Reconstruction method for sunspot positions from observations of Honoré Flaurergues in the end of 18th century

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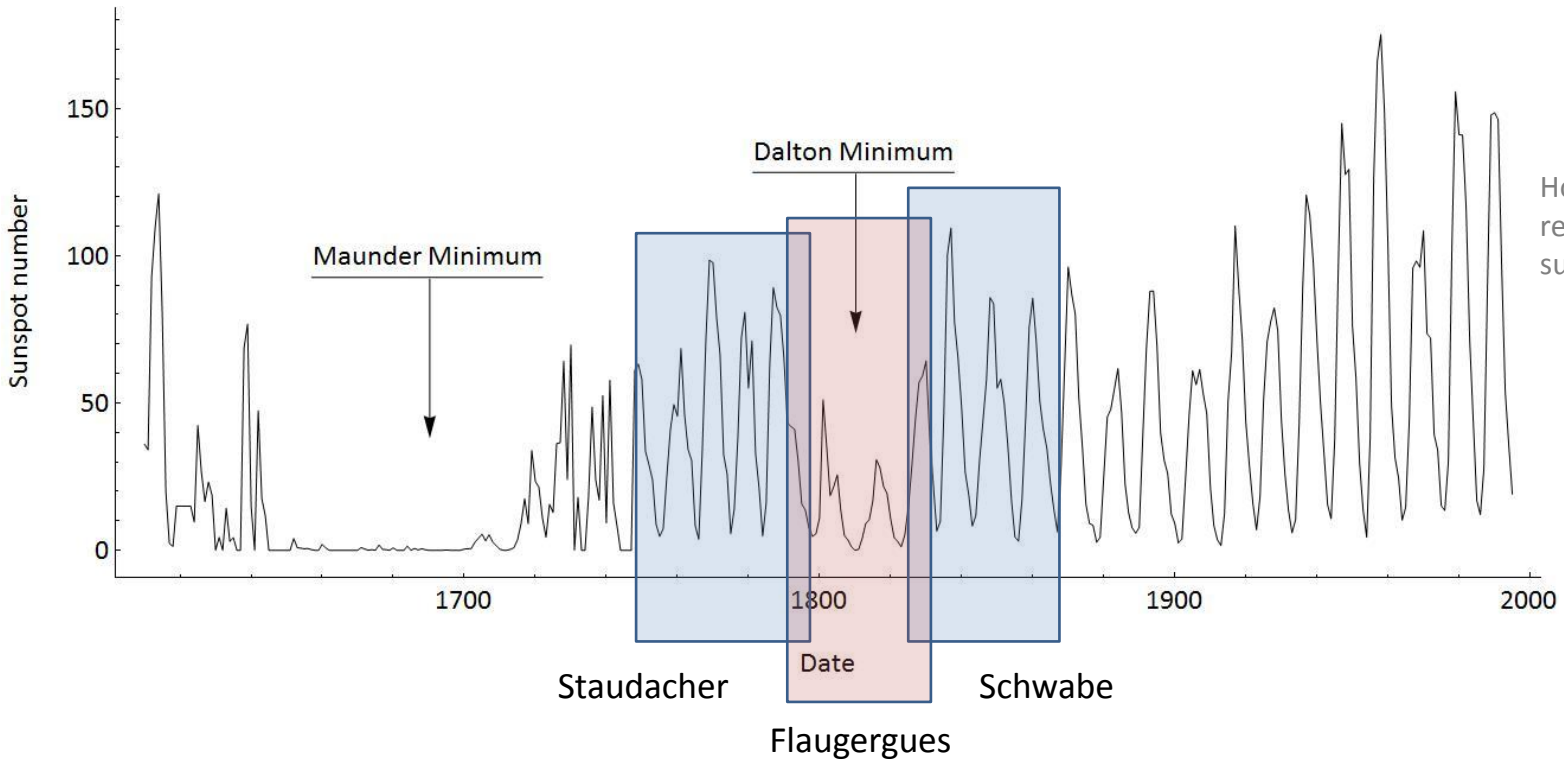
In a search of sunspots during the Dalton Minimum



Hoyt & Schatten reconstruction of sunspot numbers

Wolf: more than 2050 observations of solar disk in the period 1788–1830 allow to connect series of Staudacher and Schwabe and contain the best material about the Dalton Minimum

