

Are the sunspots vanishing ?

Sunspot Number Workshop

May 21st to 25th 2012

Brussels Belgium

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Why this question ?

What happened ?

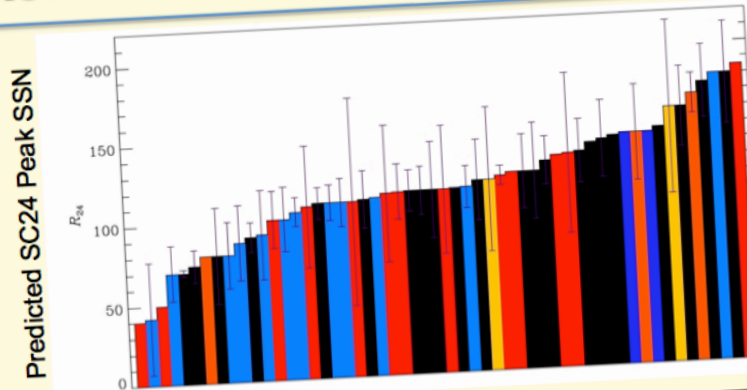
- ◆ Unpredicted abnormally long minimum after cycle 23
- ◆ Strange disruptions of mutual relations between indices:
 - ◆ for example $F_{10.7}$ ($\sim 25\% > R_i$)
 - ◆ but also NOAA vs. R_i
 - ◆ and others.
- ◆ Lots of solar indices reached unprecedented low levels (TEC, TSI, foF2, EUV flux...)

Why this question ?

What happened ?

- ◆ Unpredicted abnormally long minimum after cycle 23

Ask 12 Scientists: Get 54 Answers



Empirical Methods

- ◆ Precursor (22)
- ◆ Climatology (13)
- ◆ Recent Climatology (2)
- ◆ Neural Network (2)
- ◆ Spectral (12)

Physics-Based Methods*

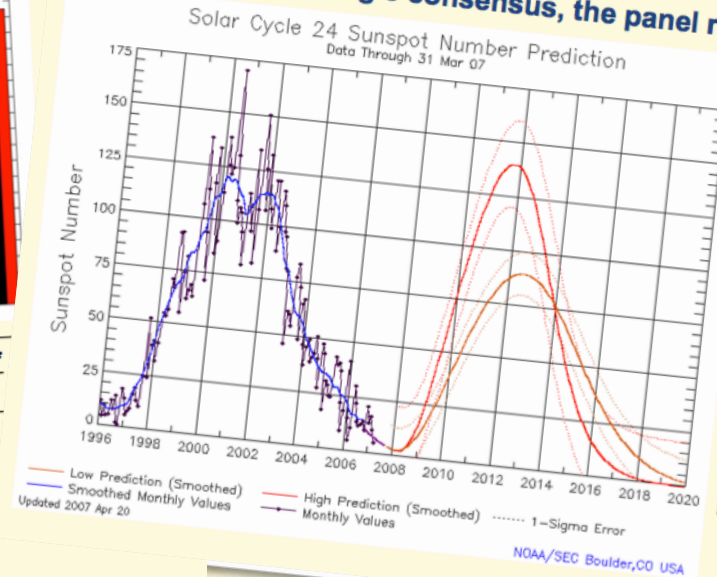
- ◆ Dynamo Model (3)

* SC24 was the first panel to solar dynamo models available making predictions.

Pesnell, W.D., Predictions of Solar Cycle 24, *Solar Phys.*, 252, 209-220, 2008.

2007 Panel Prediction: A Split Decision

Unable to reach a single consensus, the panel released two predictions.



- Solar Min:
 - Mar 2008 (± 6 mo)
- Low SC24 Peak:
 - SSN = 90 (± 10)
 - Aug 2012
- High SC24 Peak:
 - SSN = 140 (± 20)
 - Oct 2011

Note: The mean of cycles 1-23 predicts SSN = 115 ± 40 on Apr 2011.

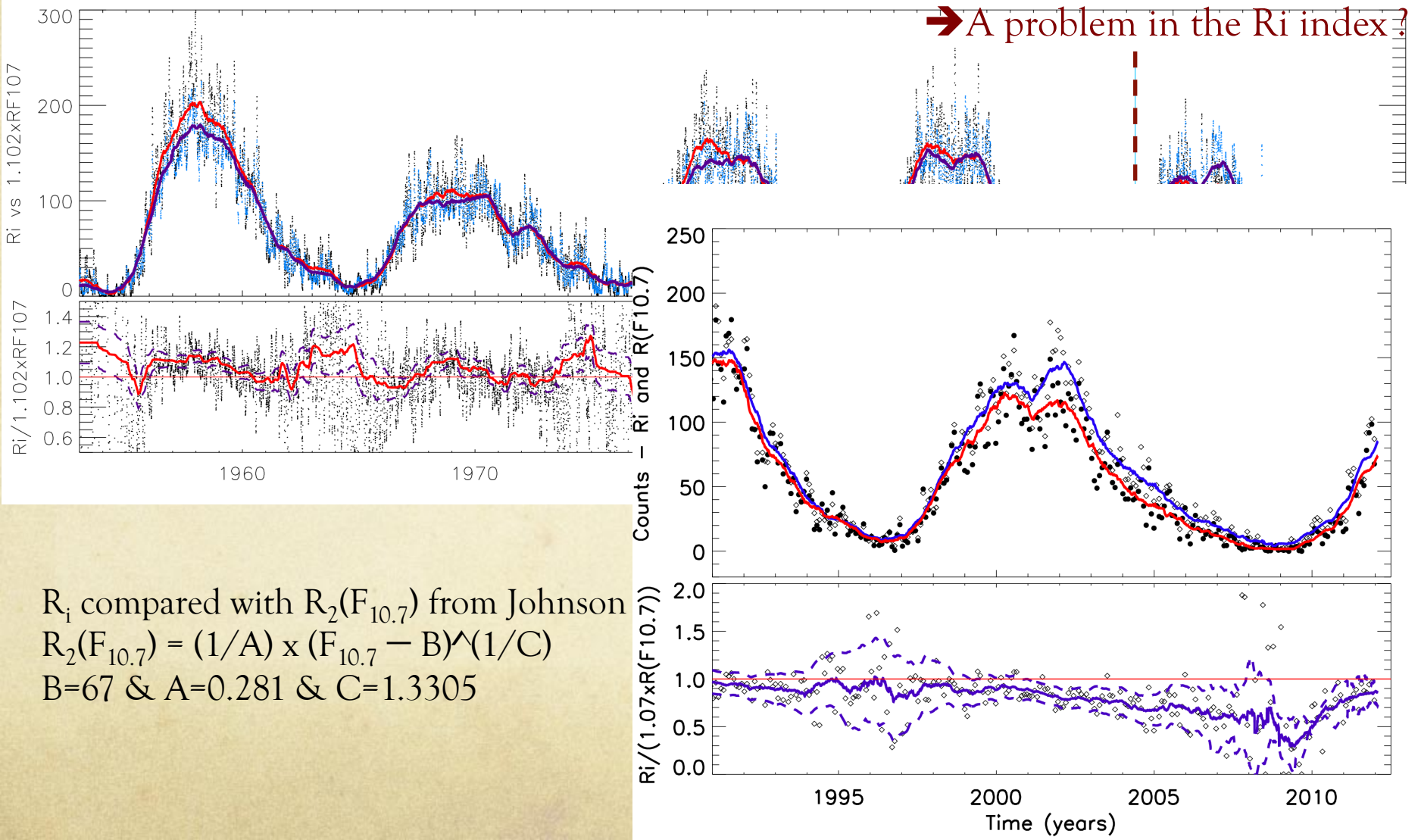
Minimum was predicted as March 2008 ± 6 months \rightarrow in reality it was more 2009 !

