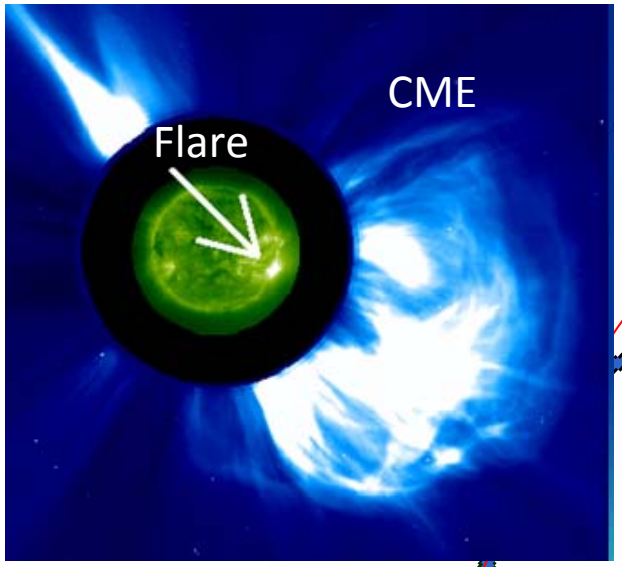
Flux Rope CDAW Agenda

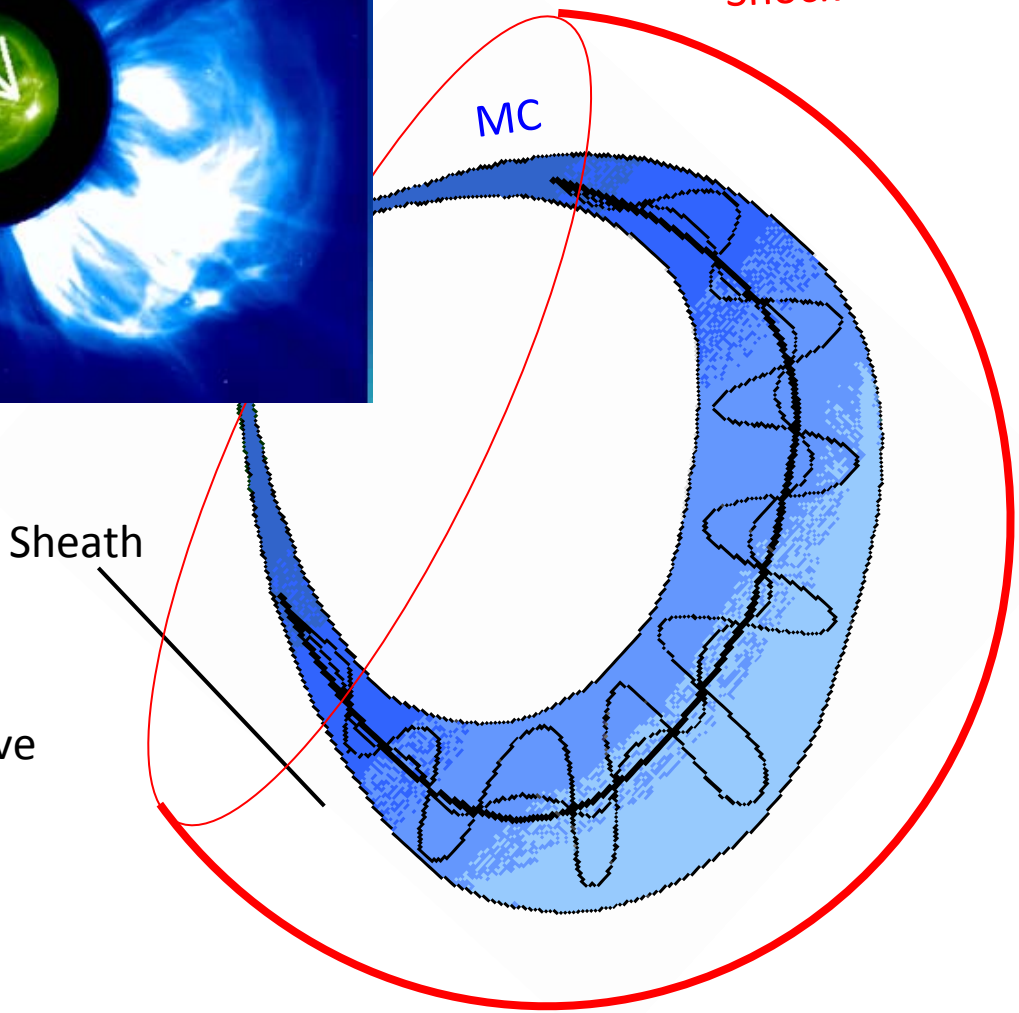
- Sep 21 Tuesday
- 9:00 Welcome
- 9:05 Logistics (Jon Linker/Pete Riley)
- 9: 15 Flux rope Tutorial (K. Marubashi)
- 10:30 Coffee Break
- 11:00 CDAW overview (N. Gopalswamy)
- 11:45 Solar Source Properties (S. Yashiro)
- 12:30 Lunch
- 14:00 The visibility of flux ropes in the coronagraphic images (A. Vourlidas)
- 14: 45 STEREO/SMEI-era ICME list relevant to the flux-rope question (D. Webb)
- 15:30 Coffee Break
- 16:00 The effect of direction parameter on the classification of MC and EJ (R-S Kim)
- 16:30 : Looking for the physical parameters which control the classification of MC and Ejecta
- 17:00 Krall Flux rope fitting (H. Xie)

- 9:00 Grad-Shafranov fitting (Q. Hu)
- 9:45 Cylindrical & Spheromak fitting (K. Marubashi)
- 10:30 Coffee break
- 11:00 Fitting of a STEREO Flux rope (C-C Wu)
- 11:30 Solar sources (Jie Zhang)
- Multi-spacectaft observations of flux ropes (C. Moestl)
- Flux rope Rotatin (T. Torok)

Flux-Rope CDAW: Overview

N. Gopalswamy



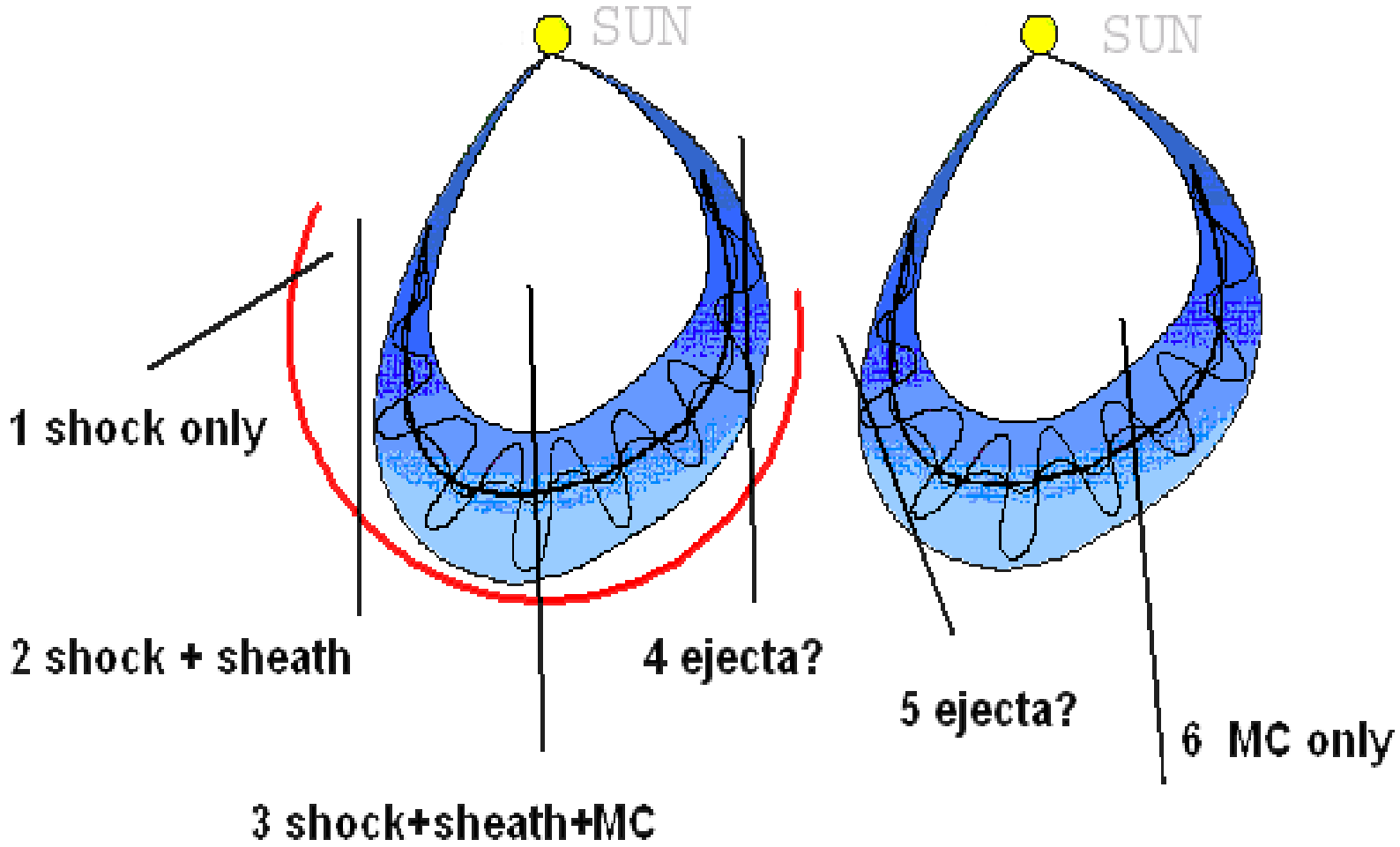


Hypothesis: All ICMEs have
Flux rope structure

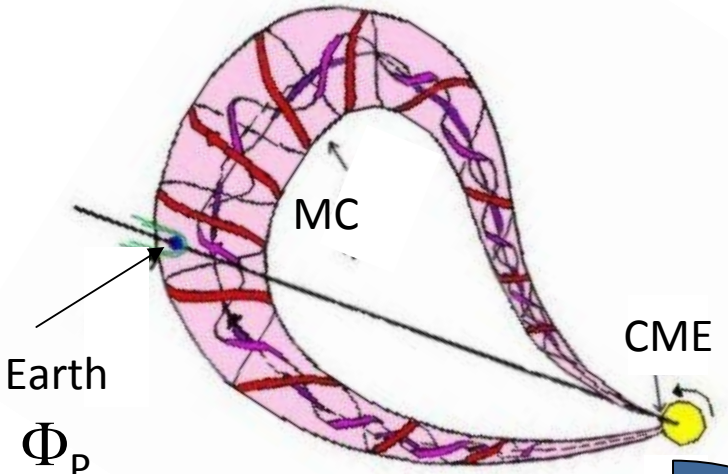
The observed difference
Between flux ropes and
non-flux ropes is due to
Different Sun-observer angles

Arguments in support
Deviations from this picture

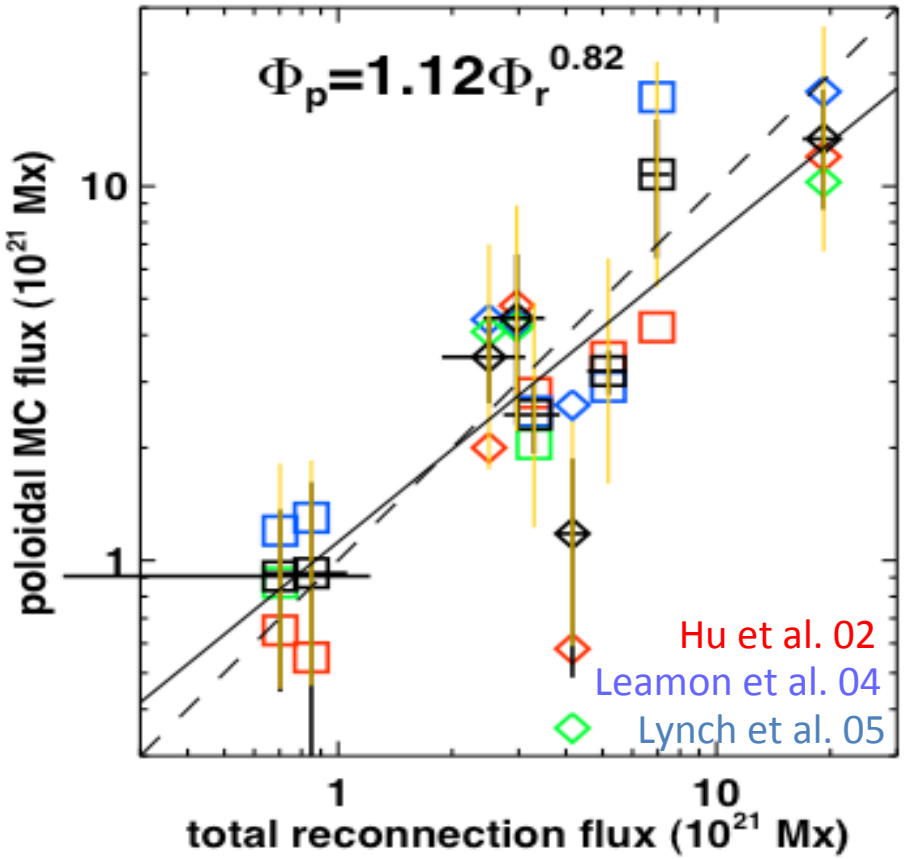
ICMEs: Variation due to Geometry



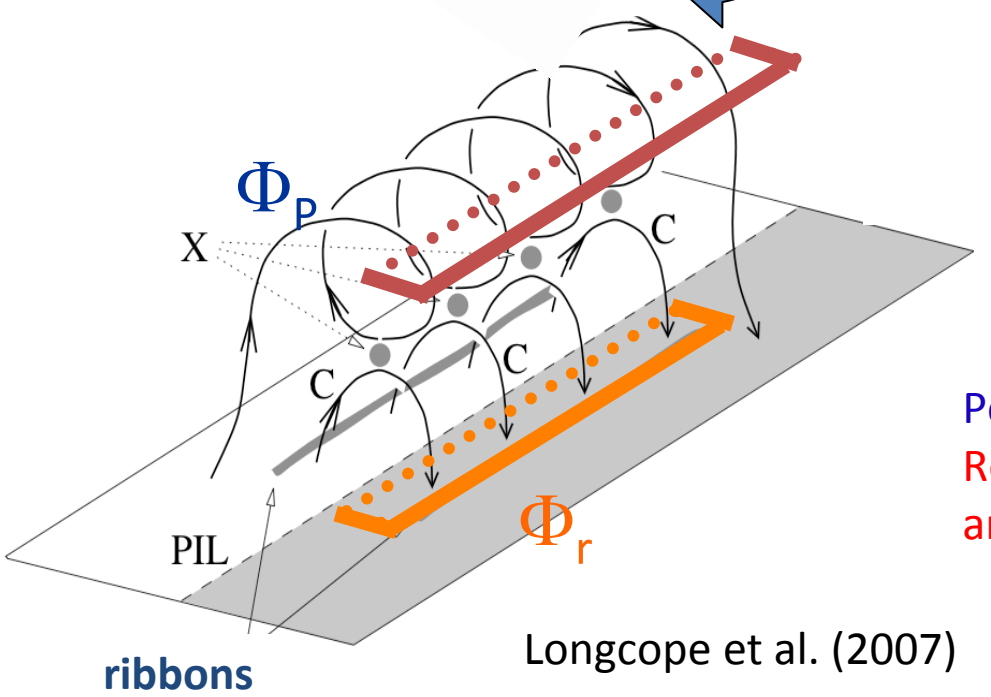
Gopalswamy, 2006 SSRv



Marubashi, 1997



Qiu et al. 2007

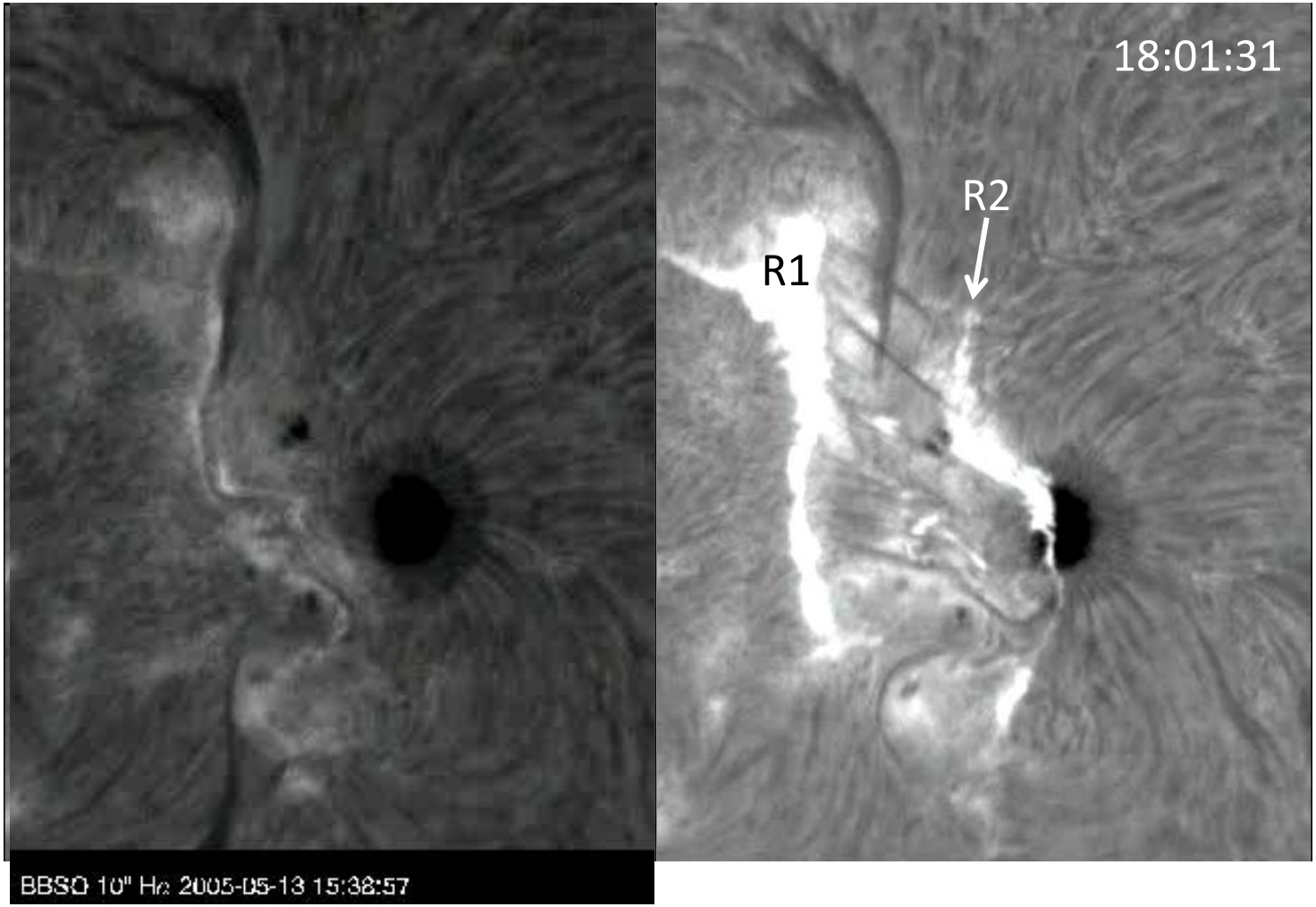


Longcope et al. (2007)

Post-eruption arcade with every ICME

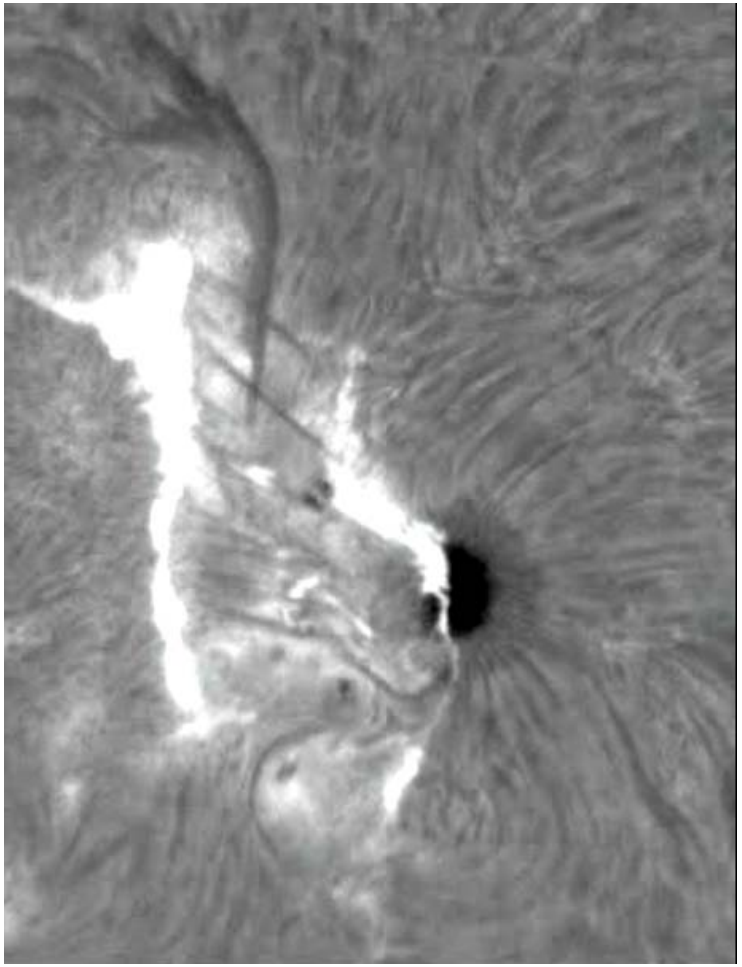
Reconnection creates flux ropes and flare arcades

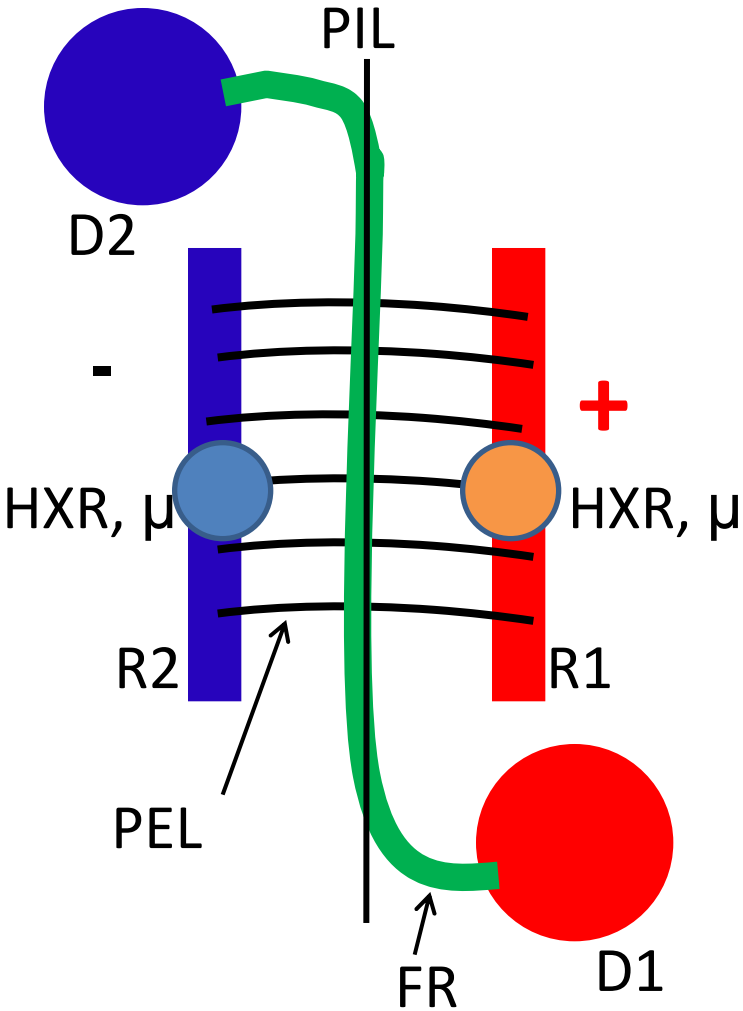
Chromospheric Change



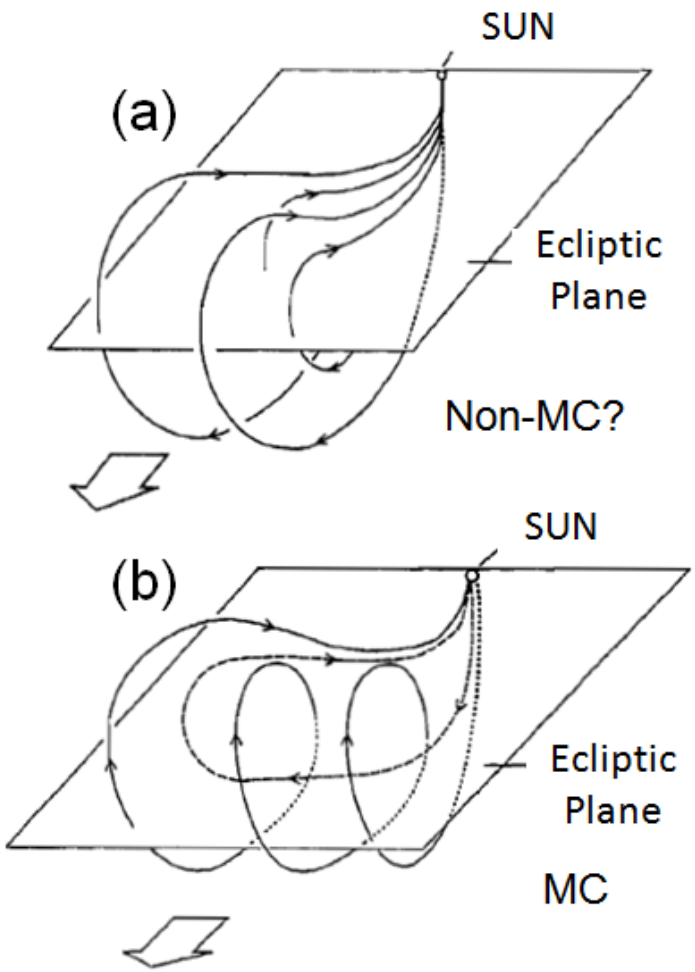
Courtesy:. YurchyShyn

Eruption Geometry is also common to all ICME sources





Flux-rope & Non-flux-rope Structures



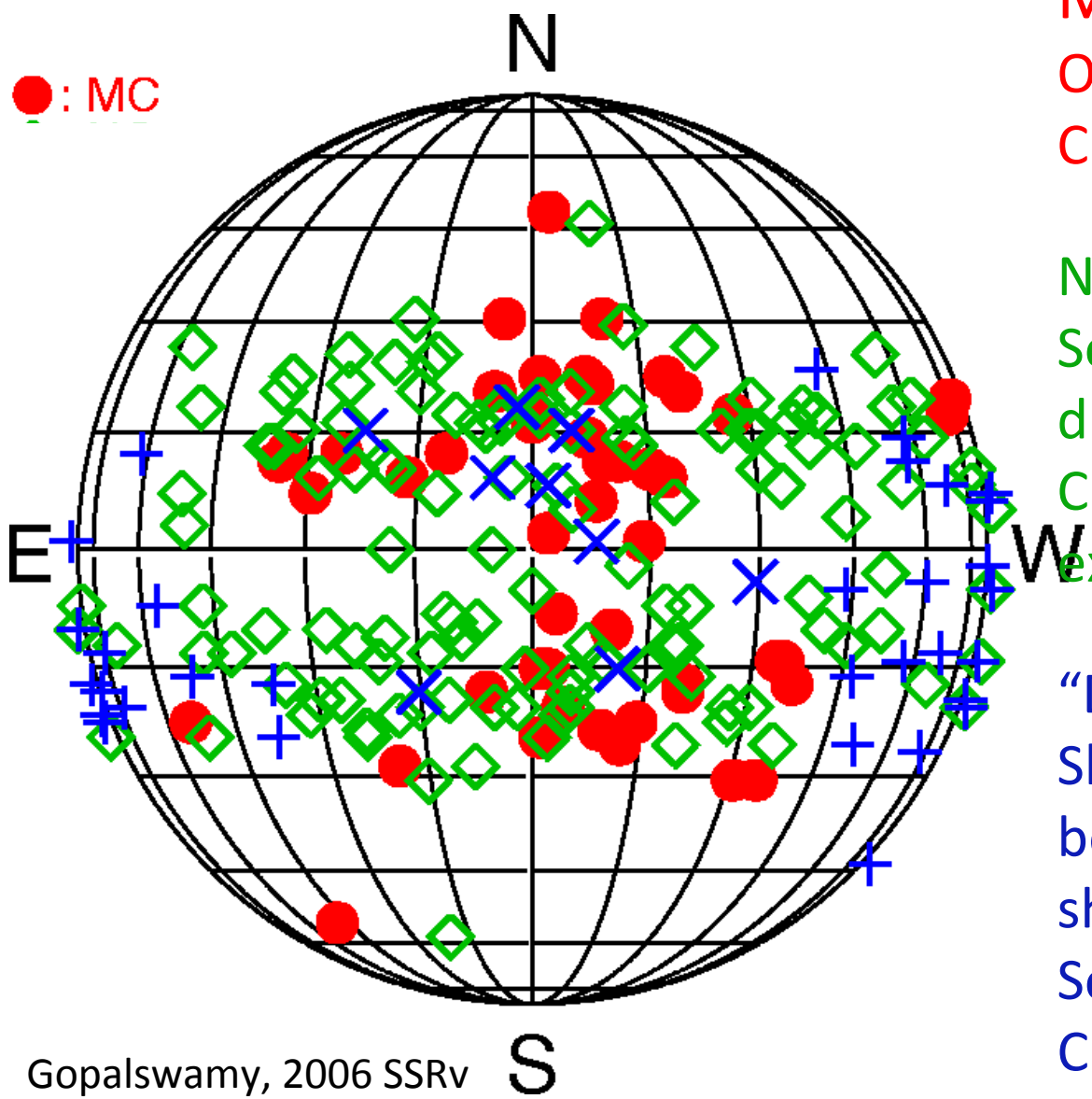
Gosling 1990

- The flux rope structure is formed by the reconnection of sheared loops at the Sun during the eruption.
- How are the non-flux-rope structures formed? Do they have different flare geometry?

If all ICMEs are Flux Ropes…

- Geometry is Key
- MCs must be coming from the disk center
- Non-MCs at intermediate angles
- “Driverless” shocks at large angles from the Sun-Earth line – due to limb CMEs (Gopalswamy et al., 2001 JGR)

Solar Sources



Gopalswamy, 2006 SSRv

MCs

Only a few sources outside CMD ≤ 30°

Non-MCs (NCs)

Solar sources widely distributed. Most sources at CMD > 15°. Many exceptions

"Driverless Shocks"

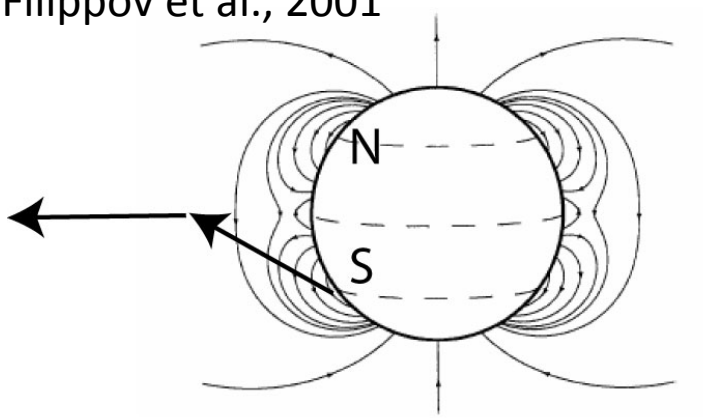
Shocks without an ICME behind them. All we see is a shock and some sheath. Solar sources generally have CMD > 30° except for a few central events.

