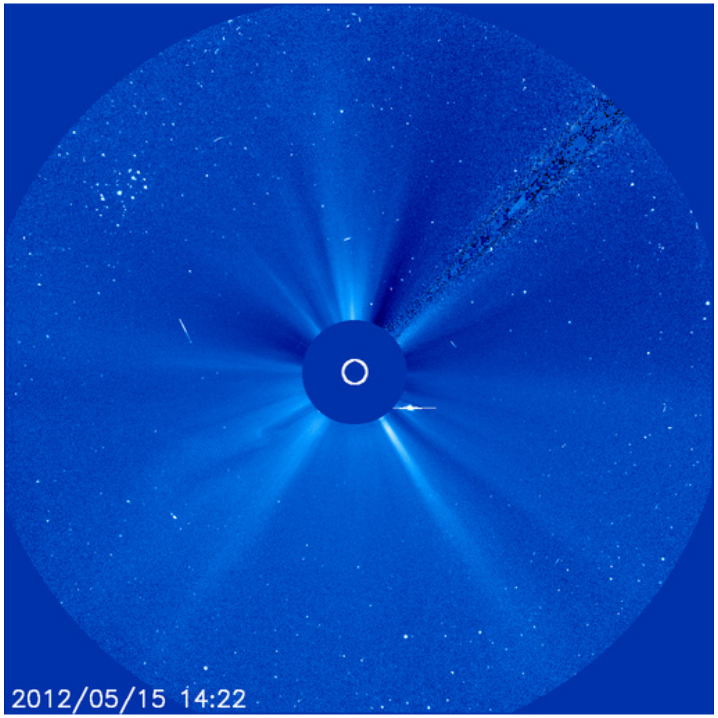
Faraday Rotation as a Probe of the Coronal Magnetic Field



Steven R. Spangler

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