Honoré Flaugergues: biography

- 1755–1835(0?), Viviers, France

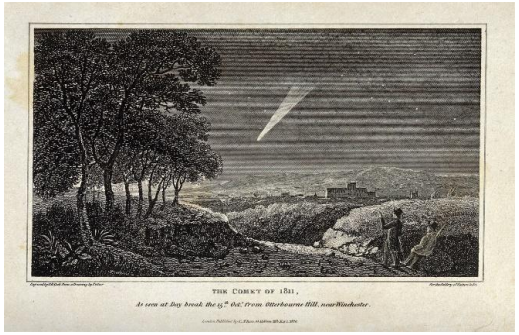
- Very little is known, however, his life spanned the most momentous period in the political history of France

- Many publications of great merit on physics, astronomy, archeology, history and medicine. Obtained several Academic awards

- Arranged a small observatory in Viviers, refused a position of Director of observatory in Toulon

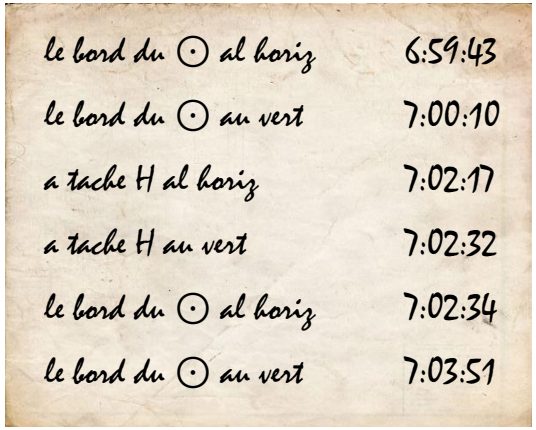
- Concentrated on comet hunting, observation of sunspots, solar and lunar eclipses, planets, occultations

- First discovered the Great Comet of 1811



Sunspot observations

- No detailed information about the procedure
- Generally observations are a combination of transitional times of solar disk and sunspots through a set of wires situated towards movement direction of the Sun
- We distinguish at least two ways of positioning of the wires
- Some spots are labeled by letters
- Repeated observations within one day
- Several textual comments are difficult to interpret



Reconstruction method

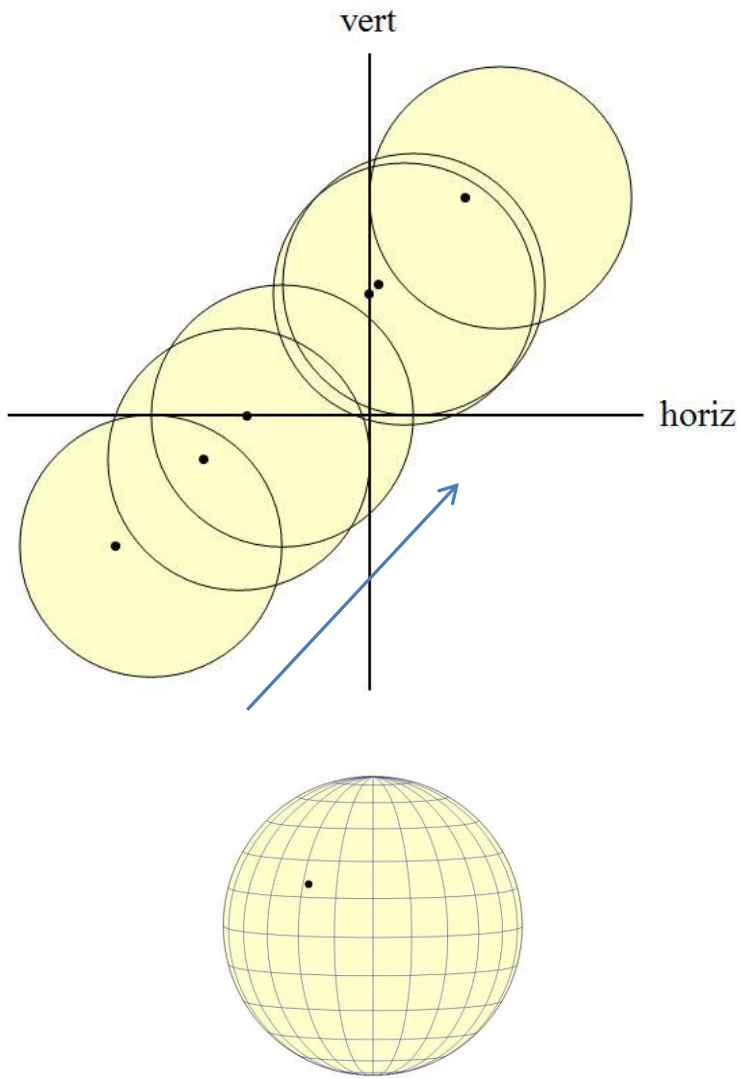
le bord du ⊙ al horiz	6:59:43
le bord du ⊙ au vert	7:00:10
a tache H al horiz	7:02:17
a tache H au vert	7:02:32
le bord du ⊙ al horiz	7:02:34
le bord du ⊙ al vert	7:03:51