Higher MC Lat. in the Rise Phase

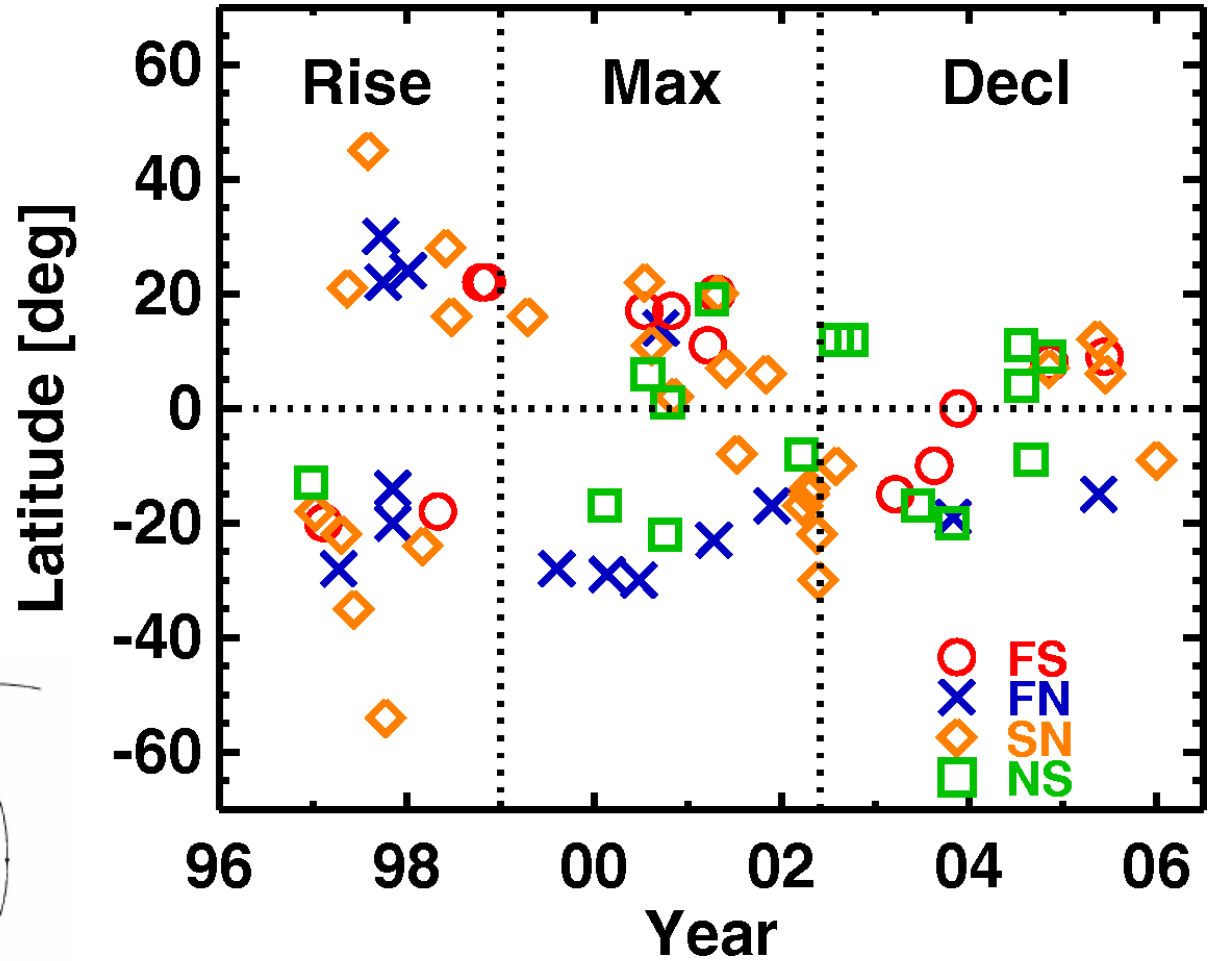
More MCs during the
Rise phase (Riley et al. 2006)

The global dipolar field guides
CMEs towards equator, so they
End up as MCs (geometrical)

Gopalswamy & Thompson 2000
Filippov et al., 2001

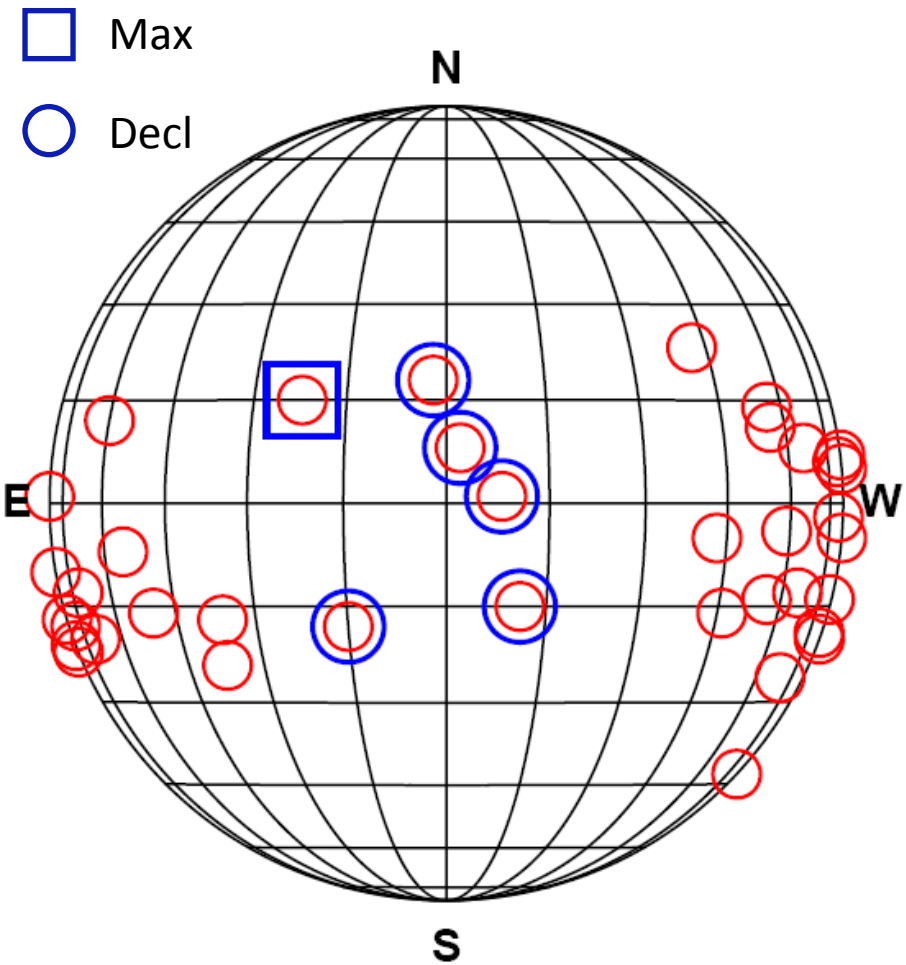


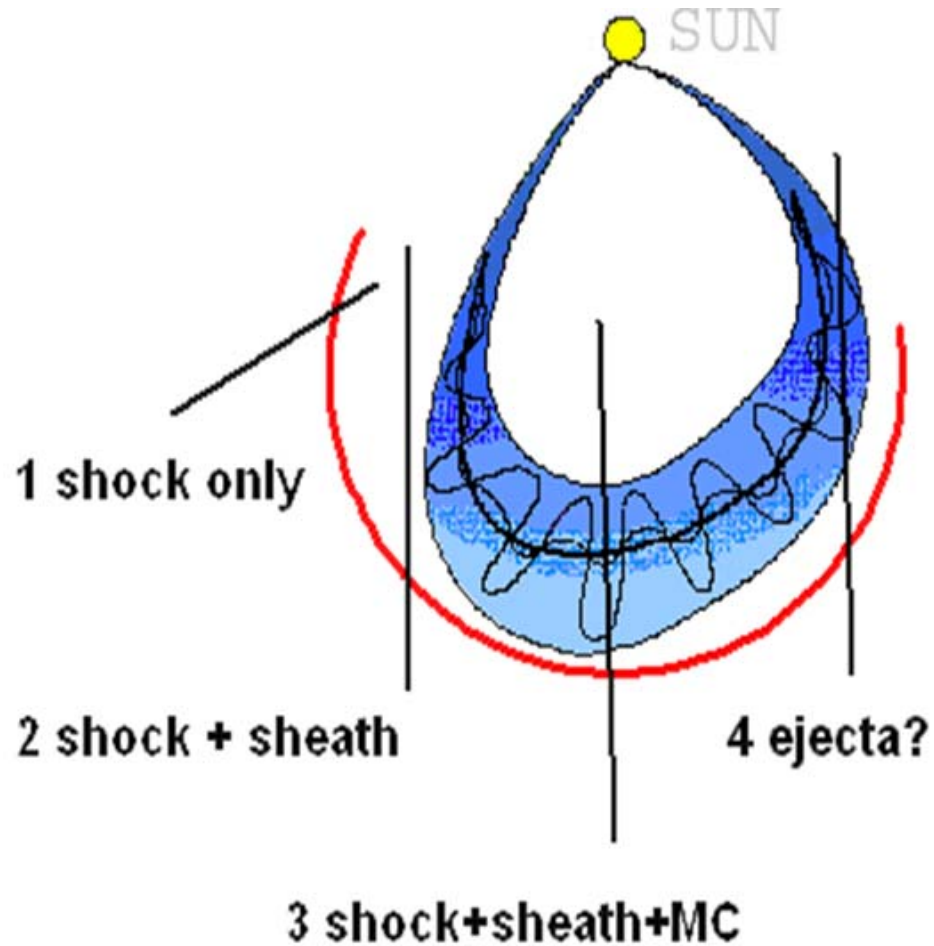
Gopalswamy et al., 2007



Butterfly diagram of CME source regions

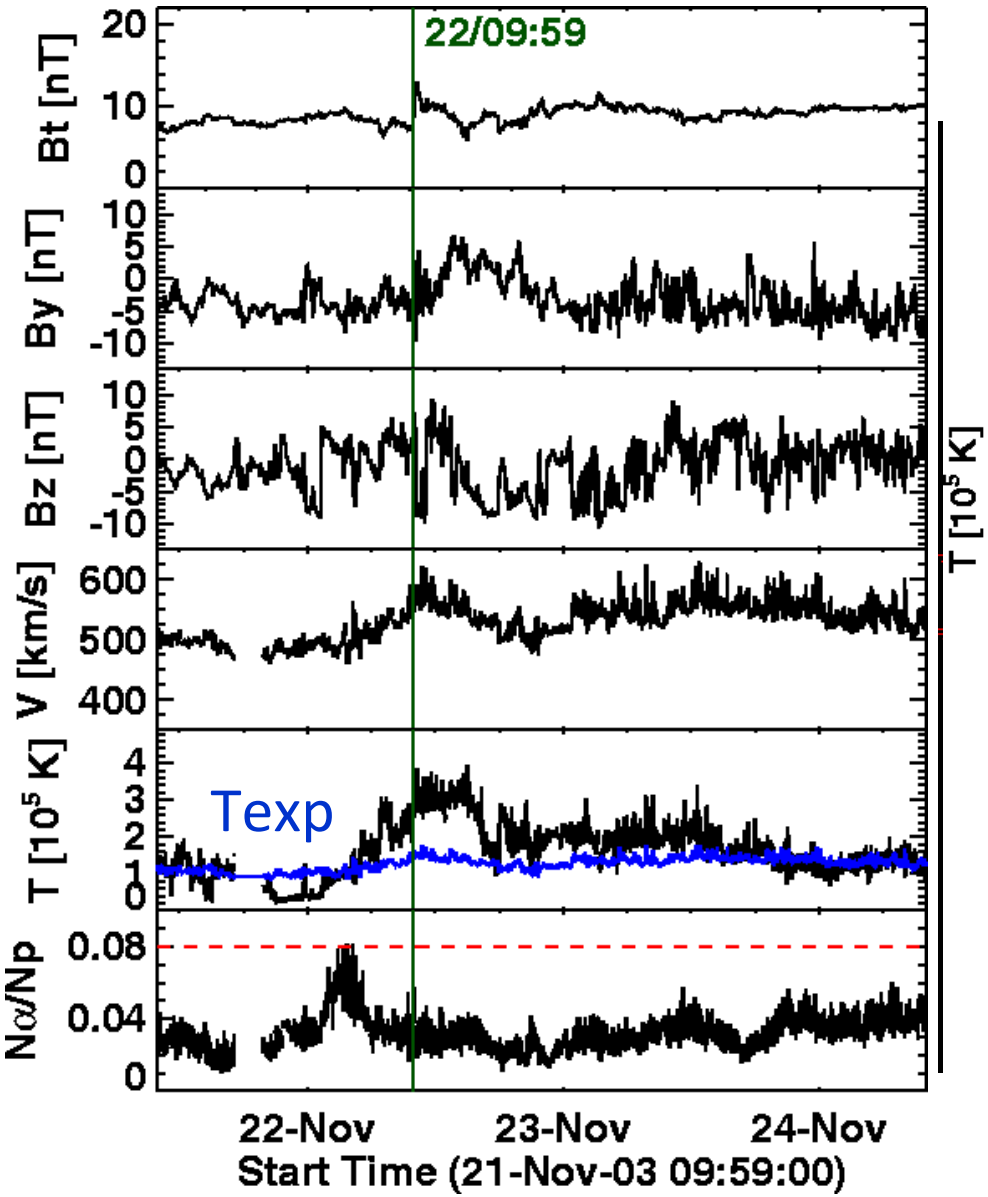
Solar Sources of "driverless" IP shocks (ICME not intercepted at Earth)

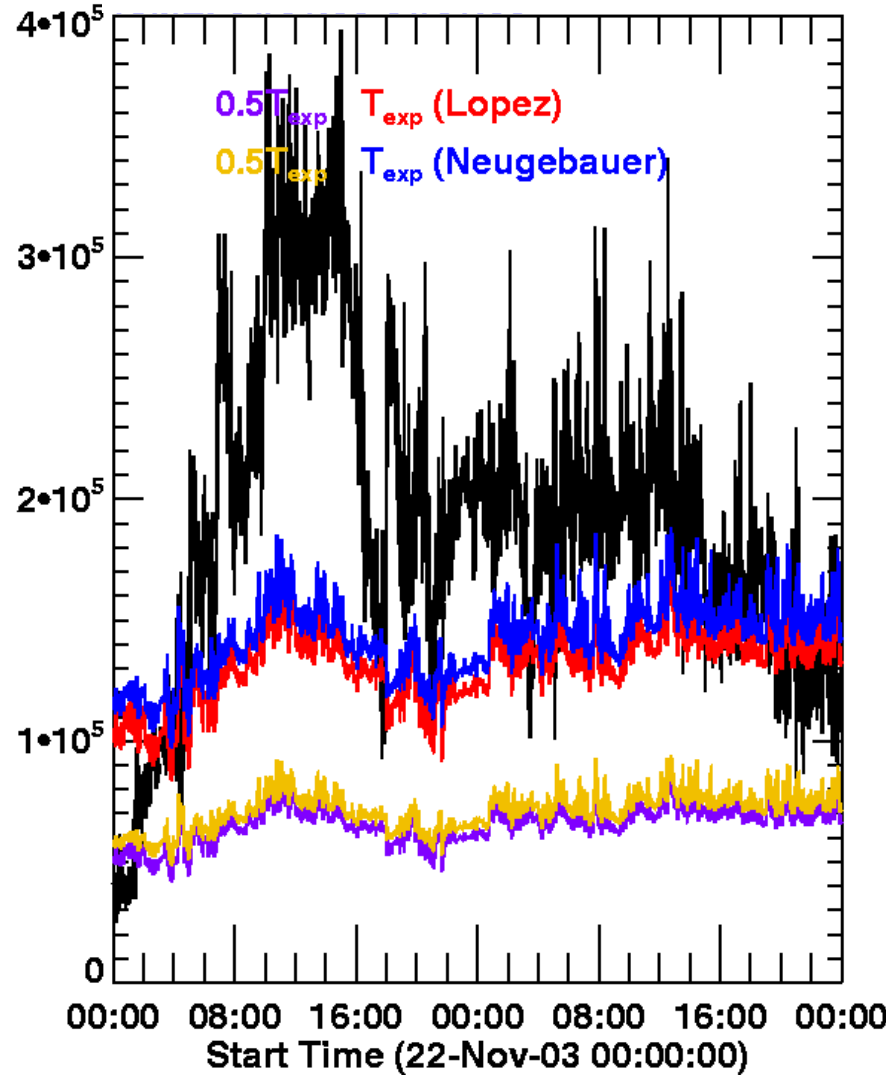




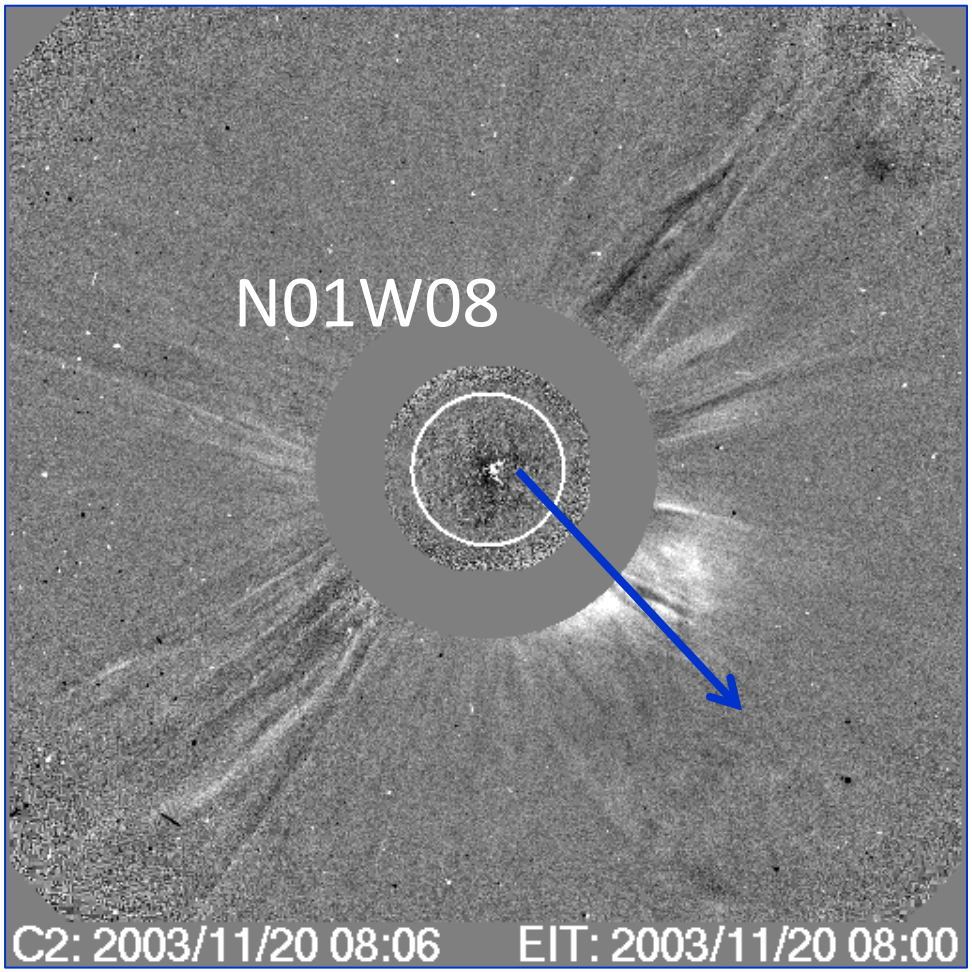
Gopalswamy et al., 2001; 2009 JGR

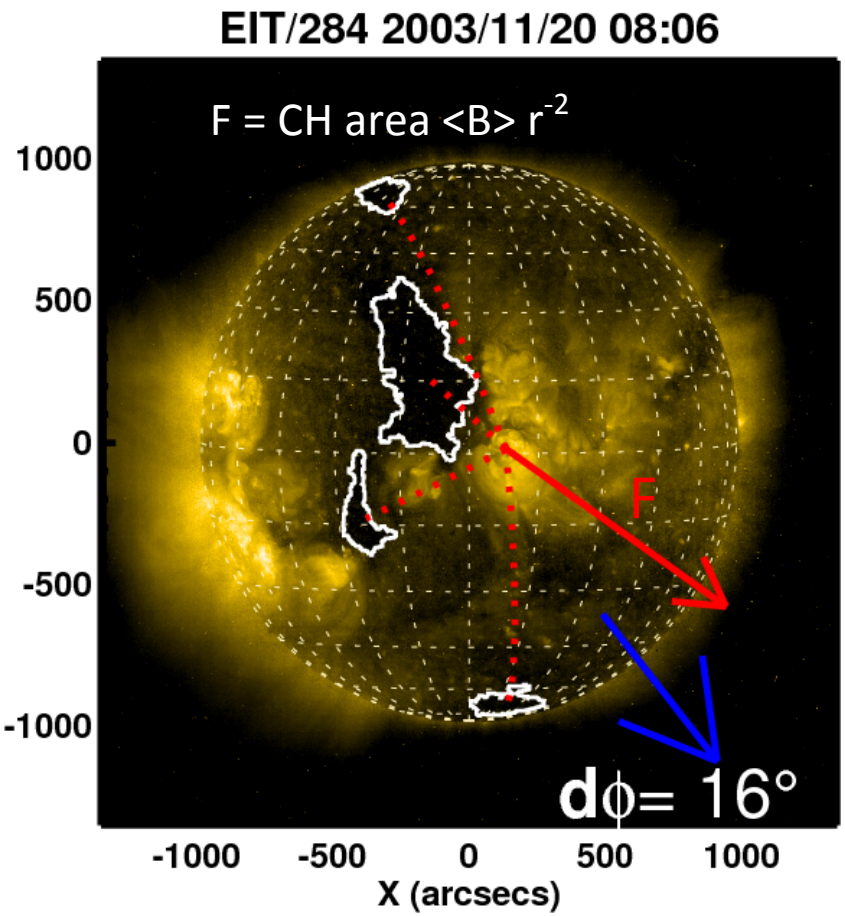
At 1 AU: Just the Shock & Sheath





Some CMEs from Disk Center do not Reach Earth





Mäkelä presentation: Coronal hole influence on MCs and EJ

Possible Deviations

- Rise Phase: Global dipolar field is strong → Higher lat. CMEs may become MCs

- Max Phase: more CME collisions → deflections & merger are common (complex ejecta) – needs systematic study

- Declining Phase: More equatorial coronal holes → CMEs are deflected

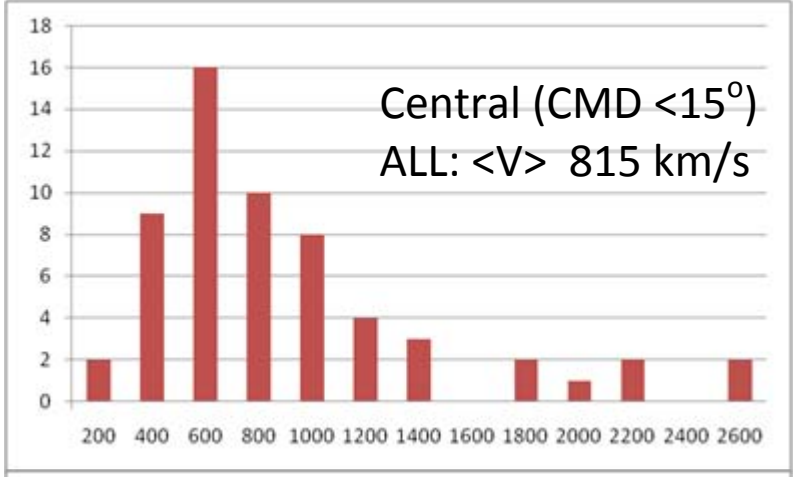
How to make Progress?

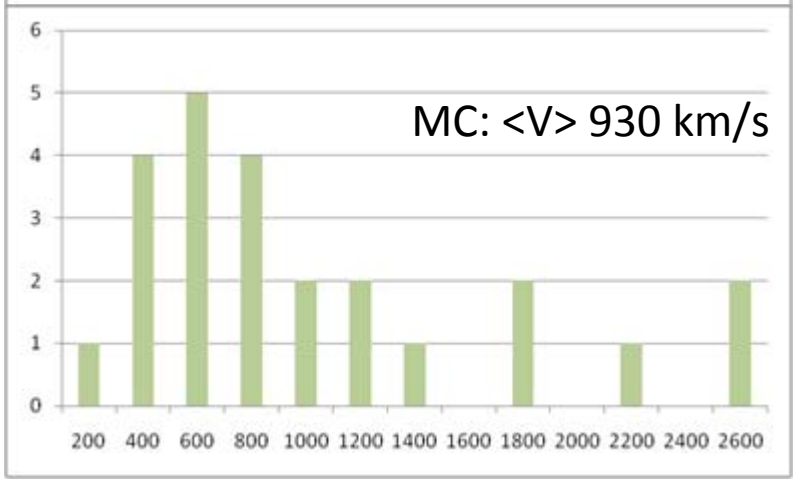
- Consider Central Sources (CMD $\leq 15^{o}$)
- All types are present in this zone: 24 MCs, 35 non-MCs and 5 driverless shocks
- Driverless shocks explained as due o coronal holes
- This CDAW is to understand why so many central ICMEs are not MCs

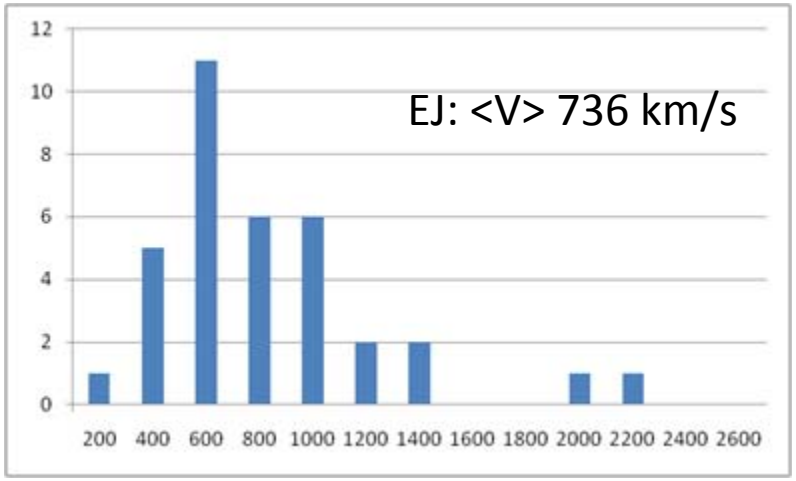
What can we compare?

- Solar sources: Active region properties, flare properties, neutral line orientation, filaments,
- CME properties: Kinematics, angular width, non-radial ejection, …
- ICME properties: magnetic (B, By, Bz), Plasma (V, Tp, Np), charge state (O7+/O6+ & <QFe>)
- Modeling (flux-rope fitting to MC and non-MC events)
- MHD simulation
- Comparison with STEREO events
- Others

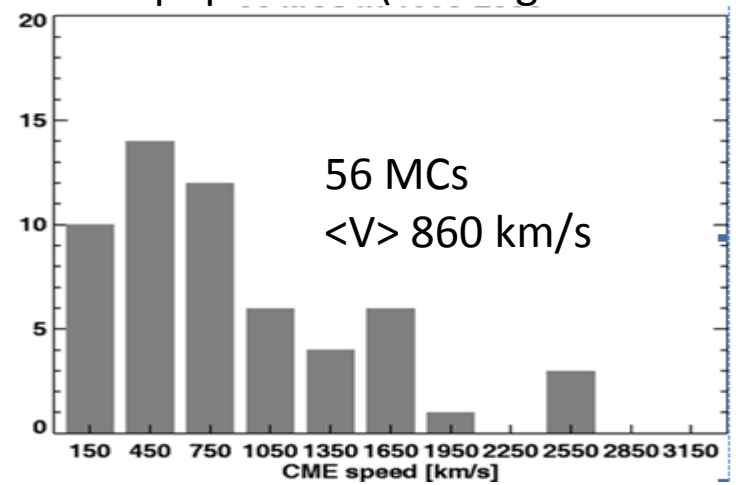
MCs and non-MCs have similar speeds

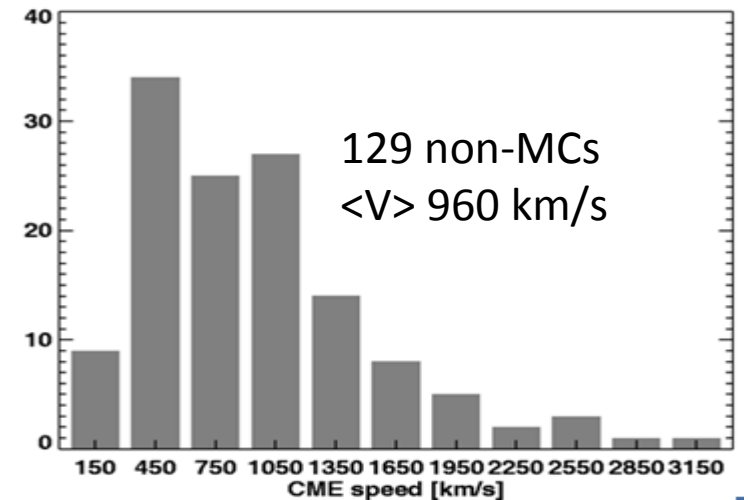






General population (no long. Restriction)



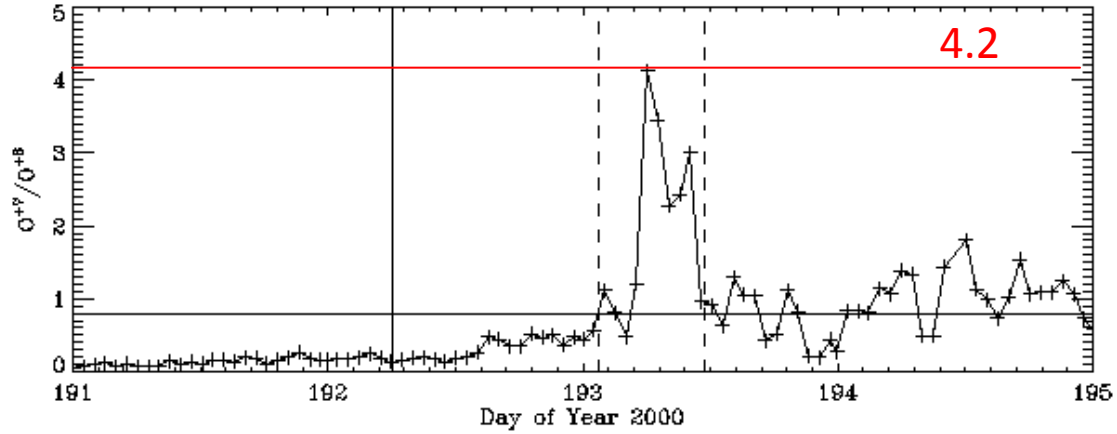


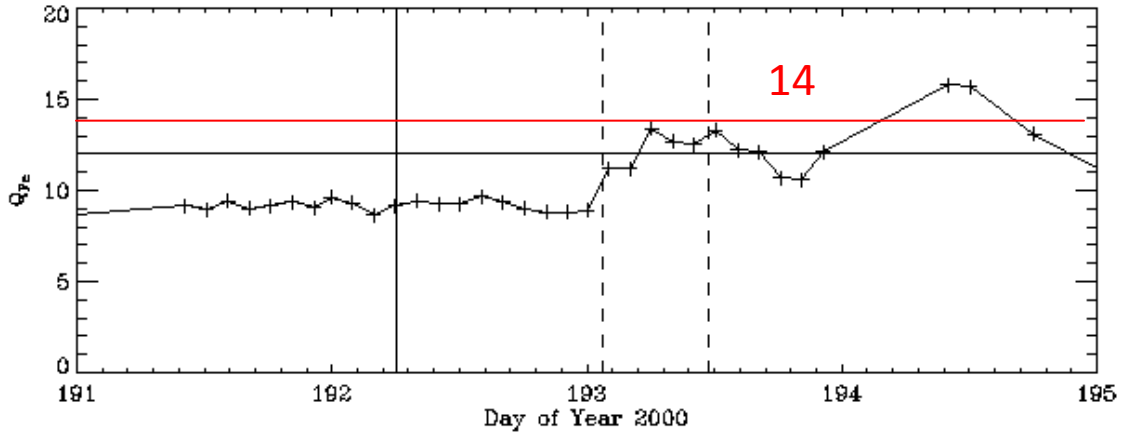
Angular Width

- Fraction of Halos is a good indicator of the width of a CME population
- 75% of MCs (18/24) are full halos (W = 360°)
- 60% of EJ (21/35) are full halos
- 17 partial halos (6 MC; 14 EJ)
- 3 narrow (W < 60°) (MC – 59°; EJ – 40°; EJ – 45°) – incorrect identification?

