Kinematics Analysis of Coronal Mass Ejection-Driven Compression Waves Using EUV Observations

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Outline

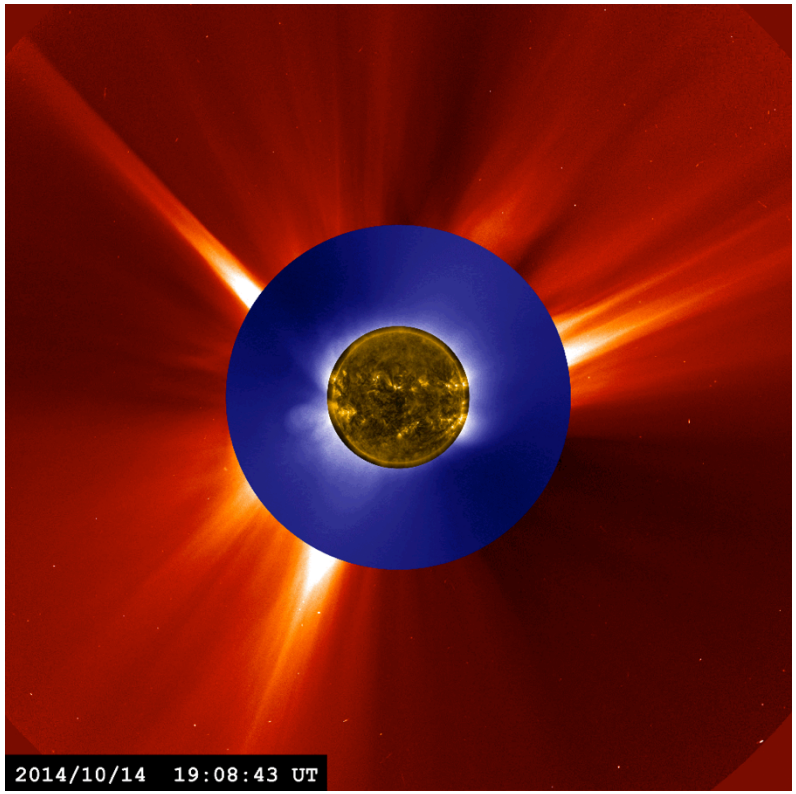
- Introduction to Coronal Mass Ejections and Coronal Bright Fronts
- Discussion of new events
- Explanation of processing of events
  - Base difference images
  - Annulus plots
- Manual collection of data
- Kinematics derived from data
  - Base difference images
  - Kinematics averages

Goal

- To process data from different CME events
- To use manual measures to collect kinematics data from those different events
- To present the statistical summary of our findings
- To create an automatic system that will, in the future, complete these goals for us

Coronal Mass Ejections

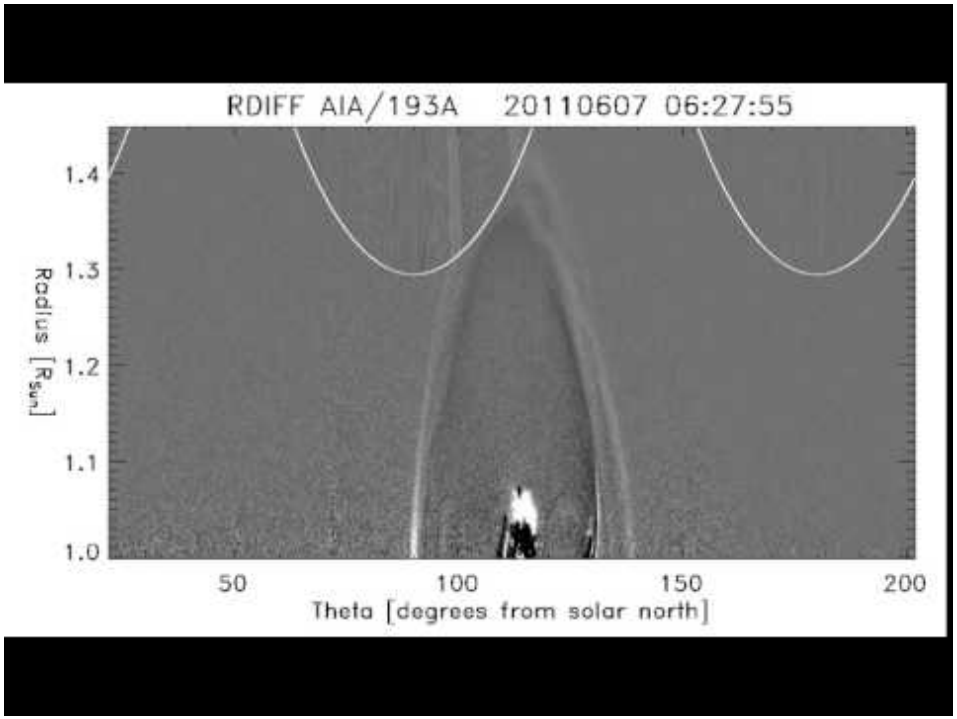
- Solar eruptions of material
- Cause: Magnetic Reconnection
- May originate from an active region on the sun
- The most useful CME events to us are on the limb of the sun
- Releases broadband radiation and energetic particles



