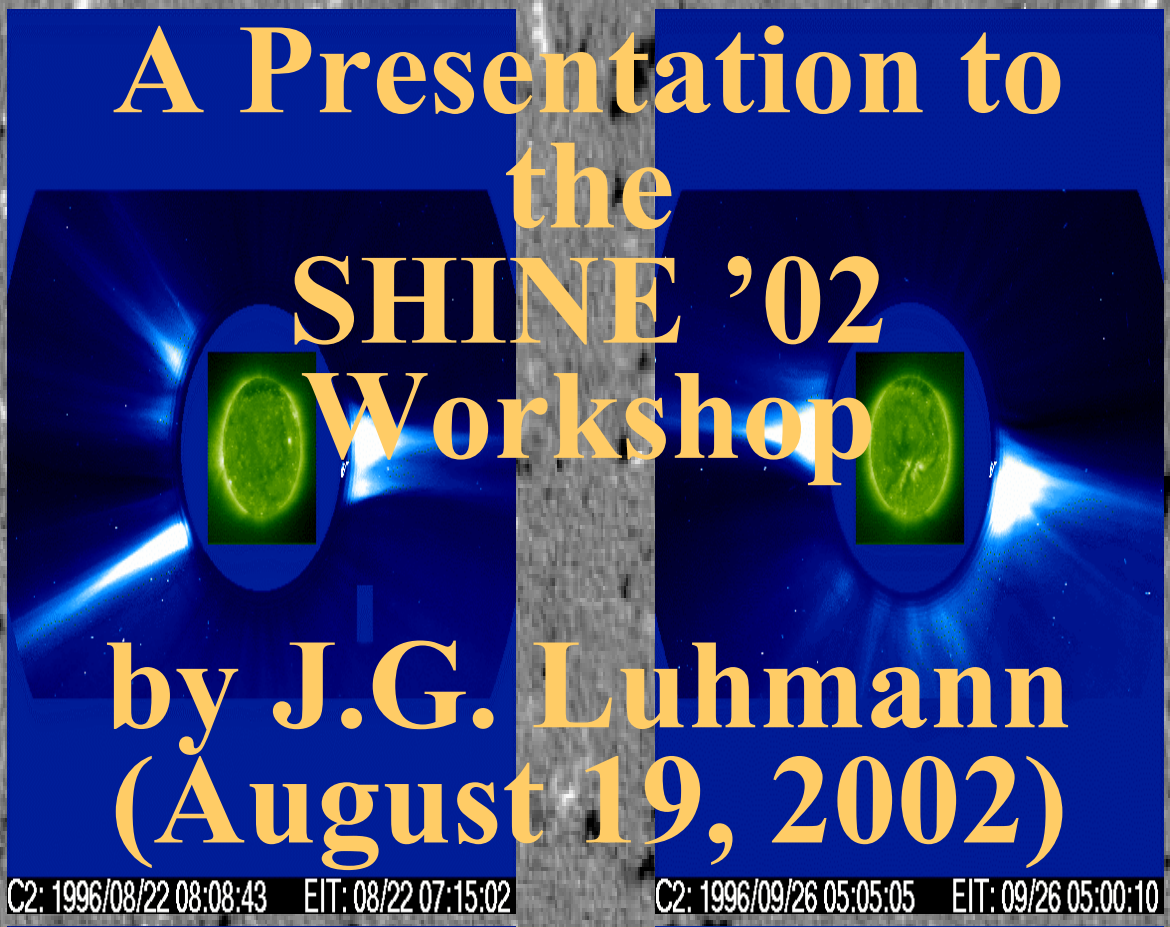
# A Presentation to the SHINE '02 Workshop

by J.G. Luhmann

(August 19, 2002)




# CME initiation: A zoo not an animal

*(Images from the on-line CDAW CME catalogue by Seiji Yashiro)*

# Collaborators

- Yan Li — UCB, Space Sciences Laboratory
- Xuepu Zhao — Stanford University

Also special thanks to:

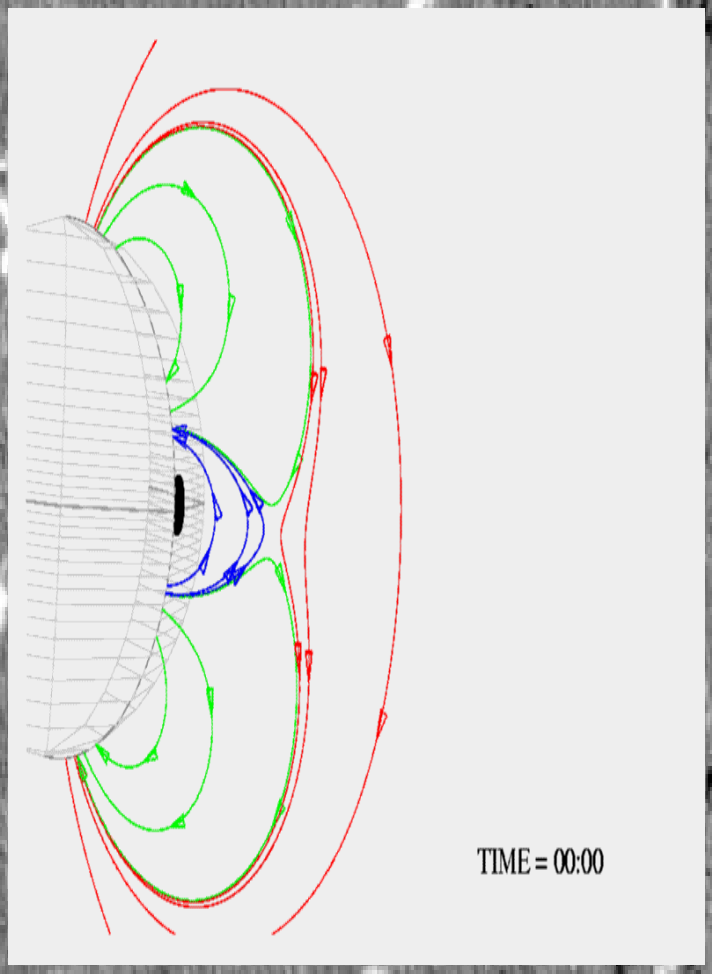
Seiji Yashiro

Chris St. Cyr

Spiro Antiochos

Jon Linker

for some of their graphics used in this presentation.

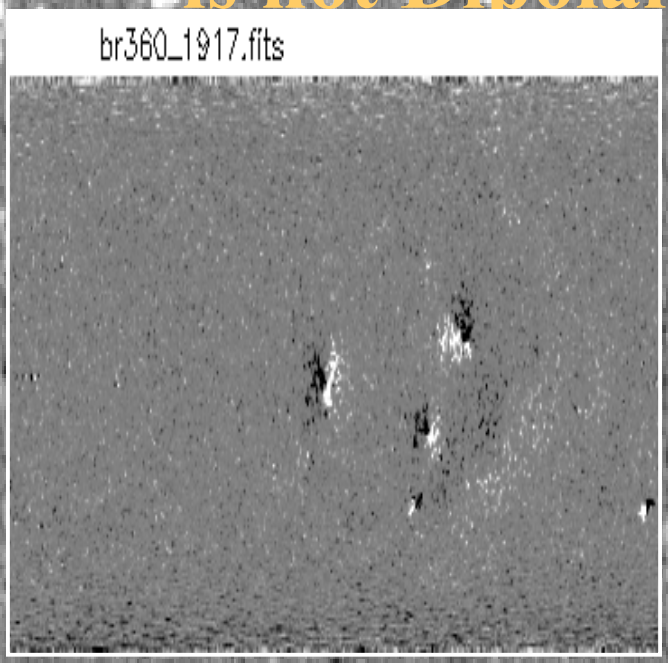


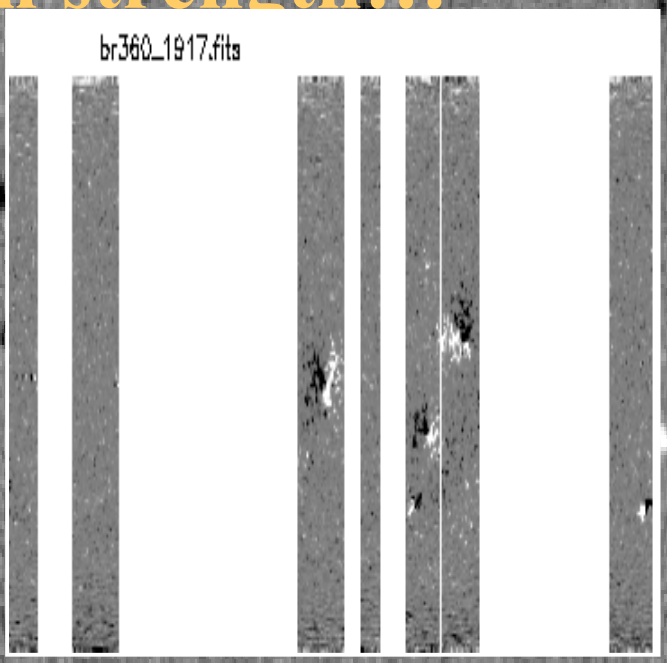

*Antiochos, et al. model*

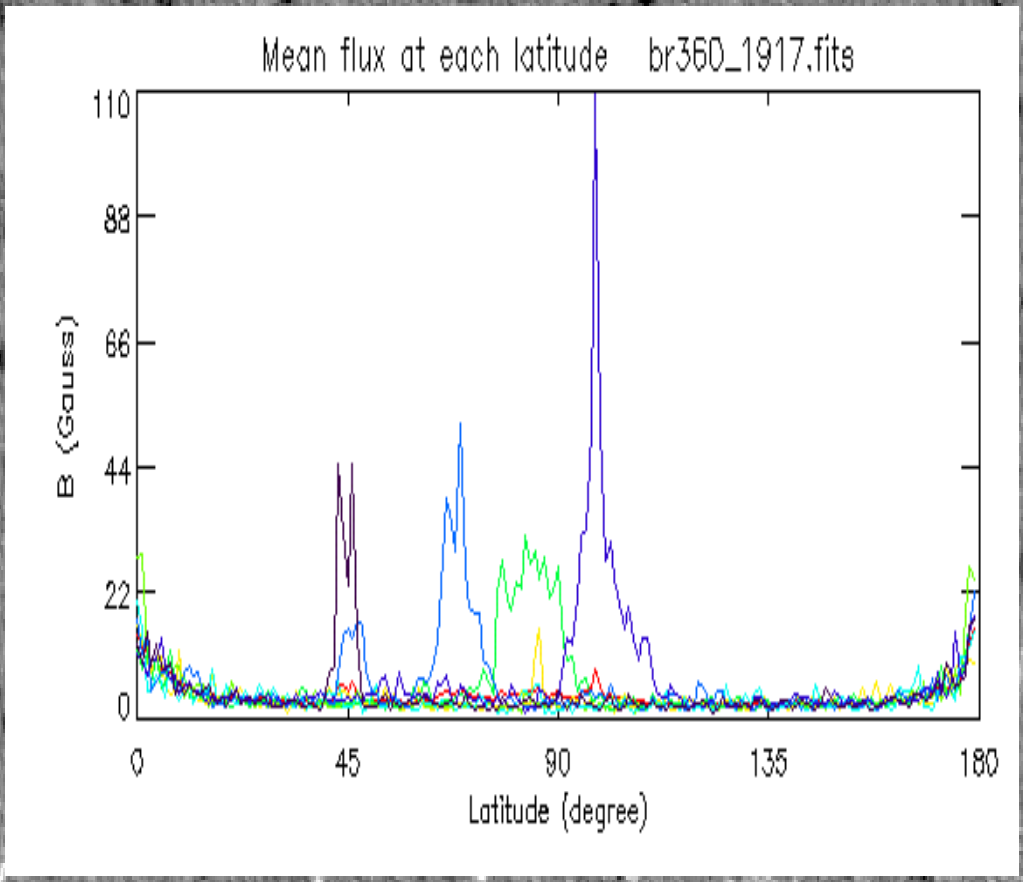
*SAIC model*

**Several current CME models "in competition"**
**include "Breakout" and flux emergence/cancellation in sheared arcades.**

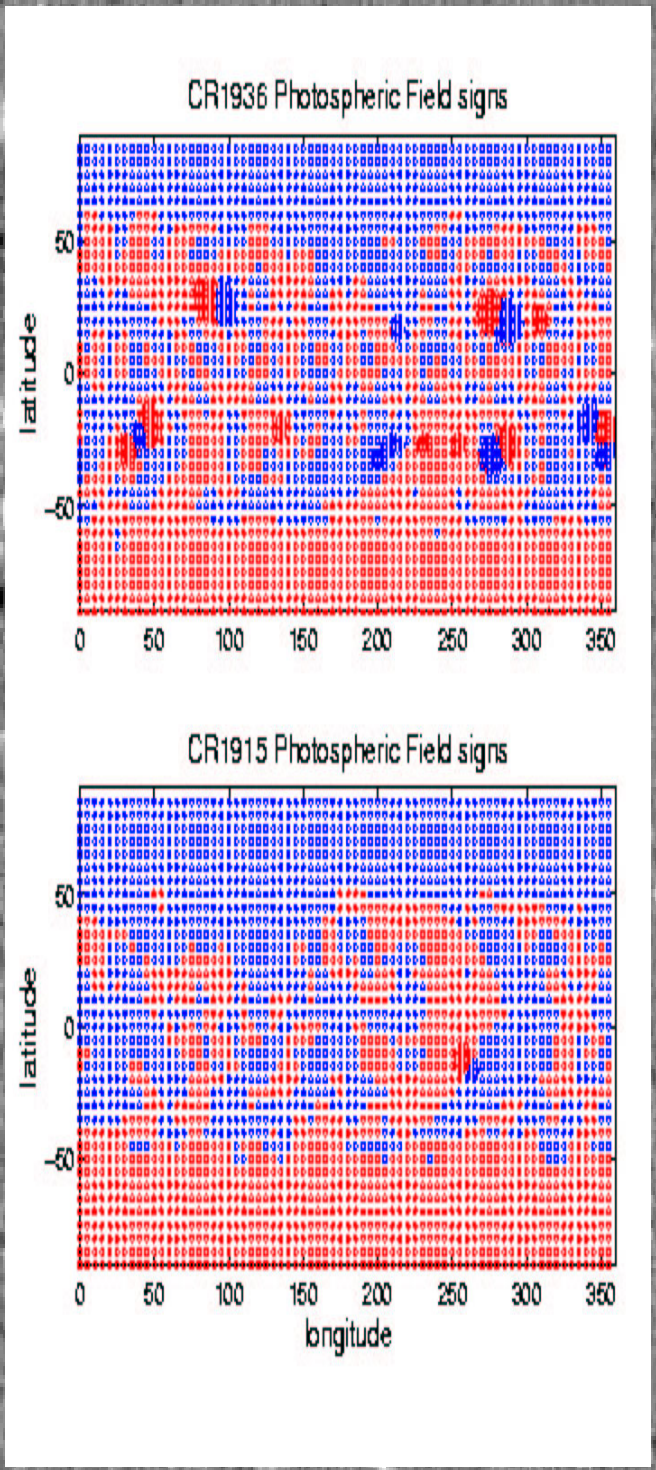
# The Photospheric Background Field is not Dipolar in strength…

