Historical sunspot observations in their originals

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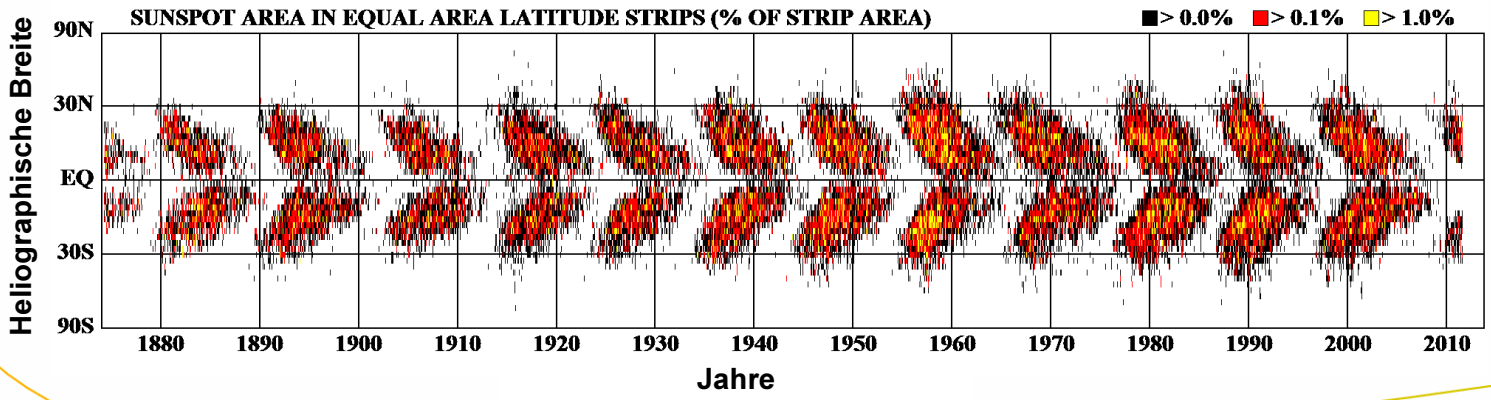
Heliographic observations since 1874

- Royal Greenwich Observatory until 1976
- USAF/NOAA from 1977 to the present
- Only average group positions and total area
- **Has it always been like this?**



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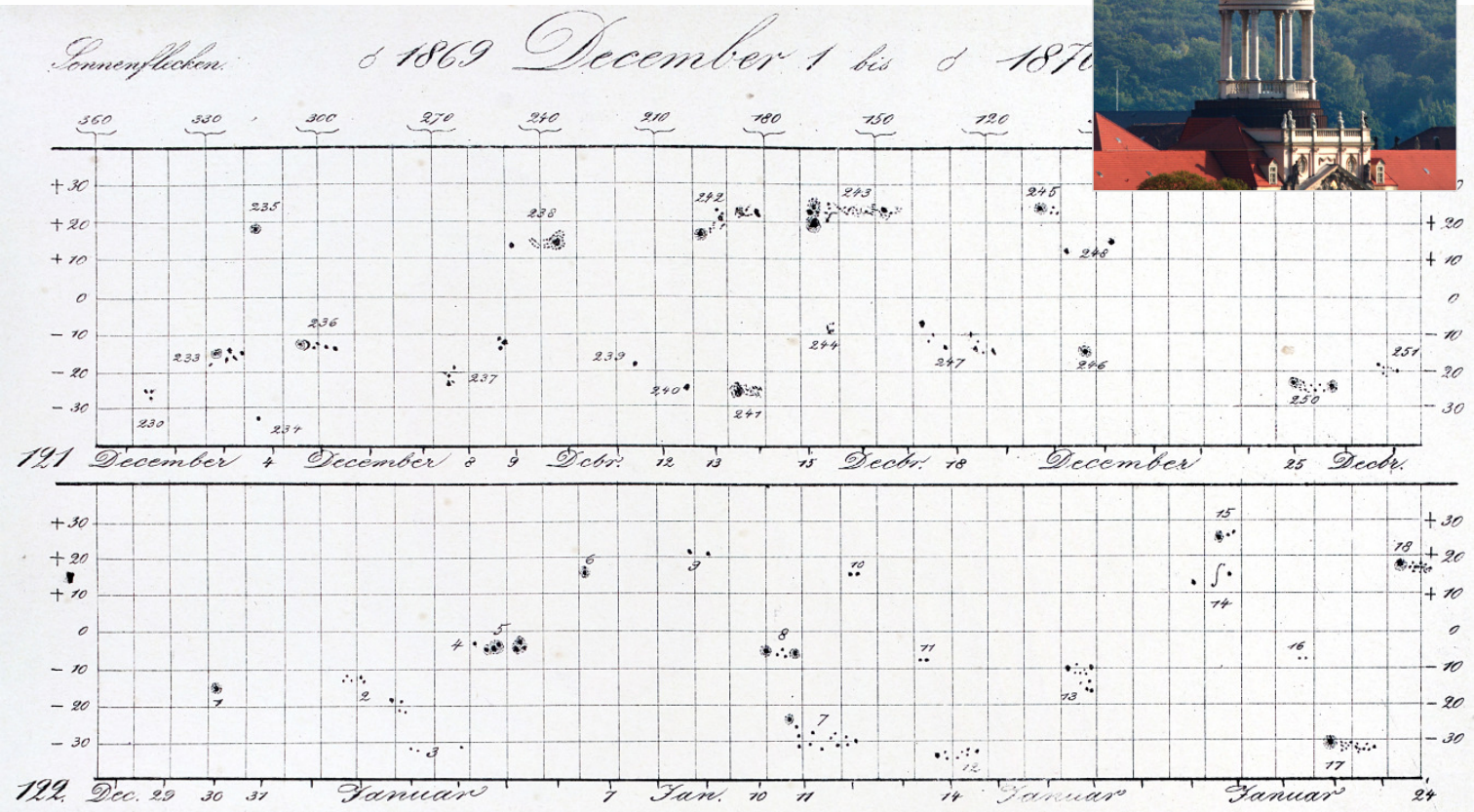
Gustav Spörer 1861–1884

- 1861–1874 in Anklam, 1874–1884 in Potsdam



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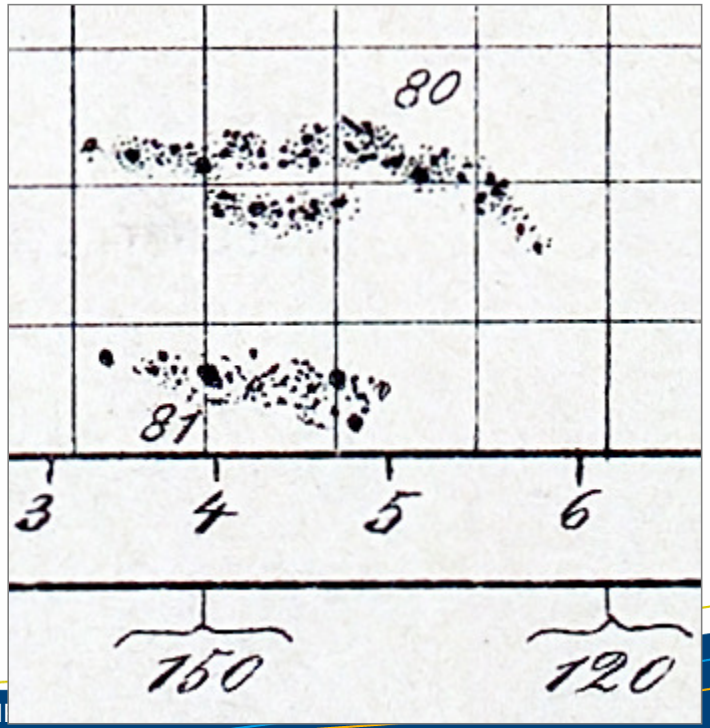
Gustav Spörer 1861–1884

- See also talk by Andrey Tlatov
- Digitized images from publications
- Tables with positions digitized by (a student of) Ilkka Tuominen
- Some discrepancies between tables and synoptic maps found
- Some may be clarified with Schwabe and Greenwich



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Samuel Heinrich Schwabe 1825–1867

- More than 8000 pages of observational reports
- Stored in archives of the Royal Astronomical Society, London

S.H. Schwabe 1789-1875, Dessau

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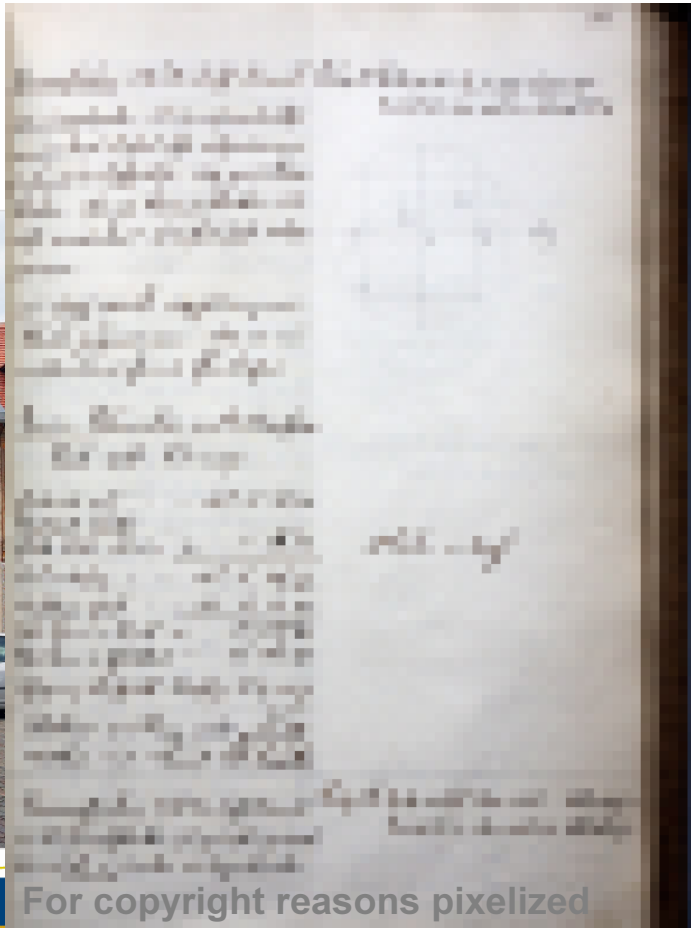
Samuel Heinrich Schwabe



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R. Arlt, AIP

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Schwabe‘s drawings

- Precise drawings of the solar disk with sunspots for 8486 days
- Additional 3699 verbal reports