Why this question ?

What happened ?

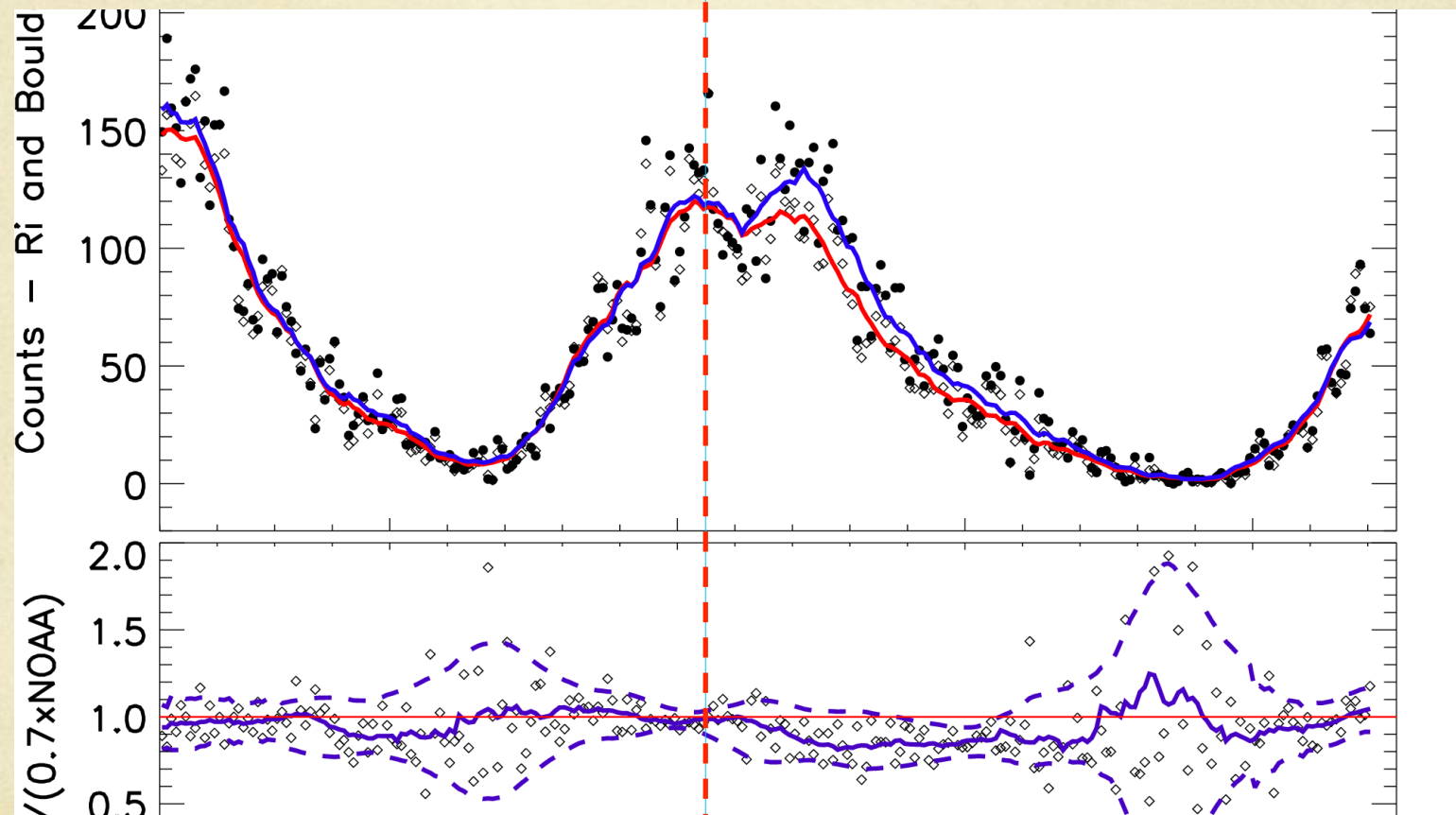
- ◆ Strange disruptions of mutual relations between indices:
 - ◆ for example $F_{10.7}$ ($\sim 25\% > R_i$)
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 - ◆ and others.