Coordinates on the disk are extracted unambiguously:

$$x = \frac{bv_2 - sv}{bv_2 - bv_1}$$

$$y = \frac{bh_2 - sh}{bh_2 - bh_1}$$

We calculate P and B angles to obtain heliographic coordinates of sunspot



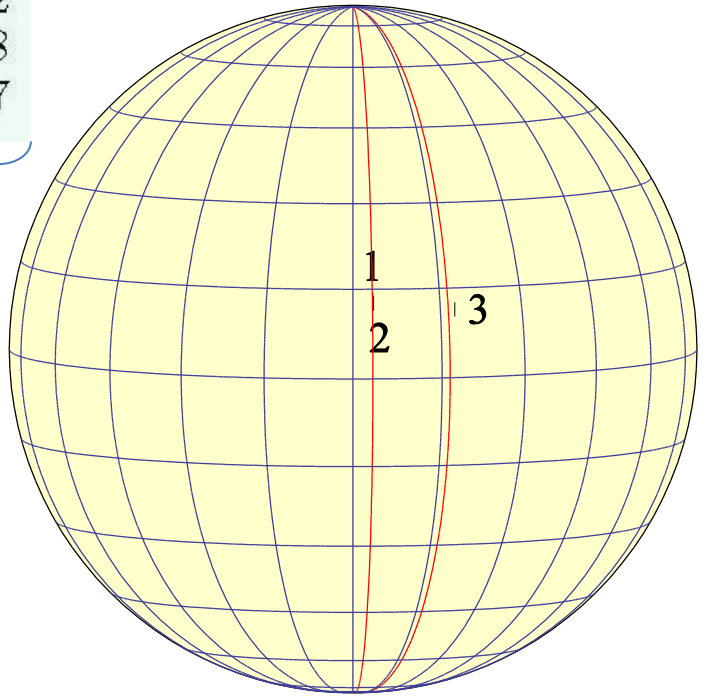
19 and 20 July 1796

Sunspot with label G was measured twice on 19 July 1796 and once on the next day:

	1	2	3
le bord du ⊙ al horiz	7:43:13	7:48:18	7:29:54
le bord du ⊙ au vert	7:43:35	7:48:13	7:29:50
a tache G al horiz	7:44:29	7:49:33	7:30:54
a tache G au vert	7:55:36	7:50:16	7:31:32
le bord du ⊙ al horiz	7:46:06	7:51:08	7:32:48
le bord du ⊙ al vert	7:47:17	7:52:00	7:33:27

