# A HEK survey of flows around sunspots

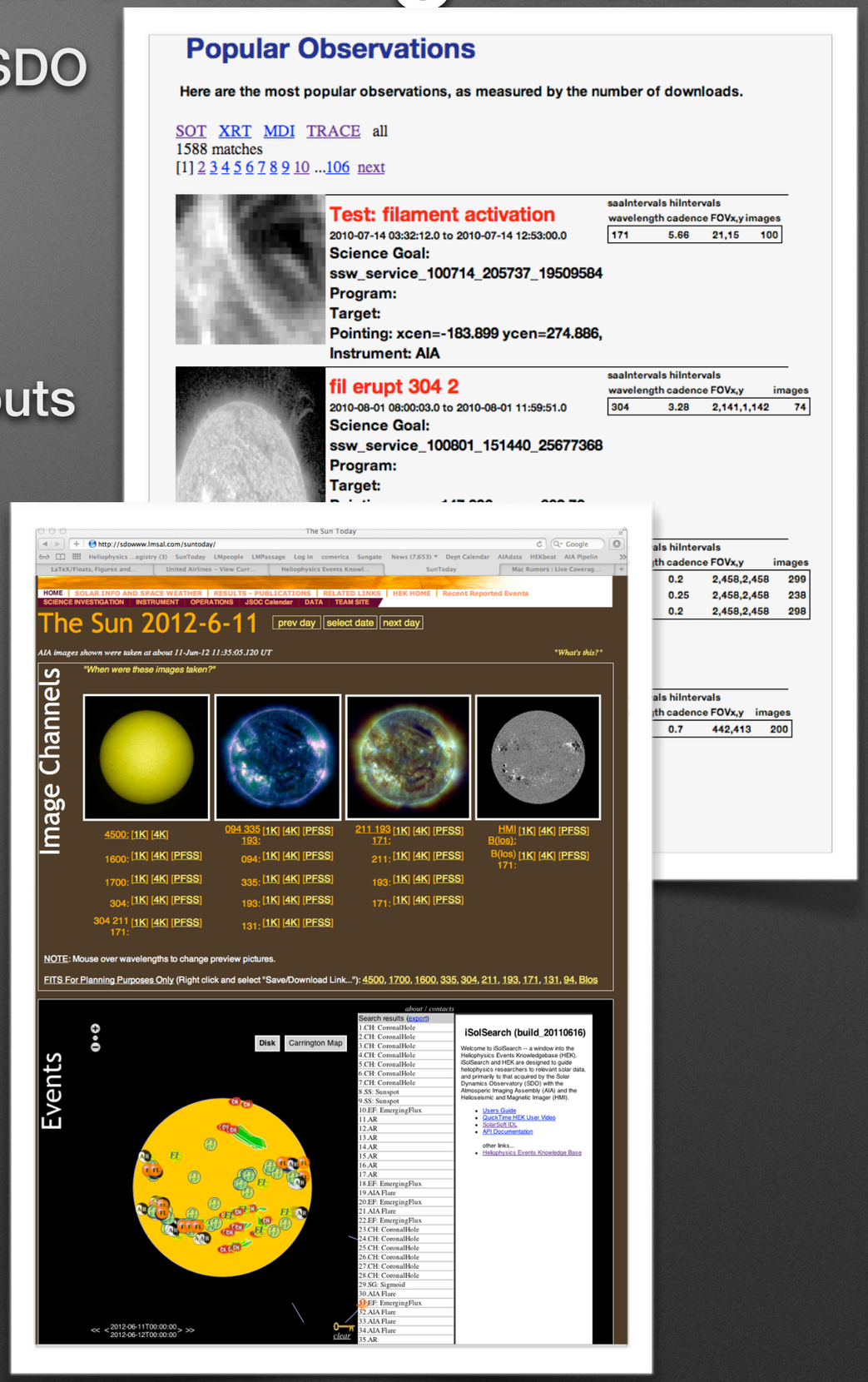
Neal Hurlburt

# Outline

- What's the HEK?
- Sunspot motions: Moats & Rotation
- Parameterizing flows
- Connections
- Future Work

# Heliophysics Event Knowledgebase

- Developed to guide researchers to relevant SDO (and other) data
- Includes:
- Observation Coverage
  - Supports IRIS, Hinode, TRACE & AIA cutouts
  - 70k entries
- Heliophysics Events
  - 23+ event classes
  - 1.4M entries
- HEK & related web services
  - http://www.lmsal.com/hek
  - Used by VSO, Helioviewer & LMSAL tools
- LMSAL web tools
- SolarSoft tools



INTERFACE REGION IMAGING SPECTROGRAPH
IRIS + HINODE DATA SEARCH

<< < Start > >>  2014-08-24T12:0(
<< < End > >>  2014-09-01T12:0(

Events | IRIS

Event Types  All Invert Common Clear

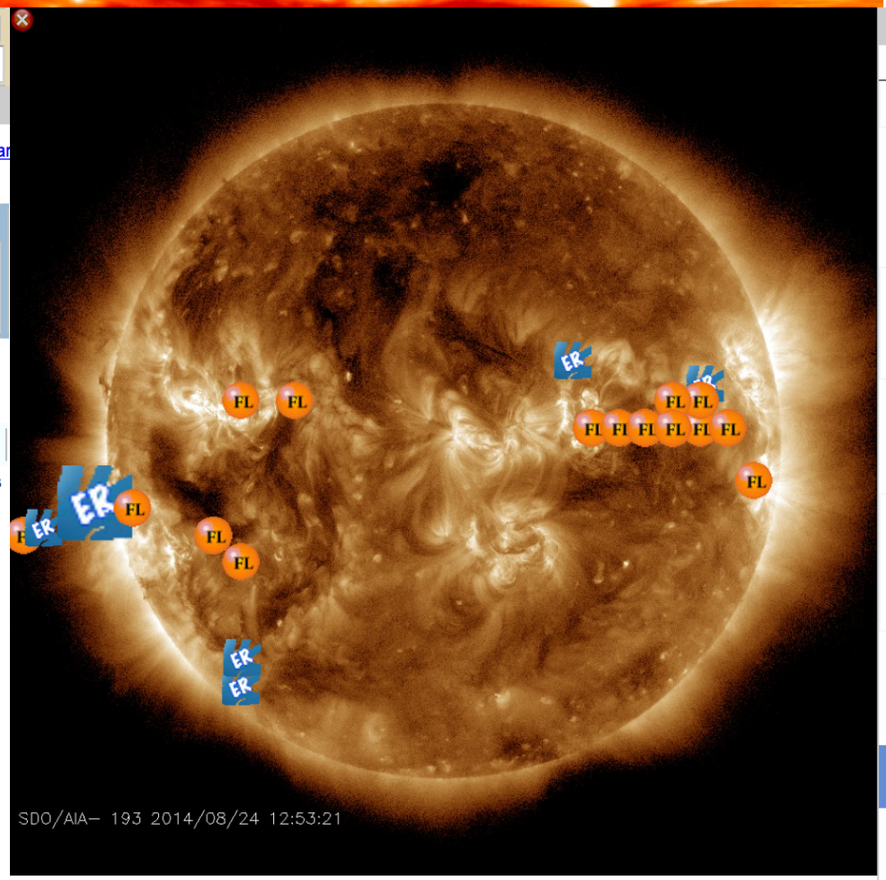
Method
Name
Channel
Instrument
Wave(Å)
Annotated Only

