

Determining the Magnetic Structure of CMEs from Faraday Rotation

Ying Liu, Justin Kasper, John Richardson, John Belcher,
and Many Others

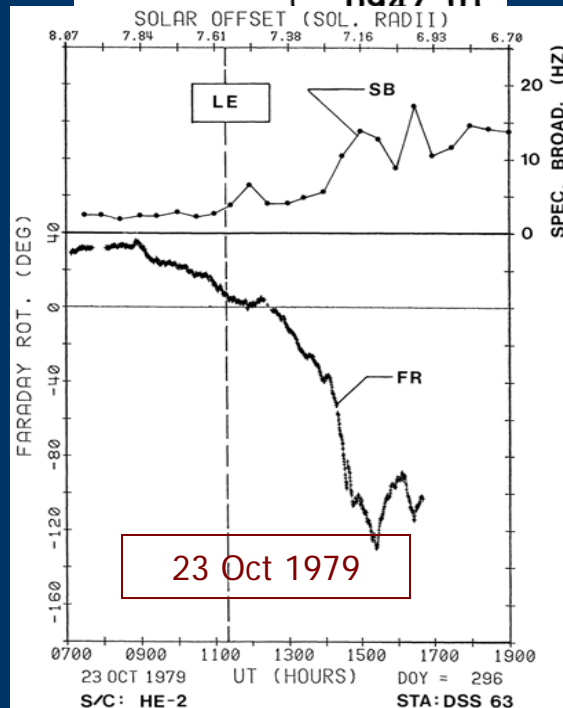
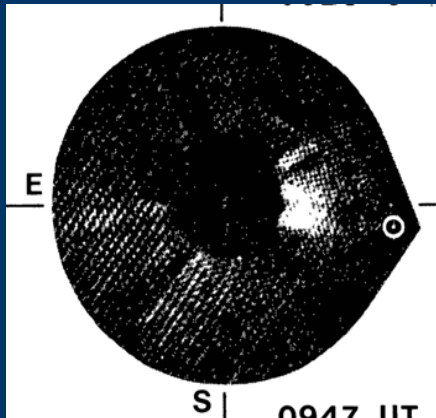
MWA meeting, Nov 1

Outline

- Can CMEs be described as flux ropes?
- Show methods to determine the field orientation and helicity of CMEs from multiple radio sources
- Are CMEs still connected to the Sun?

Helios Observations

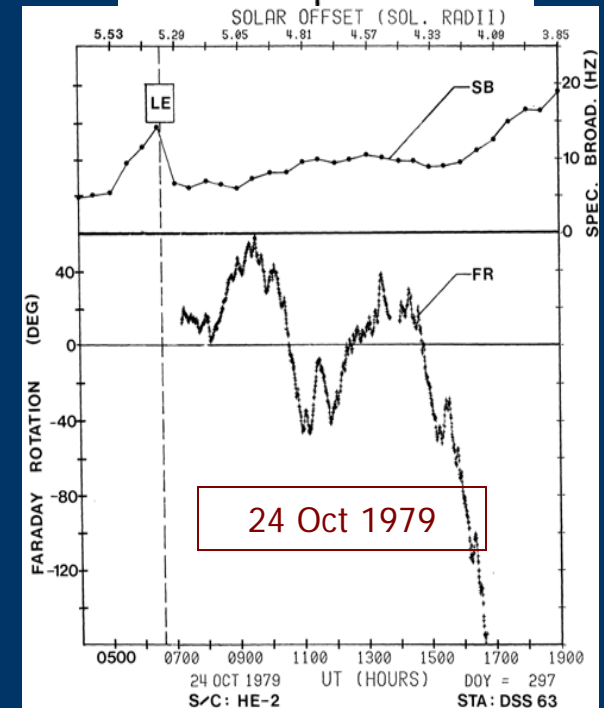
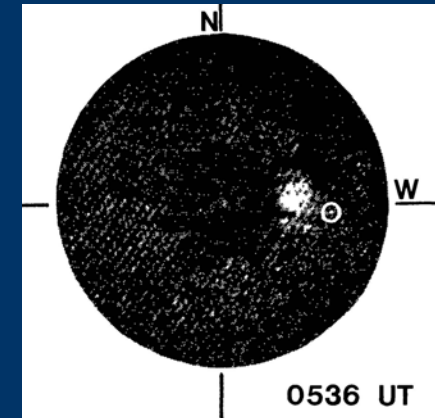
CMEs as Flux Ropes