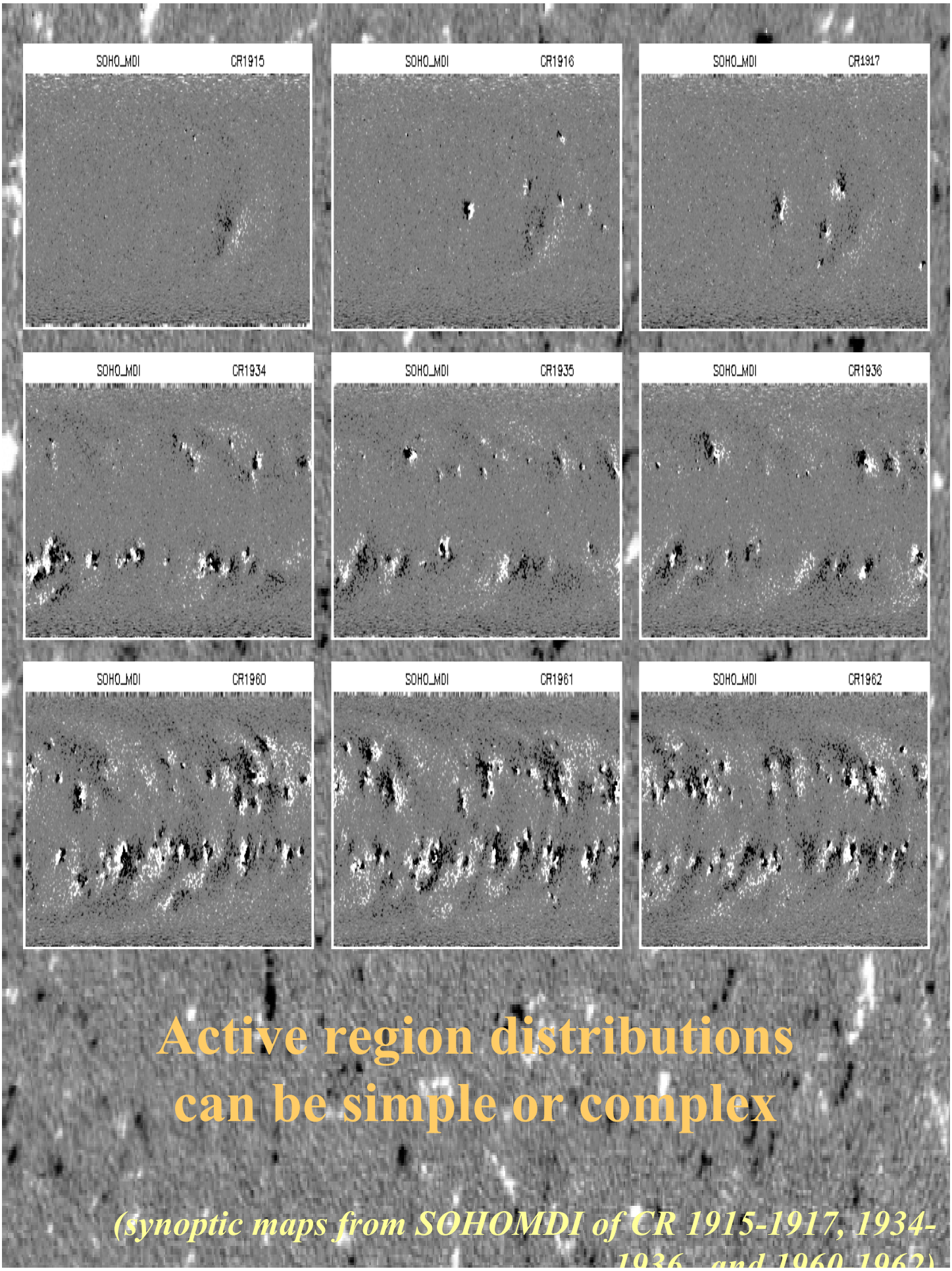


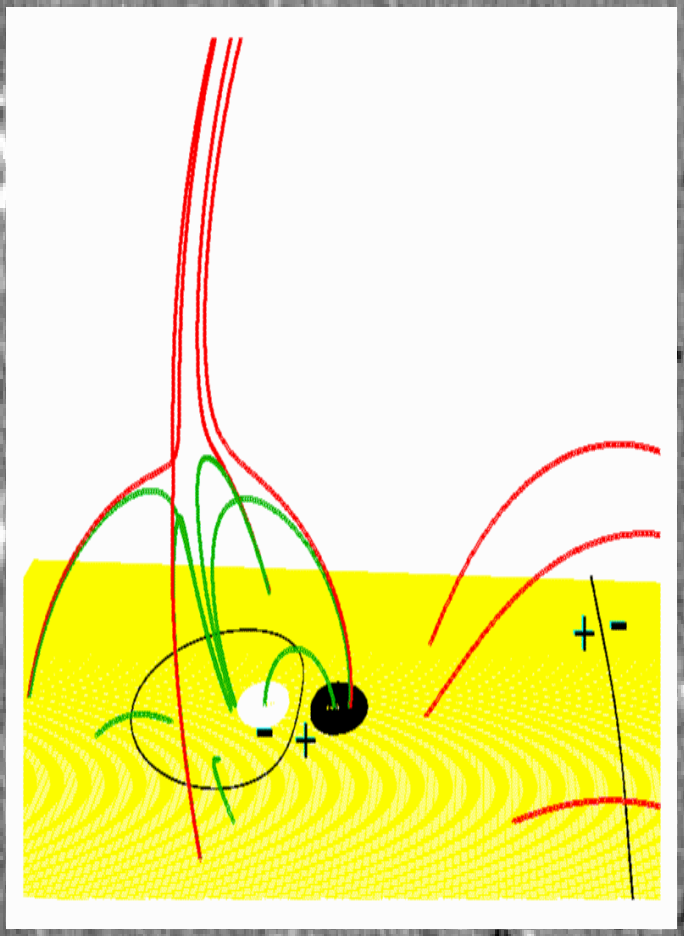
# …or in polarity

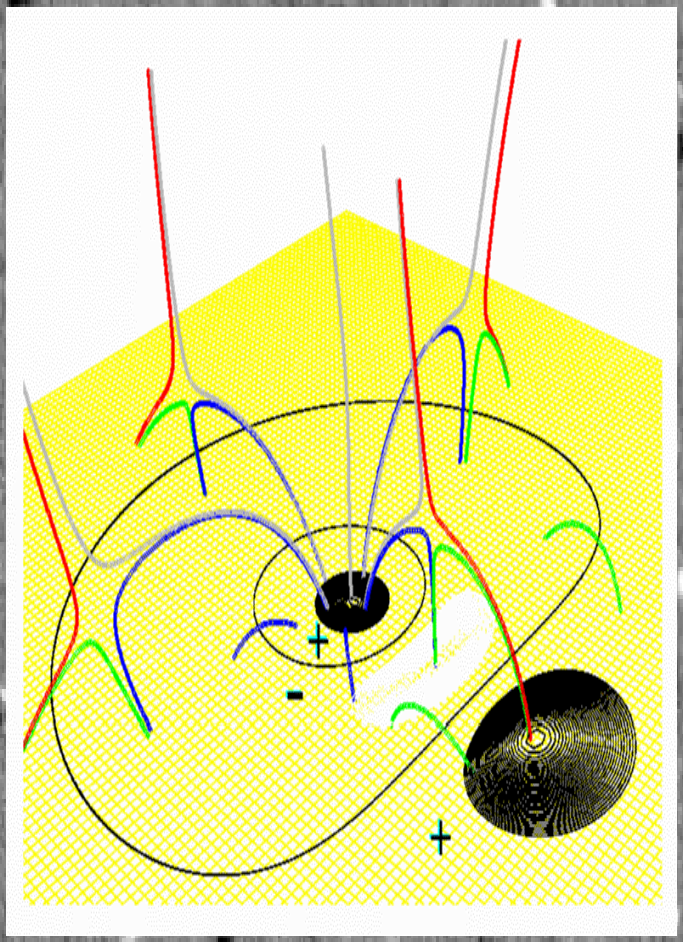





# Active region distributions can be simple or complex

*(synoptic maps from SOHOMDI of CR 1915-1917, 1934-1936, and 1960-1962)*

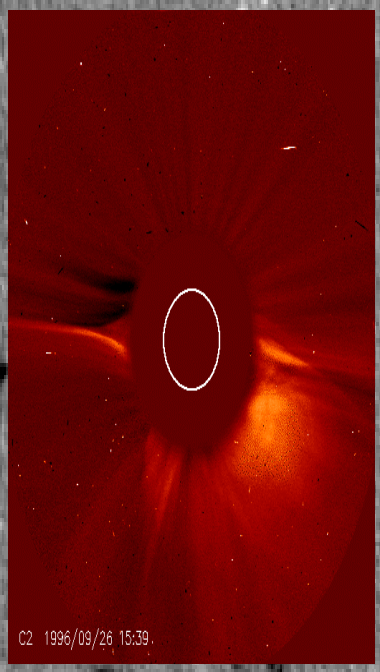


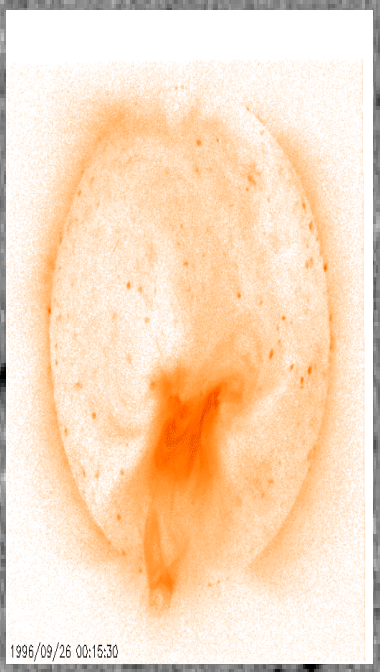



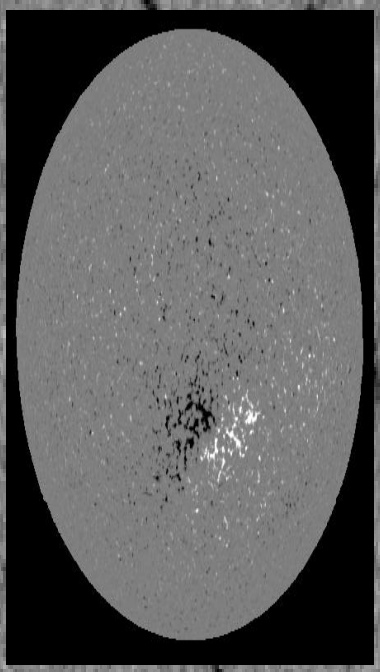

**Coronal field helmets like these exist outside of the Helmet Streamer Belt**

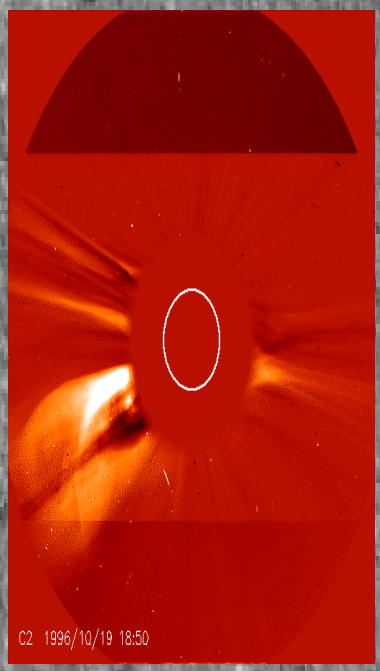
***(cartoons from Antiochos, ApJ, August 1998)***

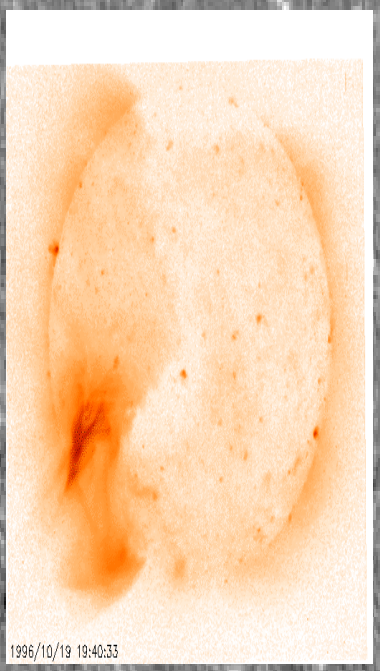
# Real Sun CMEs can be simple if the photospheric field is simple

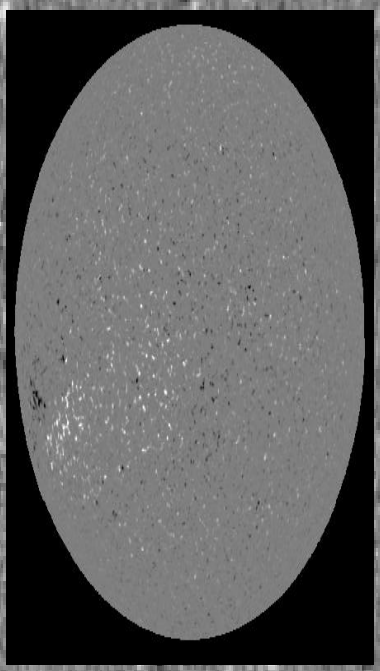




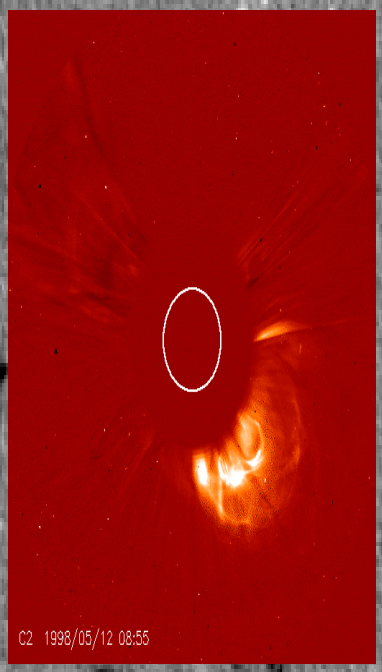



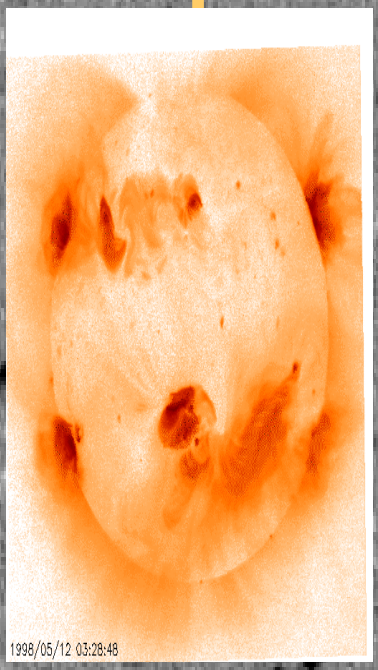



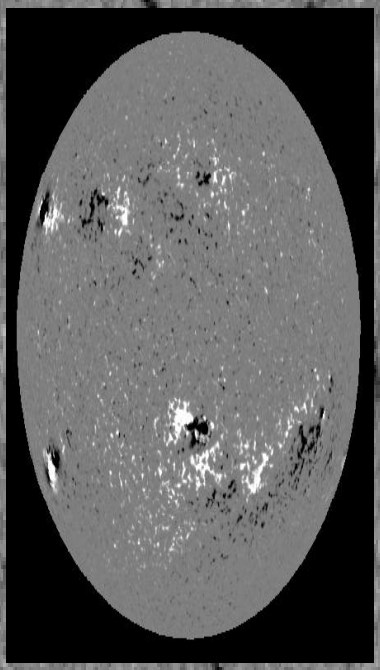
*(Images from SOHO LASCO C2 and Yohkoh SXT:*

