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# Cosmic Ray modulation and geoeffectiveness of corotating Interaction Regions derived from coronal hole area measurements



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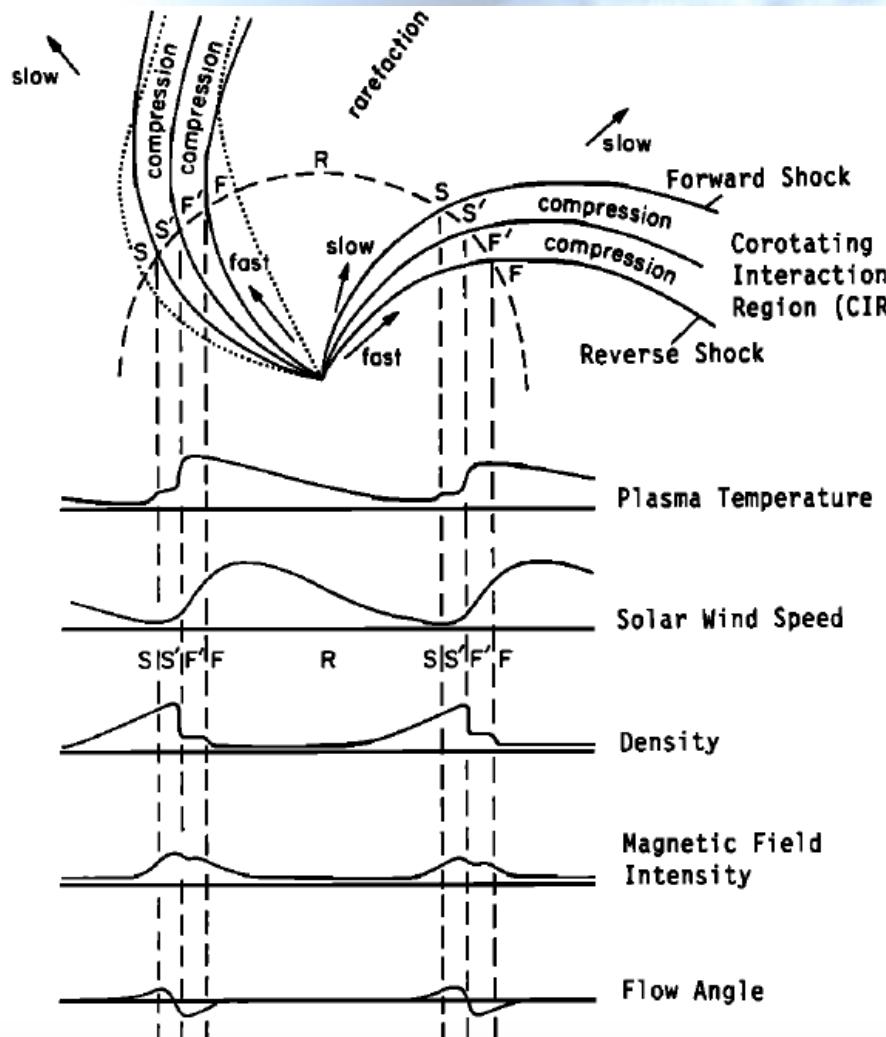


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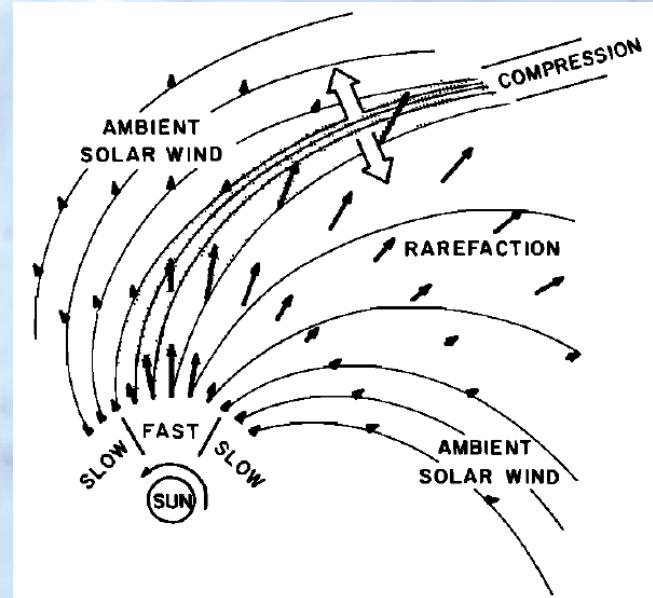
Christian-Albrechts-Universität zu Kiel

# Corotating Interaction Regions (CIR)



Richardson, 1993

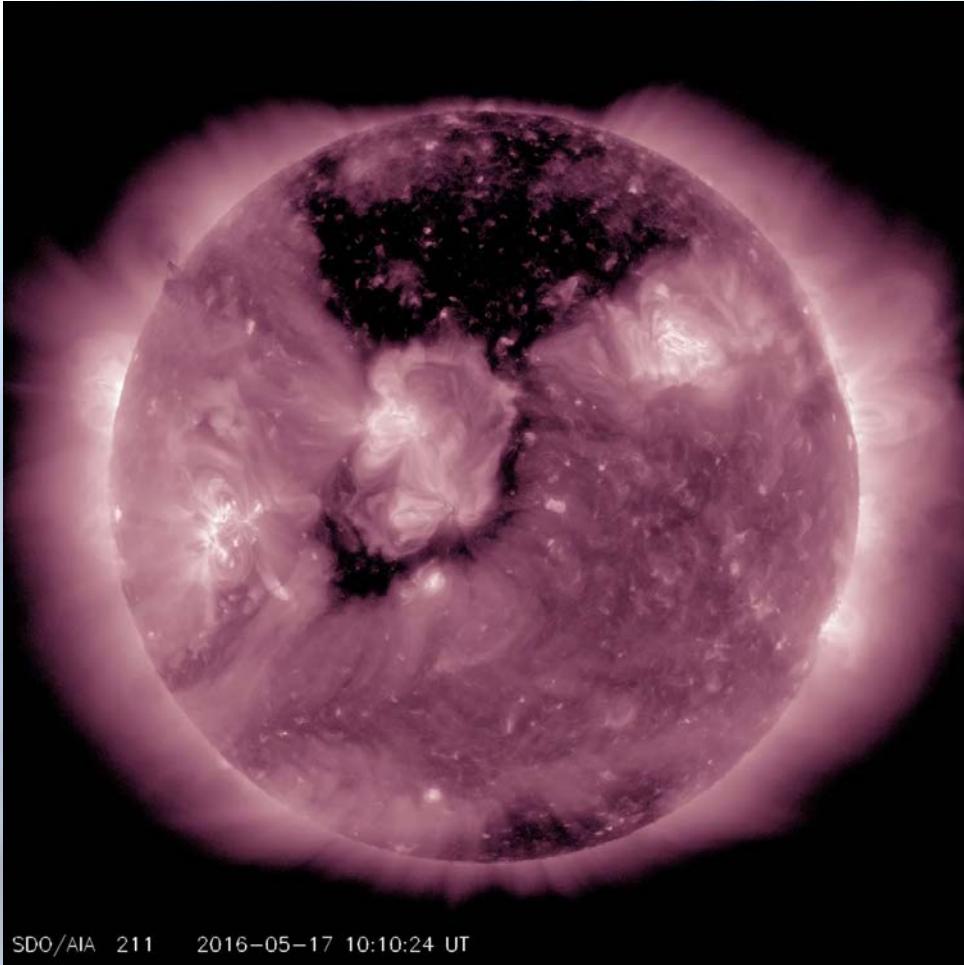
- compression regions formed from the interaction of high- and low-speed solar wind streams
- corotating with the Sun
- Major driver of solar-wind disturbances and geomagnetic storms during solar minimum (low CME activity)