White light and radio sounding observations of CMEs [Bird et al., 1985]:

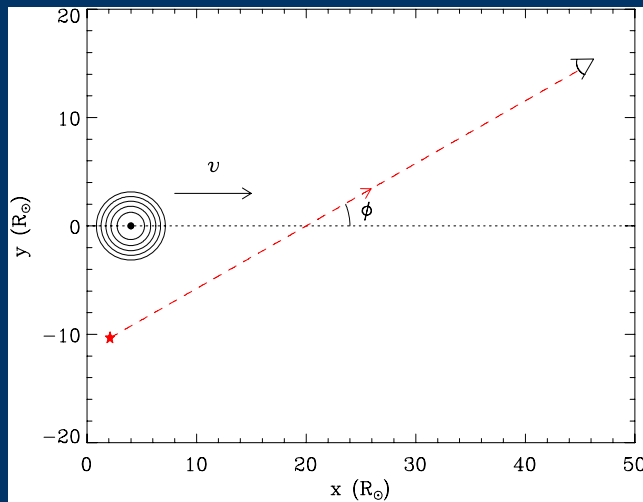
- Establish correspondence between Faraday rotation disturbances and white light transients;
- Indicate monopolar / dipolar structures of CMEs.

What can we learn about the CME geometry from these observations?

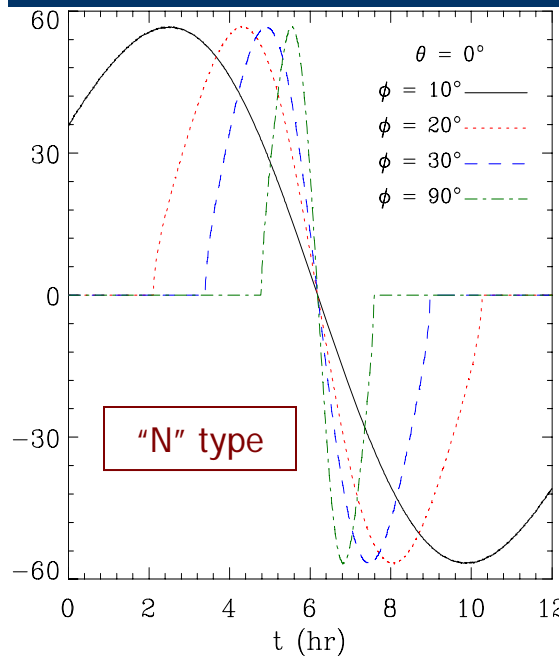
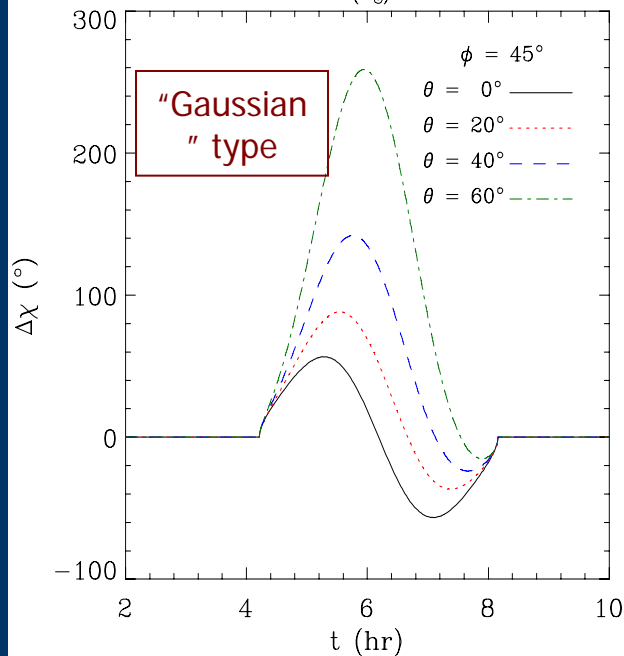


