HAO High Altitude Observatory NCAR

Sunspots in Cycle 24
(Are we heading for a Maunder Minimum?)

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collaborators:
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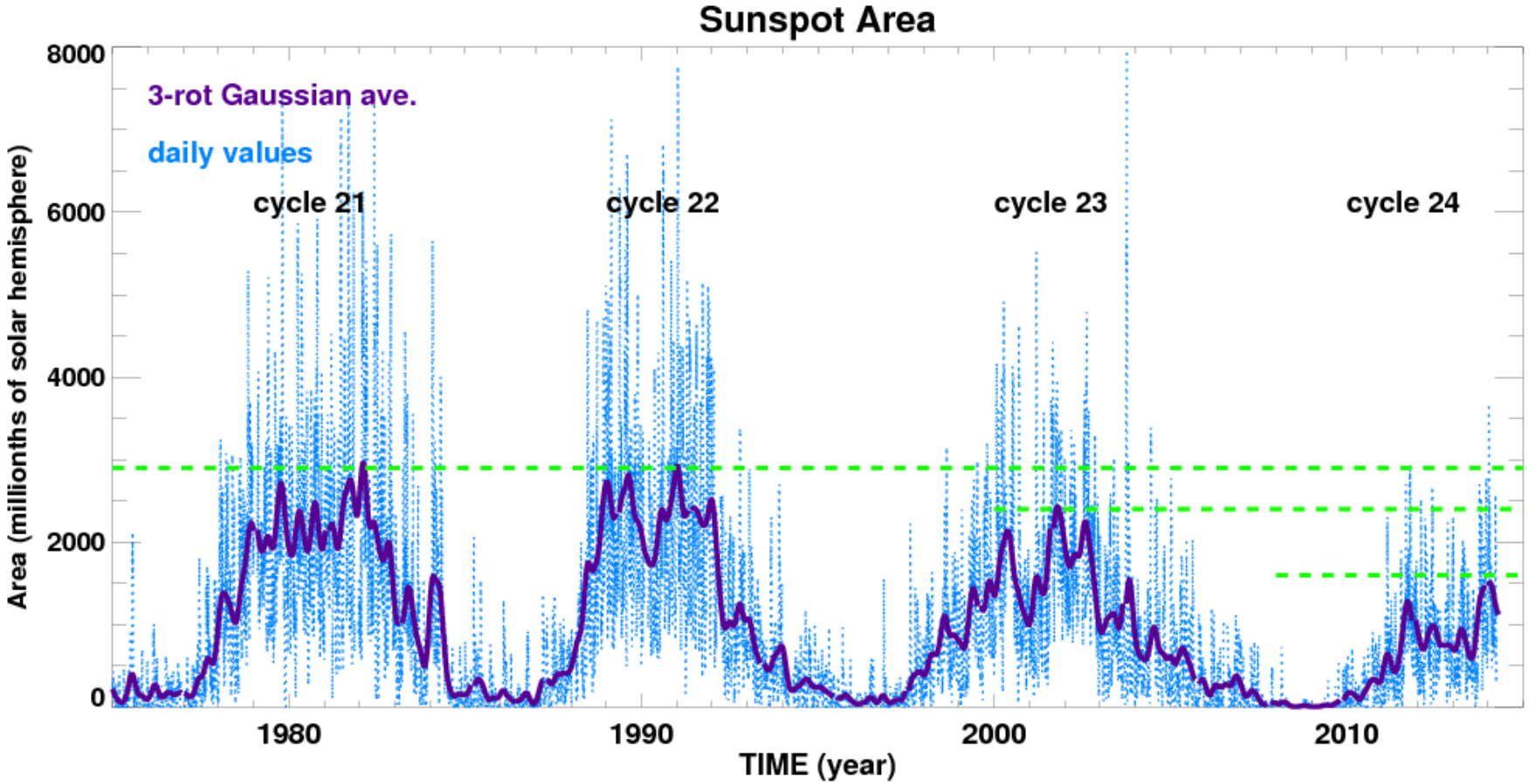
4th SSN Workshop, Locarno, May 2014

Decline in activity continues in cycle 24

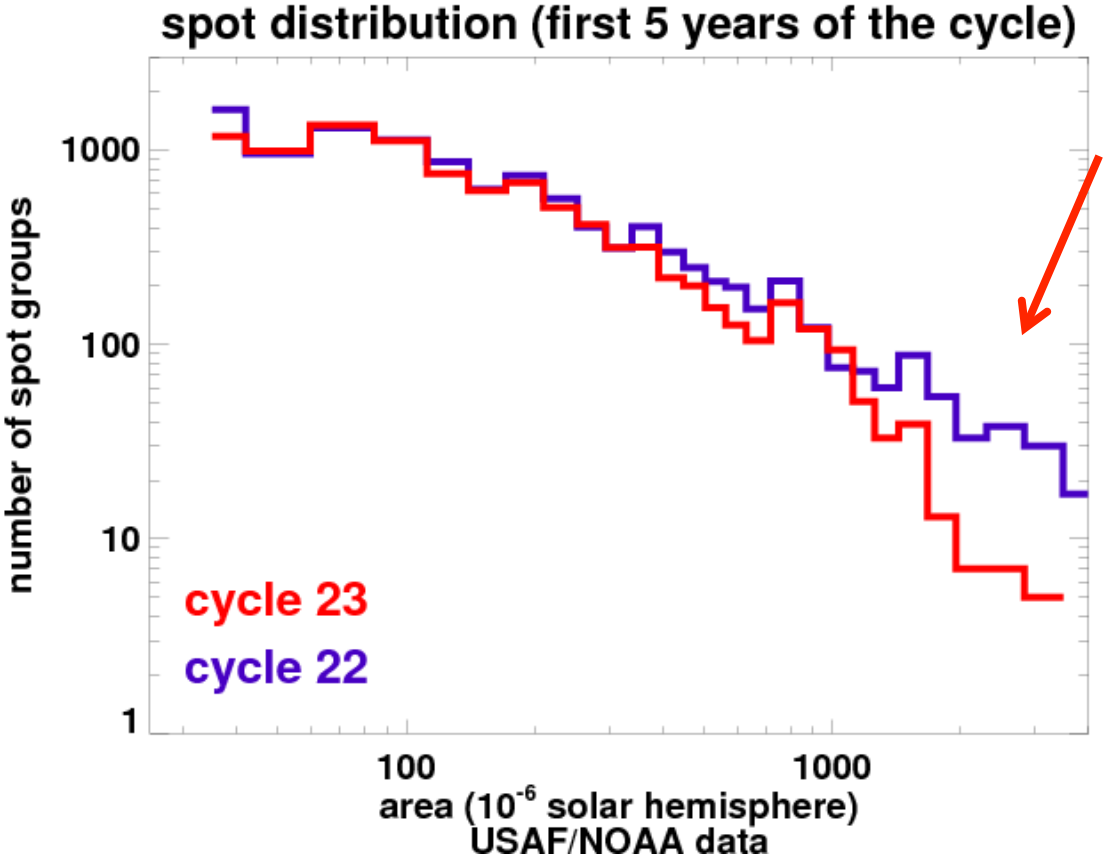


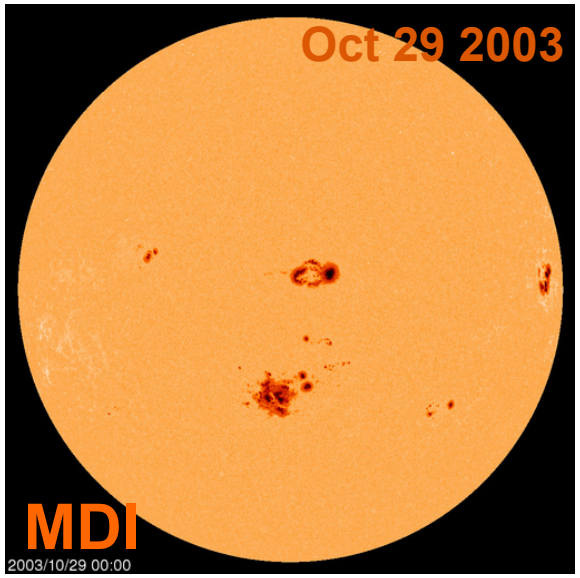
(USAF/NOAA areas are corrected for the 1.4 factor)

- largest spot group ~2000μhem
  compared to ~3000 and ~4000μhem in cycle 23 and 22