Pizzo, 1978

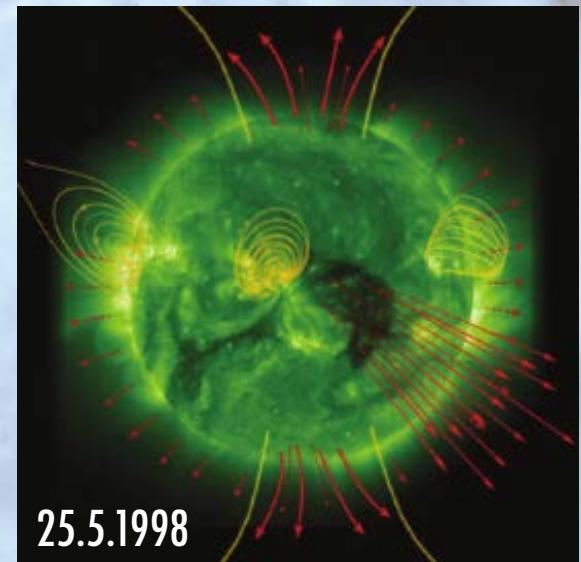
# Coronal Holes (CH)

Large CH, May 17 – 19, 2016



SDO/AIA 211 2016–05–17 10:10:24 UT

- source regions of the high-speed solar wind
- connected with open magnetic field form the Sun
- visible as dark regions in EUV or X-ray observations of the solar corona

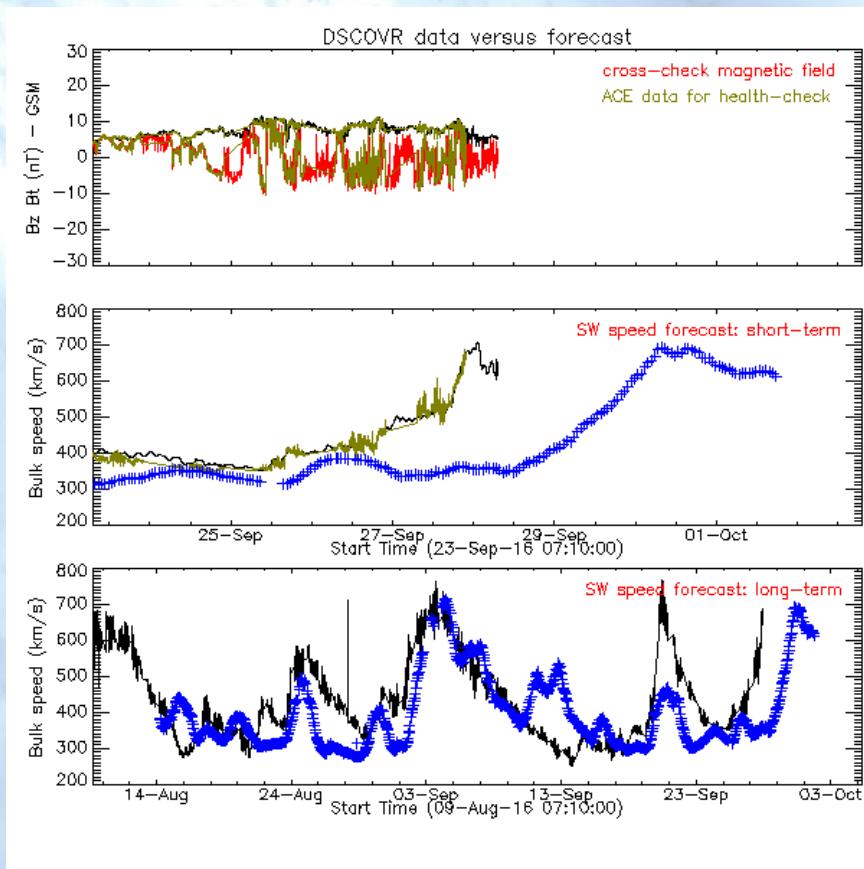
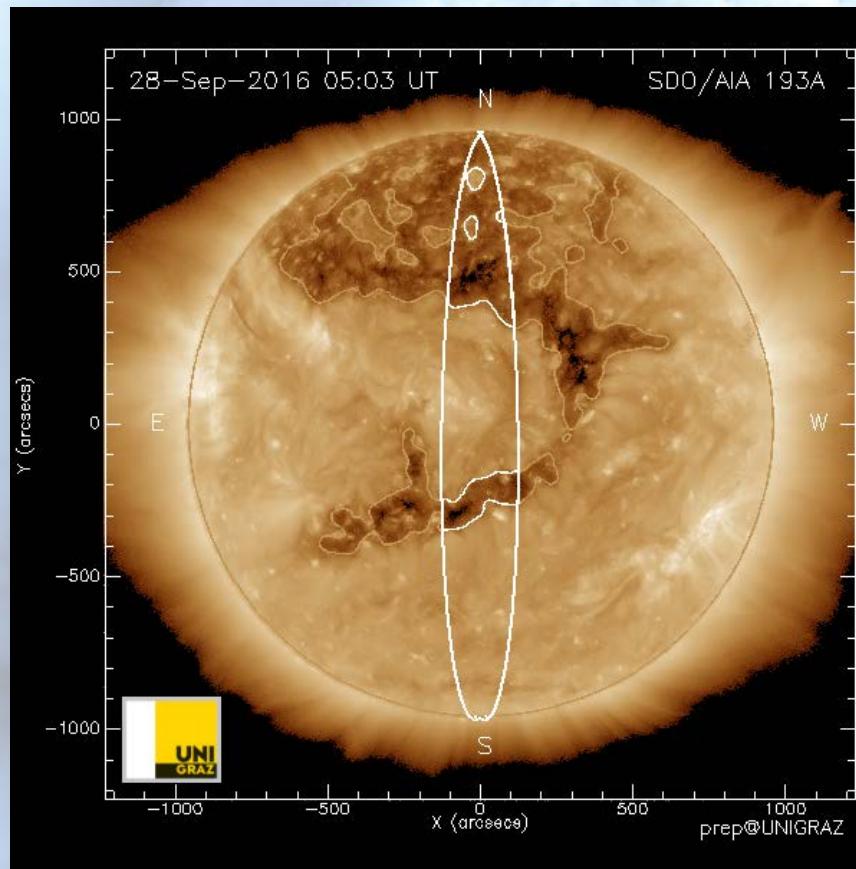