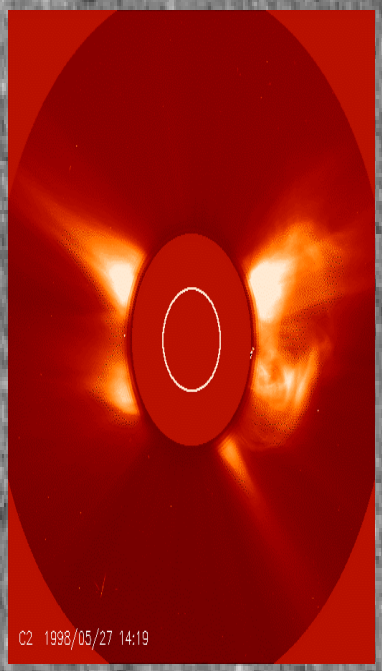
*NRL & MSSL websites, respectively, KPNO*

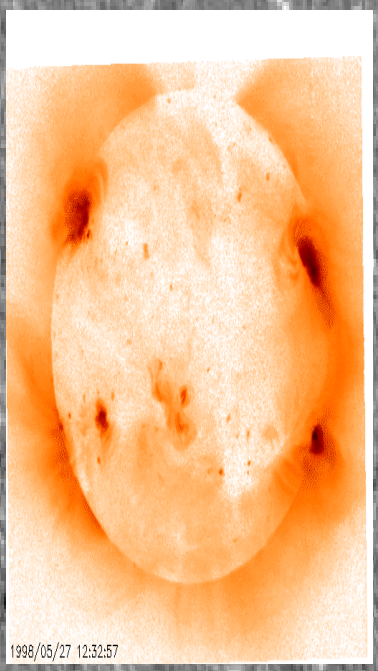
# Real Sun CMEs can be complex if the photospheric field is complex

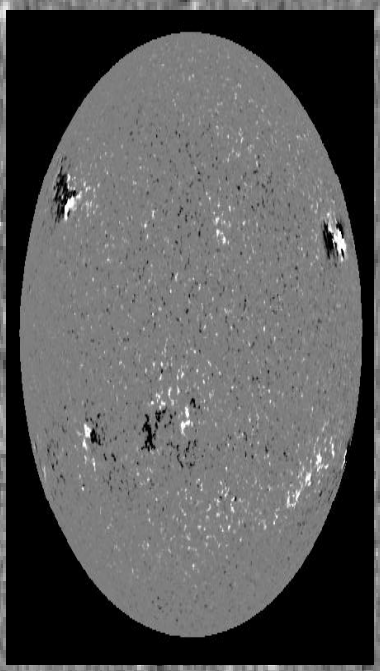




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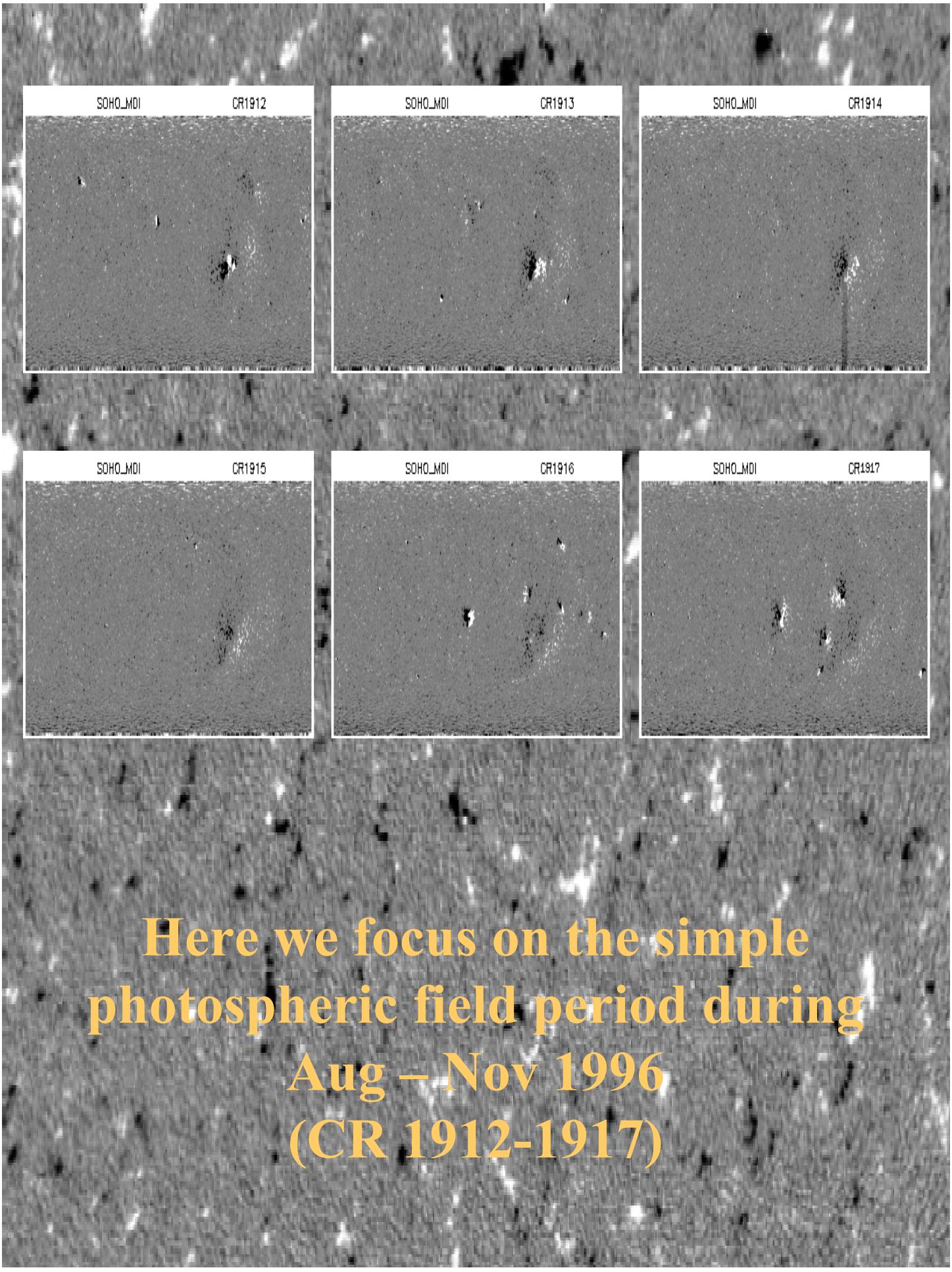
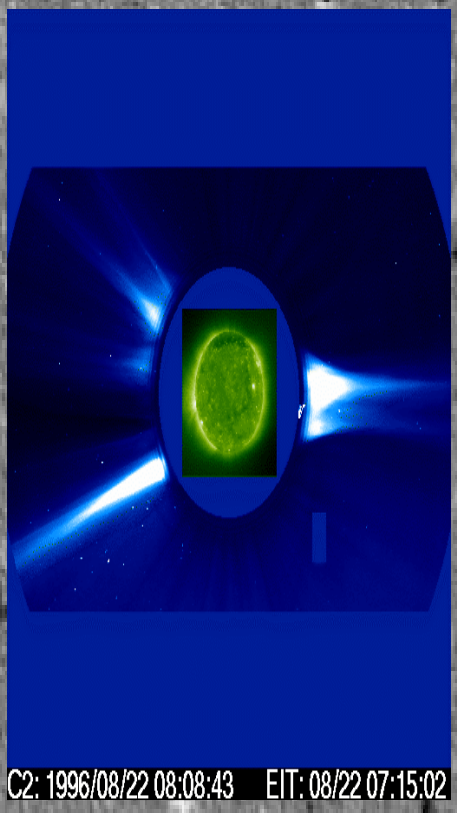
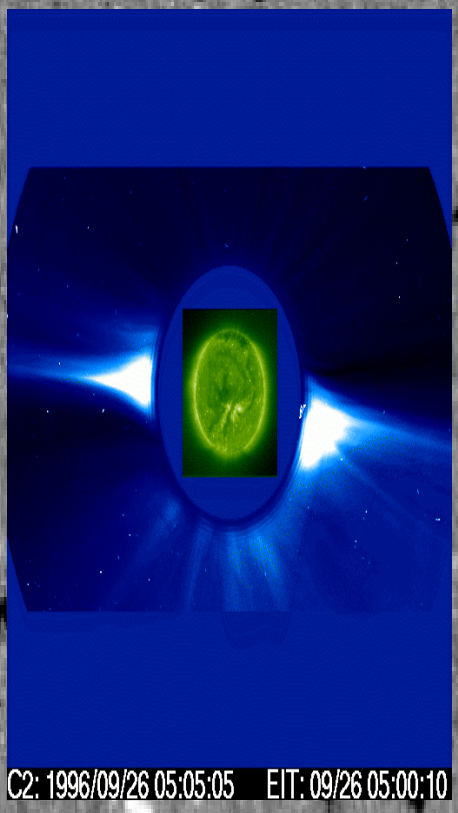
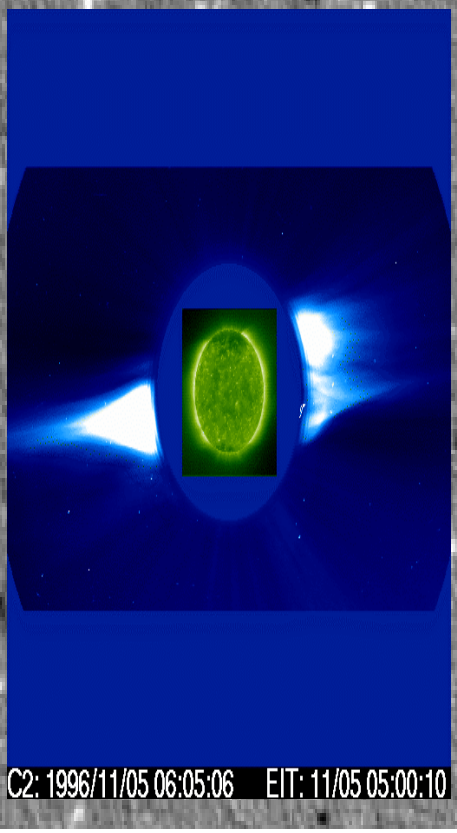


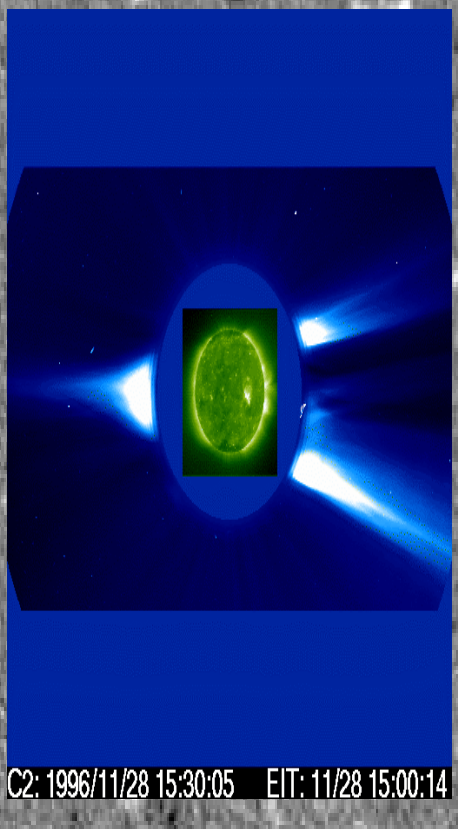

**Here we focus on the simple photospheric field period during Aug – Nov 1996 (CR 1912-1917)**

# All these CMEs (and more) occurred during this simple photospheric field period



# In fact, many CMEs were entered in the CDAW online CME catalogue for Aug - Nov 1996

CME heights are measured at the fastest segment of the leading edge
PA= Position Angle measured from Solar North in degrees (Counter clockwise)
Click on date to view java script movies
Click on time to see height-time digital files
Click on speed to view height-time plot
Numbers in 2nd order fit columns correspond to the speed at the last height of measurement and at a distance of 20 solar radii.

| First C2 Appearance Date Time [UT] | | Central PA [deg] | Angular Width [deg] | Linear fit Speed [km/s] | 2nd order fit Speed [km/s] | | Accel [m/s^2] | Measurement PA [deg] | Daily MPEG @ NRL | Remark |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996/08/01 | 12:36:35 | 274 | 35 | 499 | 551 | 615 | 7.4 | 270 | C2 C3 195 SXT | |
| 1996/08/01 | 18:12:21 | 210 | 82 | 118 | 142 | 324 | 4.0 | 229 | C2 C3 195 SXT | Only C2 |
| 1996/08/03 | 19:45:37 | 231 | 26 | 71 | 84 | 128 | 0.5 | 240 | C2 C3 195 SXT | |
| 1996/08/07 | 13:15:05 | 242 | 27 | ---- | ---- | ---- | ---- | 249 | C2 C3 195 SXT | Only 2 points, Only C2, Unable to measure |
| 1996/08/10 | 09:25:05 | 68 | 68 | 148 | 164 | 201 | 1.0 | 65 | C2 C3 195 SXT | |
| 1996/08/10 | 16:55:05 | 290 | 42 | 413 | 575 | 652 | 17.5 | 285 | C2 C3 195 SXT | |
| 1996/08/12 | 16:16:56 | 89 | 37 | 210 | ---- | ---- | ---- | 89 | C2 C3 195 SXT | Only 2 points, Only C3 |
| 1996/08/13 | 07:15:05 | 259 | 92 | 298 | 266 | 243 | -2.2 | 263 | C2 C3 195 SXT | |
| 1996/08/13 | 16:09:18 | 258 | 153 | 620 | 604 | 610 | -1.8 | 231 | C2 C3 195 SXT | Only 3 points, Only C3 |
| 1996/08/14 | 07:26:22 | 204 | 169 | 244 | 254 | 292 | 1.4 | 231 | C2 C3 195 SXT | Only 3 points |

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|---|---|---|---|---|---|---|---|---|---|---|
| 1996/09/02 | 09:45:05 | 66 | 13 | 571 | 464 | 0 | -48.1 | 73 | C2 C3 195 SXT | Only 3 points |
| 1996/09/03 | 06:25:10 | 246 | 52 | ---- | ---- | ---- | ---- | 247 | C2 C3 195 SXT | Only 3 points, Only C2, Unable to measure |
| 1996/09/03 | 23:10:10 | 86 | 31 | 260 | ---- | ---- | ---- | 86 | C2 C3 195 SXT | Only 2 points, Only C2 |
| 1996/09/04 | 23:05:05 | 243 | 13 | 255 | 234 | 0 | -3.8 | 248 | C2 C3 195 SXT | Only 3 points |
| 1996/09/08 | 12:45:06 | 93 | 46 | 195 | 196 | 196 | 0.0 | 96 | C2 C3 195 SXT | Only C3 |
| 1996/09/09 | 01:50:06 | 246 | 63 | 146 | 123 | 0 | -2.0 | 233 | C2 C3 195 SXT | |
| 1996/09/09 | 07:10:06 | 285 | 61 | 245 | 384 | 400 | 6.8 | 292 | C2 C3 195 SXT | |
| 1996/09/17 | 11:10:05 | 266 | 27 | ---- | ---- | ---- | ---- | 265 | C2 C3 195 SXT | Only 2 points, Only C2, Unable to measure |
| 1996/09/17 | 20:50:08 | 269 | 15 | 71 | ---- | ---- | ---- | 271 | C2 C3 195 SXT | Only 2 points, Only C2 |
| 1996/09/18 | 00:10:05 | 285 | 59 | 191 | 201 | 215 | 0.6 | 298 | C2 C3 195 SXT | |