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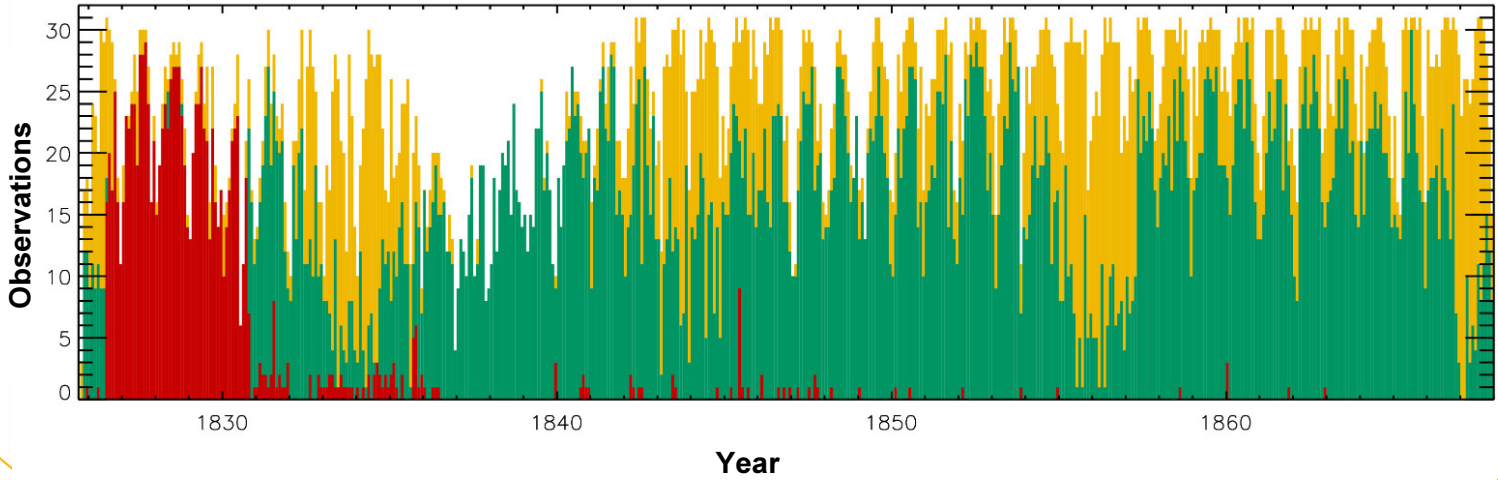
Schwabe‘s drawings

- Yellow: all solar observations
- Green: drawings
- Red: drawings without coordinate system



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Schwabe‘s discovery

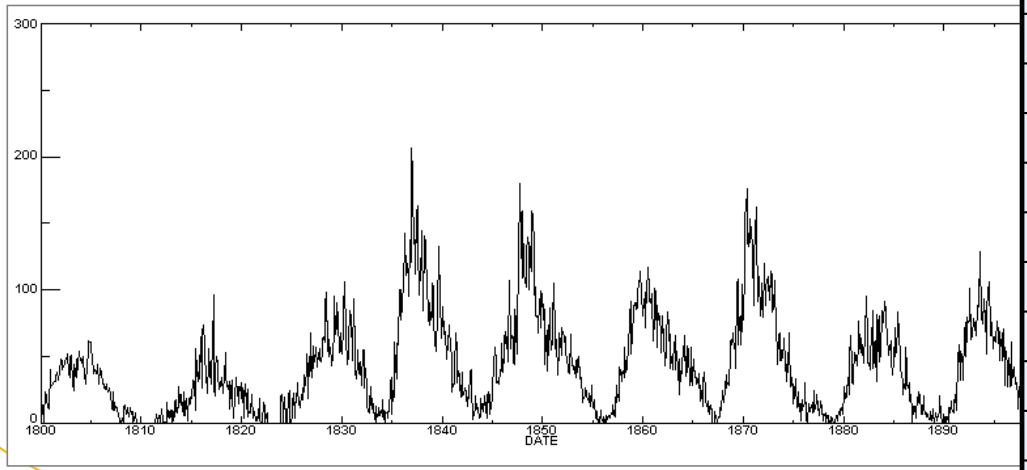
- On 31.12.1843, Schwabe writes an article for *Astronomische Nachrichten*
- Suggests 10- year period of sunspot abundance

Jahr.	Gruppen.	Fleckenfreie tage.	Beobach-tungstage.
1826	118	22	277
1827	161	2	273
1828	225	0	282
1829	199	0	244
1830	190	1	217
1831	149	3	239
1832	84	49	270
1833	33	139	267
1834	51	120	273
1835	173	18	244
1836	272	0	200
1837	333	0	168
1838	282	0	202
1839	162	0	205
1640	152	3	263
1841	102	15	283
1842	68	64	307
1843	34	149	324

Schwabe's observations

- 35 notes about aurorae

Zürich number



1826		1847	4
1827	1	1848	2
1828		1849	2
1829		1850	
1830		1851	1
1831	2	1852	1
1832		1853	
1833	1	1854	
1834	1	1855	
1835		1856	
1836		1857	
1837	2	1858	
1838	3	1859	3
1839		1860	
1840	1	1861	2
1841		1862	1
1842		1863	2
1843		1864	
1844	1	1865	
1845		1866	
1846	1	1867	

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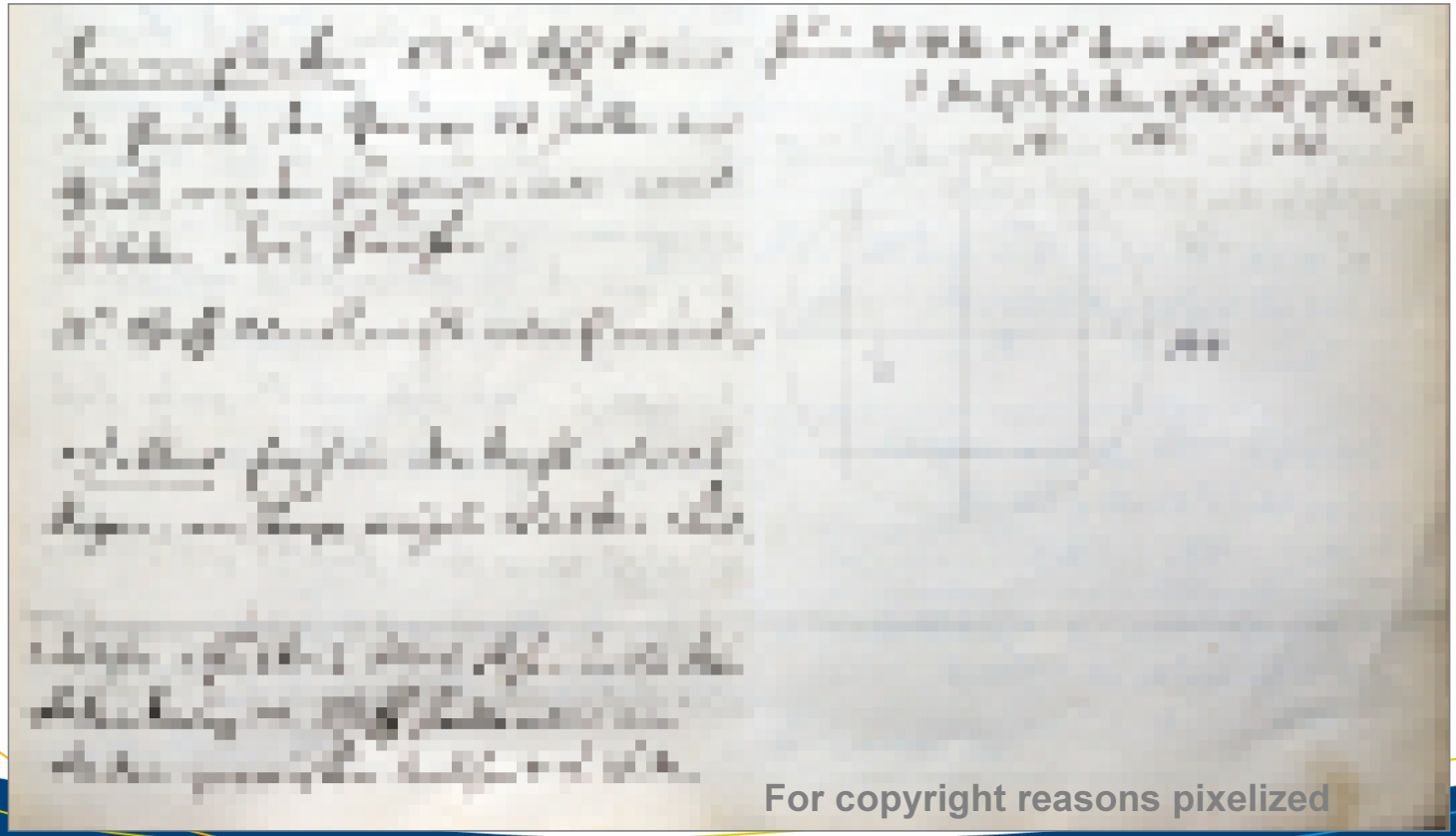
Schwabe‘s drawings



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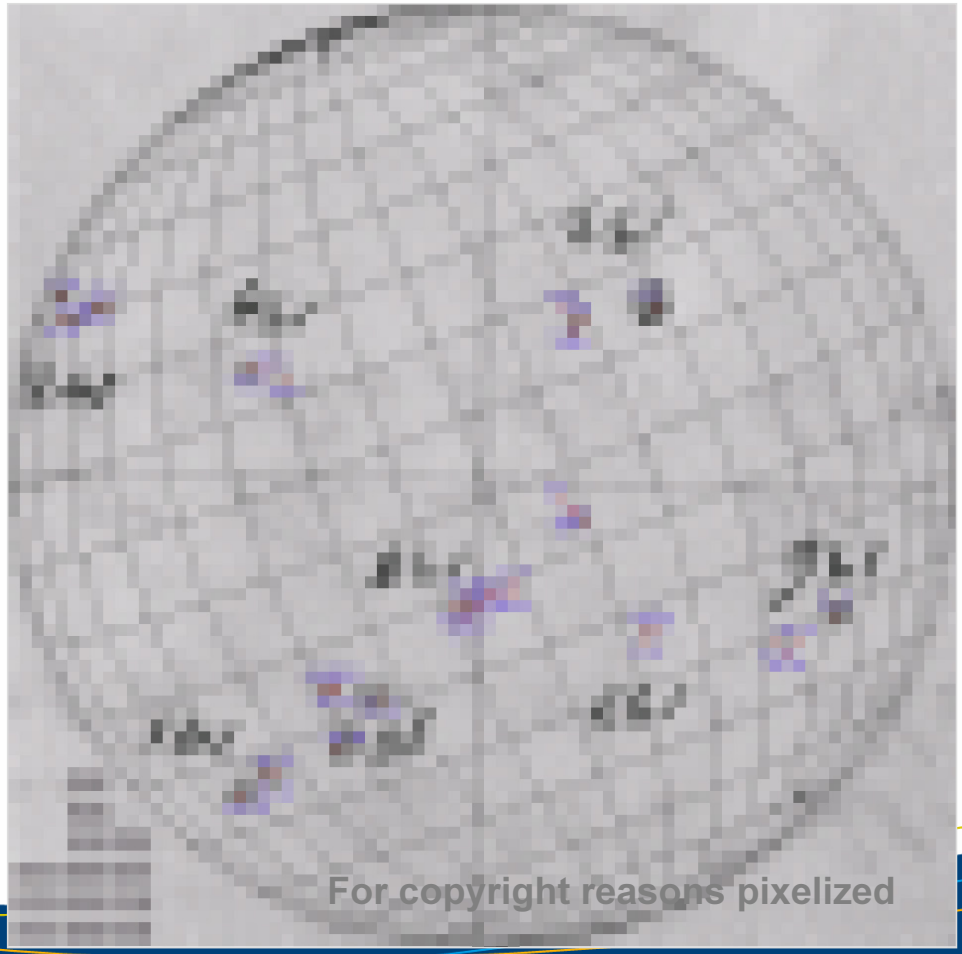
Schwabe‘s drawings