# Coronal holes and solar wind

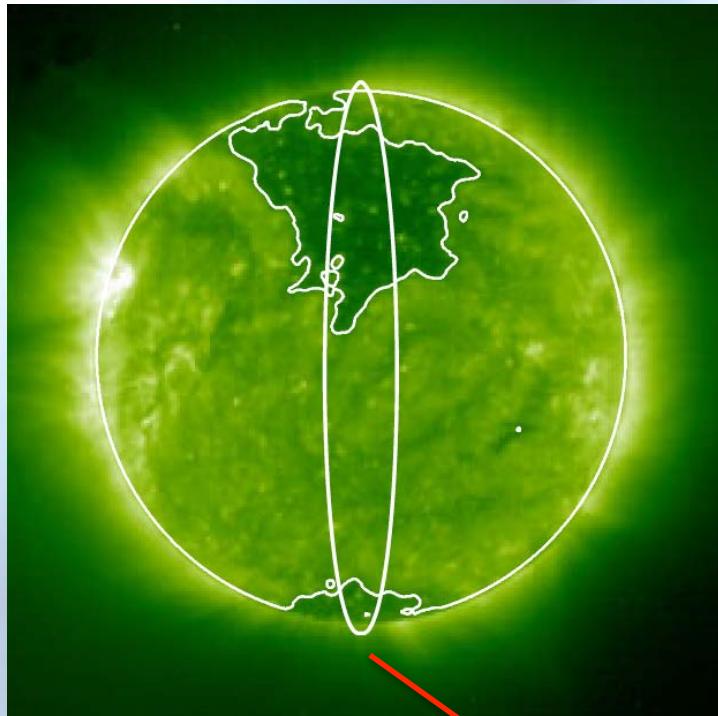
## Forecasting solar wind high-speed streams (ESWF)

<http://swe.uni-graz.at/index.php/services/solar-wind-forecast>

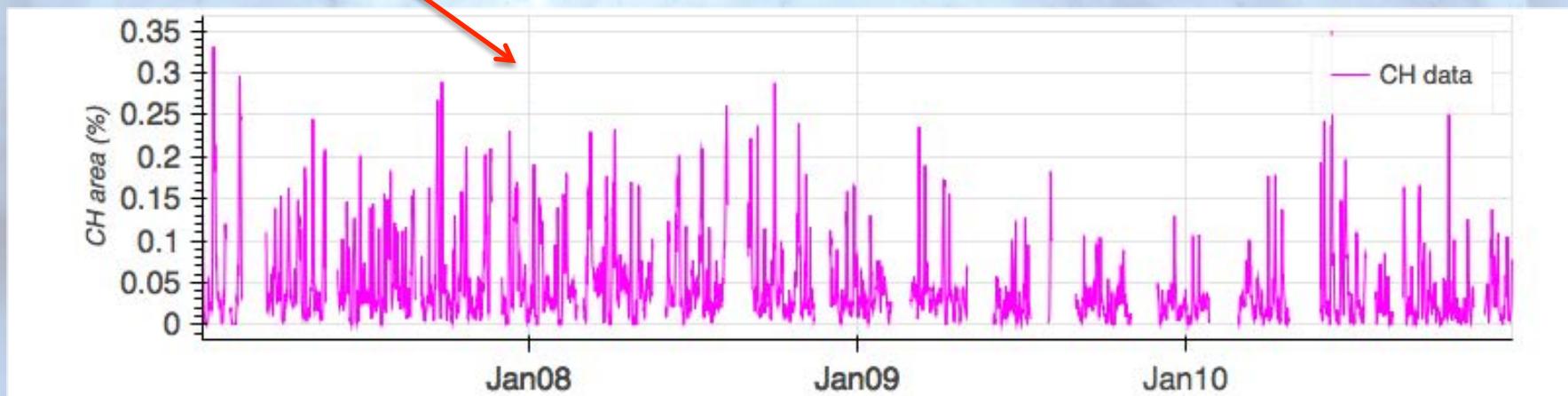
- based on an empirical relation between CH and high speed streams measured at Earth (Vršnak et al. 2007)
- CH areas are extracted from EUV images (Rotter et al., 2012; Reiss et al., 2015; 2016)



# CH area data

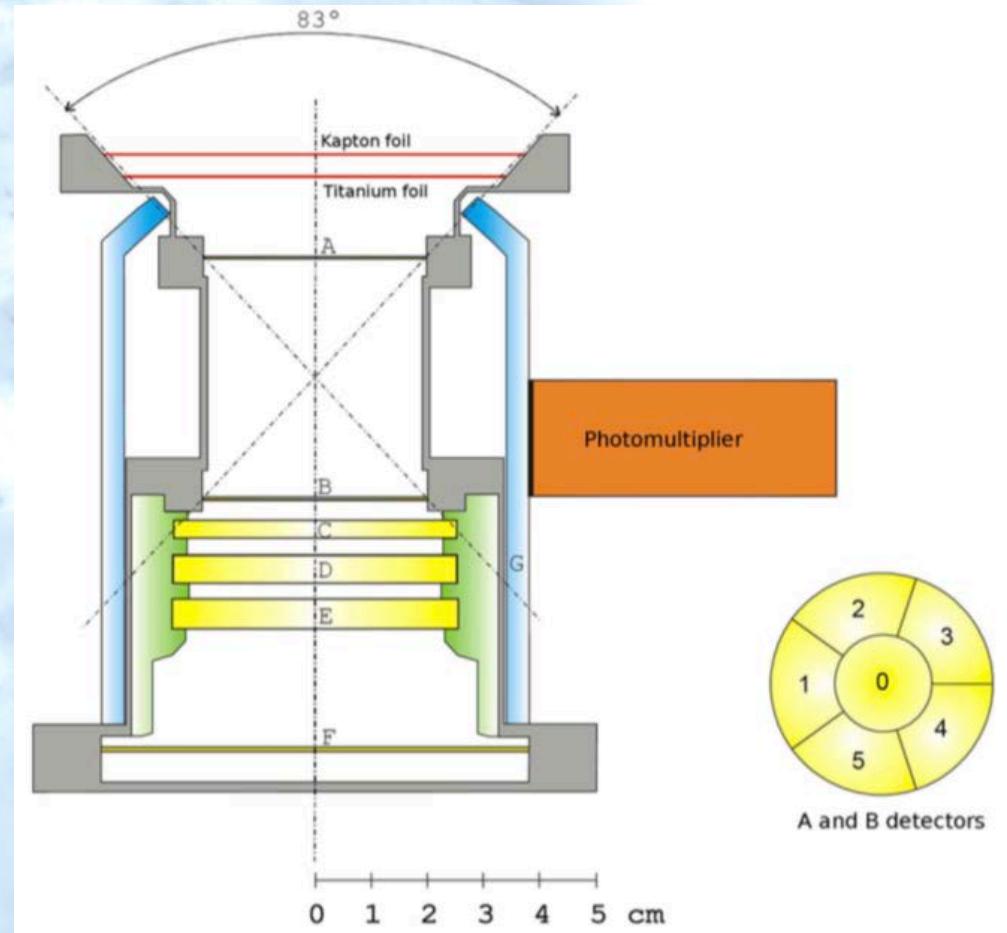
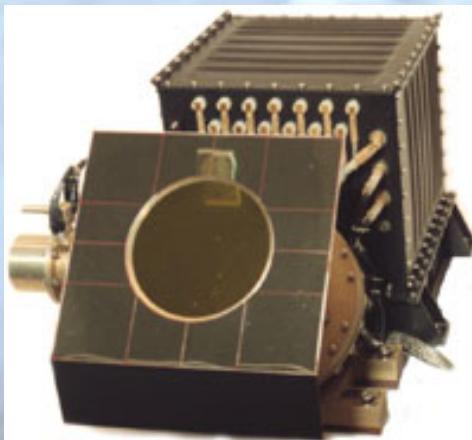