Unprecedented disagreement between R_i and $F_{10.7}$



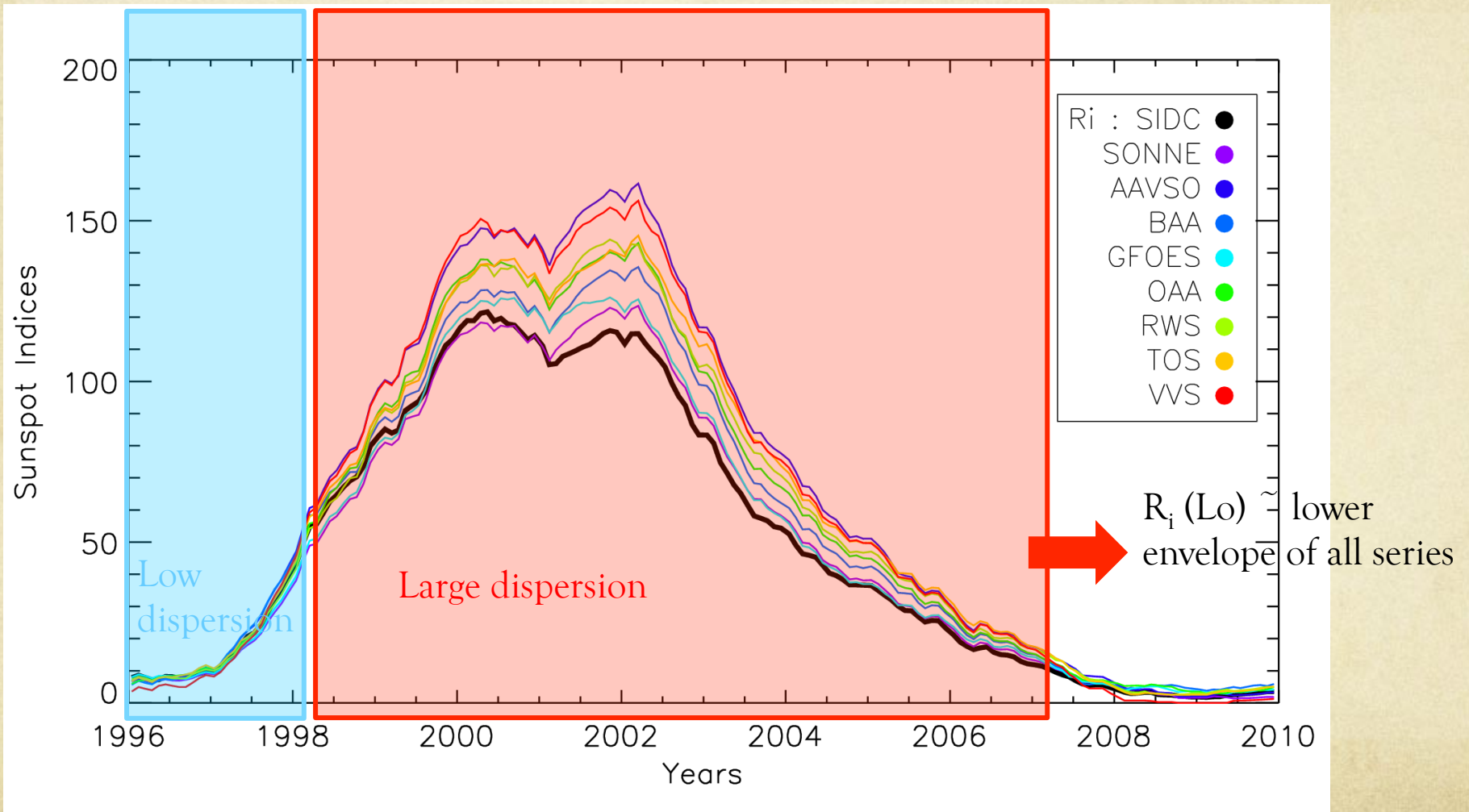
Indices disagreements : R_i vs. NOAA

Boulder

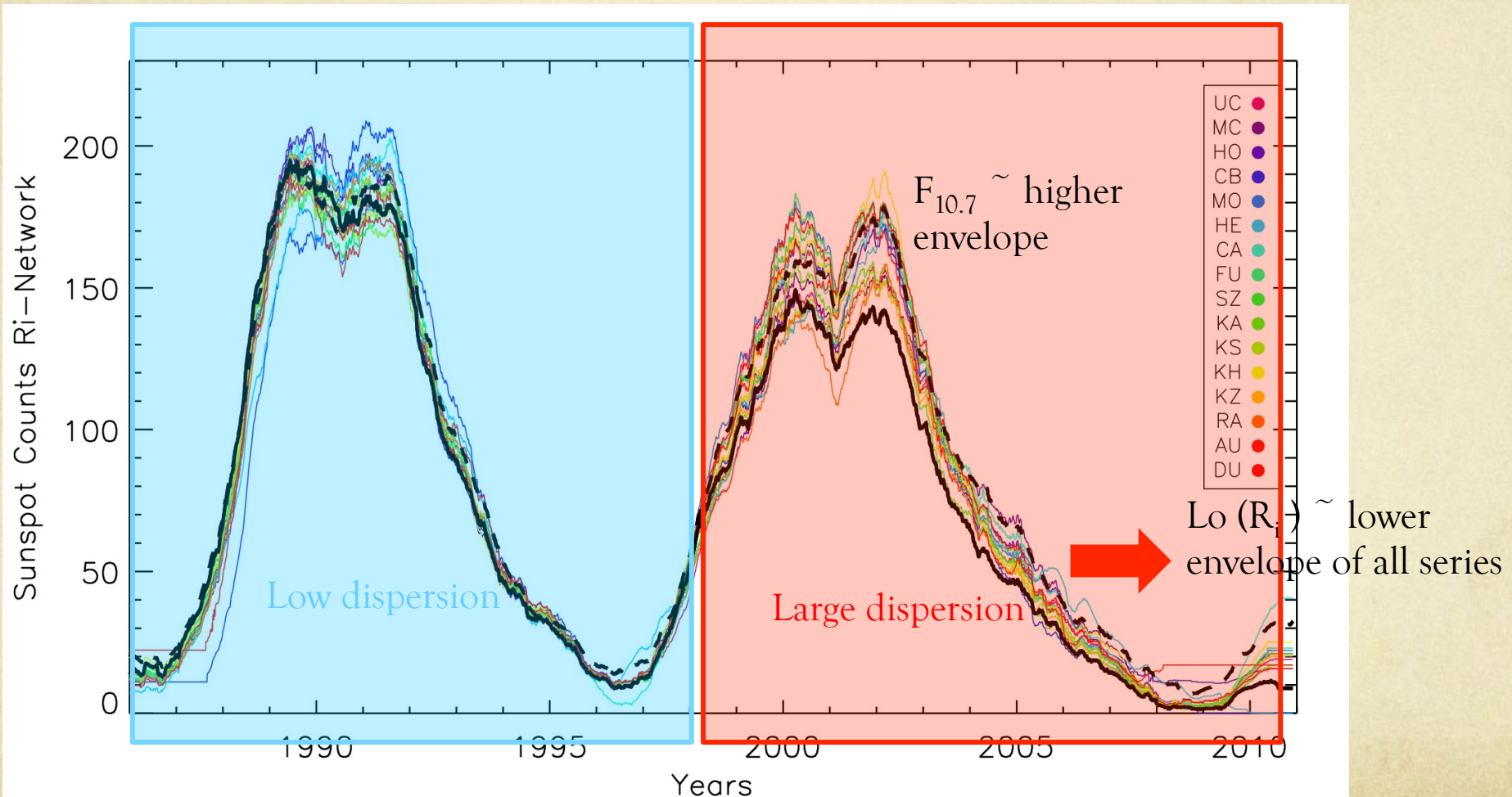


Ri got 20% lower than NOAA

Indices disagreements: outside the R_i -network

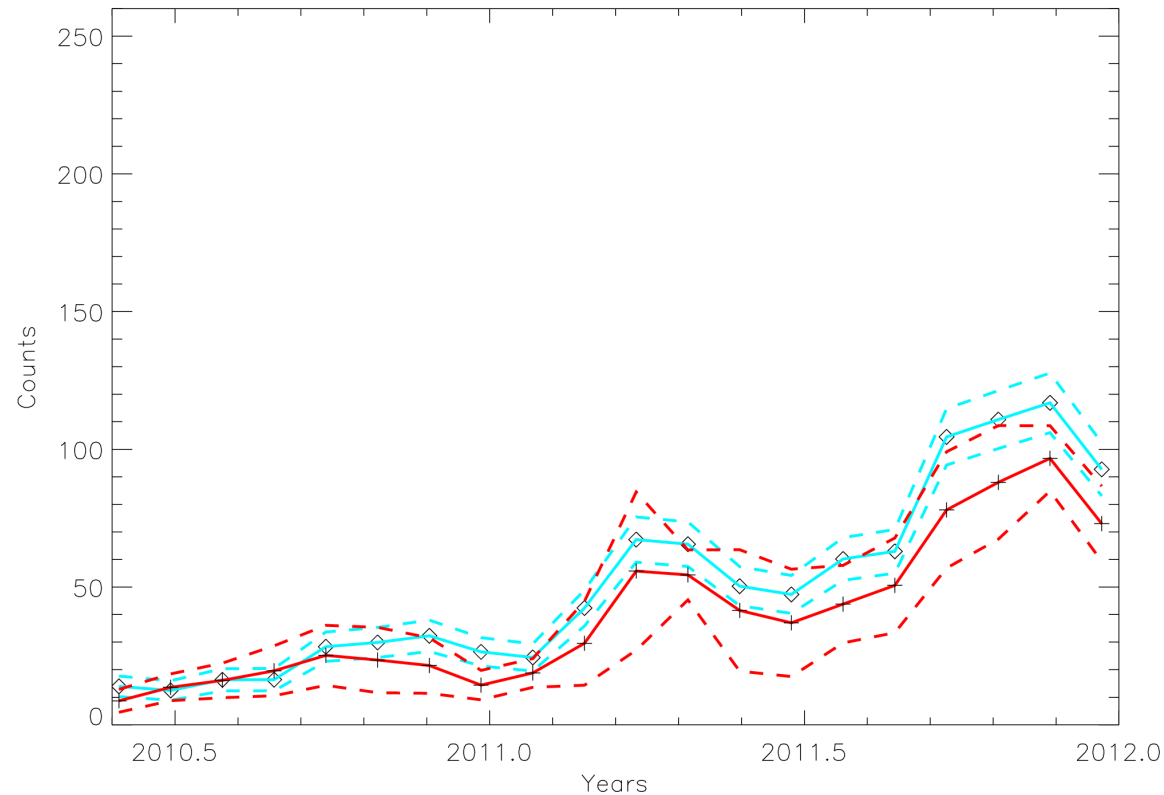
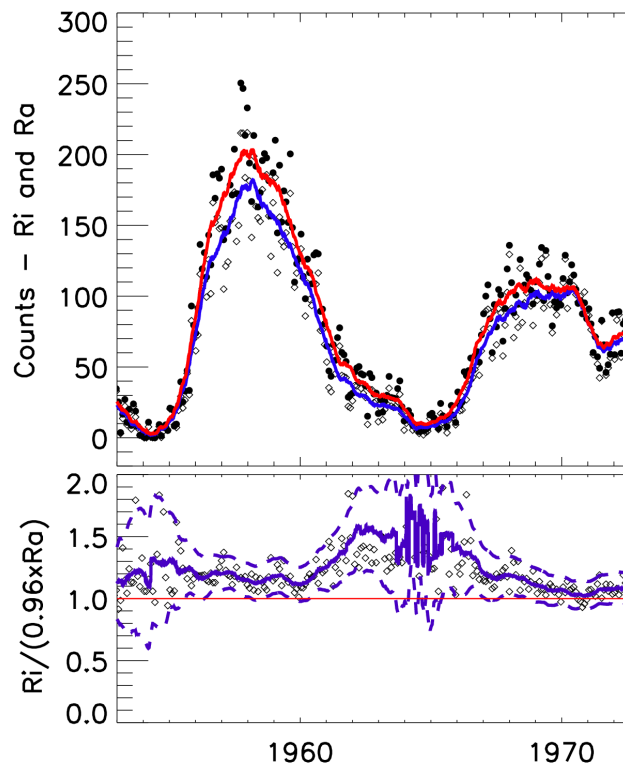


Indices disagreements: inside the R_i -network



16 Stations : Kawaguchi, Fujimori, Kislovodsk, Kandili, Kanzelhöhe, Uccle, Helwan (Egypt), Camaguey (Cuba,CB),Holloman, Mac Kenzie, Mochizuki, Ramey, Coonabarabran (Australia,AU), Dubois (Belgium), Suzuki, Catania + **Locarno** + $R_2(F_{10.7})$

Ri compared to the AAVSO sunspot number Ra



Why this question ?

What happened ?

- ◆ Lots of solar indices reached unprecedented low levels (TEC, TSI, foF2, EUV flux...)

Does the $F_{10.7}$ index correctly describe solar EUV flux during the deep solar minimum of 2007–2009?

Yiding Chen,^{1,2} Libo Liu,¹ and Weixing Wan¹

Received 18 November 2010; revised 19 February 2011; accepted 1 March 2011; published 8 April 2011.