Decrease of large spots in cycle 23

- fewer very large spots and spot groups in cycle 23

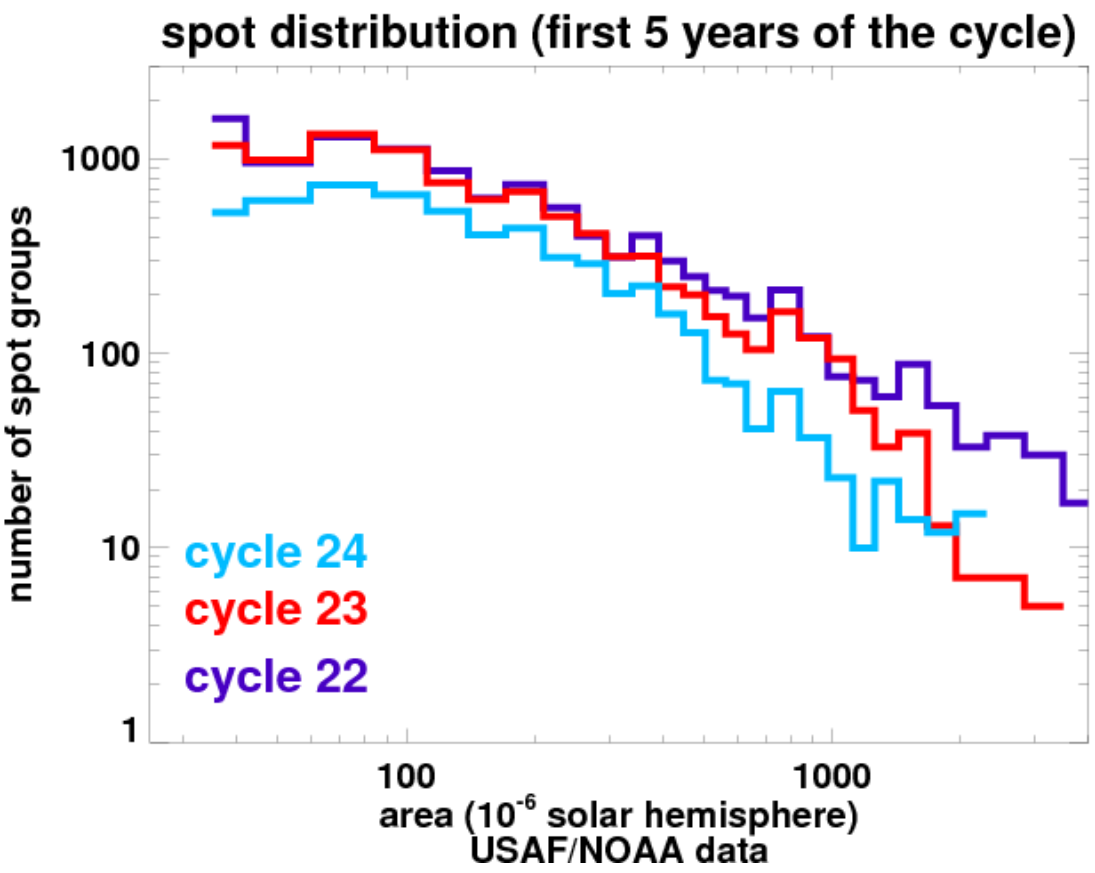


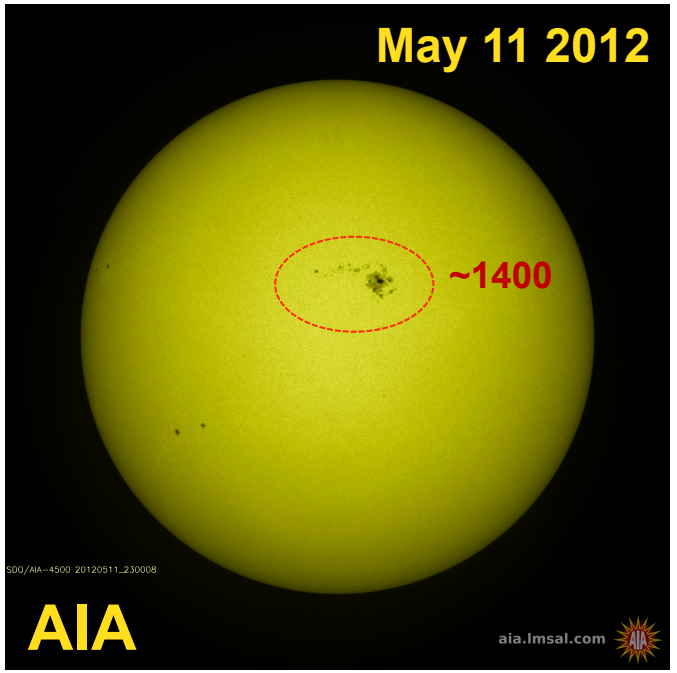


- spot groups larger than 1000μhem decreased by ~50%

Decrease of all spots in cycle 24

- spot groups of all sizes have decreased in cycle 24, especially the large ones



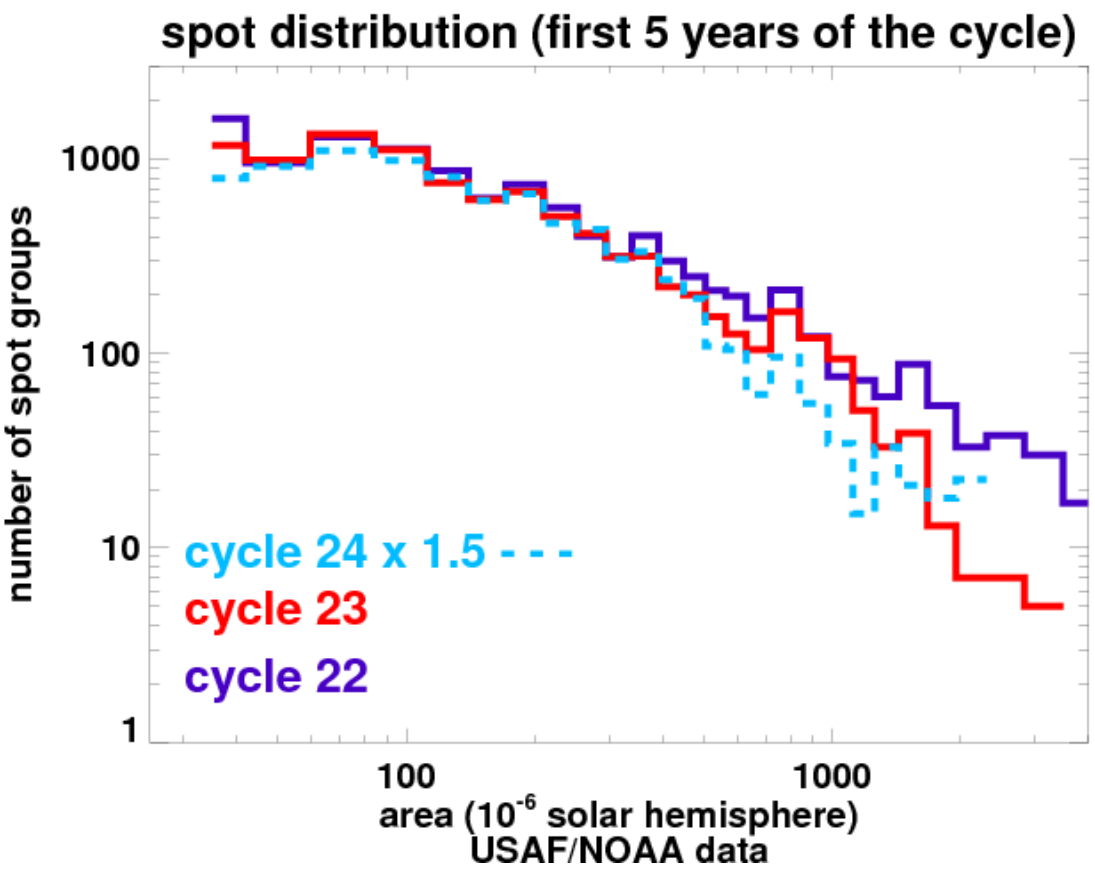


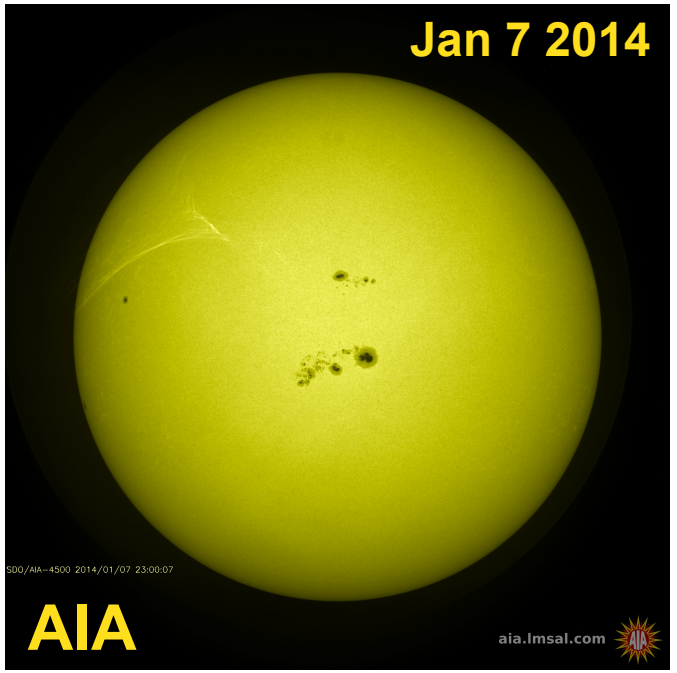
- decrease in total sunspot area of more than 80%