2014/10/14 Event, from HAO, https://www2.hao.ucar.edu/mlso/mlso-gallery

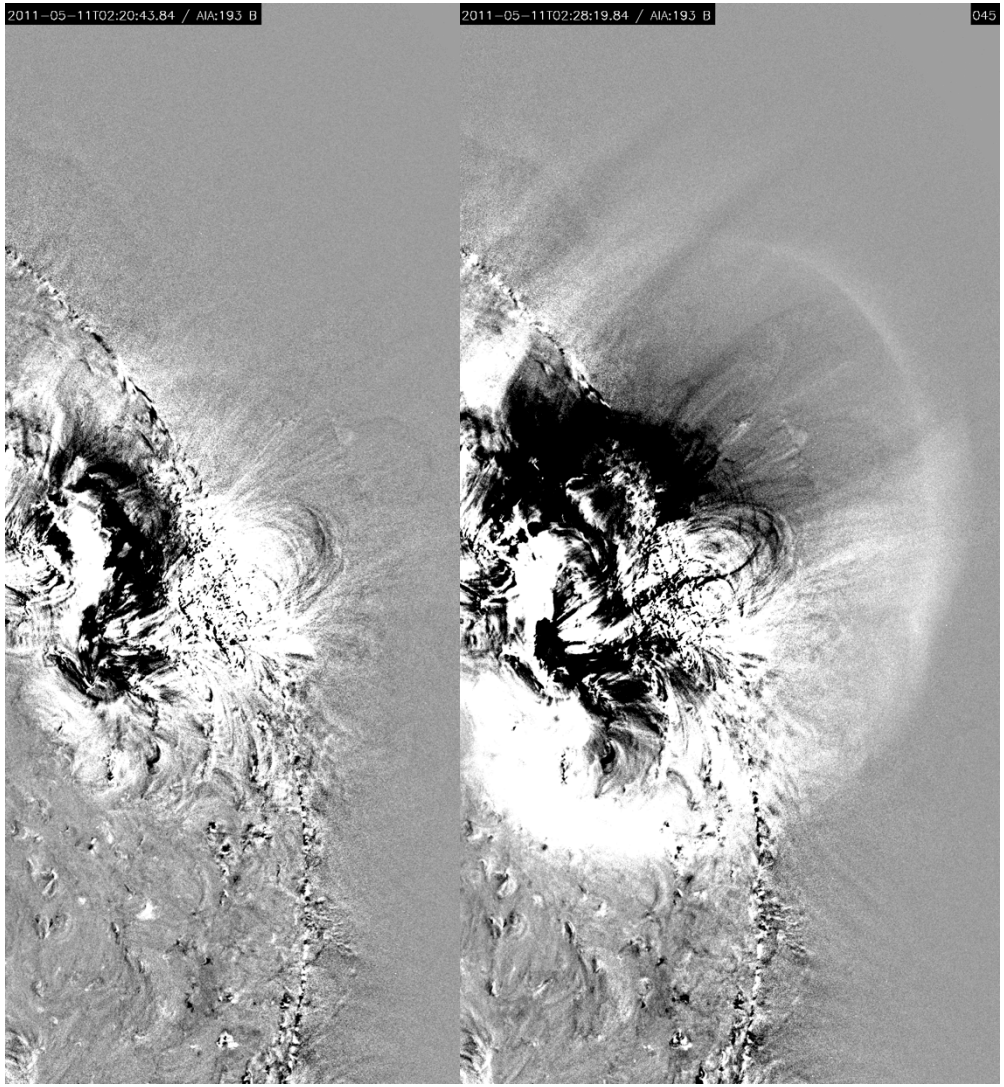
Compression Fronts

- When enhanced, compression fronts become visible ahead of the material in CME's
- We study these fronts to enable modeling the acceleration of particles in the corona
- SDO/AIA Data
- More events must be collected



Search for New Events

- Some events already had been identified
- Further events from 2013-present were searched
  - An additional 25 events were identified
- Important features
  - Limb of the sun
  - Large eruption



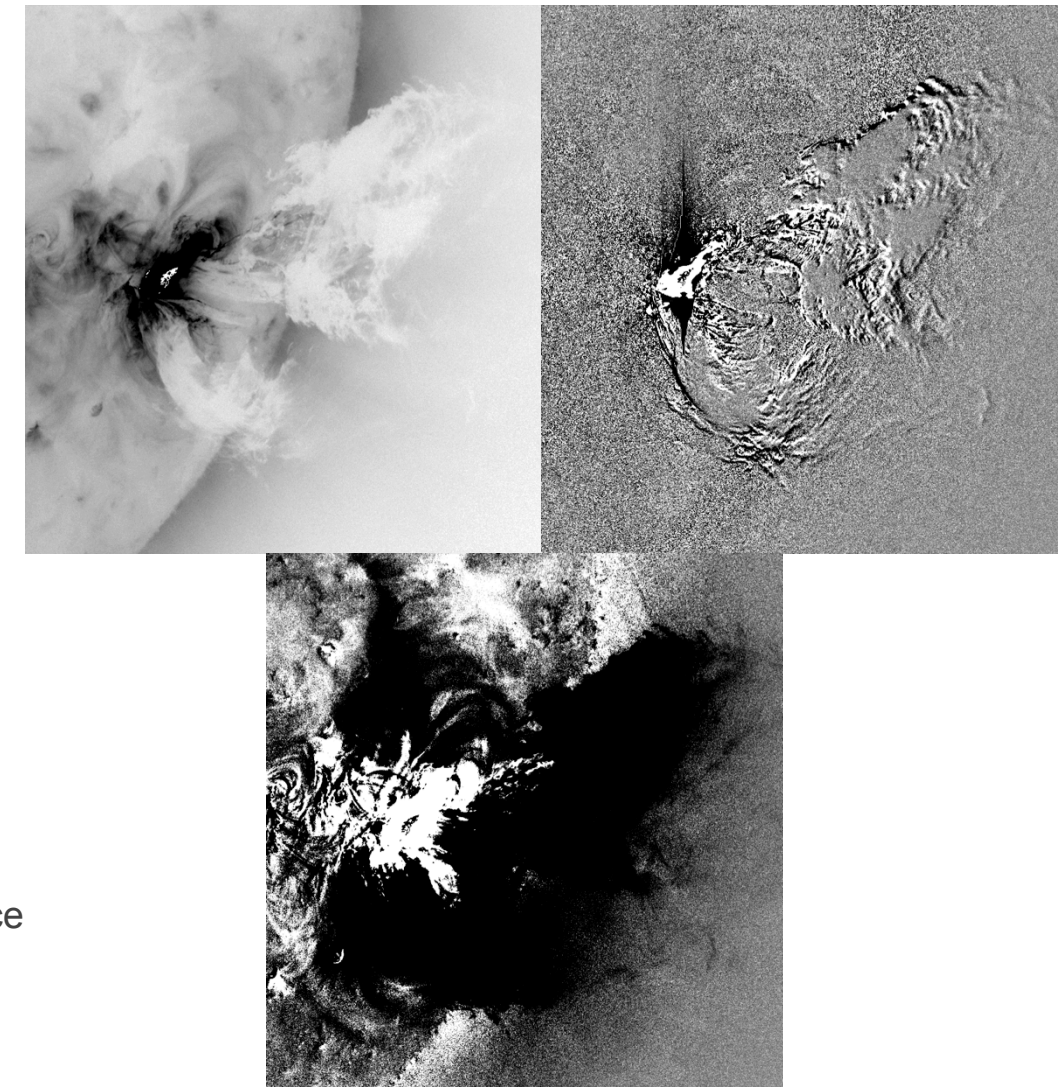
Search for New Events (cont.)

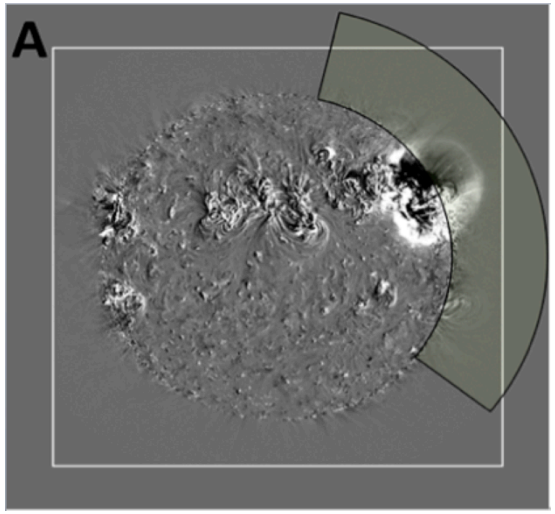
- 120 total event candidates
  - Over previously identified and new
- Narrowed down to ~30 of the best candidates
- Used CorWav code to process events and prepare them for study