[1] This paper shows that the relationship between solar EUV flux and the $F_{10.7}$ index during the extended solar minimum (Smin) of 2007–2009 is different from that in the previous Smin. This difference is also seen in the relationship between f_oF_2 and $F_{10.7}$. We collected SOHO/SEM EUV observations and the $F_{10.7}$ index through June 2010, to

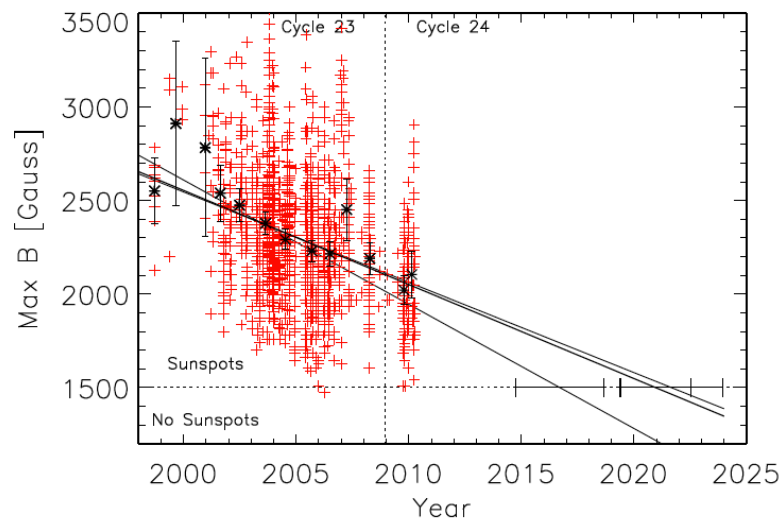
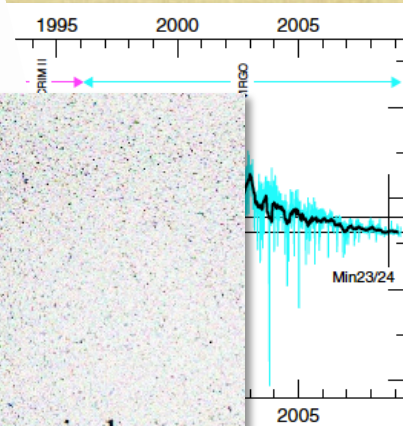


Fig. 1.— Measurements of the total magnetic field strength at the darkest location in umbrae and pores as a function of time. The crosses show the individual measurements, the asterisks show annual bins. Three linear fits are shown: the bottom fit line fits data from 1998–2006 as done in our 2006 paper. The top line fits all the data from Cycle 23, and the middle line fits all of the data.



end of March
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and then in-
the minima
and solar EUV
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the last one for the
recent Smin as it
 f_oF_2 . For the
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of this paper, we
behavior of the thermo-
minimum with that of the
of globally averaged