- extracted with SOHO EIT 195 Å images
- CH can be identified with intensity-based thresholding technique (Rotter et al., 2012, Reiss et al. 2016)
- fractional coronal hole area is derived from a central meridional slice ( $\pm 7.5^\circ$ ) corresponding to the solar rotation within approx. 1 day
- period of CH data: 1.1.2007 – 31.12.2010

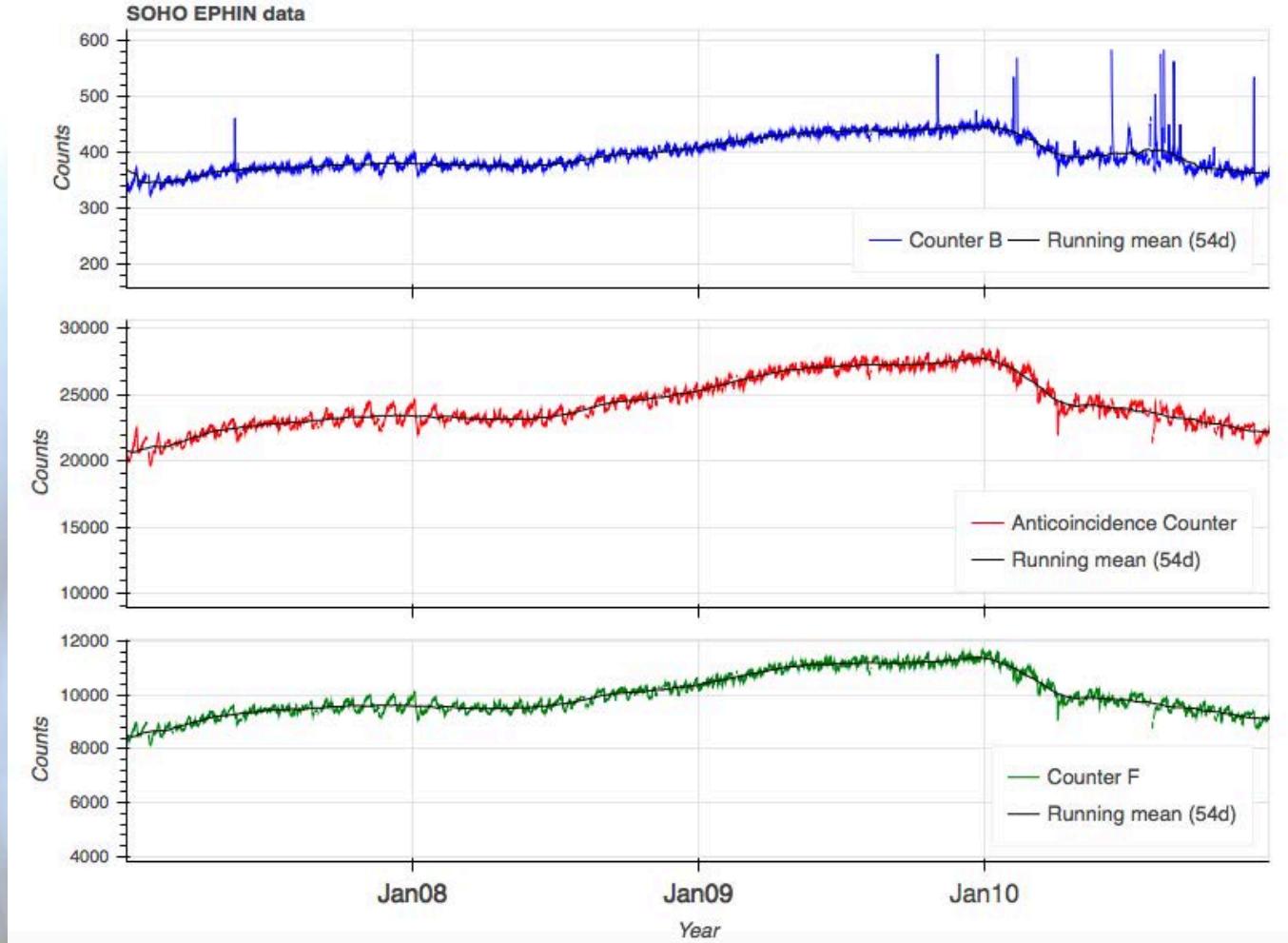


# SOHO EPHIN

- Electron Proton Helium Instrument (EPHIN)
- onboard SOHO spacecraft
- data available from December 07 1995
- consists of several semiconductor detectors in layers (A-F) and a scintillation detector, operated in anticoincidence