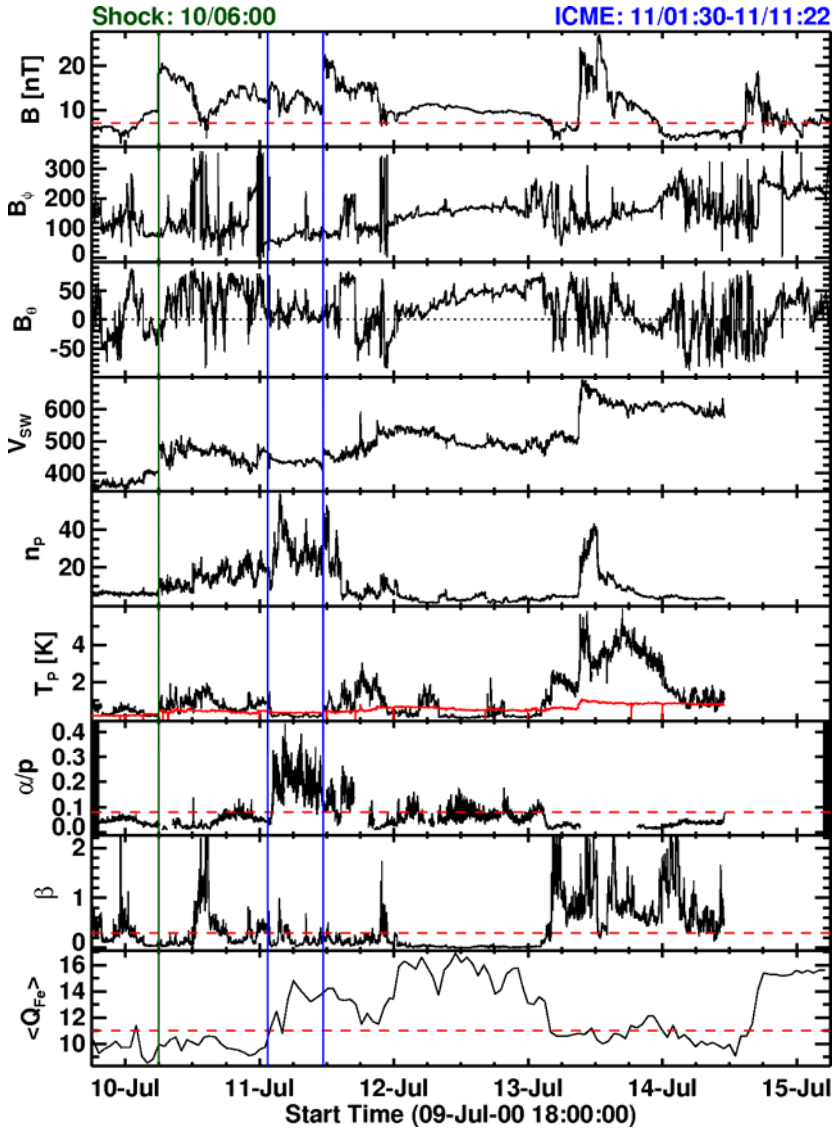
Charge States

17 EJ: 2000 July 10





Solar Wind Signatures: 2000 July 10 EJ



Magnetic signatures – not MC-like

SW Speed – not MC-like

Temperature – MC like

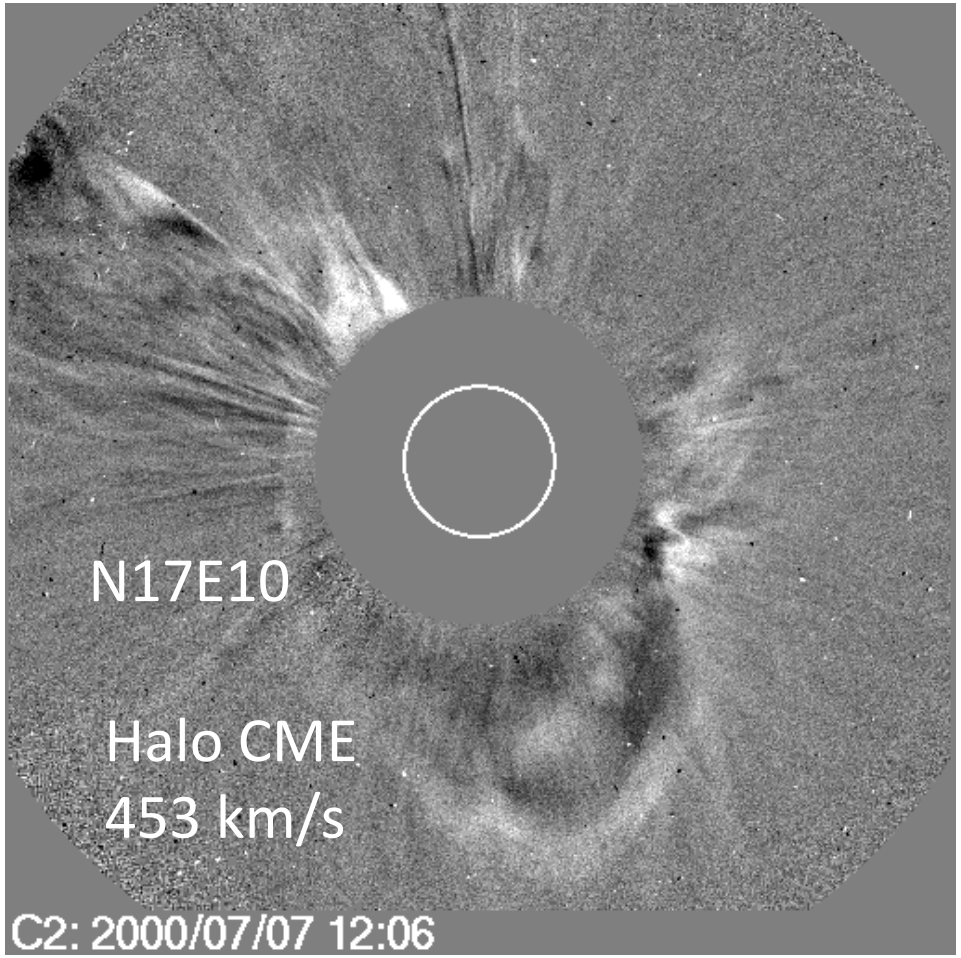
α /p : Good signature

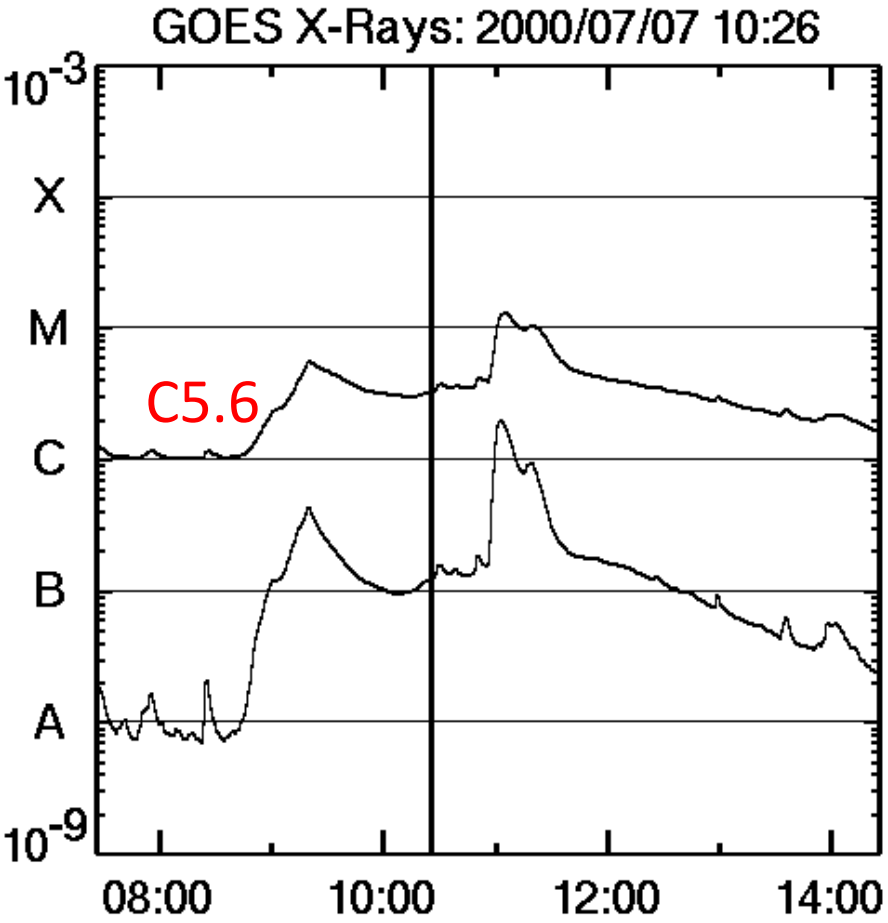
β : not MC-like

<QFe> enhanced

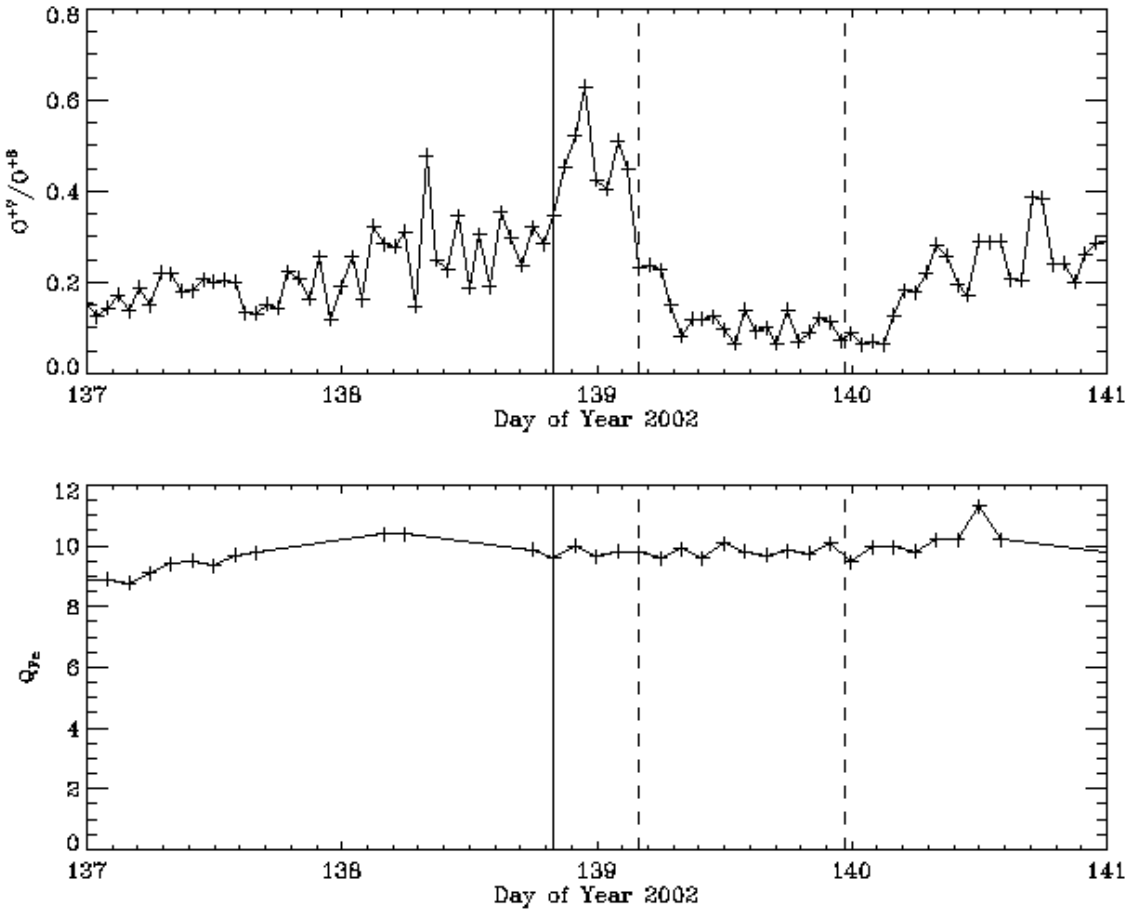
Oxygen ratio: one of the highest

17 MC: Solar Source



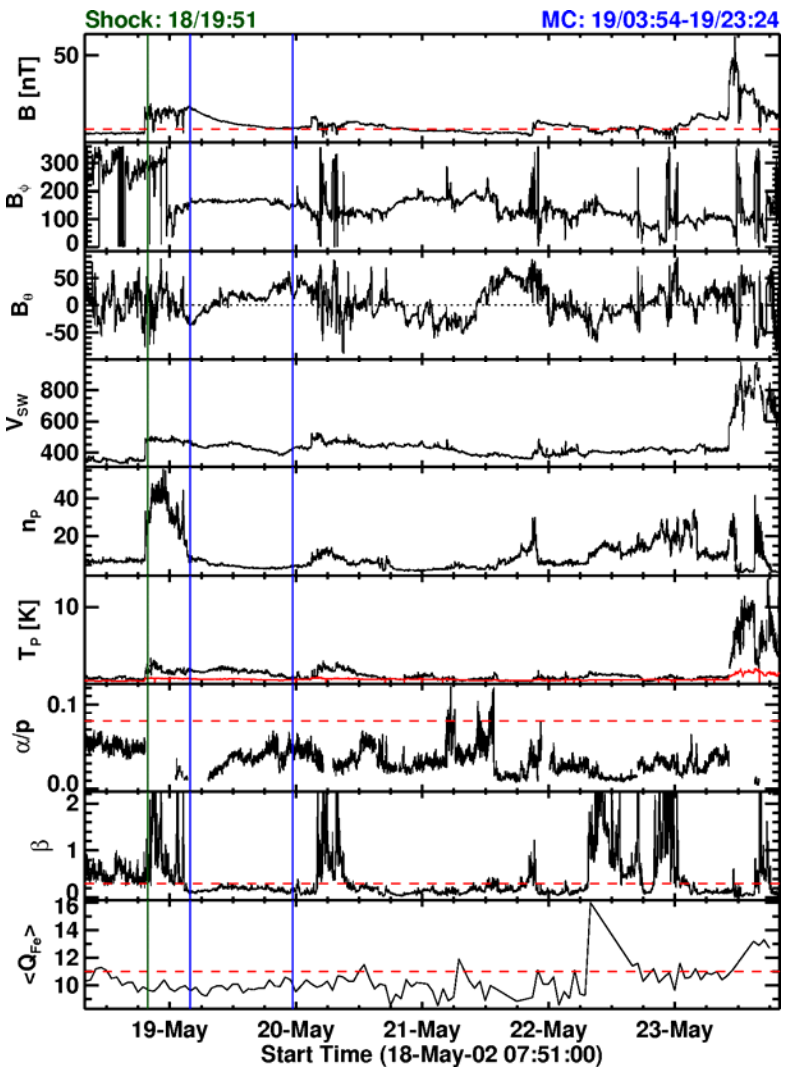


39 MC: 2002 May 18



The only MC event with no charge state signatures

2002 May 18 MC: No O, QFe Signature



Magnetic signatures – MC-like

SW Speed – MC-like

Temperature – MC like ?

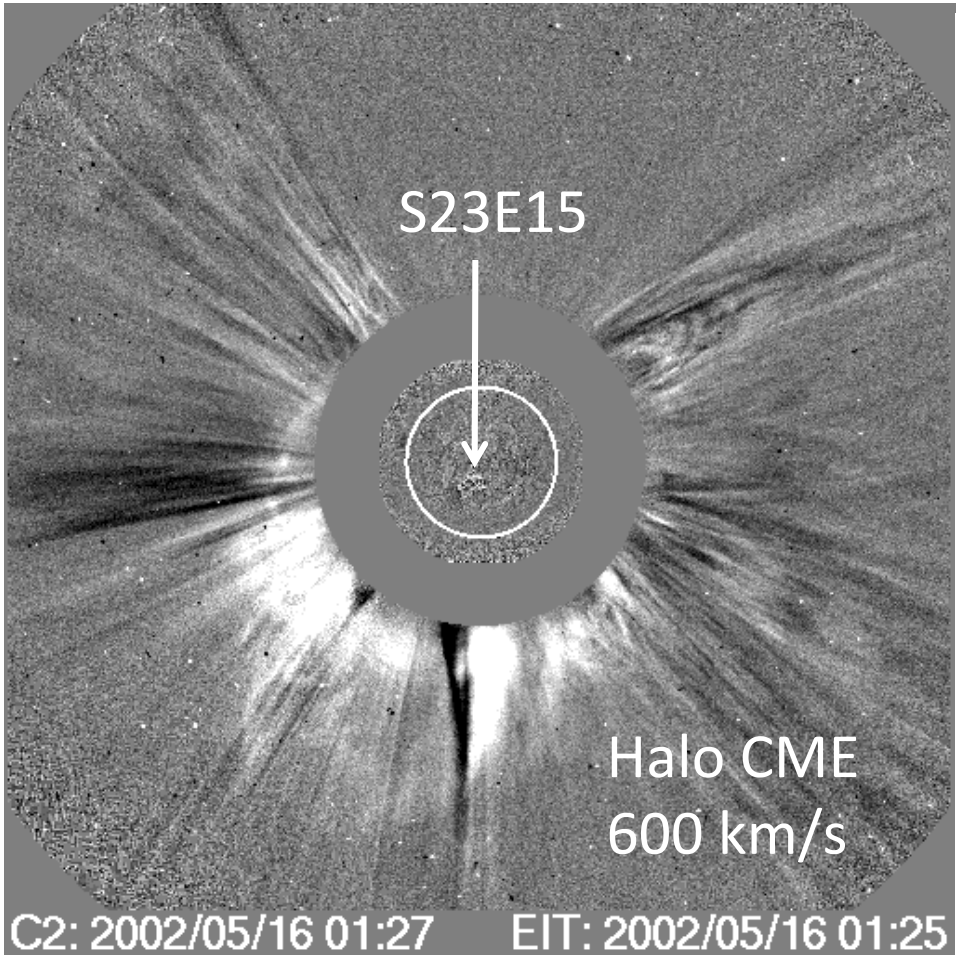
α /p : Not a good signature

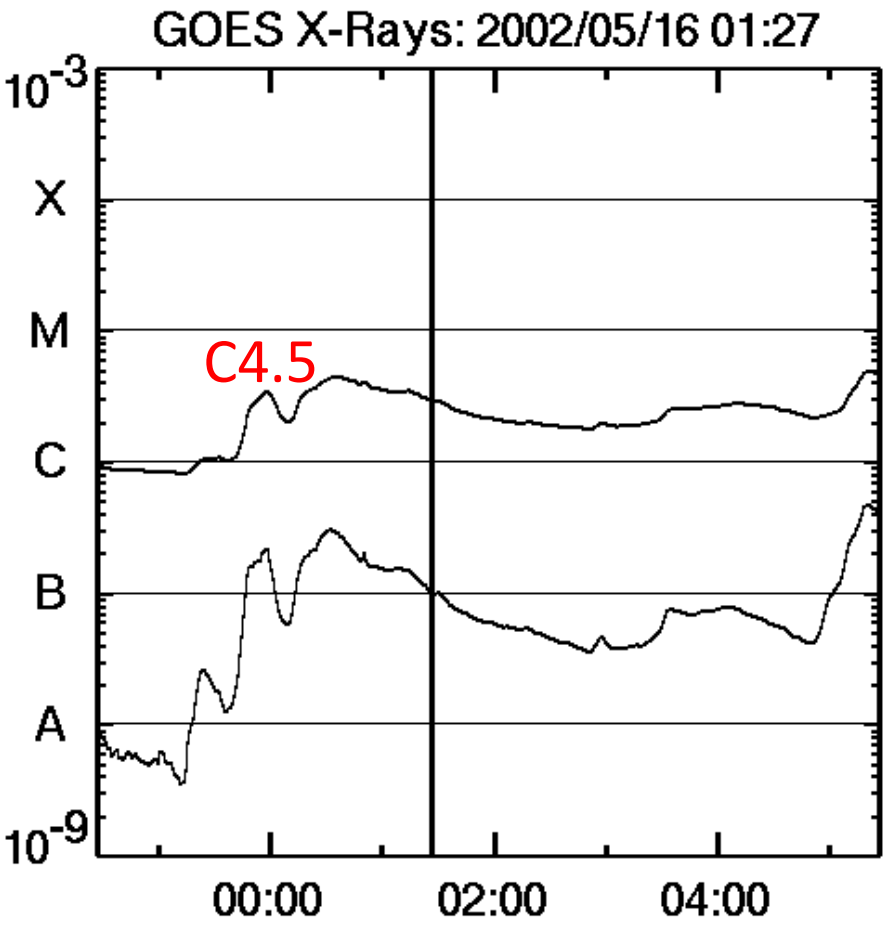
β : MC-like

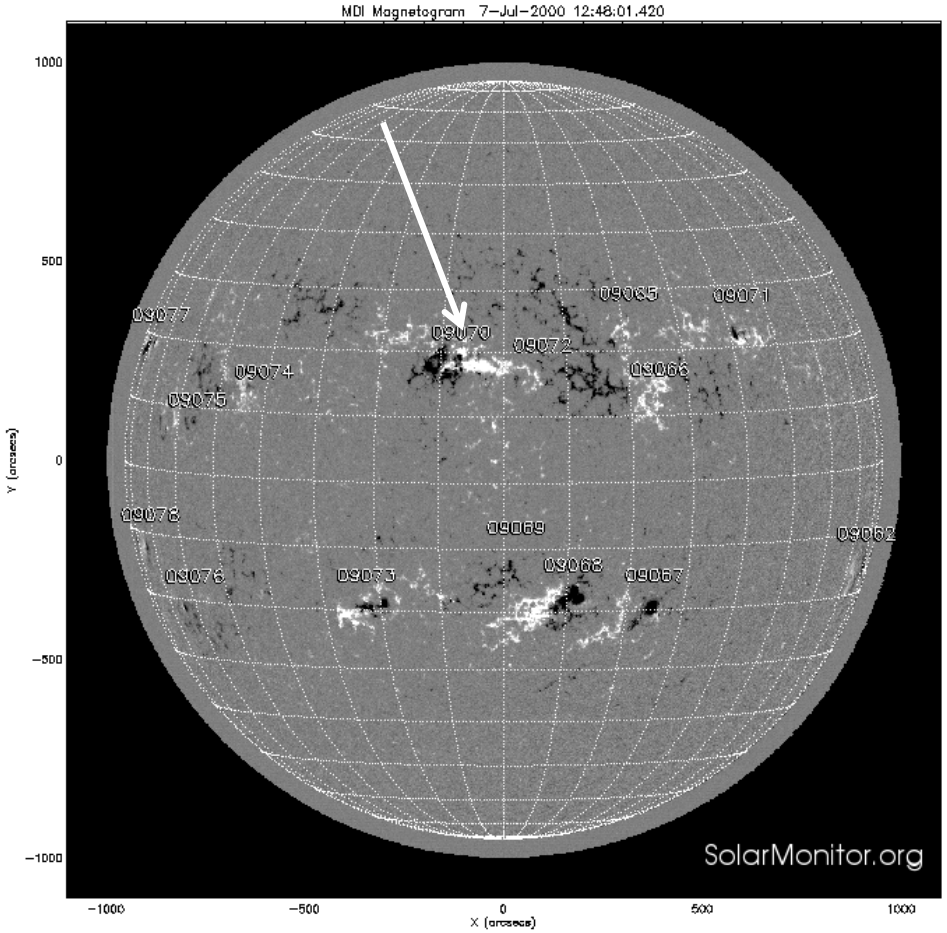
<QFe> No Signature

Oxygen ratio: No Signature

30 MC: Solar Source






MDI Magnetogram 7-Jul-2000 12:48:01.420
09065
09071
09077
09070
09072
09074
09066
09075
09078
09069
09062
09076
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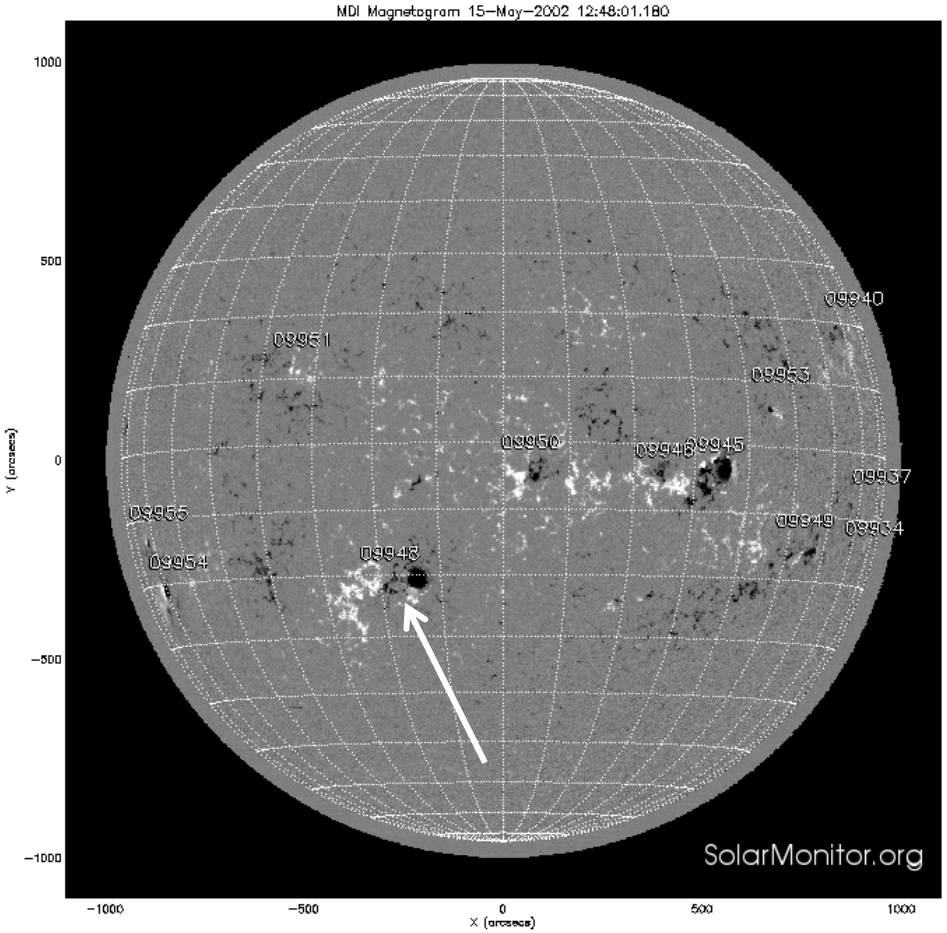
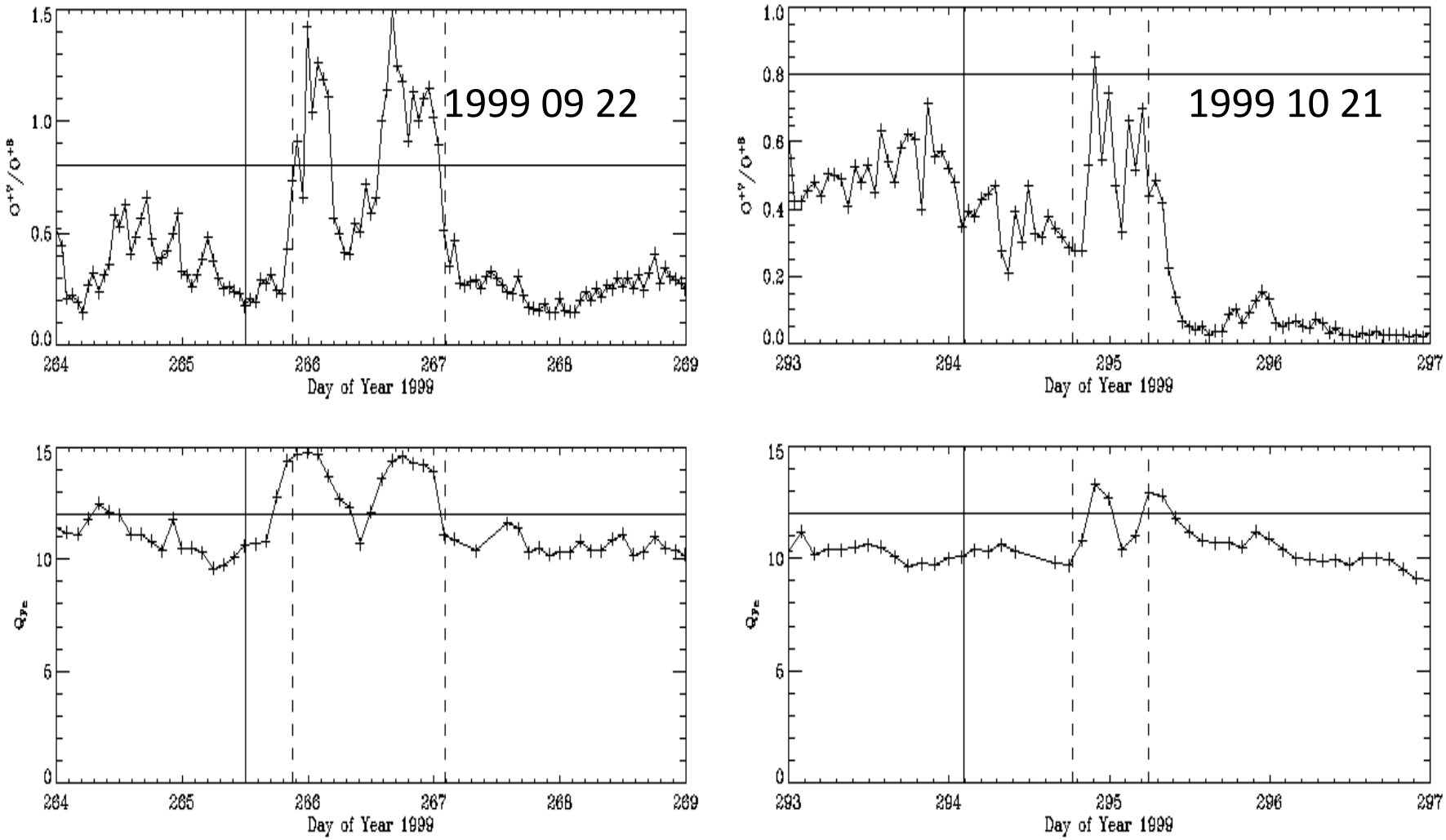
SolarMonitor.org
Y (arcsecs)
X (arcsecs)
1000
500
0
-500
-1000


MDI Magnetogram 15-May-2002 12:48:01.180
09940
09951
09953
09950
09948
09945
09937
09955
09949
09934
09954
09943
SolarMonitor.org
Y (arcsecs)
X (arcsecs)
1000
500
0
-500
-1000

EJ: O7/O6 & QFe


1999 09 22
1999 10 21
Day of Year 1999
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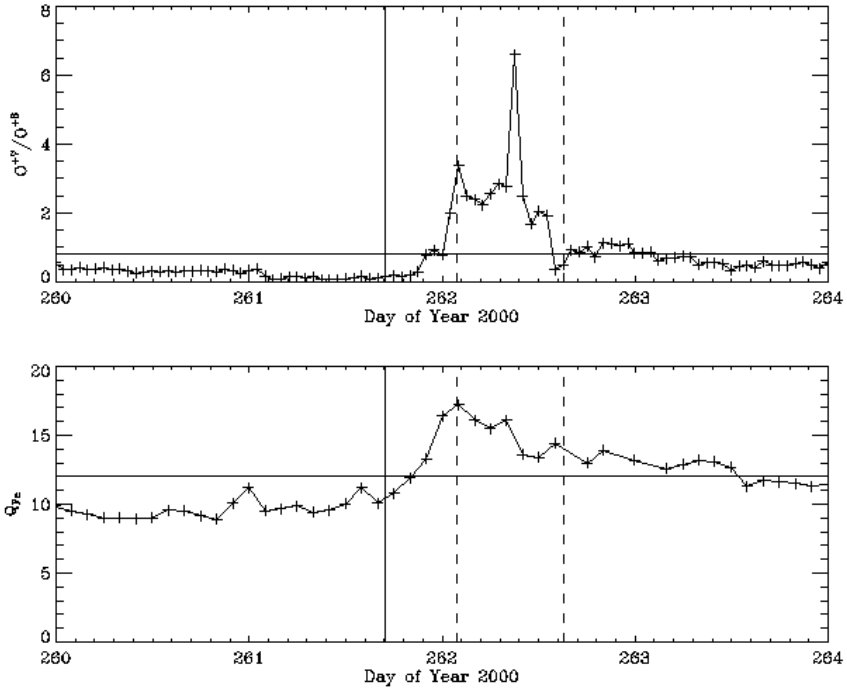
Day of Year 1999

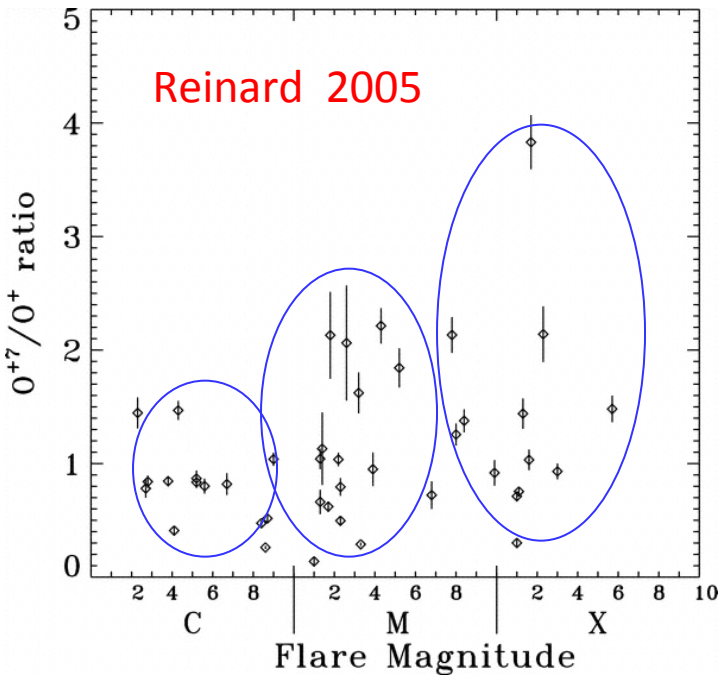

8
6
4
2
0
O^{+7}/O^{+6}
260
261
262
263
264
Day of Year 2000
20
15
10
5
0
Q_{fe}
260
261
262
263
264
Day of Year 2000

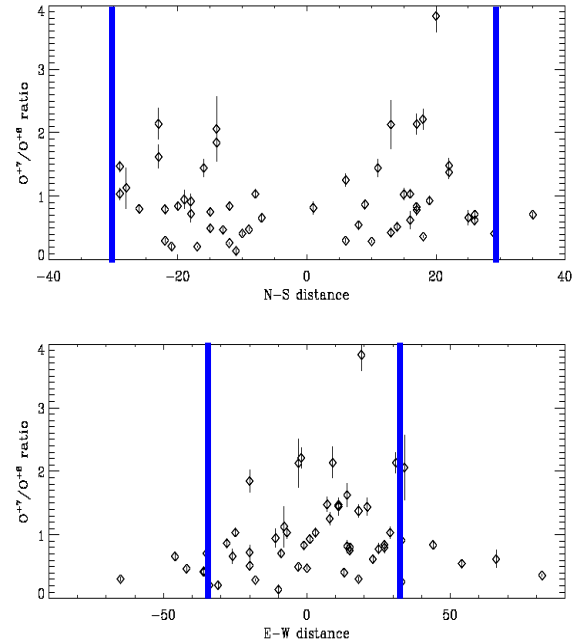
Almost all of the MCs had enhanced O7+/O6+ and <QFe>