Large spots very scarce in cycle 24 (so far)

- total # spot groups with area > 1000μhem

cycle 22	cycle 23	cycle 24* (*first 5 years)
641	443	94*

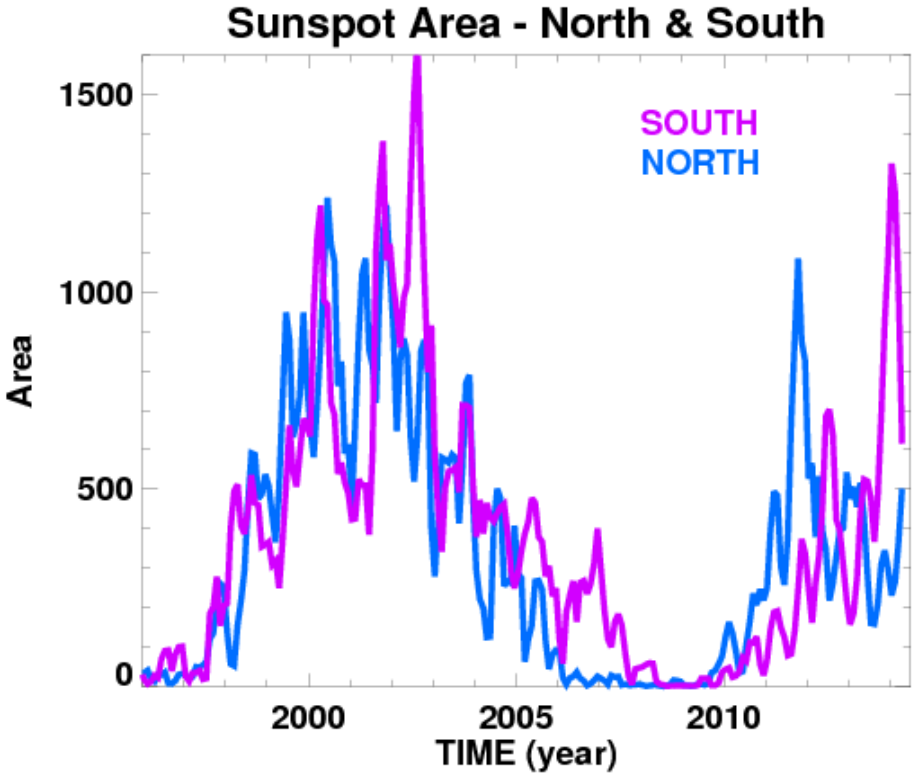


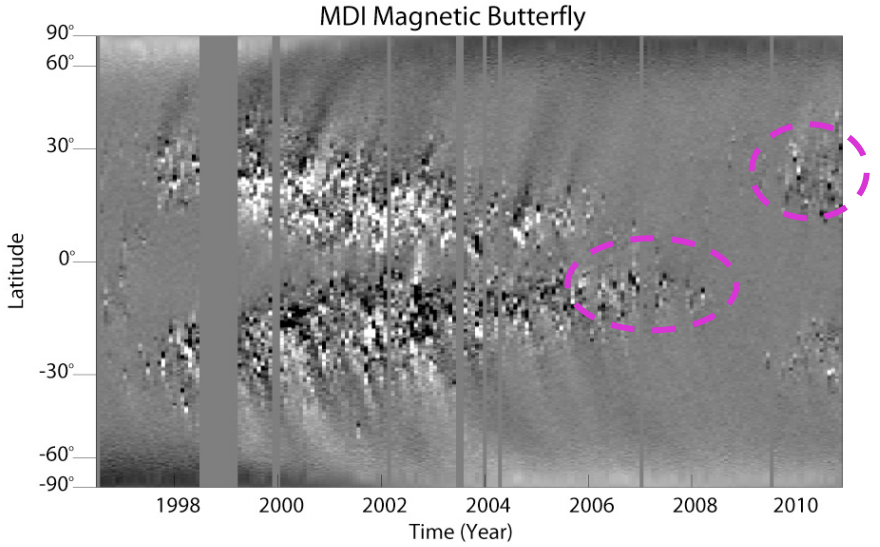


- North more active in 2011-2012 South more active now

Hemispheric asymmetry started in cycle 23

- North-South asymmetry started in ~2006



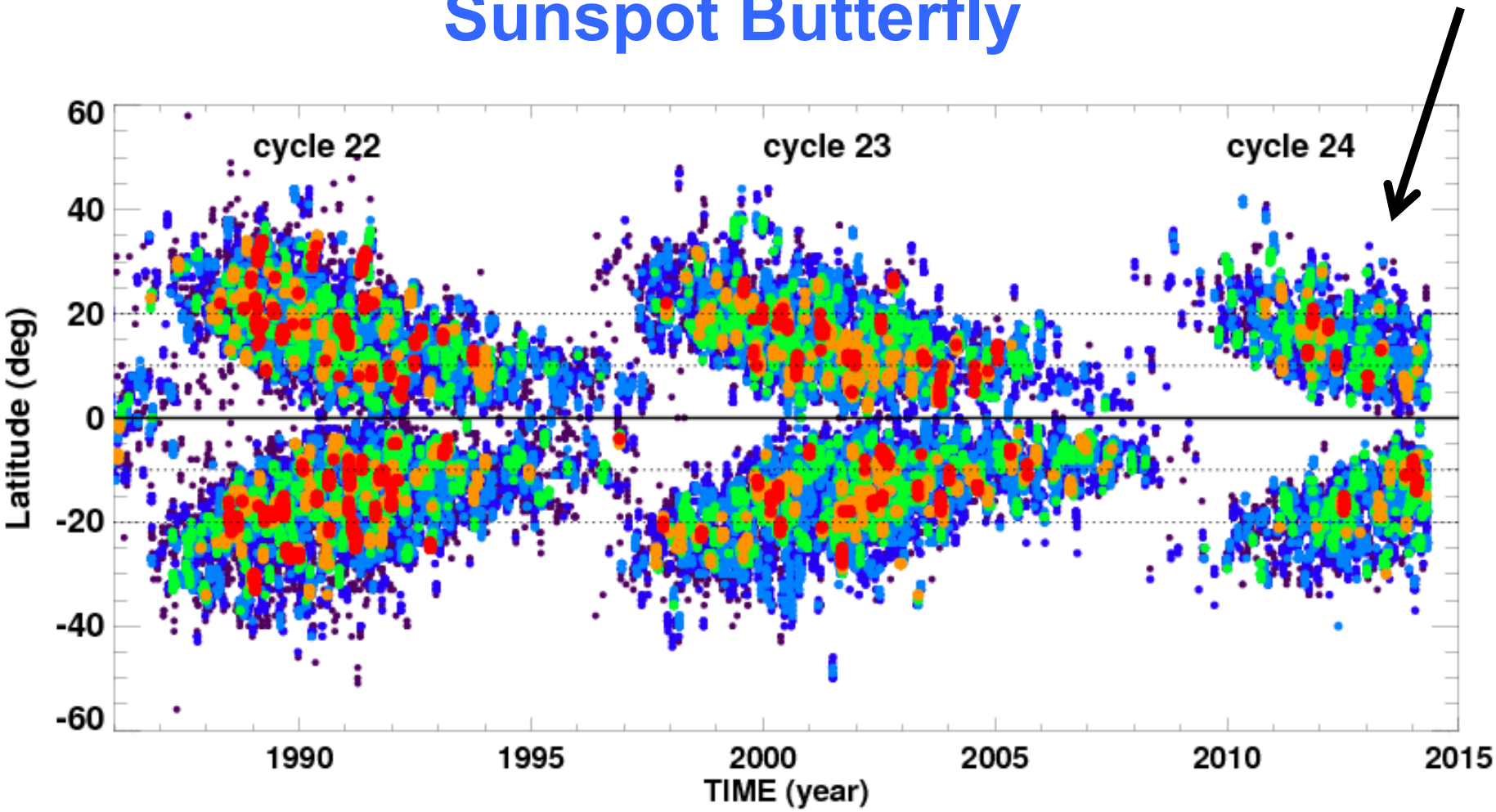


current spot latitude
N = 10.9deg
S = -13.7deg

~2-year time lag

- hemispheres out of phase for an unusually long time
- activity in the South started late but has matched the one in the North