# SOHO EPHIN data



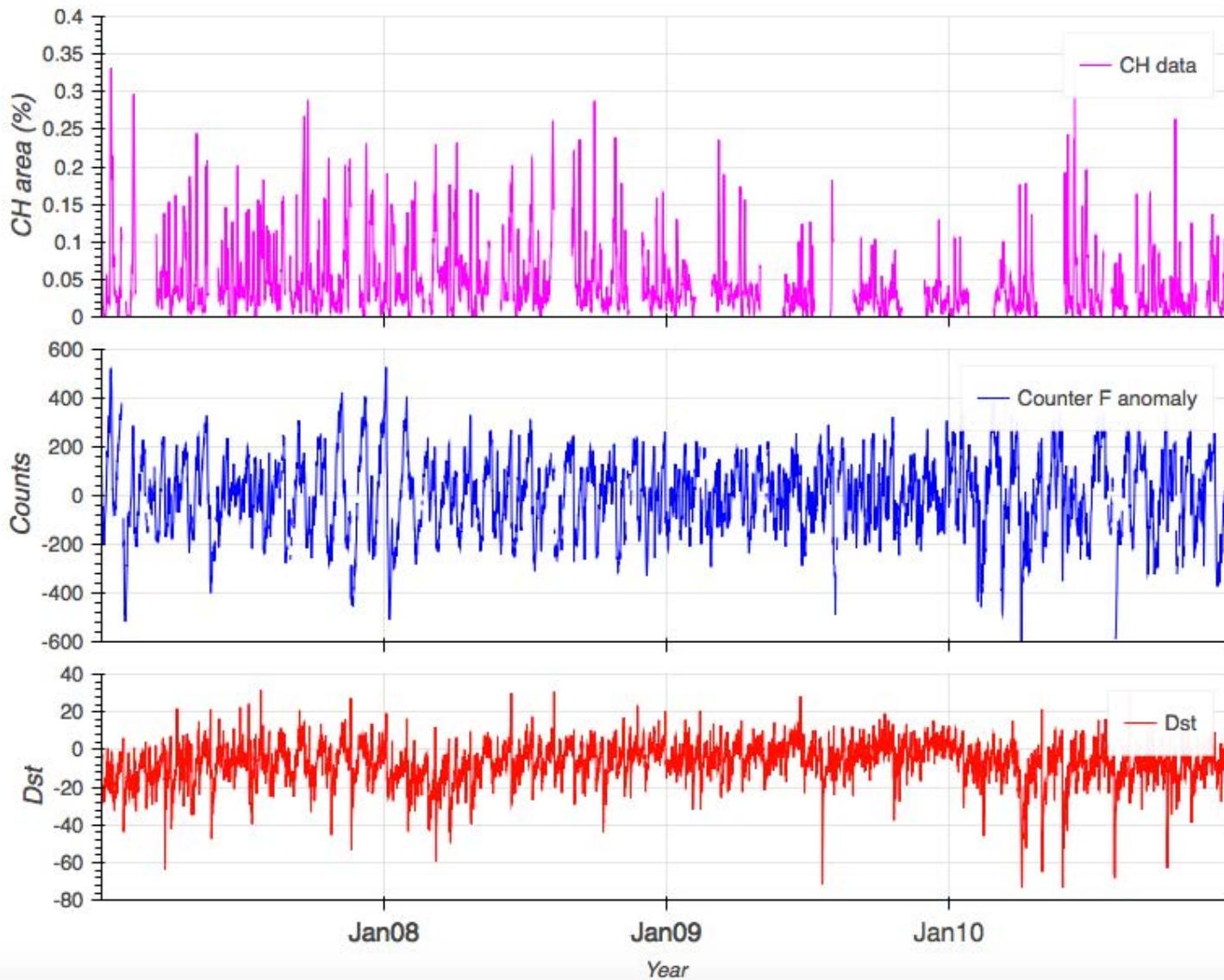
Counter B  
 $> 4 \text{ MeV/n}$

Anticoincidence  
Counter

Counter F  
 $> 50 \text{ MeV/n}$

- interpolation of small gaps in the data (up to 18h)
- anomalies are calculated subtracting the running mean (54 days)

# CH – EPHIN – Dst data (2007 – 2011)

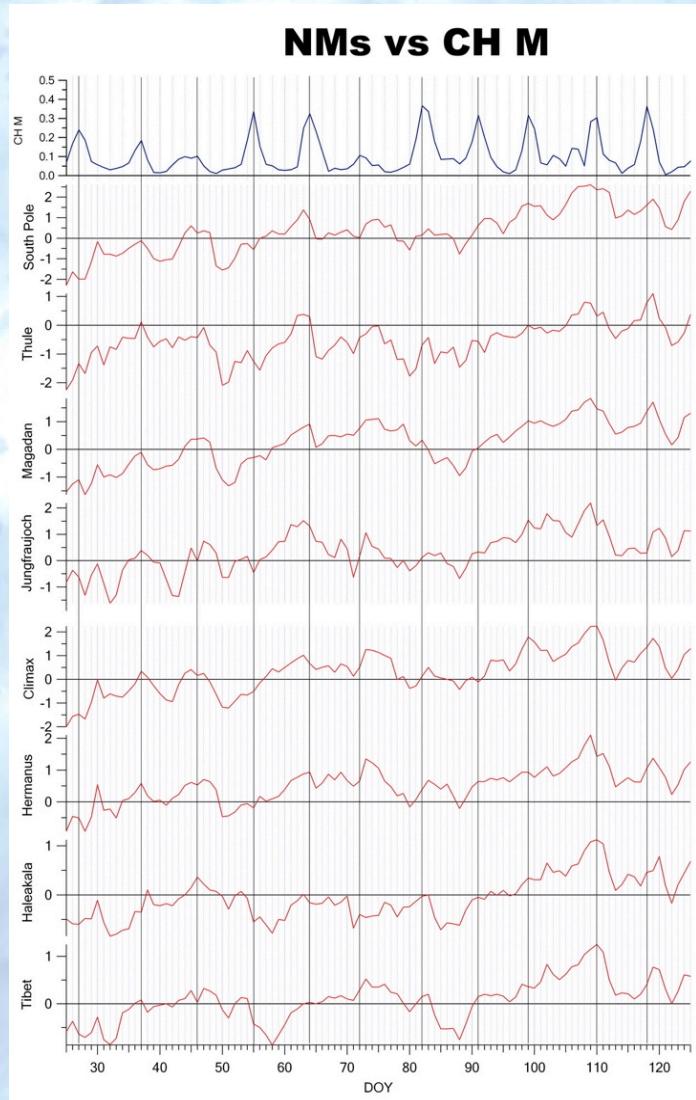
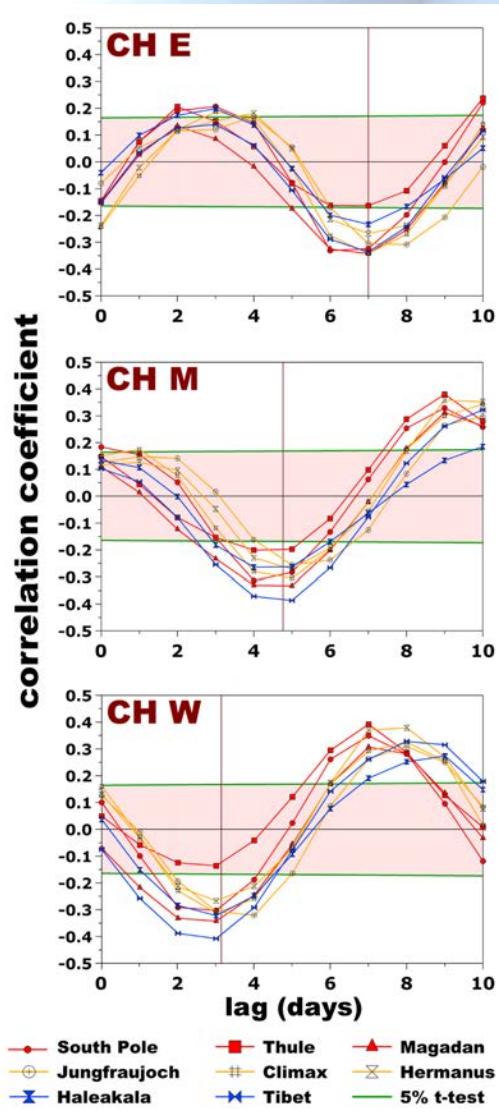