ICME Type	O7/O6 Enhancement		QFe Enhancement	
	Y	N	Y	N
MC	21/22 (95%)	1/22 (5%)	20/22 (91%)	2/22 (9%)
EJ	18 /33 (55%)	15/33 (45%)	16/33 (48%)	17/33 (52%)

ICME Type	Average O7/O6 Enhancement	Average QFe Enhancement
MC	2.7	15.4
EJ	1.7	14.4

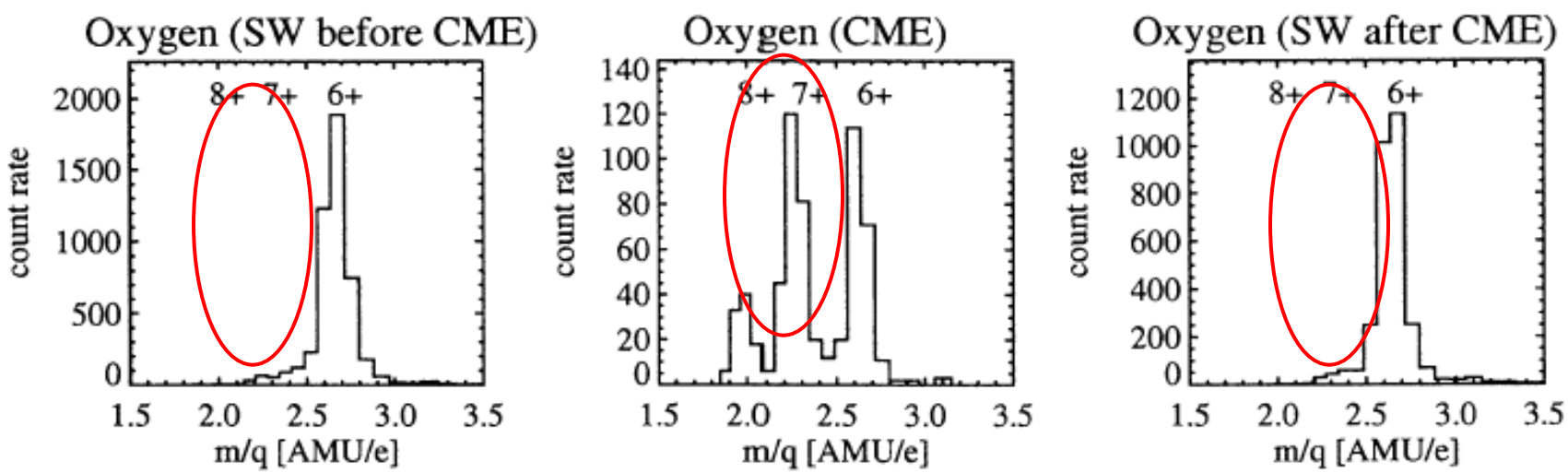
O7+/O6+





High charge states for disk-center events

Disk Center events become MCs



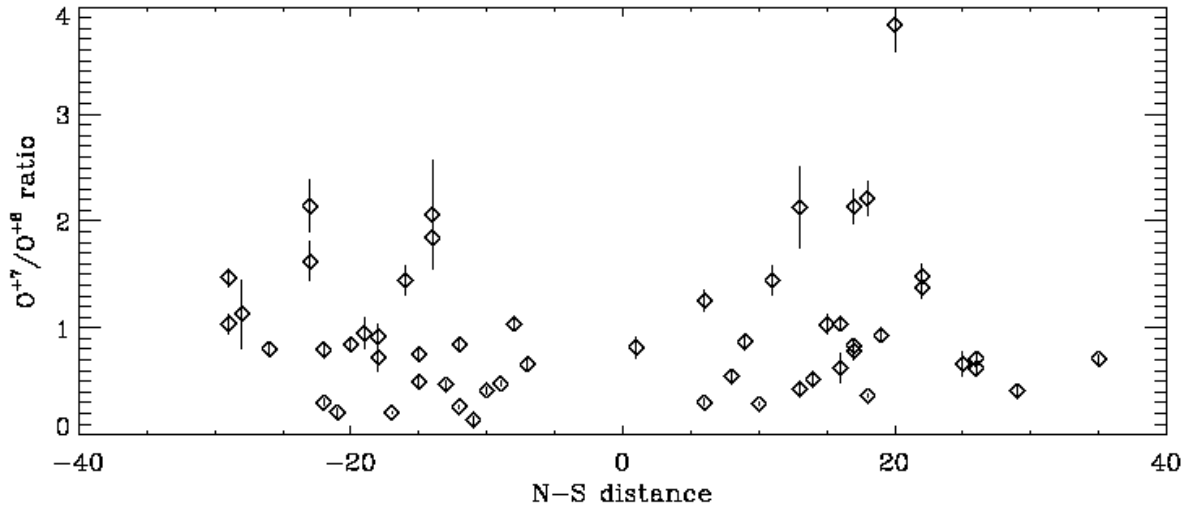
Temperature increase in the source: RC

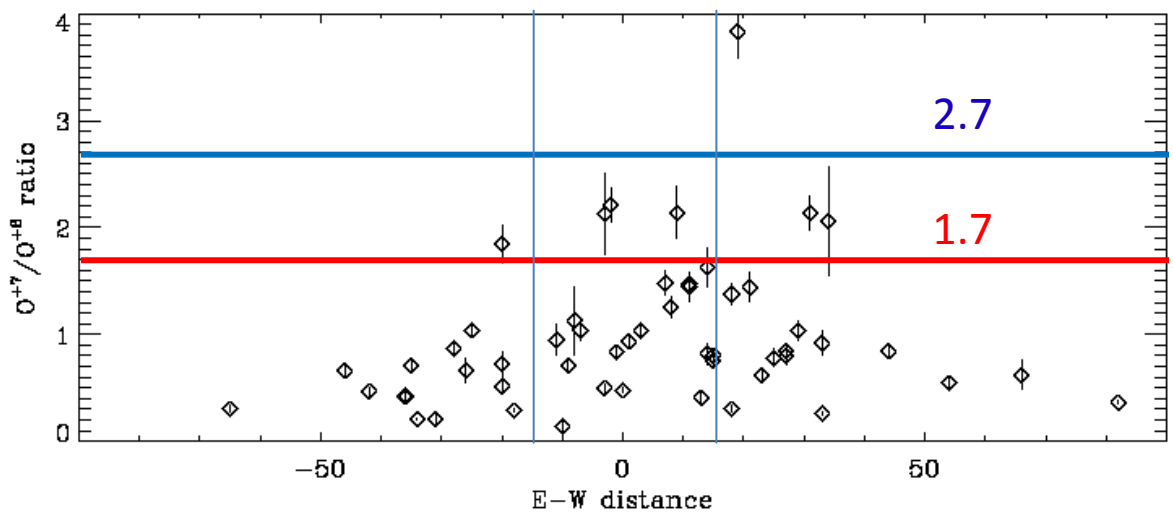
Henke et al. 2001

Central O^{7+}/O^{6+} compared with all events

The Oxygen ratio is higher by ~60% for MCs compared to Ejecta

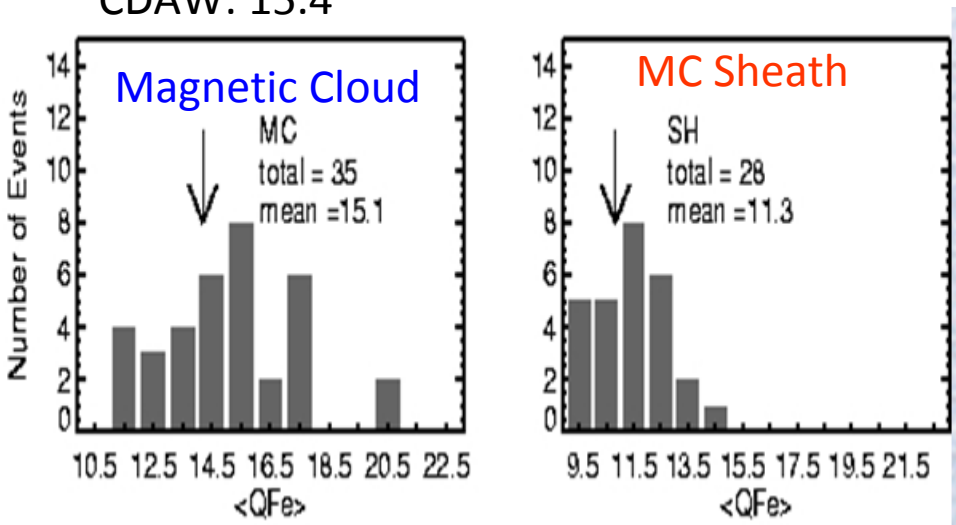
The ratio for CDAW events is higher than that for the general population (CDAW events are from disk center



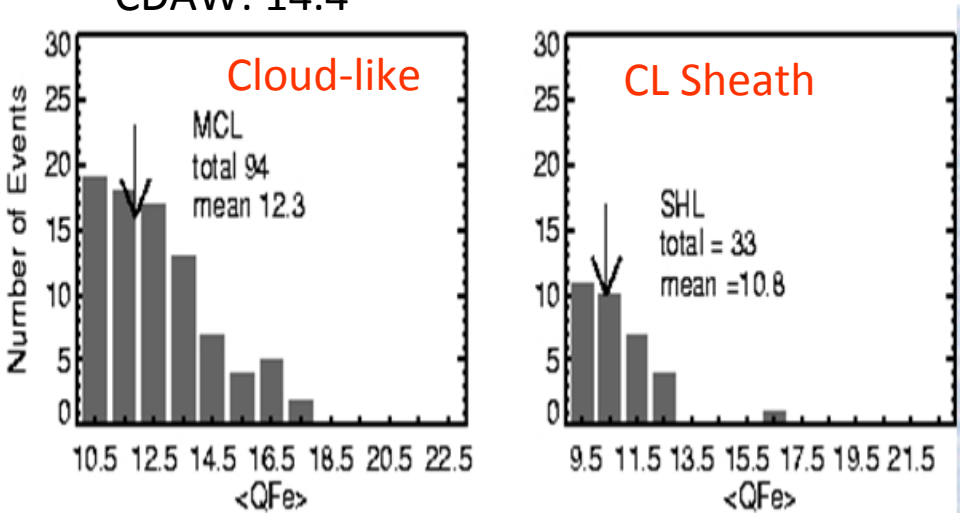


Central QFe Compared with all Events

CDAW: 15.4



CDAW: 14.4



Gopalswamy 2006

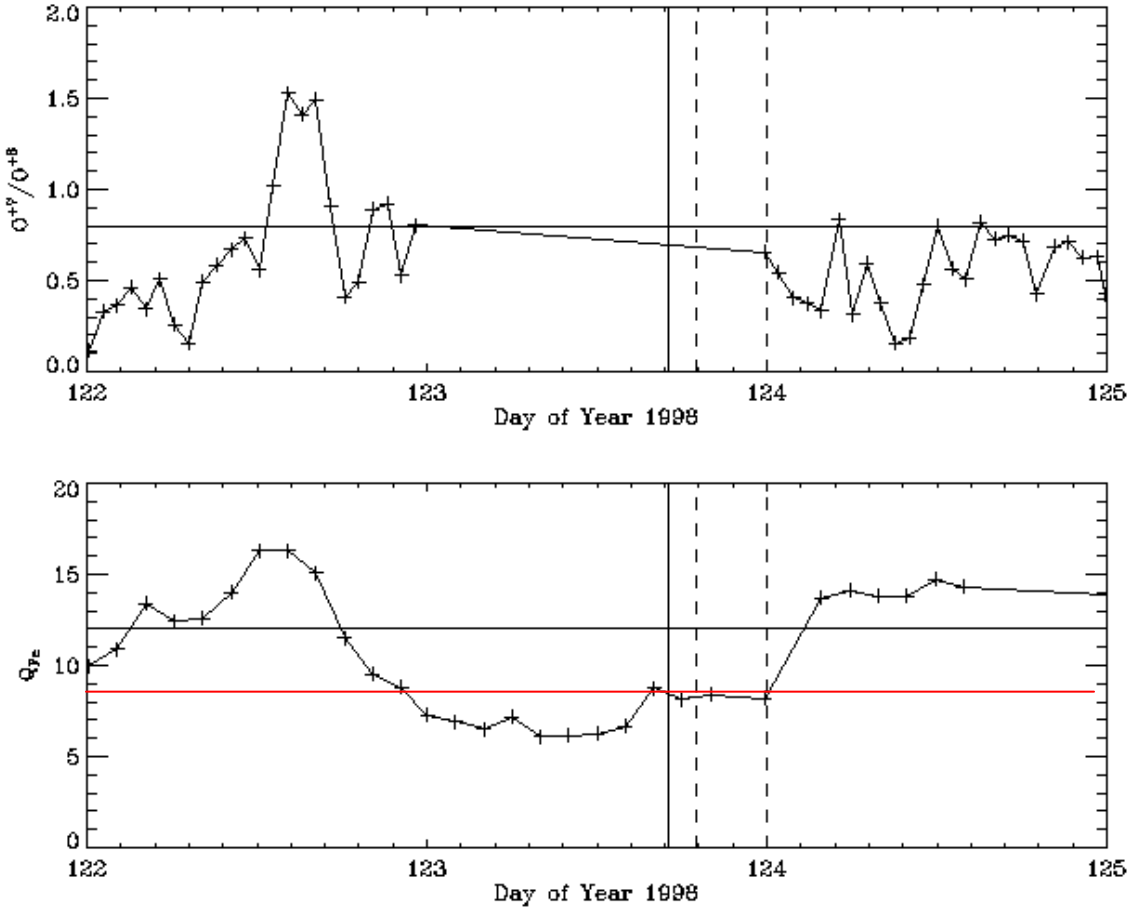
MC values consistent with the
Previous events

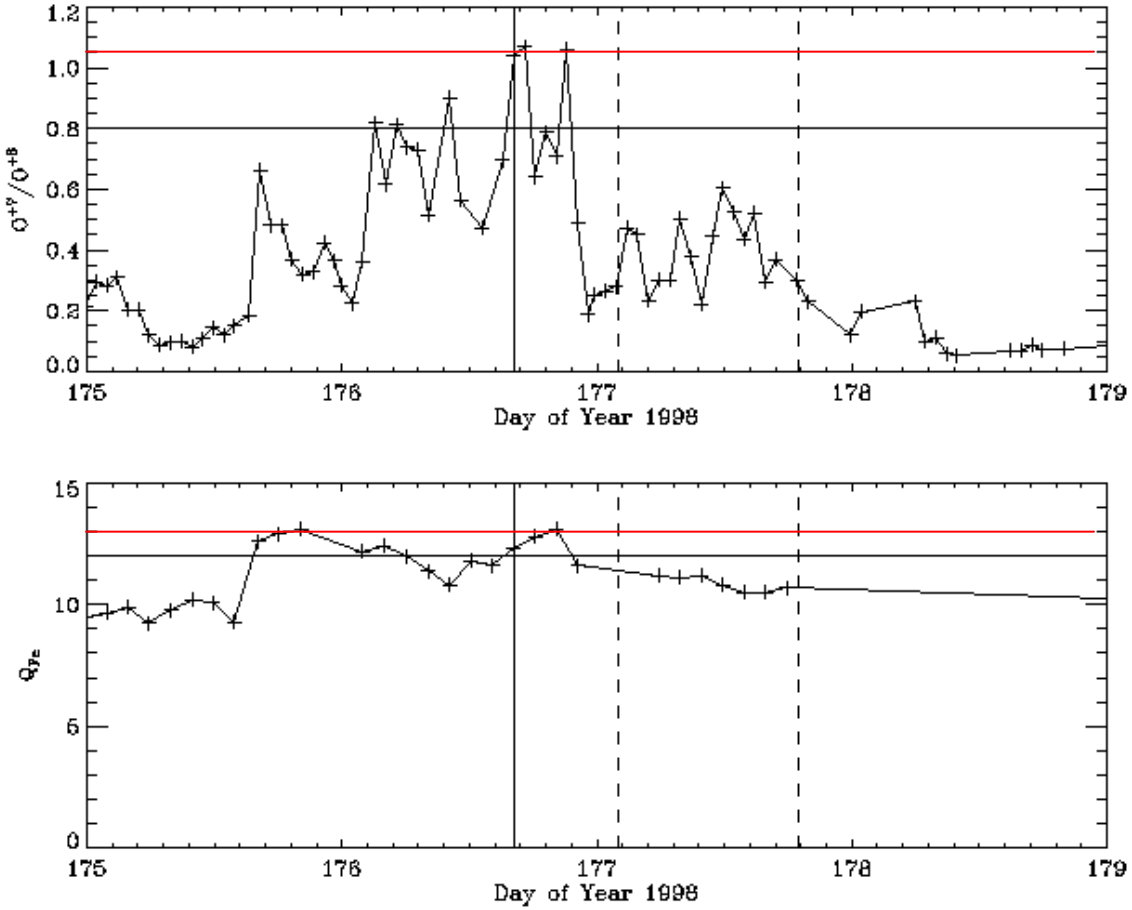
Ejecta values slightly higher probably
Because we consider only disk-center events

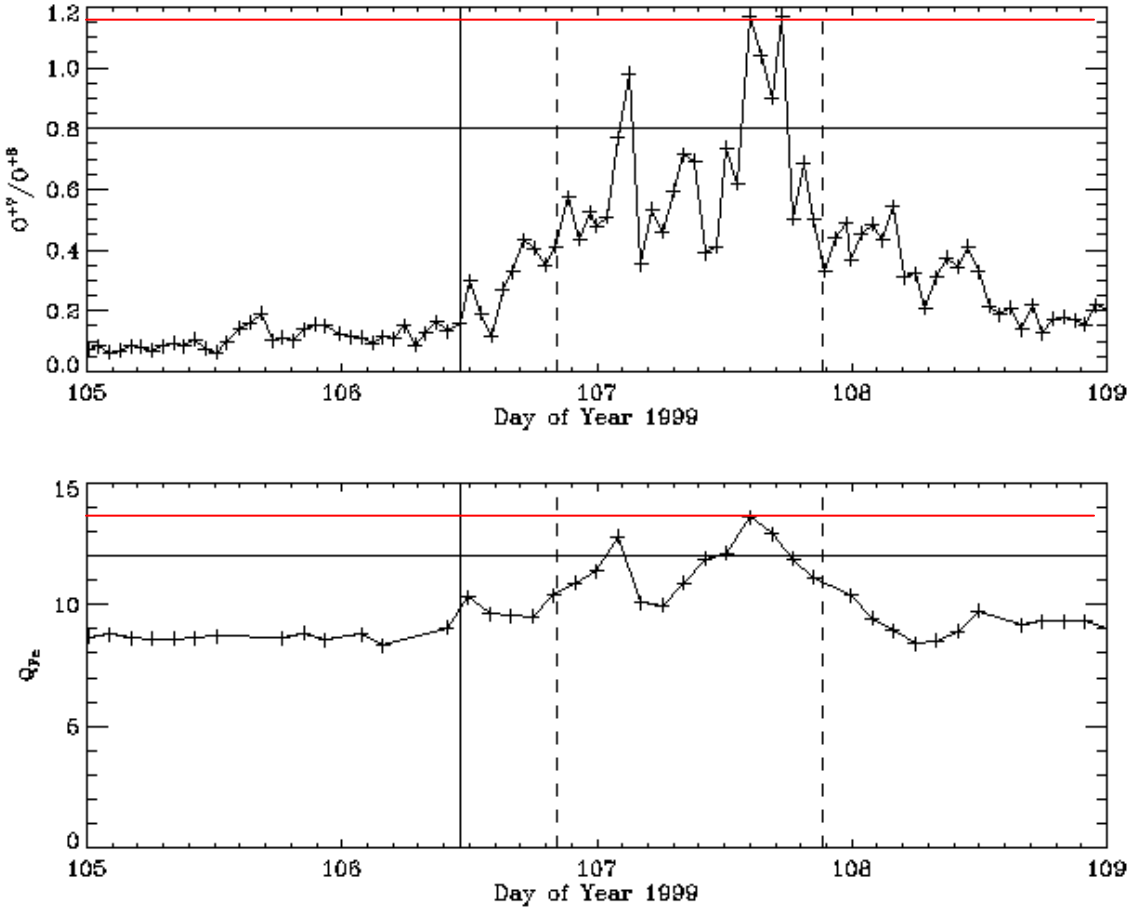
Question: High QFe Ejecta magnetic clouds
classified mistakenly?

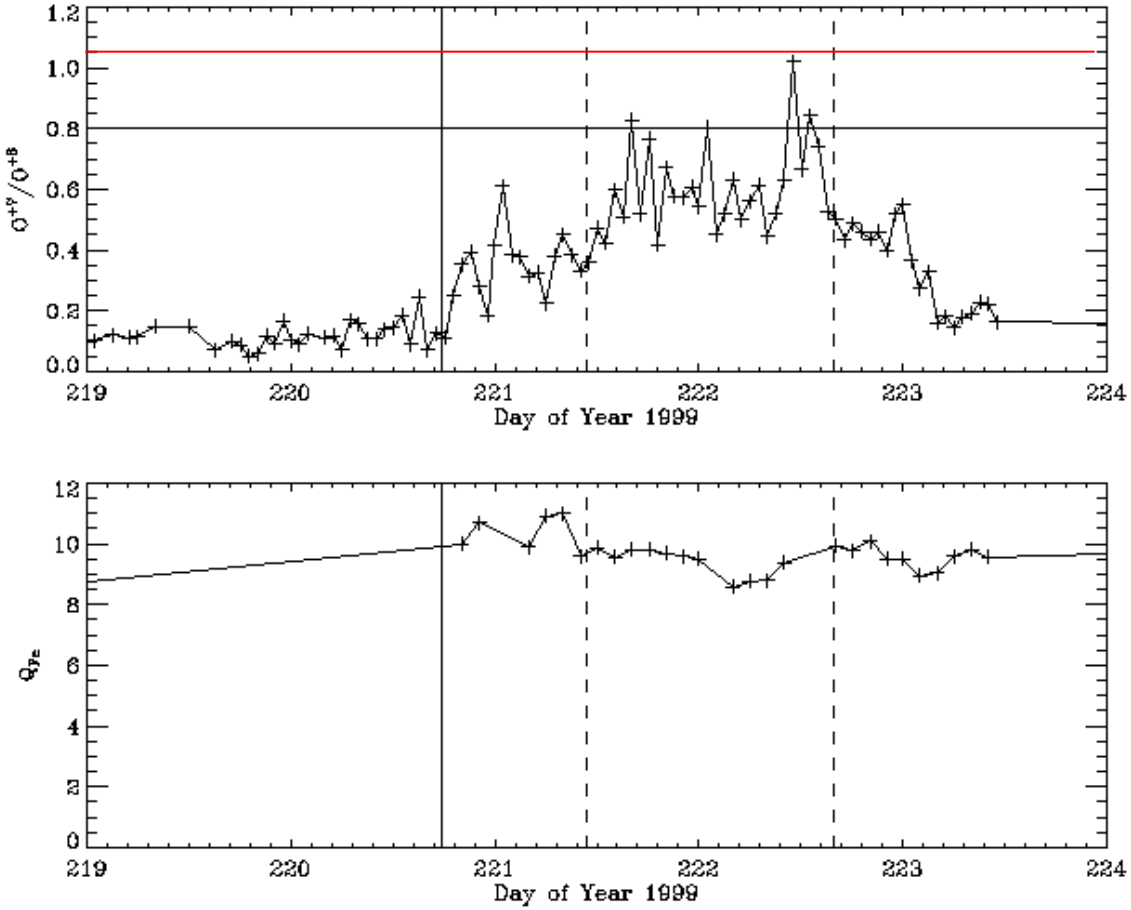
Charge State Analysis

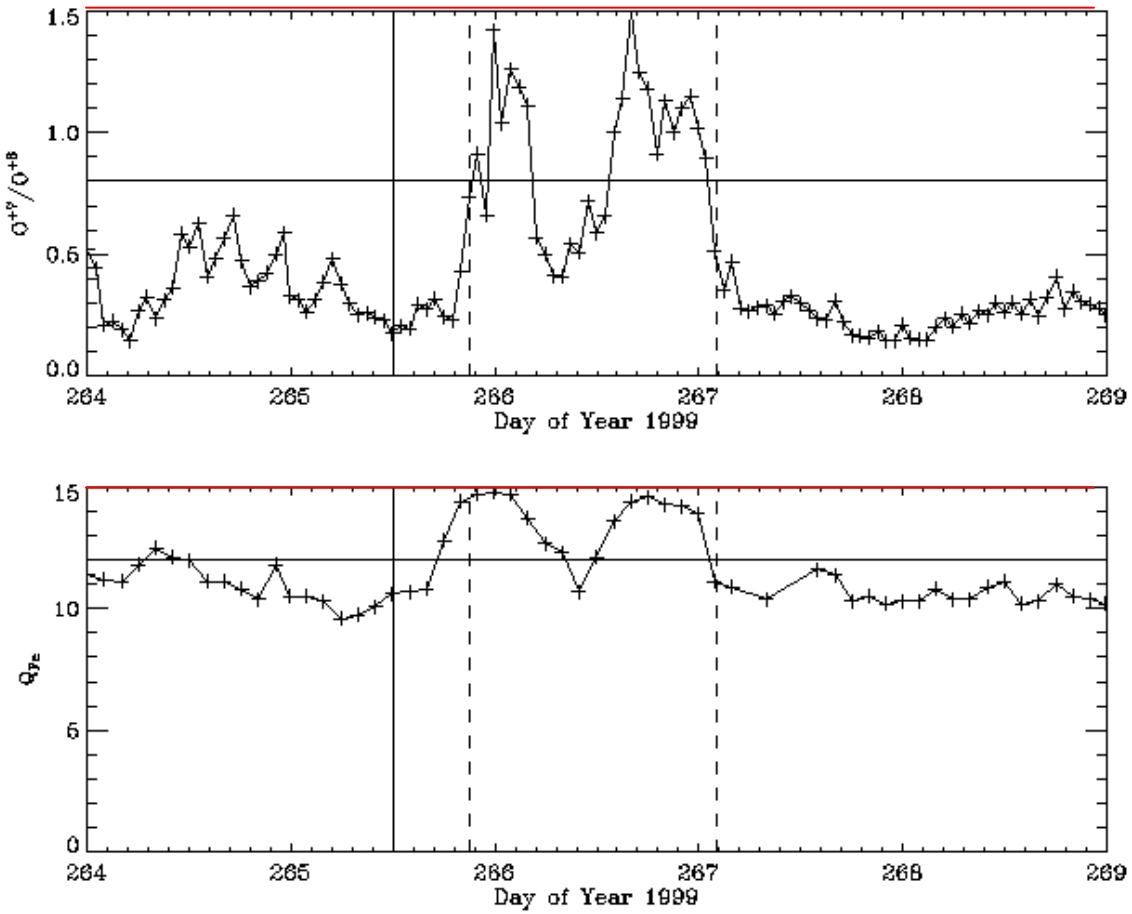
- Nearly all MCs have high O7+/O6+ ratio (> 0.8) and average Fe charge state (<QFe> > 12)
- Only ~half of non-MCs have high O7+/O6+ and QFe
- $\langle QFe \rangle_{MC} \sim 1.07 \langle QFe \rangle_{EJ}$
- $\langle O7+/O6+ \rangle_{MC} \sim 1.6 \langle O7+/O6+ \rangle_{EJ}$
- Comparison with the general population

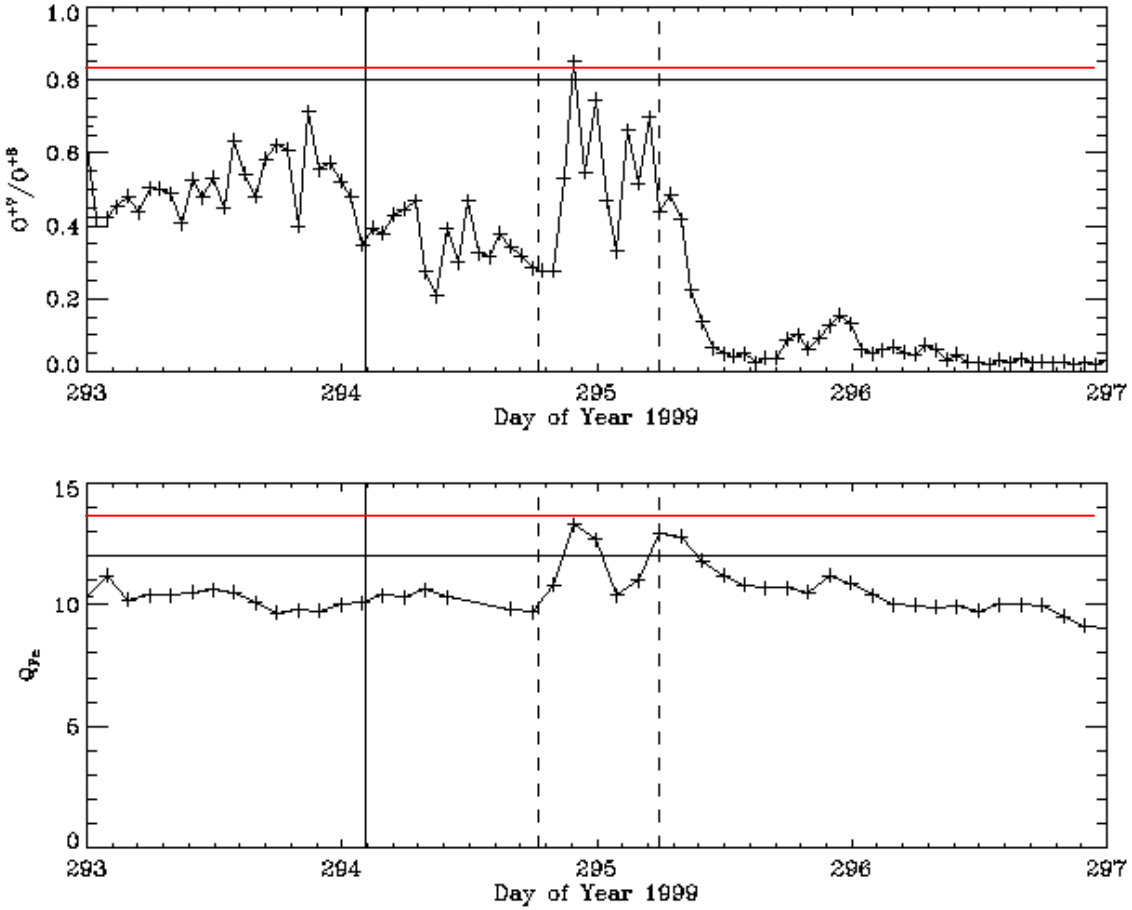

2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
122
123
124
125
Day of Year 1998
20
15
10
5
0
Q_{Fe}
122
123
124
125
Day of Year 1998

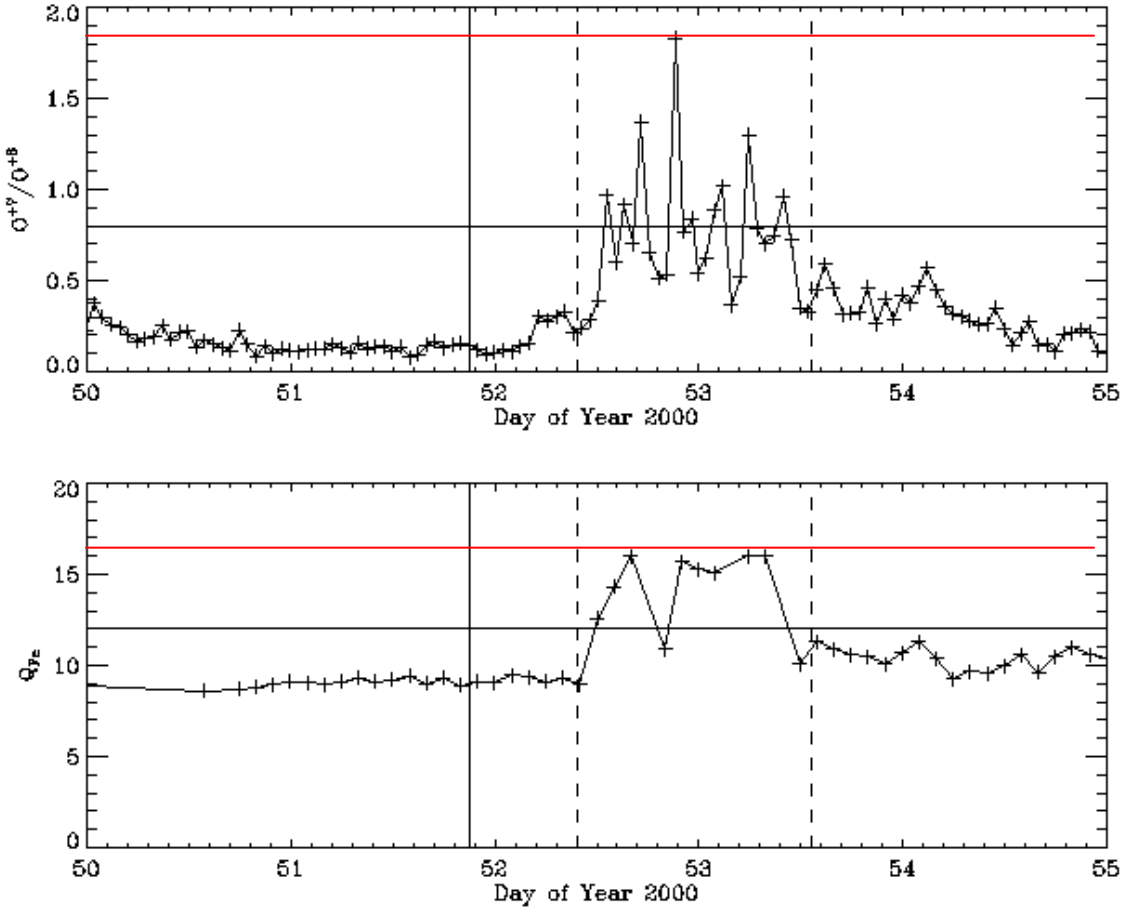

1.2
1.0
0.8
0.6
0.4
0.2
0.0
O^{+9}/O^{+8}
175
176
177
178
179
Day of Year 1998
15
10
5
0
Q_{Fe}
175
176
177
178
179
Day of Year 1998