- From 1831 onwards, nearly all drawings have a coordinate system
- Parallel to celestial equator
- Use JPL Horizons to get tip and tilt of heliographic coordinate system



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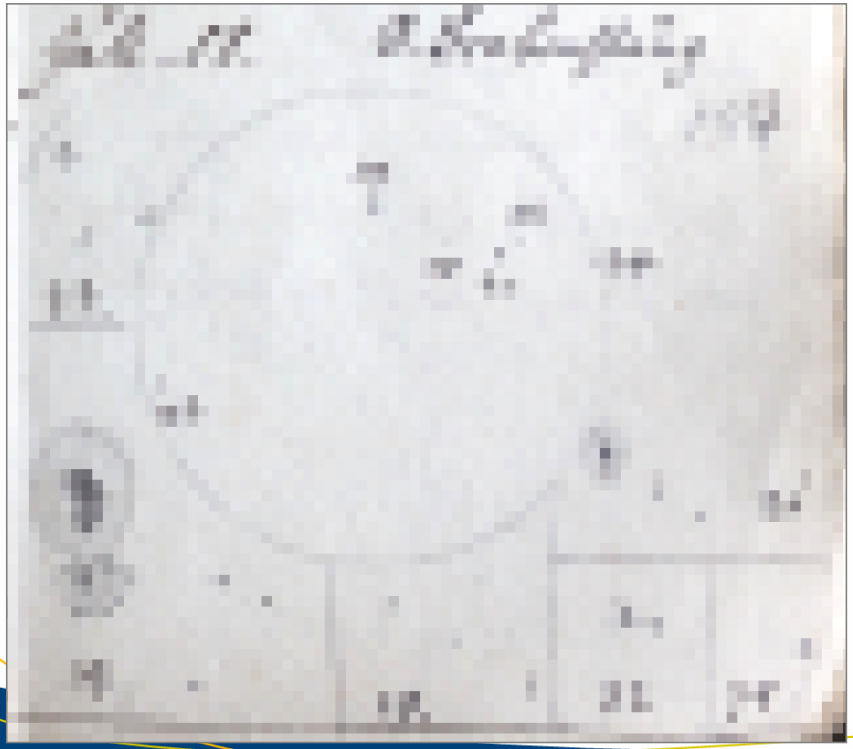
Schwabe‘s drawings

- Find sizes by visually fitting 12 different cursor masks
- Size will be overestimated
- Effect probably stronger for A-C than for D-H groups
- Would like to do full classification and calibrate group types individually

Class Size	Sq.pixels Area
0	5
1	9
2	21
3	37
4	69
5	97
6	145
7	185
8	206
9	270
10	308
11	364

Schwabe‘s drawings

- Plotting style changed: 1826 Jul 11 1846 Dec 11



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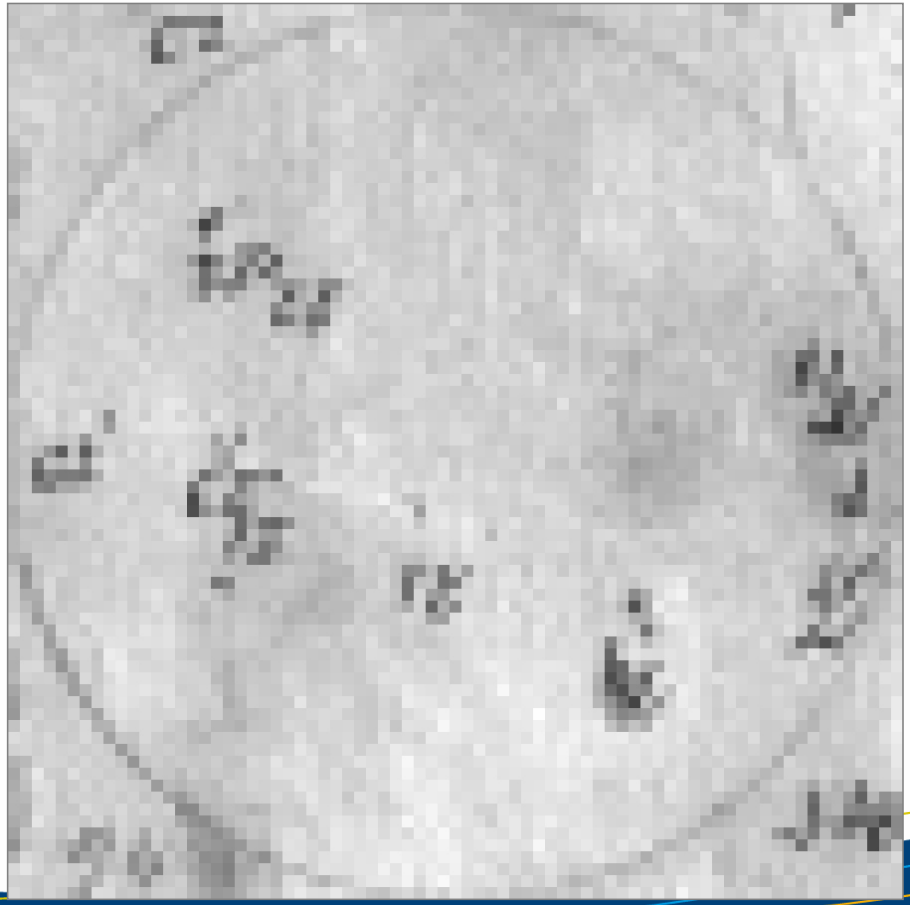
Schwabe‘s drawings

- Observations without coordinate system: rotational matching
- Free parameters:
  - Longitudes
  - Latitudes
  - Position angles
- Fixed:
  - Rotation profile



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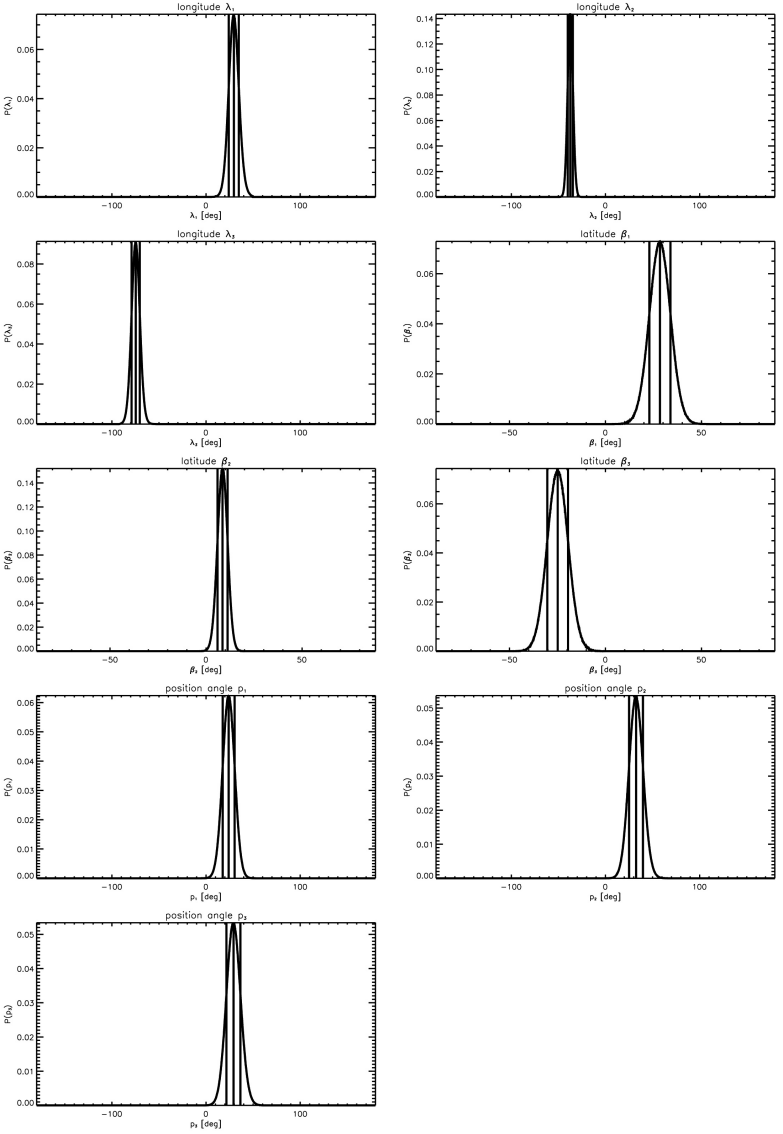
Schwabe's drawings

- Obtain full probability distribution for the $2n_s + n_d$ dimensional parameter space
- Marginalize for each parameter
- Use the averages for the position angles
- Store both measured and inferred coordinates



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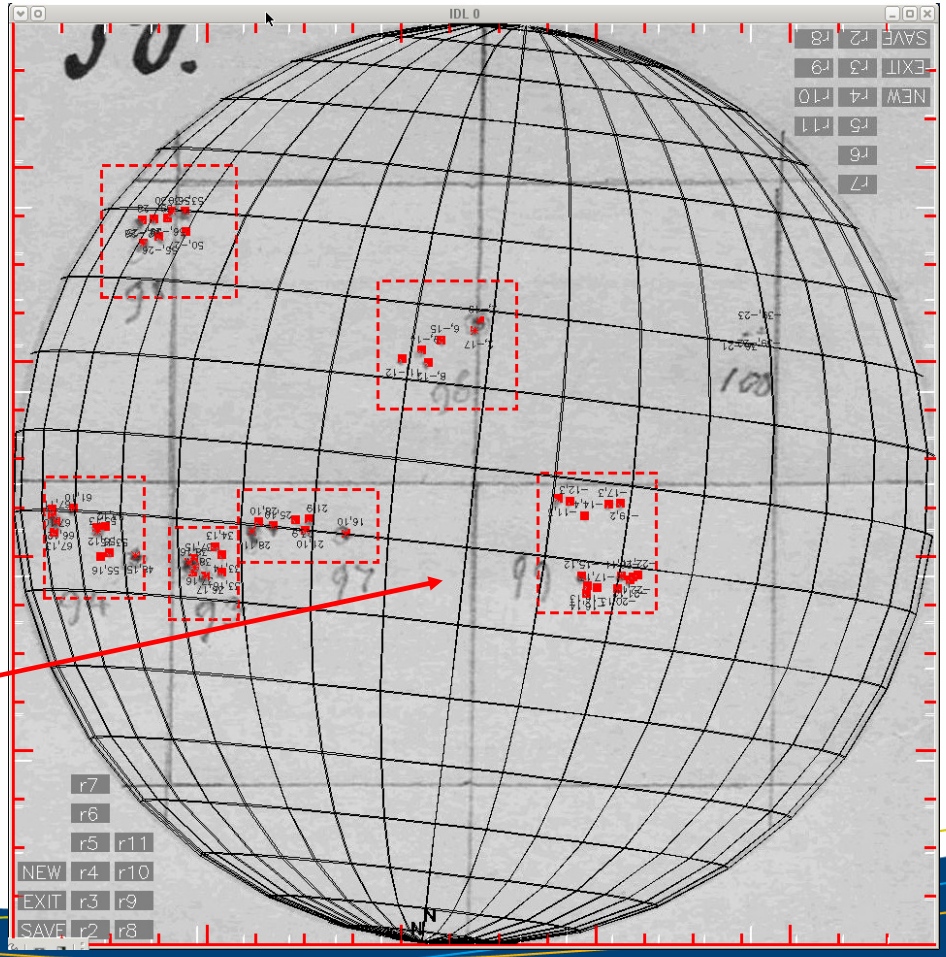
Schwabe‘s drawings