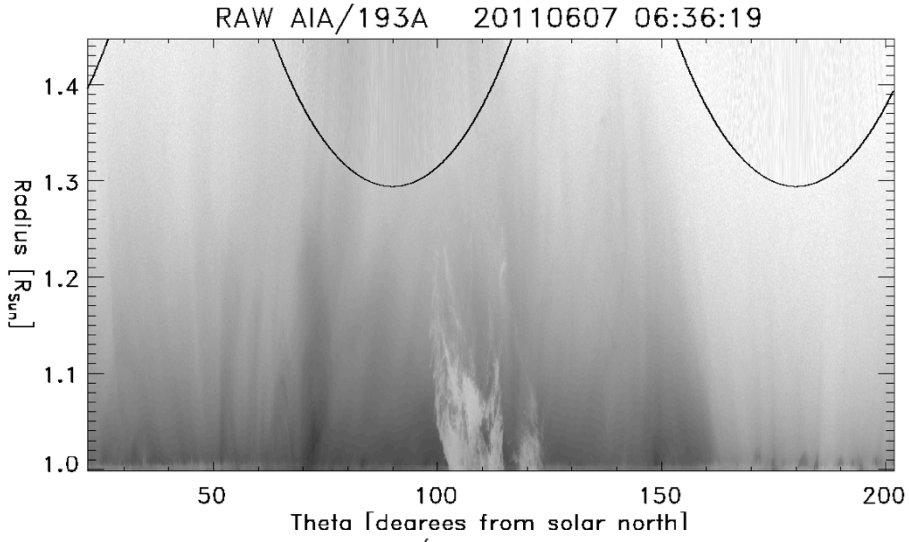
Date	Start Time	End Time
20131212	2013/12/12 03:03:00	2013/12/12 03:33:00
20110607	2011/06/07 06:15:00	2011/06/07 06:40:00
20130423	2013/04/23 18:05:00	2013/04/23 18:35:00
20120424	2012/04/24 07:39:00	2012/04/24 07:55:00
20140708	2014/07/08 16:08:00	2014/07/08 16:28:00
20110211	2011/02/11 12:30:00	2011/02/11 13:00:00
20130501	2013/05/01 02:28:00	2013/05/01 02:45:00
20120915	2012/09/15 22:50:00	2012/09/15 23:20:00
20120915	2012/09/15 22:50:00	2012/09/15 23:20:00
20120526	2012/05/26 20:30:00	2012/05/26 20:58:00
20110327	2011/03/27 05:02:00	2011/03/27 05:27:00
20110125	2011/01/25 11:56:00	2011/01/25 12:26:00
20100613	2010/06/13 05:34:00	2010/06/13 05:49:00
20140217	2014/02/17 04:48:00	2014/02/17 05:05:00
20131207	2013/12/07 07:17:00	2013/12/07 07:36:00
20131107	2013/11/07 10:14:00	2013/11/07 10:25:00
20130517	2013/05/17 08:41:00	2013/05/17 09:09:00
20121007	2012/10/07 20:15:00	2012/10/07 20:45:00
20120728	2012/07/28 20:43:00	2012/07/28 20:59:00
20120307	2012/03/07 00:05:00	2012/03/07 00:35:00
20110904	2011/09/04 04:34:00	2011/09/04 04:54:00
20110515	2011/05/15 23:27:00	2011/05/15 23:47:00
20101231	2010/12/31 04:20:00	2010/12/31 04:35:00
20101103	2010/11/03 12:09:00	2010/11/03 12:29:00
20151109	2015/11/09 12:51:05	2015/11/09 13:27:05
20150920	2015/09/20 17:33:29	2015/09/20 18:07:05
20150421	2015/04/21 10:01:11	2015/04/21 10:39:35
20150303	2015/03/03 01:25:59	2015/03/03 01:49:58
20141205	2014/12/05 05:42:47	2014/12/05 06:21:11
20141105	2014/11/05 19:05:35	2014/11/05 19:41:35
20140901	2014/09/01 21:33:11	2014/09/01 22:18:47

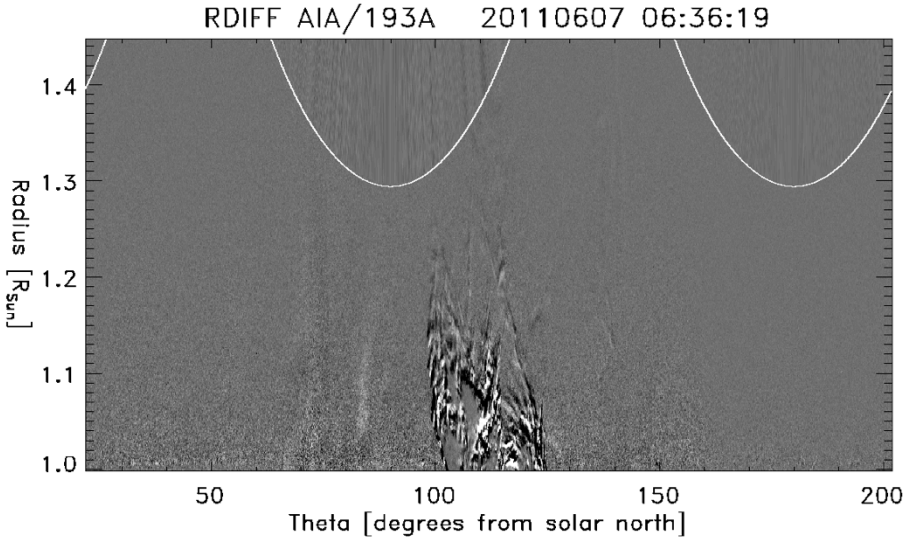
Processing of Events

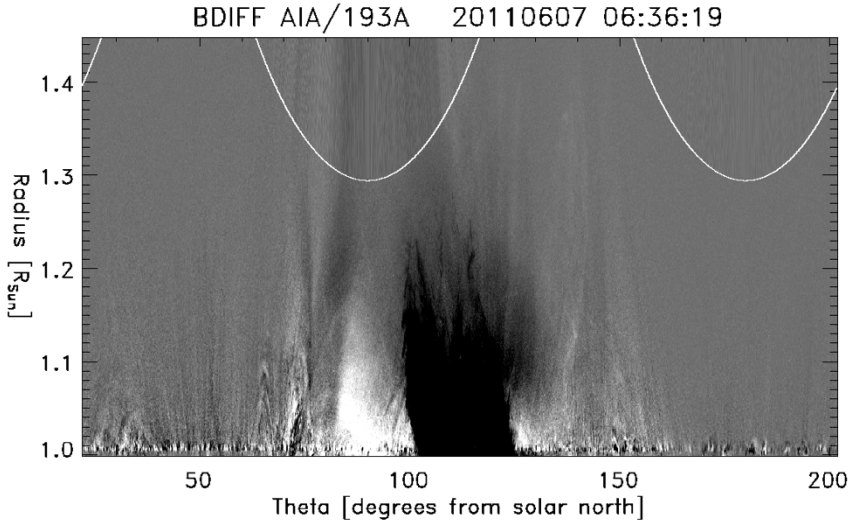
- CorWav code
- Creates images of each step of the event
  - Raw, Base, Run
- Convert images into annulus images
  - Flatten out the sun so radial distance from surface can be measured




A

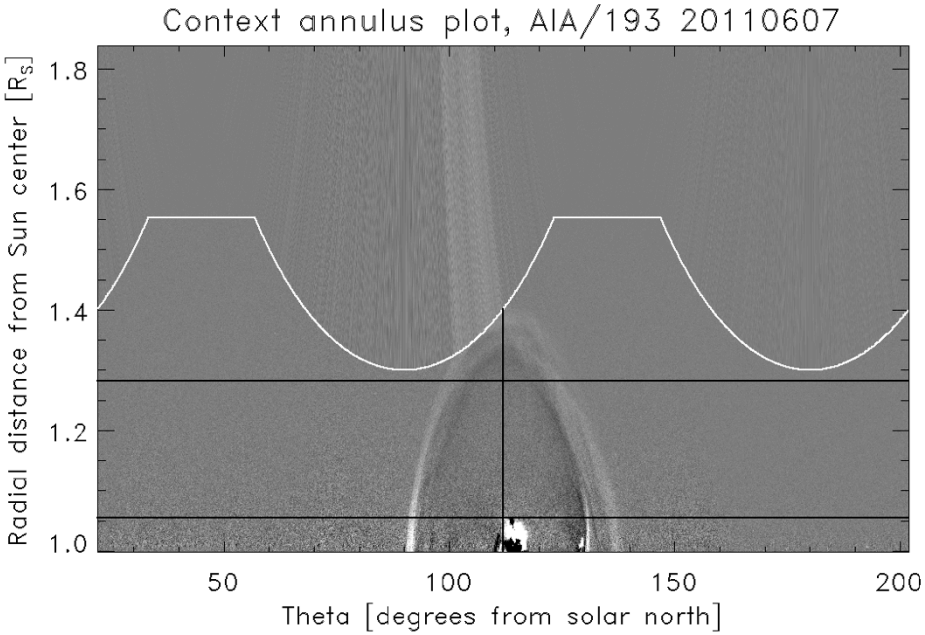

RAW AIA/193A 20110607 06:36:19
Radius [R$_{sun}$]
1.0
1.1
1.2
1.3
1.4
50
100
150
200
Theta [dearees from solar north]