Location
XCEN
YCEN
Radius

Desc:

Search | Clear HER | 193 | Chaincodes

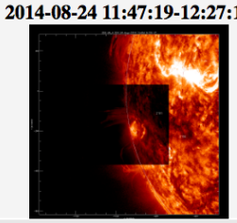
Result Limit: 200




Help/About
JSON (HCR)
JSON (HER)

Events | IRIS | SOT | XRT | EIS

| Type | Time | X,Y | FRM | Inst | Channel | Scor |
|---|---|---|---|---|---|---|
| | | | CME Tracking) | | clear filter | |
| CE | 2014-08-25 21:48-22:36 | 555",1815" | CACTus (Compute Aided CME Tracking) | c2 c3 | C2 orange filter, C3 clear filter | 0.3 |
| FL | 2014-08-25 20:09-20:42 | 653",38" | Flare Detective - Trigger Module | AIA | 131 | 0.29 |
| FL | 2014-08-24 12:07-12:55 | -883",-192" | Flare Detective - Trigger Module | AIA | 211 | 0.27 |
| CE | 2014-08-25 15:24-19:48 | 1890",165" | CACTus (Compute Aided CME Tracking) | c2 c3 | C2 orange filter, C3 clear filter | 0.26 |
| FL | 2014-08-24 11:59-13:10 | -883",-192" | Flare Detective - Trigger Module | AIA | 131 | 0.25 |
| ER | 2014-08-24 11:47-12:27 | -990",-179" | EruptionF | AIA | 304 | 0.24 |
| FL | 2014-08-25 20:10-21:13 | 653",38" | Flare Detective - Trigger | AIA | 171 | 0.24 |

| Overview | Where | Details | Context & Metadata | Data Links |
|---|---|---|---|---|
| 2014-08-24 11:47:19-12:27:19  | EruptionPatrol ER | x,y: -990",-179"<br>Boundbox: 120"x120"<br>Type: ER | Coord Sys: UTC-HPC-TOPO<br>Observatory: SDO<br>Instrument: AIA<br>Channel: 304<br>FRM: EruptionPatrol<br>Archived: 2014-08-24T12:30:11 | FRM_URL<br>SDO Movie<br>SSW Context Image<br>SSW Context Thumbnail<br>Helioviewer.org<br>HER Event Summary | SDO Get Cutout |

# Dynamic events in HEK

See http://www.lmsal.com/isolsearch
or http://www.lmsal.com/heksearch

# SolarSoft routines

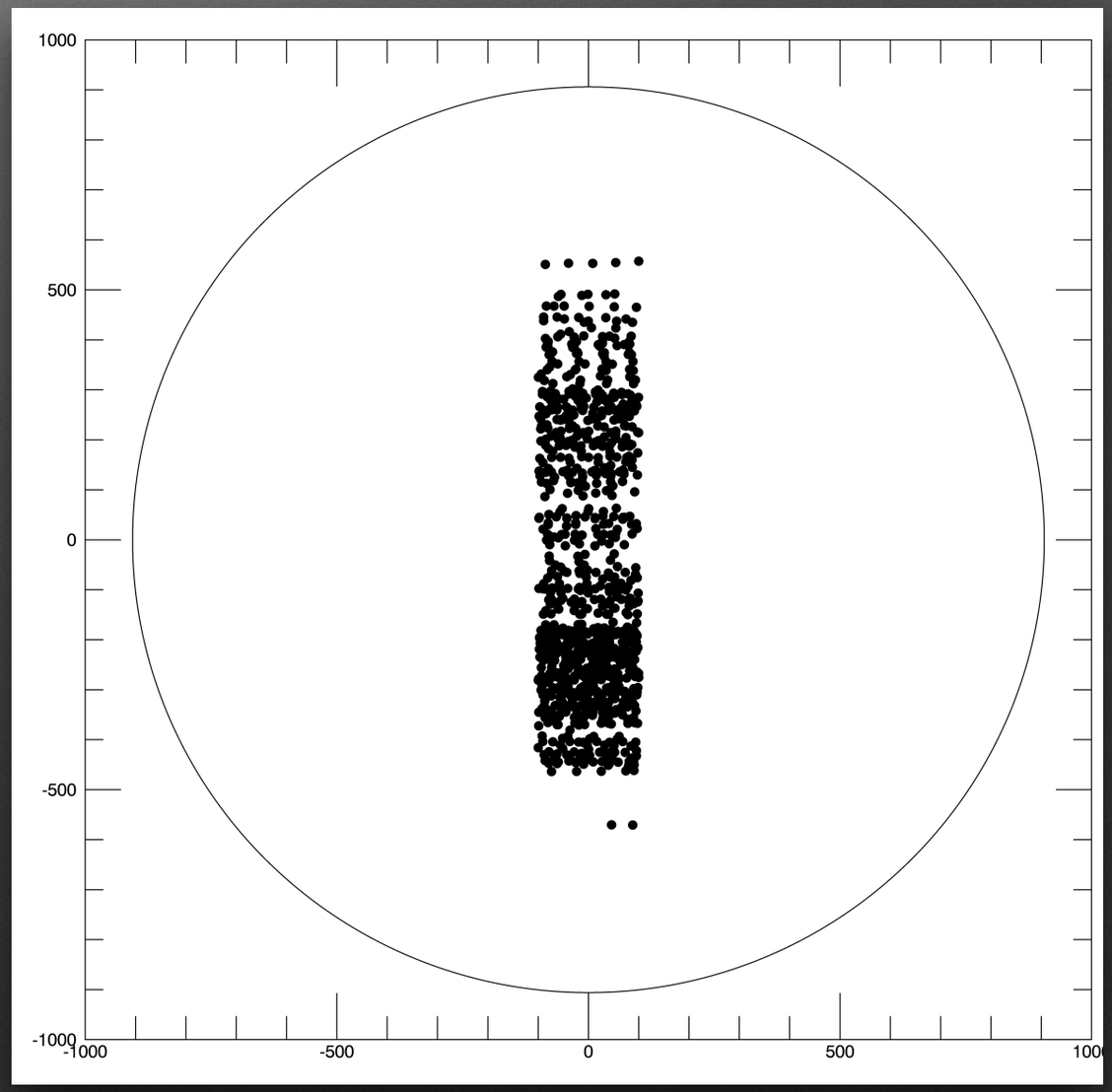
- Generic ssw query routines:
  - ssw_hcr_query, ssw_her_query, ssw_hcr_make_query, ssw_her_make_query, ssw_hcr_where
- Simple Versions
  - hek_find_events(time1,time2,xcen,ycen,radius,trange, target=target,instrument=instrument,type=type, count=count)
  - hek_bounds,event,boundbox,center,timespan
  - hek_match_events(event,radius,trange,target=target, instrument=instrument,type=type,count=count)