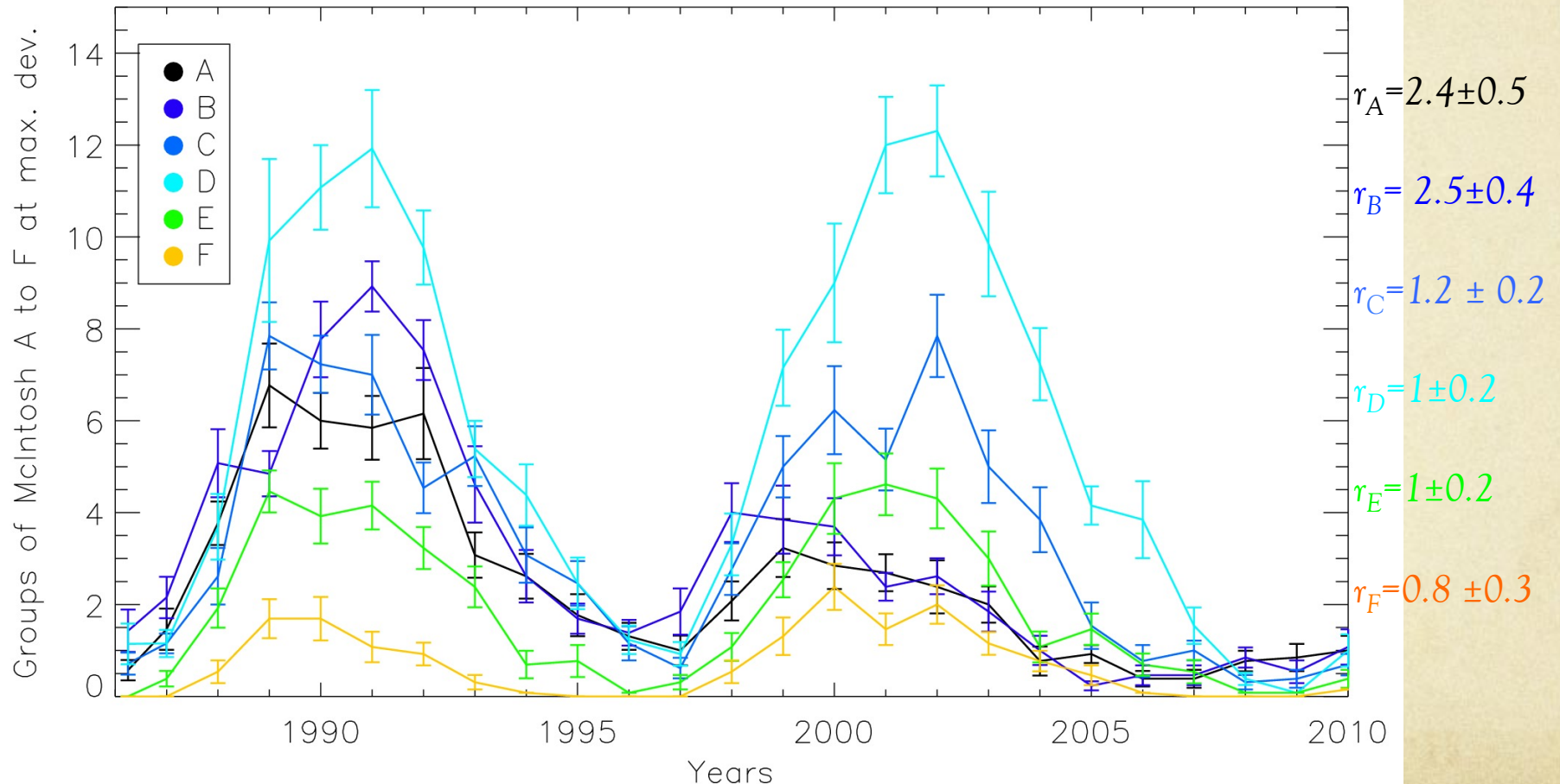
If it is not a technical problem, then
what is it? A physical change in the
Sun?

To answer this question we use the information about individual
sunspots that we have in **our merged catalog**.

Our merged catalog

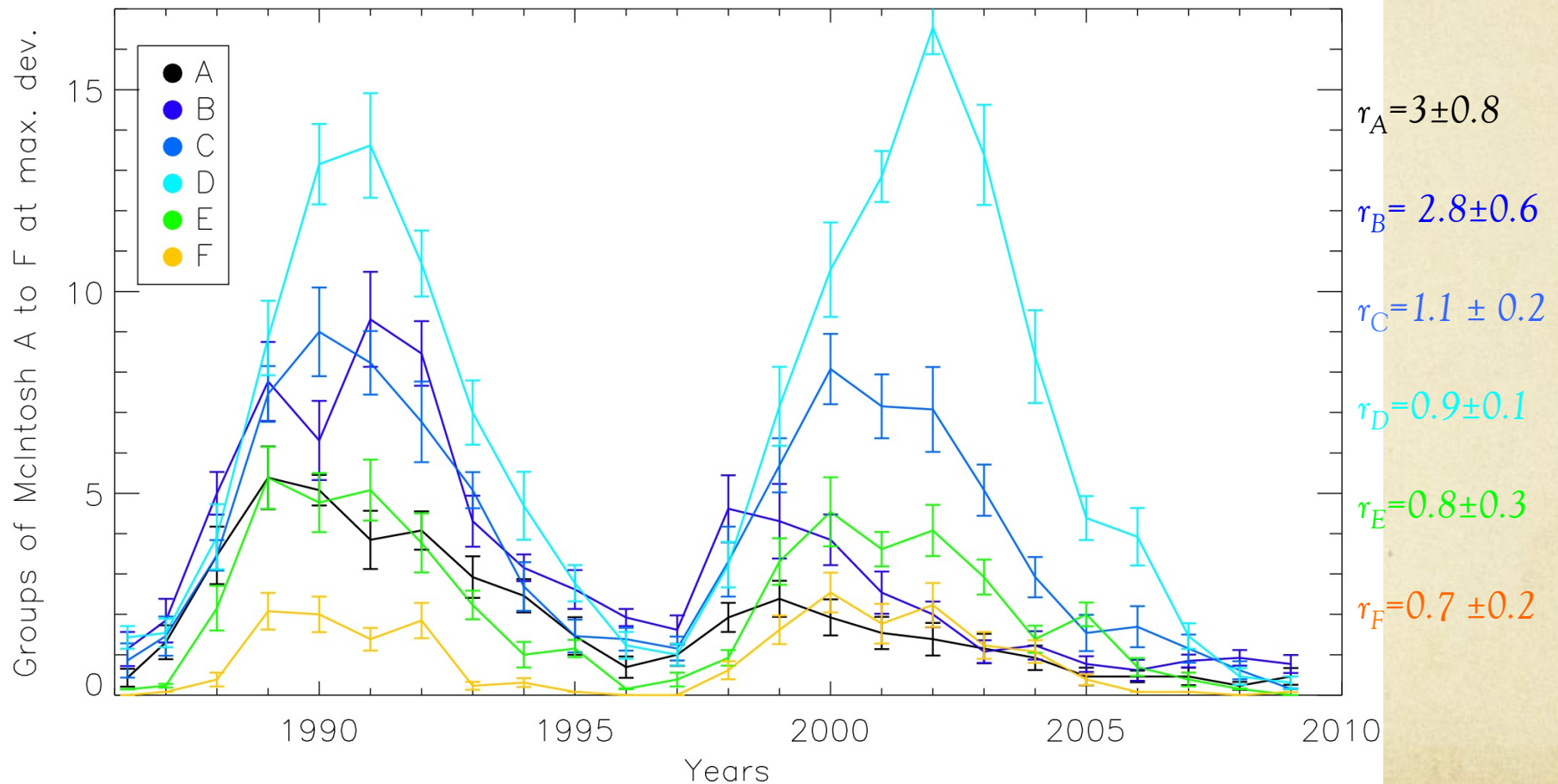
- Merged Catalog based on DPD and SOON-USAF
 - USAF -> end of 2010 (January 5th 2011) : Still waiting for answers on the rest of this dataset.
 - DPD -> 2012
 - Merged catalog is till beg. of January 2011 at this point
- Details down to individual sunspots
- Added information about McIntosh types

Groups of each McIntosh type at maximum development (Merged catalog)