Sunspot Butterfly



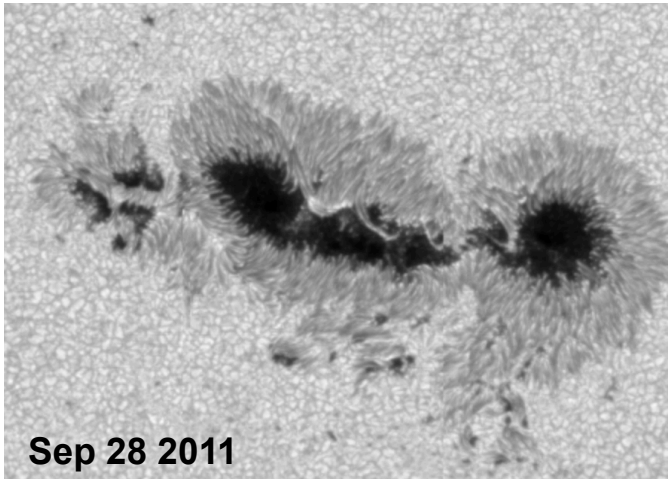
100 < area < 300μhem

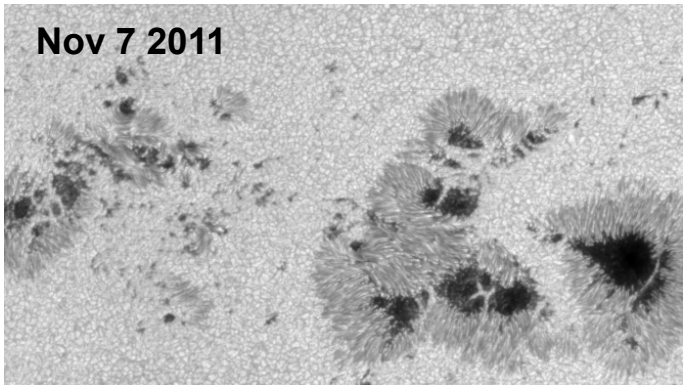
300 < area < 700μhem

700 < area < 1200μhem

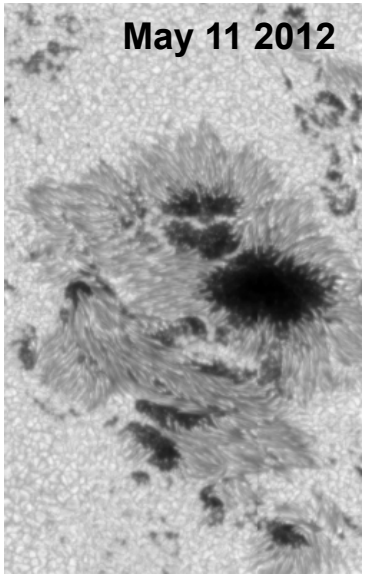
area > 1200μhem

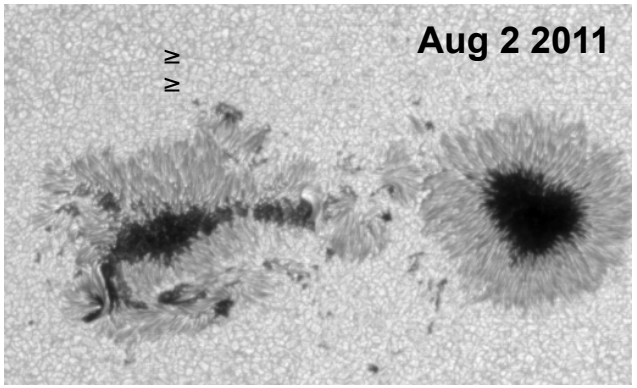
but there are still some large spots on the Sun with strong magnetic fields