CMEs as Flux Ropes

A Simple Model

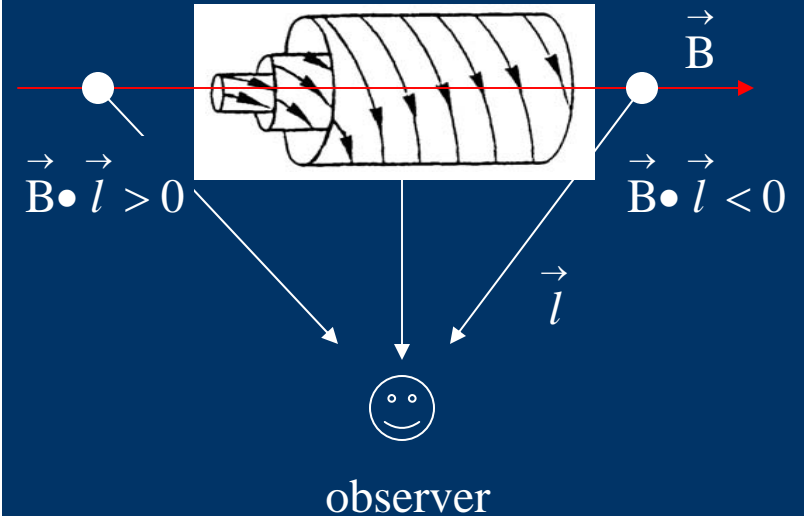
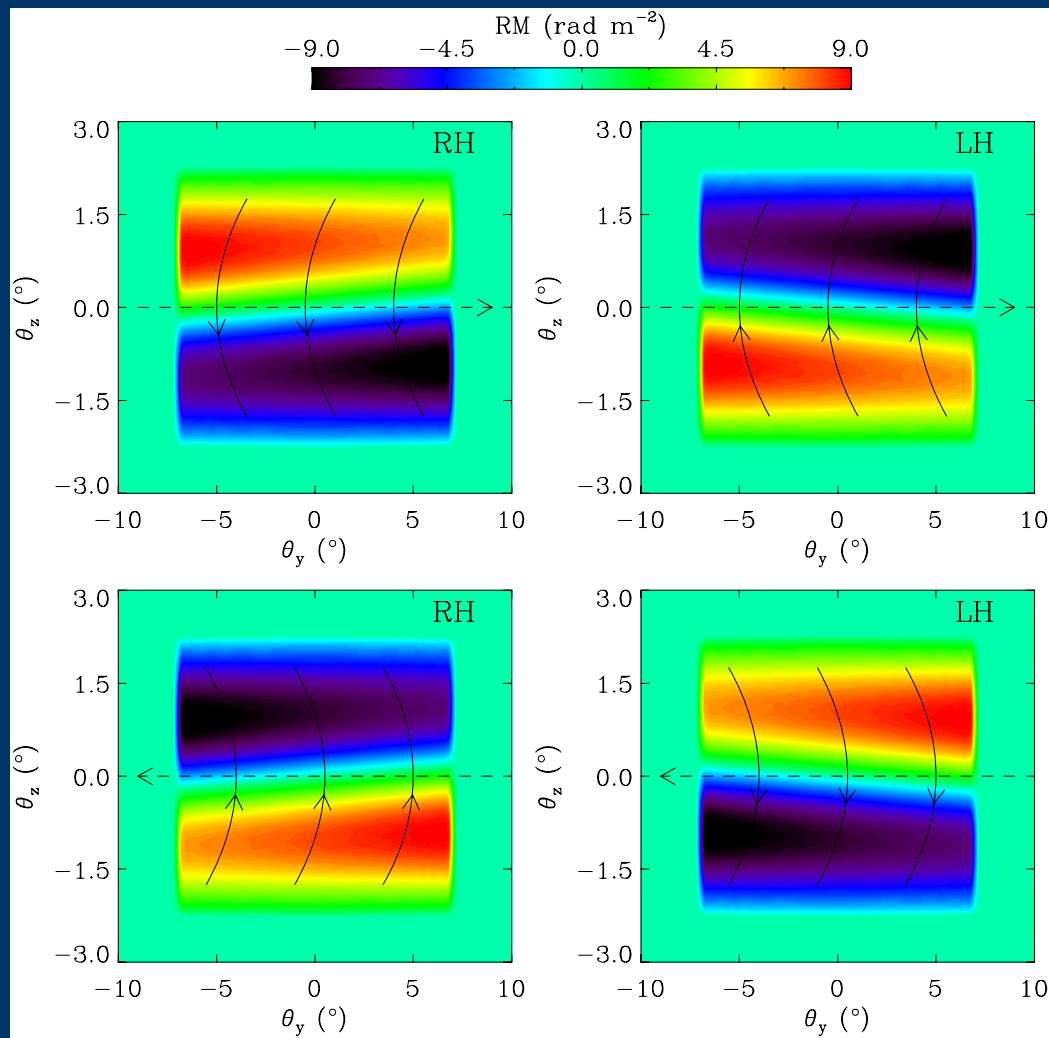