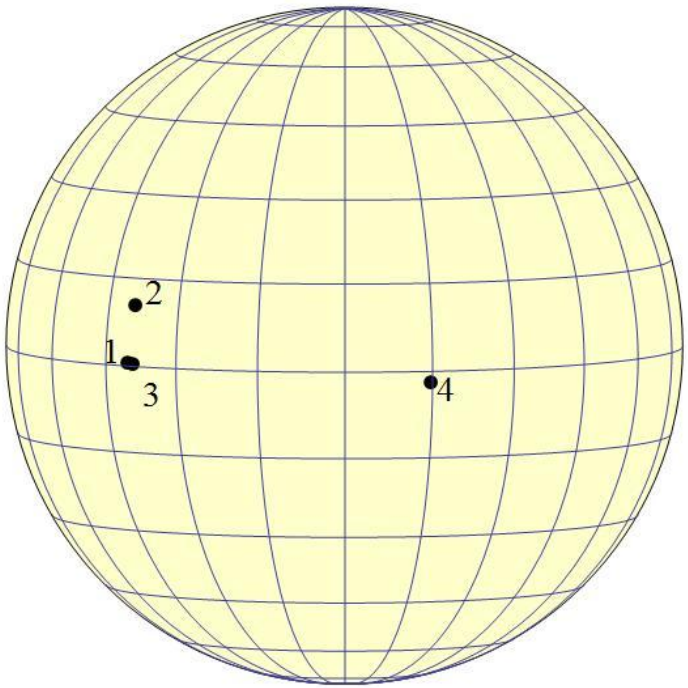
19 July 20 July

Reconstruction gives a very close coordinates for measures 1 and 2 and expected longitudinal drift for measure 3



Sunspot with label E was measured four times on 13 July 1796, however, reconstruction of original notes do not give the same positions on the disk

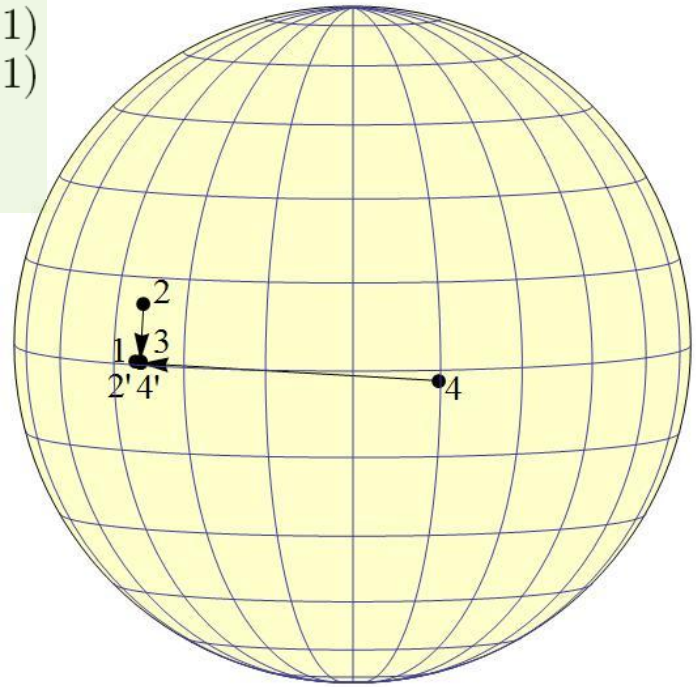
	1	2	3	4
b ⊙ v	6:12:01	6:17:14	6:22:16	6:27:38
b ⊙ h	6:12:31	6:17:44	6:23:09	6:27:50
t E v	6:14:16	6:19:36	6:24:32	6:28:52
t E h	6:14:52	6:19:59	6:25:11	6:29:13
b ⊙ v	6:15:19	6:20:22	6:25:34	6:30:54
b ⊙ h	6:15:37	6:21:01	6:26:15	6:30:59



Sunspot with label E was measured four times on 13 July 1796, however, reconstruction of original notes does not give the same positions on the disk

	1	2, 2’	3	4, 4’
b ⊙ v	6:12:01	6:17:44	6:22:16	6:27:38
b ⊙ h	6:12:31	6:17:14	6:23:09	6:27:50
t E v	6:14:16	6:19:59	6:24:32	6:29:52 (+1)
t E h	6:14:52	6:19:36	6:25:11	6:30:13 (+1)
b ⊙ v	6:15:19	6:21:01	6:25:34	6:30:54
b ⊙ h	6:15:37	6:20:22	6:26:15	6:30:59