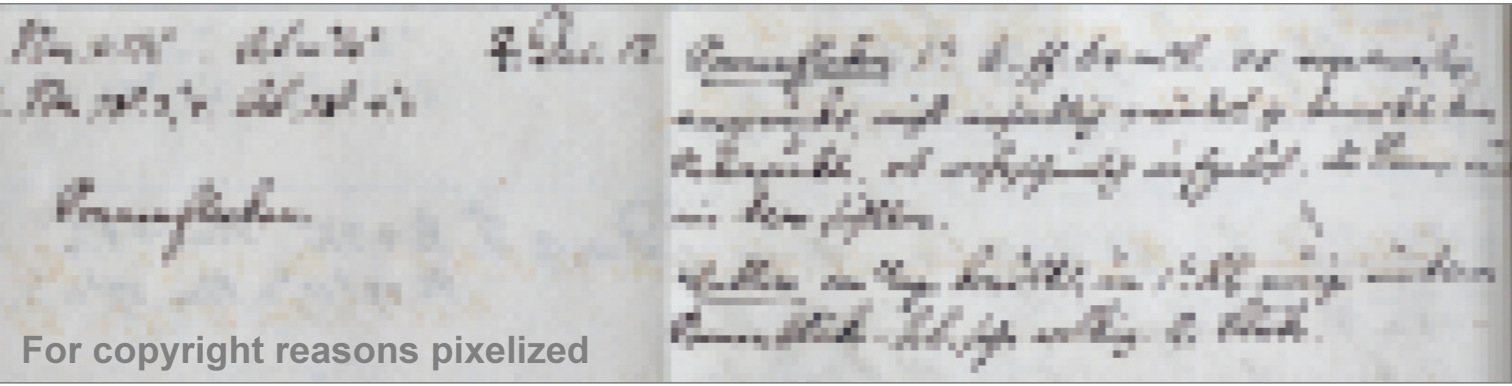
- Visibility of pores described in verbal reports – usually not included in drawings
- Count multiple umbrae in penumbra
- Full-disk drawings are not complete
- Group assignments underestimate group number?

➢ But see talk by Ilya Usoskin



Schwabe‘s drawings

- Verbal reports contain information on lifetime of sunspots



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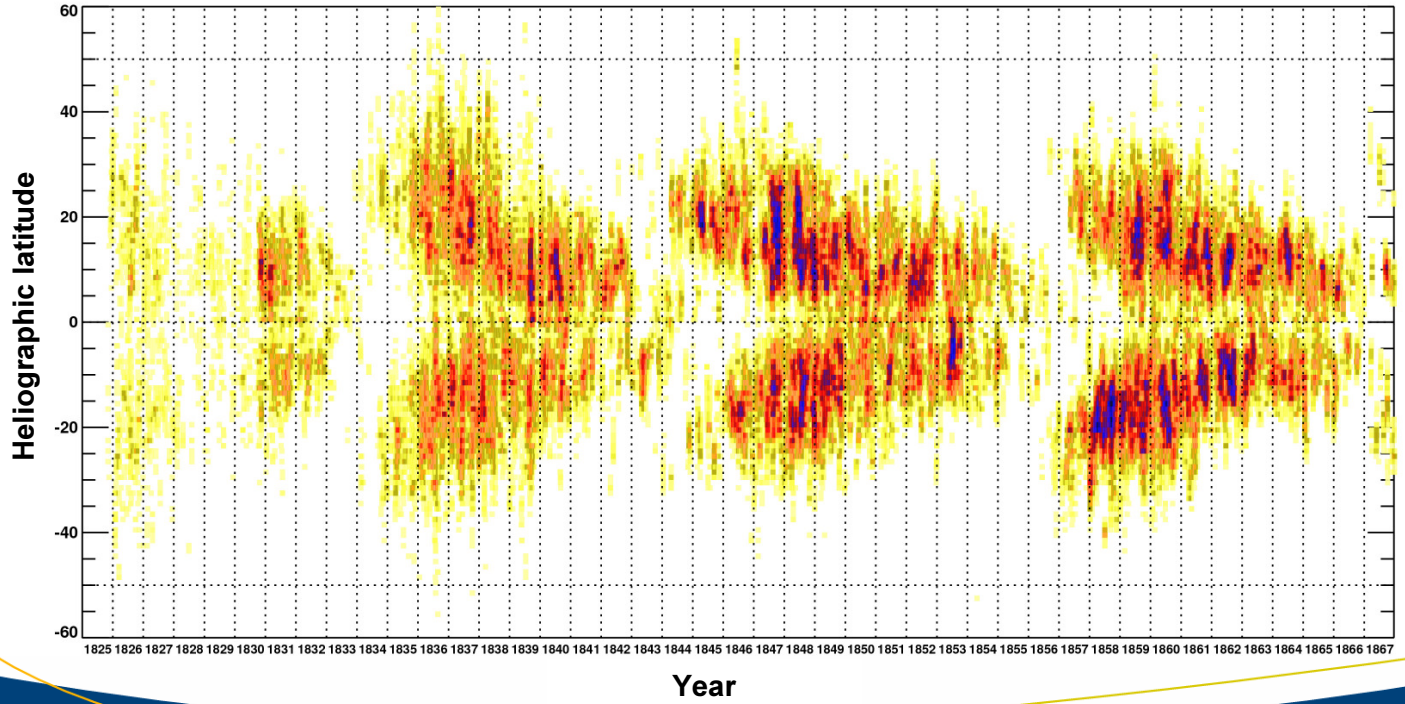
Samuel Heinrich Schwabe

- Butterfly diagram with 130,000 spots (incomplete)



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More observers in the 19th century

- Tevel, Böhm, Petersen, Peters, Bond
- Coordinates determined by Spörer
- No sizes of sunspots
- Originals largely unknown

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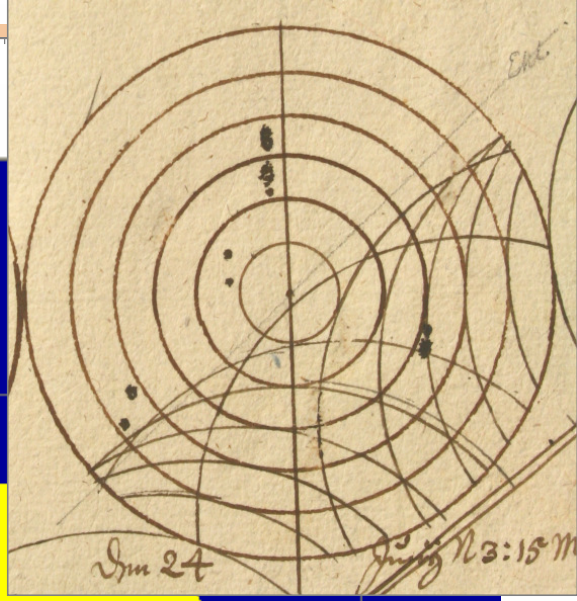
Johann Staudacher 1749–1799

- About 1000 drawings in ink and water colour
- Observed from Nuremberg
- One of very few observers in second half of 18th century
- Preserved at AIP

Sep 09, 1749

Staudacher, 24 Jun 1778



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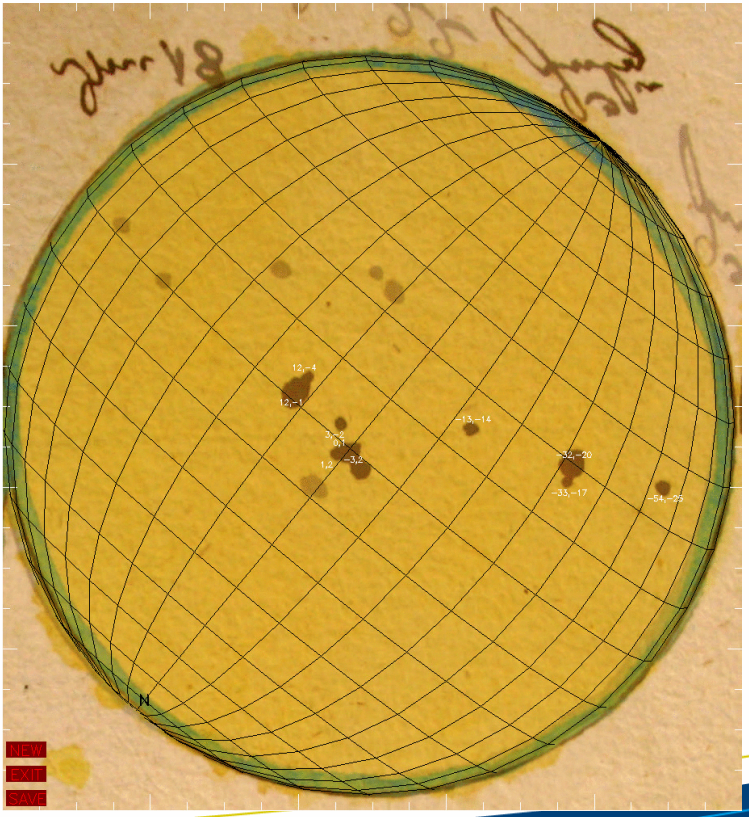
Staudacher‘s drawings

- Rotation of the Sun fixes orientation best
- Example shows superposition of July 18 and July 22, 1752



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Staudacher‘s drawings

- Compare Staudacher and what Wolf did with them

1751.			1752.		
III	23	1.2	III	5	2.3
IV	6	2.5	—	12	2.2
—	13	1.2	—	19	3.4
—	15	2.3	—	25	3.5
—	23	1.2	IV	16	1.2
—	25	1.2	V	14	1.1
V	2	0.0	—	20	2.4
—	4	1.1	VI	14	1.2
—	7	2.4	—	16	1.2
—	8	3.4	—	23	0.0
—	12	3.4	—	27	2.4
—	14	3.3	VII	13	4.4
—	18	2.4	—	18	3.8
—	23	2.3	—	22	3.6
—	30	3.6	—	24	2.6
VI	12	2.3	—	30	1.3