1.2
1.0
0.8
0.6
0.4
0.2
0.0
O^{+9}/O^{+8}
105
106
107
108
109
Day of Year 1999
15
10
5
0
Q_{Fe}
105
106
107
108
109
Day of Year 1999

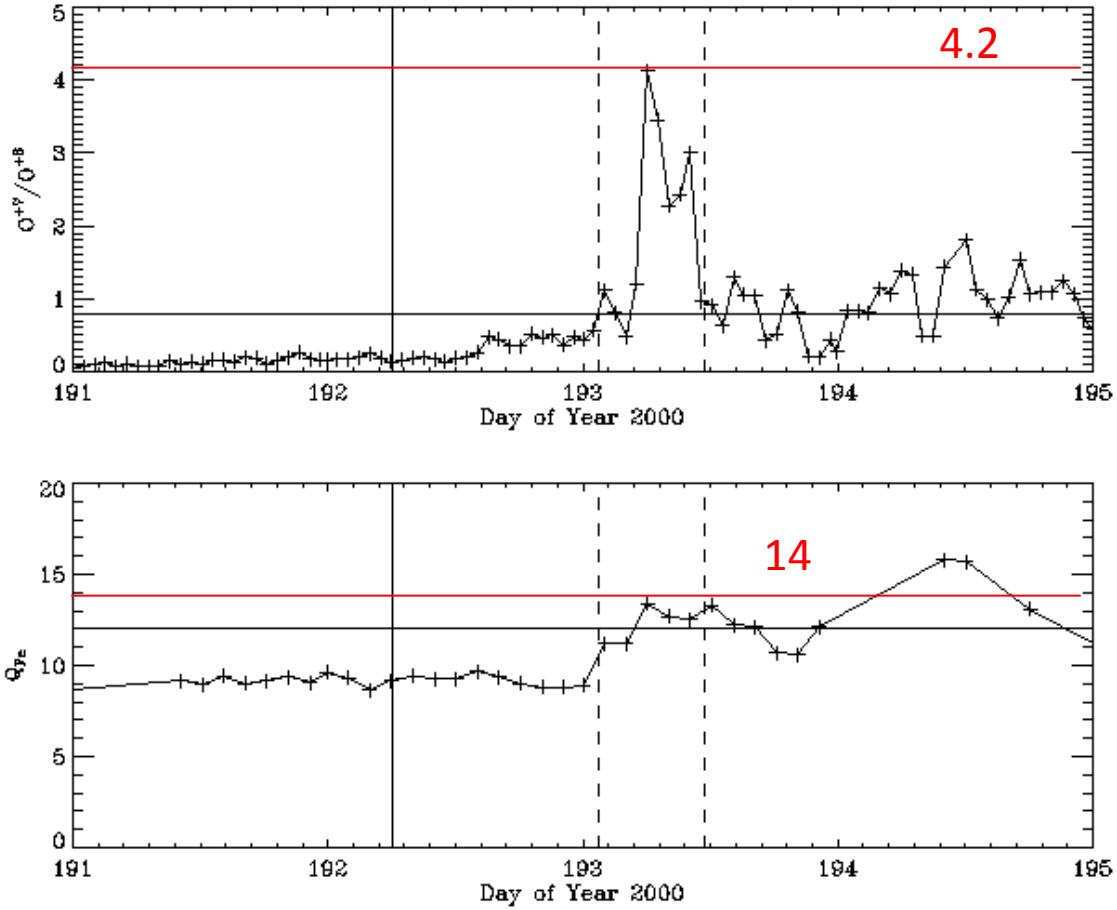

1.2
1.0
0.8
0.6
0.4
0.2
0.0
O^{+9}/O^{+8}
219
220
221
222
223
224
Day of Year 1999
12
10
8
6
4
2
0
Q_{Fe}
219
220
221
222
223
224
Day of Year 1999

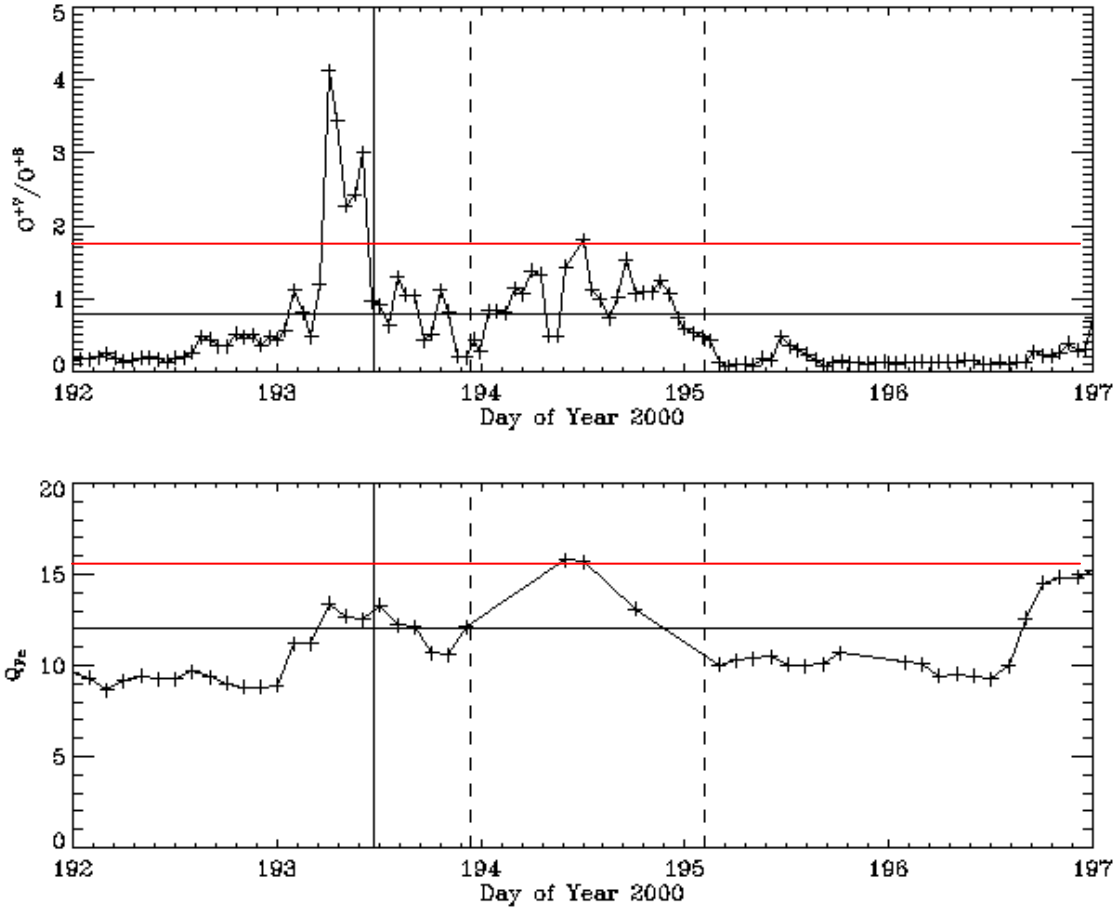

1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
264
265
266
267
268
269
Day of Year 1999
15
10
5
0
Q_{Fe}
264
265
266
267
268
269
Day of Year 1999

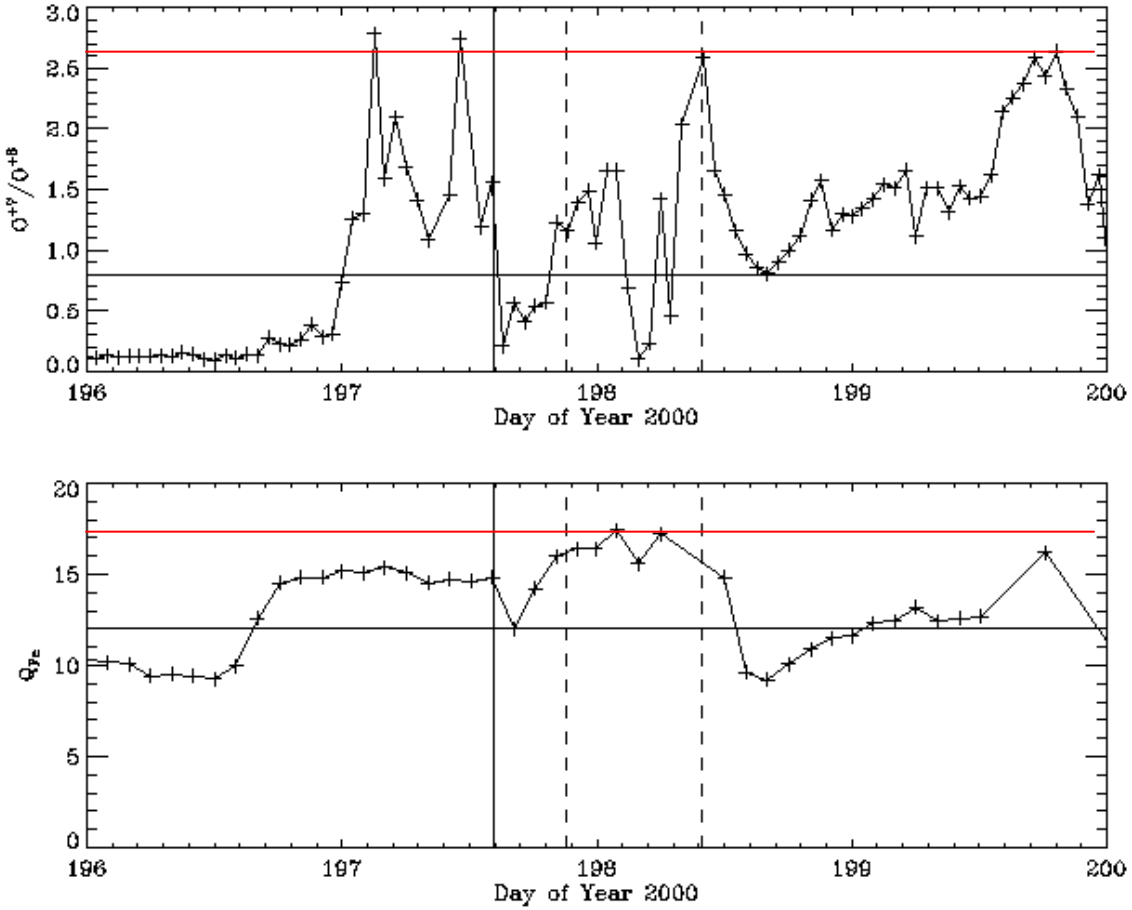

1.0
0.8
0.6
0.4
0.2
0.0
O^{+9}/O^{+8}
293
294
295
296
297
Day of Year 1999
15
10
5
0
Q_{Fe}
293
294
295
296
297
Day of Year 1999

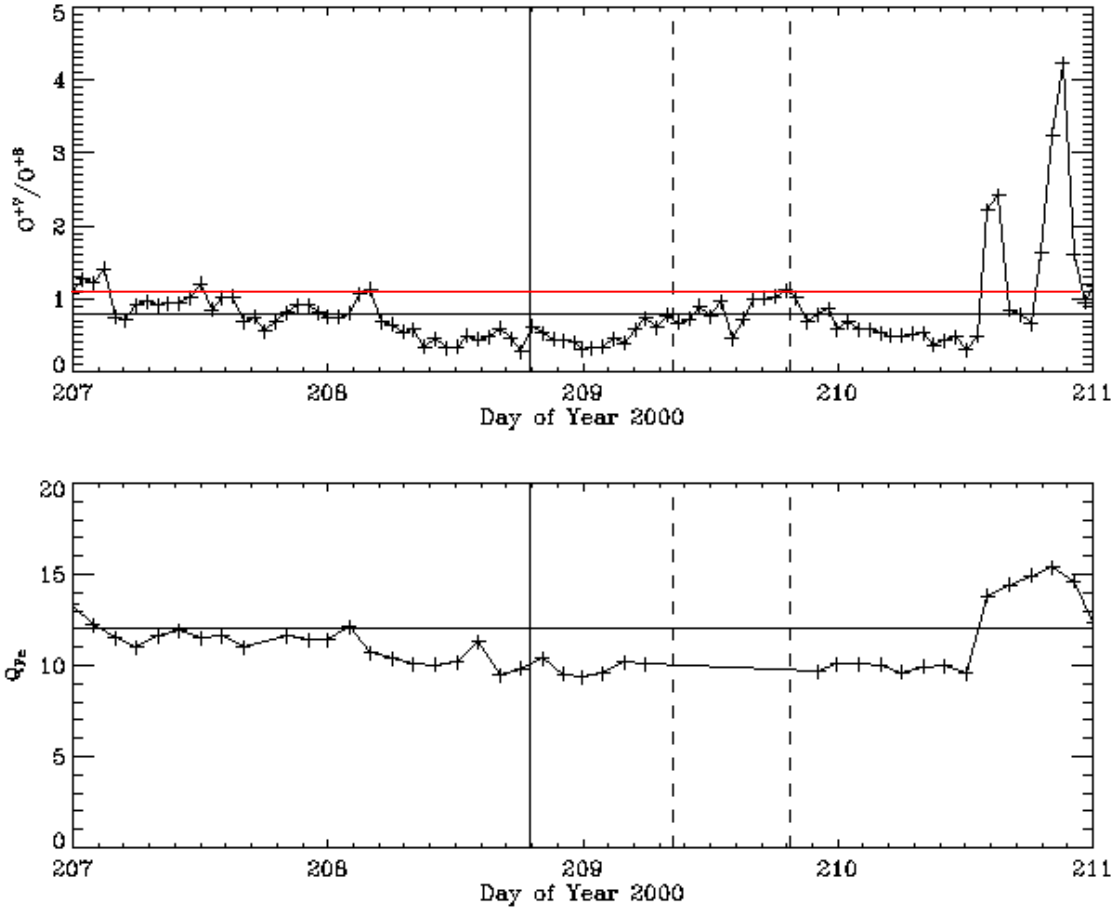

2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
50
51
52
53
54
55
Day of Year 2000
20
15
10
5
0
Q_{Fe}
50
51
52
53
54
55
Day of Year 2000

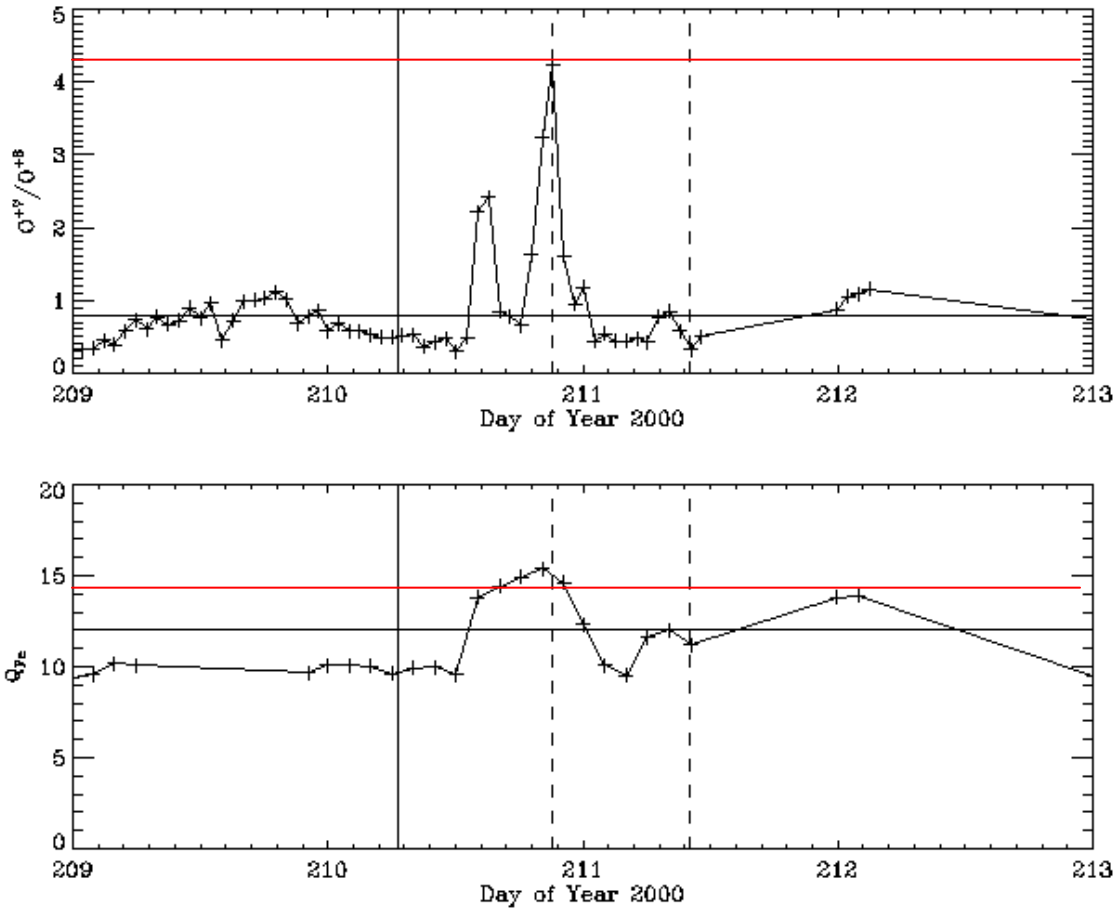
17 EJ: 2000 July 10



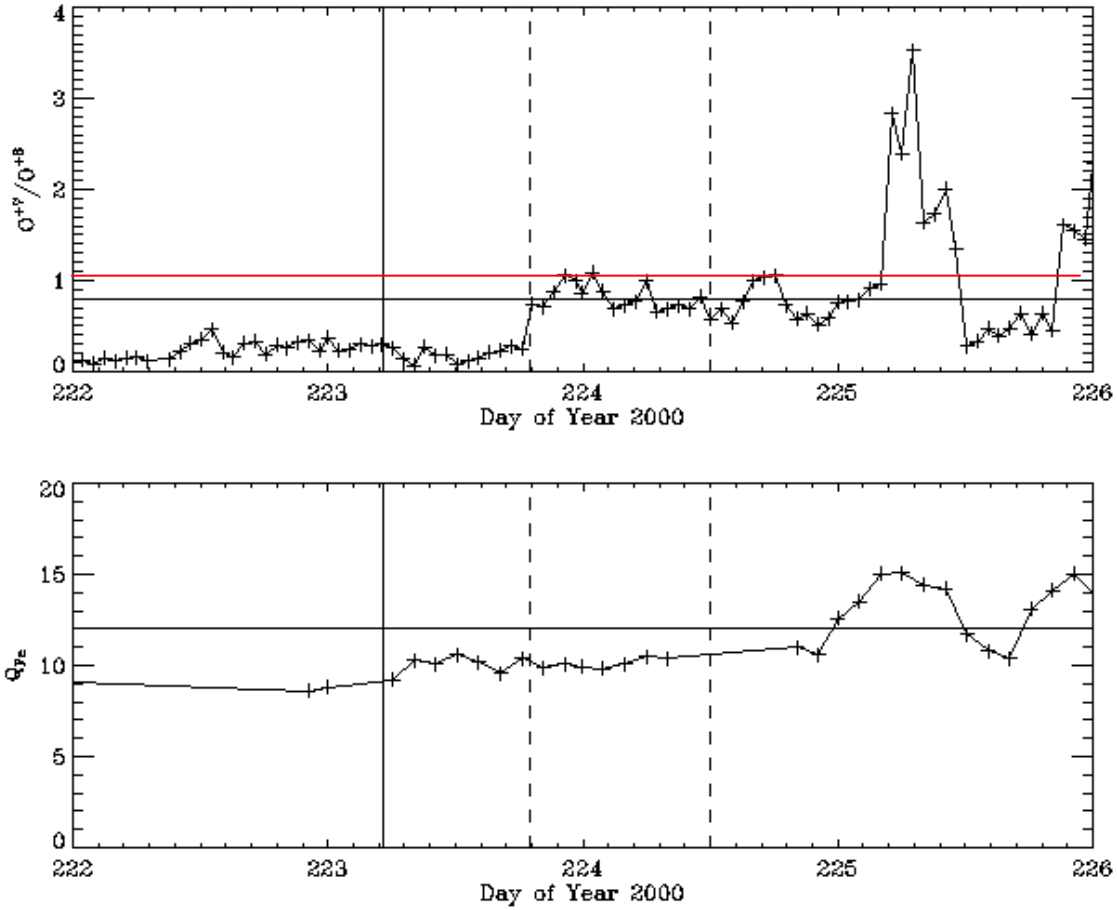

O^{+7}/O^{+8}
Day of Year 2000
Q_{Fe}
Day of Year 2000


3.0
2.5
2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
196
197
198
199
200
Day of Year 2000
20
15
10
5
0
Q_{Fe}
196
197
198
199
200
Day of Year 2000

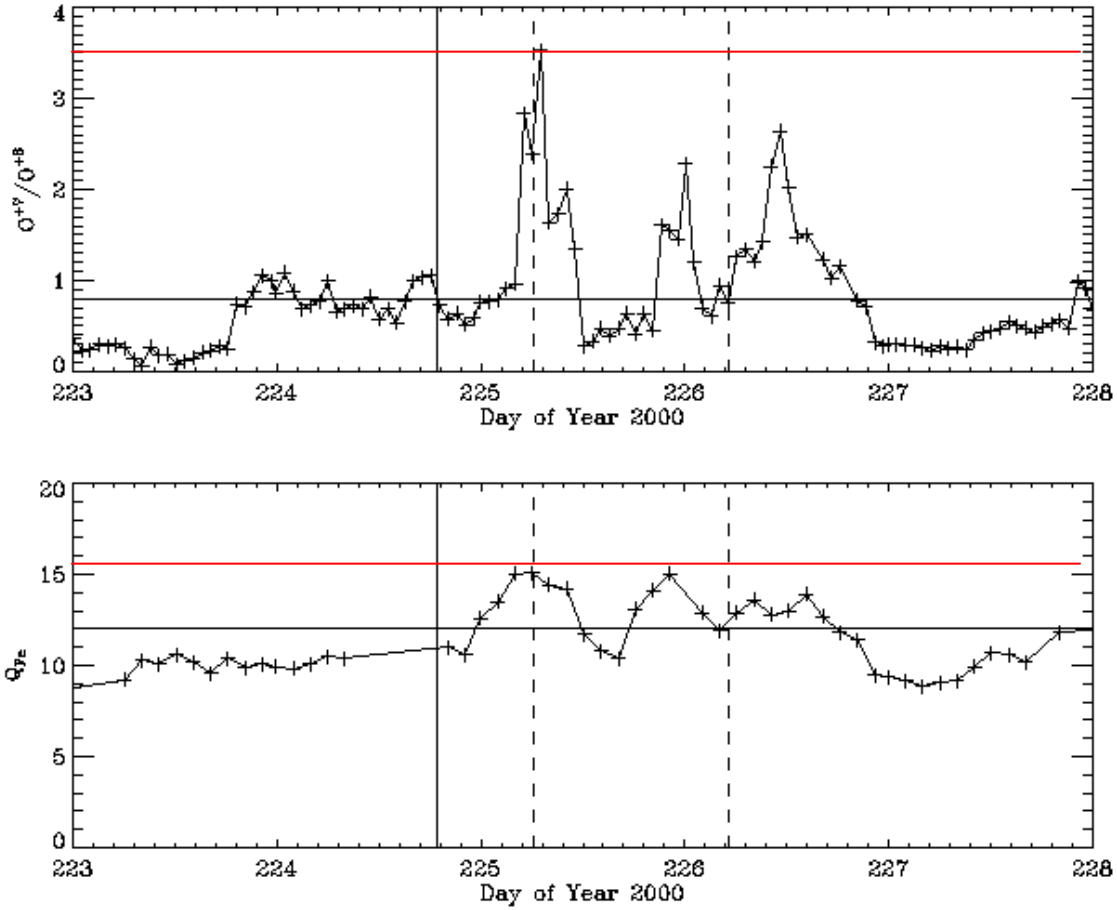

O^{+9}/O^{+8}
0
1
2
3
4
5
207
208
209
210
211
Day of Year 2000
Q_{Fe}
0
5
10
15
20
207
208
209
210
211
Day of Year 2000


5
4
3
2
1
0
O^{+7}/O^{+8}
209
210
211
212
213
Day of Year 2000
20
15
10
5
0
$Q_{7\pi}$
209
210
211
212
213
Day of Year 2000

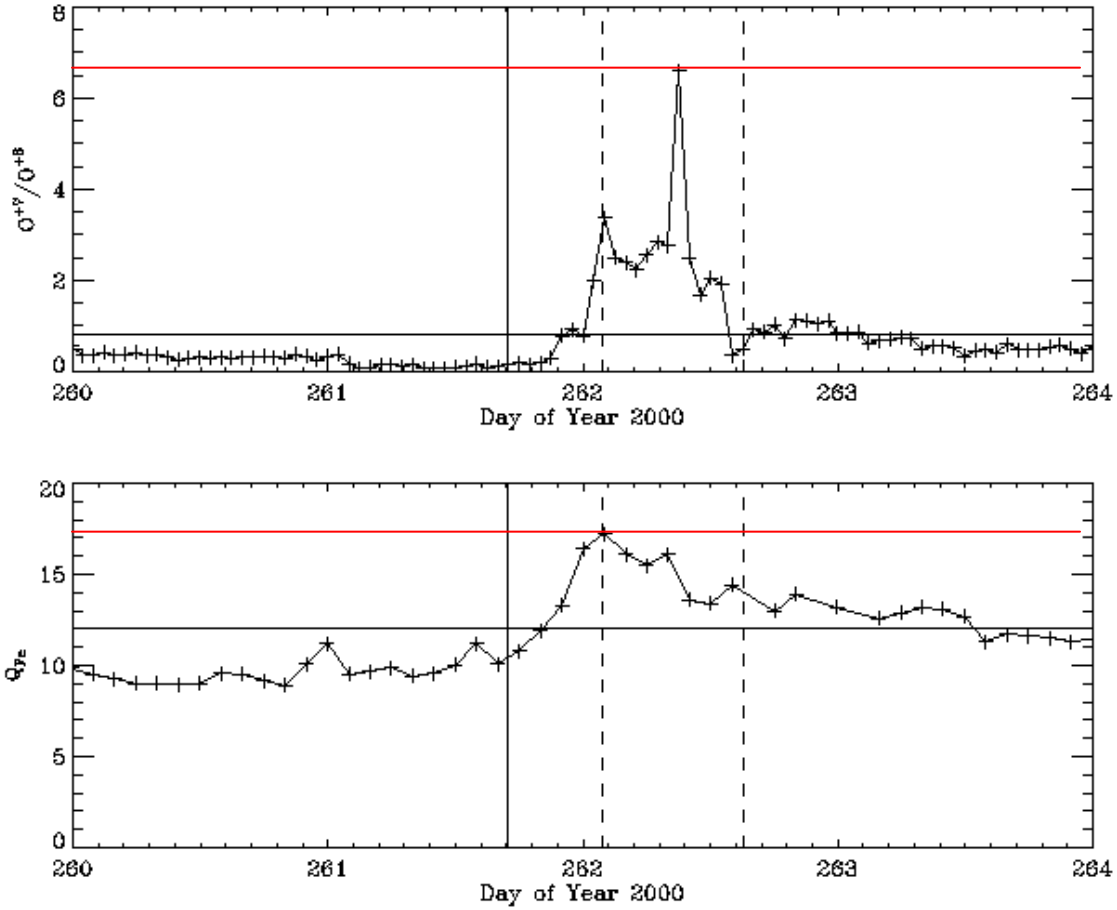
22



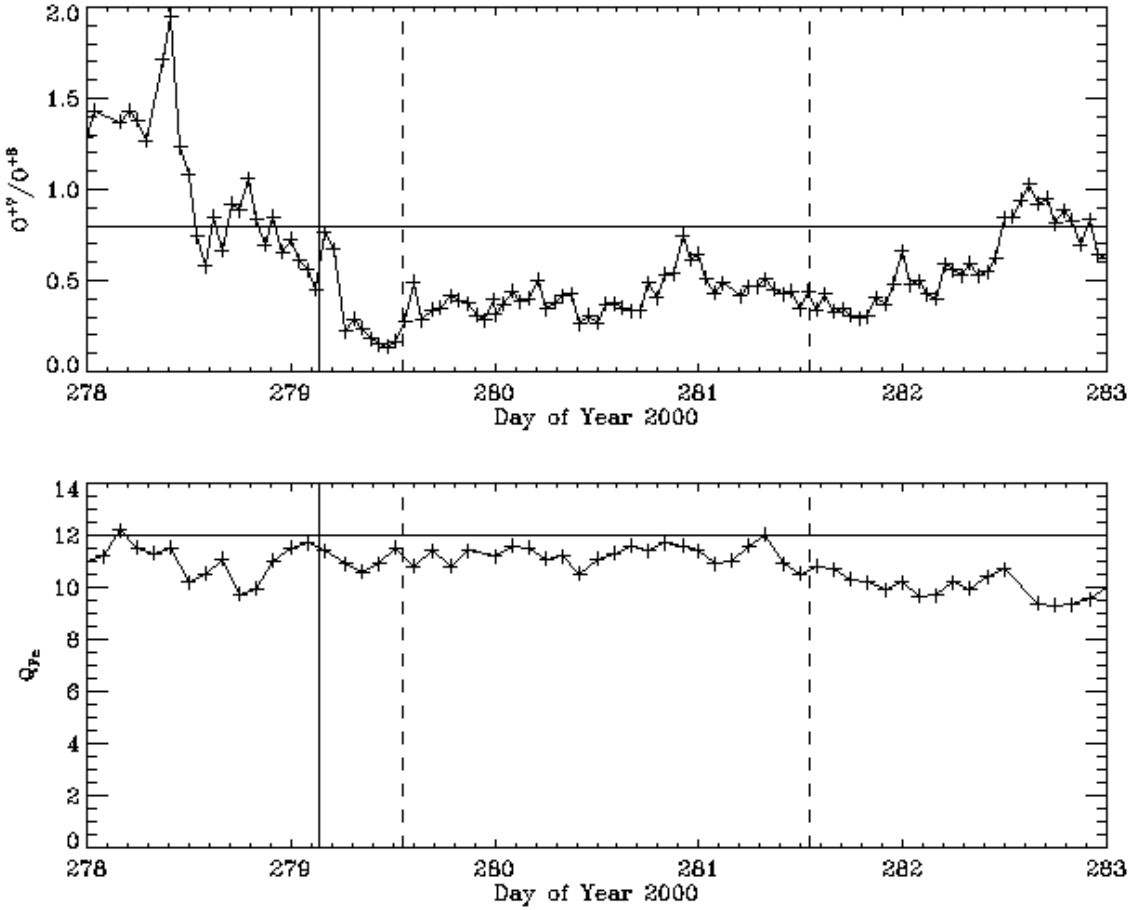
23



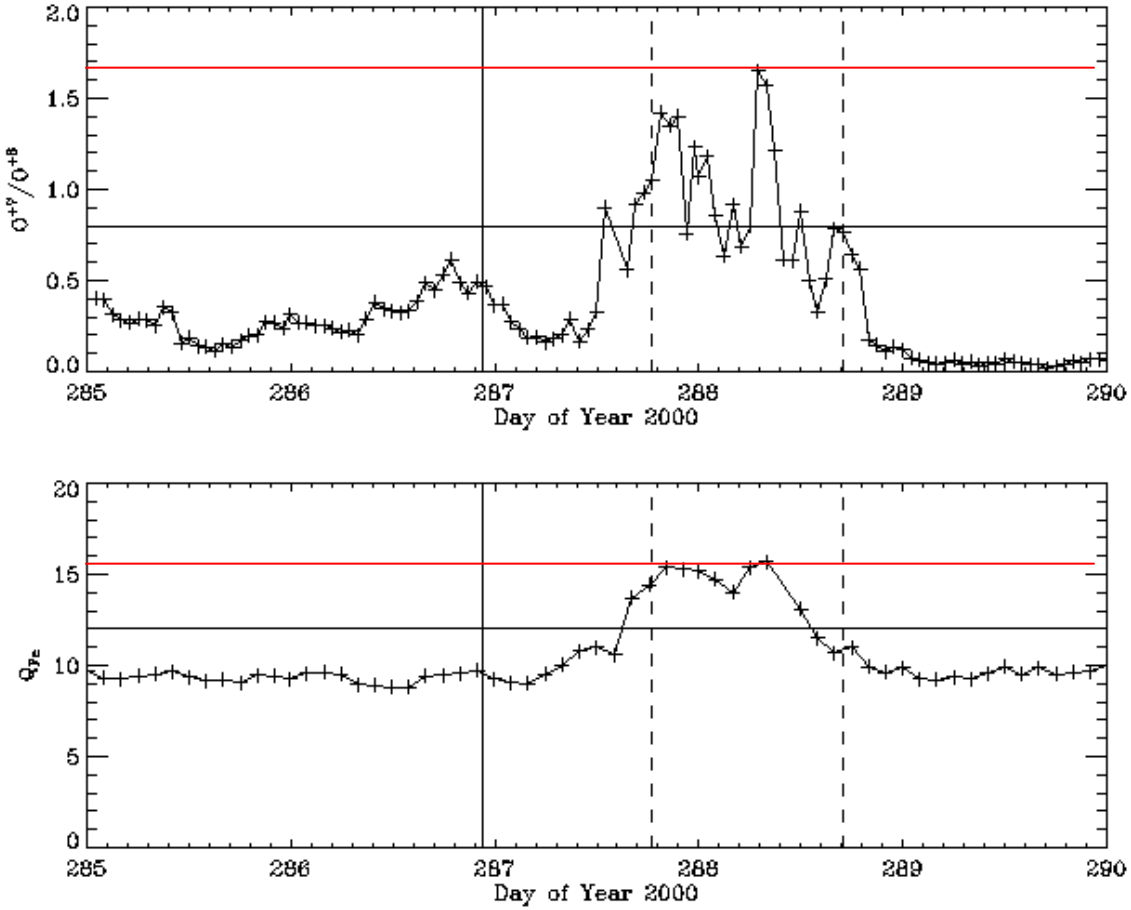
24


8
6
4
2
0
O^{+9}/O^{+8}
260
261
262
263
264
Day of Year 2000
20
15
10
5
0
Q_{Fe}
260
261
262
263
264
Day of Year 2000