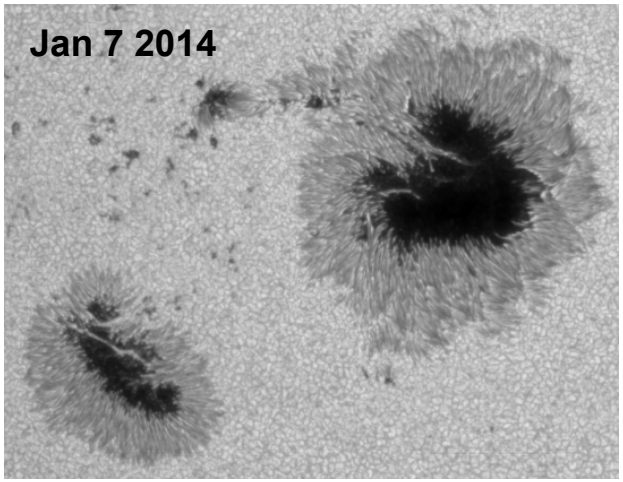


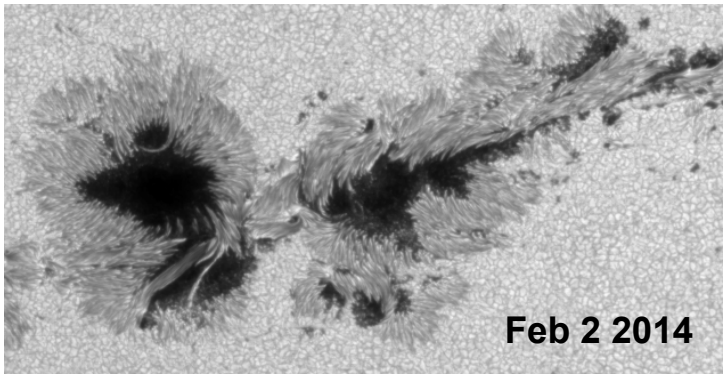


B > 3000G



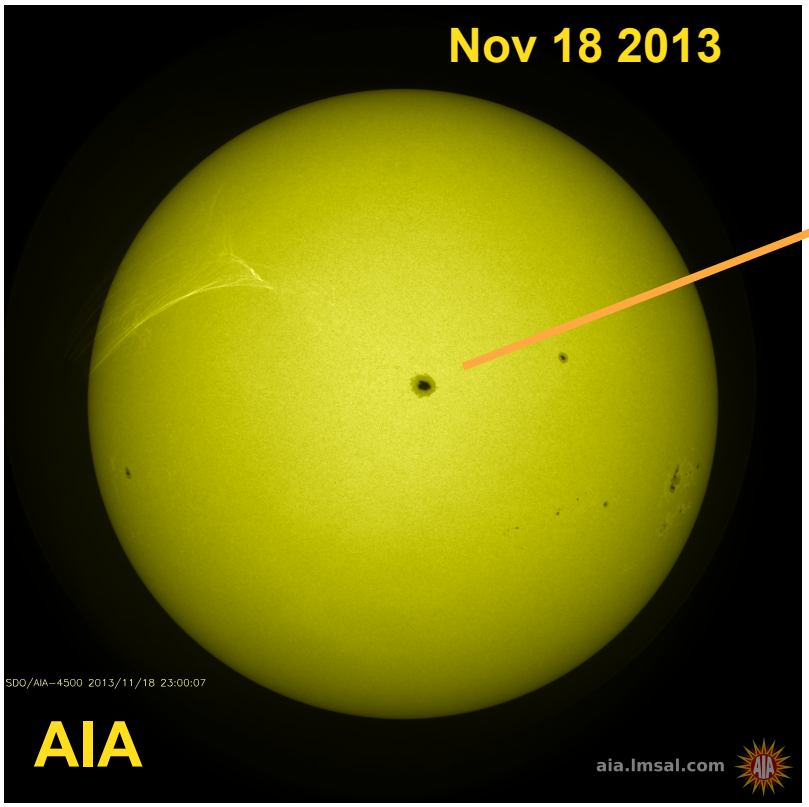


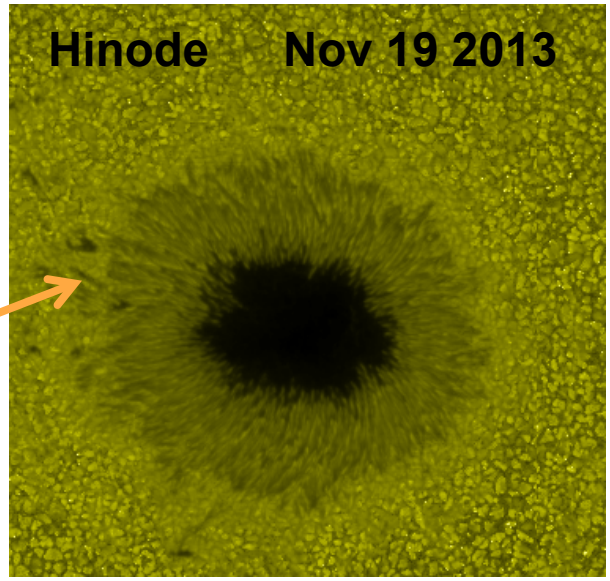


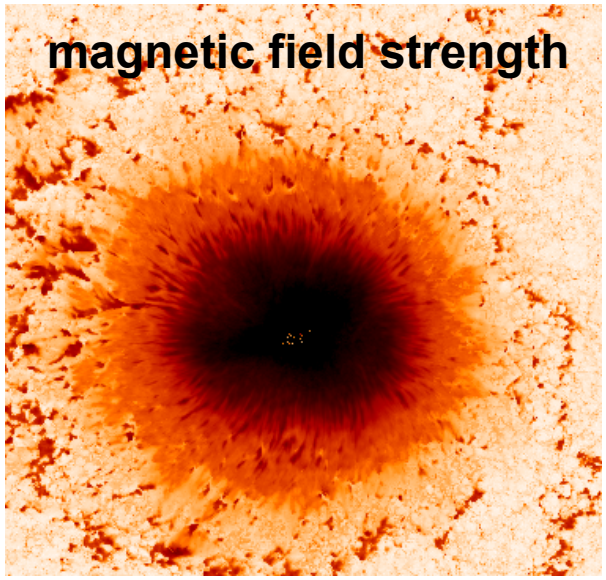


a large, simple spot with strong magnetic field

|B| ~ 4000Gauss

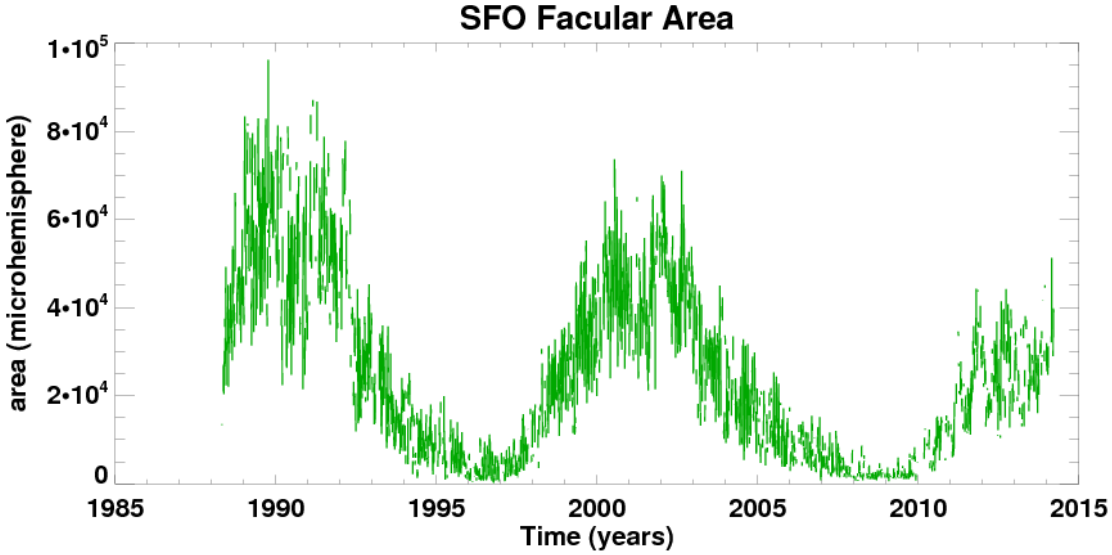






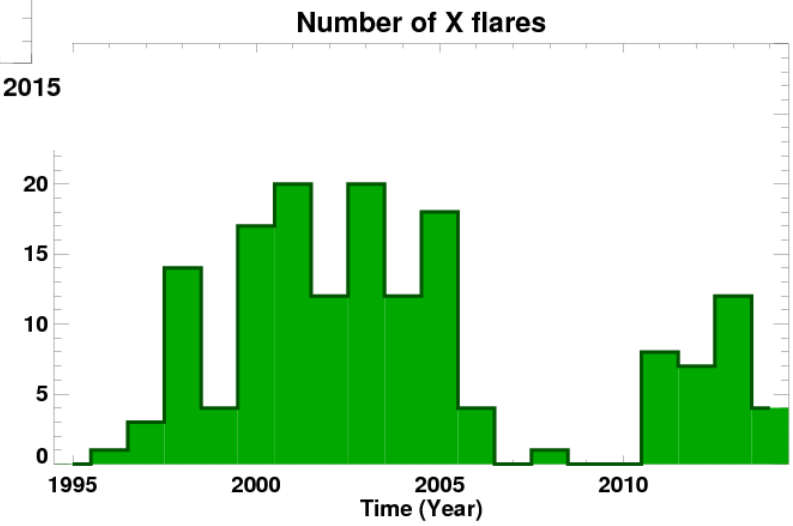
area ~1200μhem
one of the largest (top 1%) group
observed in cycle 24 but
relatively simple (βγ) symmetric spot

Cycle 24 follows a long and very deep minimum and is the weakest cycle in about a century



general decrease in solar activity, not just sunspots

weaker solar dynamo but still capable to produce some large spots with strong magnetic fields



Is this a sign of a new Maunder Minimum?

McMath-Pierce spot observations: Are sunspots different?


EOS

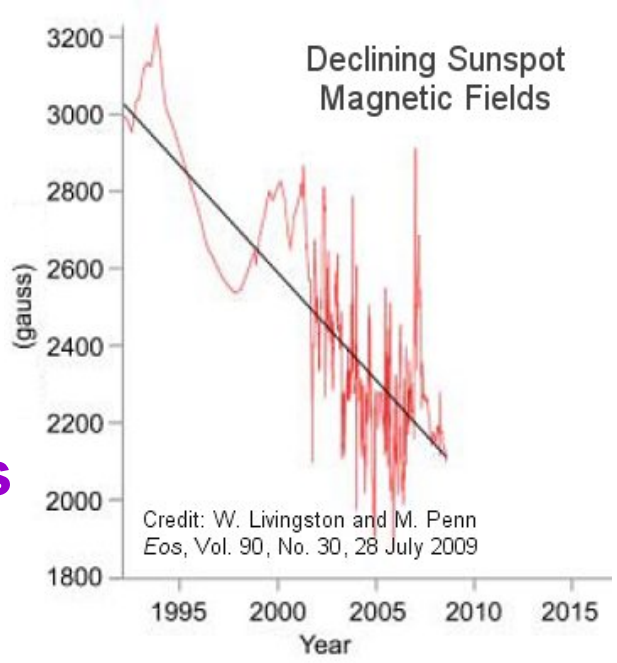
Are Sunspots Different During This Solar Minimum?

(Livingston & Penn 2009)

(Penn & Livingston 2006)

decline in sunspot magnetic fields

corresponding increase in sunspot brightness of ~2% a year



extrapolate trend forward in time

magnetic field falls below 1500Gauss

no more spots after 2015!!

sunspots will disappear by 2022

A new Maunder Minimum??