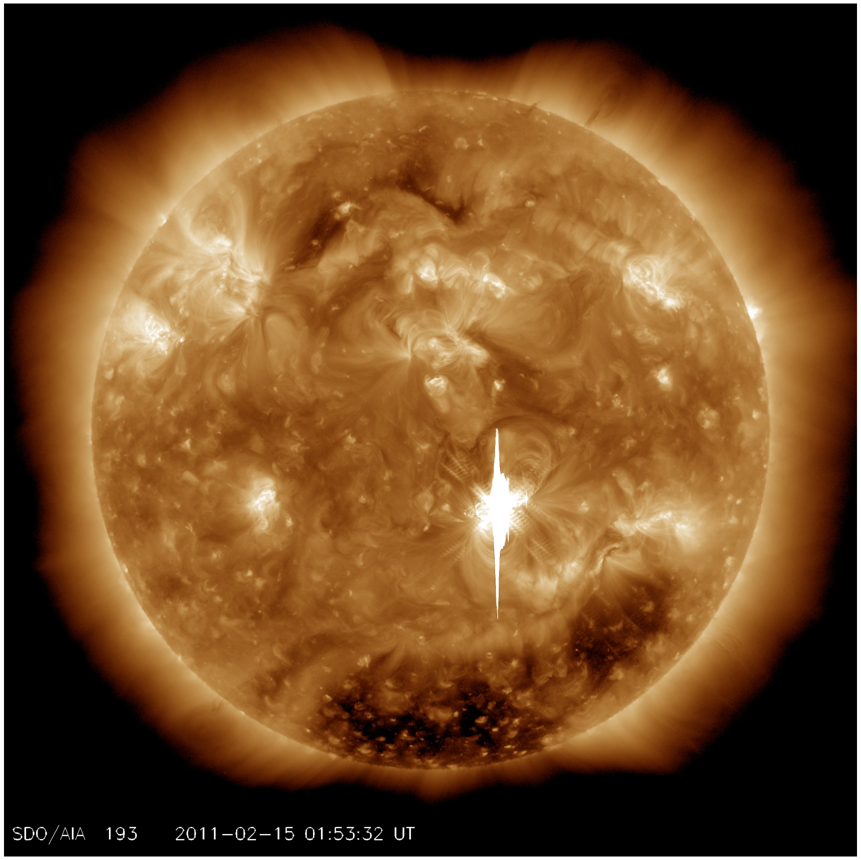
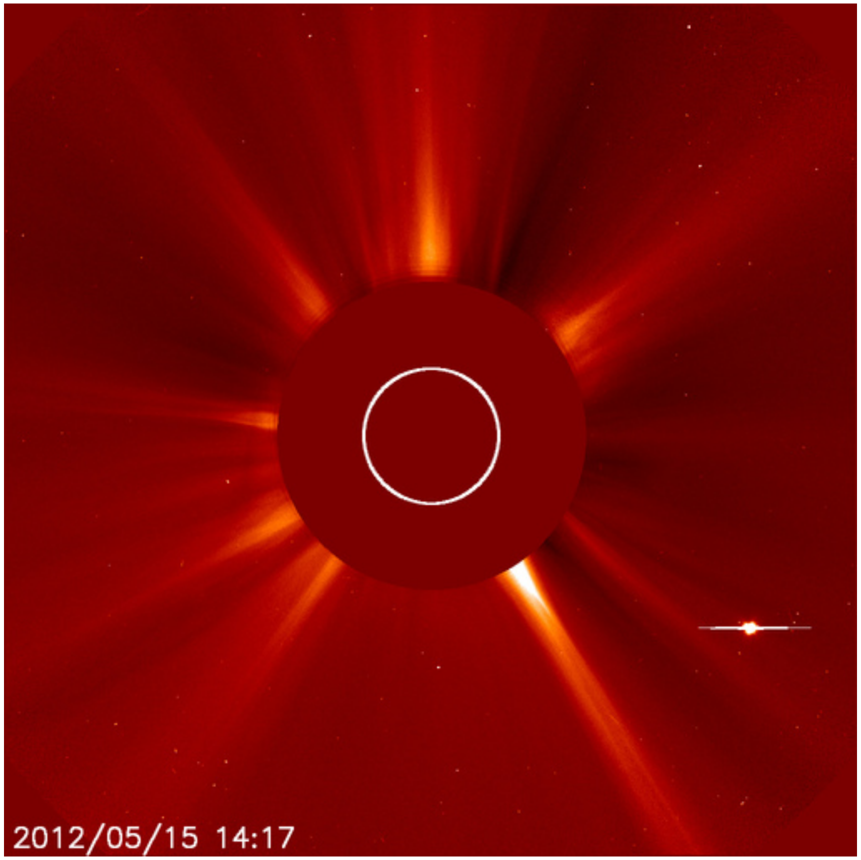
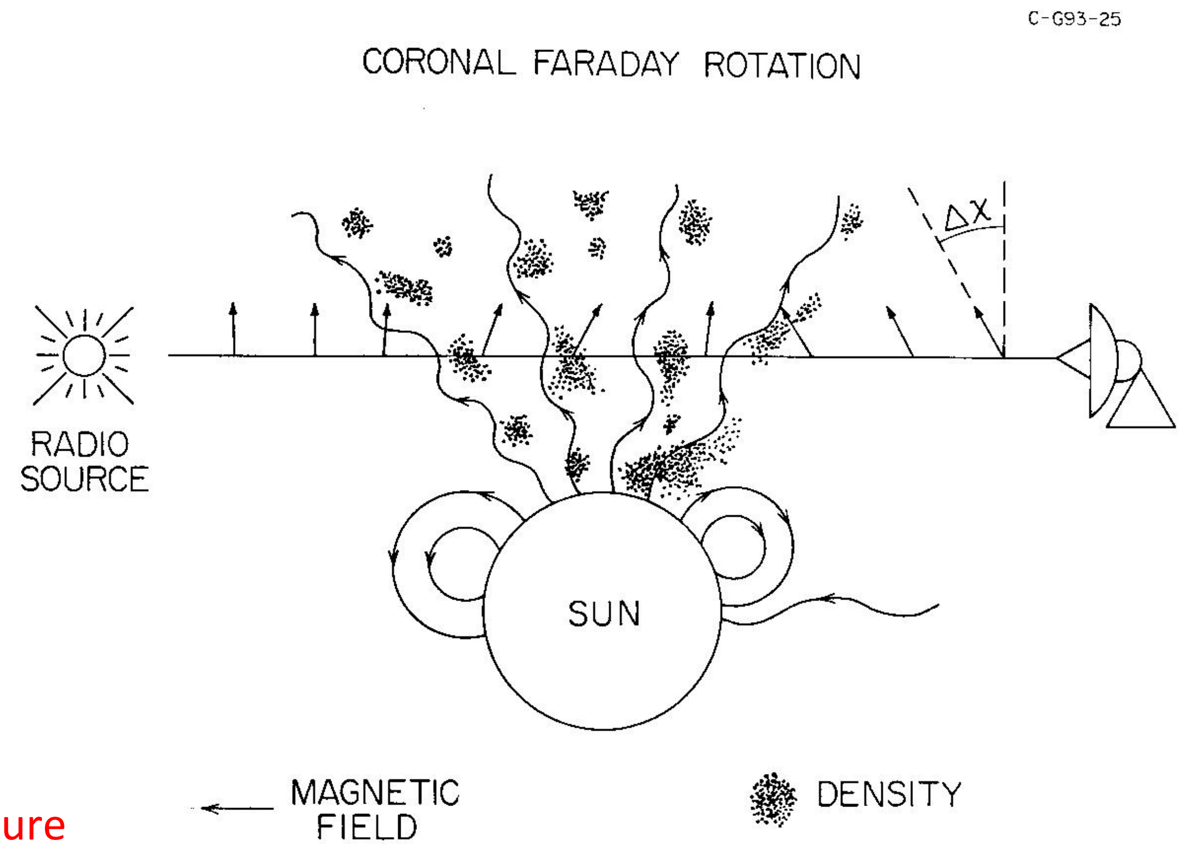