# Parameterizing flows

- Use HEK to extract datacubes of 80 HMI continuum images centered on sunspots
- Use optical flow method (Hurlburt & Jaffey 2015) to derive velocity fields
- Compute line integrals along series of concentric ellipses of: normal flows (in/out) tangential (rotation), mean & rms intensity (for reference)

# Sunspot Selection

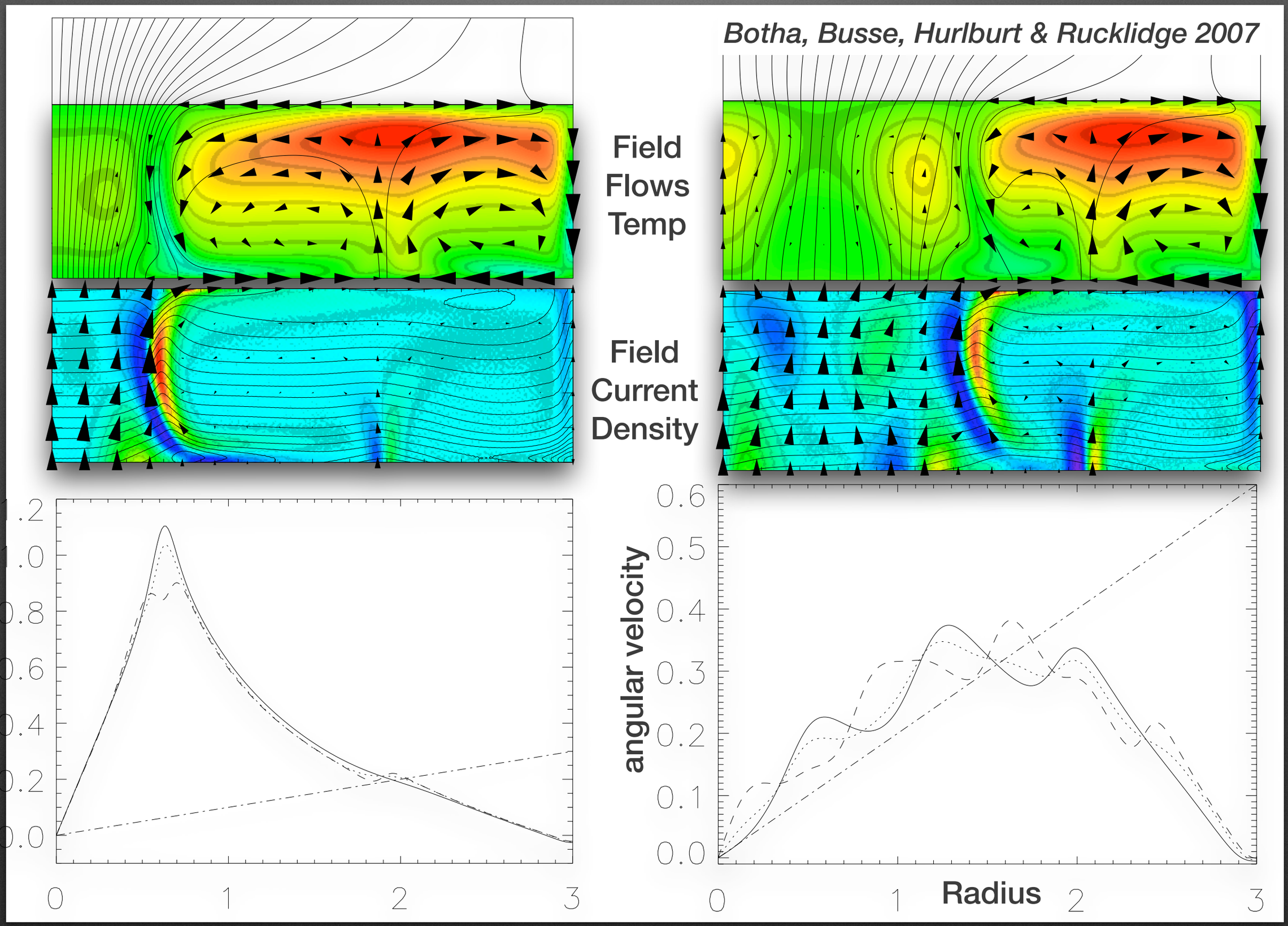
- Sunspots reported by EGSO_SFC module using HMI continuum (Zharkova et al. 2005)  (from 1997-now)
- 1000 spots detected near disk center between 2011-12-29 and 2014-11-11
  - hek_find_events
  - 10 Mm < $R_{spot}$ < 60 Mm
- 100 randomly selected subset for initial studies