CH area  
23% missing  
data  
4 measurements  
per day

Counter F  
anomaly

Dst index

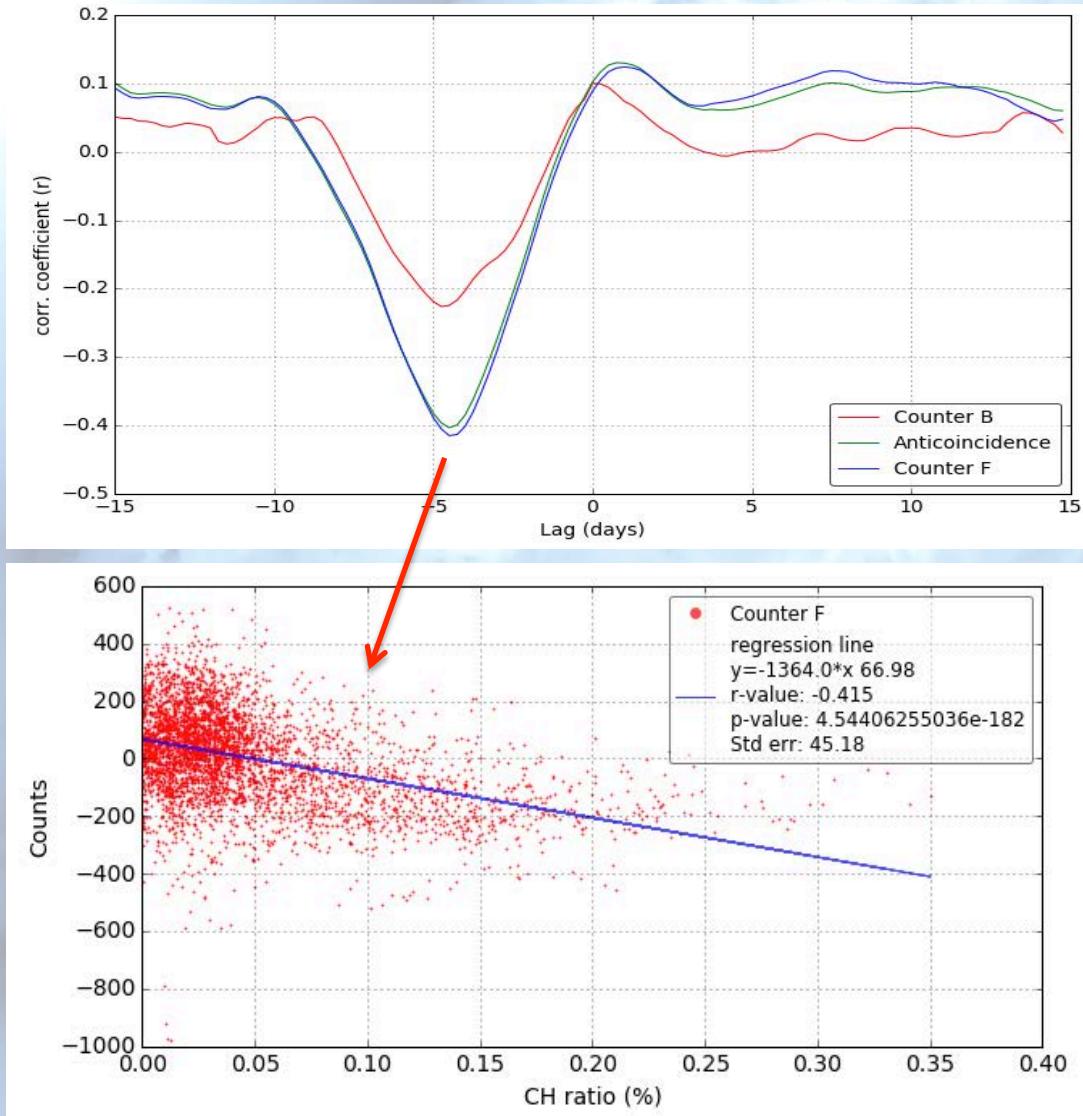
# CH and neutron monitor data



- Period of analysis:  
DOY 25 – 125 in  
2005
- GCR flux reduced  
by 0.5% – 2%
- Typical lag: 4 - 5  
days