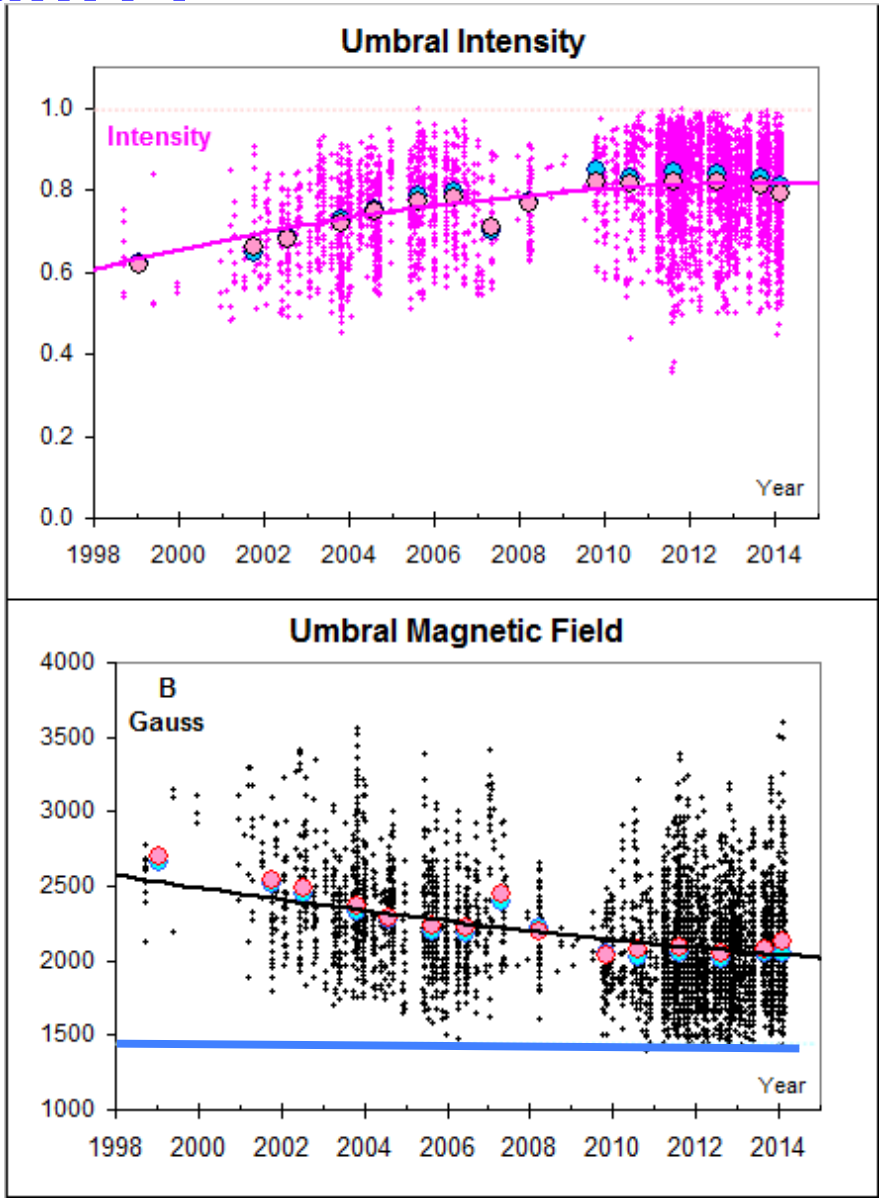
brightness increase
magnetic field decline

if linear trend continues almost no spots in cycle 25

(Livingston, Penn & Svalgaard 2012)

But is this trend real?

not confirmed by other datasets



Courtesy of L. Svalgaard

San Fernando Observatory (SFO)

California State University at Northridge

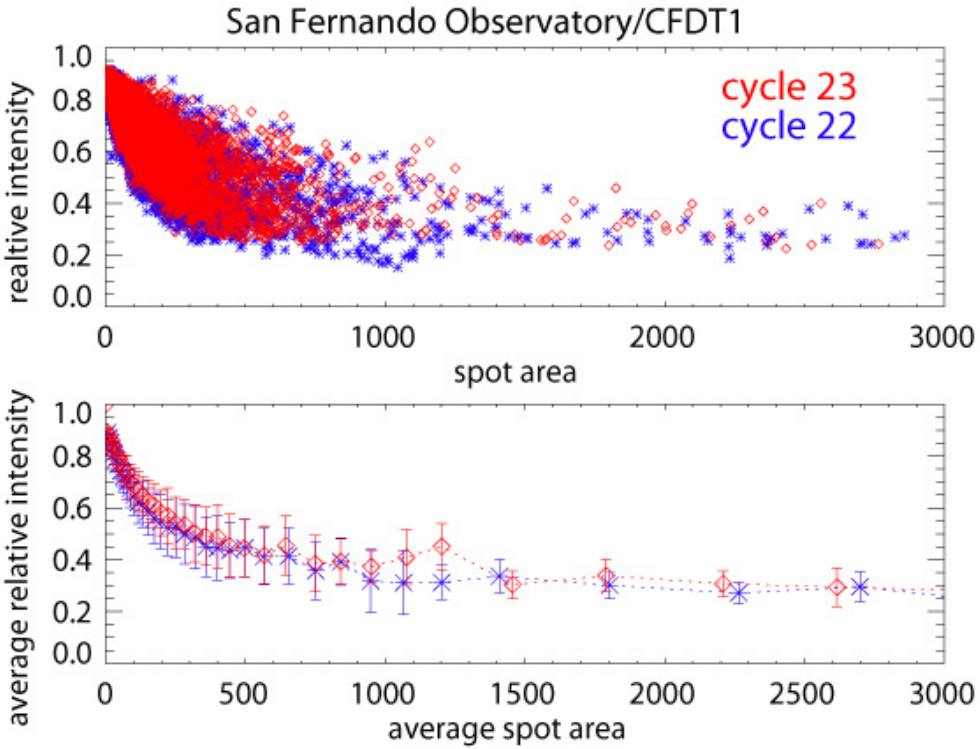
Gary Chapman

Dora Preminger

Angie Cookson

longest record of full-disk photometric measurements of spots 1986-present

Sunspots have the expected intensity for a given area



large variation in intensity for a given spot area

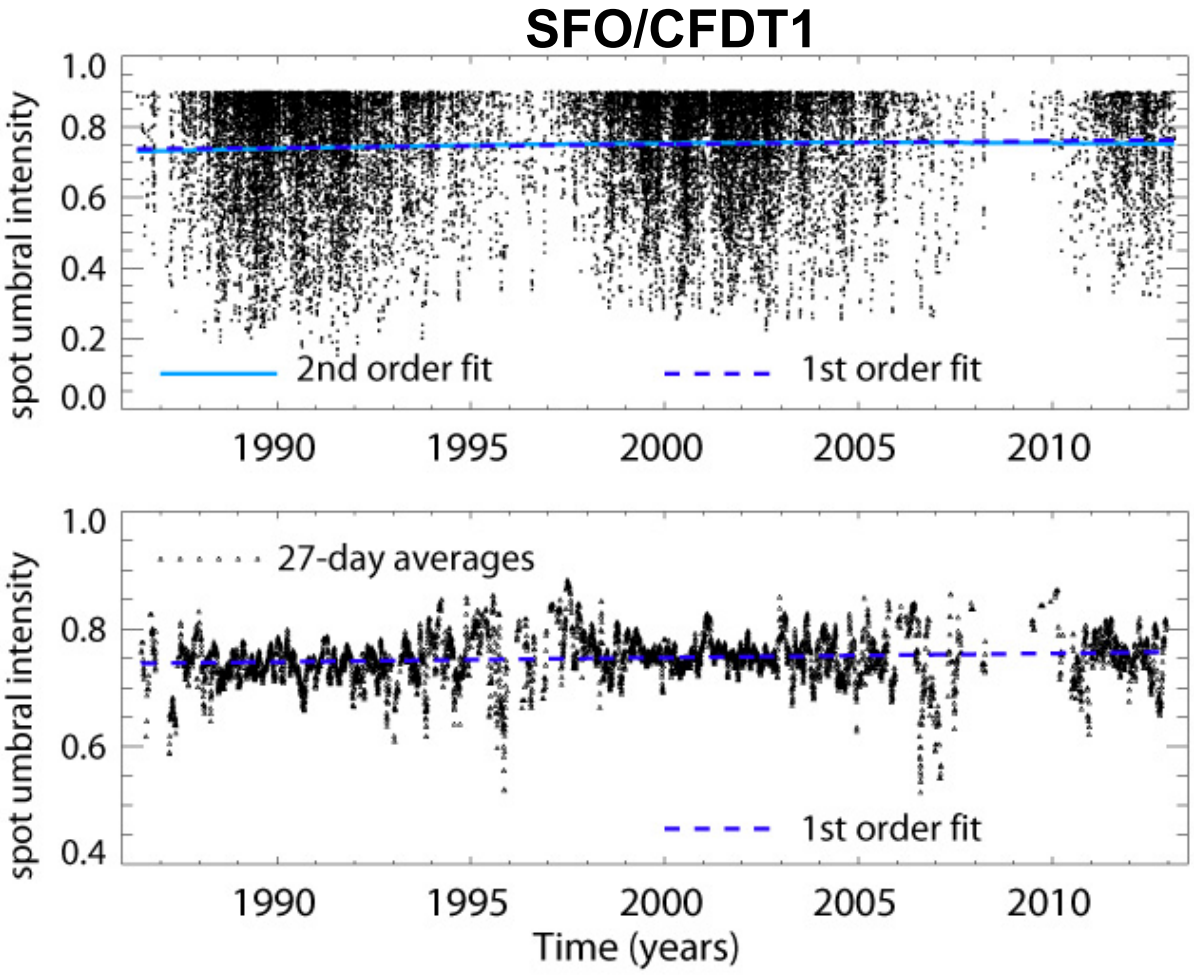
when data are averaged clear relationship