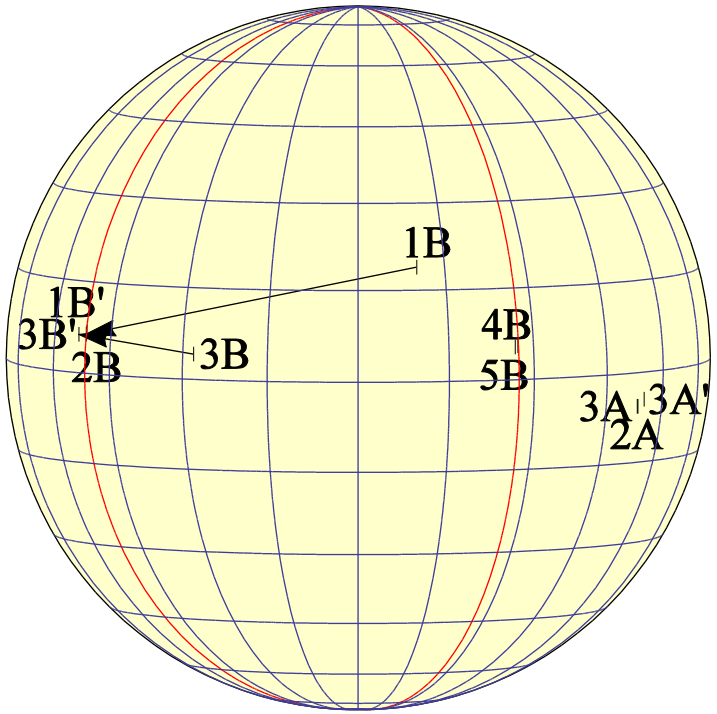
We assumed natural mistakes in notes and after their corrections the sunspots are close again!



Sunspot B is mentioned twice with a difference in 5 days, but only a series of corrections allows to make coordinates agree

	1, 1′	2	3, 3′
b ⊙ v	9:19:28	9:24:43	9:31:23 (+1)
b ⊙ h	9:19:14	9:24:11	9:31:03
t A v		9:25:18	9:31:56 (+1)
t A h		9:25:01	9:31:55
t B h	9:21:39 (+1)	9:26:34	9:33:29 (+1)
t B v	9:22:08 (+1)	9:27:21	9:33:59 (+1)
b ⊙ h	--:--:--	9:27:21	9:34:16
b ⊙ v	9:22:50	9:28:02	--:--:--

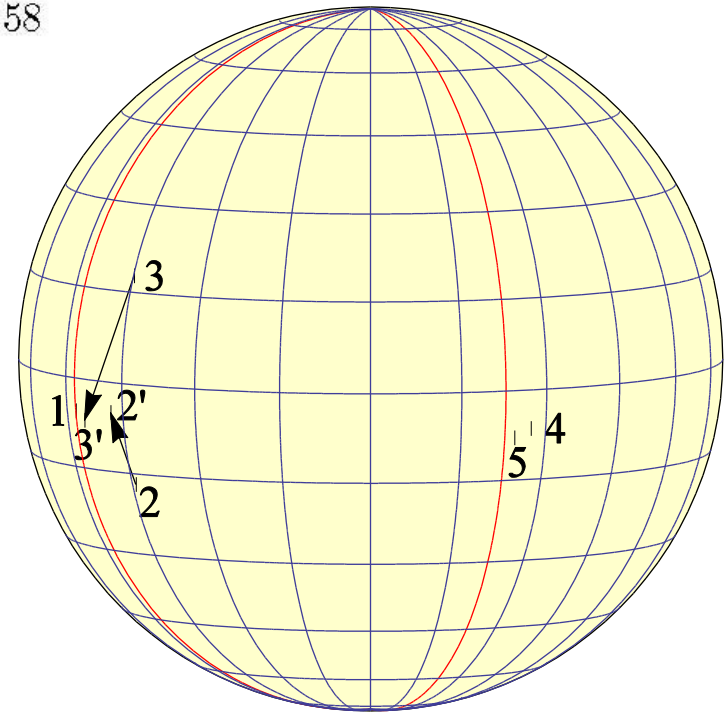
	4	5
le bord du ⊙ al horiz	7:12:06	7:18:19
le bord du ⊙ au vert	7:12:21	7:18:31
a tache B al horiz	7:13:01	7:19:13
a tache B au vert	7:13:43	7:19:56
le bord du ⊙ al horiz	7:15:04	7:21:13
le bord du ⊙ al vert	7:15:58	7:22:13