CME heights are measured at the fastest segment of the leading edge
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| First C2 Appearance Date Time [UT] | | Central PA [deg] | Angular Width [deg] | Linear fit Speed [km/s] | 2nd order fit Speed [km/s] | | Accel [m/s^2] | Measurement PA [deg] | Daily MPEG @ NRL | Remark |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996/10/01 | 00:20:05 | 258 | 52 | 320 | 352 | 377 | 2.9 | 254 | C2 C3 195 SXT | |
| 1996/10/04 | 03:15:05 | 299 | 28 | 355 | 172 | 158 | -17.4 | 293 | C2 C3 195 SXT | Only C3 |
| 1996/10/05 | 09:37:05 | 266 | 161 | 569 | 729 | 748 | 16.8 | 312 | C2 C3 195 SXT | |
| 1996/10/08 | 14:10:08 | 229 | 21 | 154 | 129 | 0 | -4.3 | 231 | C2 C3 195 SXT | |
| 1996/10/09 | 00:25:06 | 221 | 13 | 299 | 313 | 382 | 2.7 | 227 | C2 C3 195 SXT | Only 3 points |
| 1996/10/11 | 02:50:06 | 111 | 45 | 209 | 271 | 420 | 7.0 | 108 | C2 C3 195 SXT | |
| 1996/10/14 | 15:15:05 | 268 | 37 | 195 | 338 | 935 | 37.3 | 270 | C2 C3 195 SXT | Only 3 points, Only C2 |
| 1996/10/19 | 12:45:05 | 120 | 25 | 71 | 68 | 0 | -0.3 | 118 | C2 C3 195 SXT | Not LE |
| 1996/10/19 | 17:17:05 | 159 | 170 | 480 | 593 | 600 | 9.4 | 124 | C2 C3 195 SXT | |
| 1996/10/20 | 09:01:41 | 68 | 31 | 74 | ---- | ---- | ---- | 61 | C2 C3 195 SXT | Only 2 points, Only C2 |
| 1996/10/20 | 13:19:08 | 300 | 35 | 254 | 270 | 344 | 2.7 | 295 | C2 C3 195 SXT | |
| 1996/10/24 | 02:35:06 | 41 | 34 | 176 | 210 | 307 | 3.4 | 54 | C2 C3 195 SXT | |
| 1996/10/26 | 20:19:42 | 308 | 42 | 64 | 83 | 223 | 2.0 | 312 | C2 C3 195 SXT | Only C2 |
| 1996/10/27 | 13:57:34 | 287 | 3 | 78 | 88 | 137 | 0.6 | 296 | C2 C3 195 SXT | |
| 1996/10/28 | 20:29:14 | 279 | 42 | 206 | 427 | 484 | 11.0 | 293 | C2 C3 195 SXT | |
| 1996/10/30 | 05:40:05 | 247 | 25 | 582 | 598 | 618 | 2.6 | 253 | C2 C3 195 SXT | |
| 1996/10/30 | 07:11:06 | 87 | 40 | 217 | 273 | 459 | 8.2 | 91 | C2 C3 195 SXT | |
| 1996/10/31 | 06:25:06 | 256 | 16 | 455 | 327 | 0 | -21.7 | 260 | C2 C3 195 SXT | |

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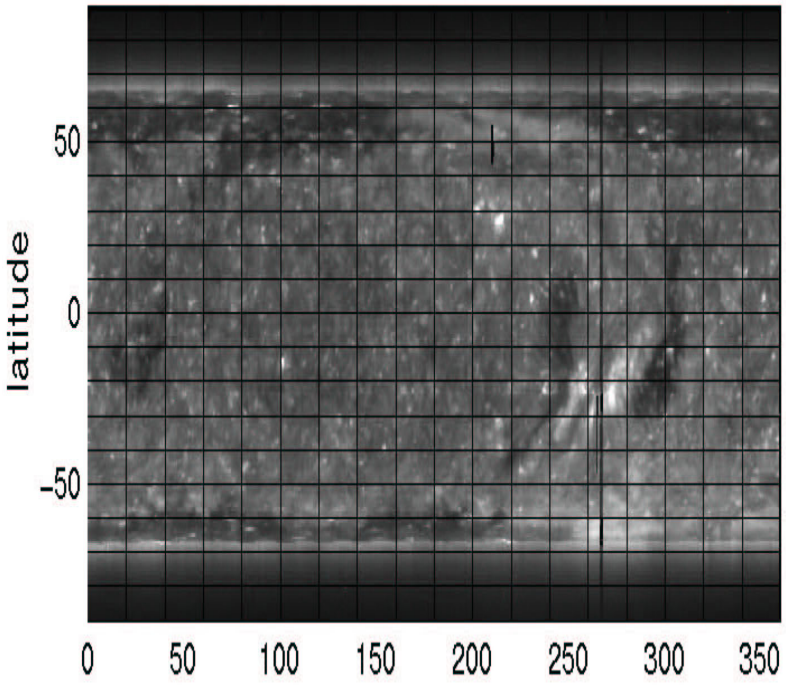
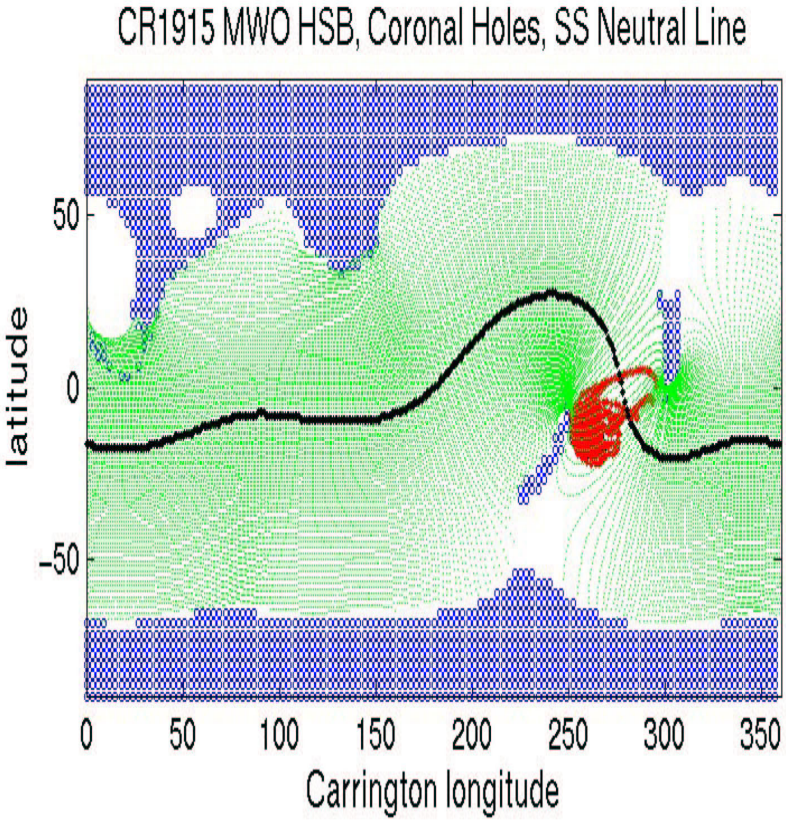
Numbers in 2nd order fit columns correspond to the speed at the last height of measurement and at a distance of 20 solar radii.

| First C2 Appearance Date Time [UT] | | Central PA [deg] | Angular Width [deg] | Linear fit Speed [km/s] | 2nd order fit Speed [km/s] | | Accel [m/s^2] | Measurement PA [deg] | Daily MPEG @ NRL | Remark |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996/11/01 | 03:21:05 | 257 | 7 | 357 | 263 | 0 | -34.9 | 261 | C2 C3 195 SXT | Only 3 points, Only C2 |
| 1996/11/03 | 13:11:09 | 279 | 47 | 185 | 179 | 0 | -1.8 | 270 | C2 C3 195 SXT | |
| 1996/11/04 | 02:35:05 | 266 | 17 | 524 | 516 | 481 | -2.4 | 271 | C2 C3 195 SXT | |
| 1996/11/04 | 17:52:23 | 104 | 41 | 90 | 106 | 183 | 1.2 | 114 | C2 C3 195 SXT | Only C2 |
| 1996/11/04 | 22:15:05 | 260 | 20 | 573 | 726 | 1044 | 41.7 | 269 | C2 C3 195 SXT | |
| 1996/11/05 | 02:35:06 | 274 | 63 | 108 | 92 | 0 | -2.6 | 276 | C2 C3 195 SXT | Only C2 |
| 1996/11/06 | 06:05:05 | 100 | 43 | 347 | 221 | 0 | -16.8 | 89 | C2 C3 195 SXT | |
| 1996/11/07 | 07:25:05 | 113 | 36 | 97 | 101 | 142 | 0.6 | 106 | C2 C3 195 SXT | |
| 1996/11/07 | 23:20:05 | Halo | 360 | 497 | 630 | 586 | 8.7 | 114 | C2 C3 195 SXT | |
| 1996/11/08 | 14:42:21 | 288 | 70 | 87 | 132 | 263 | 3.0 | 285 | C2 C3 195 SXT | |
| 1996/11/09 | 00:05:05 | 355 | 169 | 157 | 179 | 290 | 3.1 | 281 | C2 C3 195 SXT | |
| 1996/11/15 | 01:31:07 | 76 | 33 | 217 | 288 | 407 | 6.3 | 75 | C2 C3 195 SXT | |
| 1996/11/19 | 16:45:36 | 250 | 68 | 213 | 227 | 299 | 2.2 | 263 | C2 C3 195 SXT | |
| 1996/11/24 | 17:52:18 | 268 | 77 | 594 | 804 | 684 | 31.1 | 288 | C2 C3 195 SXT | Only C3 |
| 1996/11/25 | 00:40:05 | 261 | 63 | 258 | 250 | 239 | -0.6 | 256 | C2 C3 195 SXT | |
| 1996/11/26 | 06:00:06 | 268 | 72 | 313 | 428 | 563 | 13.2 | 290 | C2 C3 195 SXT | |
| 1996/11/26 | 15:35:05 | 87 | 41 | 90 | ---- | ---- | ---- | 85 | C2 C3 195 SXT | Only 2 points, Only C2 |
| 1996/11/26 | 21:35:41 | 270 | 78 | 548 | 781 | 954 | 38.1 | 283 | C2 C3 195 SXT | |

*(catalogue compiled by Seiji Yashiro)*



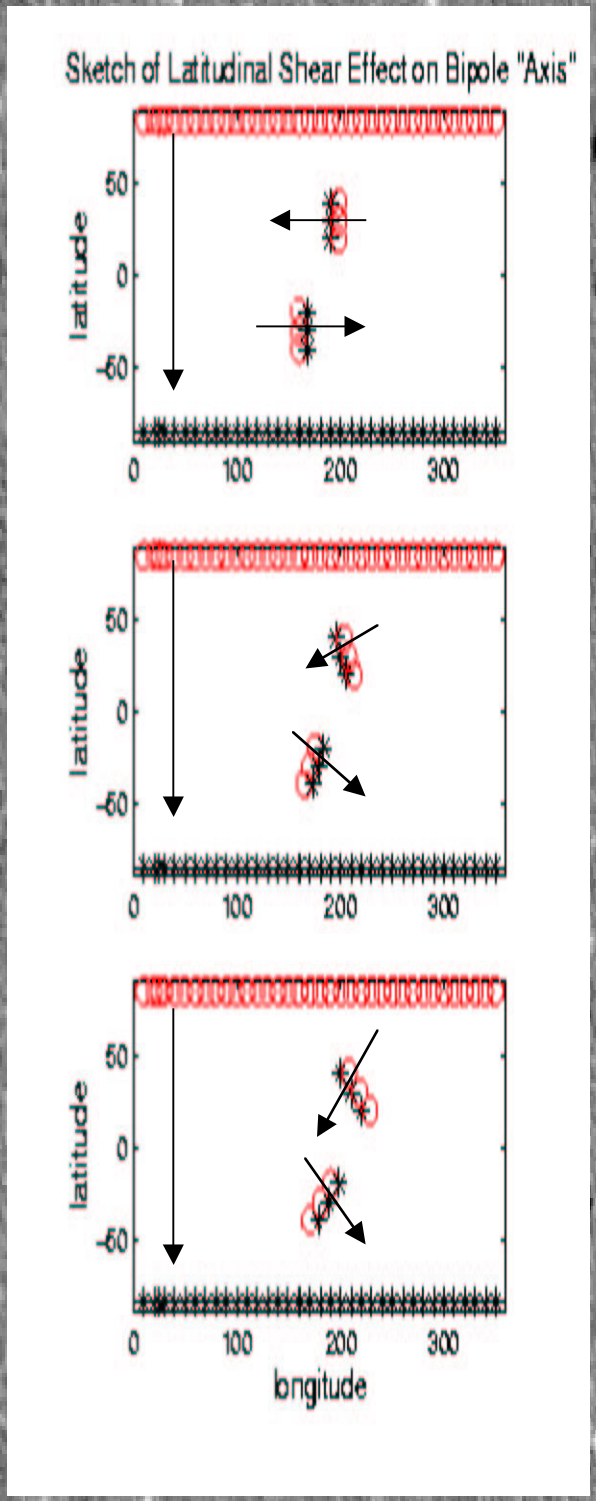

**The potential field source surface model can be used to approximate coronal holes, helmet streamer belt and active region field connections.**

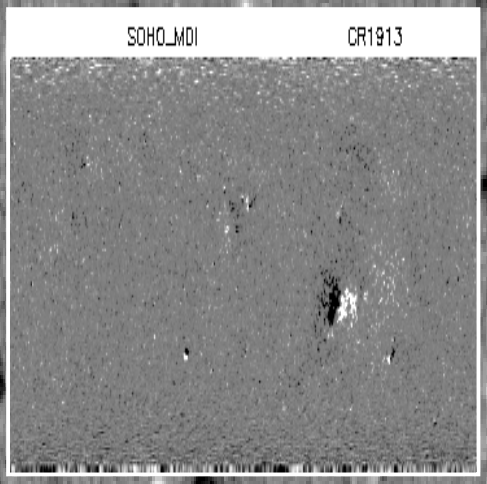
**We use it to try to learn more about CME coronal field context.**

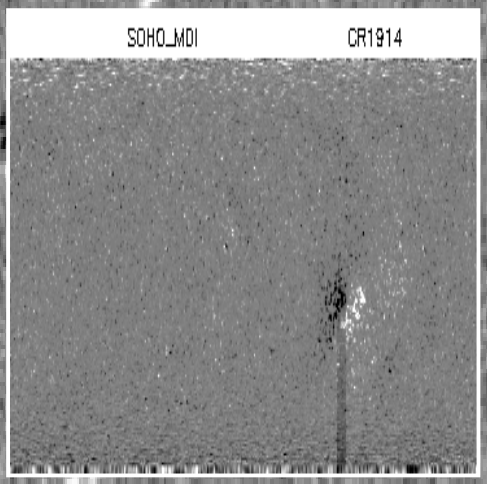
**The example shown here is for CR1915.**