- A simple flux rope crosses the line of sight with a constant speed;
- θ is the angle of the line of sight with respect to the screen, ϕ is the angle with respect to the motion direction;
- The magnitude, time scale and types of the FR curves can be reproduced.



Field Orientation

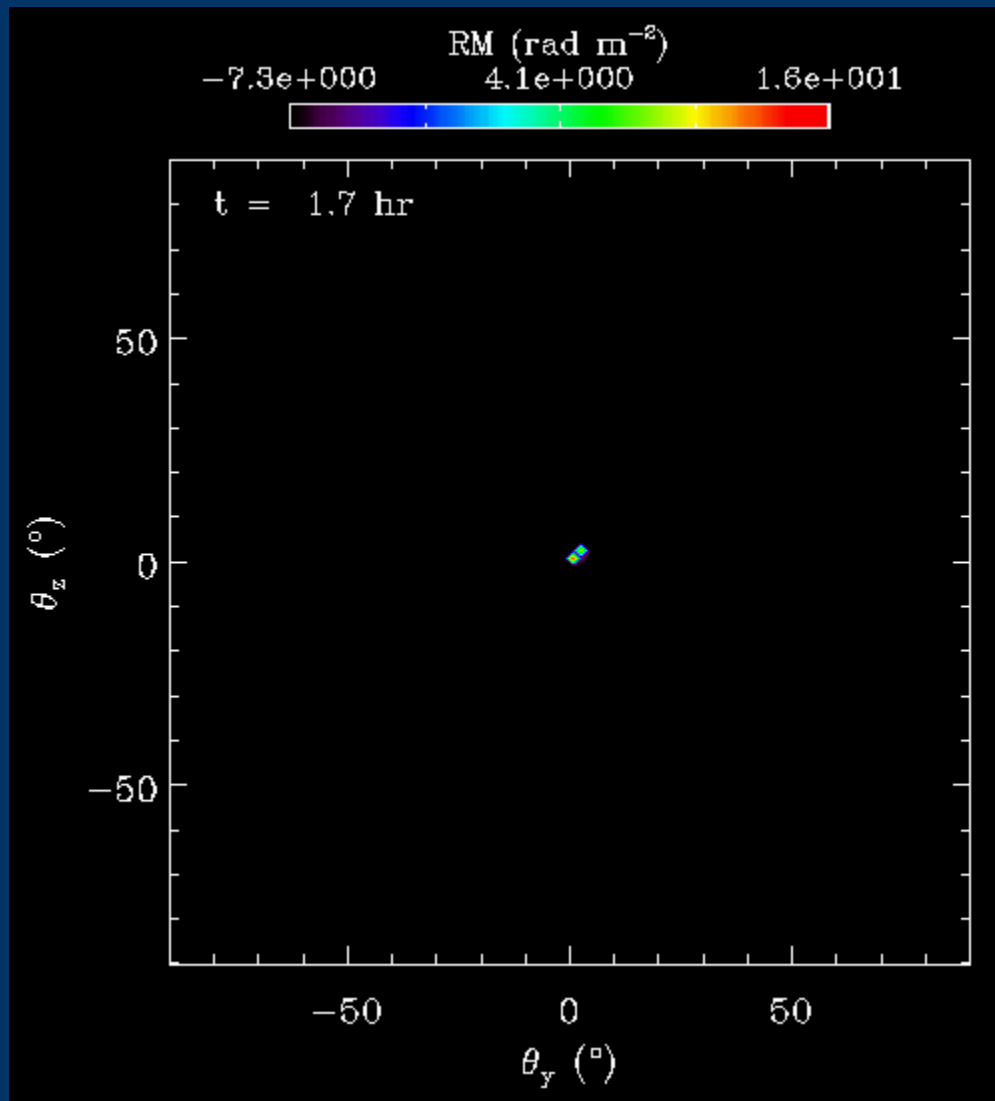
A Single Flux Rope



- Axial fields produce a gradient in FR;
- There is a one-to-one correspondence between the flux-rope configuration and FR pattern from multiple radio sources, so the field orientation and helicity can be fully determined.