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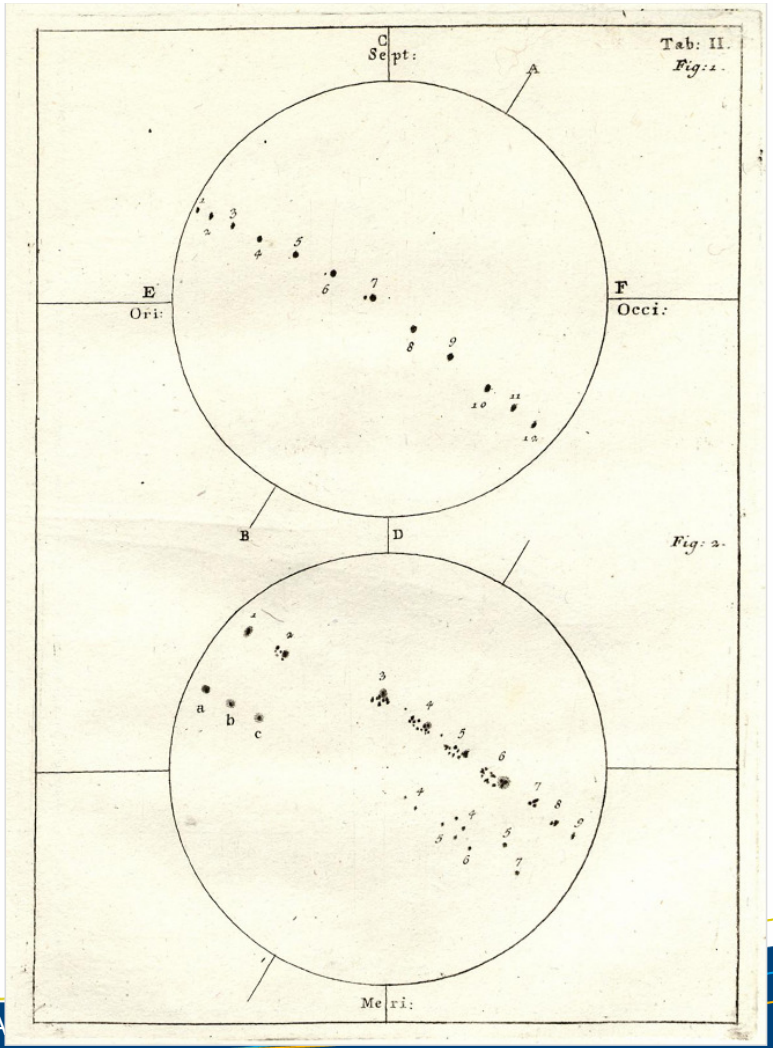
Ludovico Zucconi

- Analyzed by Cristo, Vaquero & Sànchez Bajo (2011)



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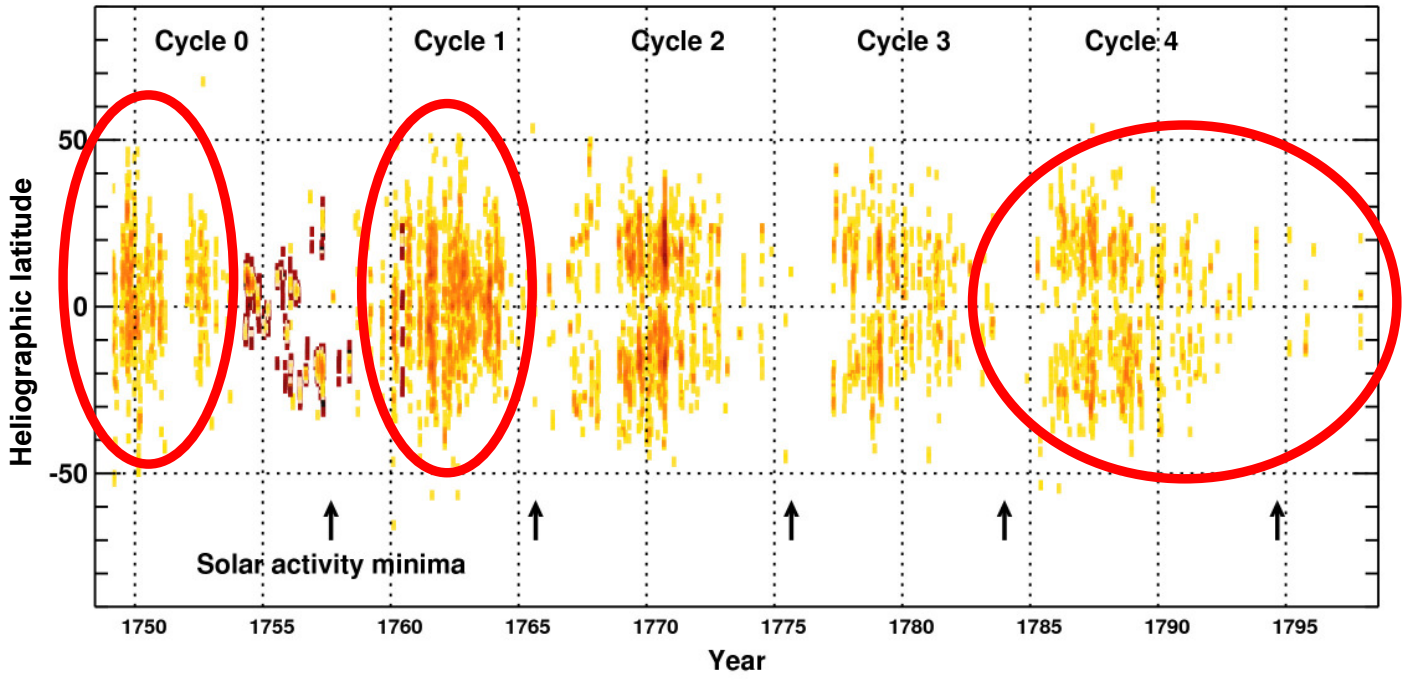
Staudacher's drawings

- Butterfly diagram for 1749 1799



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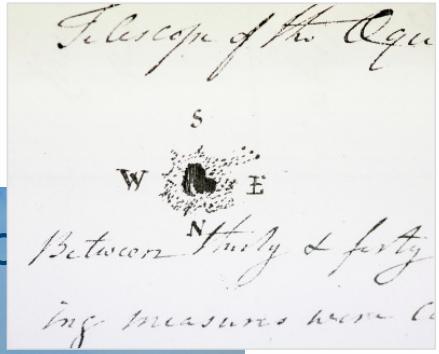
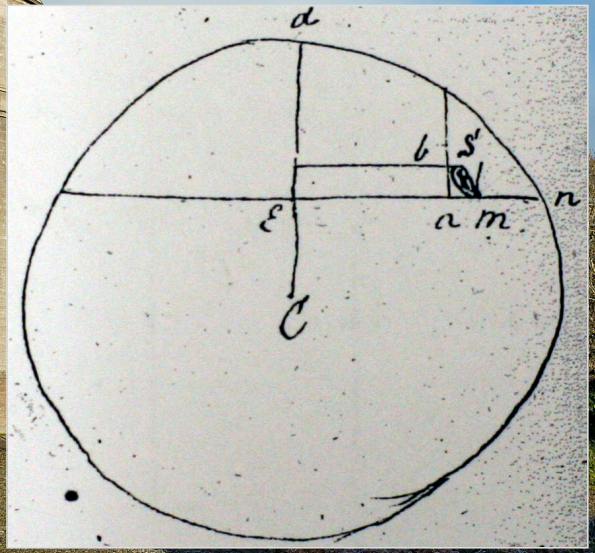
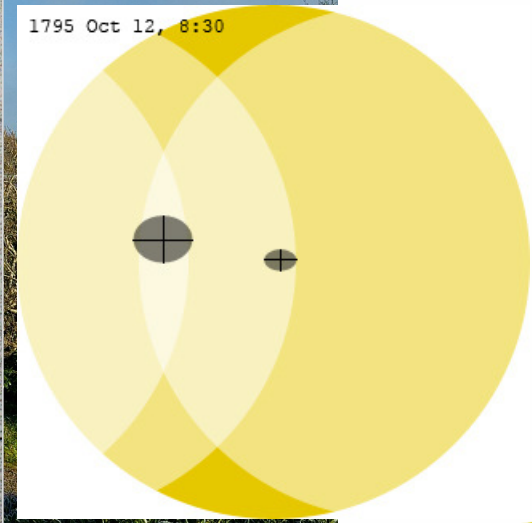
Hamilton and Gimingham



- Armagh Observatory 1795–1797, No





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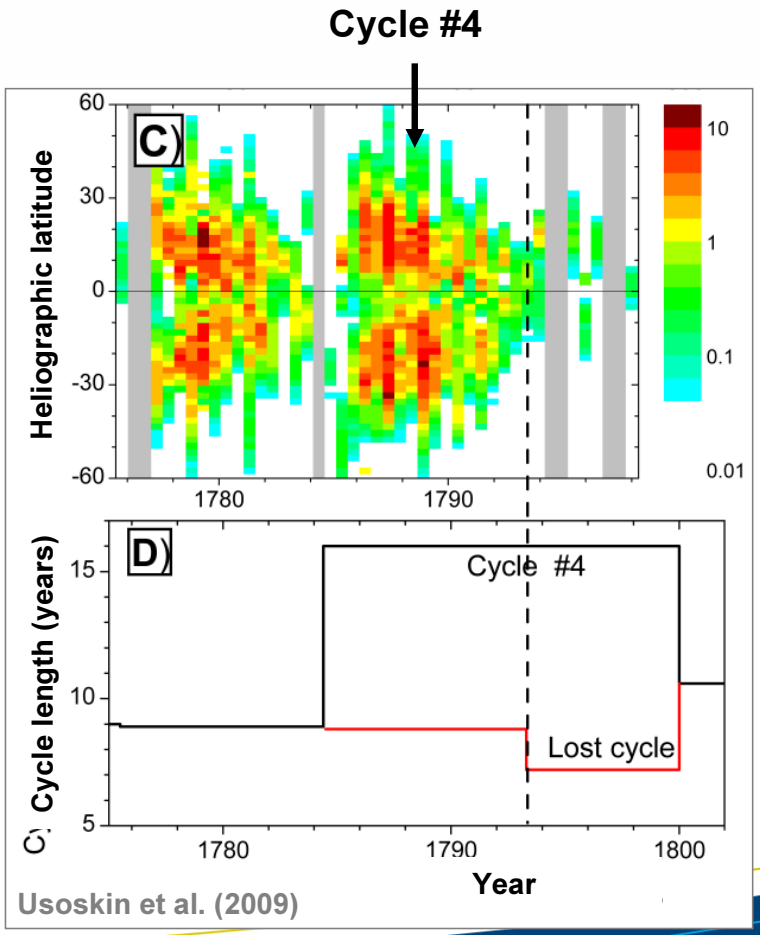
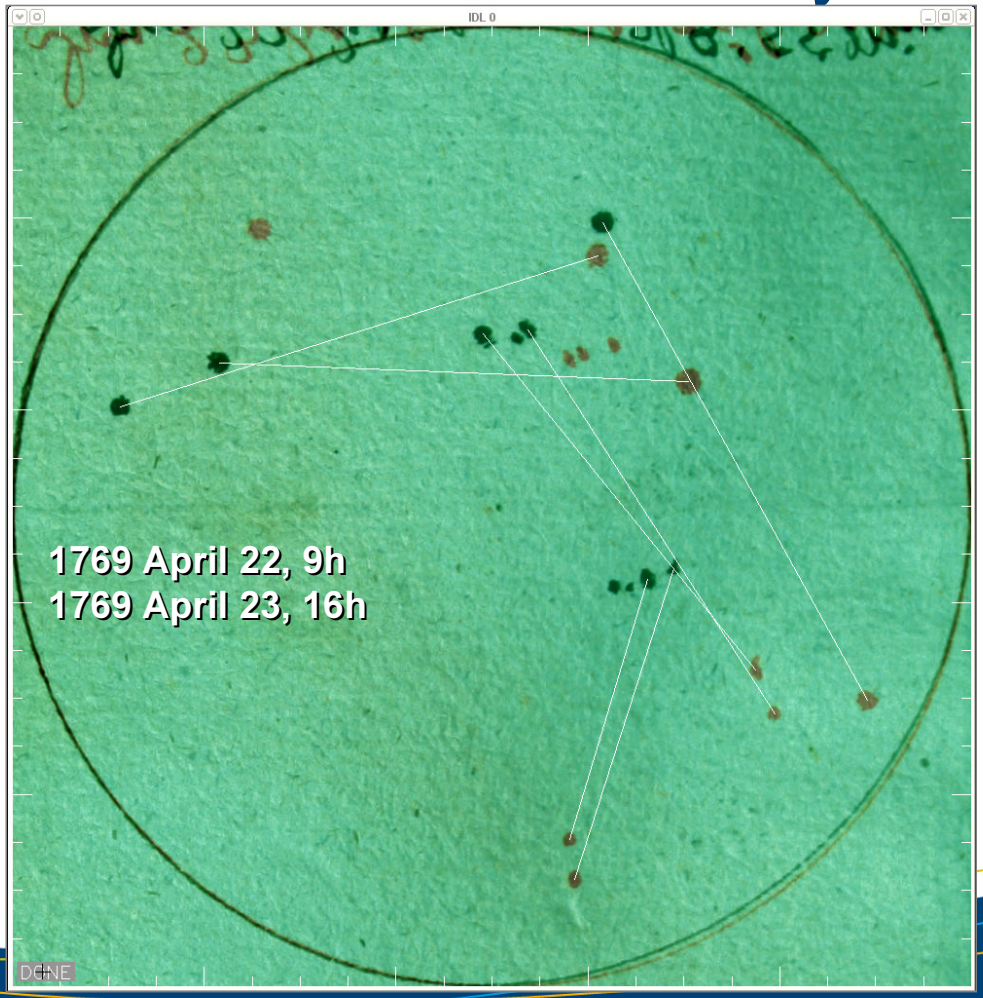
Lost cycle?