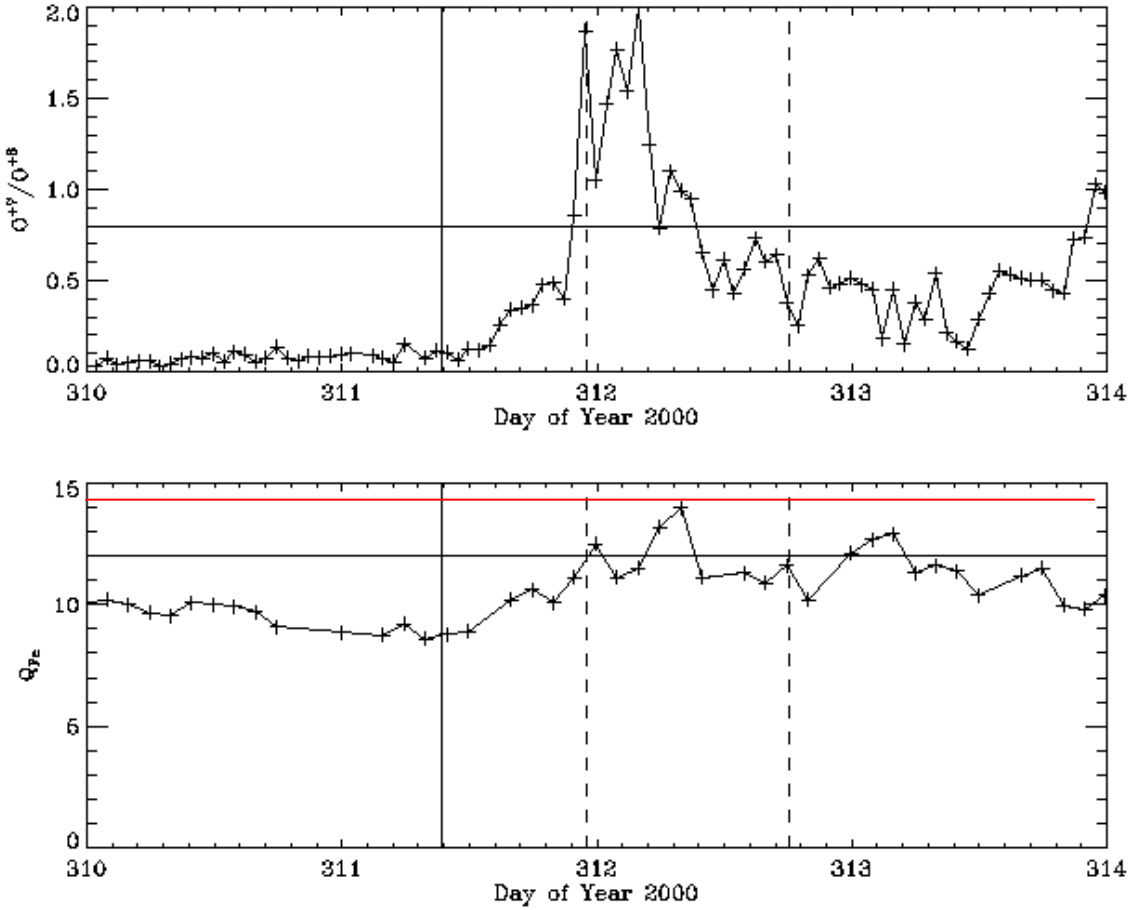
25


2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
278
279
280
281
282
283
Day of Year 2000
14
12
10
8
6
4
2
0
Q_{Fe}
278
279
280
281
282
283
Day of Year 2000

26


2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
285
286
287
288
289
290
Day of Year 2000
20
15
10
5
0
Q_{9c}
285
286
287
288
289
290
Day of Year 2000

27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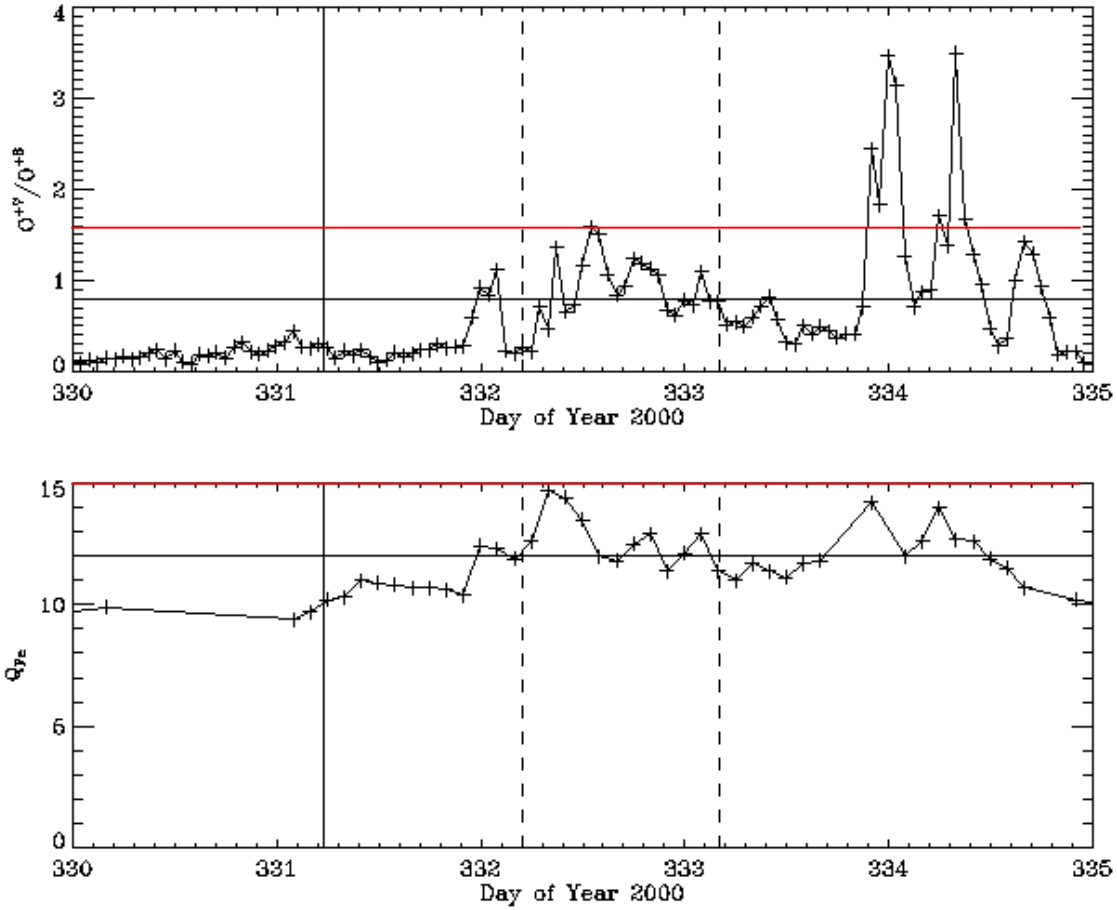
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
310
311
312
313
314
Day of Year 2000
15
10
5
0
Q_{Fe}
310
311
312
313
314
Day of Year 2000

28 EJ



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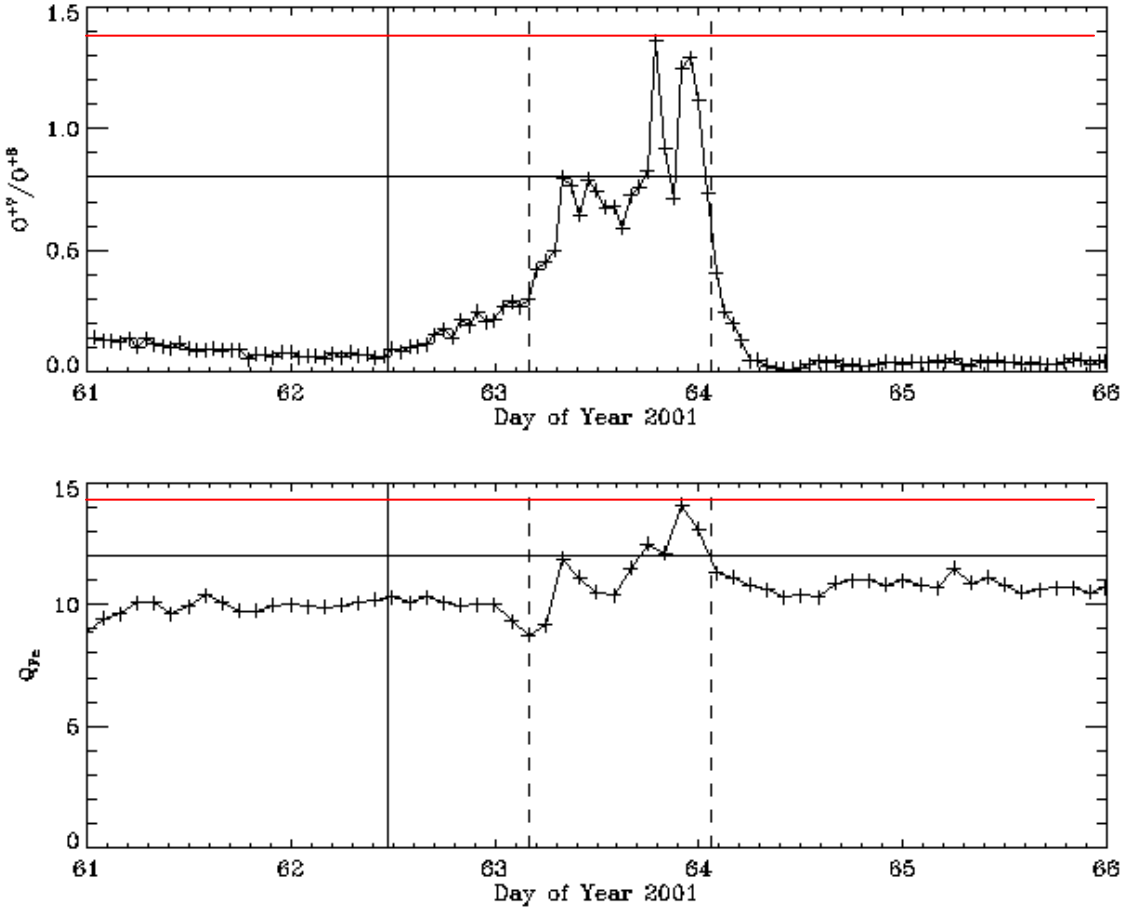
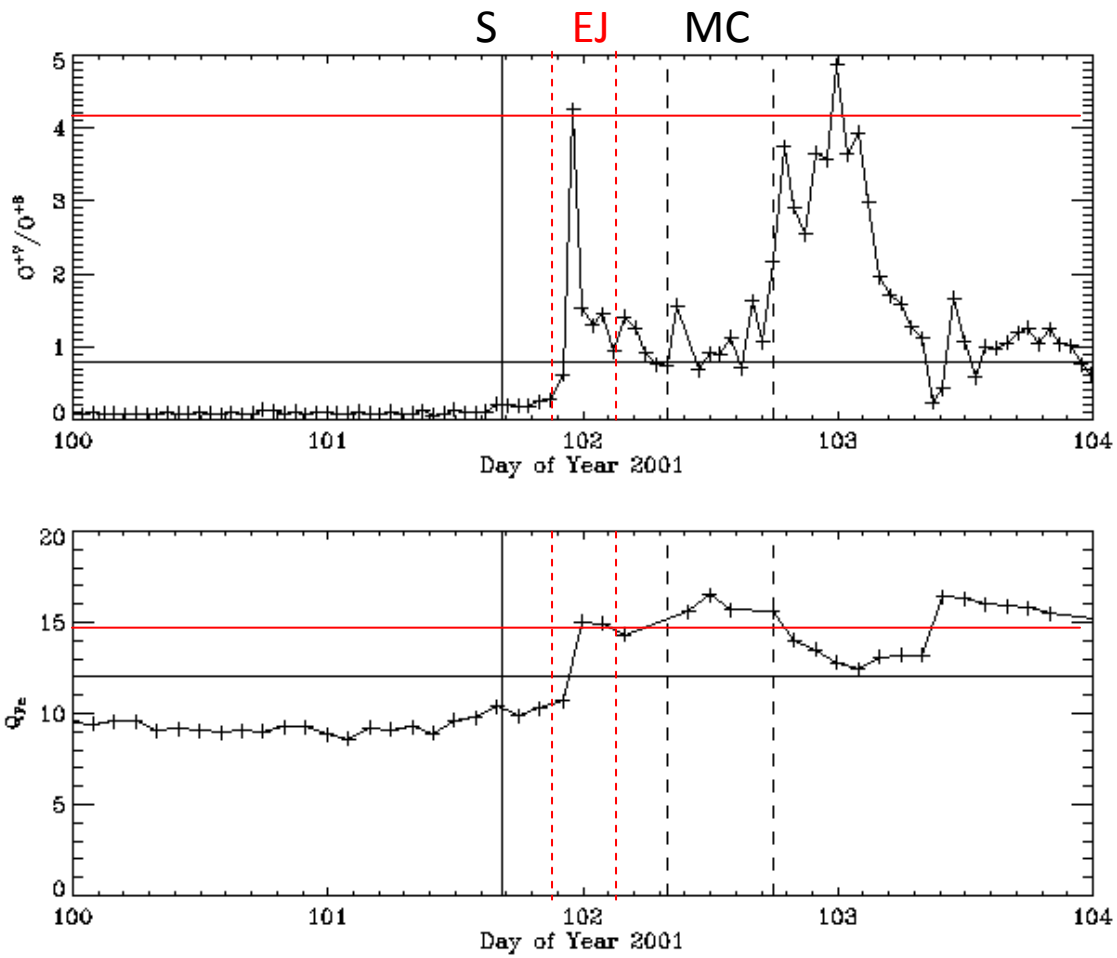
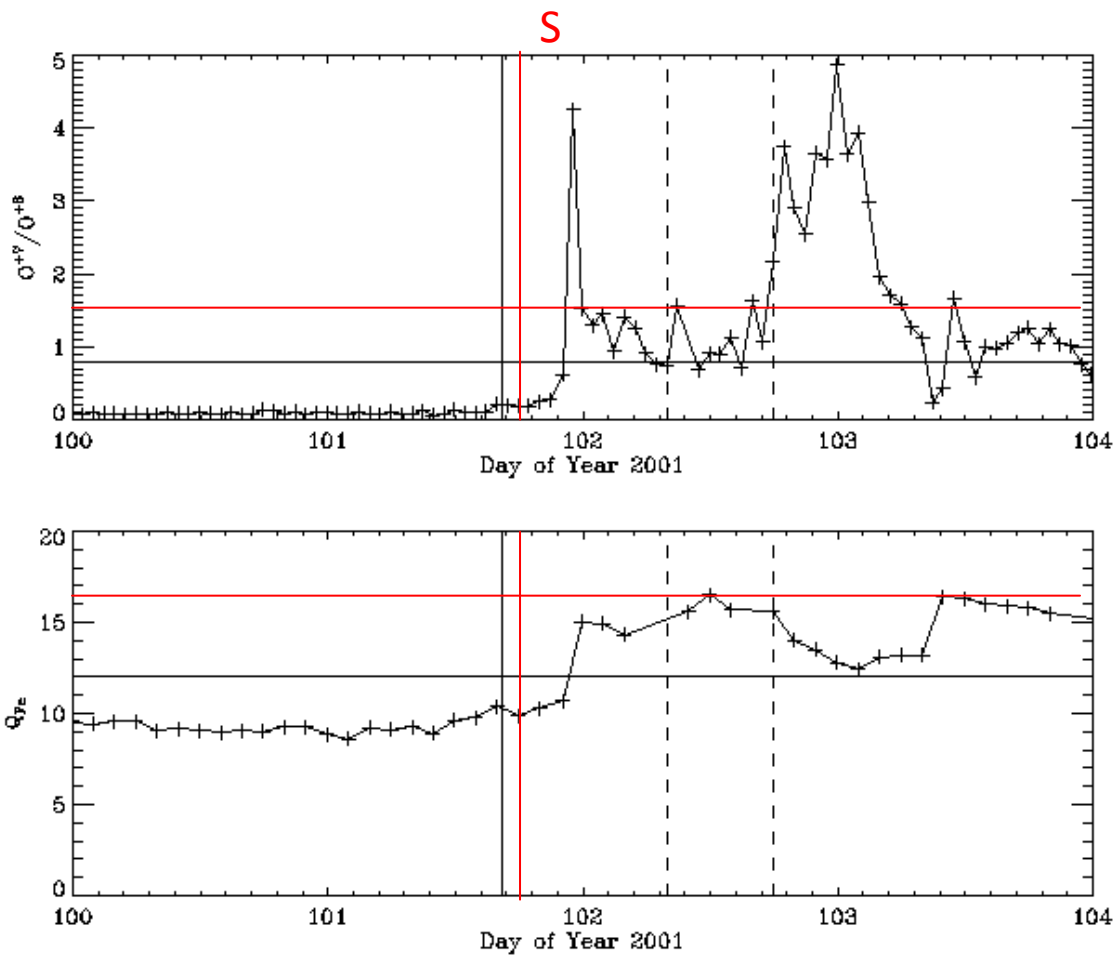

1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
61
62
63
64
65
66
Day of Year 2001
15
10
5
0
Q_{9e}
61
62
63
64
65
66
Day of Year 2001

31 EJ



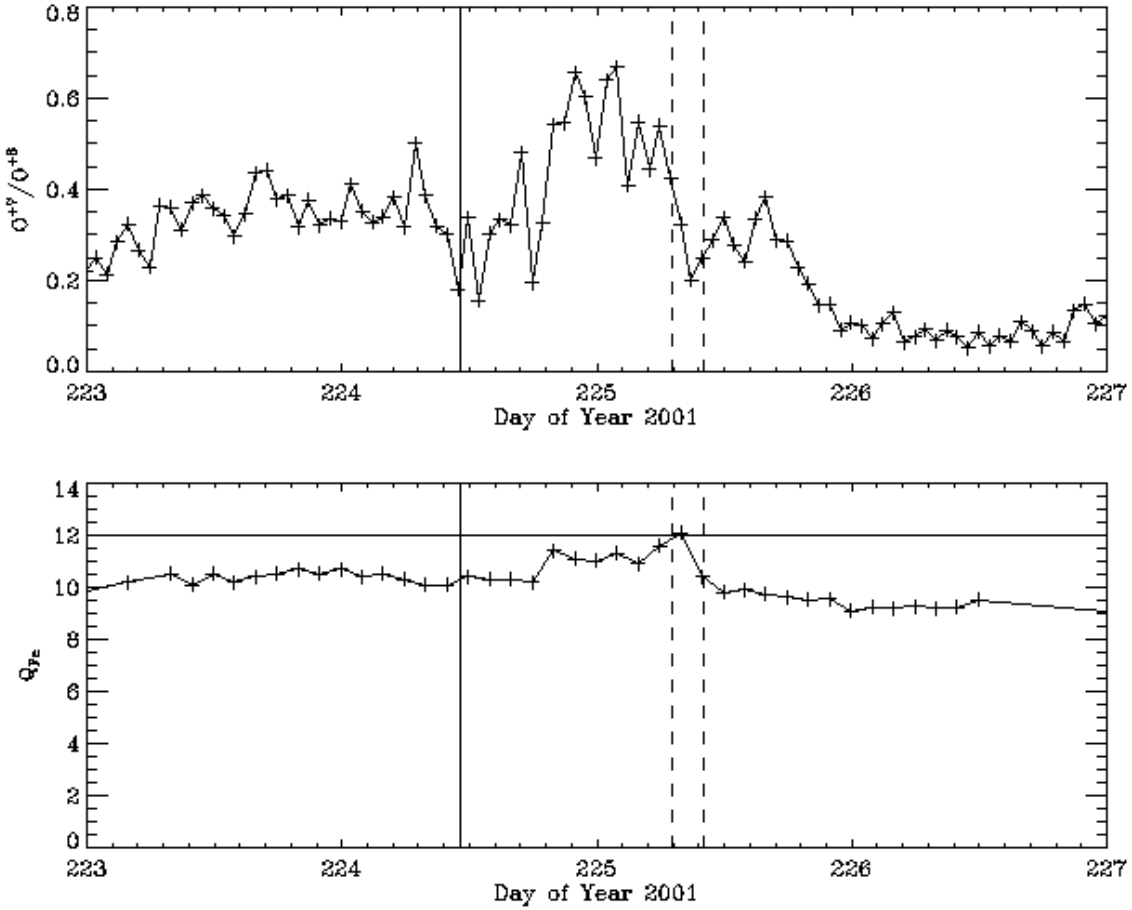
April 11 12 13 14

32 MC

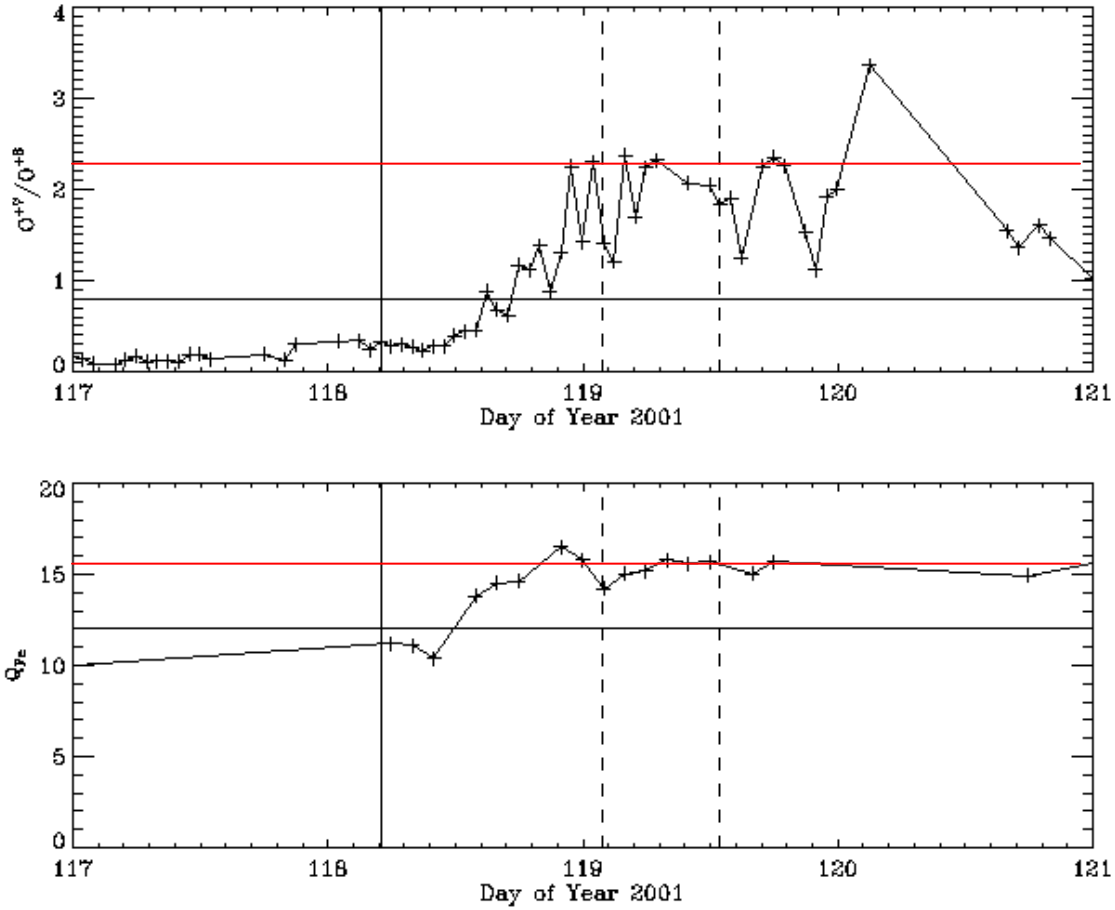


11 12 13 14

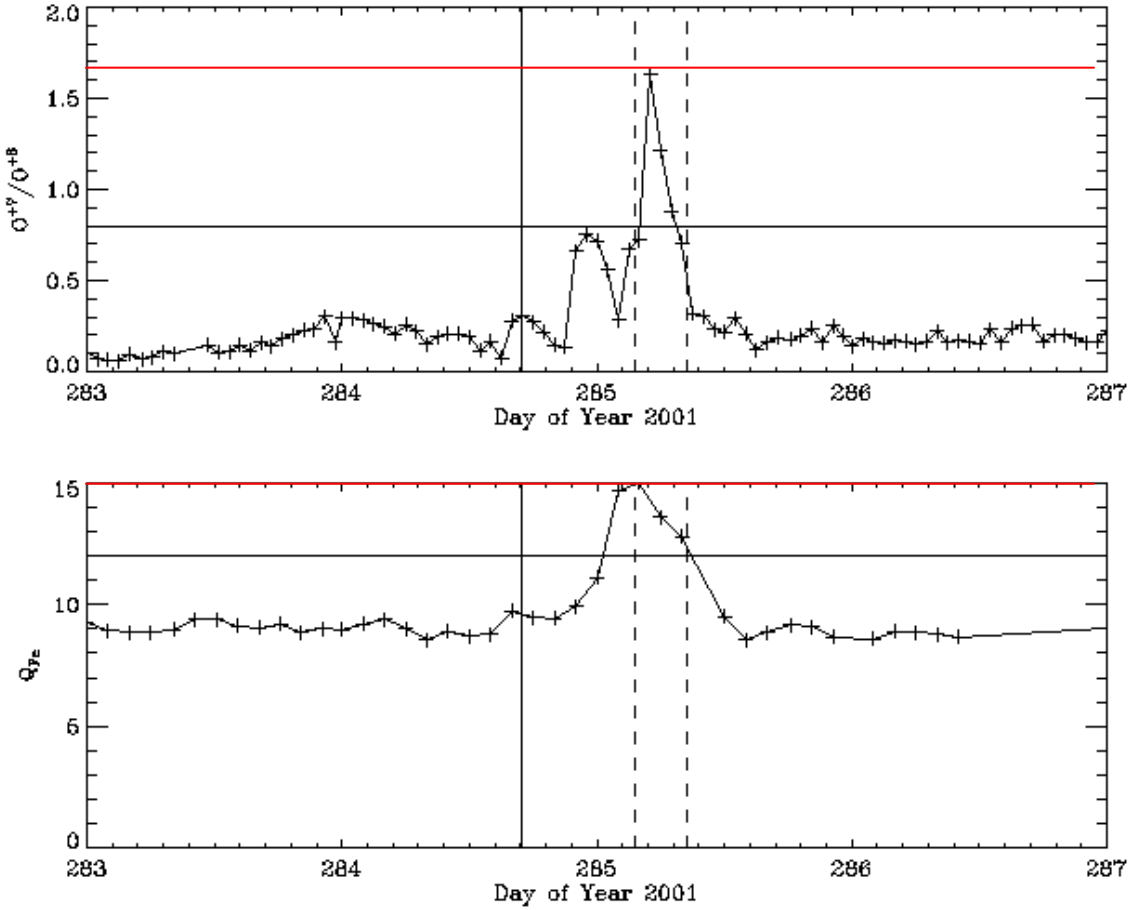
34 EJ


0.8
0.6
0.4
0.2
0.0
O^{+9}/O^{+8}
223
224
225
226
227
Day of Year 2001
14
12
10
8
6
4
2
0
Q_{9c}
223
224
225
226
227
Day of Year 2001

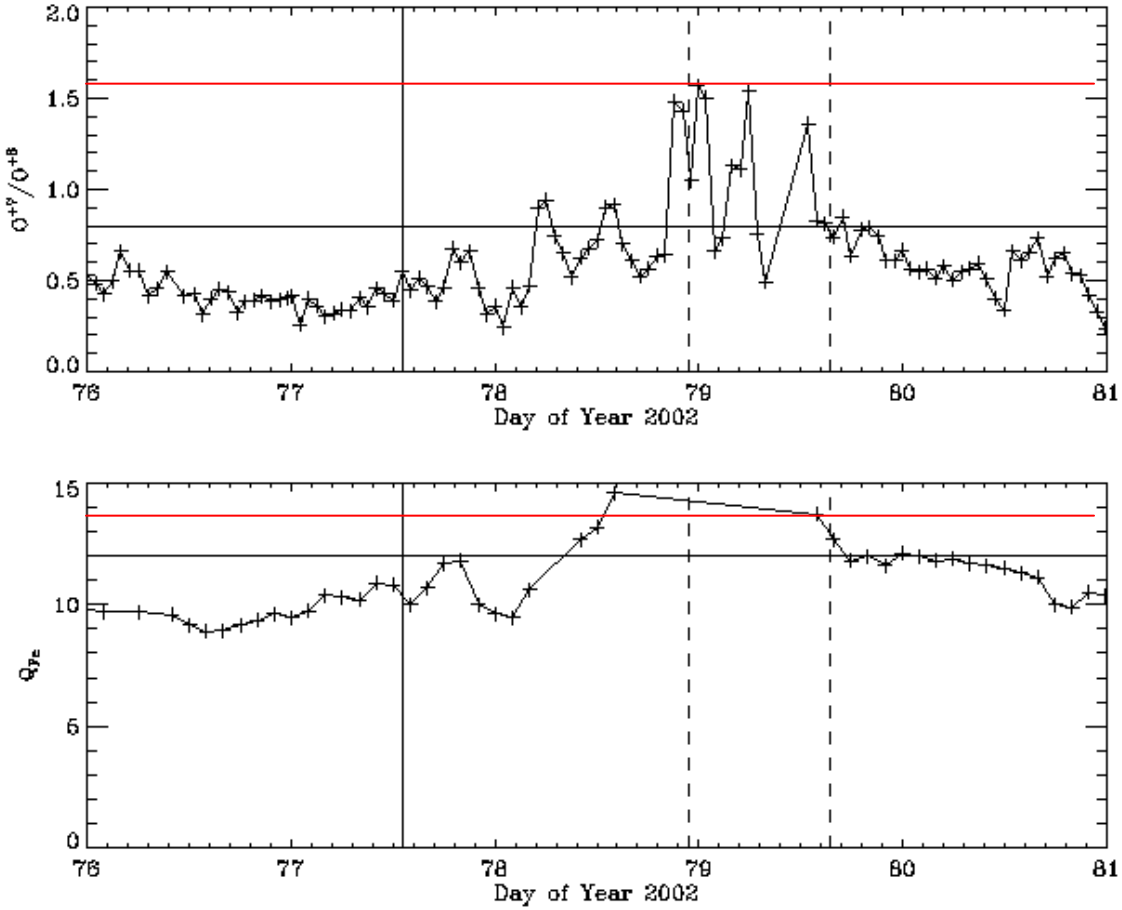
33 MC



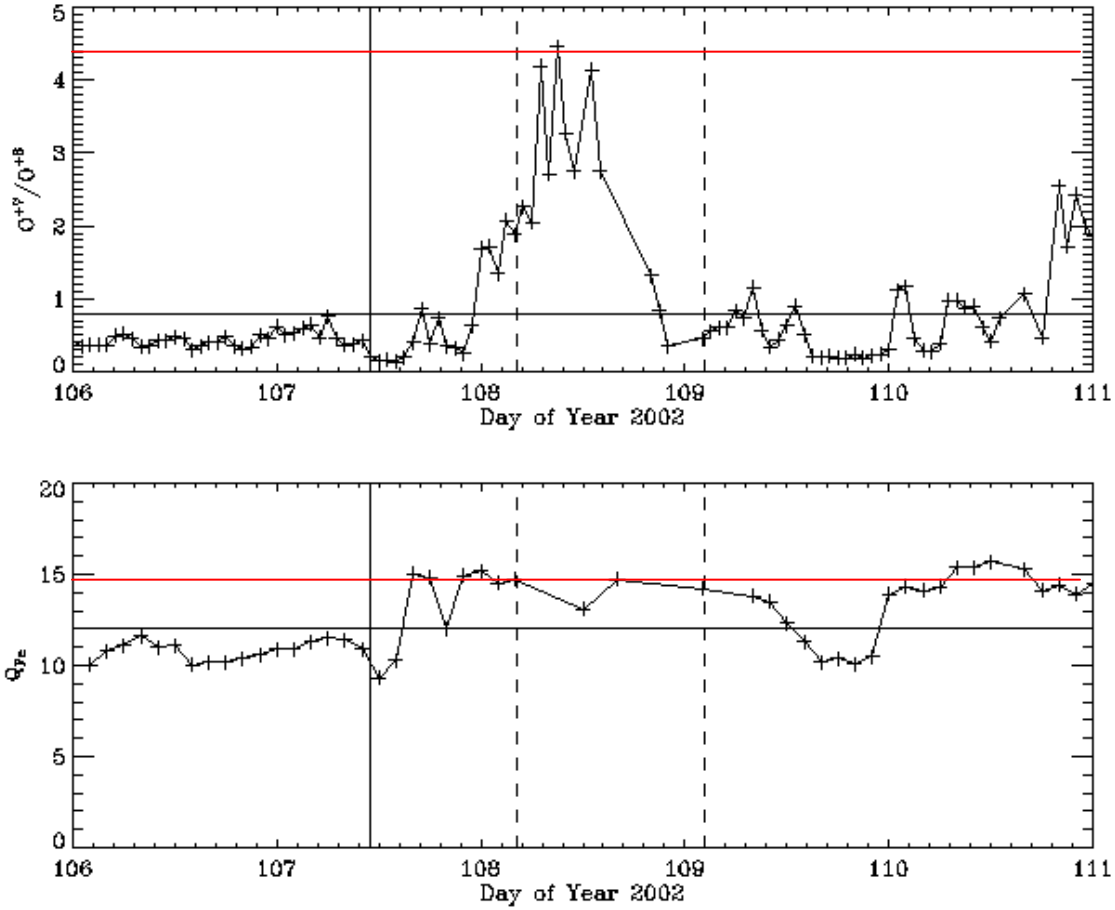
35 EJ


2.0
1.5
1.0
0.5
0.0
283
284
285
286
287
Day of Year 2001
15
10
5
0
283
284
285
286
287
Day of Year 2001