Much recent attention on coronal magnetic fields from Full Stokes Polarimeters (low corona), but there is interest in B in outer corona as well

Faraday Rotation in the corona

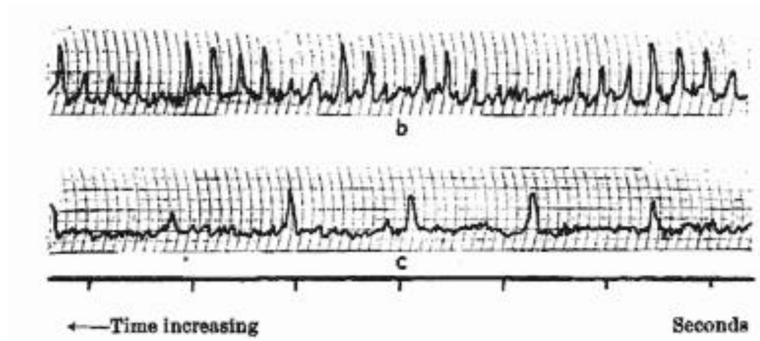


Rotation measure

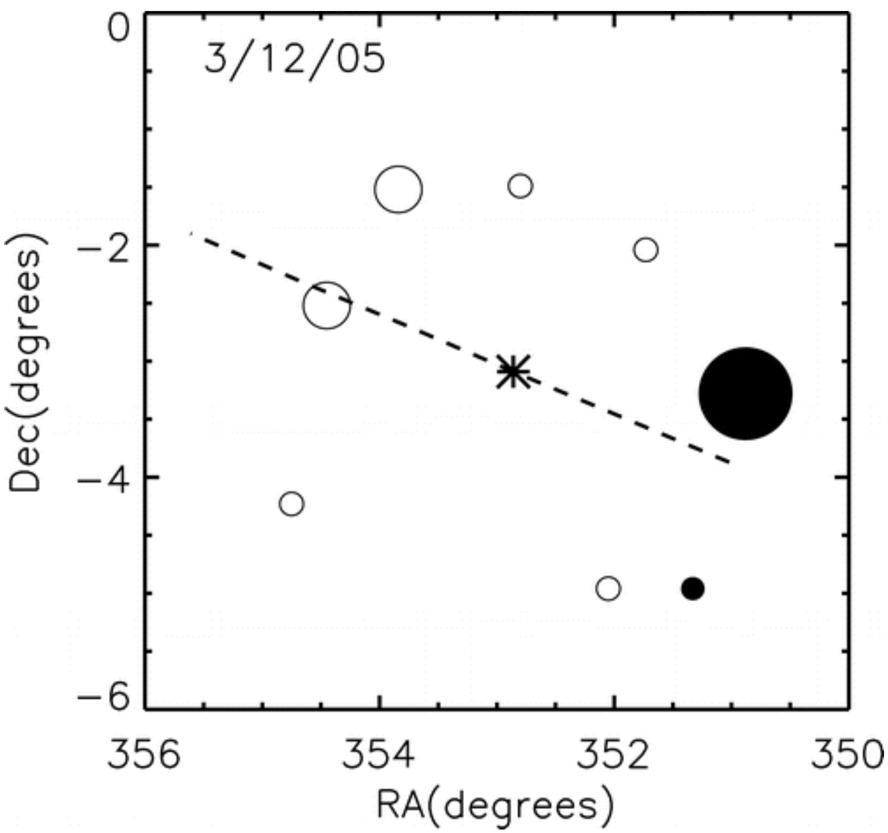
$$\Delta\chi = \left[\left(\frac{e^3}{2\pi m_e^2 c^4} \right) \int_L n_e \boldsymbol{B} \cdot d\boldsymbol{z} \right] \lambda^2 .$$

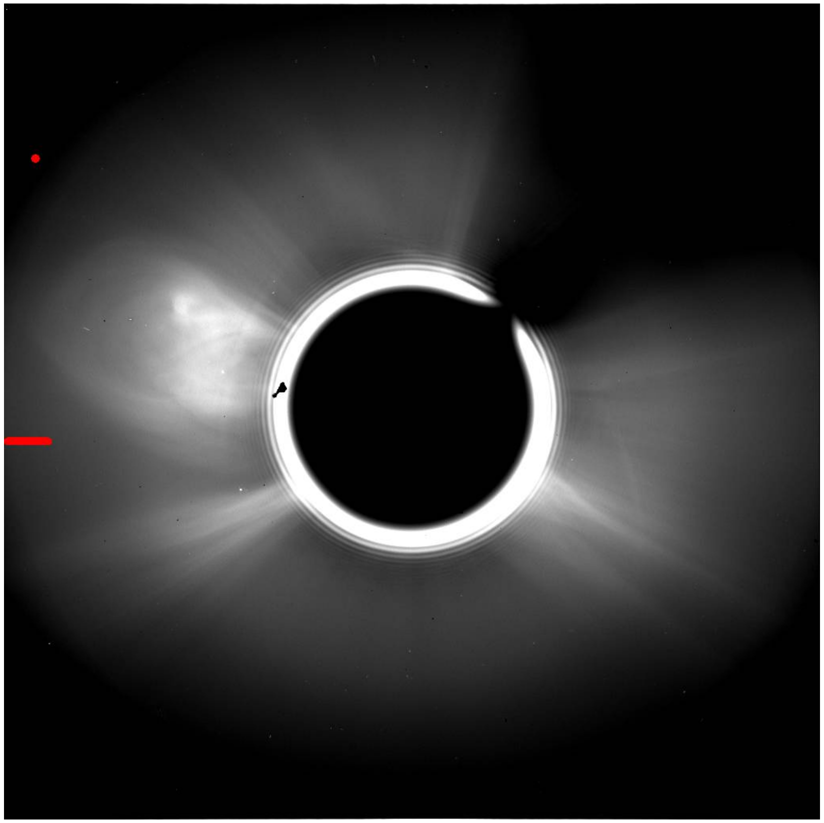
Trans-coronal sources for Faraday rotation measurements

- Spacecraft transmitters (M. Bird, E. Jensen)
- Pulsars (provide both RM and DM)
- Extragalactic radio sources (numerous, provide “constellations” and possibility of multiple lines of sight)



Constellation of radio galaxies around the Sun





Ingleby et al, ApJ 668, 520, 2007

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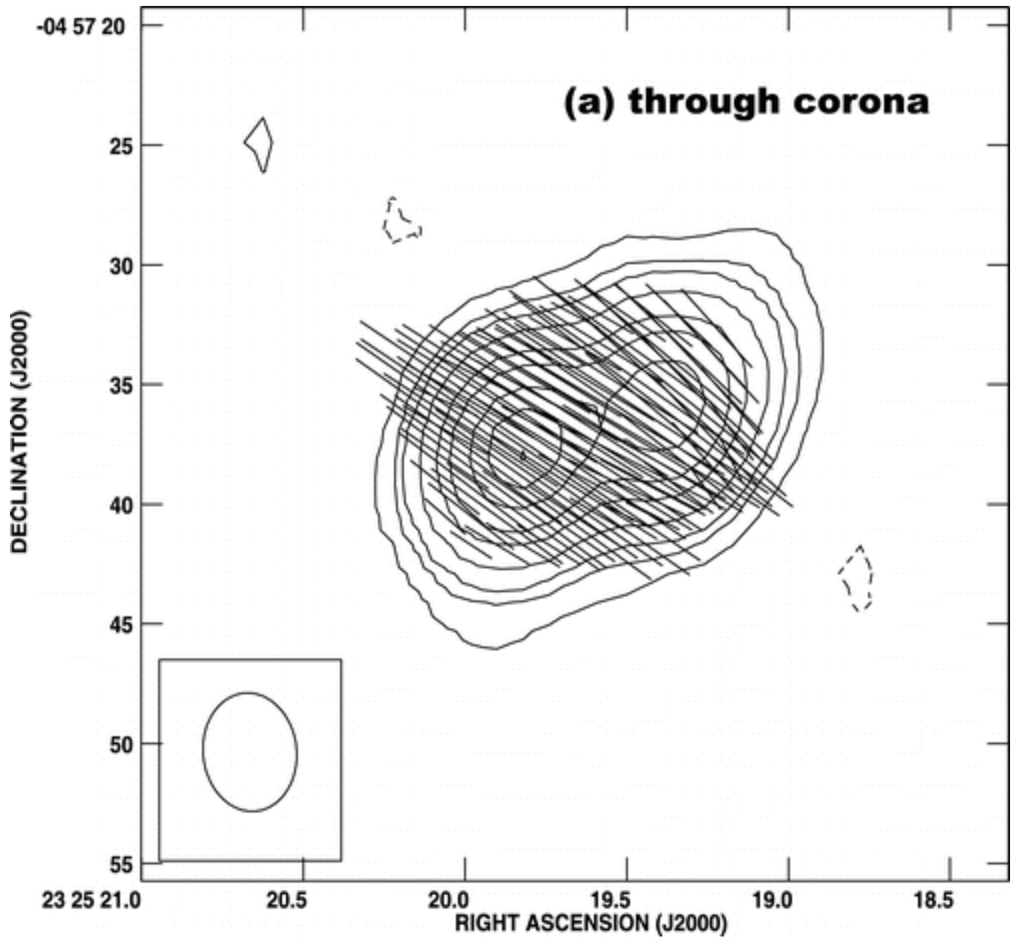