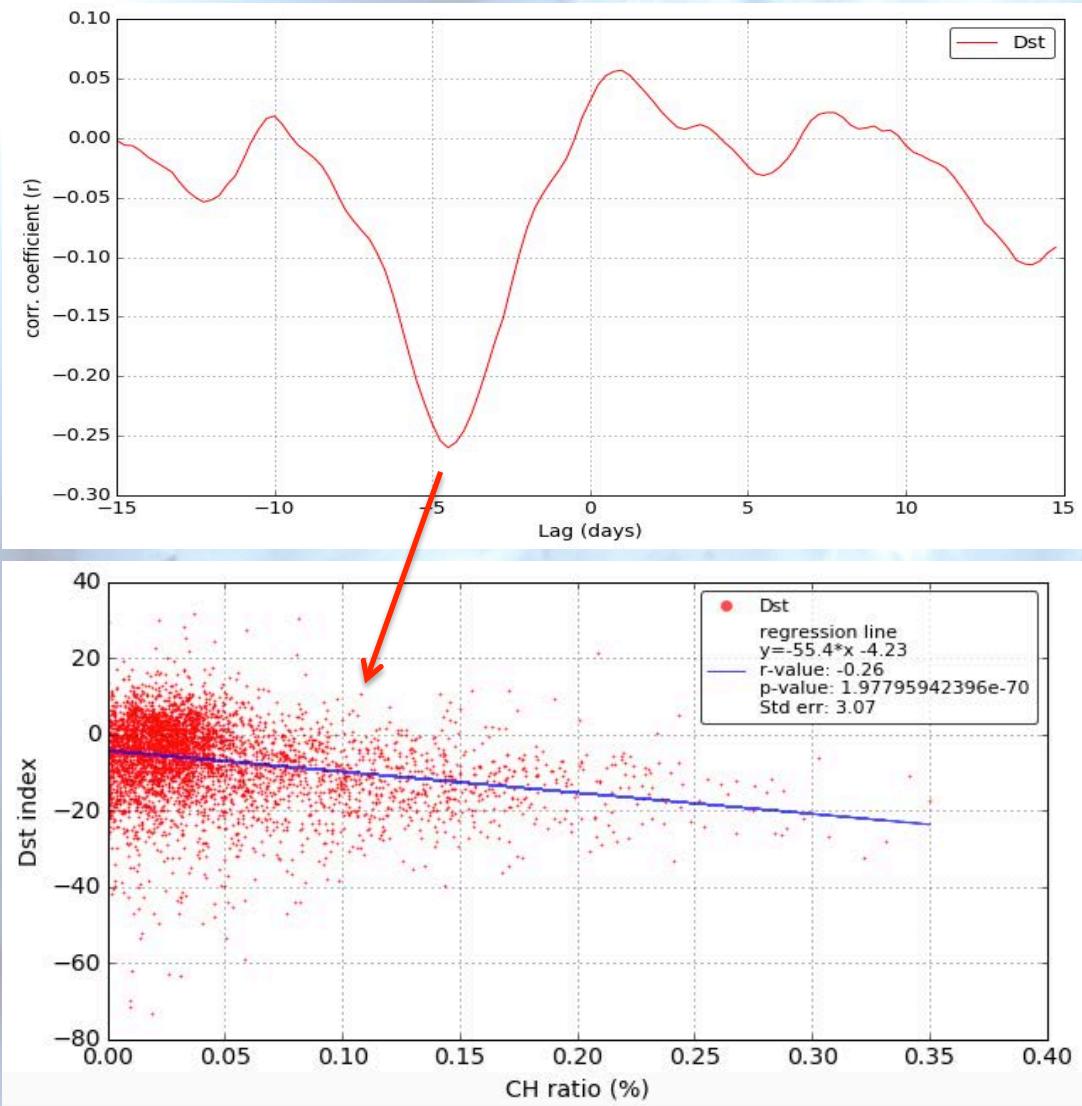
Čalogović et al. 2008

# CH area vs EPHIN



- Correlation with lag 4417 points (1104 days)
- Counter B:  
 $r = -0.23$  (lag -4.75 days)
- Anticoincidence Counter:  
 $r = -0.40$  (lag -4.50 days)
- Counter F:  
 $r = -0.42$  (lag -4.50 days)
- Difference in travel time ±1 days (solar wind speed)

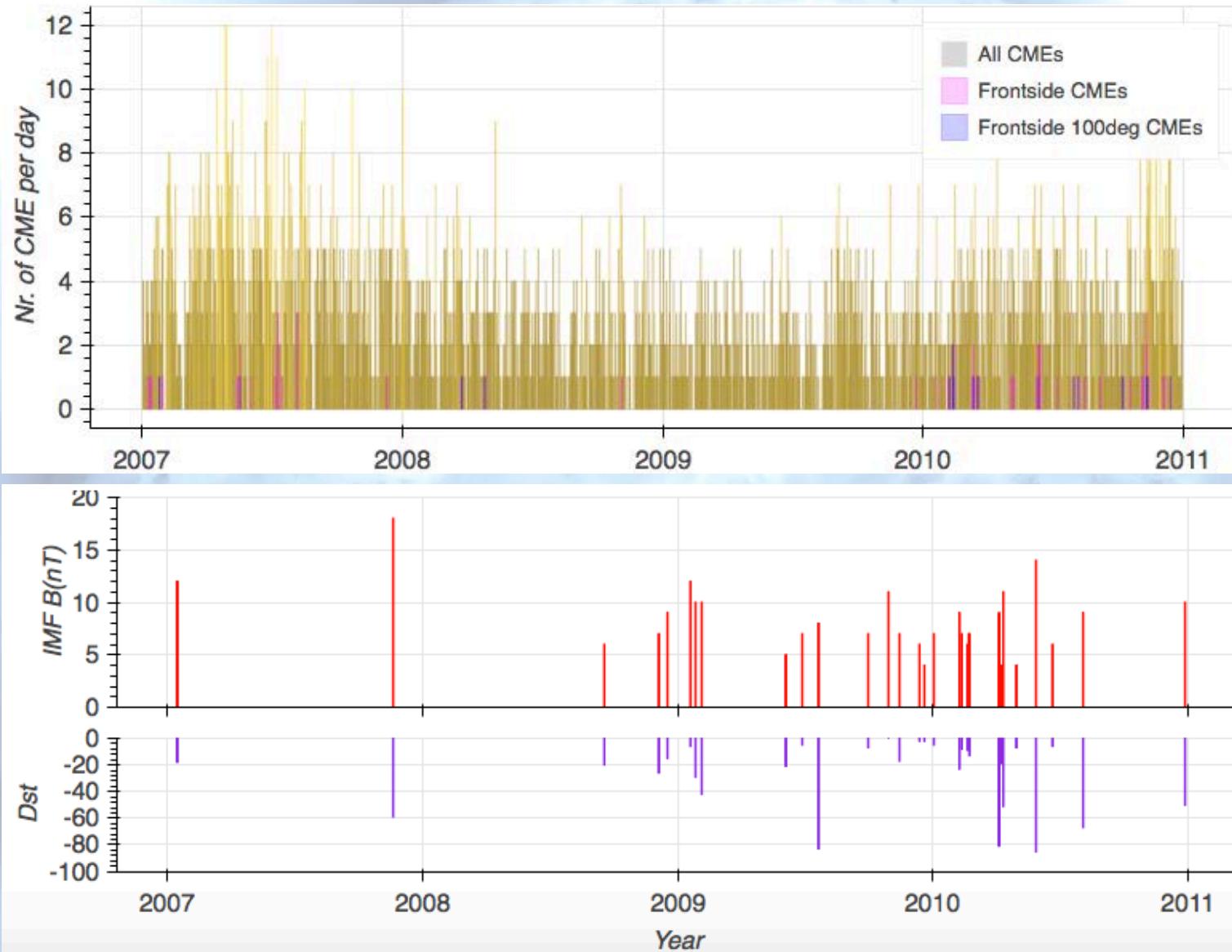
# CH area vs Dst



- Correlation with lag  
4417 points (1104 days)
- Dst  
 $r = -0.26$   
(lag -4.50 days)