36


2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
76
77
78
79
80
81
Day of Year 2002
15
10
5
0
Q_{9e}
76
77
78
79
80
81
Day of Year 2002

37



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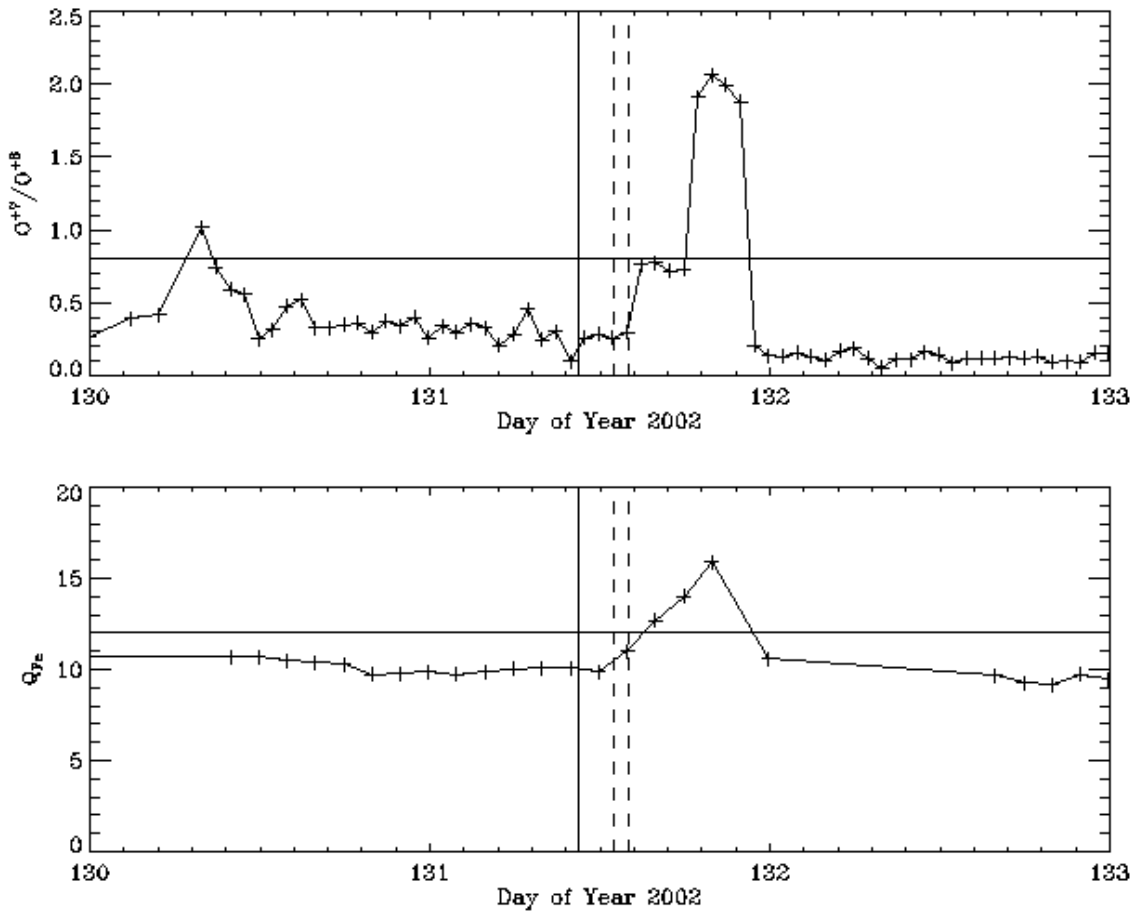
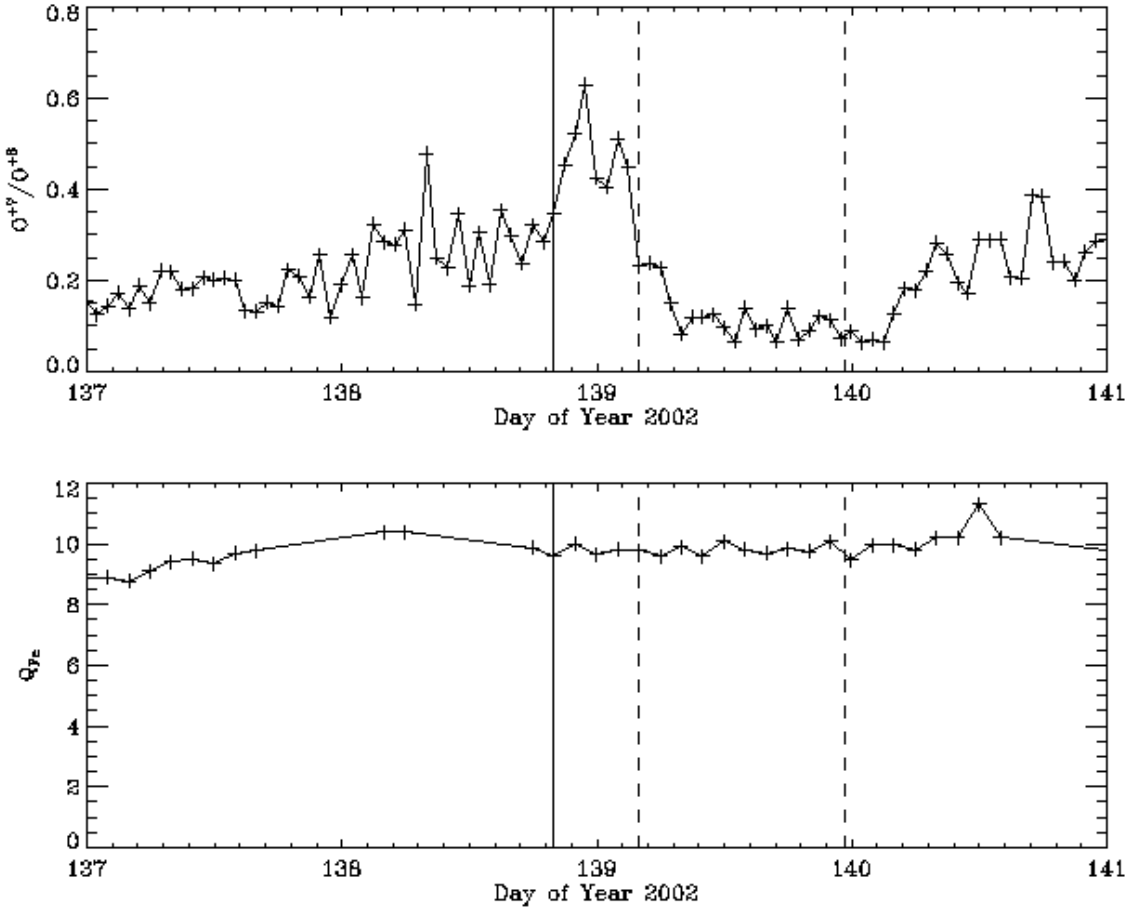
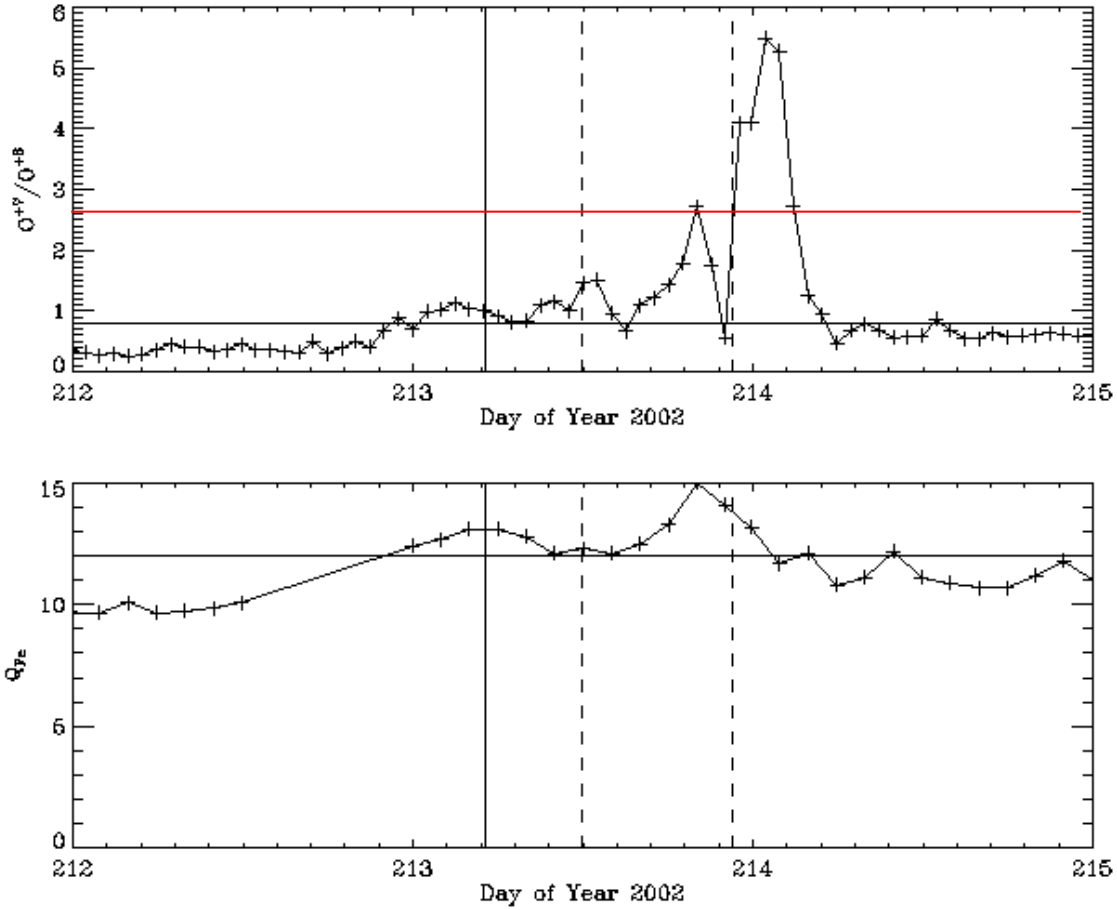
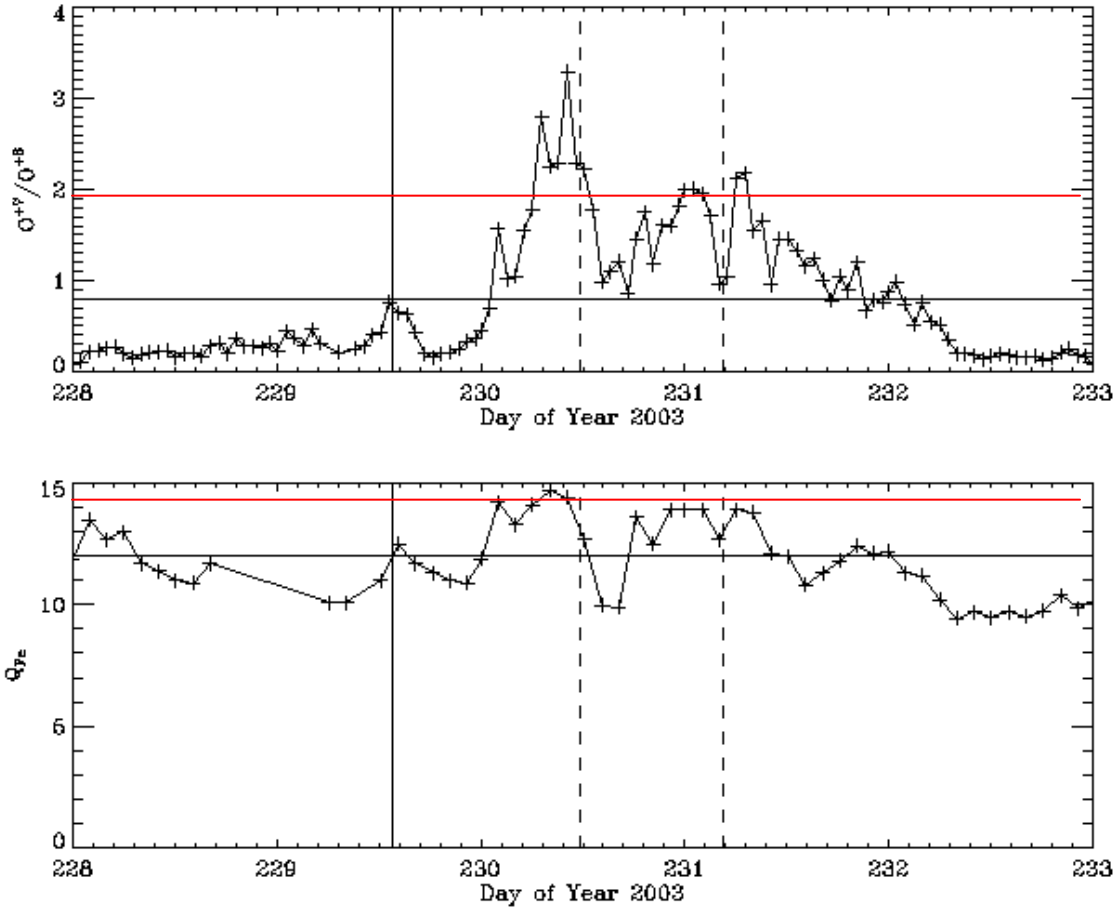

2.5
2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
130
131
132
133
Day of Year 2002
20
15
10
5
0
q_{9e}
130
131
132
133
Day of Year 2002

39 MC

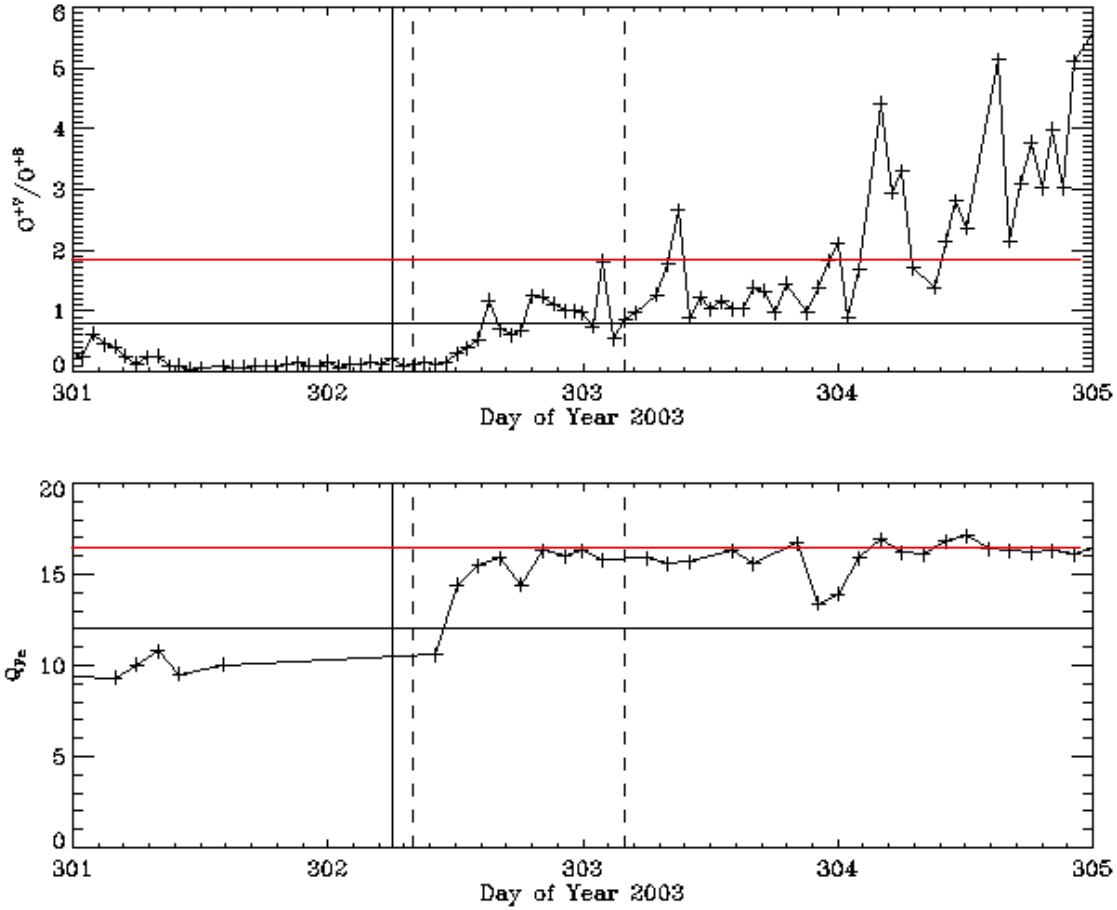

0.8
0.6
0.4
0.2
0.0
O^{+6}/O^{+8}
137
138
139
140
141
Day of Year 2002
12
10
8
6
4
2
0
Q_{fe}
137
138
139
140
141
Day of Year 2002

43

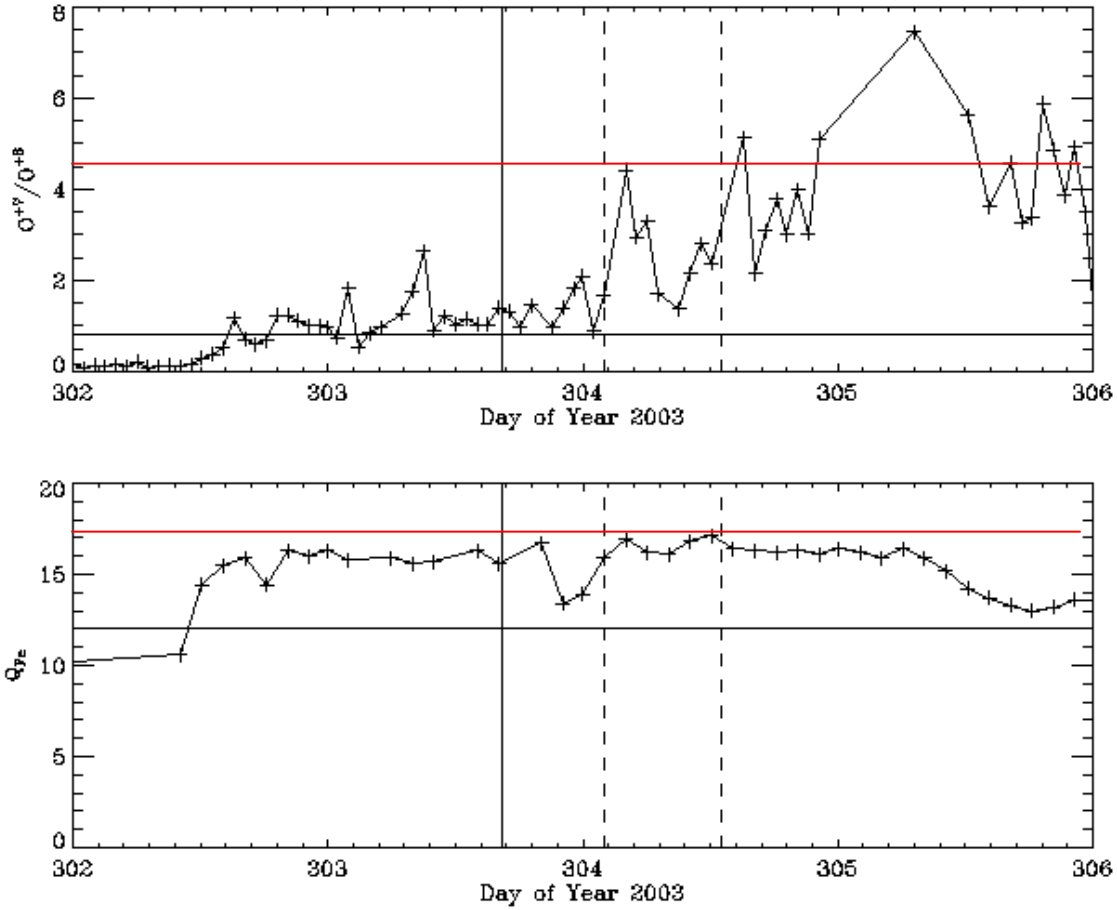

O^{+9}/O^{+8}
0
1
2
3
4
5
6
212
213
214
215
Day of Year 2002
Q_{Fe}
0
5
10
15
212
213
214
215
Day of Year 2002


O^{+9}/O^{+8}
Day of Year 2003
Q_{fe}
Day of Year 2003

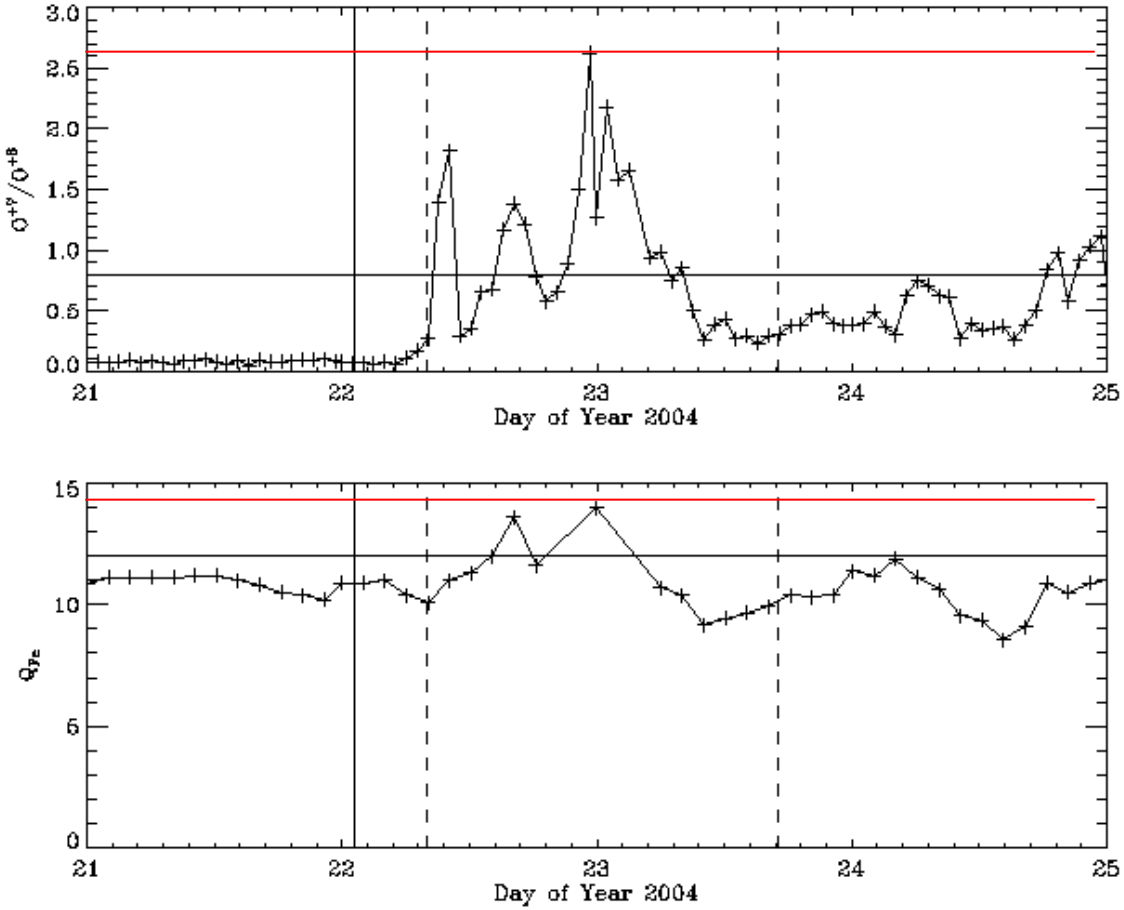
45



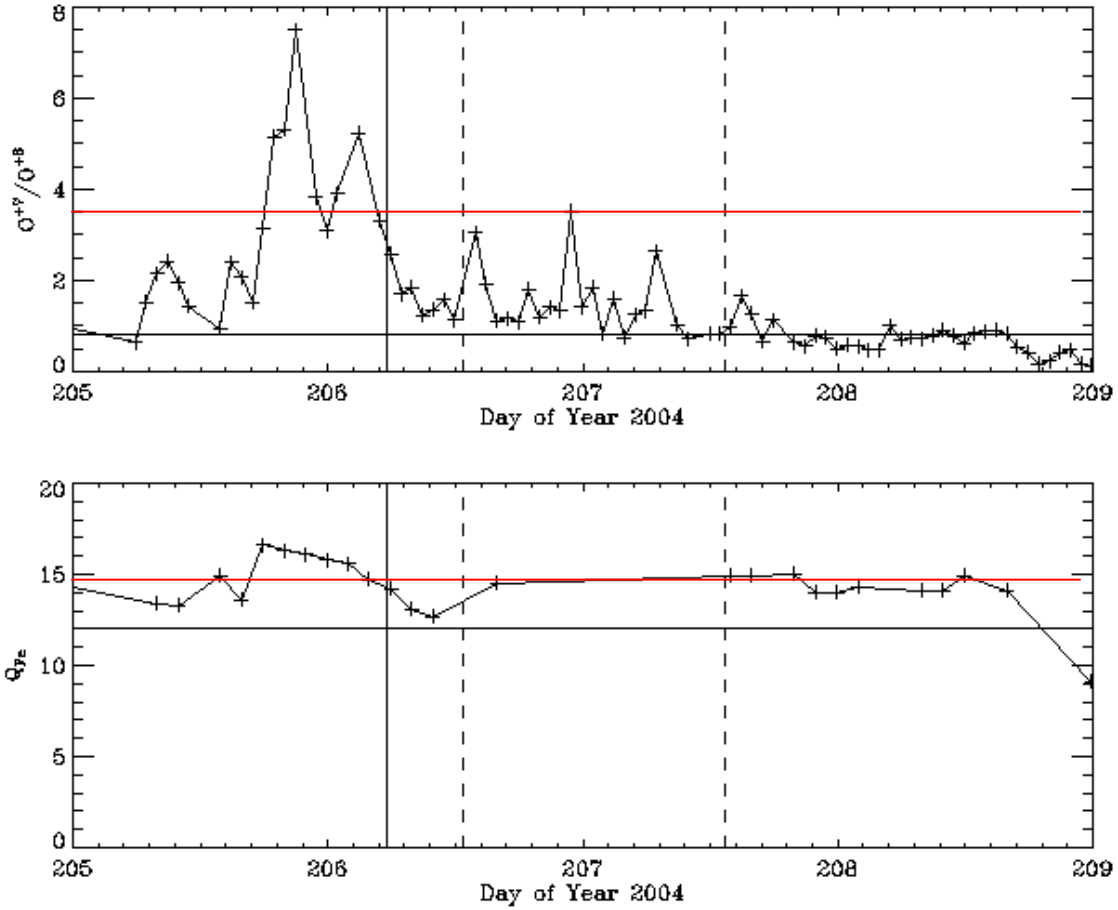
46


8
6
4
2
0
O^{+9}/O^{+8}
302
303
304
305
306
Day of Year 2003
20
15
10
5
0
Q_{Fe}
302
303
304
305
306
Day of Year 2003

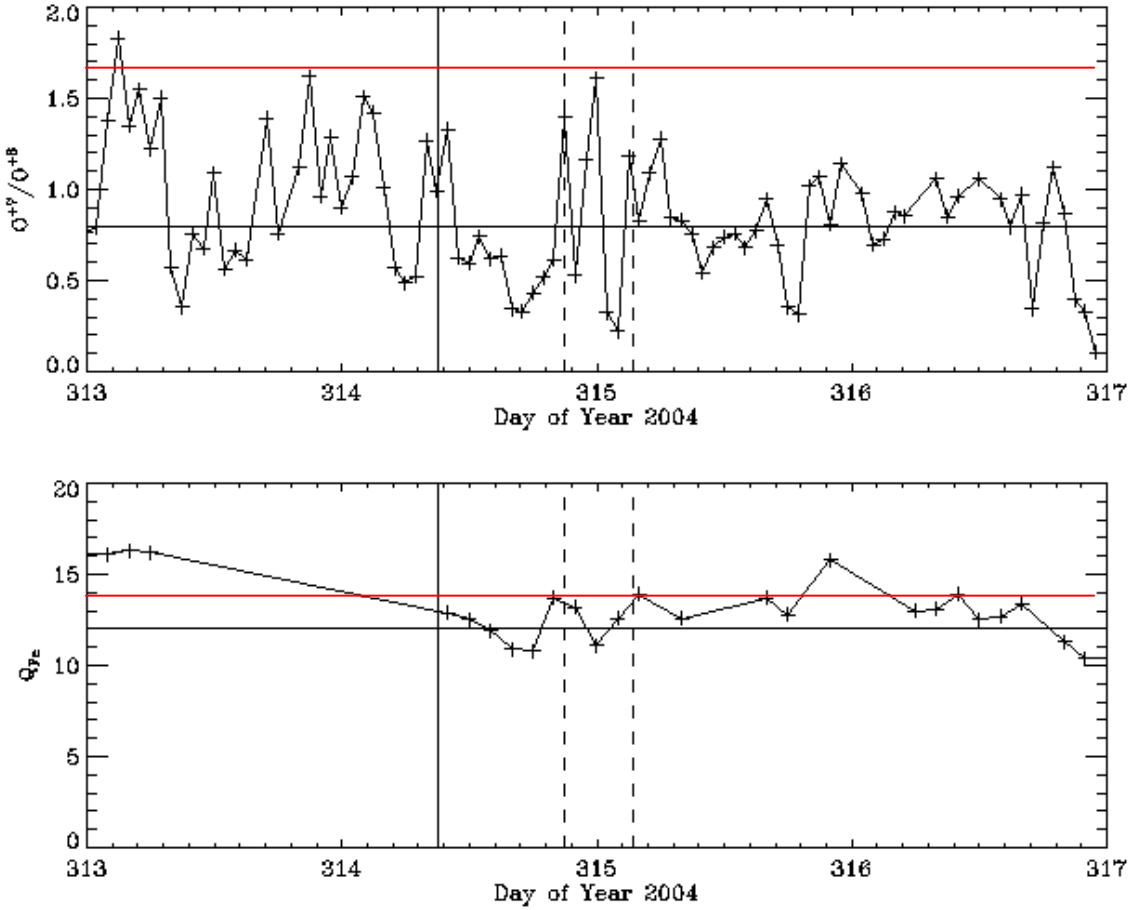
47


3.0
2.5
2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
21
22
23
24
25
Day of Year 2004
15
10
5
0
Q_{Fe}
21
22
23
24
25
Day of Year 2004