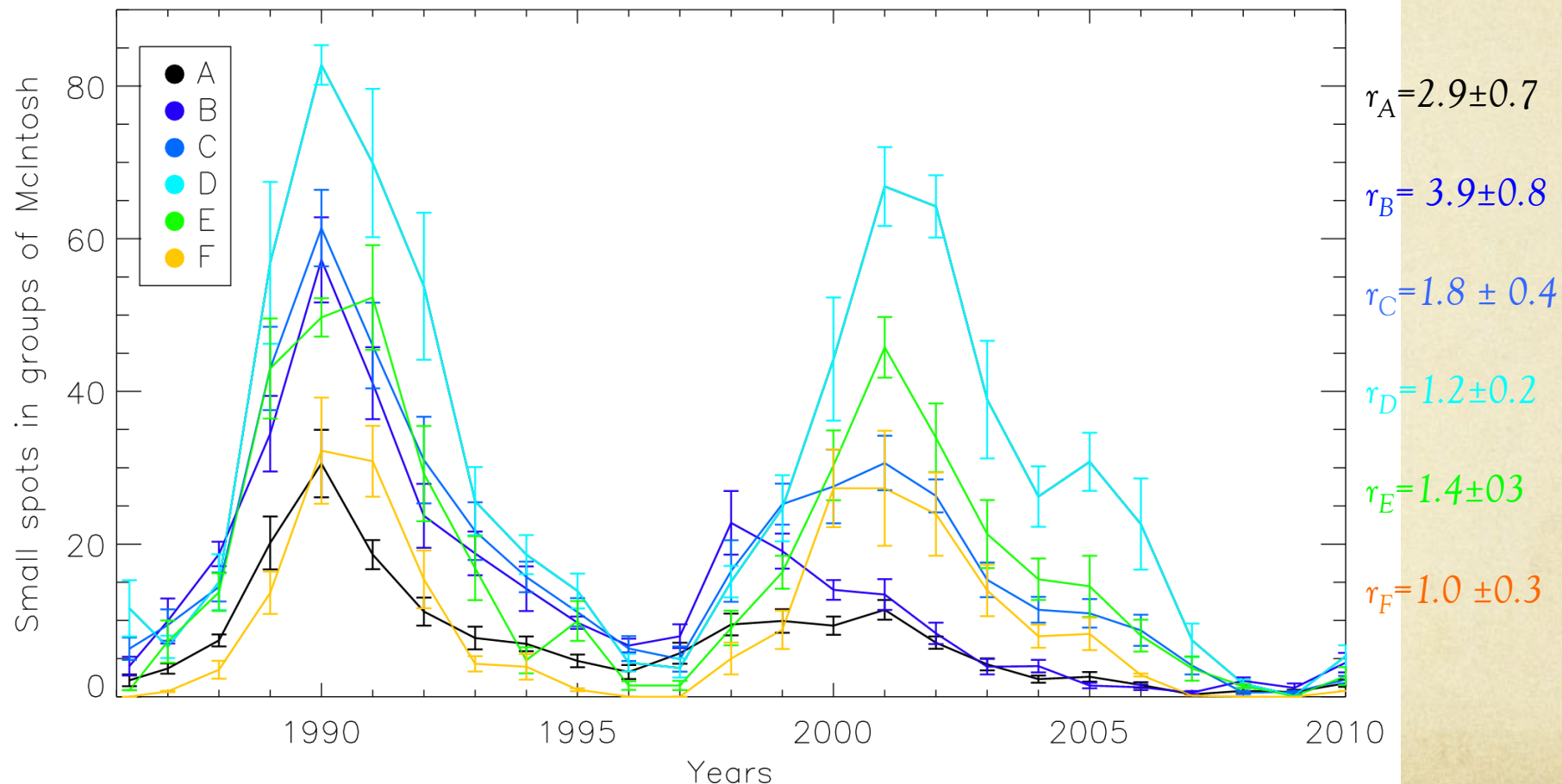


Each group is counted only once: when it reaches its maximum area. Ratios are for max22 (1989-1991) and max23 (2000-2002).

Groups of each McIntosh type at maximum development (USAF)



Number of small spots in each type of group



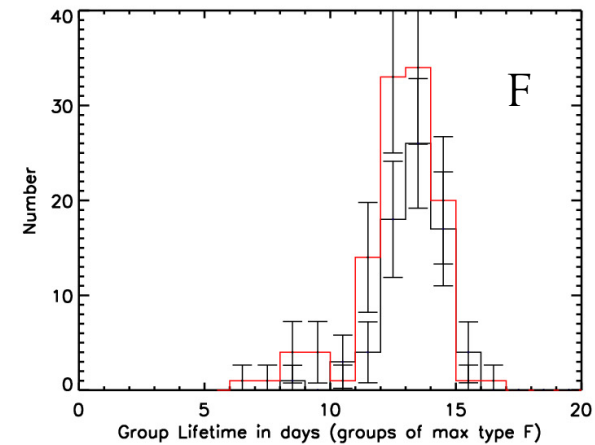
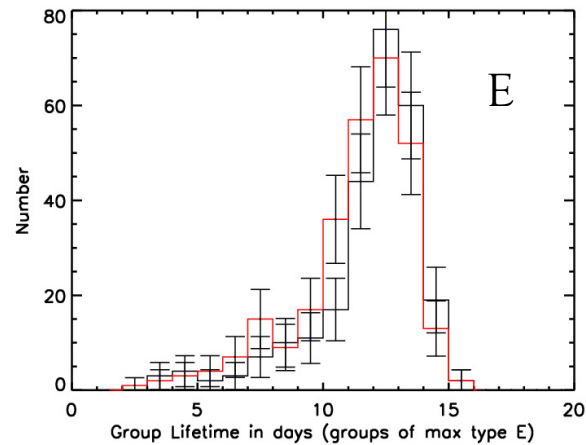
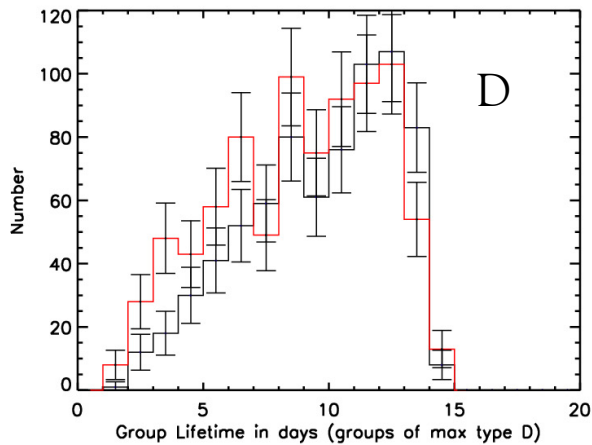
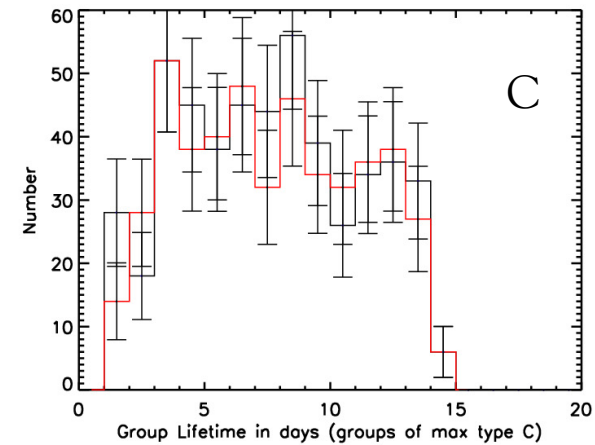
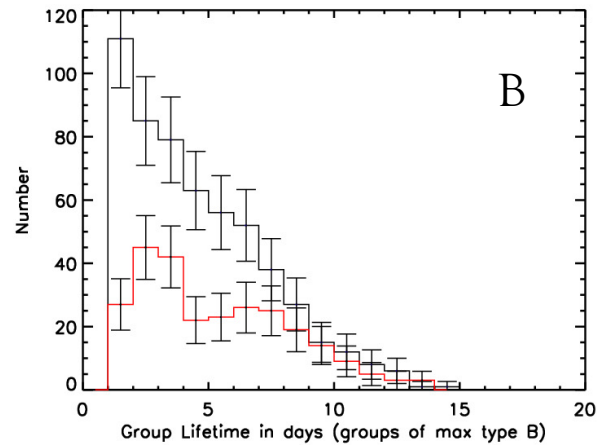
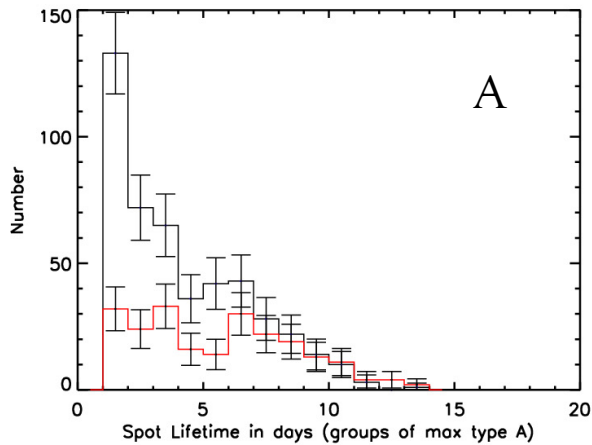
Small spots: $U+P \leq 17$ msh AND $(U+P)/U \leq 7$