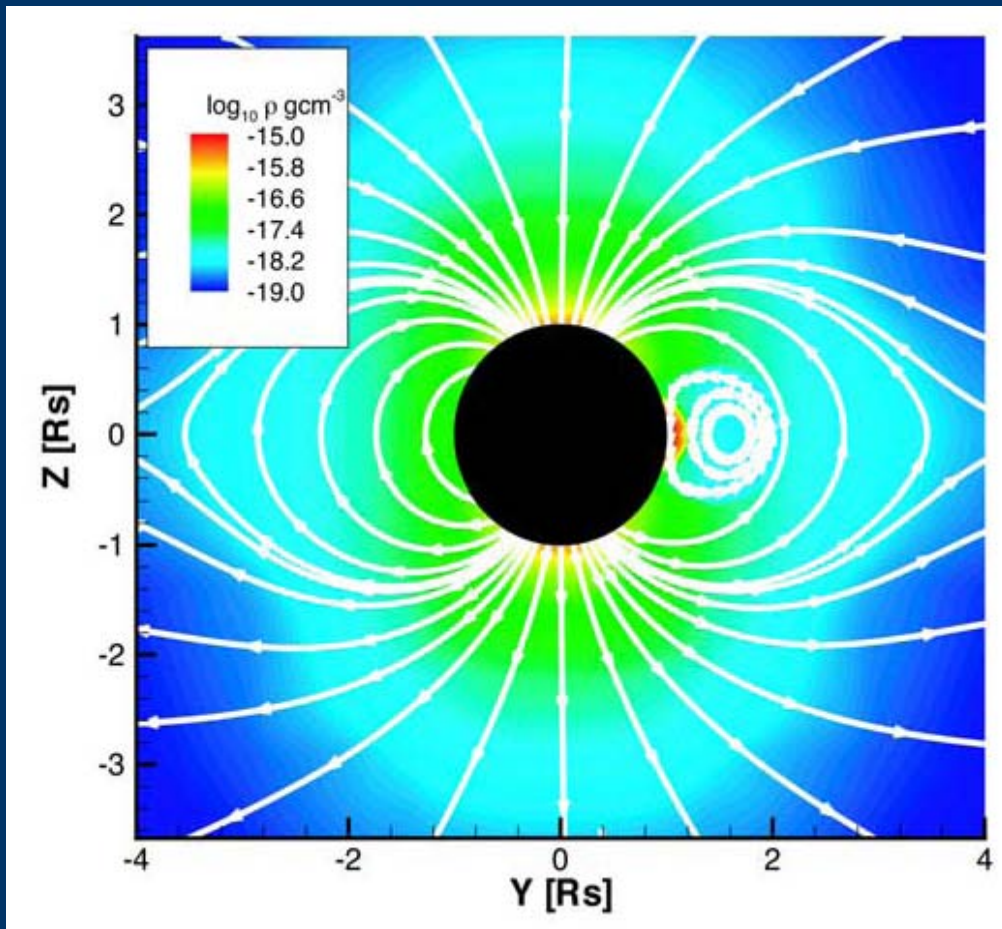
Field Orientation

A Single Flux Rope



- A tilted flux rope moves from the Sun to our side;
- Assume a power-law dependence with distance for the rope size and physical parameters;
- The field orientation and helicity can be easily obtained.