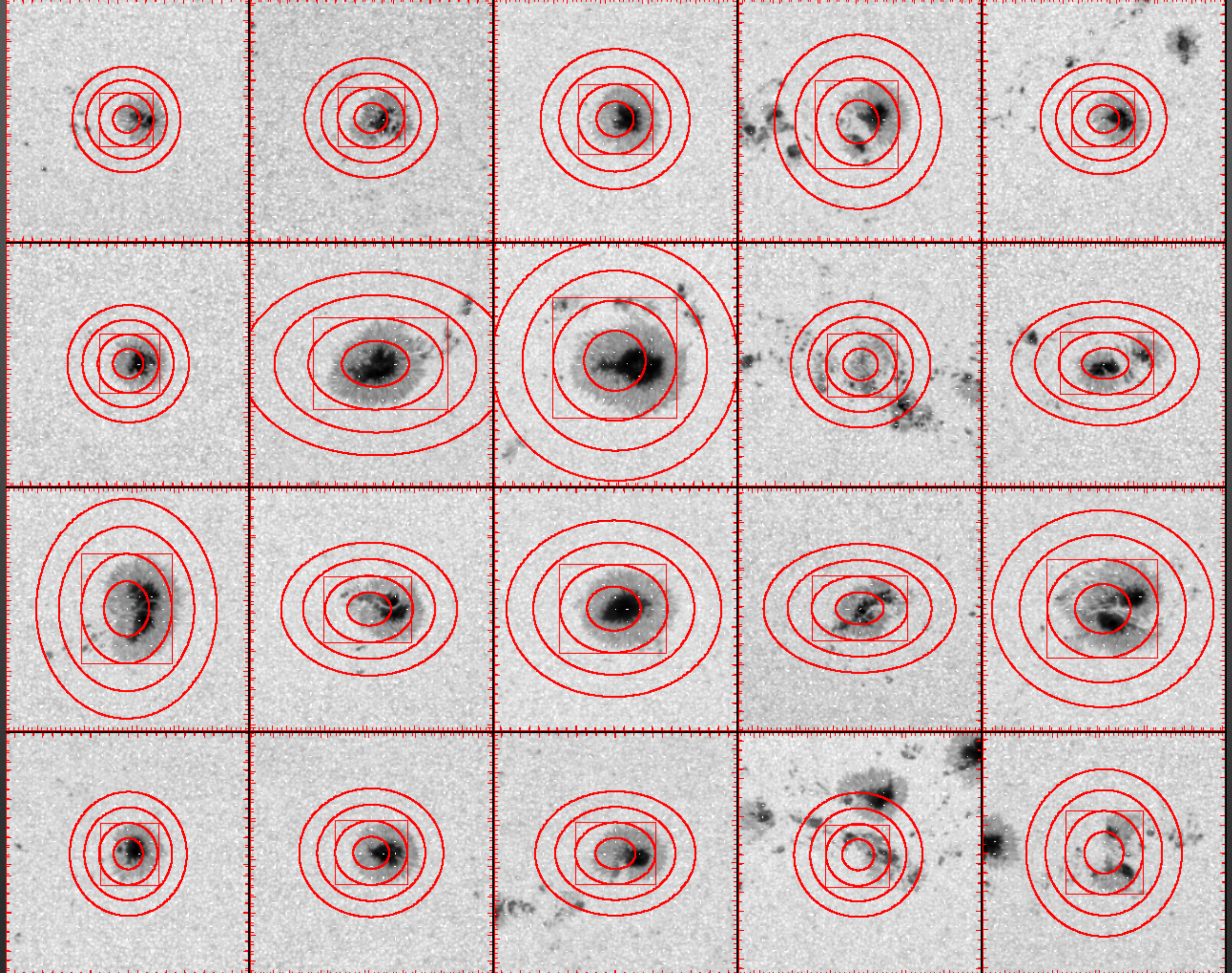


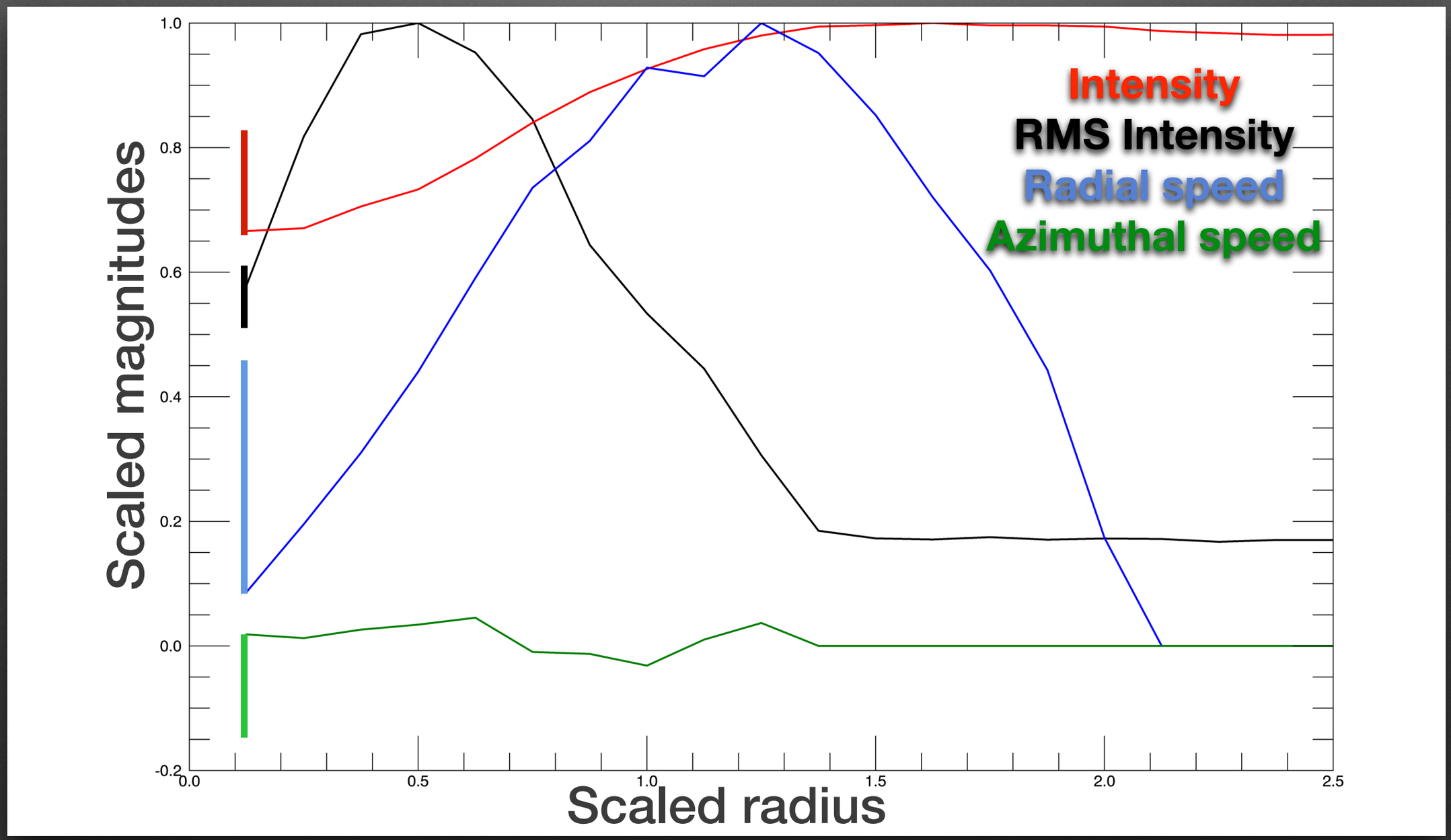
# Expectations

- Moats
  - 500 - 1000 m/sec; $R_{moat}$ ~ 10-20Mm (Sheeley 1972) (a few spots)
  - 200-400 m/s $R_{moat}$ > 7Mm (Sobotka and Roudier 2007) (30 spots)
  - 1km/s; $R_{moat}$ ~ 9Mm (Löhner-Böttcher and Schlichenmaier 2014) (30 spots)
    - Suggestions of enhanced flaring near strong moats
- Sunspot Rotation
  - Angular rotation ~200 degrees/3.5 days near R = 0.5$R_{spot}$ associated with enhanced flaring (Brown et al 2003; Kazachenko et al. 2009) (~7 spots)