RDIFF AIA/193A 20110607 06:36:19
Radius [R$_{sun}$]
1.0
1.1
1.2
1.3
1.4
50
100
150
200
Theta [degrees from solar north]


BDIFF AIA/193A 20110607 06:36:19
Radius [R$_{sun}$]
1.0
1.1
1.2
1.3
1.4
50
100
150
200
Theta [degrees from solar north]

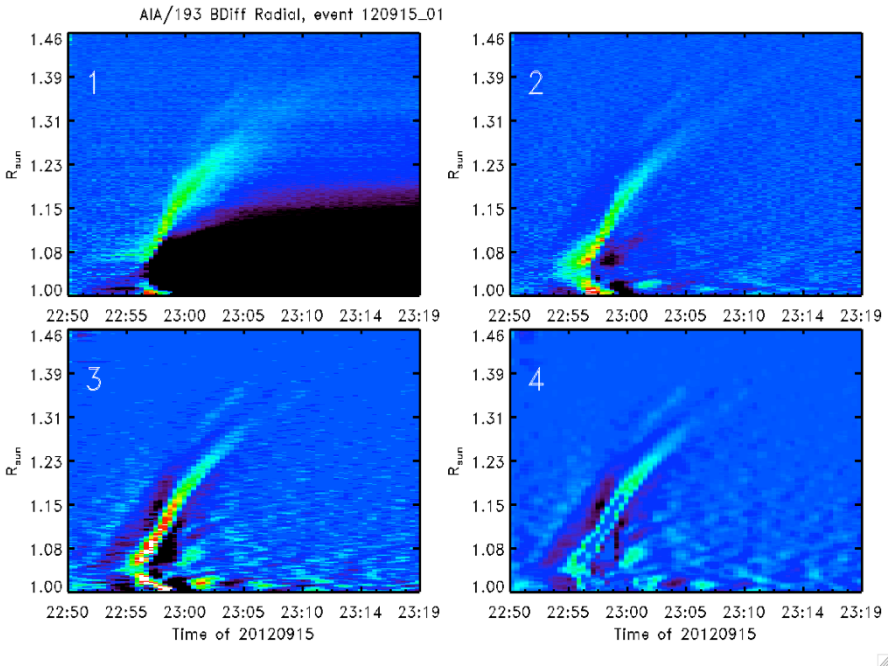
Processing of Events (cont.)

- Mainly use Base difference data



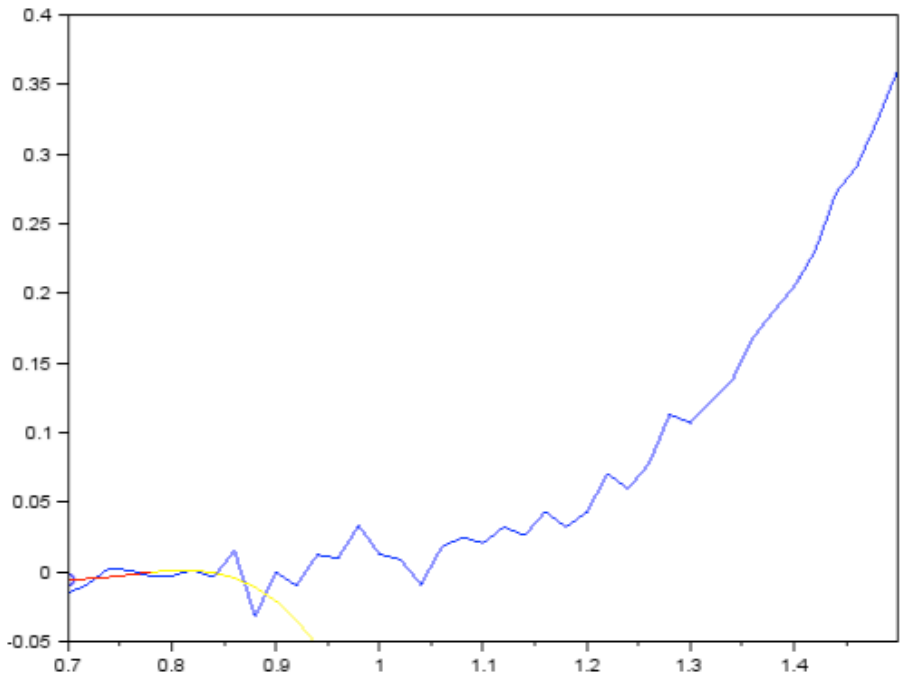
Manual Processing of Data

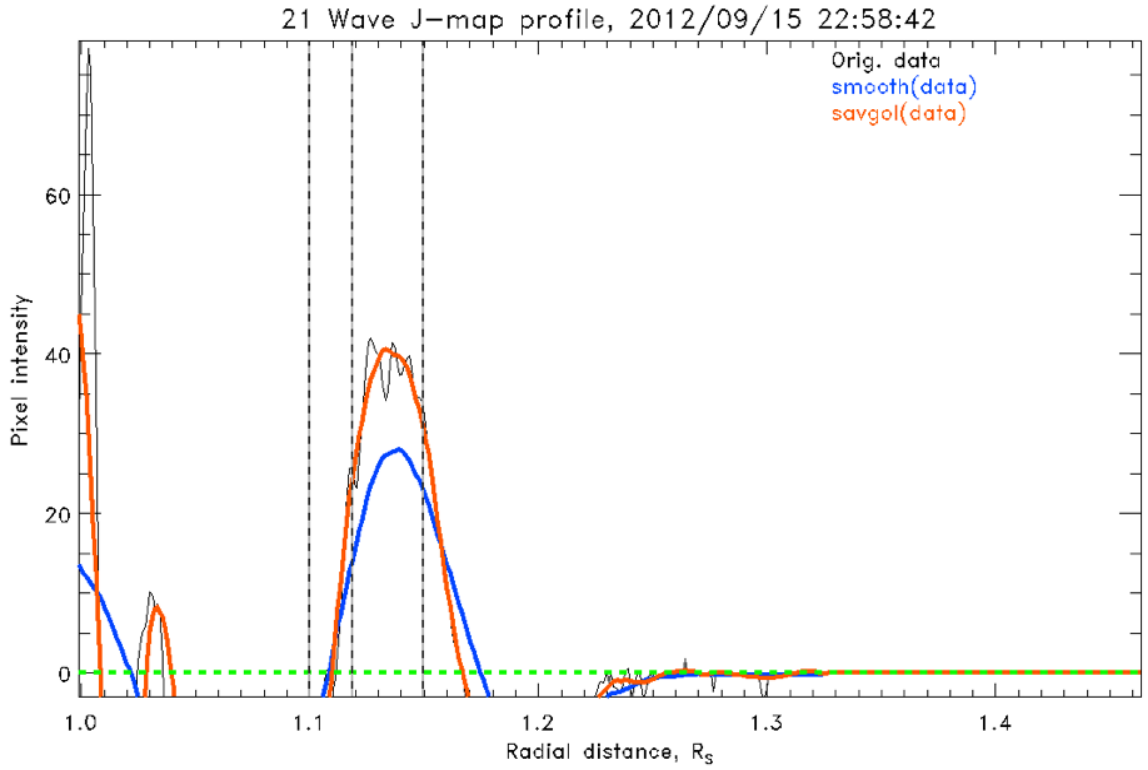
- After base difference annulus data are created, we manually selected events':
  - Peak
  - Back
  - Front
- This was done multiple times per event to estimate measurement errors
- Allows us to get kinematics data