Fig. 3.— Illustration of data used to obtain the coronal Faraday rotation for one of the lines of sight, that to 2325−049 on March 12. In all three panels, the orientation and length of the plotted lines correspond to the polarization position angle and the polarized intensity, respectively, at that position in the source. The contours are of total intensity (Stokes parameter I). (a) The 1465 MHz polarization position angle map on March 12, when the line of sight passed through the corona. (b) Similar map of the source on May 29, when the corona was far from the source. (c) Position angle difference between the two maps, Δχ, which is the Faraday rotation due to the corona. For both components of the source, the Faraday rotation is 14°, corresponding to an RM of 6 rad m−2. The resolution of all three maps is about 5$\arcsec$ (angular diameter FWHM of the restoring beam).

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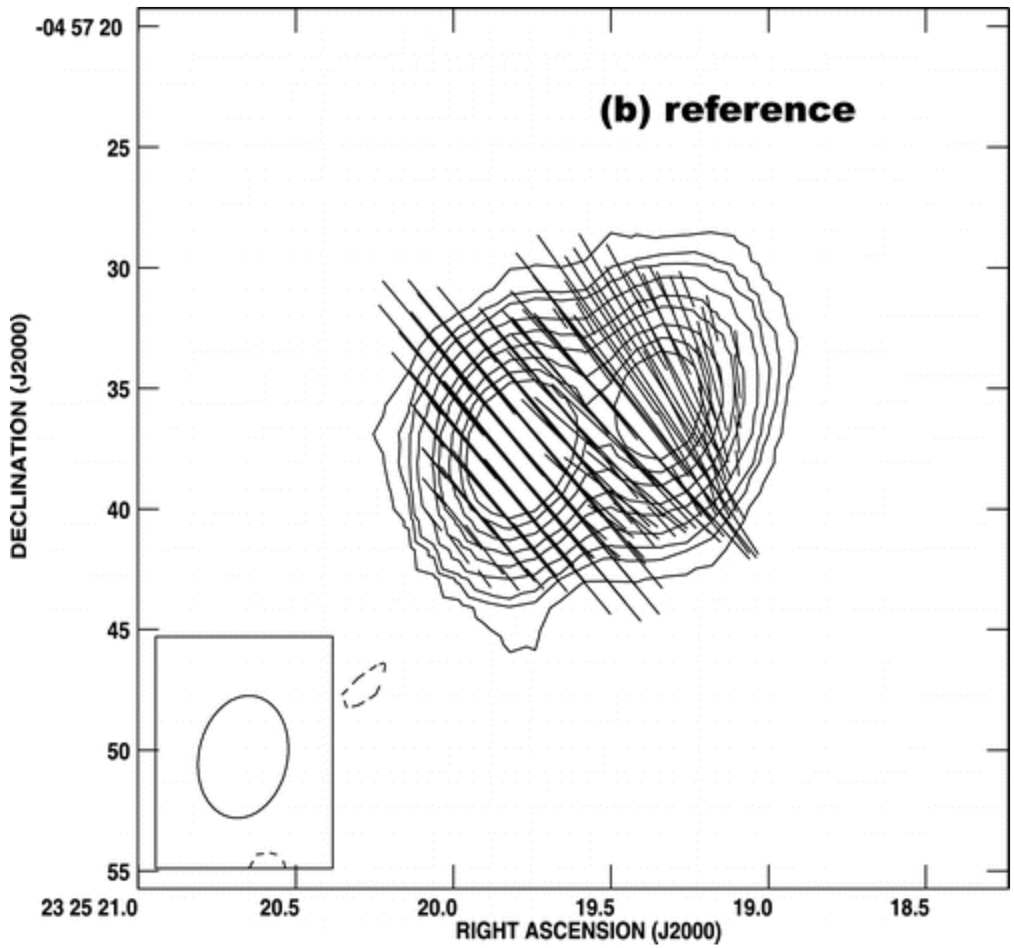