# Axisymetric rotating magnetoconvection



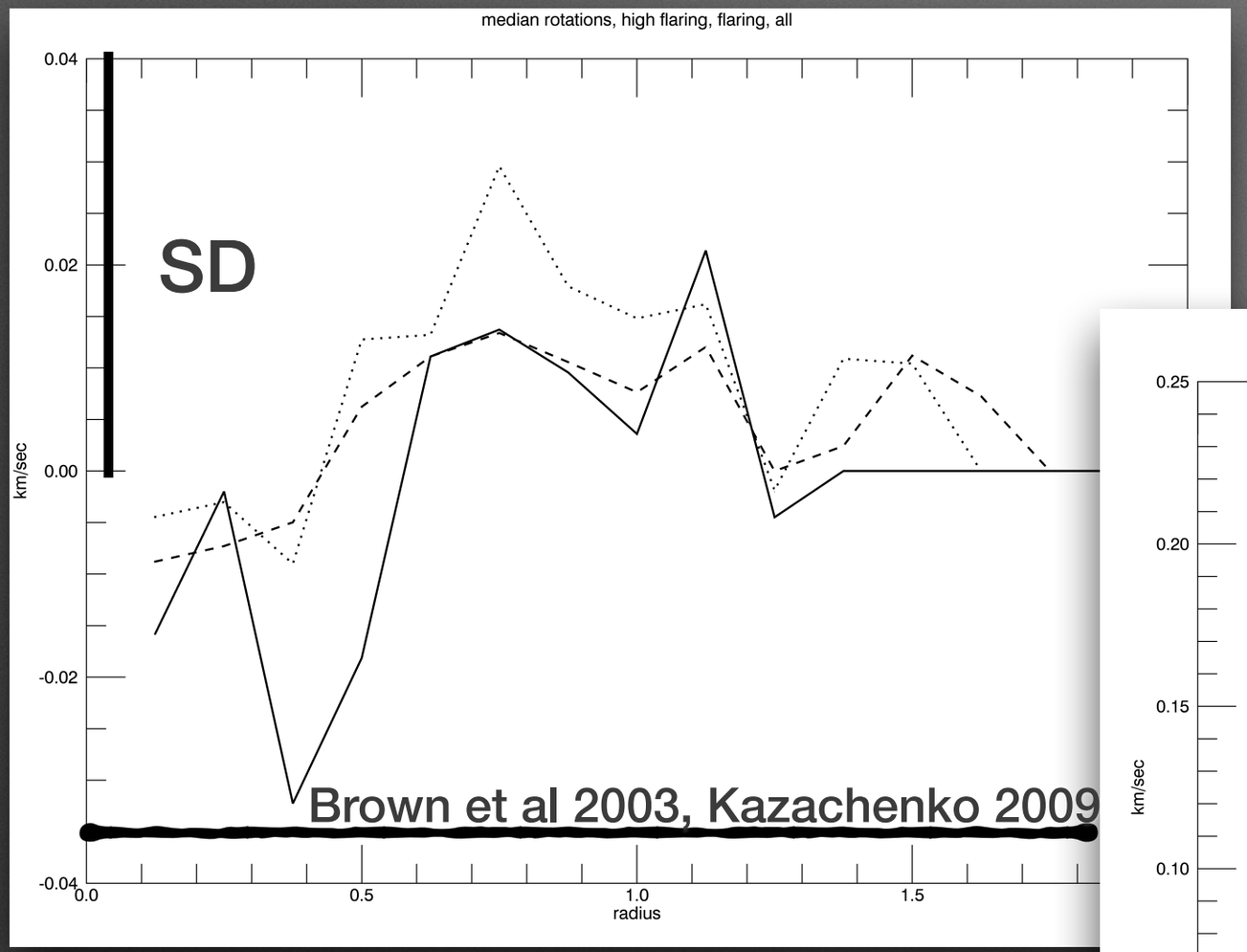


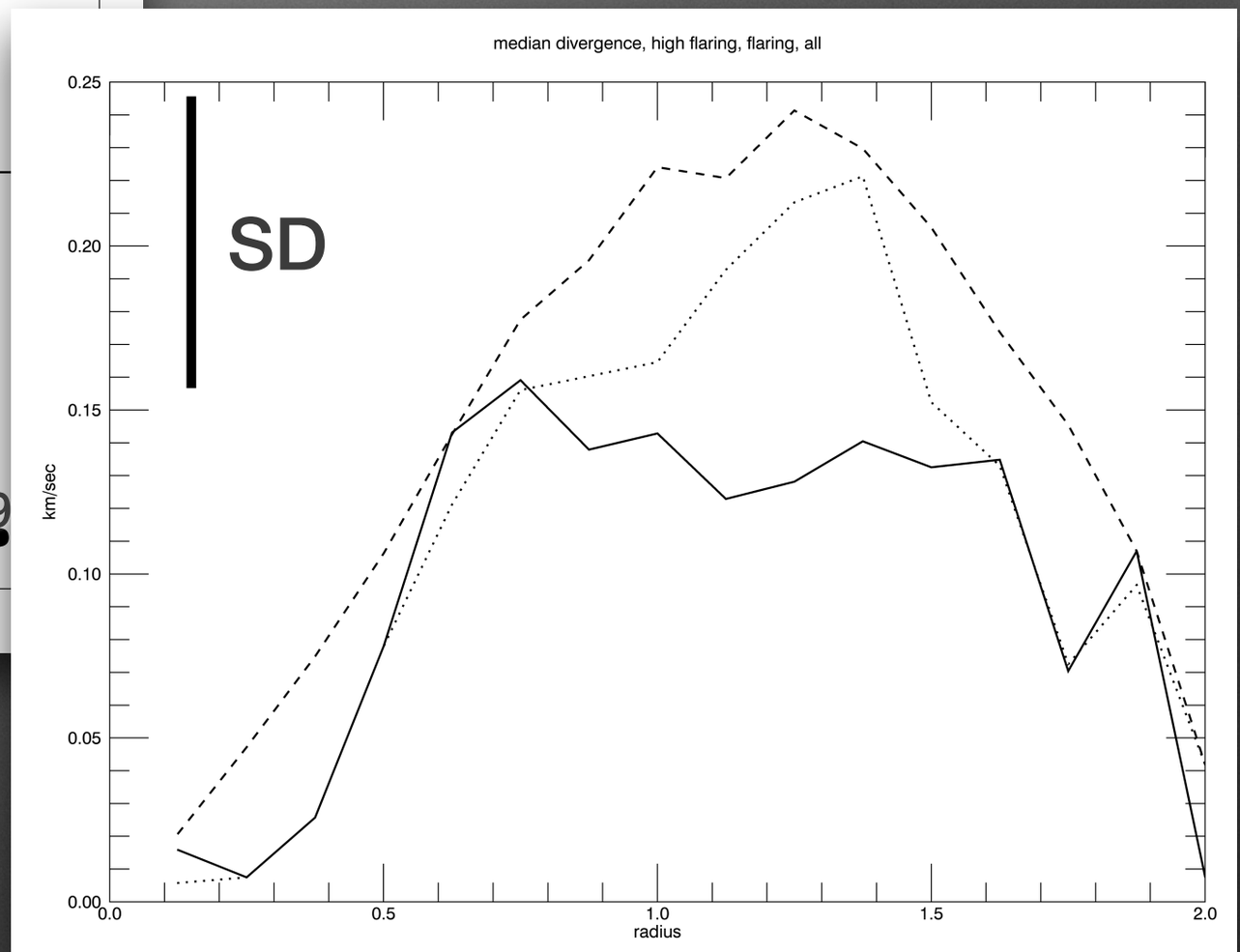



# Median Sunspot profiles

# Connections to activity

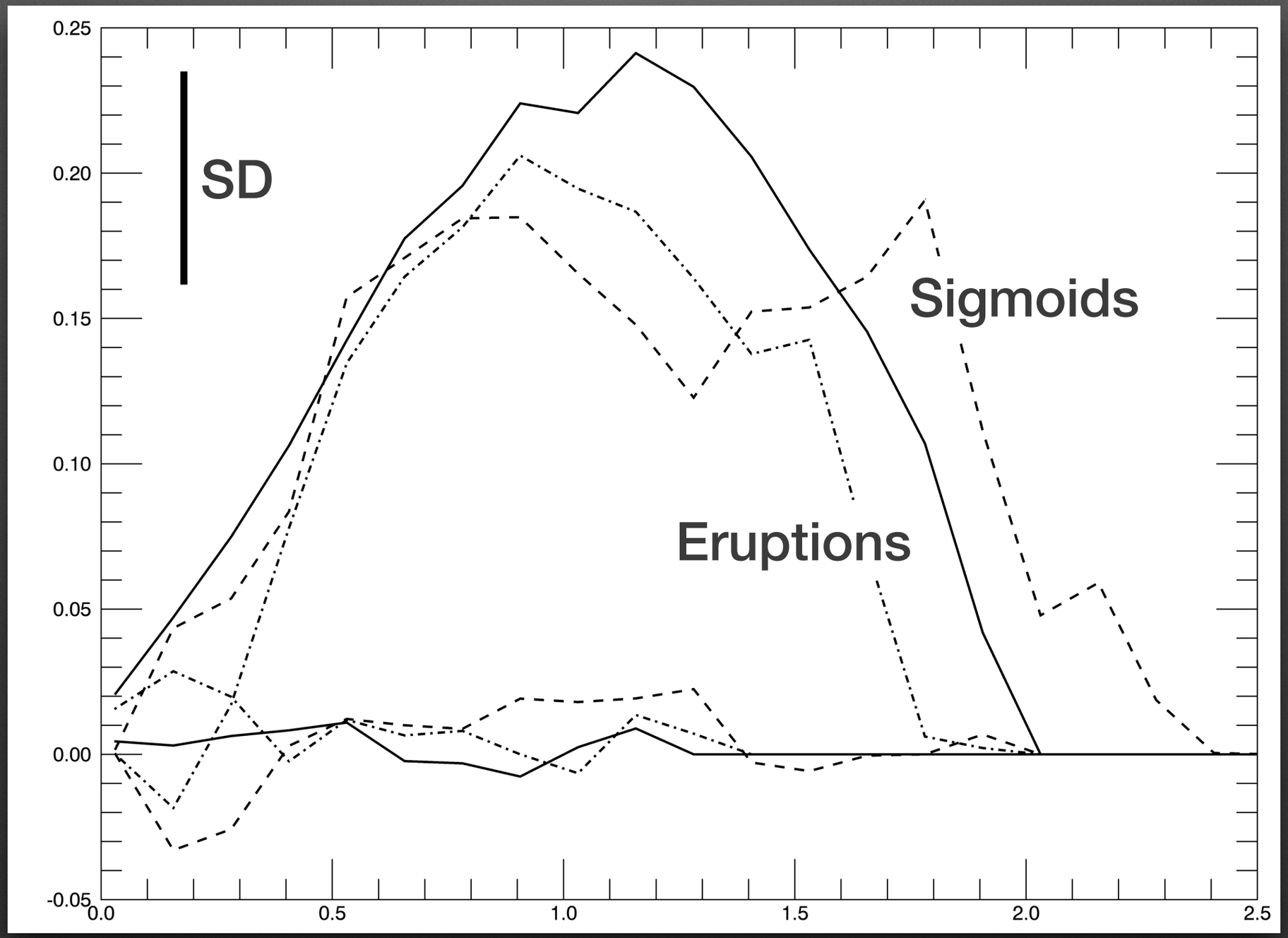
- Find flares, eruptions etc. (any magnitude) near selected sunspots using hek_match_events
- 47/100 have at least flare report
- 21 have more than 4 (combined from all sources) (max 36)
- 33/100 have nearby eruptions




# Median flows vs Flaring Rate

solid: high flare rates (21)
dotted (47): flaring
dashed: all spots (97)