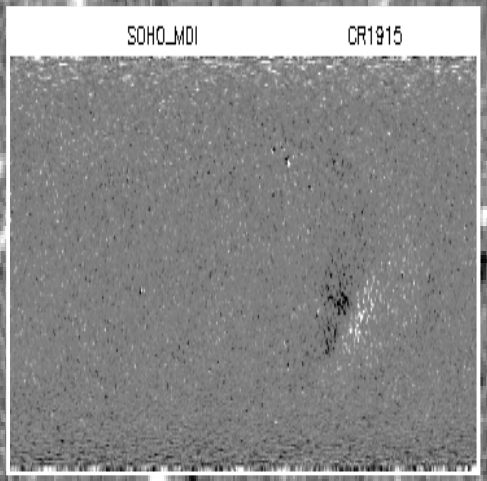
***(SOHO EIT map from NRL LASCO website)***

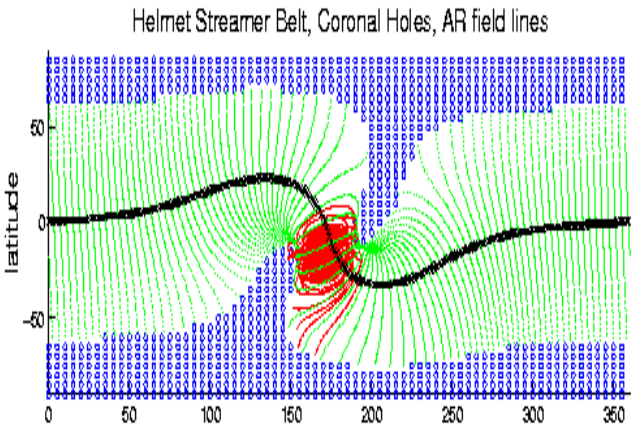
# Differential rotation can cause effective active region bipole rotation

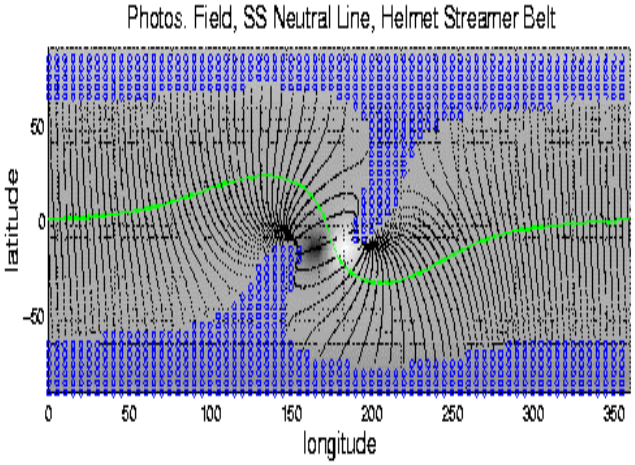


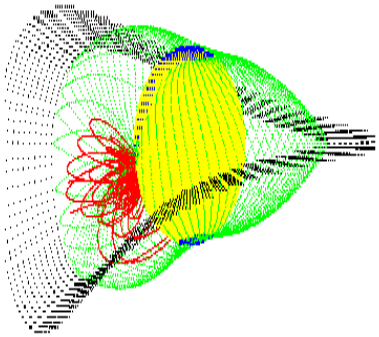



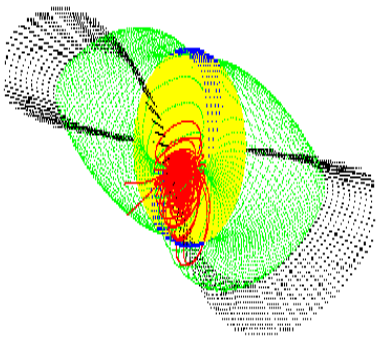


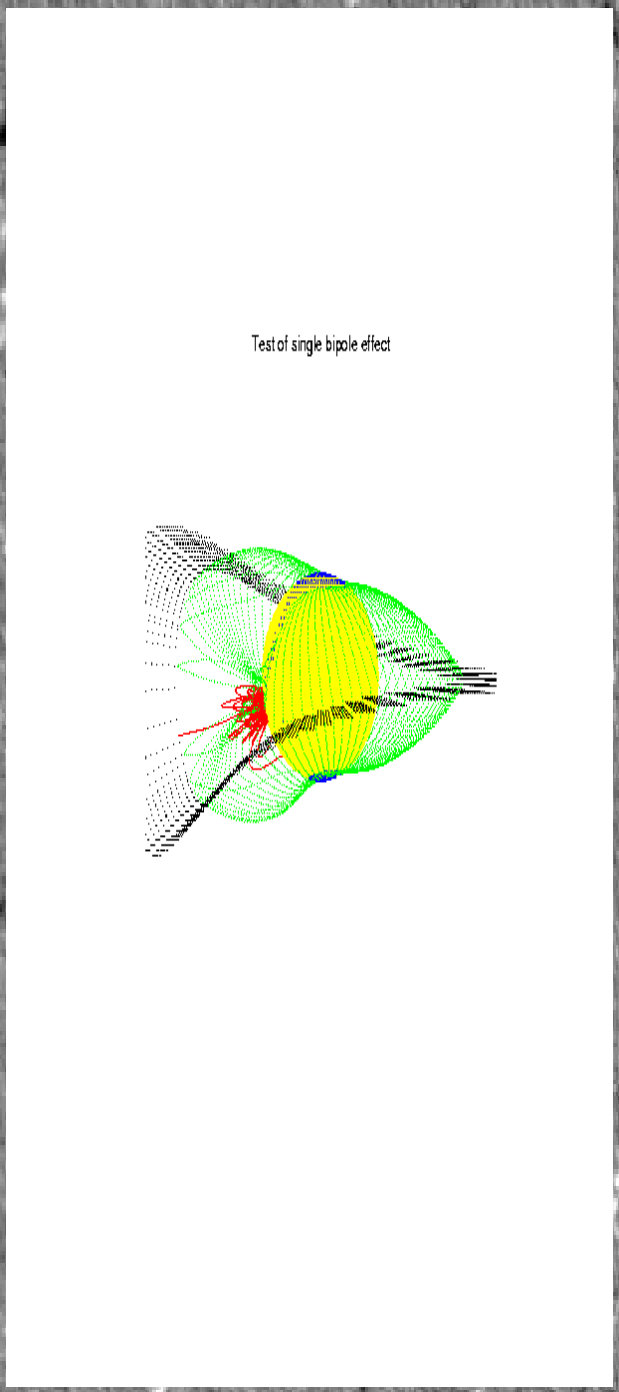

**Does a model using the basic idea of a tilting bipolar active region at -15º latitude interacting with the background field resemble the observations for our simple Sun period?**

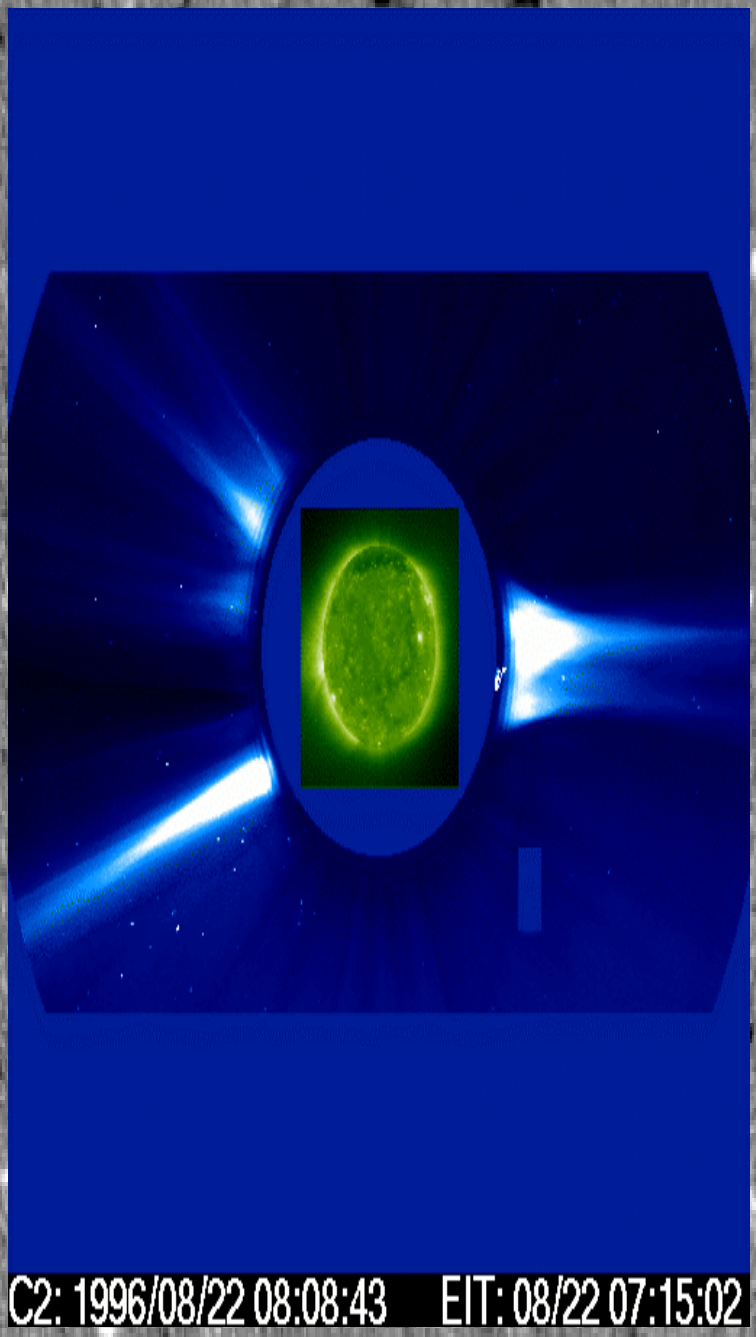
# Model Spherical Projections



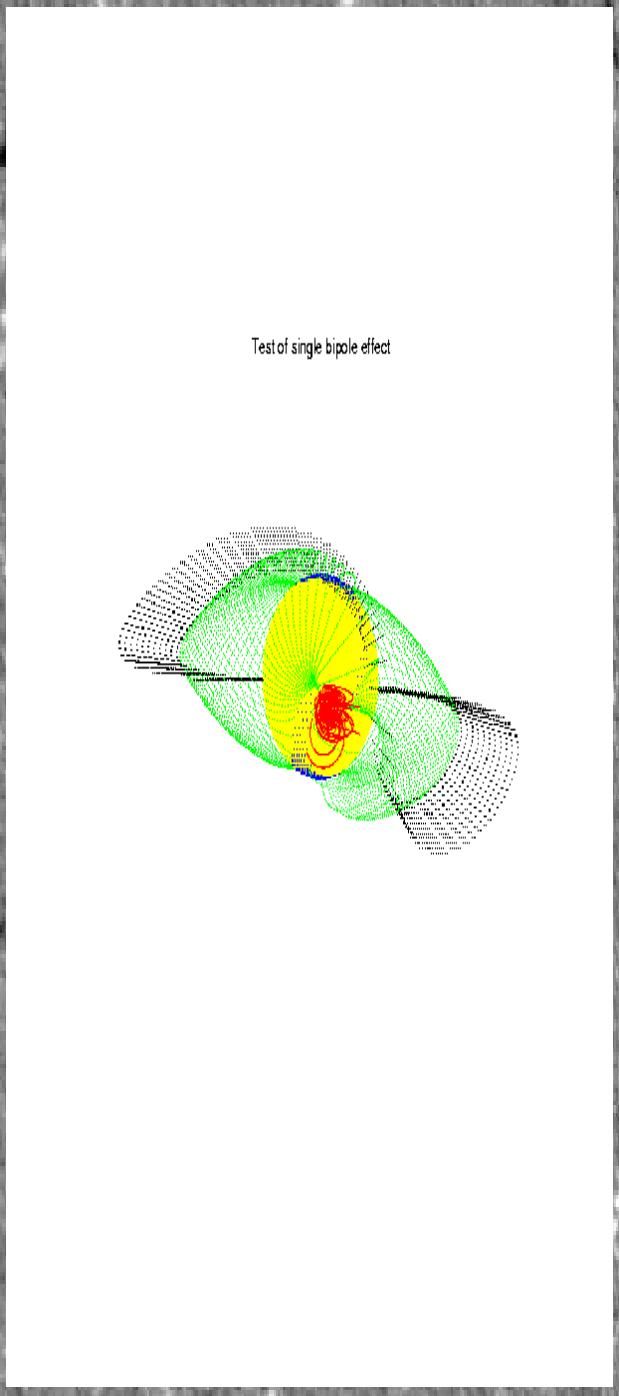


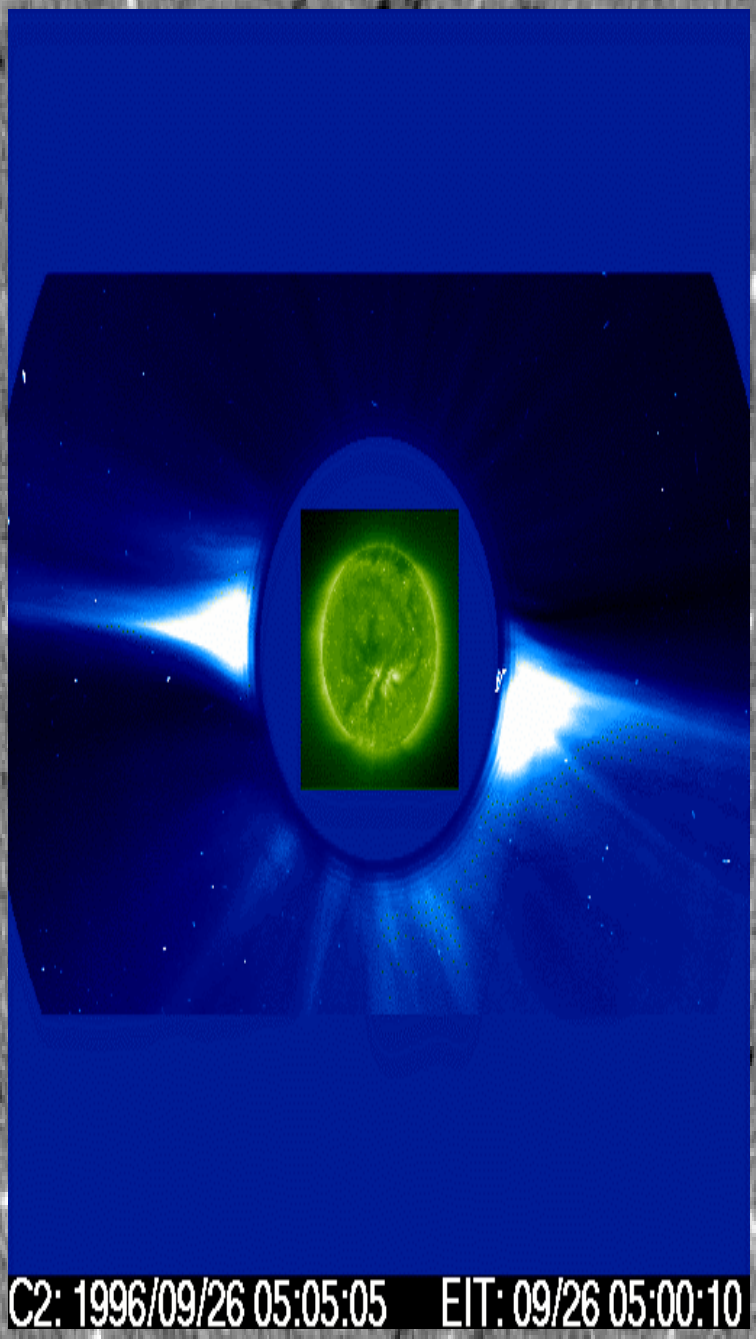
# 22 August 1996 CME: "Model" and SOHO EIT/LASCO image