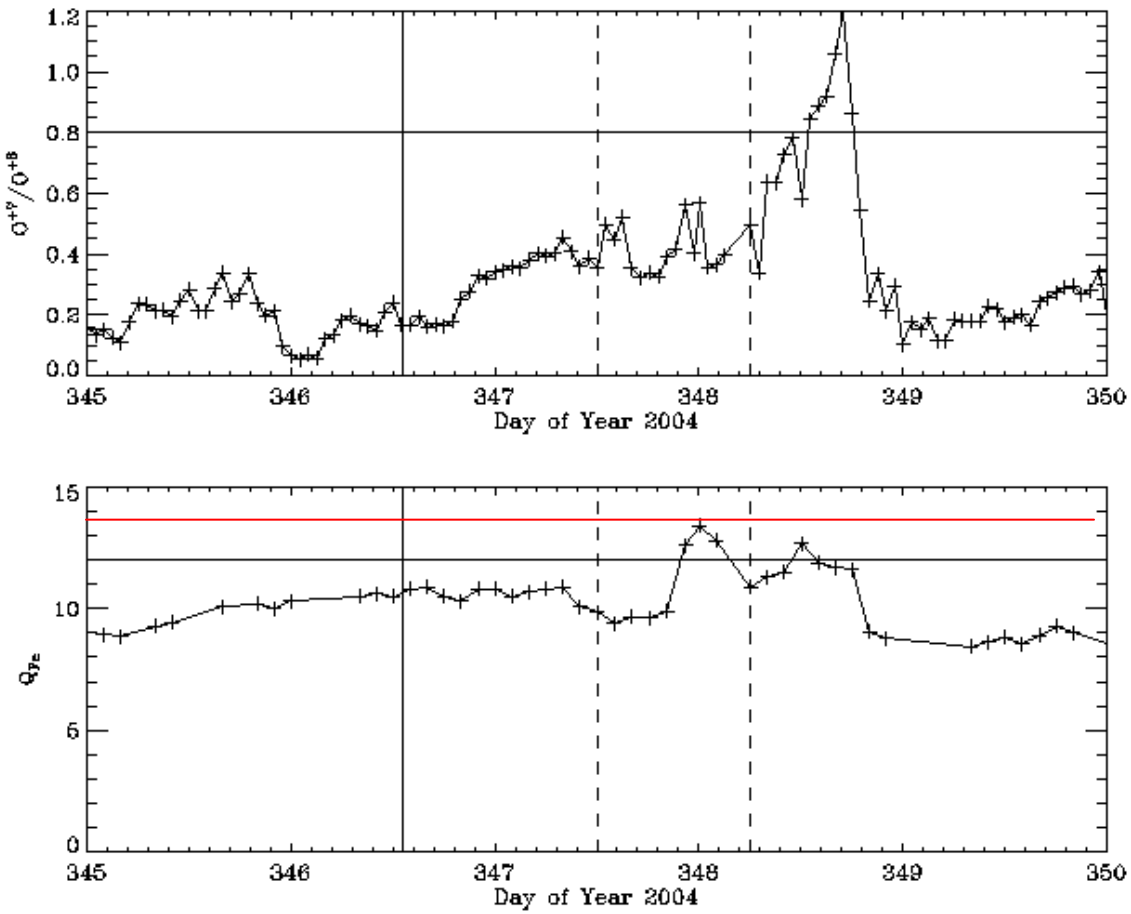
48 MC



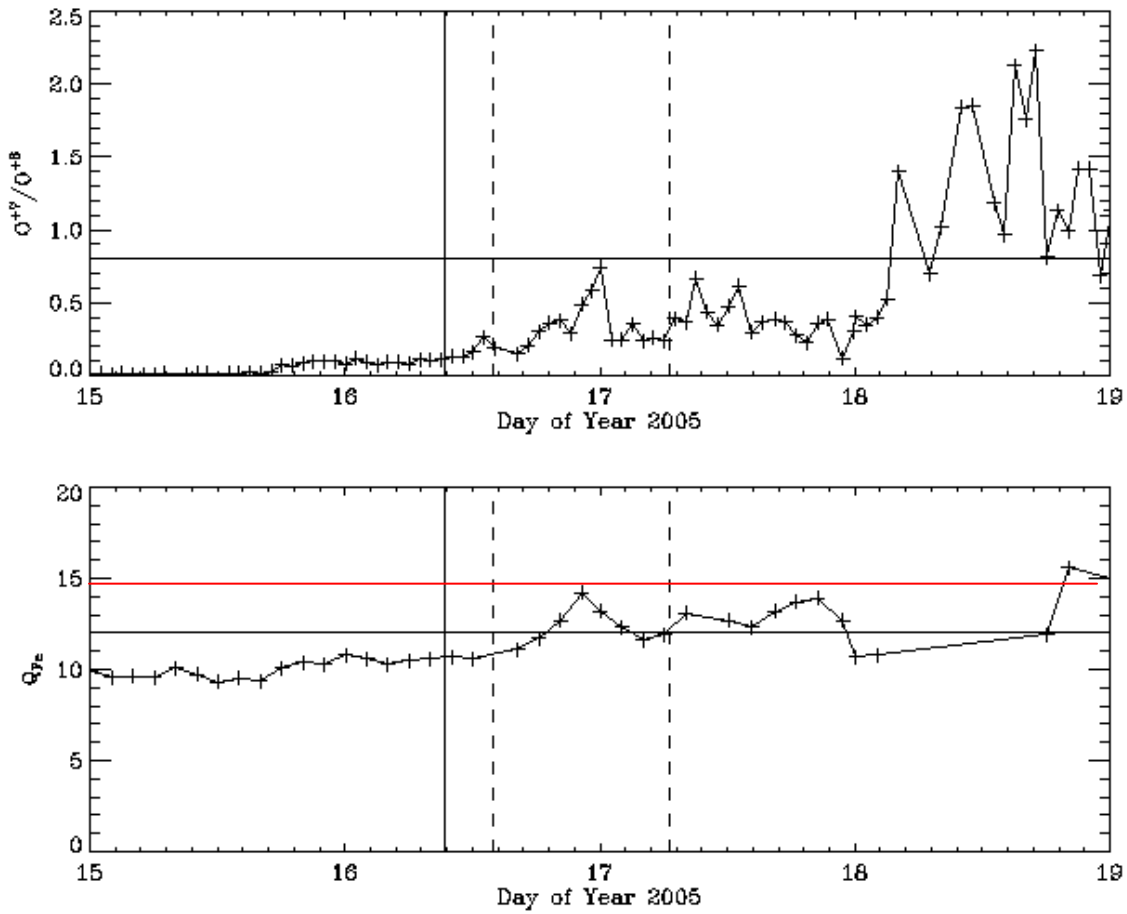
49 MC


2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
313
314
315
316
317
Day of Year 2004
20
15
10
5
0
Q_{Fe}
313
314
315
316
317
Day of Year 2004

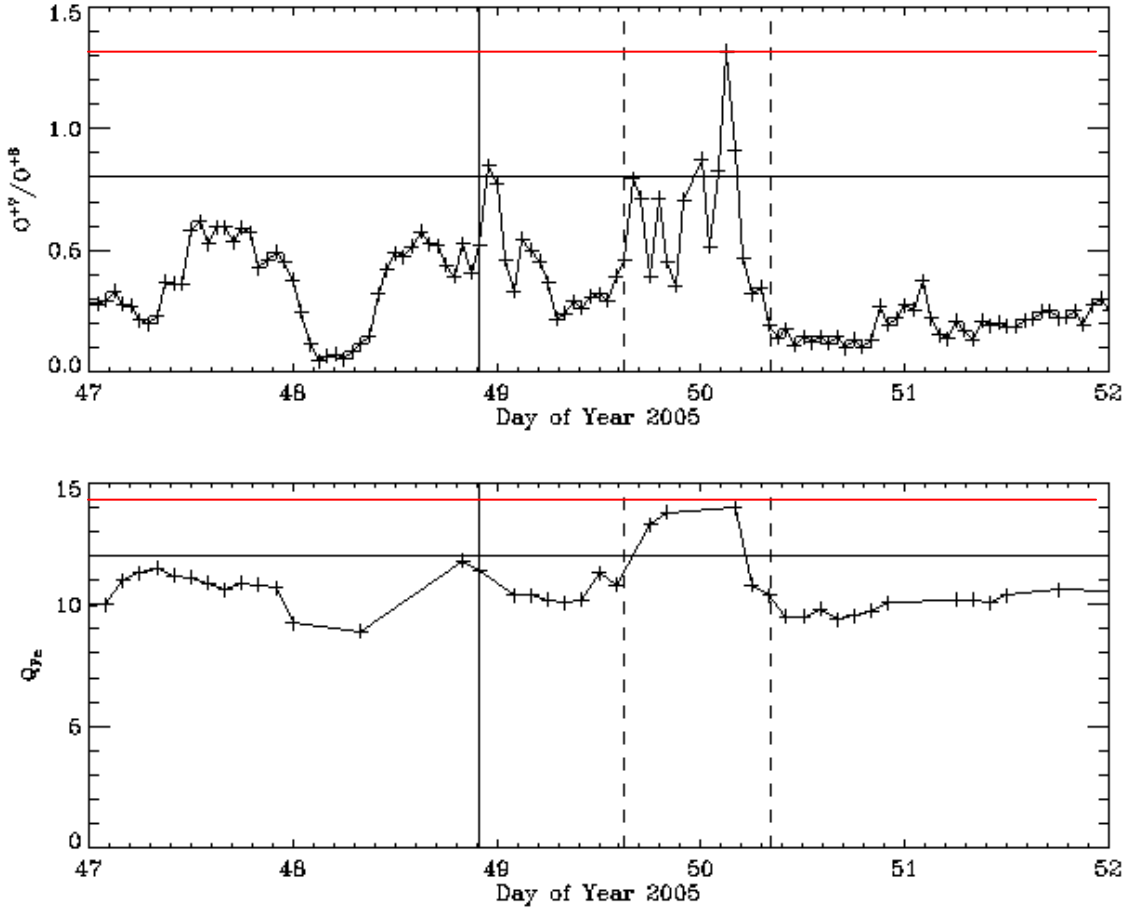
50 EJ


1.2
1.0
0.8
0.6
0.4
0.2
0.0
O^{+6}/O^{+5}
345
346
347
348
349
350
Day of Year 2004
15
10
5
0
Q_{fe}
345
346
347
348
349
350
Day of Year 2004

51 E


2.5
2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
15
16
17
18
19
Day of Year 2005
20
15
10
5
0
Q_{9e}
15
16
17
18
19
Day of Year 2005

52 EJ


1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
47
48
49
50
51
52
Day of Year 2005
15
10
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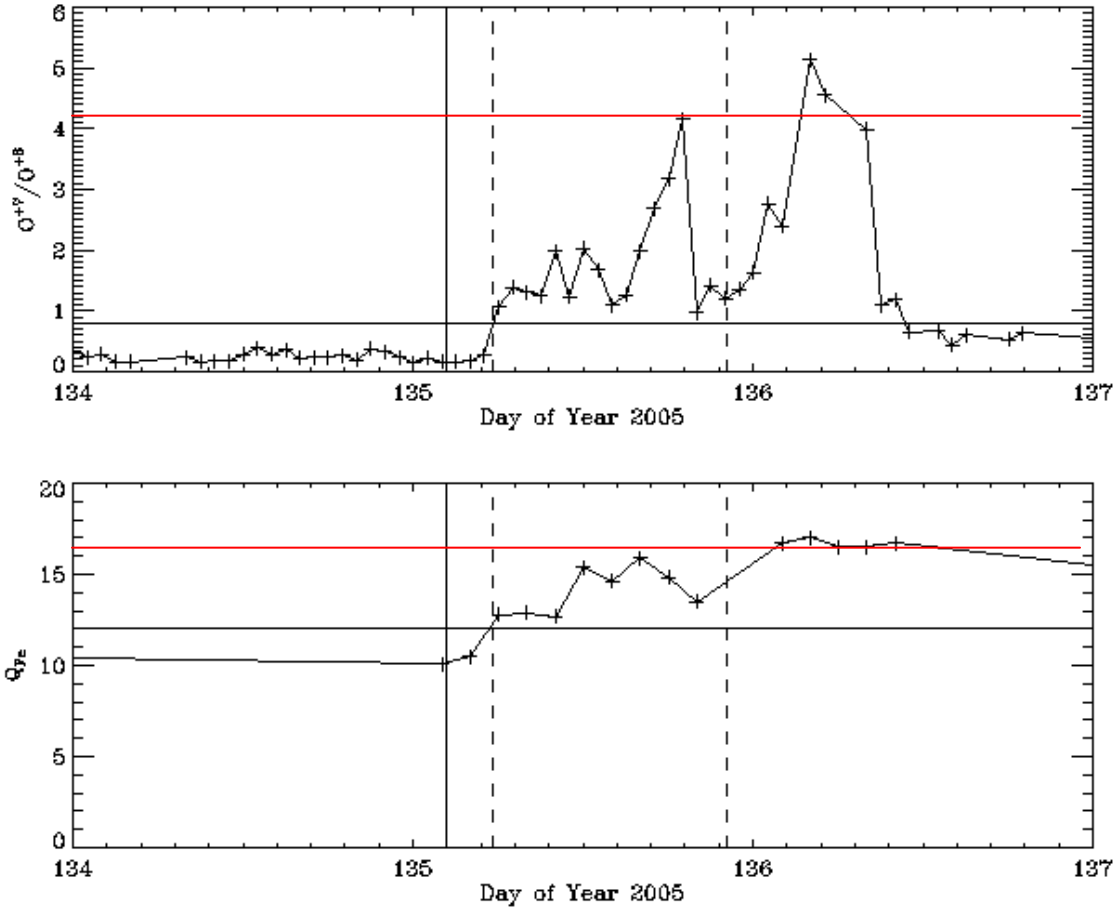
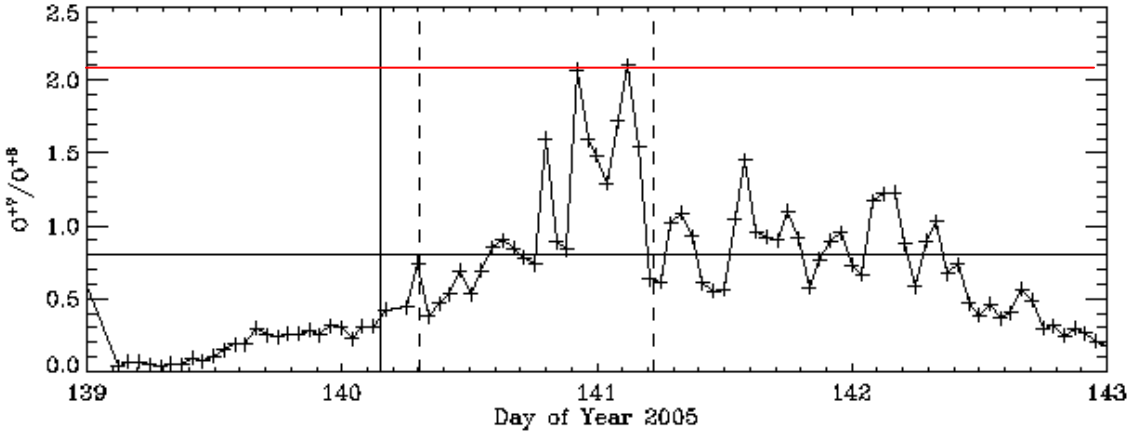
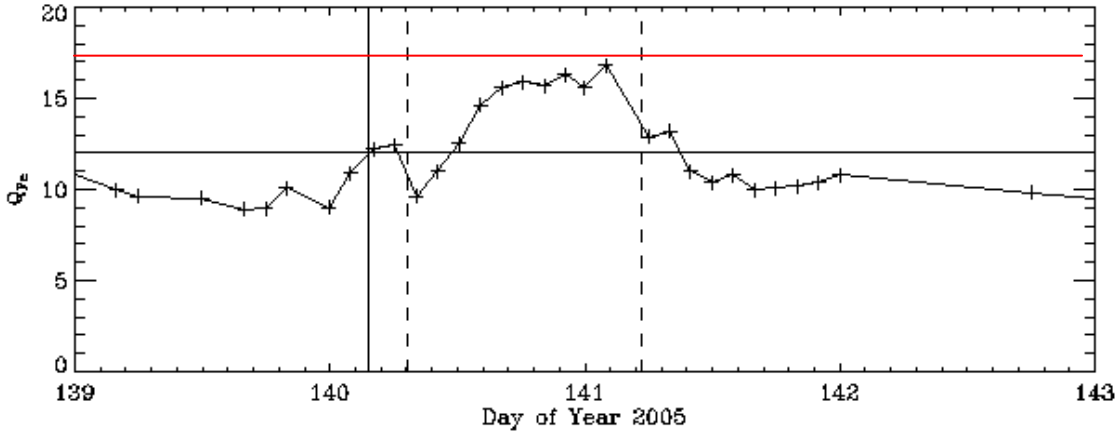
0
Q_{fe}
47
48
49
50
51
52
Day of Year 2005

53 MC

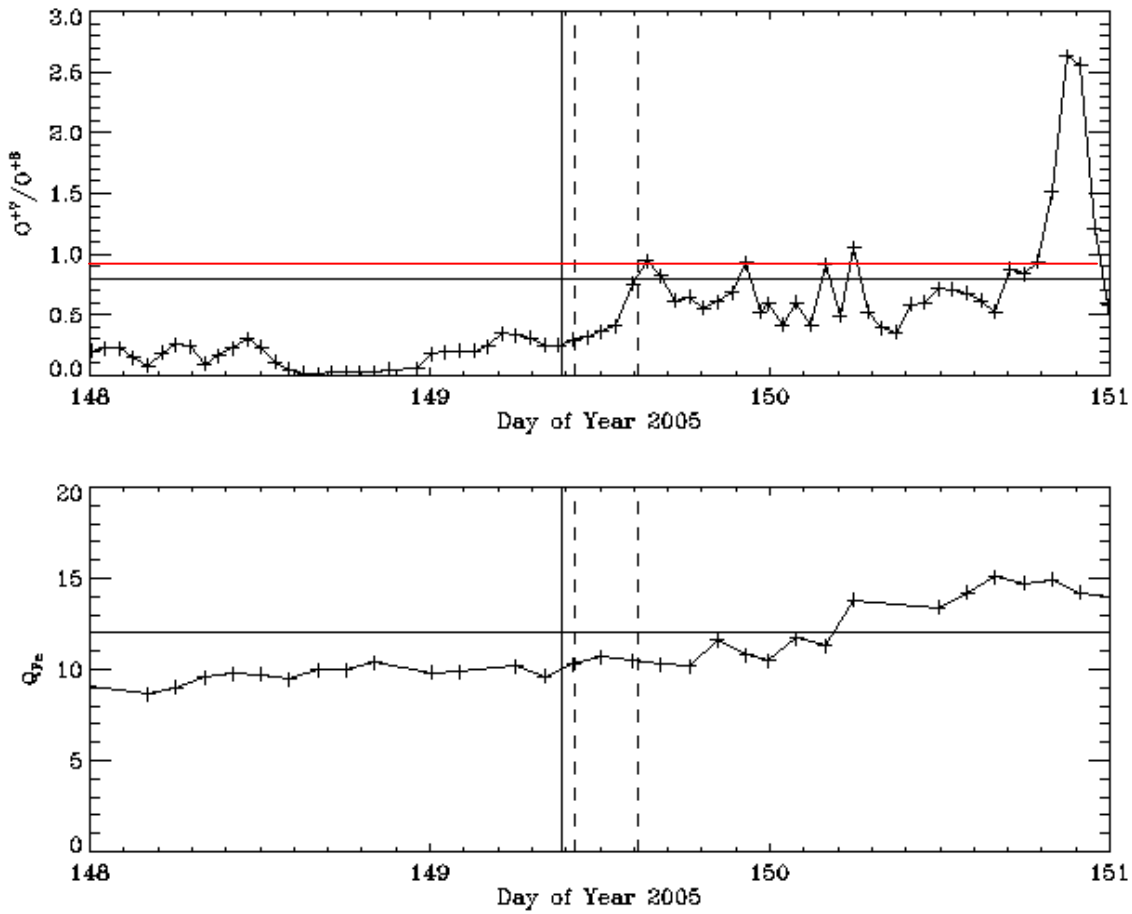


54 MC

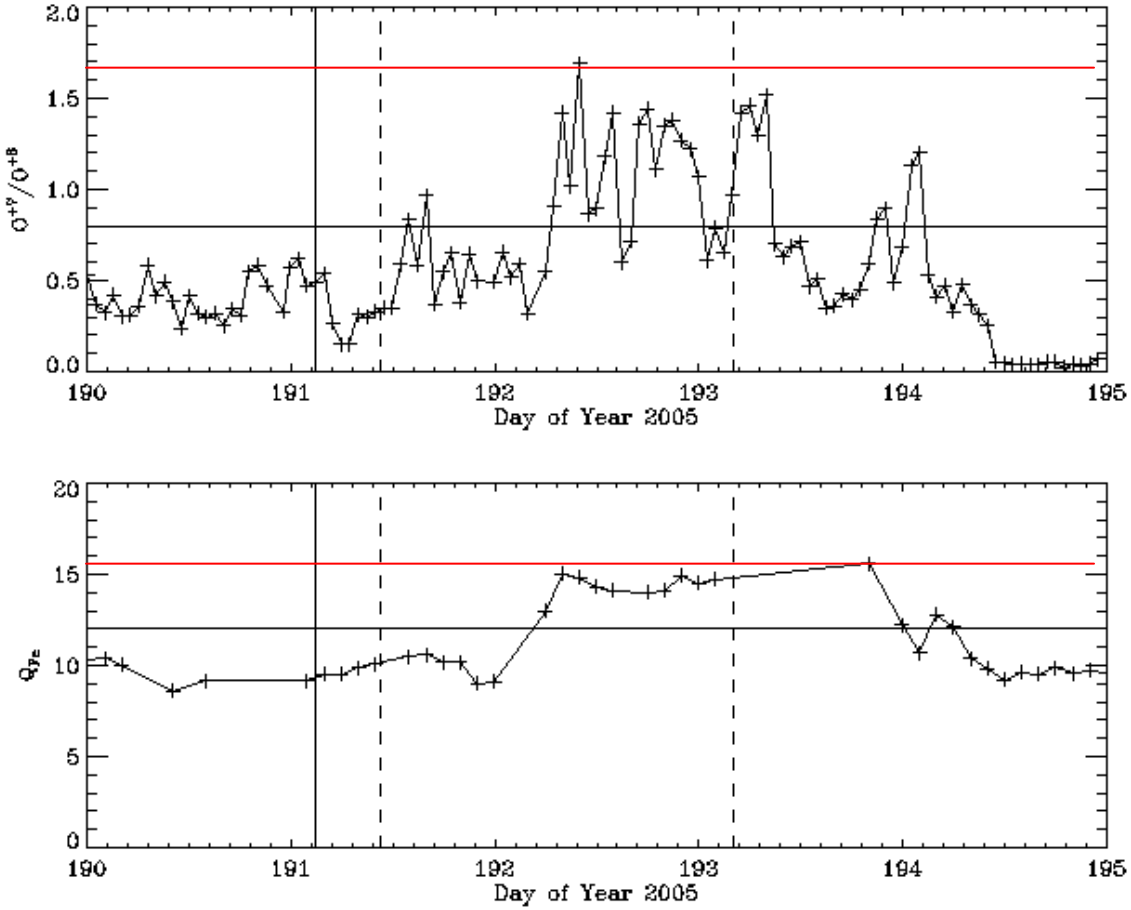

2.5
2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
139
140
141
142
143
Day of Year 2005


20
15
10
5
0
Q_{fe}
139
140
141
142
143
Day of Year 2005

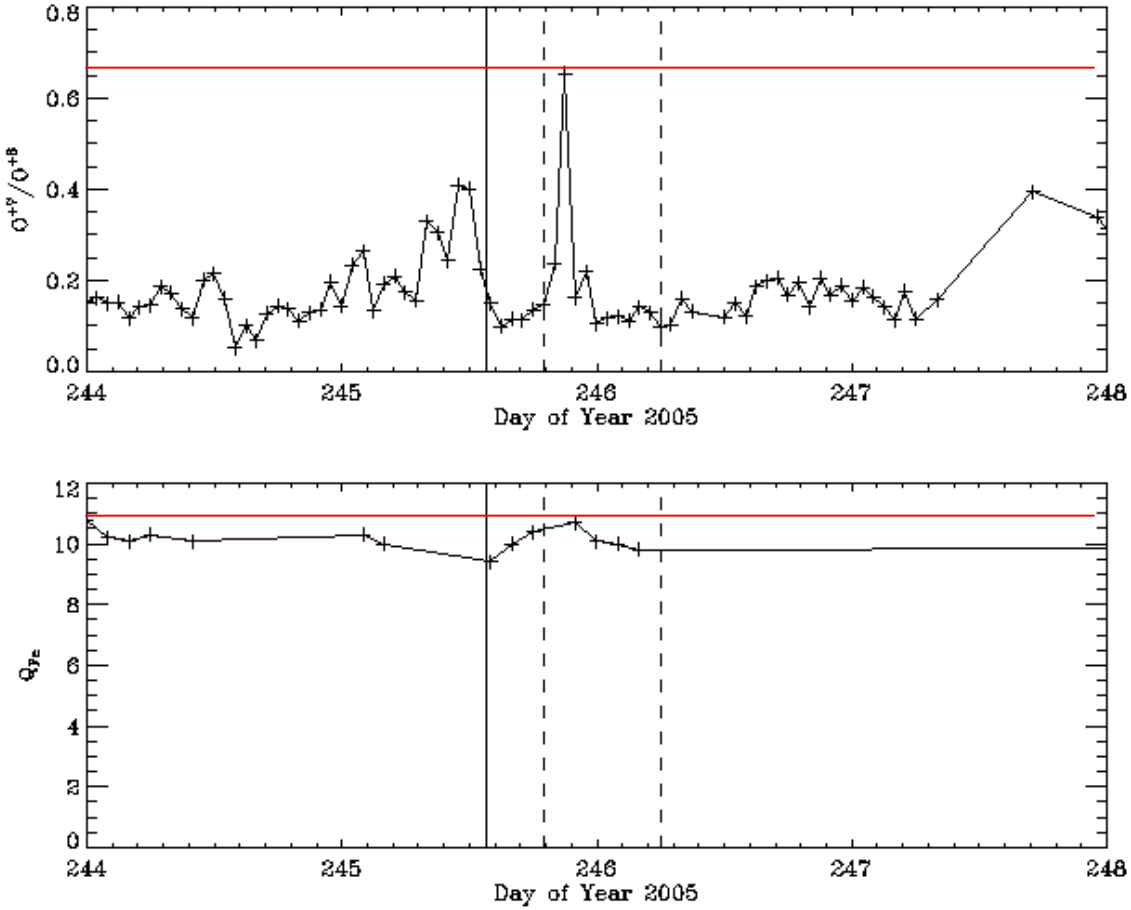
55 EJ


3.0
2.5
2.0
1.5
1.0
0.5
0.0
148
149
150
151
Day of Year 2005
20
15
10
5
0
148
149
150
151
Day of Year 2005

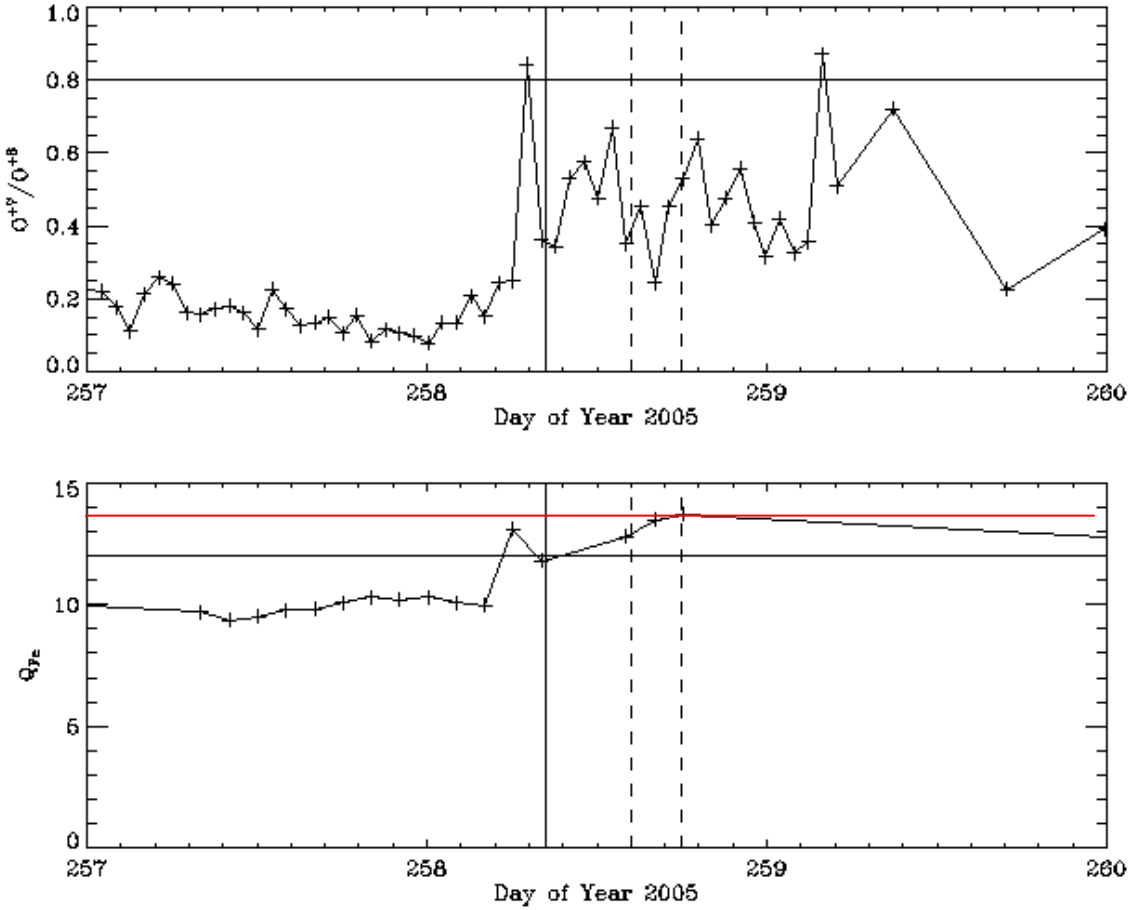
56 EJ


2.0
1.5
1.0
0.5
0.0
O^{+9}/O^{+8}
190
191
192
193
194
195
Day of Year 2005
20
15
10
5
0
Q_{fe}
190
191
192
193
194
195
Day of Year 2005

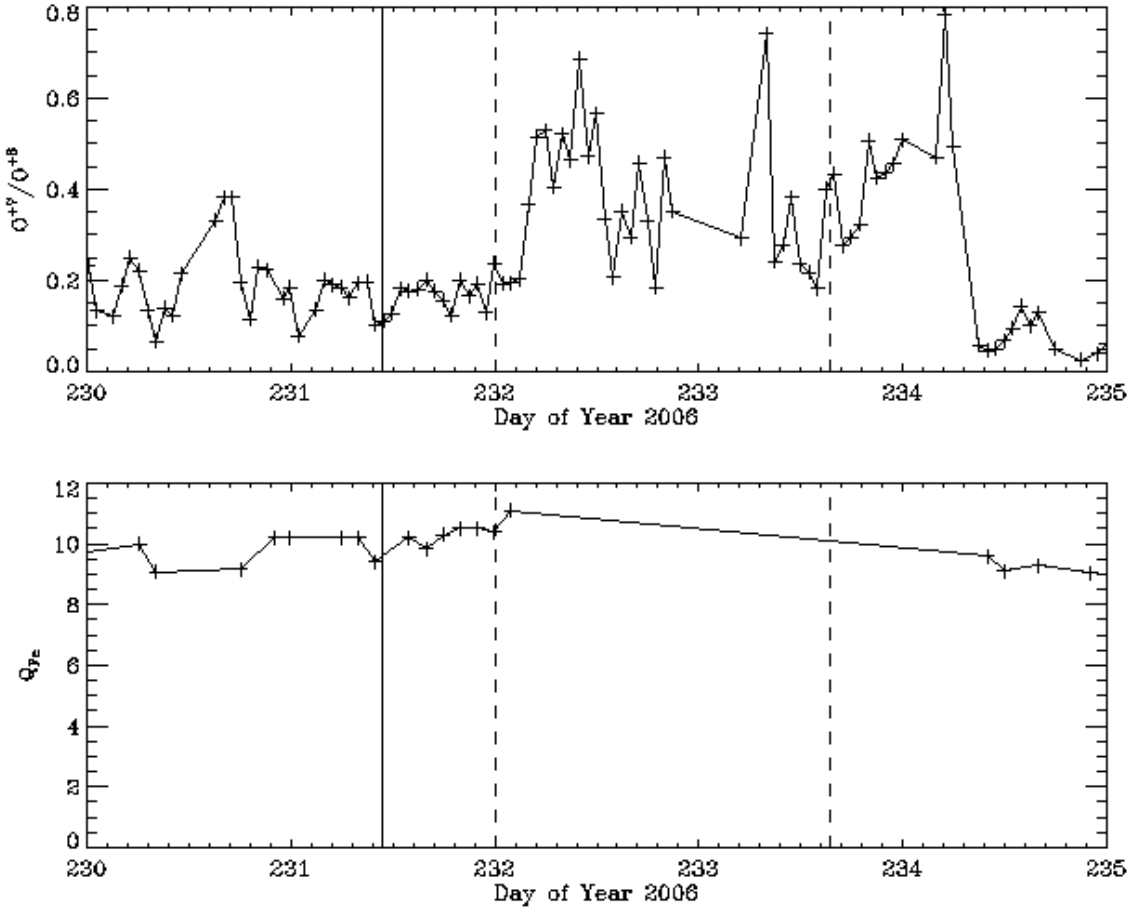
57 EJ


0.8
0.6
0.4
0.2
0.0
O^{+9}/O^{+8}
244
245
246
247
248
Day of Year 2005
12
10
8
6
4
2
0
Q_{fe}
244
245
246
247
248
Day of Year 2005

58 EJ


1.0
0.8
0.6
0.4
0.2
0.0
257
258
259
260
Day of Year 2005
15
10
5
0
257
258
259
260
Day of Year 2005

59 EJ


0.8
0.6
0.4
0.2
0.0
O^{+9}/O^{+8}
230
231
232
233
234
235
Day of Year 2006
12
10
8
6
4
2
0
Q_{Fe}
230
231
232
233
234
235
Day of Year 2006

Charge State Plots

- O7/O6 and QFe are shown with a time resolution of 1 hour. The '+' marks indicate data values, which are connected by solid lines. The solid vertical line indicates the shock, and the dashed vertical lines indicate the start and end of the ICME. The solid horizontal lines indicate threshold levels of 0.8 for oxygen and 12 for QFe, which indicate enhanced levels often found within ICMEs.