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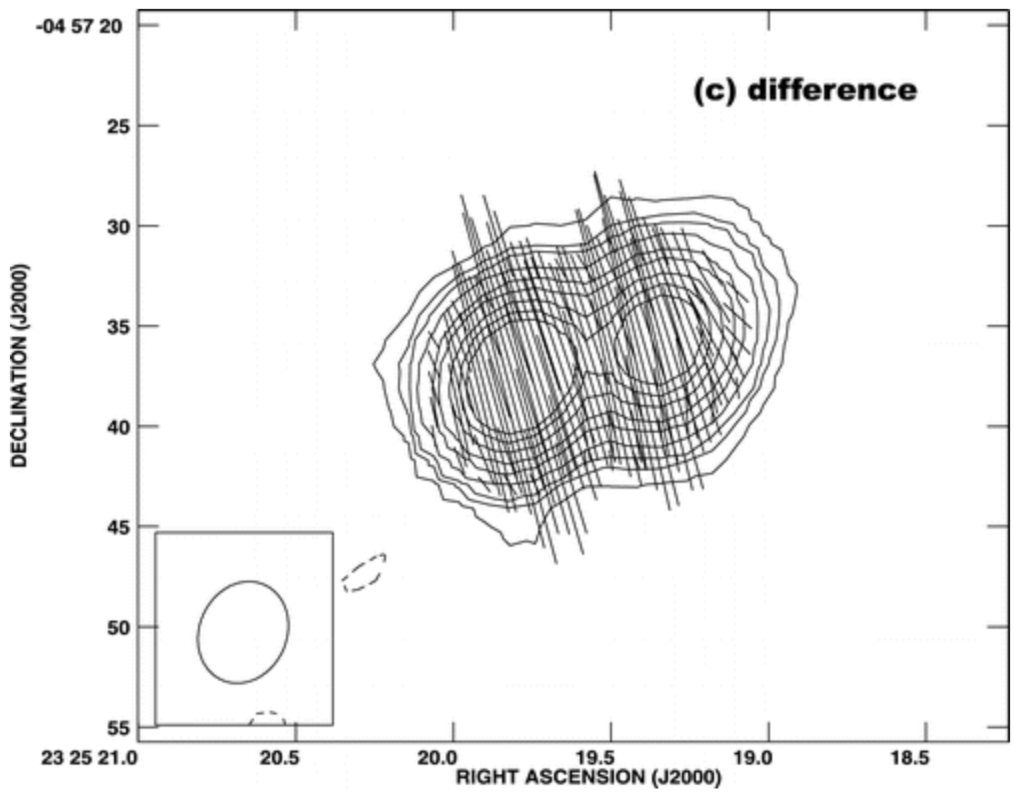

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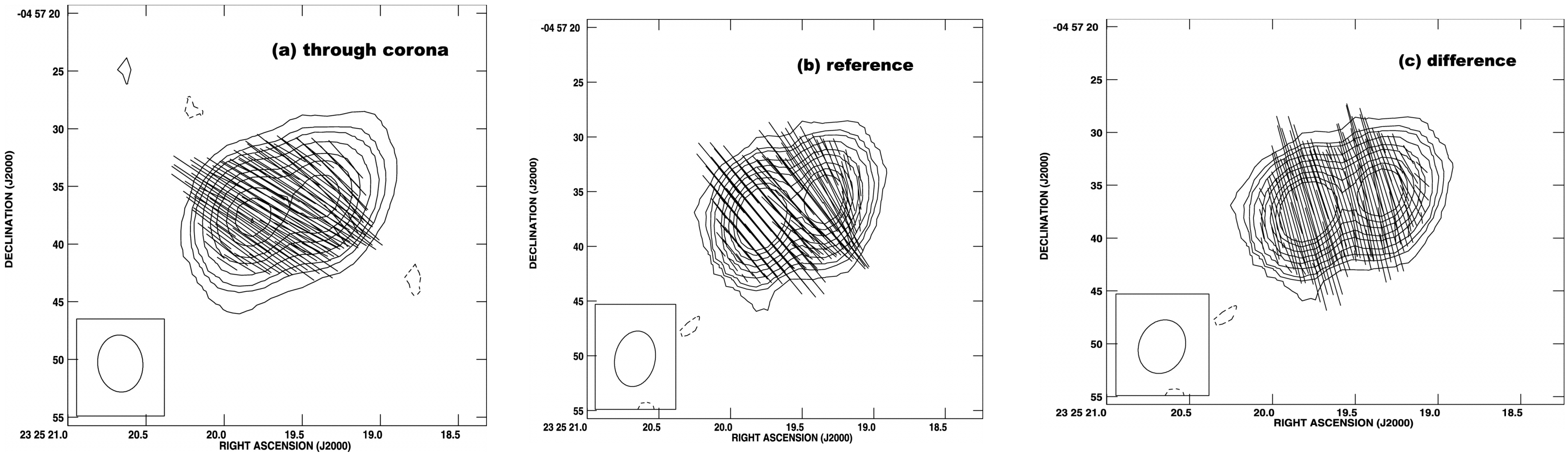
An illustration of Faraday rotation

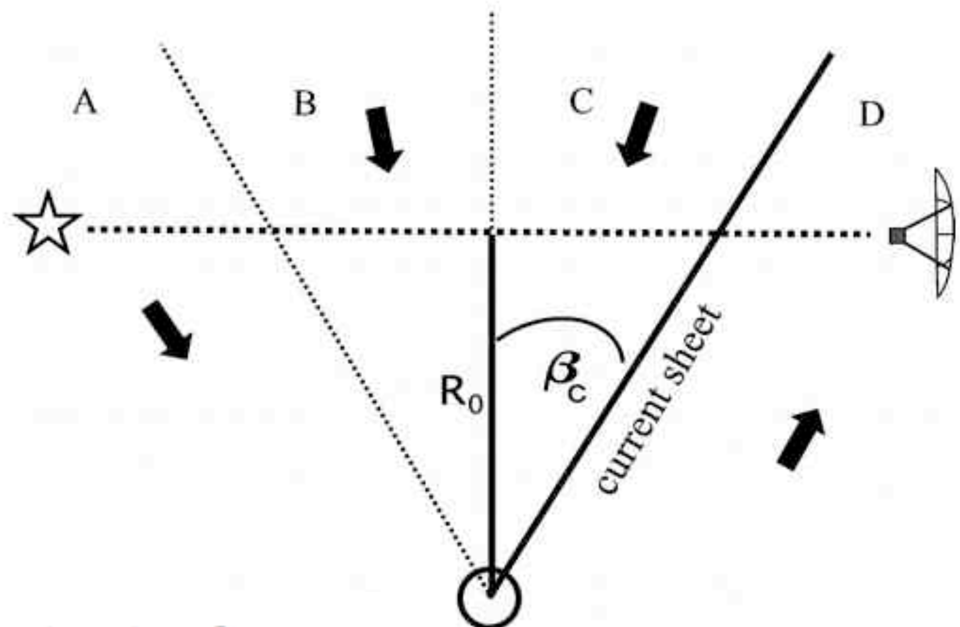


Position angle rotation (1465 MHz) = 14 degrees

Coronal RM = 6 rad/sq-m

Ingleby, Spangler, Whiting 2007, ApJ 668, 520

How do we infer the coronal field from Faraday rotation measurements (path integrals)?