larger spots are darker than smaller spots

no significant difference between the two solar cycles

sunspots were not brighter in cycle 23 than in cycle 22

Sunspot intensity has been stable in time



~ 30000 data points

less than 3% change in sunspot average intensity during the past 27 years

Penn & Livingston find an increase of about 2% a year

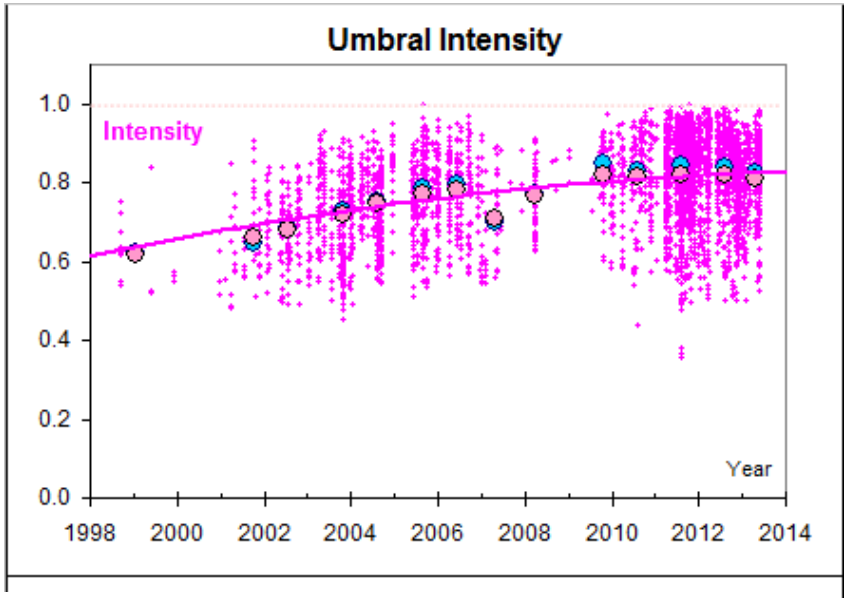
no trend in spot intensity in SFO sunspot data taken over more than two solar cycles by the same instrument

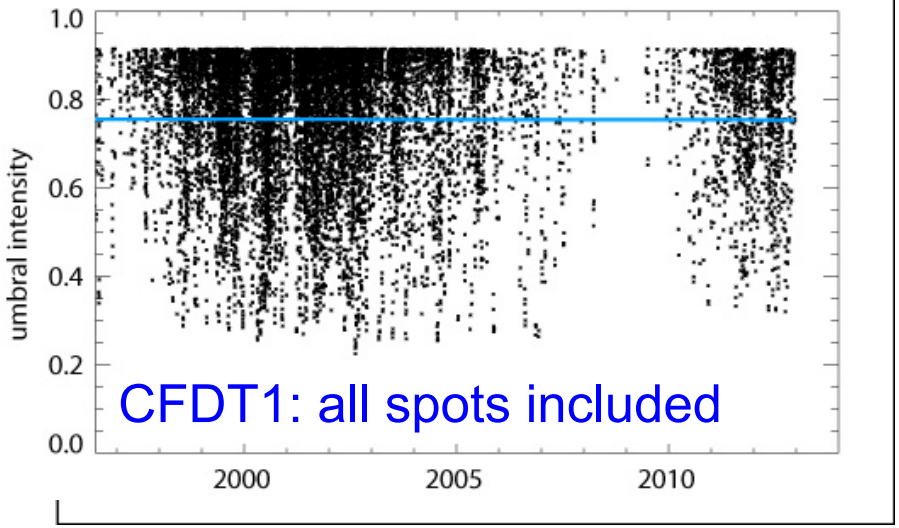
another explanation for this trend

McMath-Pierce dataset is
not homogeneous
- **fewer data early on**
- **no small spots included in early data**

this introduces a bias

no trend in recent data





sunspots have not changed

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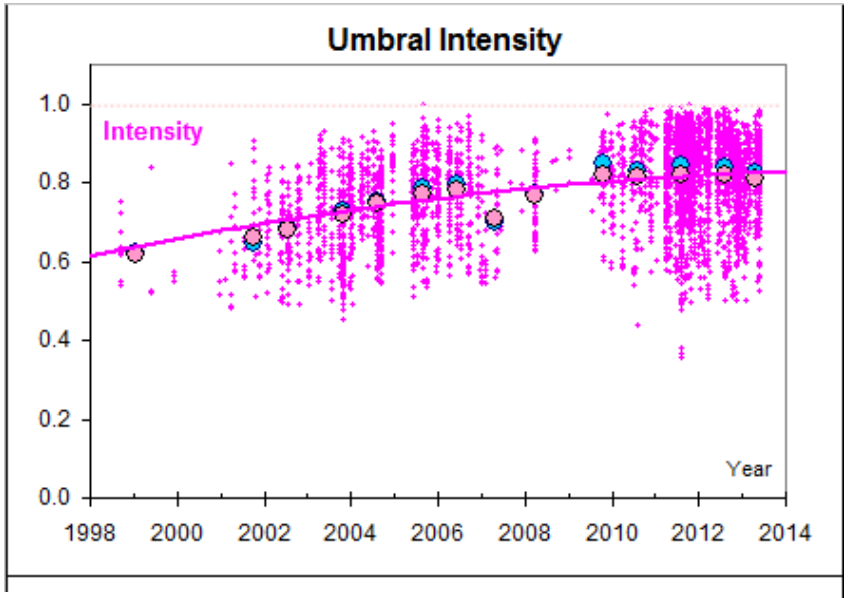
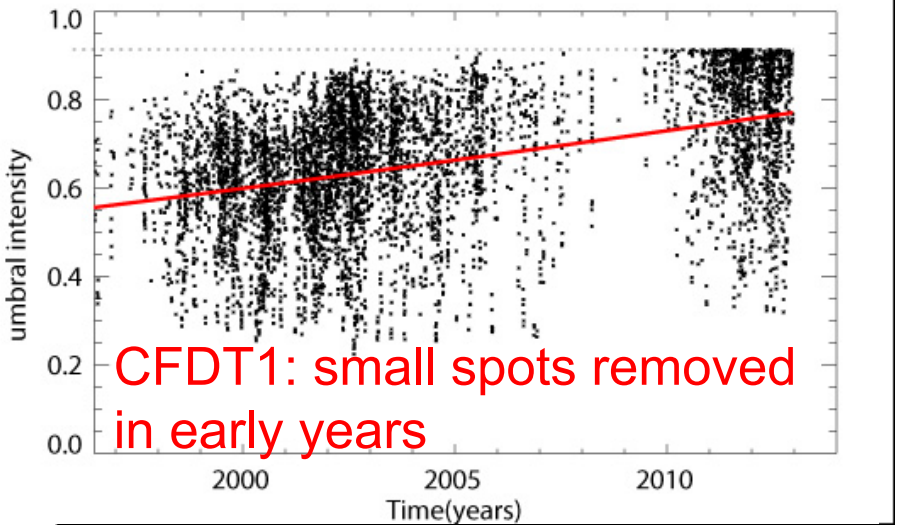
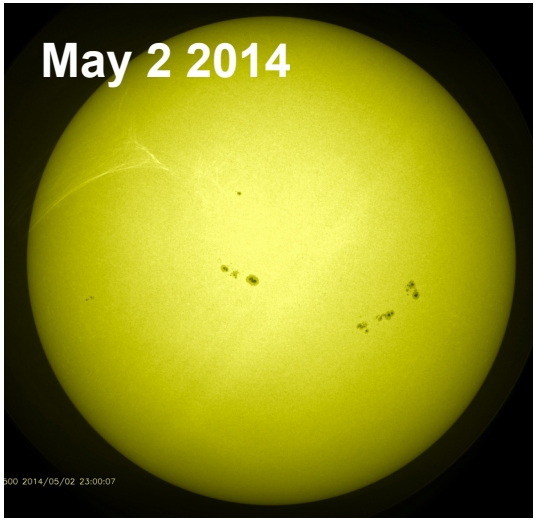