- Very long cycle #4 questioned
- Possibly weak cycle overlooked
- Now with positional data, better handle on additional cycle



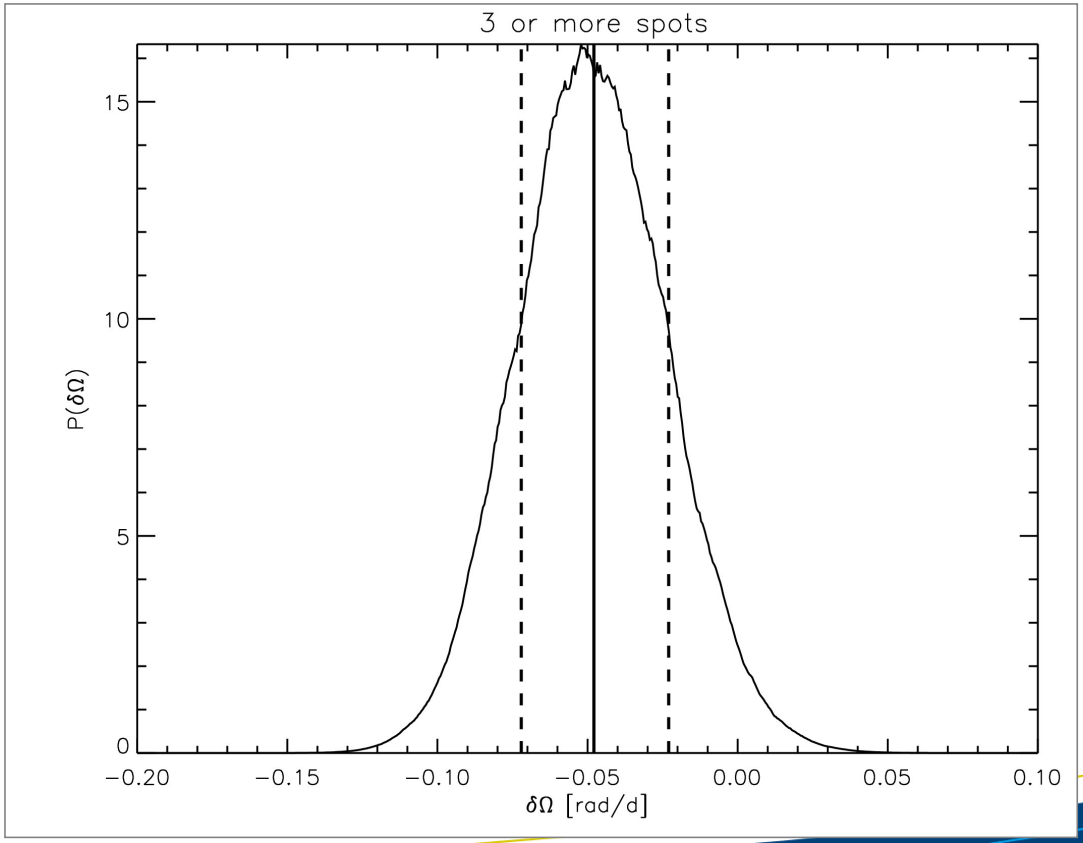
Differential rotation in 18th century

- Forget all we did before with Staudacher
- Use the method to find Schwabe orientation
- But keep differential rotation as a free parameter

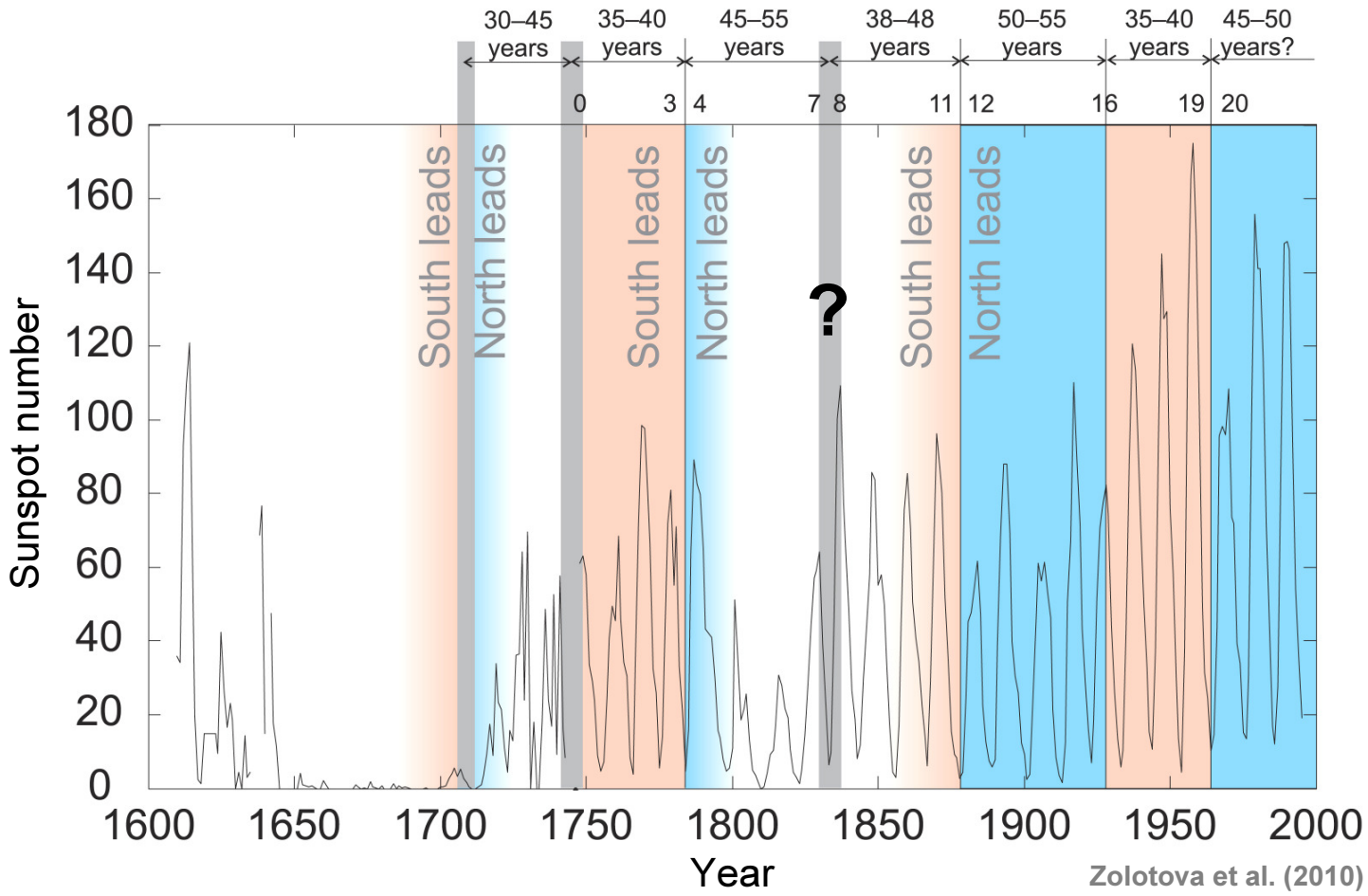


Differential rotation in 18th century

- 156 pairs of drawings
- At least 3 spots in common
- Get $\delta\Omega=0.048\ d^{-1}$ $\pm 0.024\ d^{-1}$
- present sun: $\delta\Omega=0.050\ d^{-1}$



Phase difference of hemispheres



Zolotova et al. (2010)