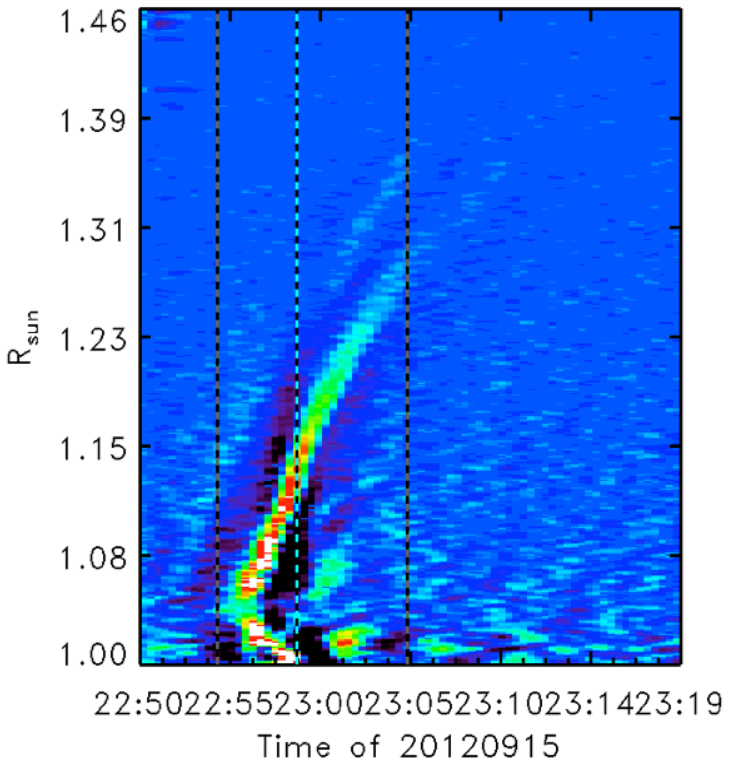


Corrections to the Data

- Smoothing (for visual inspection)
  - Savitsky-Golay filter
  - Generic smoothing function in IDL
- Removing Noise
- Removing non-physical bright areas

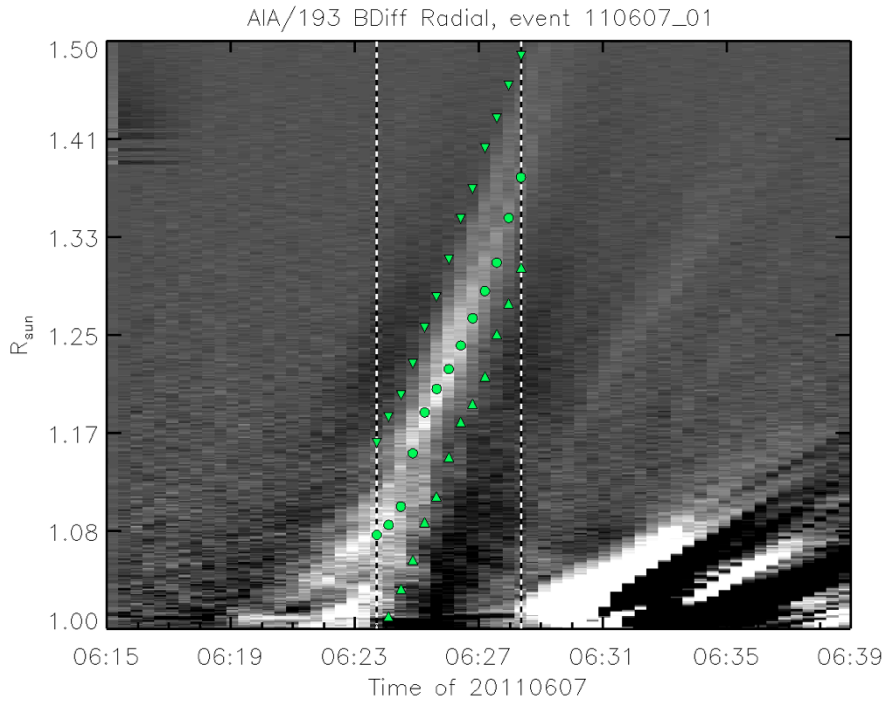


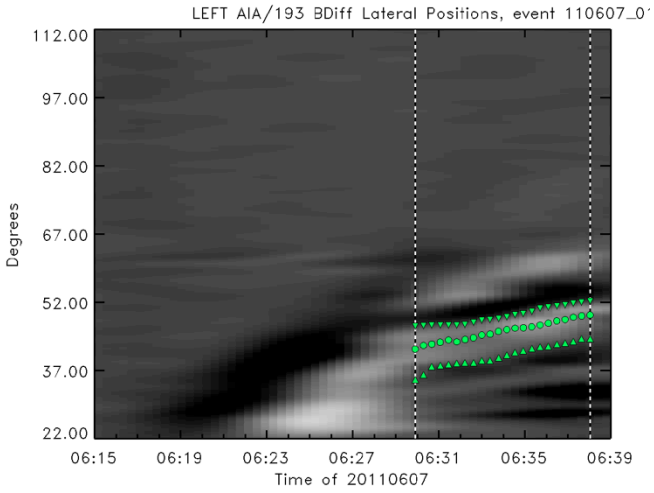

21 Wave J-map profile, 2012/09/15 22:58:42
Orig. data
smooth(data)
savgol(data)
Pixel intensity
0
20
40
60
1.0
1.1
1.2
1.3
1.4
Radial distance, Rs

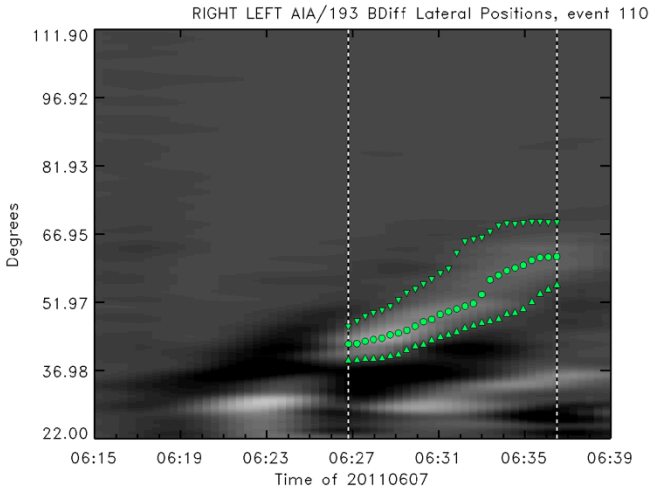

1.46
1.39
1.31
1.23
1.15
1.08
1.00
Rsun
22:5022:5523:0023:0523:1023:1423:19
Time of 20120915

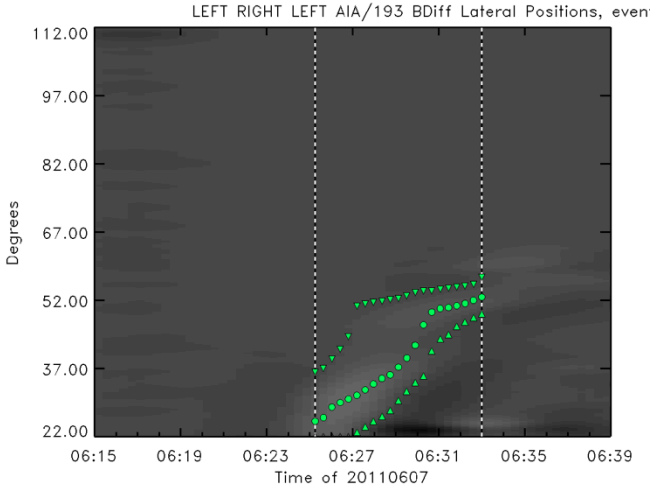
Data Analysis

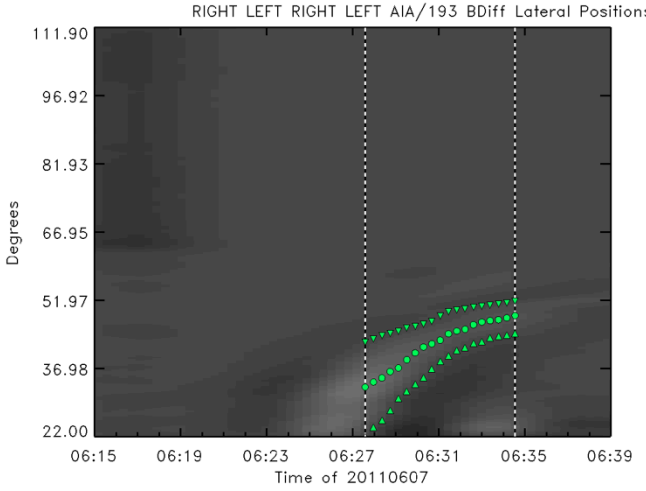
- Radial and lateral data was taken
- Statistical summary of our findings