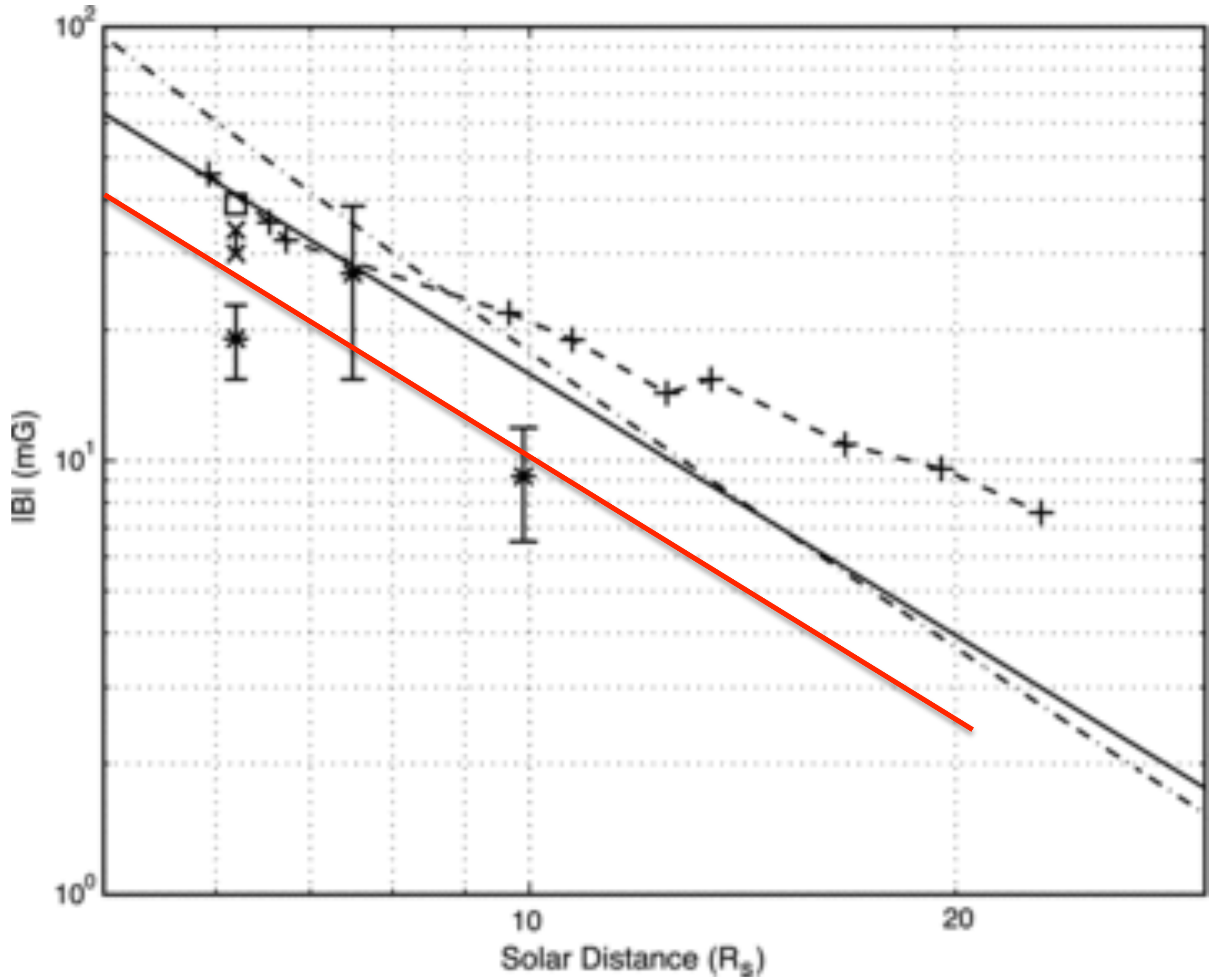


$$n_e(r) = N_0 \left(\frac{r}{R_\odot}\right)^{-\alpha},$$

$$\mathbf{B}(r) = B_0 \left(\frac{r}{R_\odot}\right)^{-\delta} \hat{e}_r.$$

$$\mathrm{RM} = \left[\frac{2CR_\odot N_0 B_0}{(\gamma - 1)R_0^{\gamma-1}}\right] \cos^{\gamma-1}\beta_c,$$

What are the results for the coronal field?



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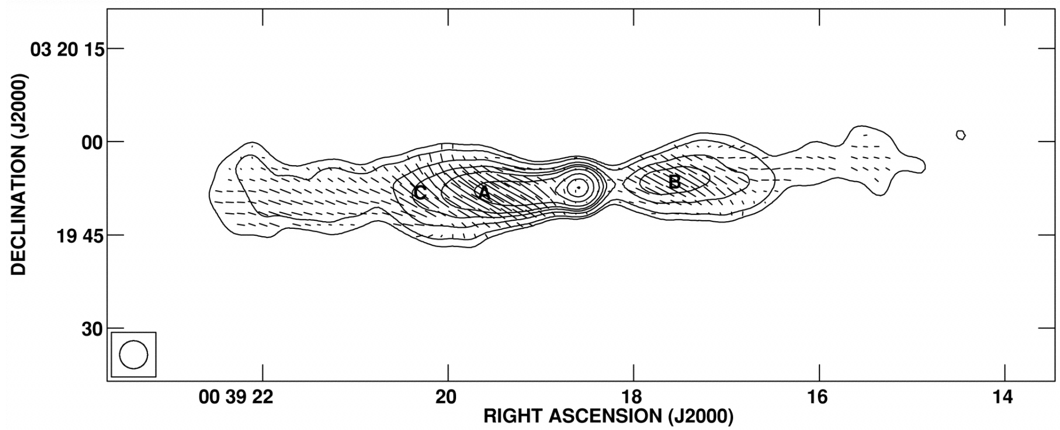
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2966.2012.20688.x/full#f5