Field Orientation

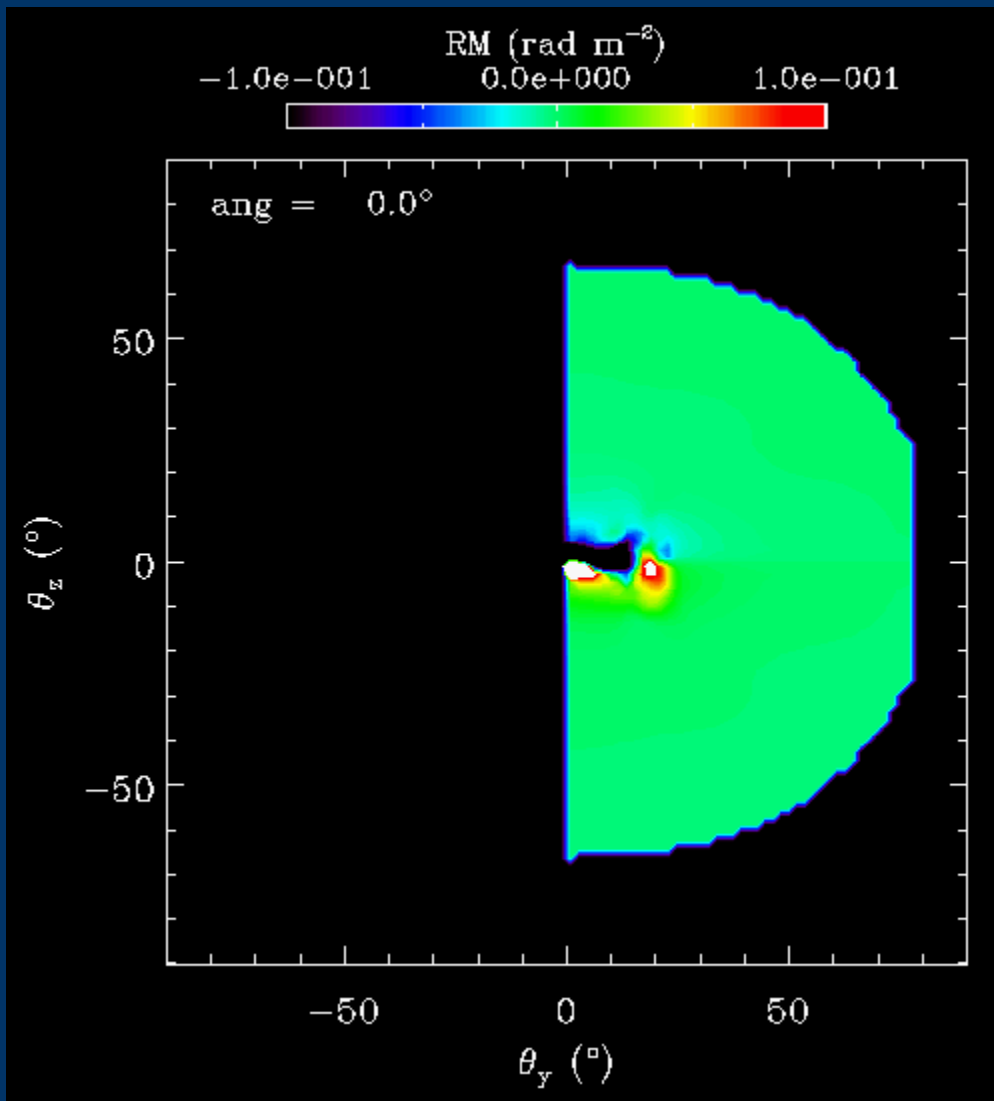


Realistic MHD simulations from U Michigan [Manchester et al., 2004]:

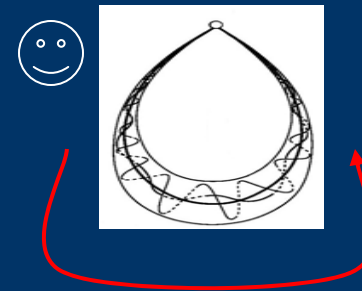
- 3-D ideal MHD modeling using BATS-R-US;
- Assume a specific heating function to reproduce bi-modal solar wind;
- Insert a Gibson and Low flux rope initially at force imbalance;
- Propagate the flux rope to 1 AU.

Currently we have the simulations at $t = 24$ hr and 60 hr; calculate FR using the simulations.