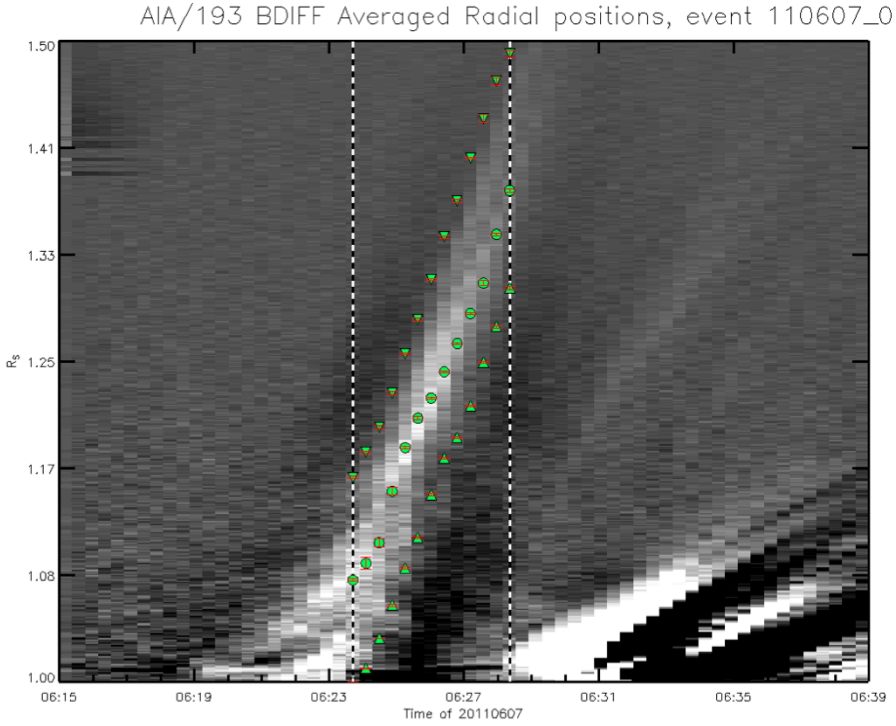


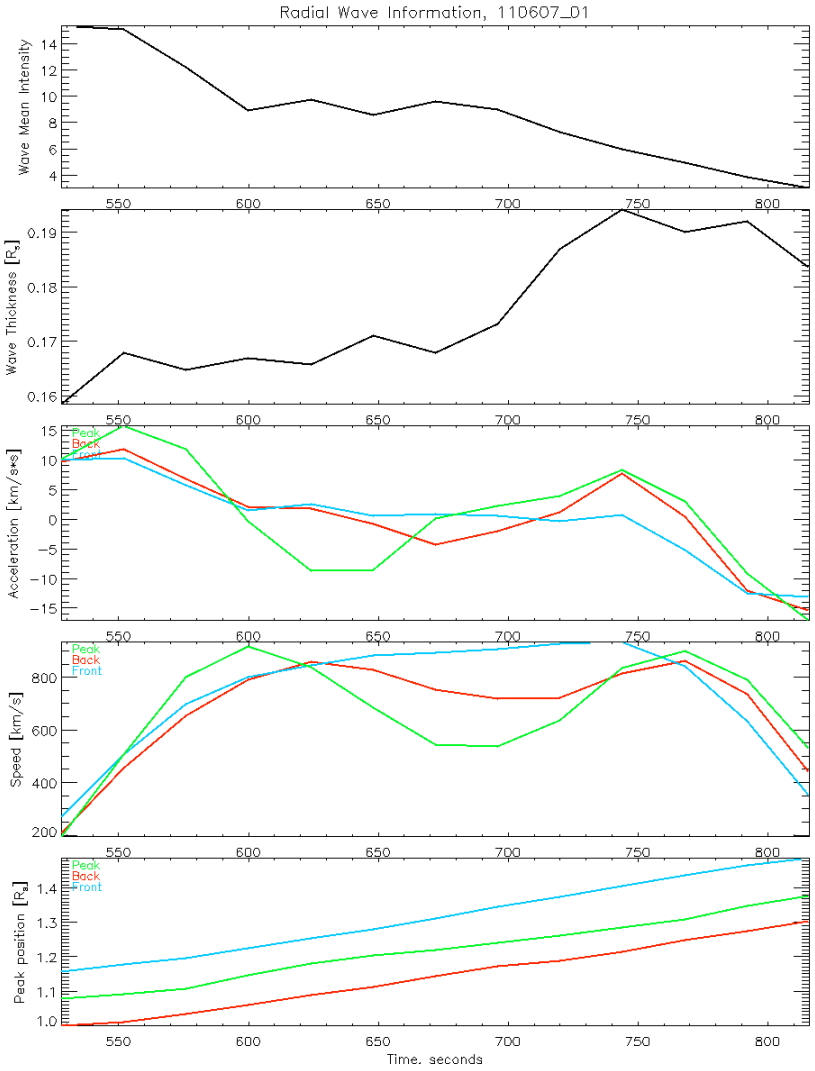

LEFT AIA/193 BDiff Lateral Positions, event 110607_0
112.00
97.00
82.00
67.00
52.00
37.00
22.00
Degrees
06:15
06:19
06:23
06:27
06:31
06:35
06:39
Time of 20110607

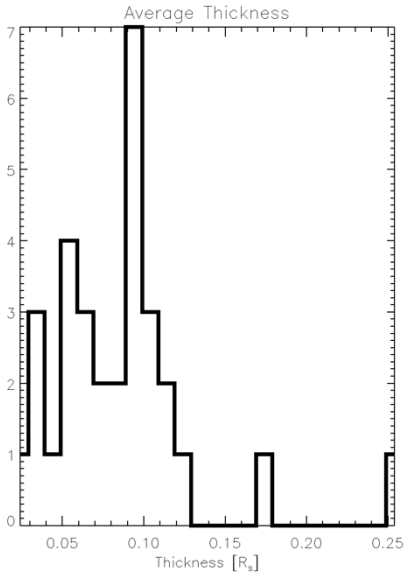

RIGHT LEFT AIA/193 BDiff Lateral Positions, event 110
111.90
96.92
81.93
66.95
51.97
36.98
22.00
Degrees
06:15
06:19
06:23
06:27
06:31
06:35
06:39
Time of 20110607