Lifetimes of the groups

Merged catalog

Cycle 22

Cycle 23



Conclusions

- ◆ The aforementioned symptoms seem to be caused by a global small sunspot deficit.
- ◆ The small sunspot deficit naturally explains the discrepancies between R_i and other indices that put less weight on the smallest magnetic features.
- ◆ It reveals an anomaly in cycle 23, begun long before the new cycle, that suggests the Sun switched to a new regime. Also note that the mentioned disagreements started to disappear recently.
- ◆ In the context of this workshop, what we should keep in mind is that what appears as a deviation in a sunspot index dataset, or a discrepancy between indices, is not necessarily caused by a technical problem in the data.
(different indices = different processes)
- ◆ And also, that keeping the drawings is important (details of sunspots), because the sunspot series cannot give us the whole story.

Small Sunspots

Sunspots vanish

The End
spots vanish

New issues

- The scale dependence of the observed change implies the existence of two different dynamos: deep and superficial (Schatten, 2005).

New issues

- Cycle 23 shares properties with cycles of the 19th and early 20th century. Did such a small spot deficit occur for those cycles ? Can it explain some enduring discrepancies between historical index series (R_i vs. R_G , Sunspot area, aa) ?
- NB: the transition to large solar cycles seems to coincide with the *Waldmeier transition*... (1945)

Complementary Material

- Our merged catalog
- Why did we chose these criteria in size ?

DPD

lists of dates (days)

station name

lists of groups

- positions (lat, long, LCM)

- areas (U, U+P projected, U, U+P corrected)

lists of spots

- positions

- areas

+informations about the sun

USAF - Mt Wilson

lists of groups

- dates

- positions (lat, LCM)

- areas

- nb of spots

- morphological types

- longitudinal extent

- magnetic class

- Station name

+informations about the sun

Merged Catalog

lists of days

- nb of groups

lists of groups :

- positions

- areas

- nb of spots

- morphological types

- longitudinal extent (2 comp)

- dipole extent and tilt

- magnetic class

lists of spots

- positions

- areas

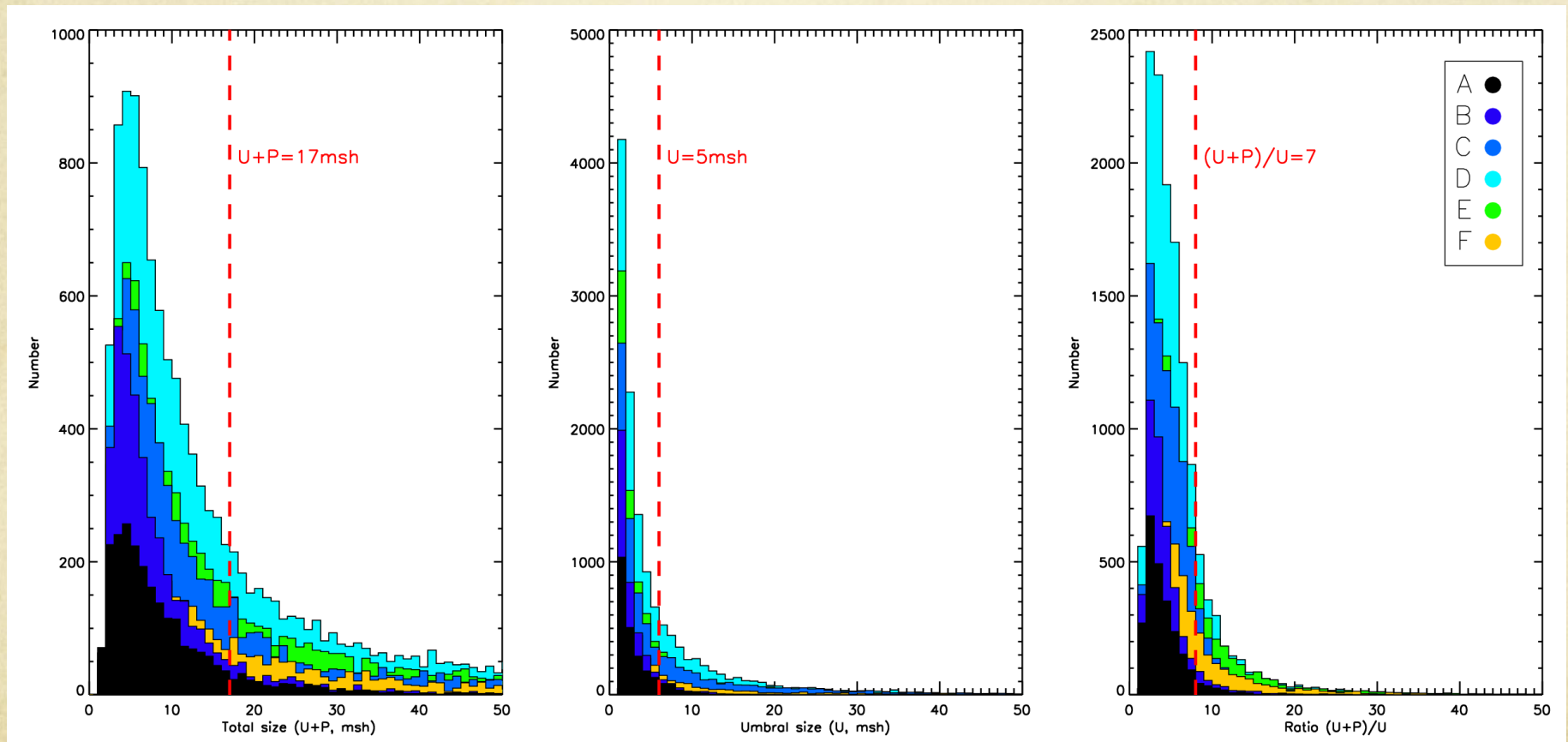
+informations about the sun

Matching groups

- Total : 54857 groups
- 78.8% of the groups can be matched without problems
- 13.5% are "penumbrae without umbrae" (pores)
- 4.3% are transitory objects (short lived sunspots or pores)
- 3.4% of cases are still to be studied (mainly different group splitting)
- → 96.5% of "real" groups are matched