Field Orientation

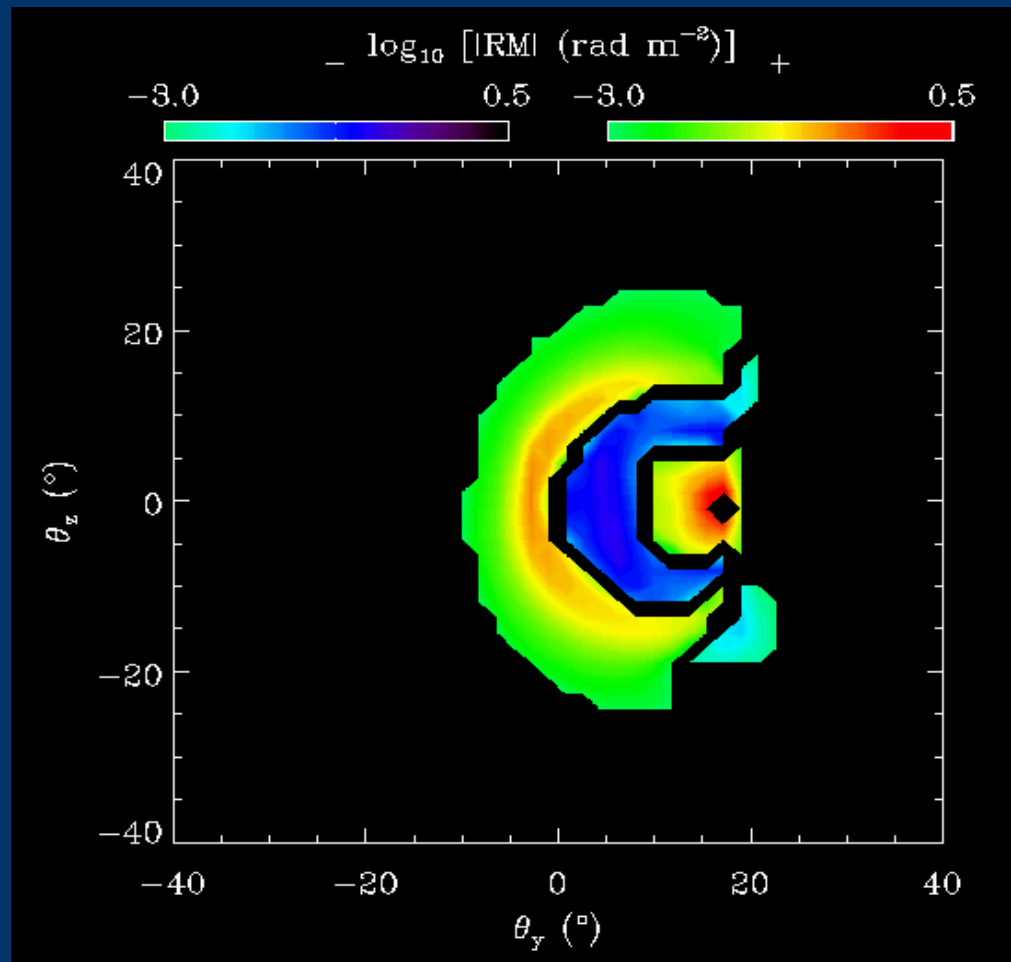


An observer moving around the CME from one side to the other sees legs of the CME in FR, which helps to determine the field orientation.

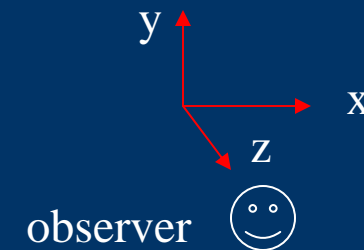
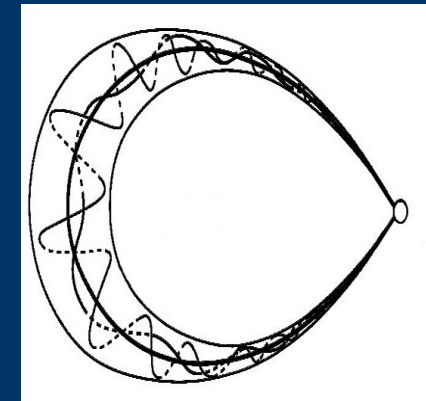