# CMEs / ICMEs

major driver of solar wind disturbances

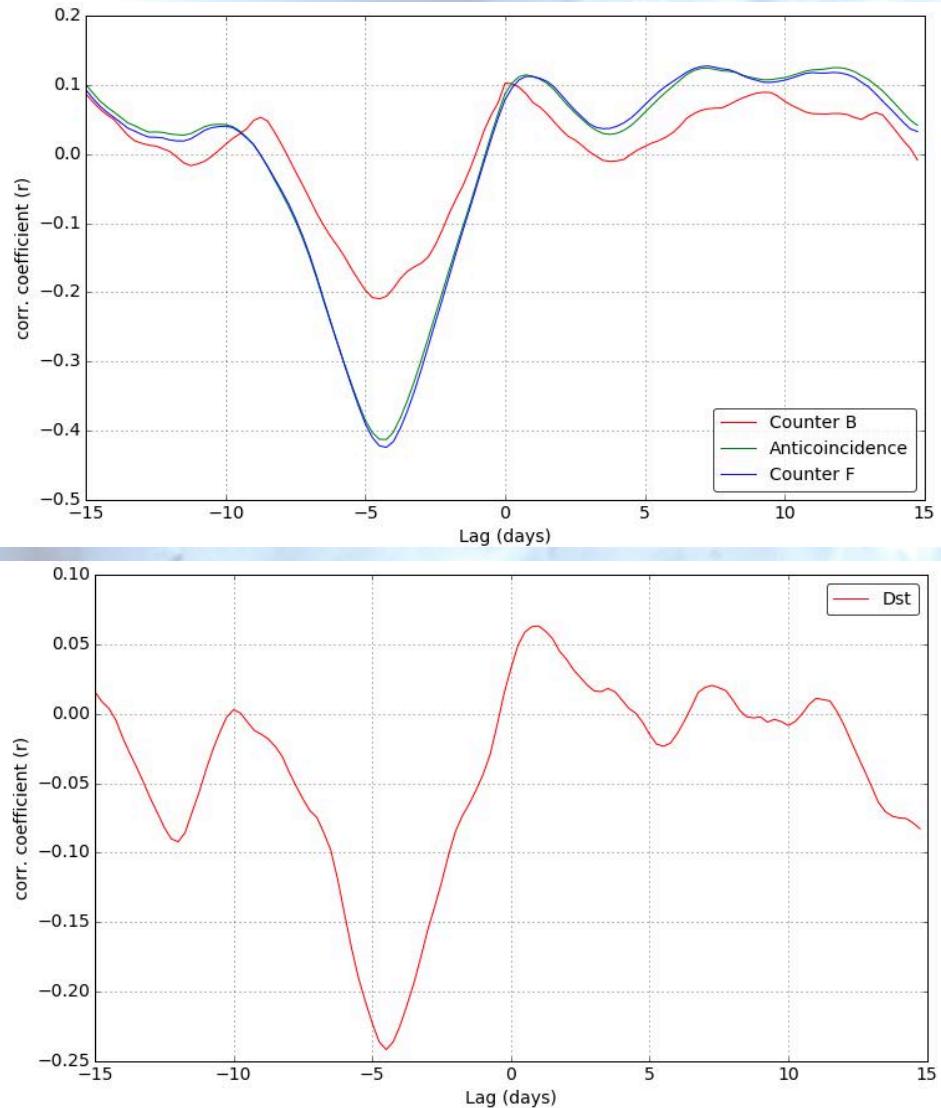


SOHO/  
LASCO CME  
daily data

ICME list  
(Richardson  
& Cane,  
2010)

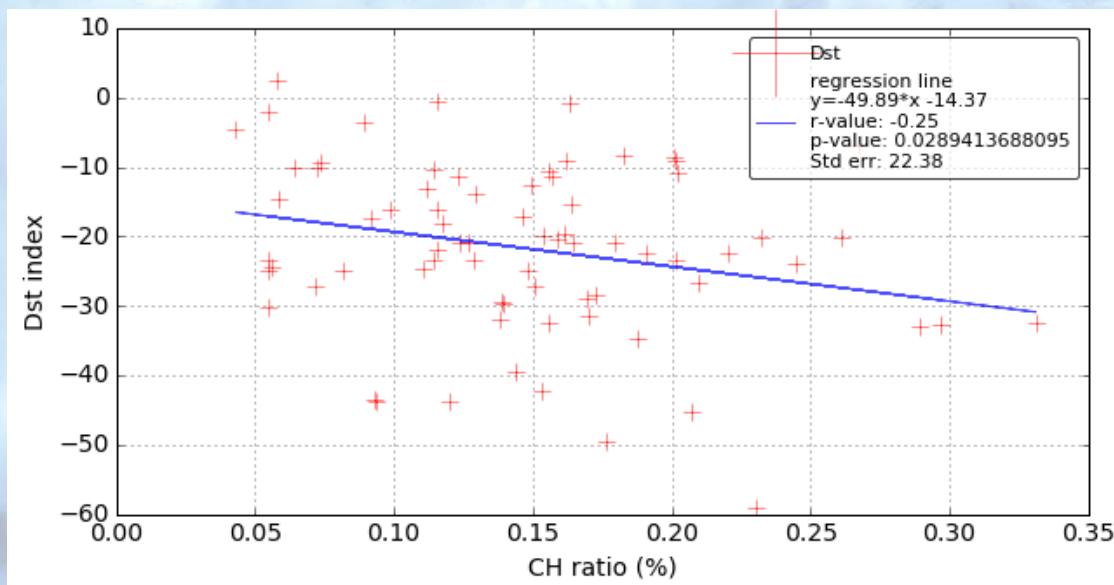
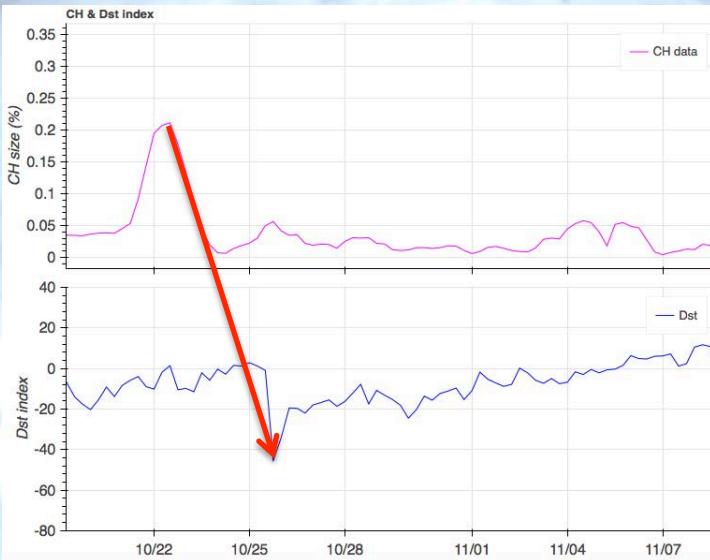
30 ICMEs  
during  
2007 -  
2011 period

# Correlation without ICME events



- 12h before ICME event removed
- 72h after ICME event removed
- in total 9.2% data excluded (101 days)
- Counter F:  
 $r = -0.42$  (lag -4.25 days)
- Dst  
 $r = -0.24$  (lag -4.50 days)
- Very small difference in correlation when using all data and data without ICME events (only 30 events)

# Peak to peak analysis



# Conclusions

- Longer analysis period 2007 – 2011 allows better statistics than in the previous studies
- Distinct correlation between Coronal Hole (CH) area and EPHIN cosmic ray flux measurements ( $r=0.4$ ) as well as Dst index ( $r=0.26$ )
- Max. correlation for lag of 4.5 days
- Opportunity to forecast a geoeffectiveness of CIRs as well as their effect on the cosmic-ray flux during the solar minimum in the absence of ICMEs
- Better forecast should be obtained by including the CH polarity data



**Thank you for your attention!**

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