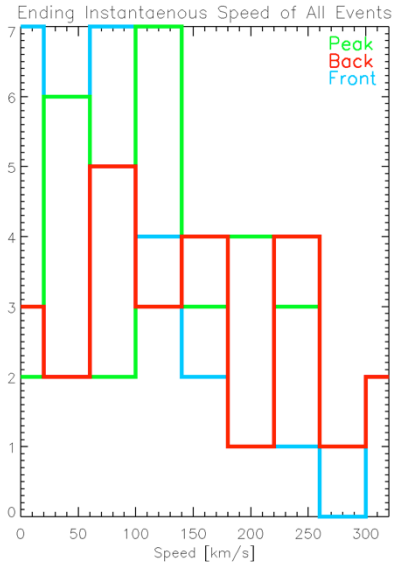

LEFT RIGHT LEFT AIA/193 BDiff Lateral Positions, even
112.00
97.00
82.00
67.00
52.00
37.00
22.00
Degrees
06:15
06:19
06:23
06:27
06:31
06:35
06:39
Time of 20110607

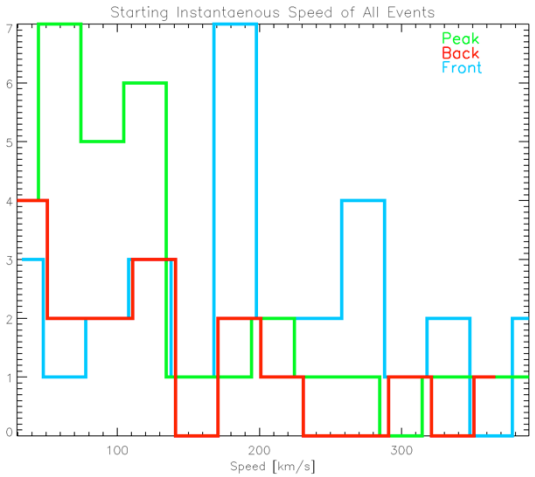

RIGHT LEFT RIGHT LEFT AIA/193 BDiff Lateral Positions
111.90
96.92
81.93
66.95
51.97
36.98
22.00
Degrees
06:15
06:19
06:23
06:27
06:31
06:35
06:39
Time of 20110607

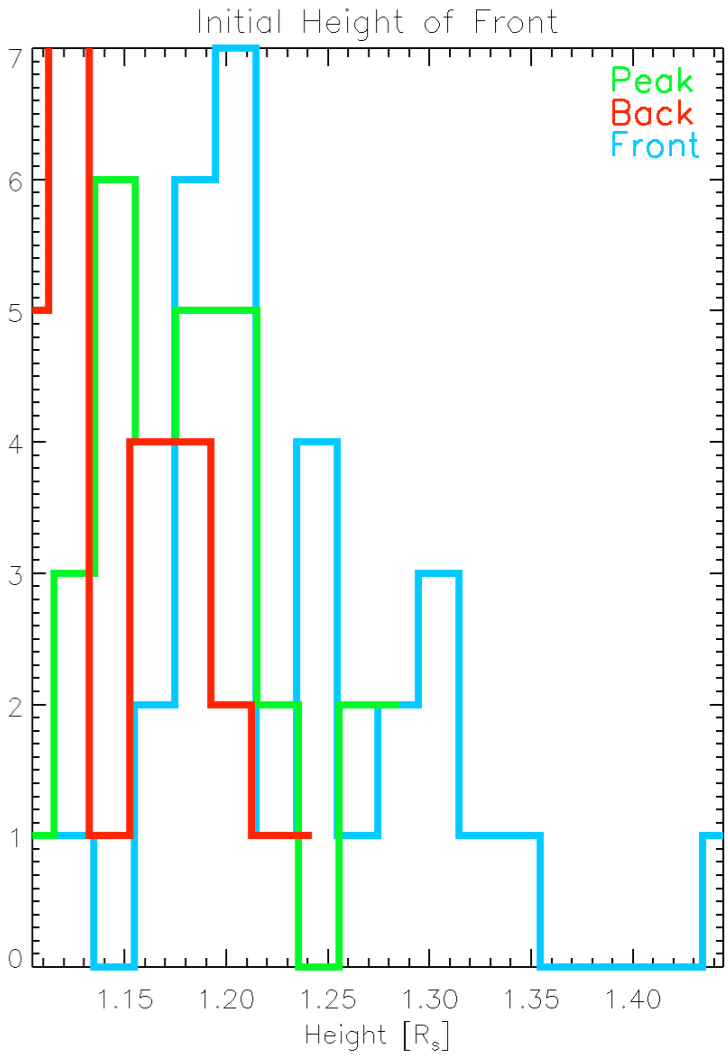

AIA/193 BDIFF Averaged Radial positions, event 110607_01
1.50
1.41
1.33
1.25
1.17
1.08
1.00
R_s
06:15
06:19
06:23
06:27
06:31
06:35
06:39
Time of 20110607

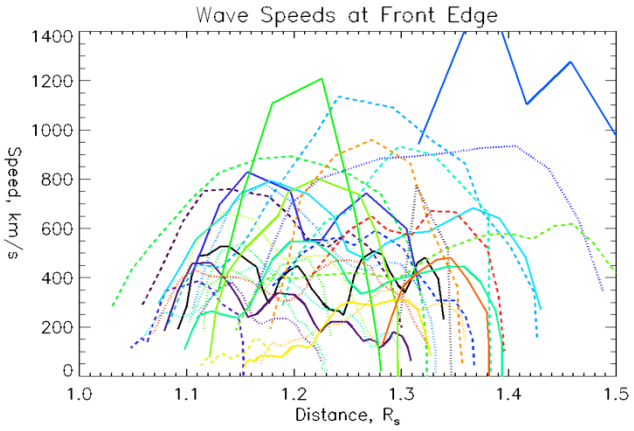

Radial Wave Information, 110607_01
Wave Mean Intensity
Wave Thickness [R_s]
Acceleration [km/s**s]
Speed [km/s]
Peak position [R_s]
Peak
Back
Front
550
600
650
700
750
800
Time, seconds

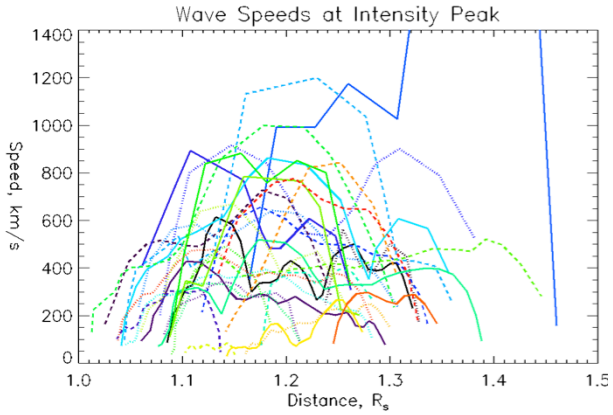

Average Thickness
0
1
2
3
4
5
6
7
0.05
0.10
0.15
0.20
0.25
Thickness [R$_s$]

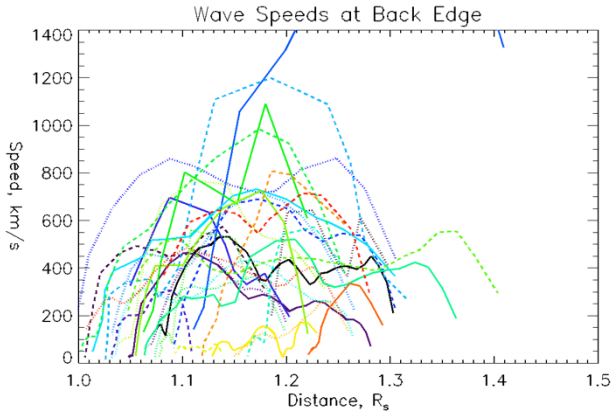

Ending Instantaenous Speed of All Events
Peak
Back
Front
0
1
2
3
4
5
6
7
0
50
100
150
200
250
300
Speed [km/s]