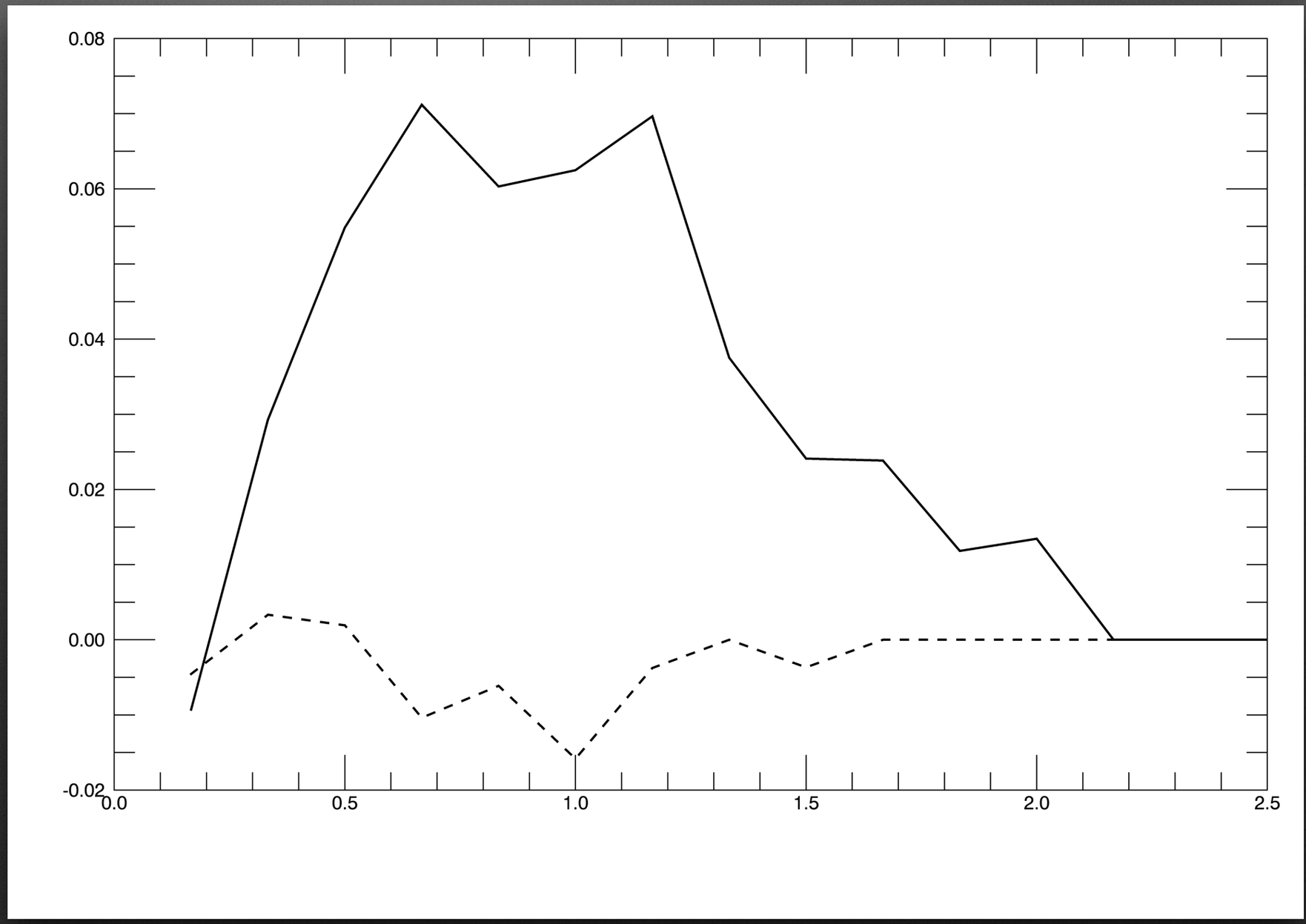


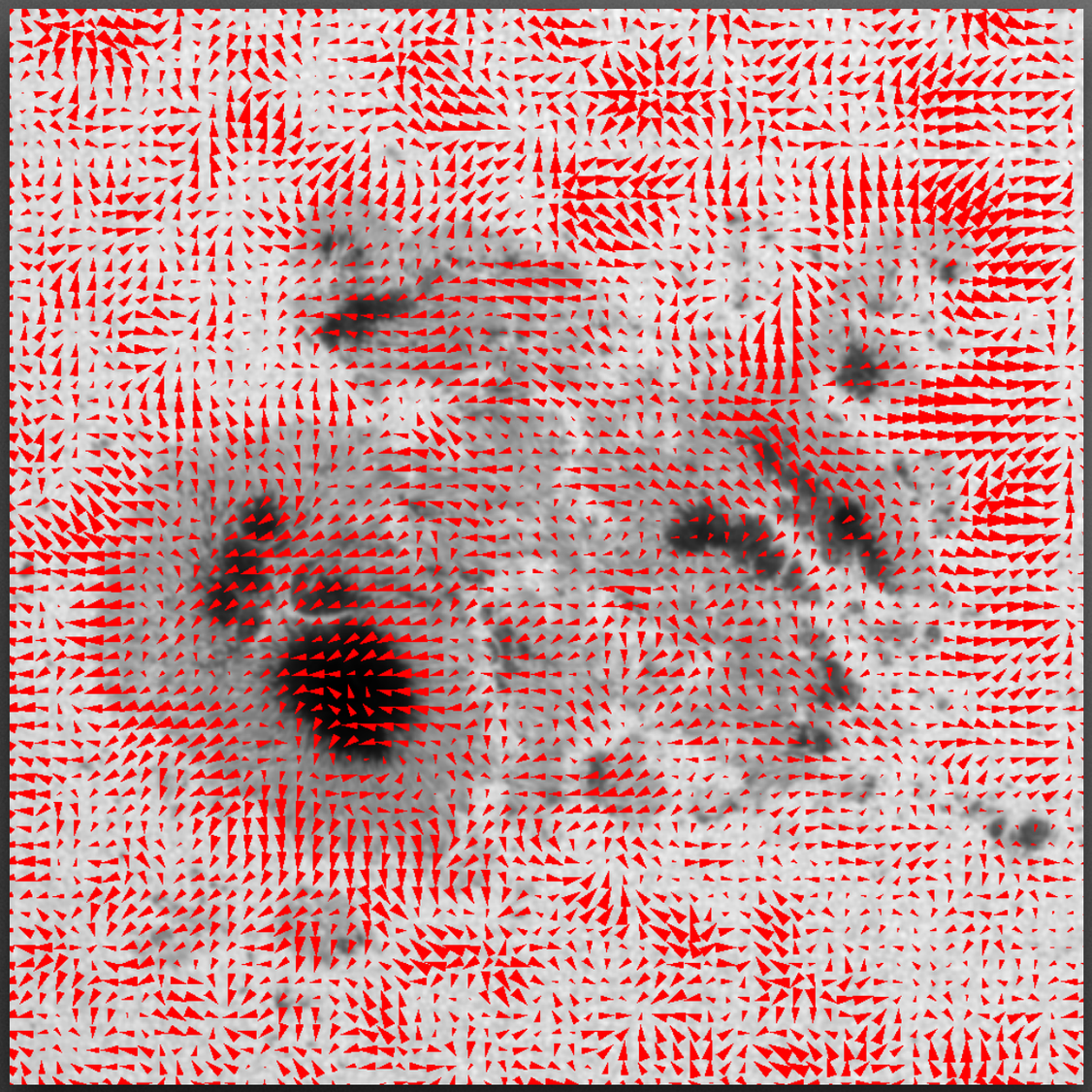

# Eruptions/Sigmoids

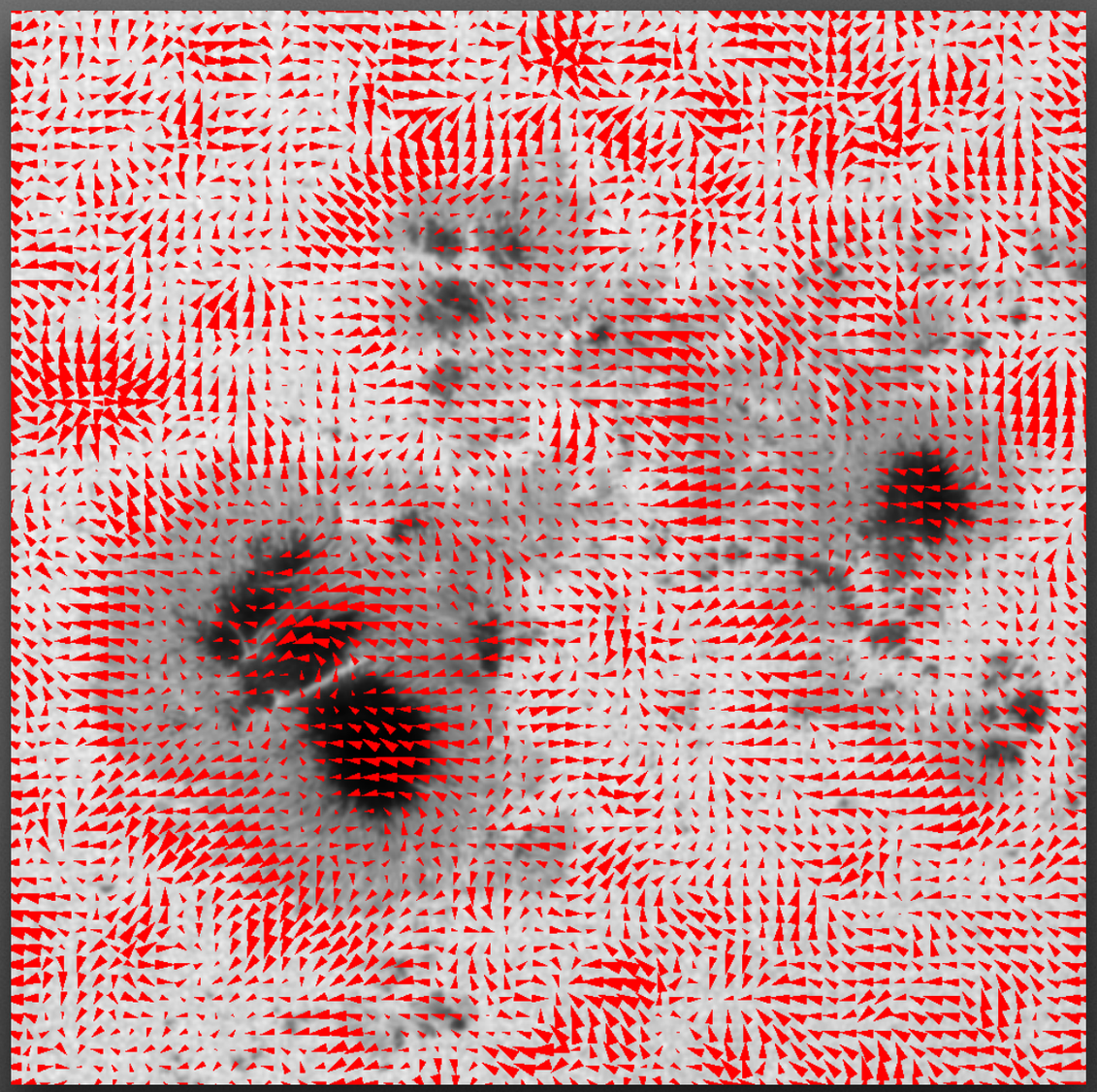
33 sunspots near eruption sites; 15 near sigmoids

# Inverse: X-class flare

- Select sunspots near X-flares (still near disk center)
- weaker outflow
- inverse rotations
- Pre- & post-flare comparisons



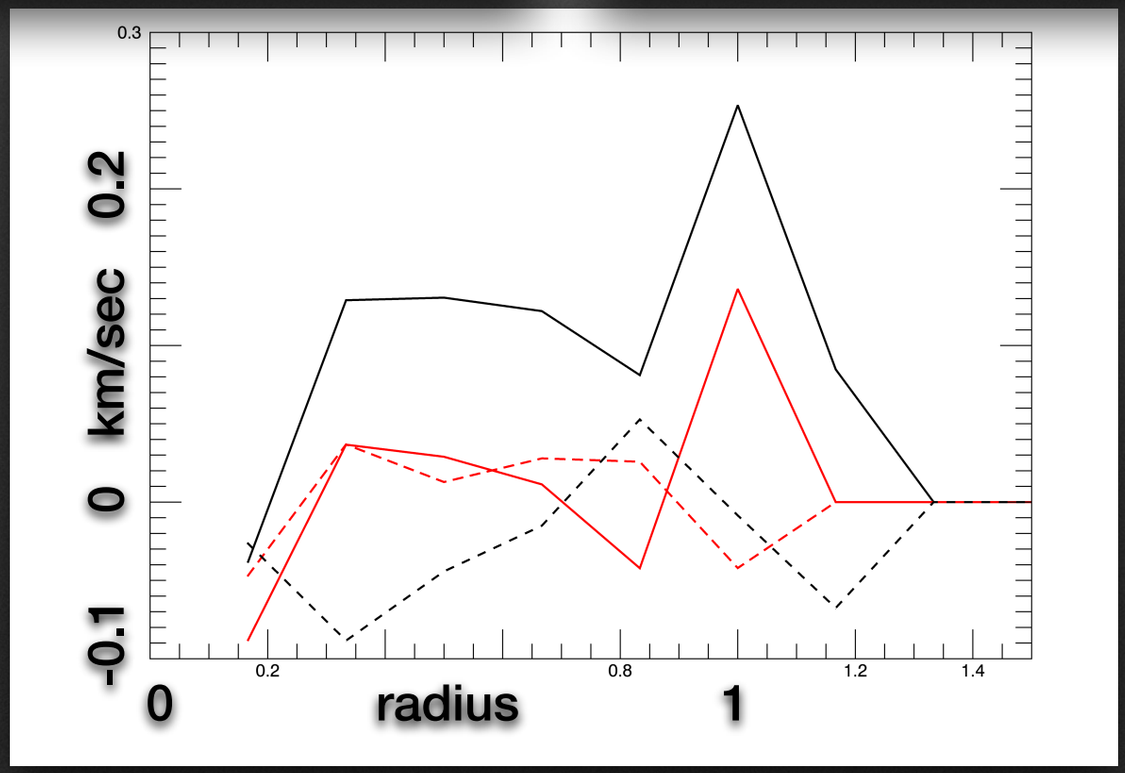




**Pre-flare**

**Post-flare**

X1.6 flare
2014-10-22
14:02



# Conclusion/Future

- Radial flow consistent previous moat flows studies
- Median rotation consistent with axisymetric models
- Suggestion of anomalous rotation near flares as seen in previous studies
- Suggestion of anomalous moats near flares
- Larger-scale survey to be incorporated into HEK
  - $R_{moat}$, maximum speed, rotation @ $R_{spot}/2$, and more?
- www.lmsal.com/hek