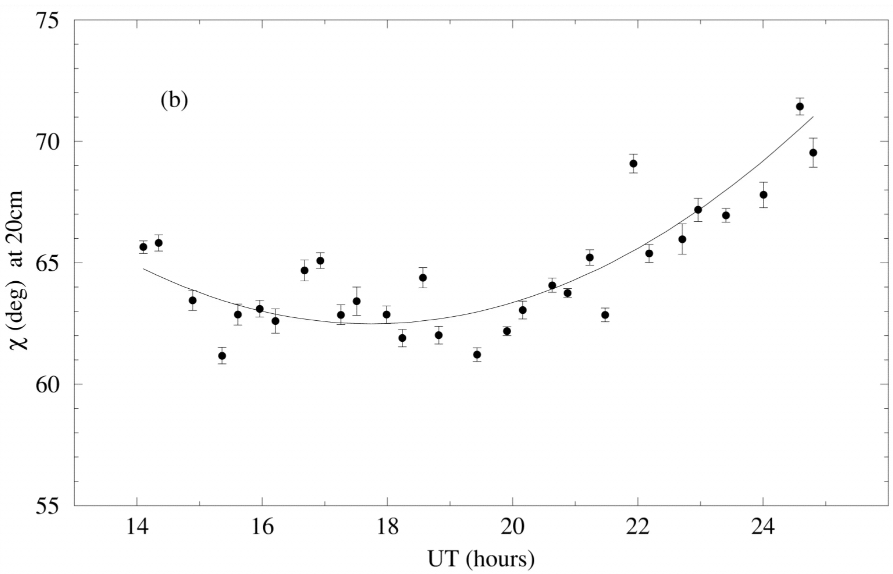
You et al 2012

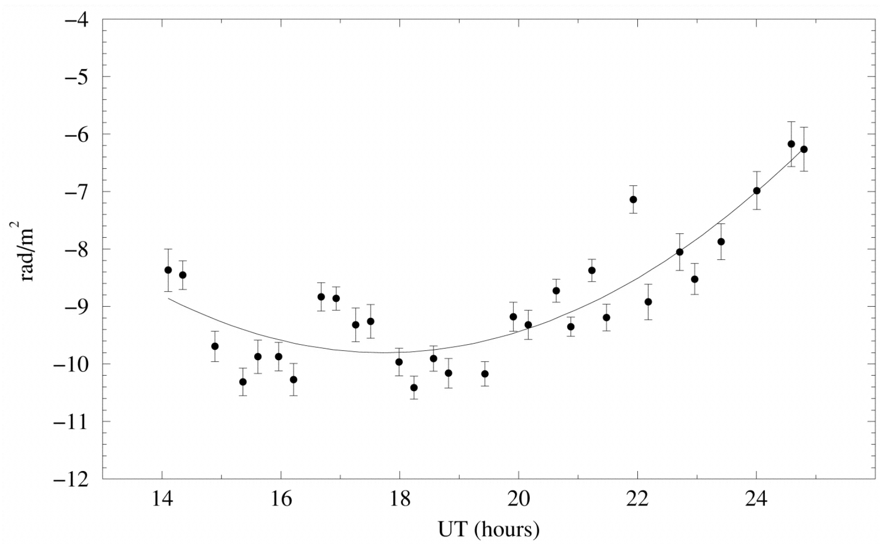
Topics of Interest

- Large scale coronal magnetic field
- MHD turbulence in the corona
- Probing electrical currents
- Faraday rotation as a probe of CMEs
- Future extensions of the technique (closer to and further from the Sun)

Faraday rotation and coronal turbulence







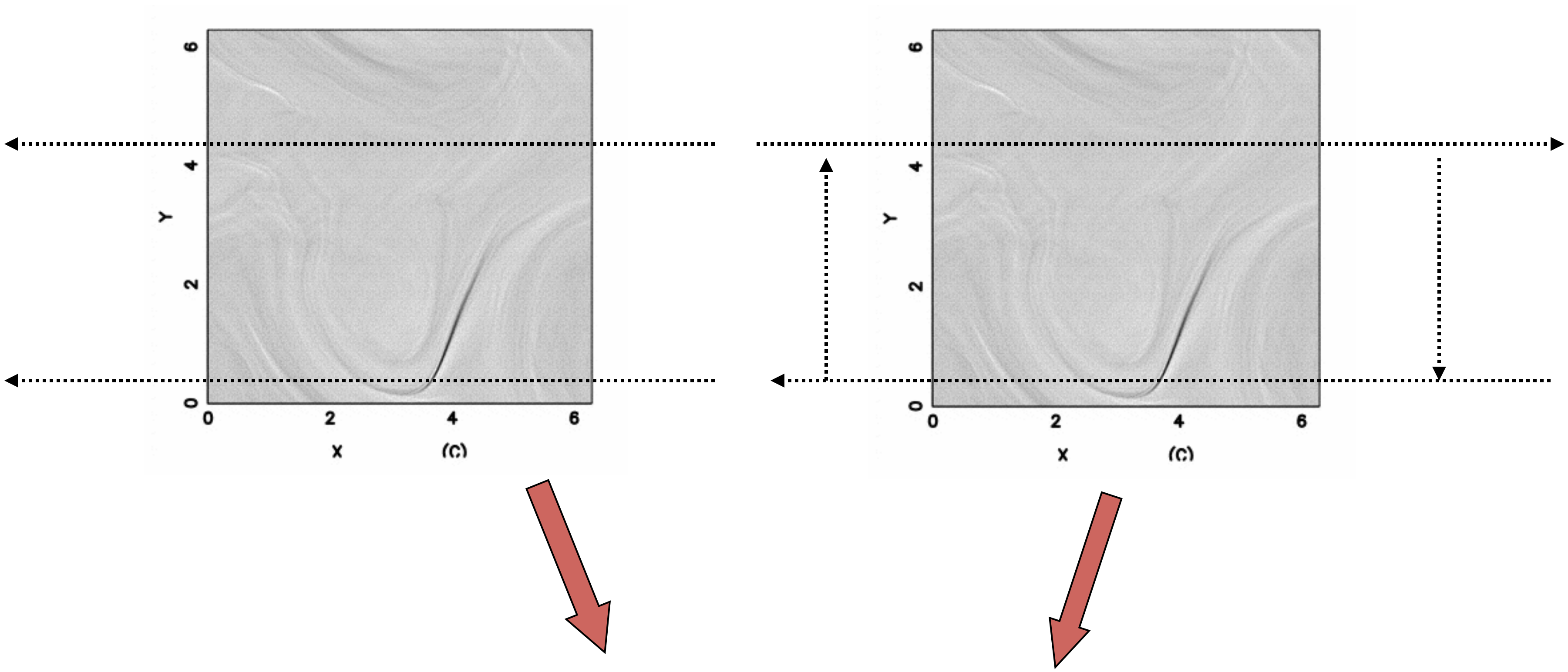
Mancuso and Spangler, ApJ 525, 195, 1999