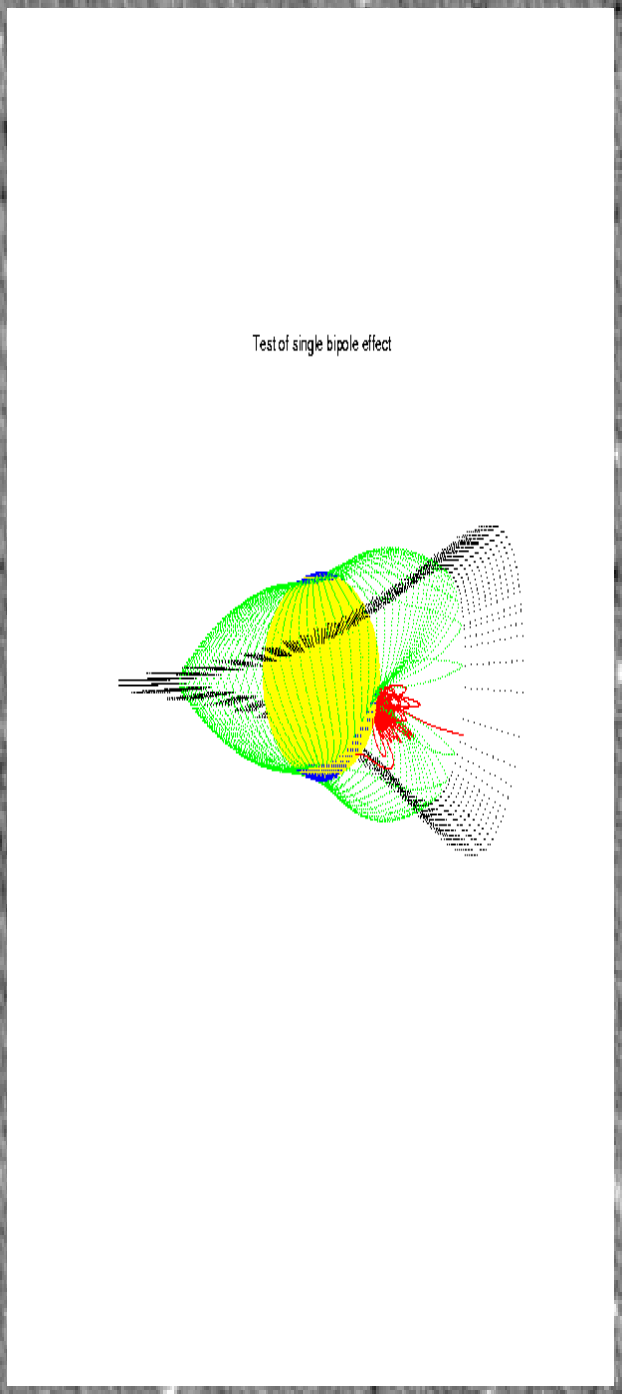



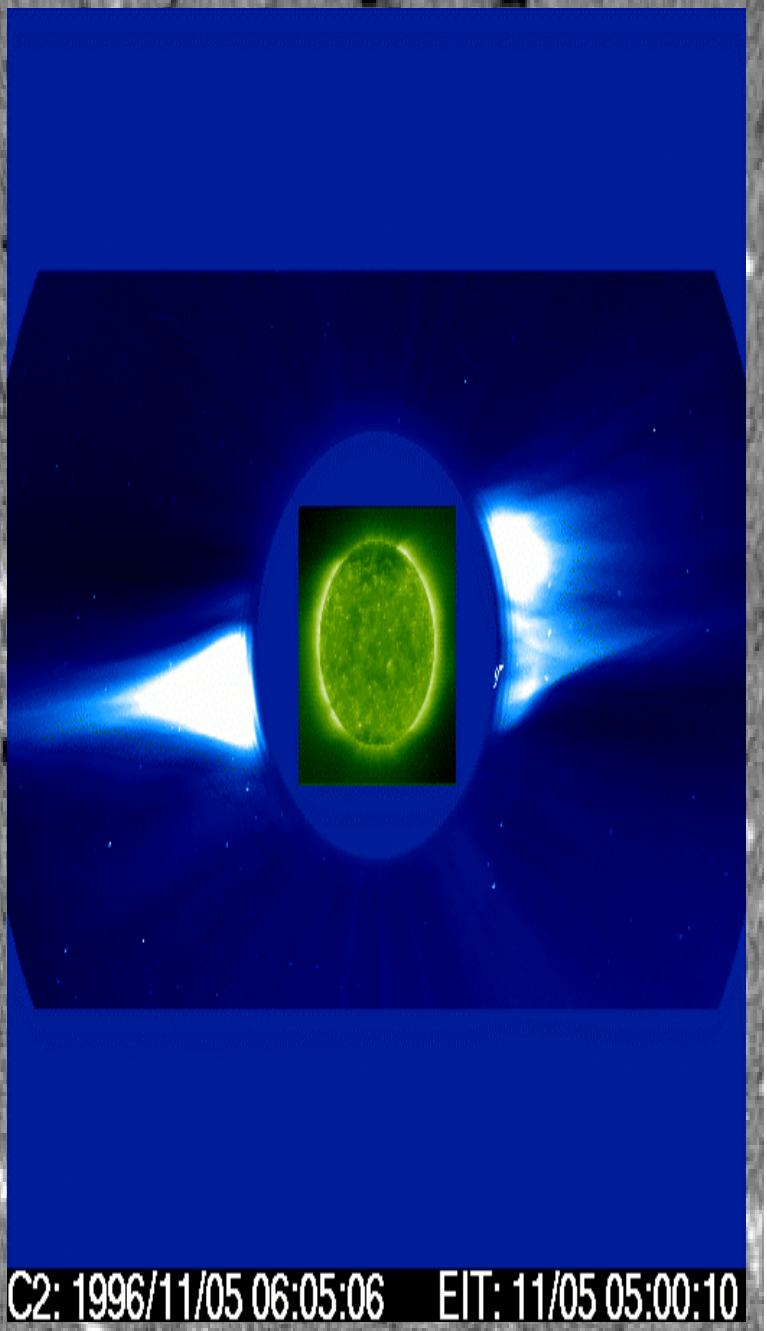
# 26 September 1996 Halo CME: "Model" and SOHO EIT/LASCO image

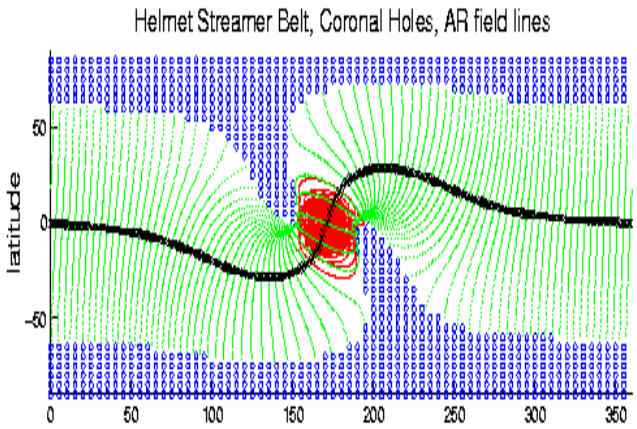


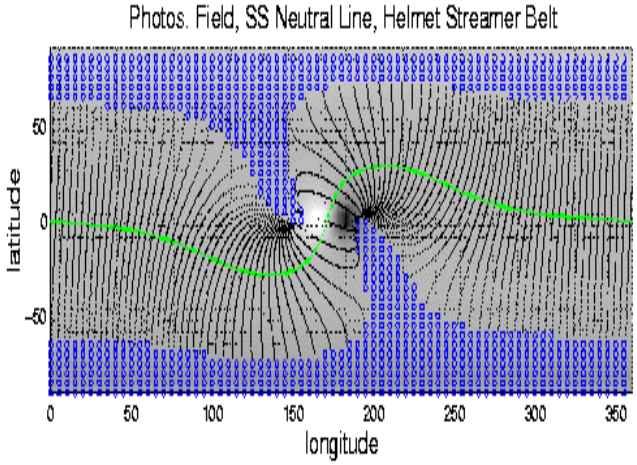



# 5 November 1996 CME: "Model" and SOHO EIT/LASCO image



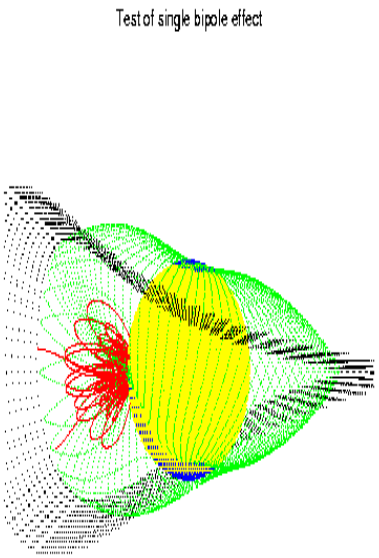



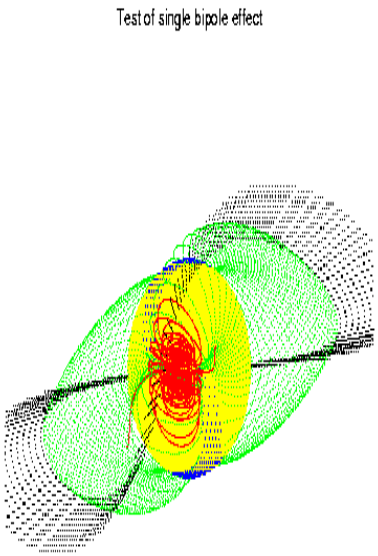


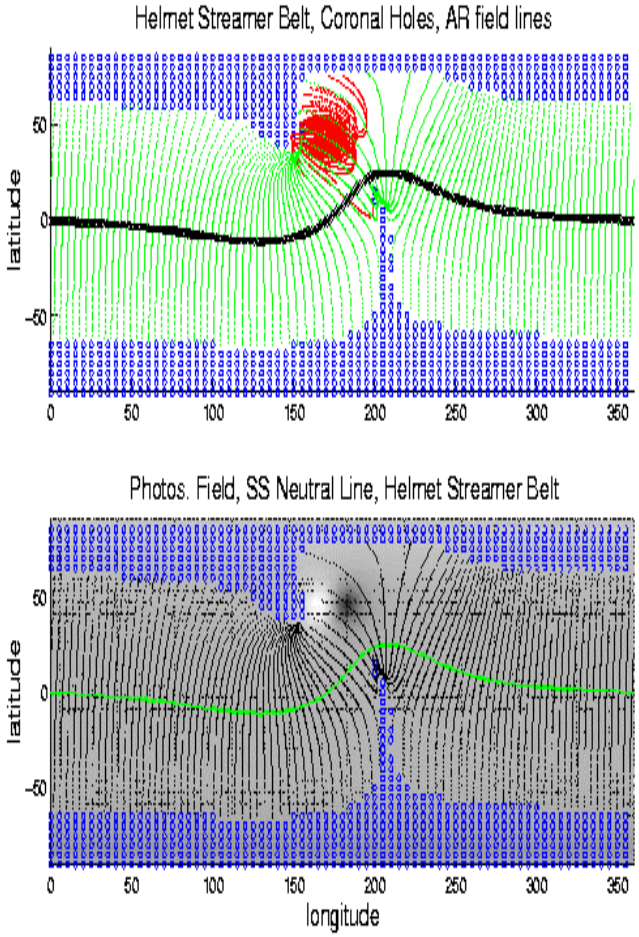

**Model "experiment" with equatorial bipolar active region, showing coronal field configurations for North, East, South, and West bipole axis orientation.**

# Equatorial Bipole Model Spherical Projections

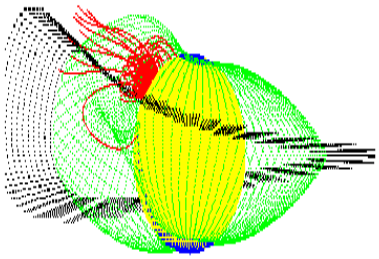


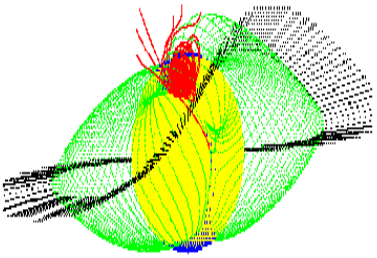



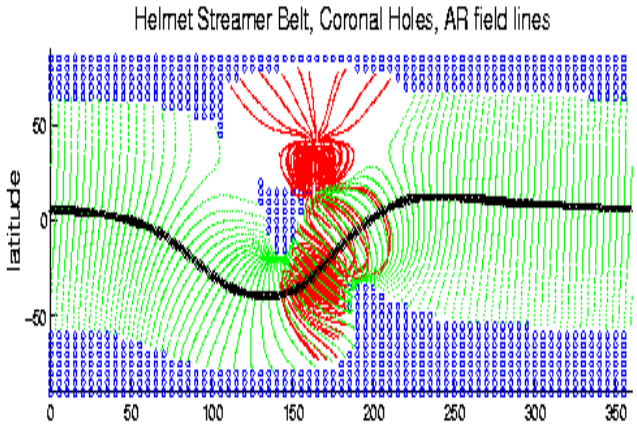
# Model "experiment" with bipolar active region at 45° N Latitude.