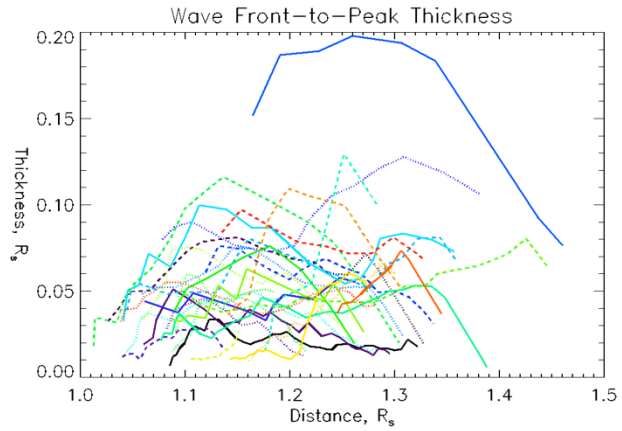

Starting Instantaenous Speed of All Events
Peak
Back
Front
0
1
2
3
4
5
6
7
100
200
300
Speed [km/s]

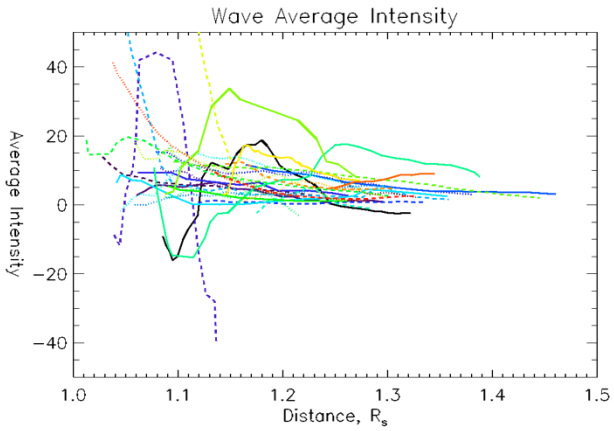

Initial Height of Front
Peak
Back
Front
0
1
2
3
4
5
6
7
1.15
1.20
1.25
1.30
1.35
1.40
Height [R$_s$]

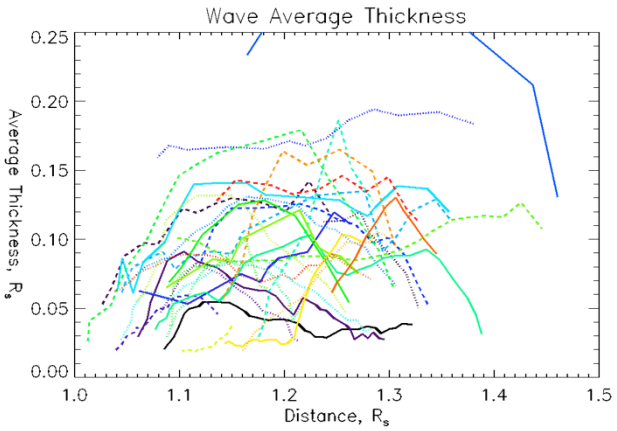

Wave Speeds at Front Edge
Speed, km/s
Distance, R_s

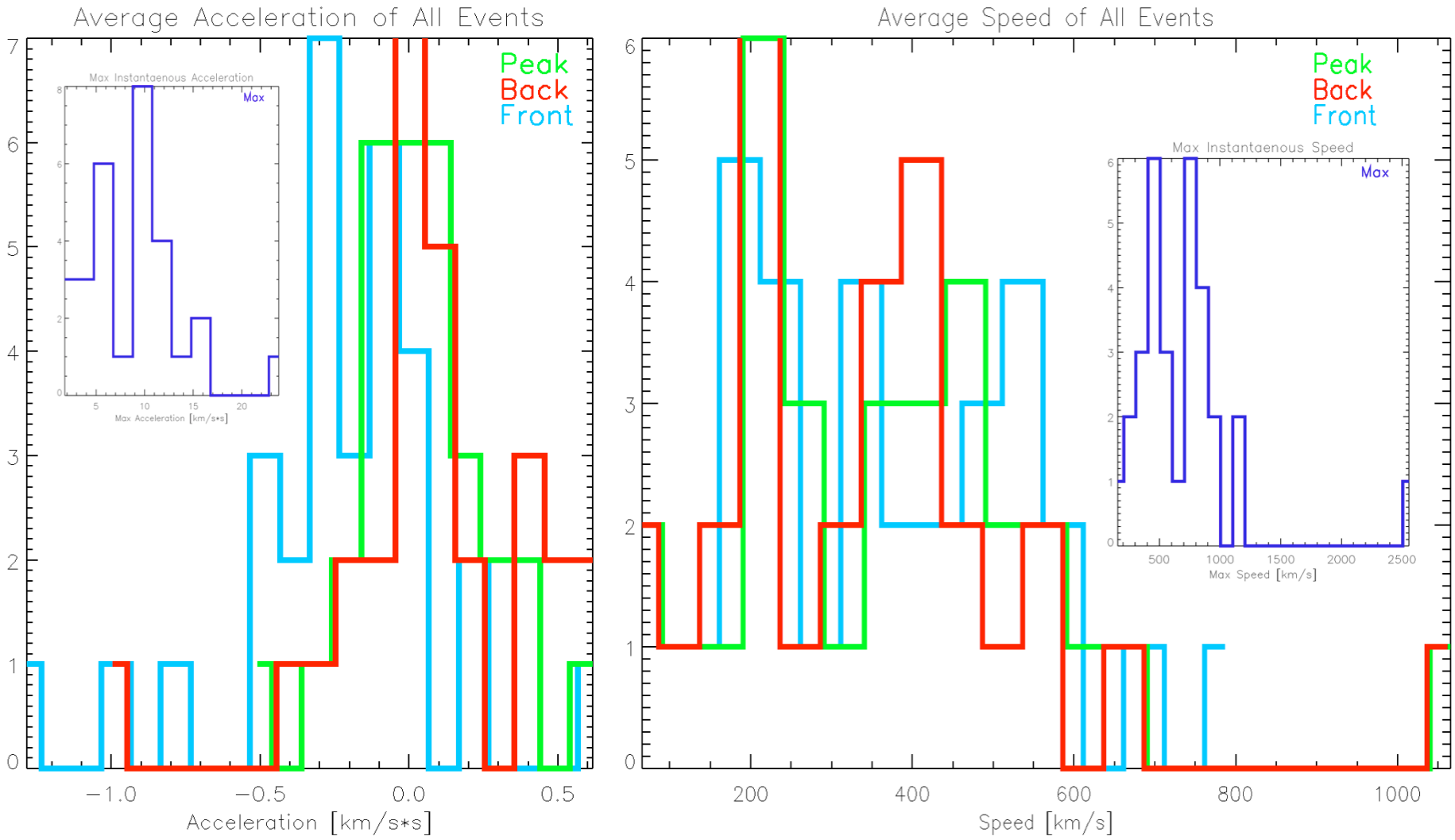

Wave Speeds at Intensity Peak
Speed, km/s
Distance, R_s


Wave Speeds at Back Edge
Speed, km/s
Distance, R_s


Wave Front-to-Peak Thickness
Thickness, R_s
Distance, R_s


Wave Average Intensity
Average Intensity
Distance, R_s


Wave Average Thickness
Average Thickness, R_s
Distance, R_s


Average Acceleration of All Events
Peak
Back
Front
Max Instantaenous Acceleration
Max
Max Acceleration [km/s*s]
Acceleration [km/s*s]
Average Speed of All Events
Peak
Back
Front
Max Instantaenous Speed
Max
Max Speed [km/s]
Speed [km/s]

Next steps

- Finish the manual lateral kinematics measurements
- Automate the process of gathering radial and lateral kinematics information
  - Improve automated measurements using comparisons to manual measurements
- Comprehensive analysis of UV Waves and their ability to accelerate particles

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