Connection to the Sun

CME at 24 hr



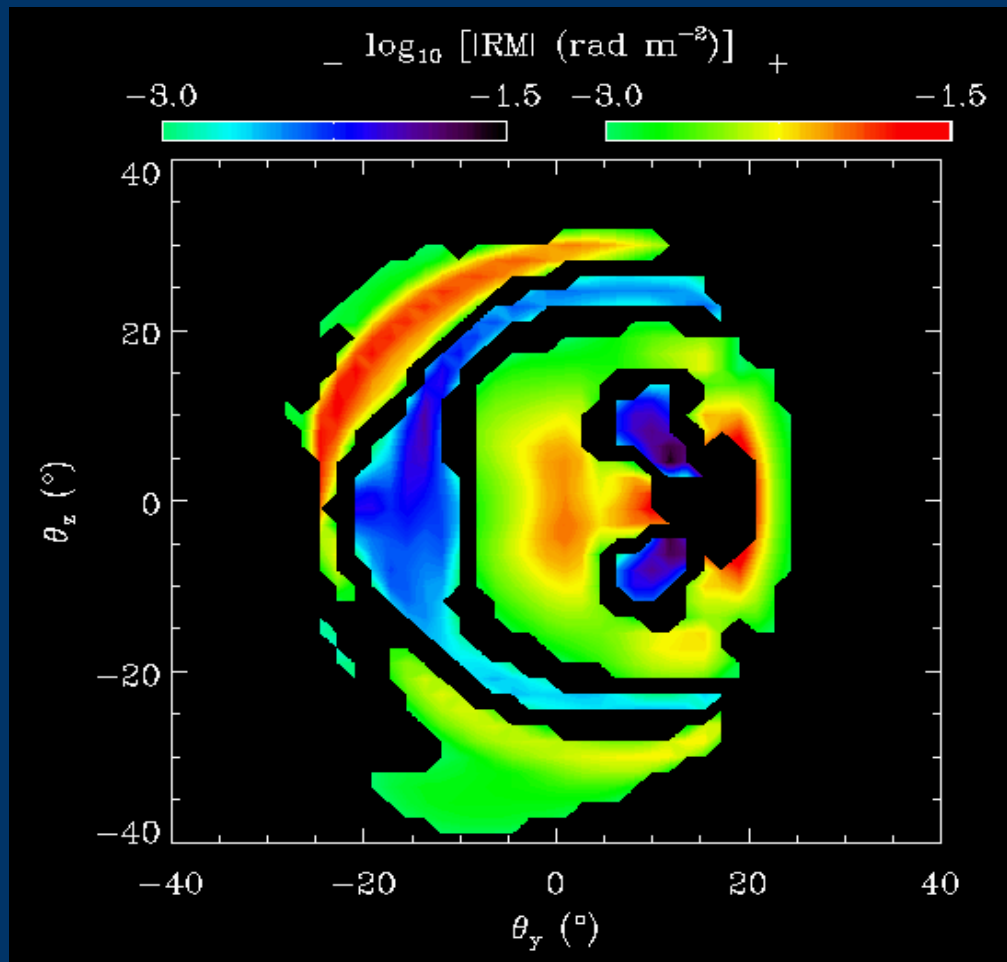
Difference image between background and CME data



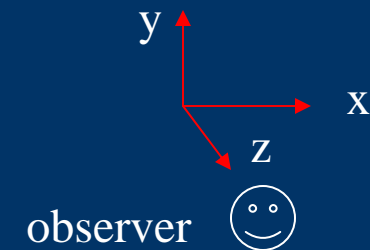
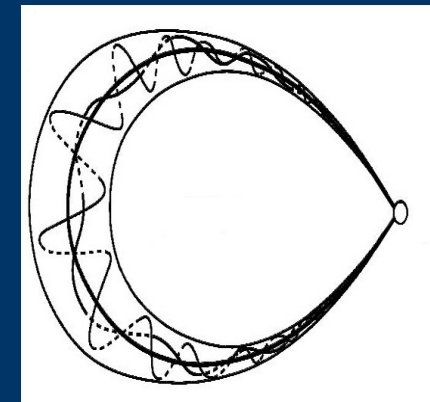
- A CME with axis in the screen;
- An observer looks into the screen;
- Would see a flux rope bent towards the Sun.

Connection to the Sun

CME at 60 hr



Difference image between background and CME data



Still see the flux rope connected to the Sun at $t = 60$ hr, but the rotation measure is rather weak.

Conclusions

- Faraday rotation will fill the missing link in coronal observations of the CME magnetic field;
- CME magnetic structures determined from Faraday rotation are of crucial importance for space weather forecast and CME breakout theories.