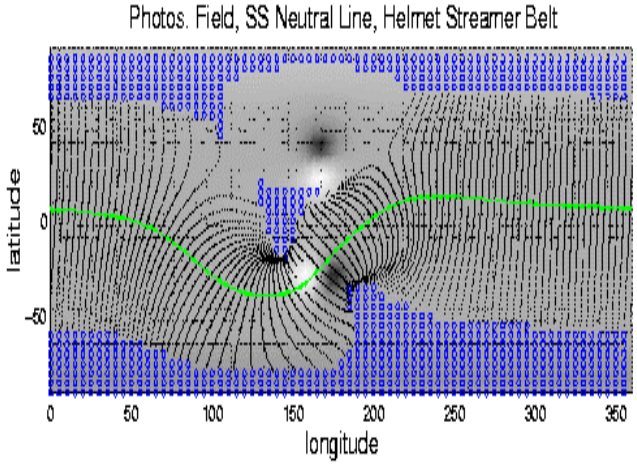


# 45° N Latitude
# Bipole Model Spherical Projections



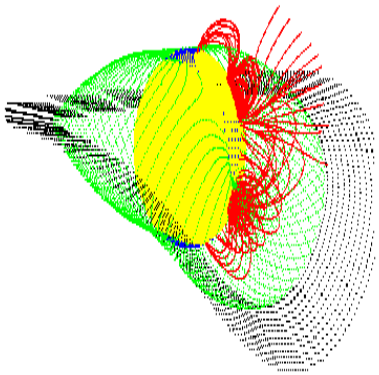


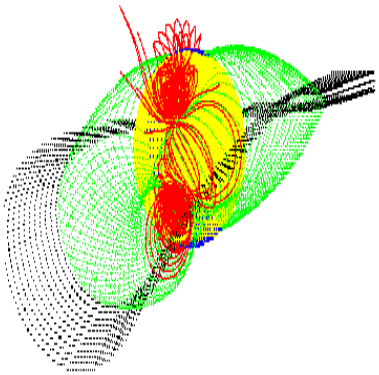


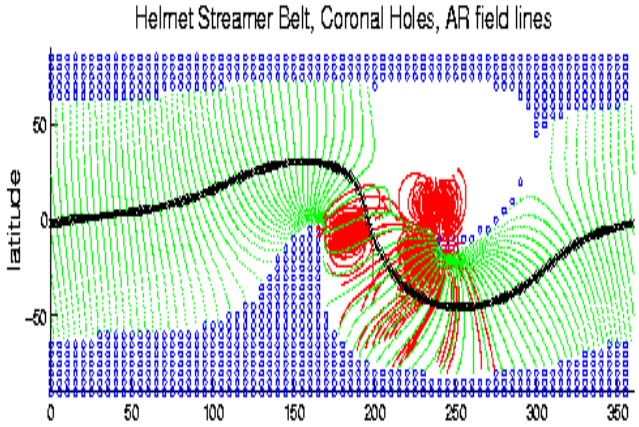

**Model "experiment" with two bipolar regions at 30º N and S Latitude. Only the N bipole axis orientation is changed.**

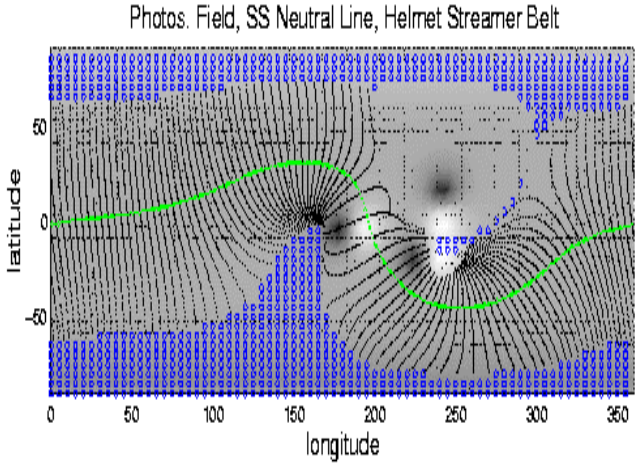
# 30° N and S Latitude
# Bipole Model Spherical Projections



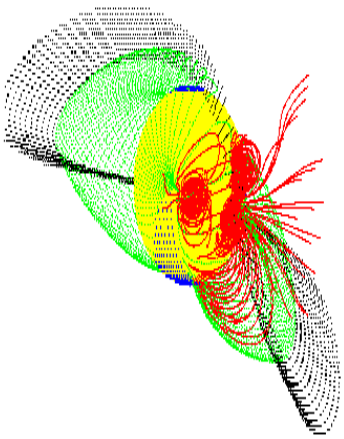


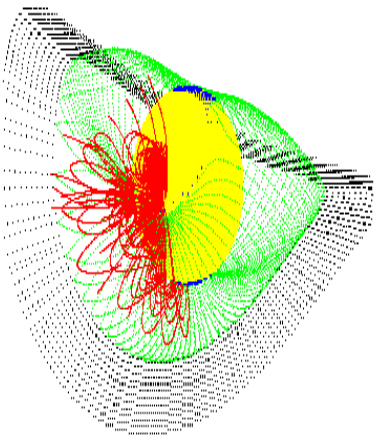
# Model "experiment" with three bipolar regions.



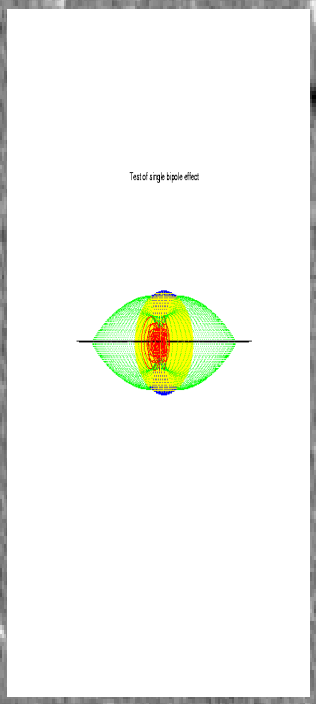



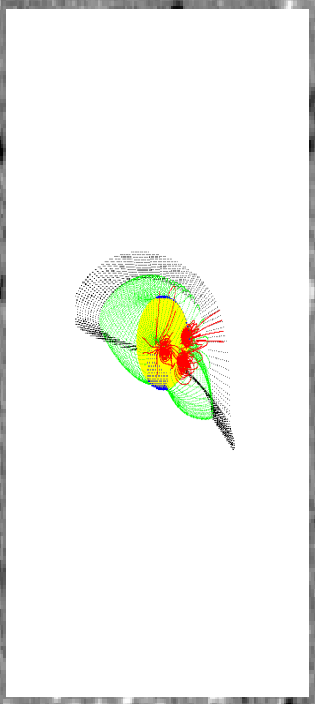
# Three Bipole Model Spherical Projections

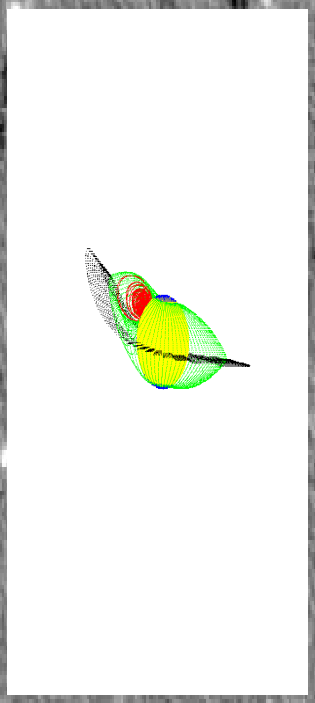


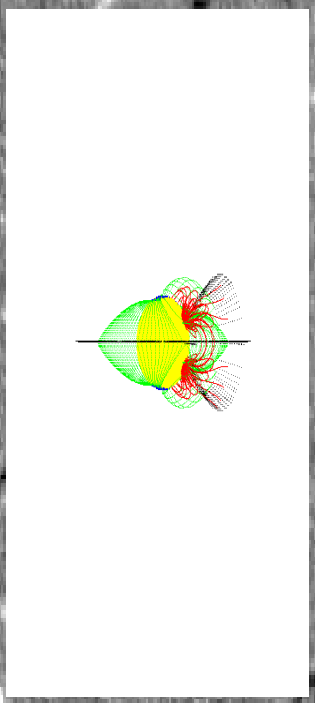


# Flux emergence that effectively introduces bipole polarity reversal would have the same effect.



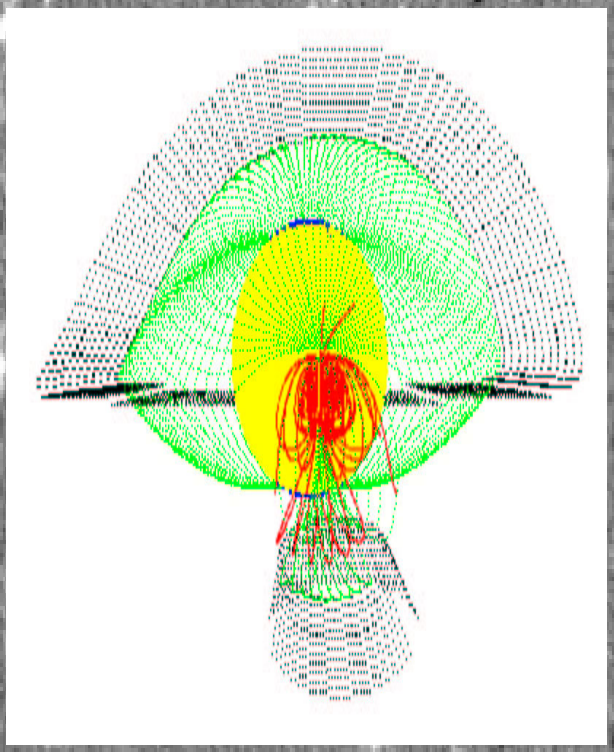



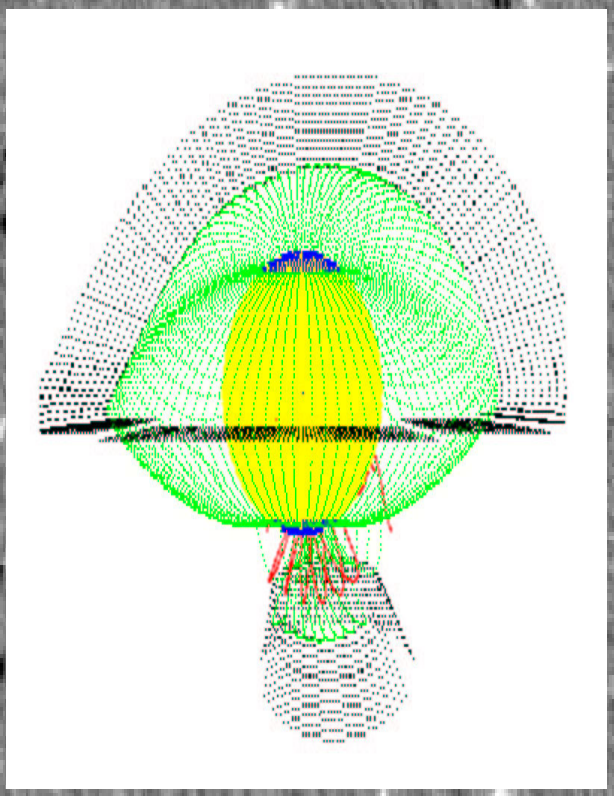


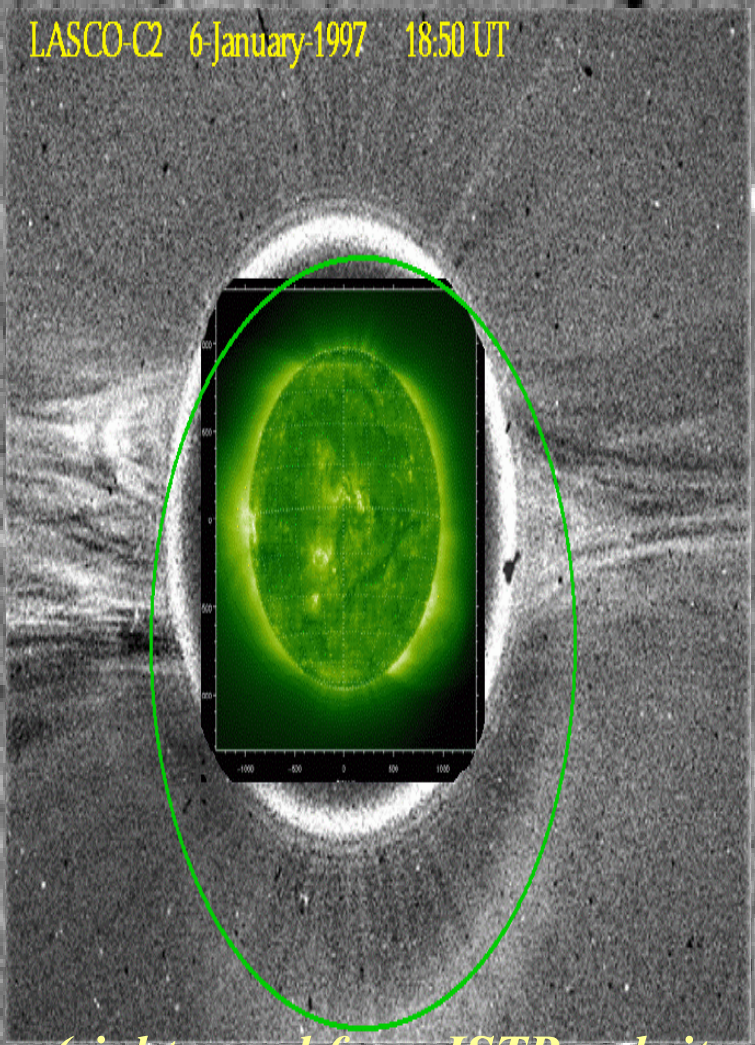


*(models without the E-W phase)*

# Halos may be secondary streamer cylinders produced as a transient phase



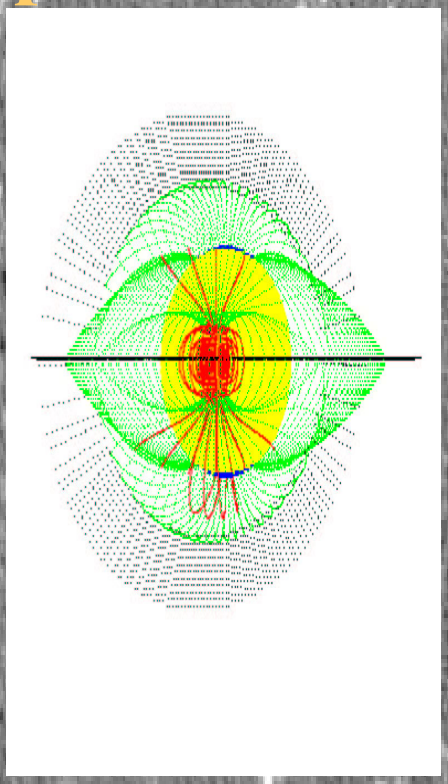


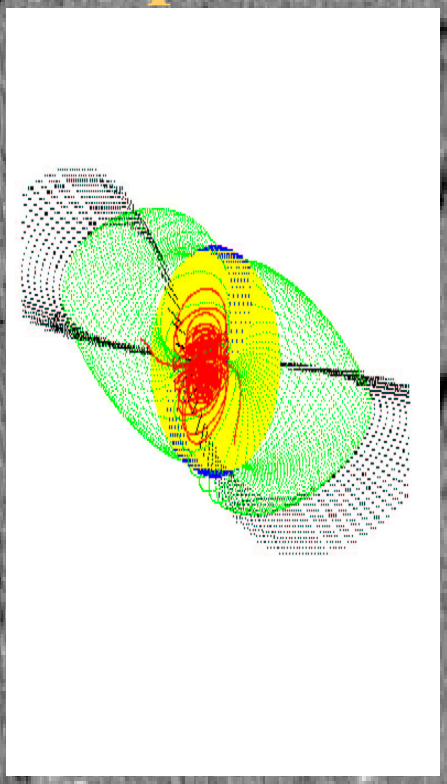


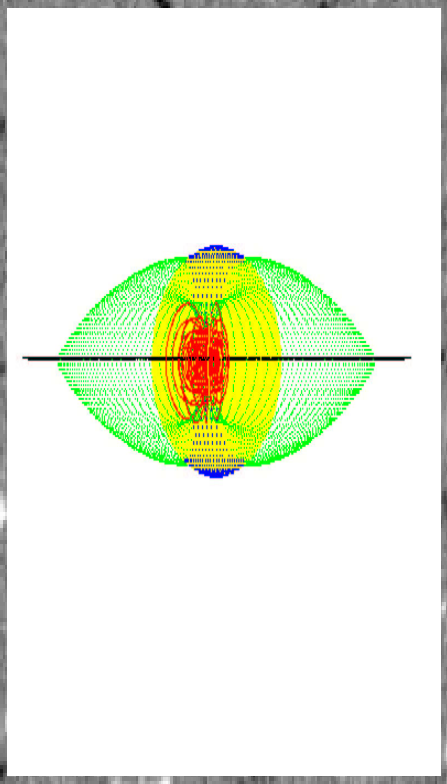

*(right panel from ISTP website at GSFC)*

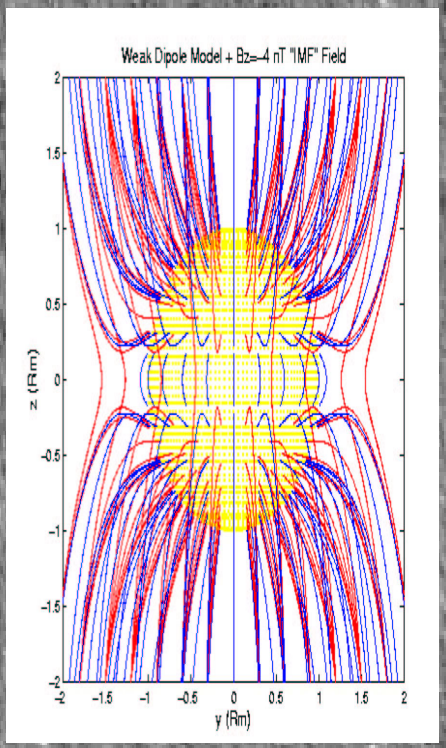
*(bottom: hypothetical backside view)*

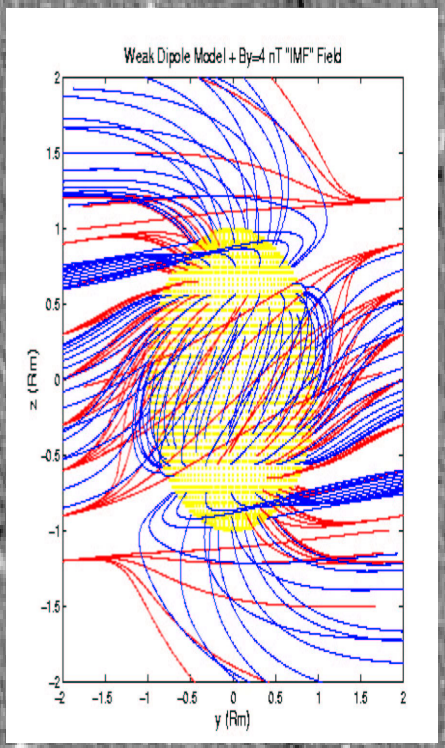
# The basic principle is reminiscent of Dungey's 1961 idea for a magnetosphere: parallel and antiparallel interactions.