sunspots have not changed

Cycle 24: a weak but normal cycle

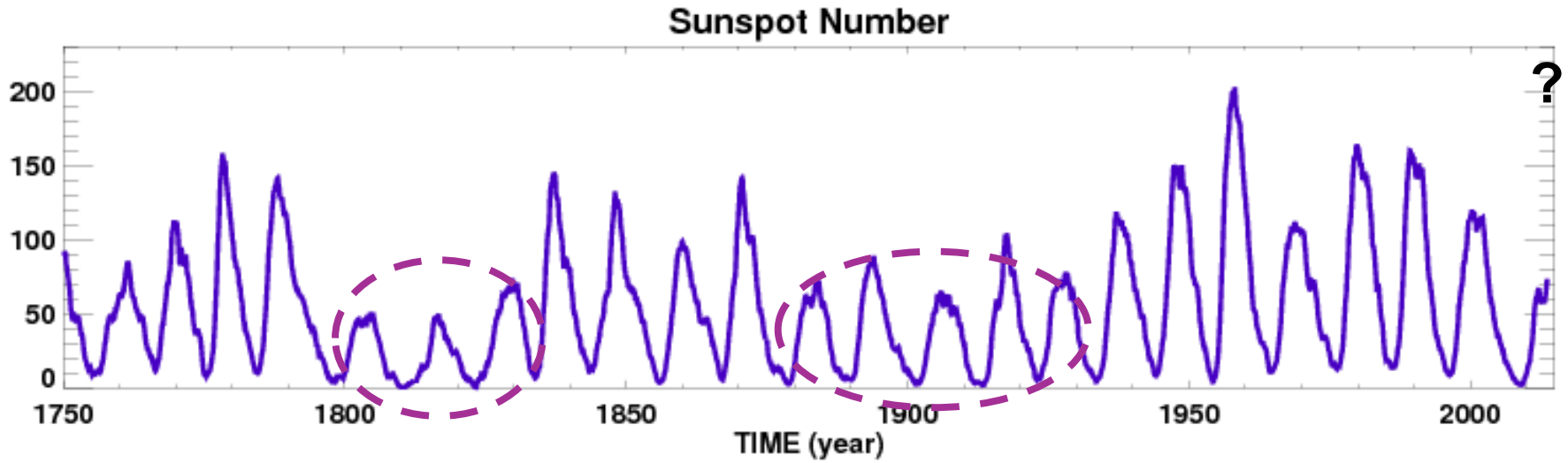


- fewer very large spots in cycle 23 indicate a weaker solar dynamo
- weakening trend continue in cycle 24: spots of all sizes have decreased and especially the large ones
- strong magnetic fields are infrequent but still present on the Sun
- no evidence that physical properties of spots have changed

Sunspots are not becoming brighter
there are just fewer of them…
…which is normal for weak cycles
This is why weak cycles are weak!!

How likely is a new Maunder Minimum?

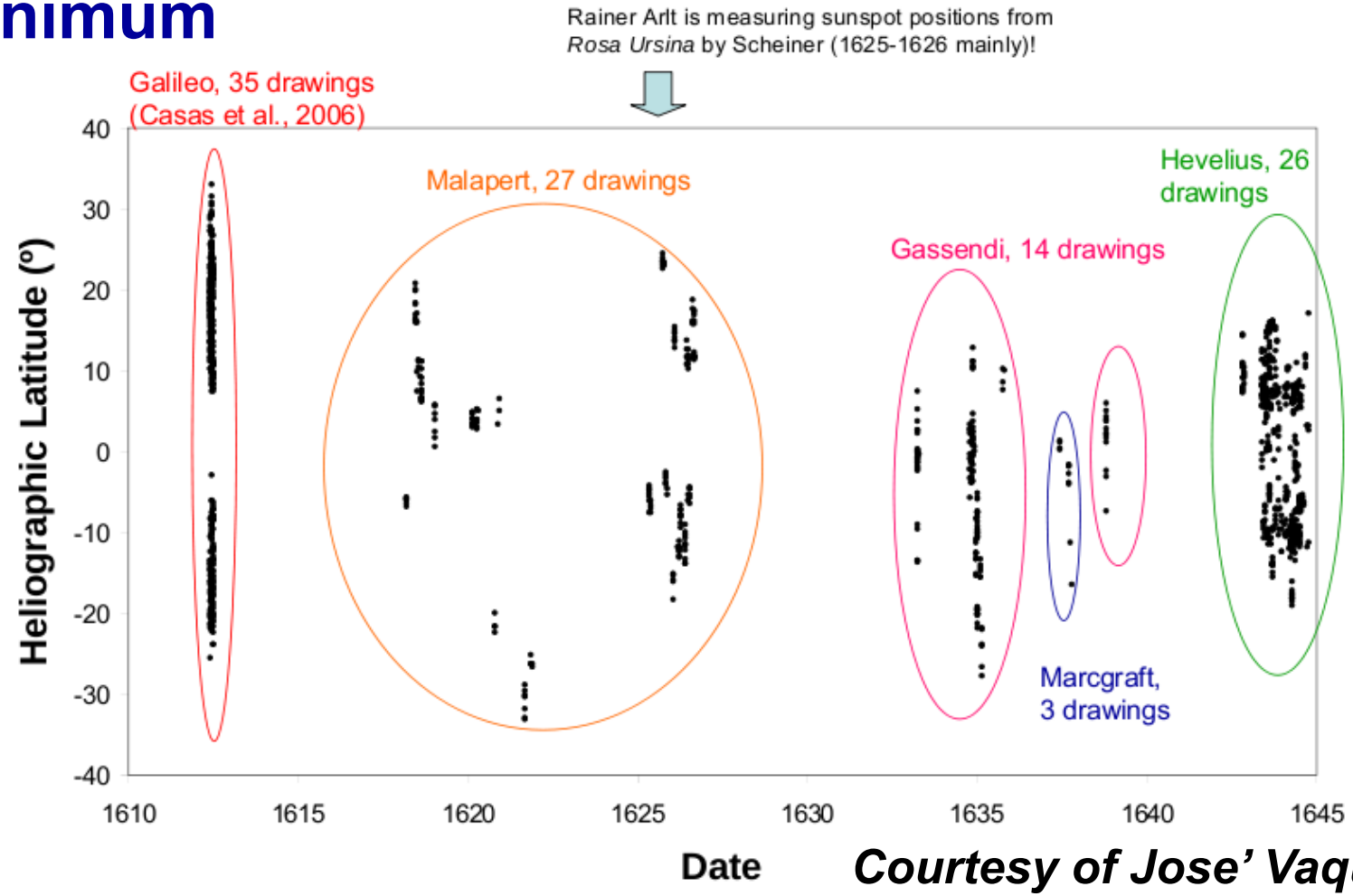
We had small cycles before and the Sun did not go into a Maunder Minimum



strong activity during most of the space age
weak activity in recent years
small cycles at the beginning of the XIX and XX century

Are we at the end of a Gleissberg cycle?

No hemispheric asymmetry before the Maunder Minimum

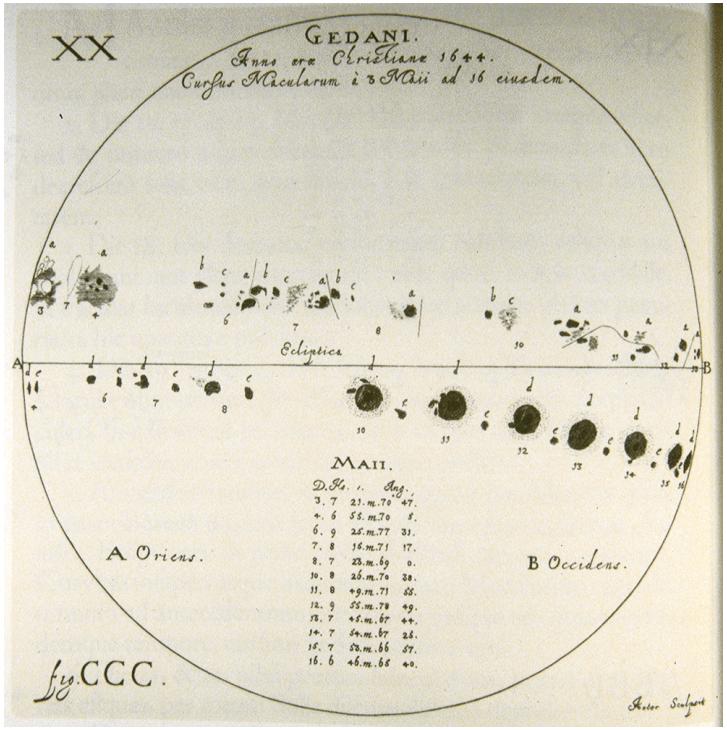


Courtesy of Jose' Vaquero

both North and South currently active

current asymmetry = time-lag of about two years

There were very large spots on the Sun before the Maunder Minimum



Hevelius drawings in 1644
(one year before the Maunder Minimum started)

Cycle before the Maunder Minimum weaker than previously thought

We still do not know how and why the Maunder Minimum started

a new Maunder Minimum does not seem more likely now than a decade ago

but if polar fields remain weak, cycle 25 will likely be another weak cycle