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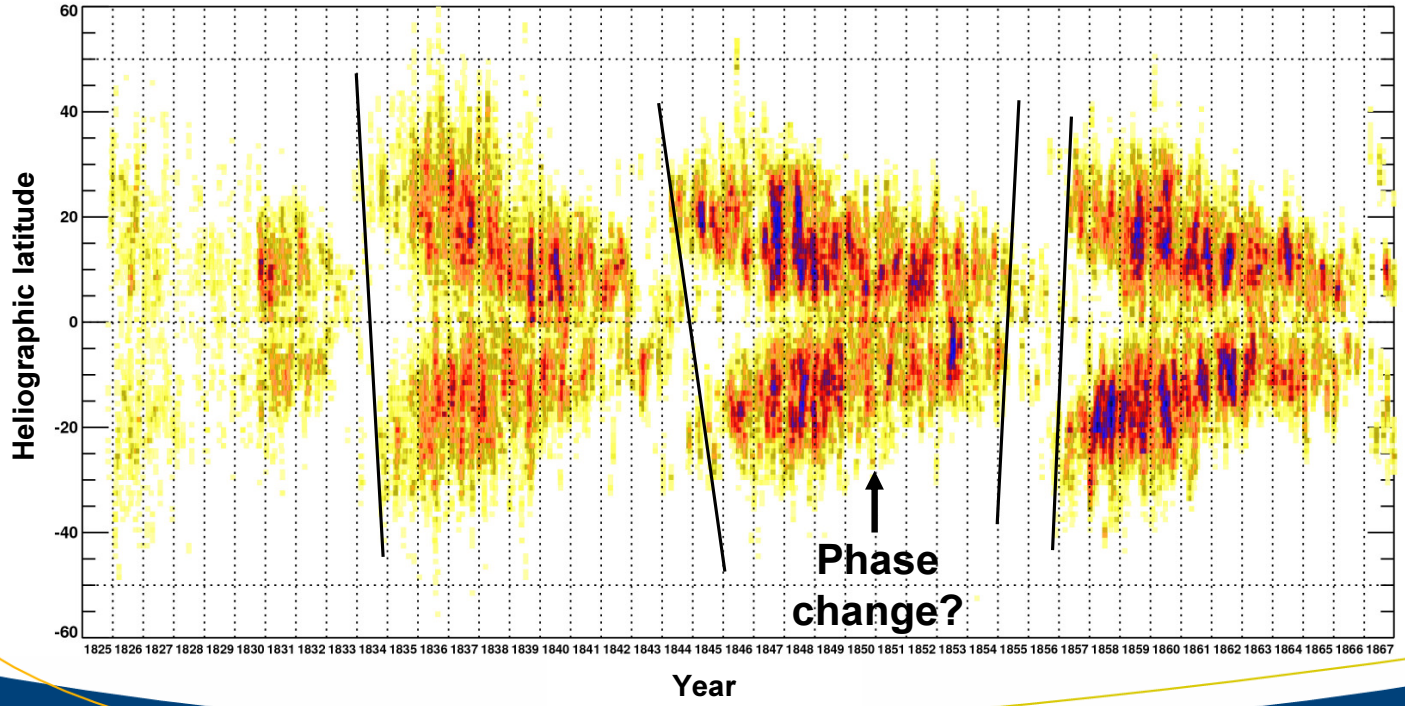
Back to Schwabe:

- Butterfly diagram with 100,000 spots (incomplete)



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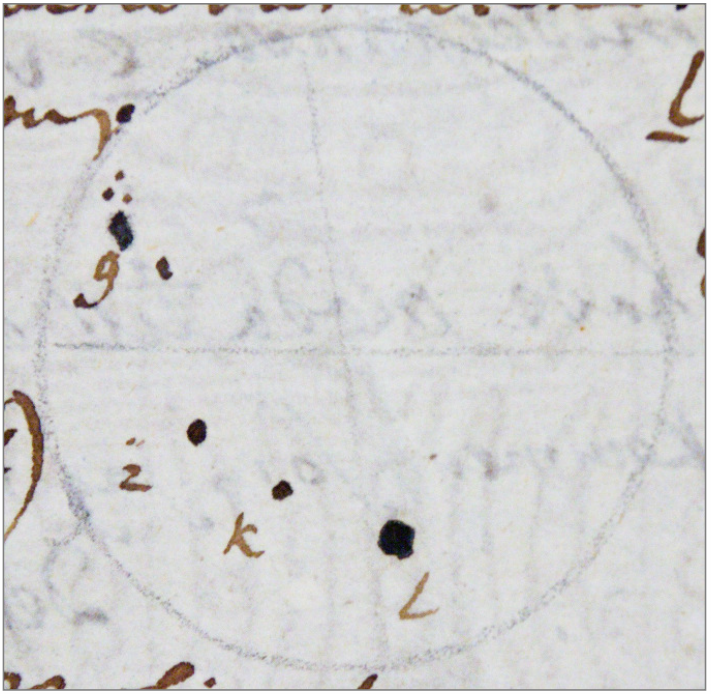
Pehr Wargentin, 1747

- Uppsala, Sweden
- 17 drawings of limited accuracy
- Note the dates are still Julian in Sweden!



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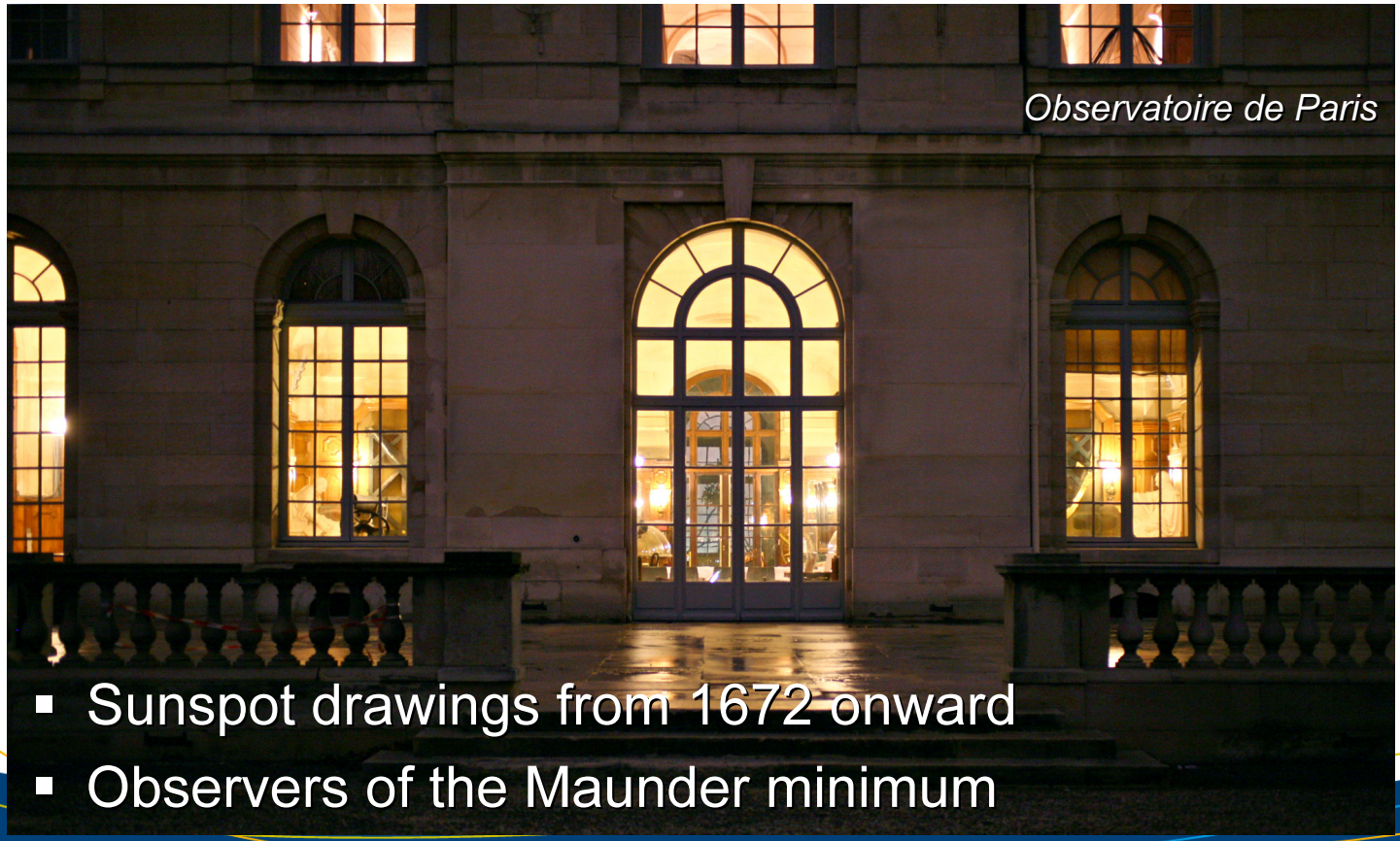
France and Italy



- Sunspot drawings from 1672 onward
- Observers of the Maunder minimum

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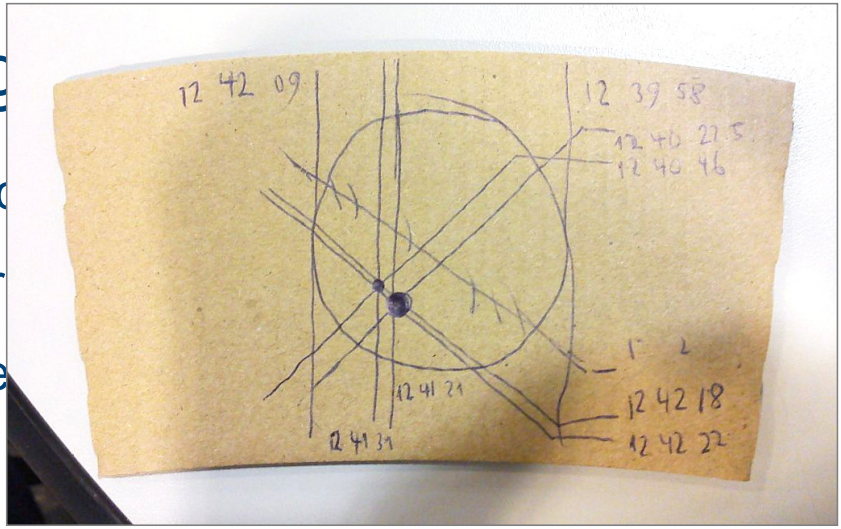
Honoré Flaug

- Several hundred sunspo
- Wolf's interpretation cor
- Today in archives of the
- Mostly contact times:



"le bord du ⊙ al horaire 12 39 58
la grande tache a l'oblique 12 40 22.5
la petite tache a l'oblique 12 40 46
la grande tache al horiare 12 41 21
la petite tache al horaire 12 41 31
le bord du soleil al horaire 12 42 09
le letite tache al oblique 12 42 18
le grande tache al oblique 12 42 22"

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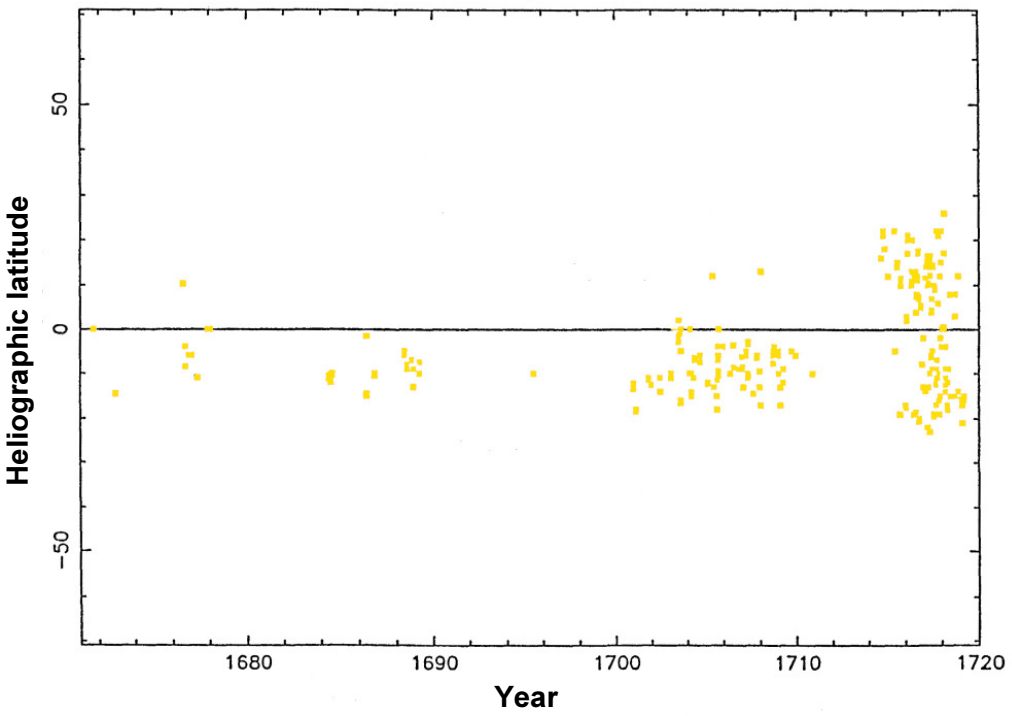
The Maunder minimum ~1650–1715