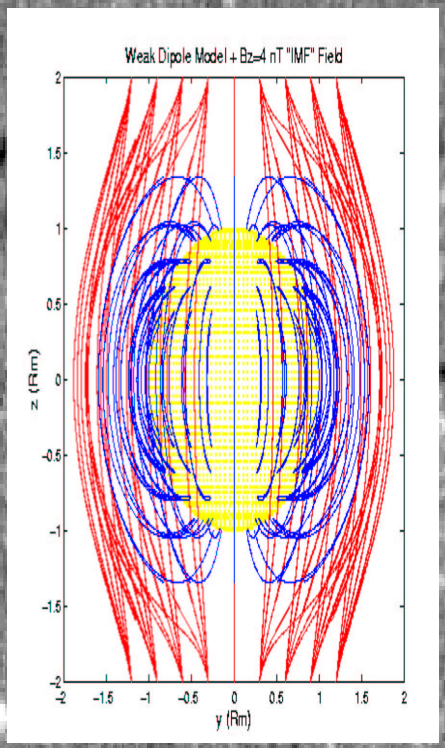




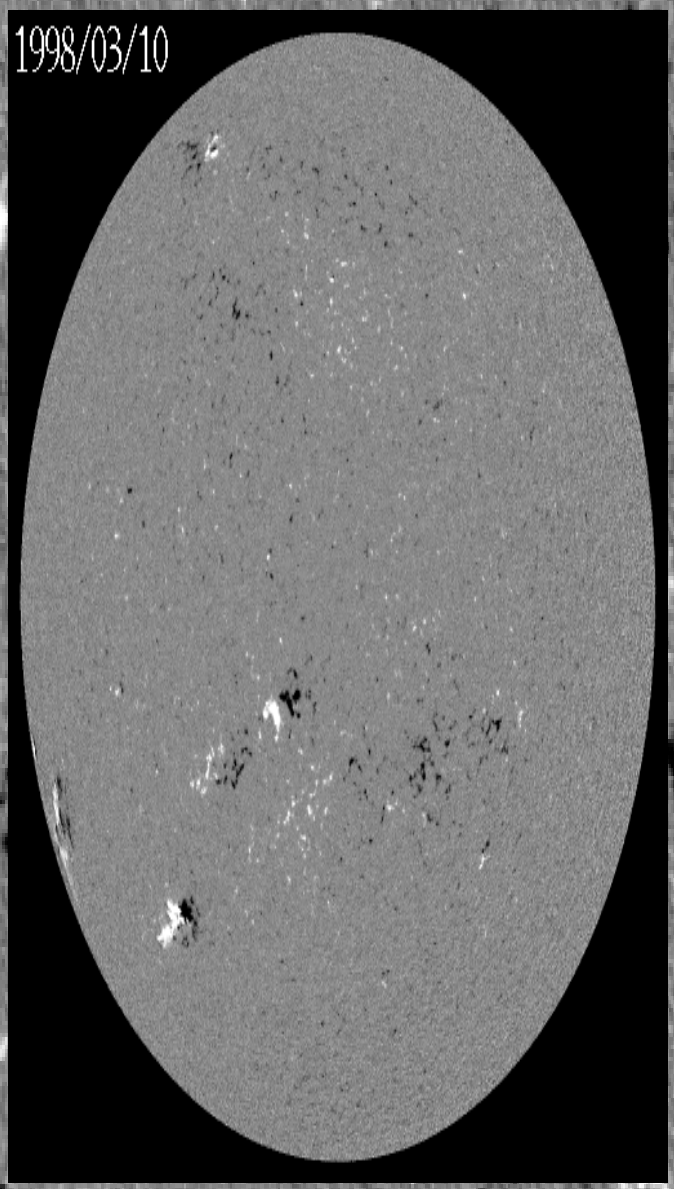




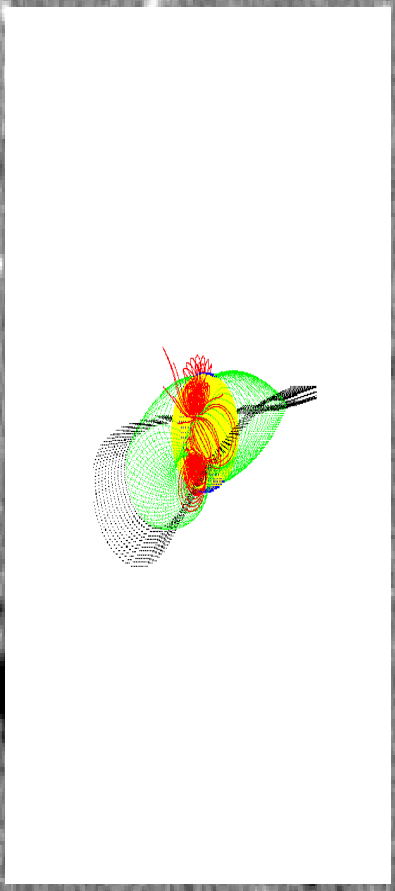



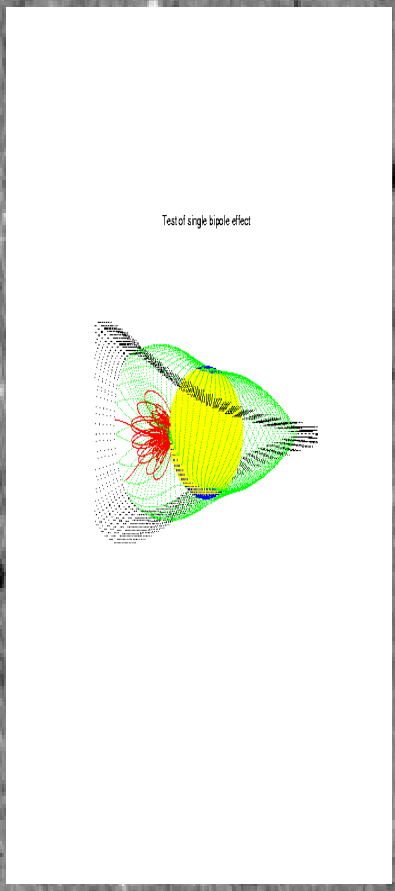
# One can think of bipolar active regions as noses of "magnetospheres" poking into the larger scale coronal magnetic field.

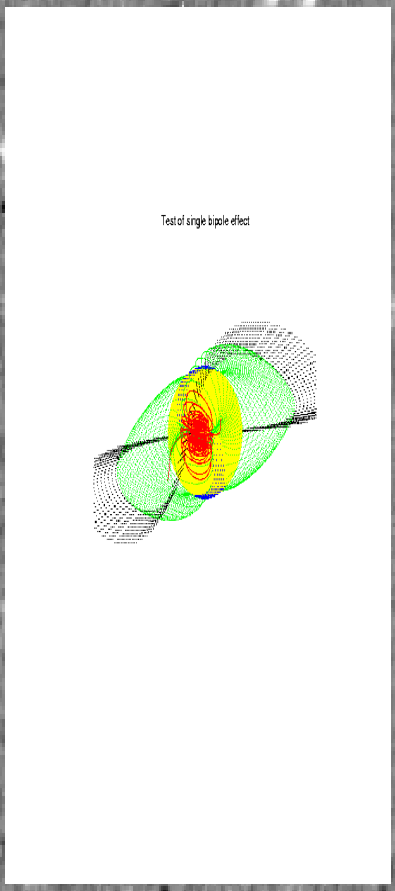


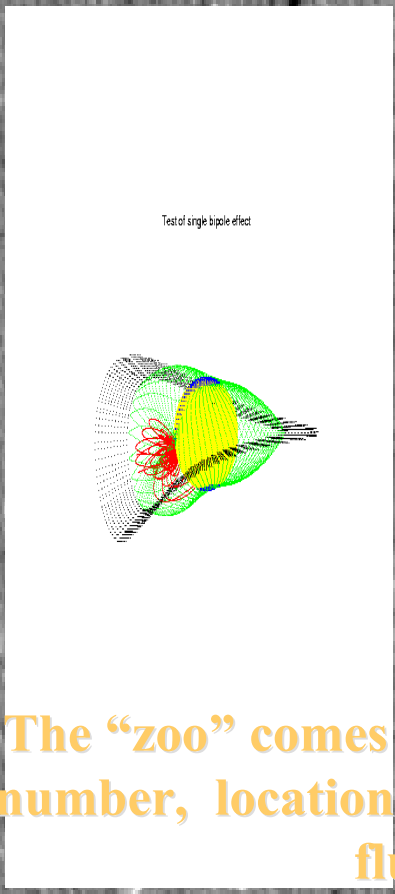

*(MDI Image)*

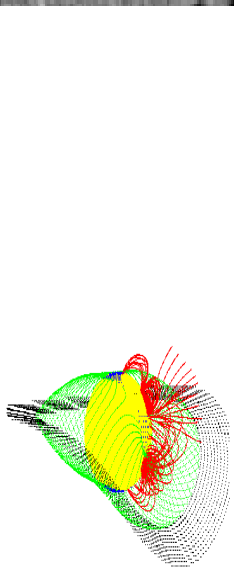
*(Image adapted from Guhathakurta and Sittler, Solar Wind Nine Proceedings, 1999)*

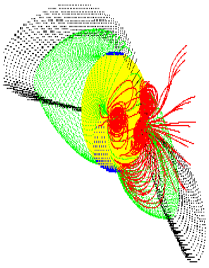




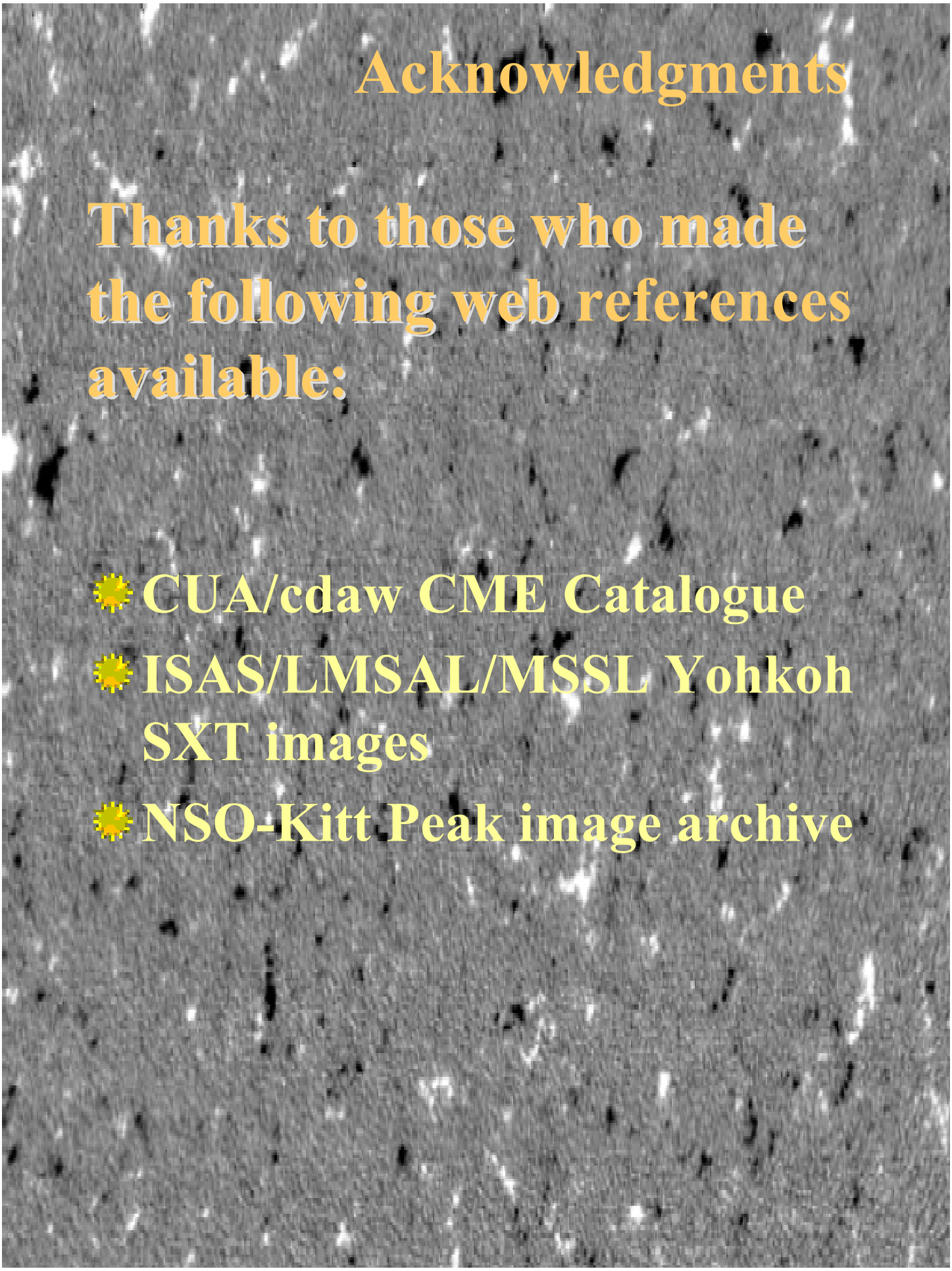





**The “zoo” comes from the many options for active region number, location, orientation, complexity, evolution, and flux emergence variations.**



# Acknowledgments

**Thanks to those who made the following web references available:**

- CUA/cdaw CME Catalogue
- ISAS/LMSAL/MSSL Yohkoh SXT images
- NSO-Kitt Peak image archive