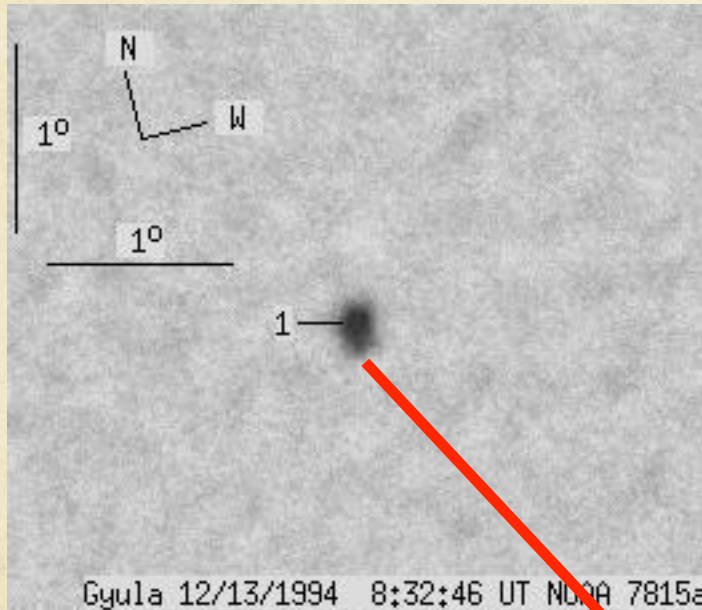
Distributions of Umbrae (U) and Penumbrae (P)

Merged / DPD catalogs



90% of A and B groups have $U+P \leq 17\text{ msh}$, $U \leq 5\text{ msh}$ and $(U+P)/U \leq 7$

DPD: $(U+P)/U$ criterion



- $(U+P)/U = 3$
- $U+P = 3U$
- $P=2U$

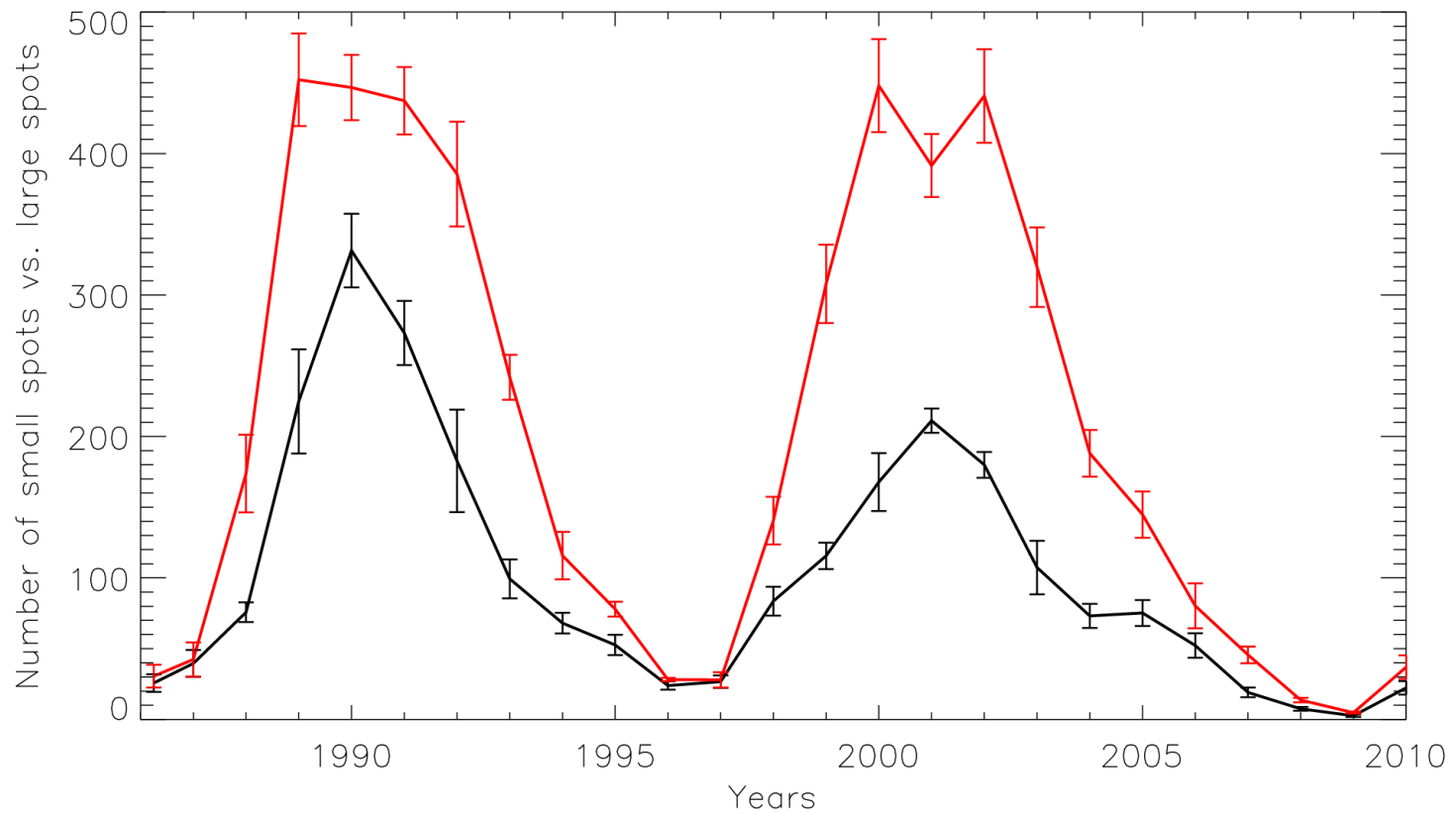
Penumbra twice the size of umbra though spot is classified AXX by USAF-ISOON catalog

Table: Description of group 7815a in the DPD catalog

	Year	mt	dy	h	mn	s	NOAA+suffix	U	U+P	$(U+P)/U$	Lat	Long	LCM	B_0	Dist from center
g	1994	12	13	08	33	29	7815a	1	6	3	-11.26	217.23	-17.40	122.11	0.3479
s	1994	12	13	08	33	29	7815a 1	1	6	3	-11.26	217.23	-17.40	122.11	0.3479

Excerpt from the DPD catalog. Columns year, mt, dy, h, mn and s correspond respectively to year, month, day, hours, minutes and seconds of observations. Lat, long and LCM are the heliographic latitude, longitude and the longitude from the central meridian. B_0 is the heliographic latitude of the center of the solar disk and the last column gives the distance from the solar disk center in units of the solar radius. Group 7815a was also observed on December 13th 1994 by the ISOON-USAf consortium and classified as McIntosh AXX.

Small spots vs. large spots



Small spots: $U+P \leq 17$ msh **AND** $(U+P)/U \leq 7$

Larger spots: $U+P > 17$ msh **OR** $(U+P)/U > 7$