A new age of opportunity for cosmic Faraday rotation measurements; the availability of the Karl G. Jansky Very Large Array

- Lower noise receivers
- Larger bandwidth
- Continuous frequency coverage

Thanks

Differential Faraday Rotation and Ampere's Law



$$\Delta RM = C\left(\int_1 n\overrightarrow{B}\cdot\overrightarrow{dz} - \int_2 n\overrightarrow{B}\cdot\overrightarrow{dz}\right) \cong C\oint n\overrightarrow{B}\cdot\overrightarrow{dz}$$

$$C \equiv \frac{e^3}{8p^2 e_0 m_e^2 c^3}$$

Differential Faraday Rotation and Ampere's Law II

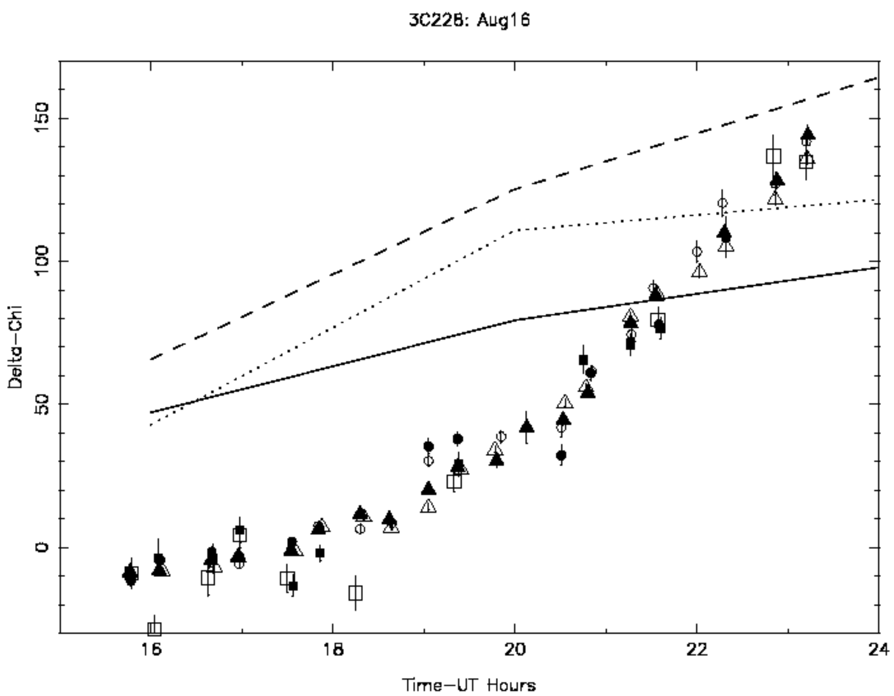
$$\Delta \mathrm{RM} \cong C \oint n\vec{B}\cdot\vec{ds} \simeq C\,\bar{n}\oint \vec{B}\cdot\vec{ds}$$

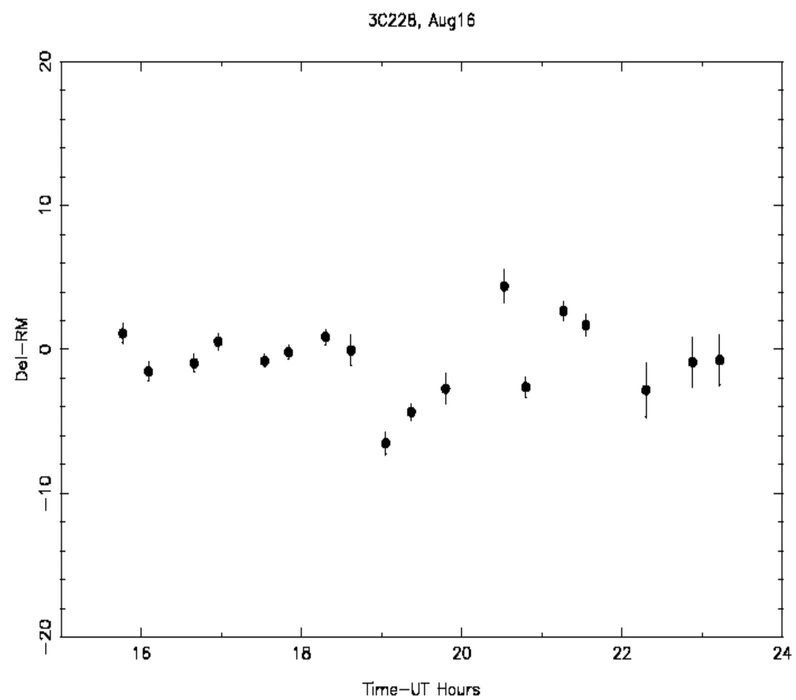
$$\Delta \mathrm{RM} \simeq C\,\bar{n}\,m_0\,I$$

$$I \simeq \frac{\Delta \mathrm{RM}}{C\,m_0\,\bar{n}}$$

Method utilized in Wisconsin Reversed Field Pinch (RFP) by Ding, Brower, et al (PRL 90, 035002, 2003)

Observations of Differential Faraday Rotation on August 16, 18 2003





Inferred current of 2.5 GA between lines of sight separated by ~ 35,000 km

Spangler, ApJ 670, 841, 2007

Determining location of coronal field reversal