- Sunspots predominantly on the southern hemisphere of the Sun
- Cycle just detectable



Ribes & Nesme-Ribes (1993)

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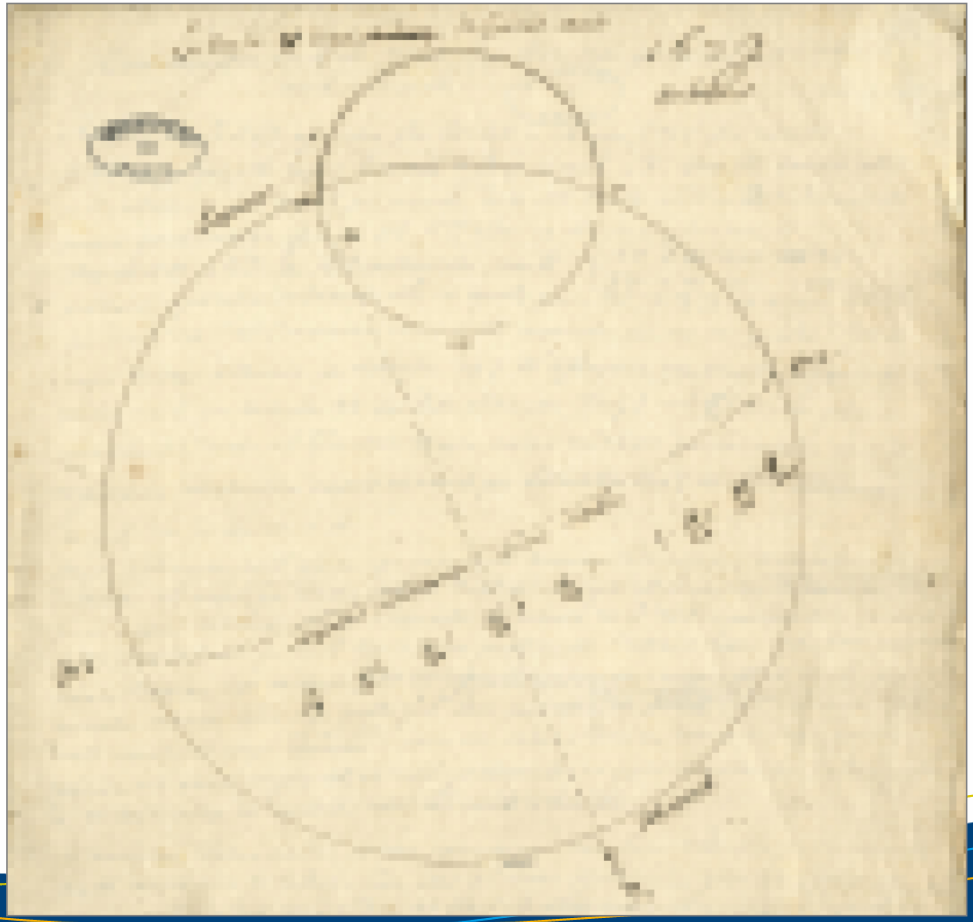
The Maunder minimum ~1650–1715

- Various sources including ~50-100 dawings starting in 1672
- Digitization by library of Paris Observatory



1600 1700

The Maunder minimum ~16

- 1706 Dec 7-10

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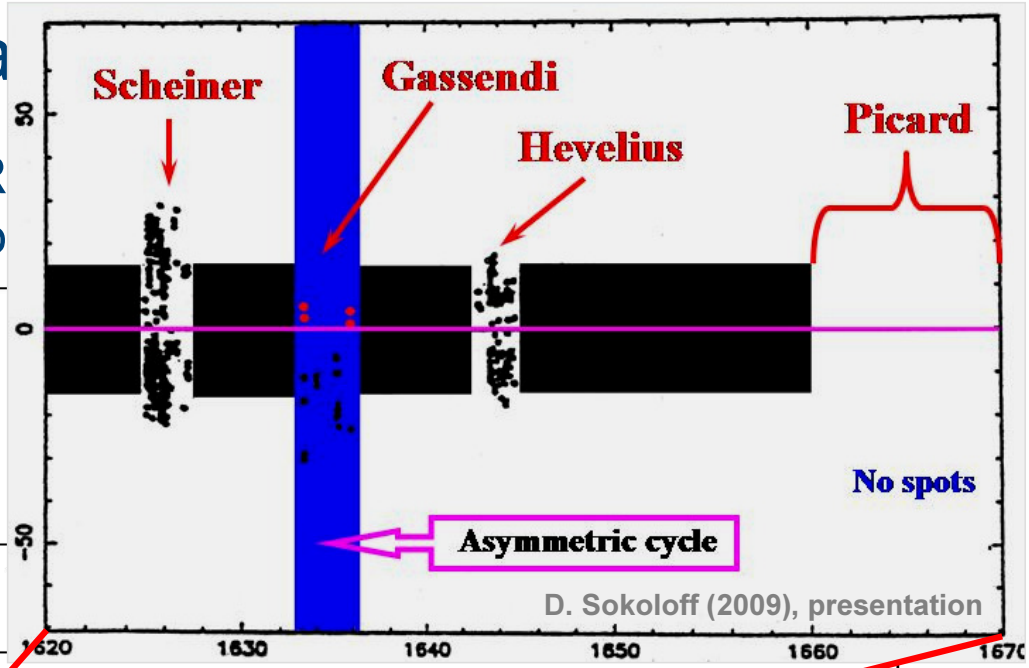
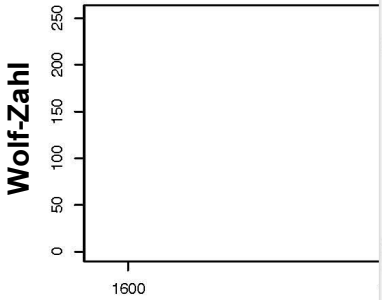
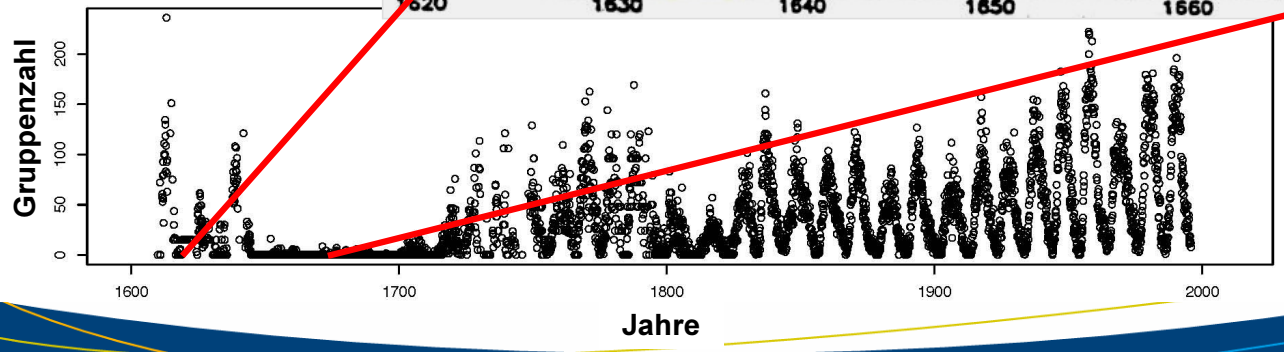
The Ma

- Data series by R
  by group sunspo







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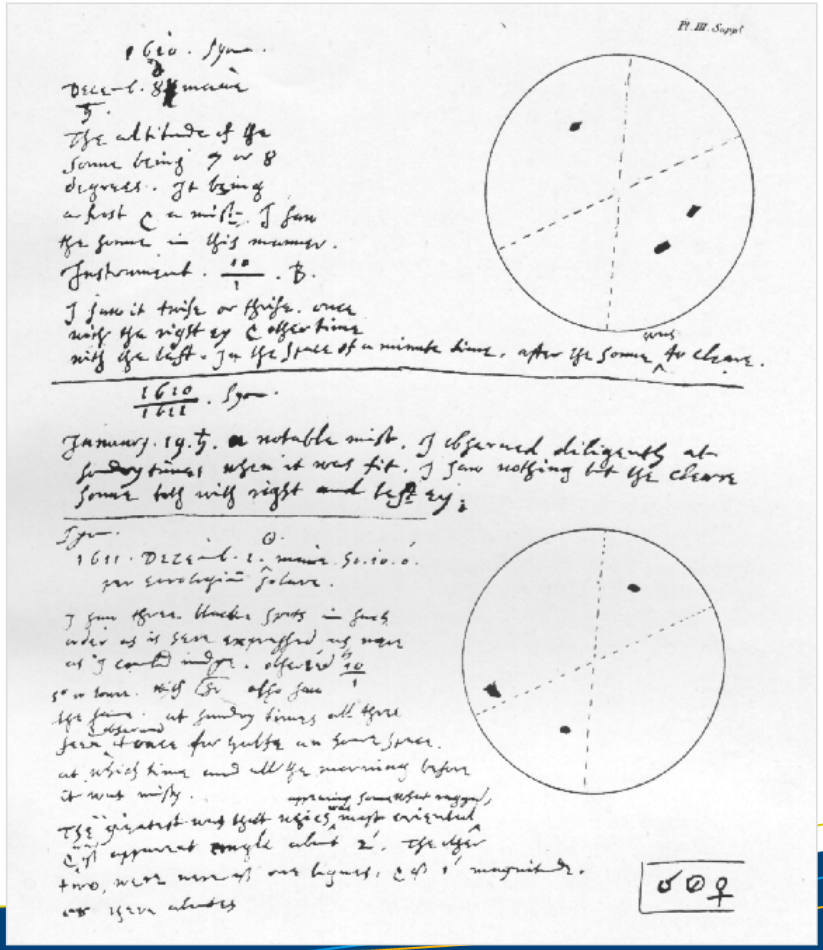
The „discoverers“ of the sunspots

- Thomas Harriott, 1610
- Galileo Galilei, 1610
- Johannes Fabricius, 1611 (first publication)
- Christoph Scheiner, 1611



Summary

- Butterfly diagram for 400 years should be possible
- Maybe other quantities tell us more about the dynamo than the sunspot number with all its calibration issues
- Spot sizes not possible in a consistent series
- Thanks to

Raisa Leussu, Kalevi Mursula, Ilya Usoskin (Oulu),
Peter Hingley, Robert Massey (RAS),
John Butler (Armagh), Regina v. Berlepsch (Potsdam),
Anastasia Abdolvand, Stela Arlt, Andrea Diercke, Jennifer Koch,
Jan Meyer, Clara Ricken, Christian Schmiel