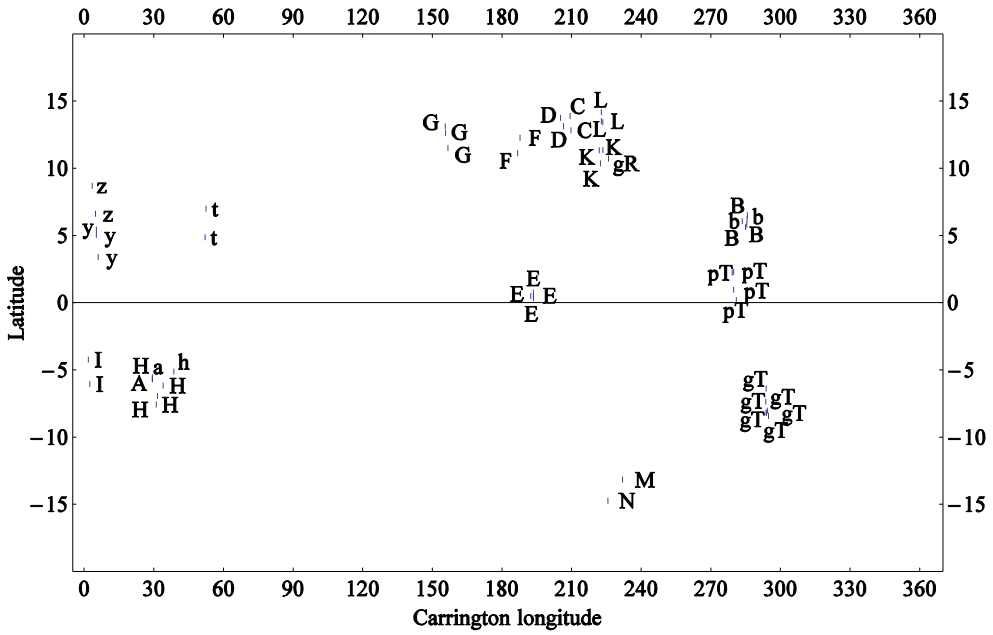
Measures of sunspot H are less accurate, but still reliable

	1	2, 2′	3, 3′
le bord du ⊙ al horiz	6:59:43	7:06:27	7:10:45
le bord du ⊙ au vert	7:00:10	7:05:34	7:10:20
a tache H al horiz	7:02:17	7:09:03 (+1)	7:13:19
a tache H au vert	7:02:32	7:07:50	7:12:37
le bord du ⊙ al horiz	7:02:34	--:--:--	7:13:37
le bord du ⊙ al vert	7:03:51	7:09:09 (+1)	7:13:58

	4	5
le bord du ⊙ al vert	7:56:22	8:02:34
le bord du ⊙ au horiz	7:57:00	8:03:43
a tache H al vert	7:57:32	8:03:40
a tache H au horiz	7:57:57	8:03:47
le bord du ⊙ al horiz	7:59:48	8:05:35
le bord du ⊙ al vert	8:00:07	8:06:10

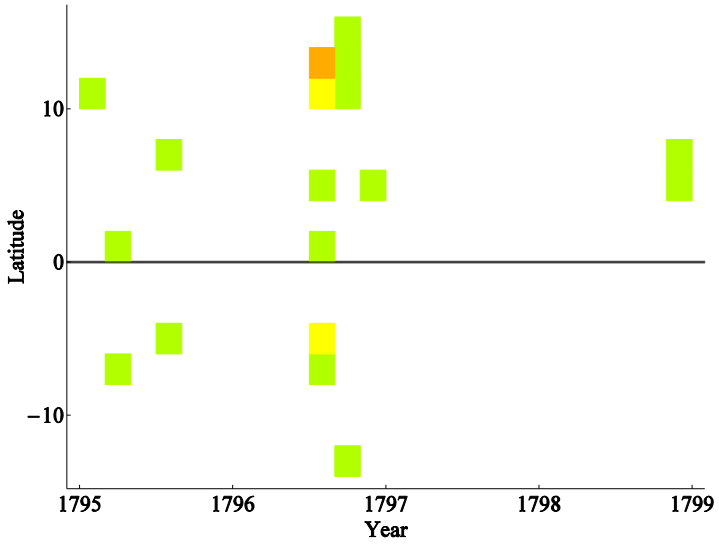


Overview of sunspot distribution



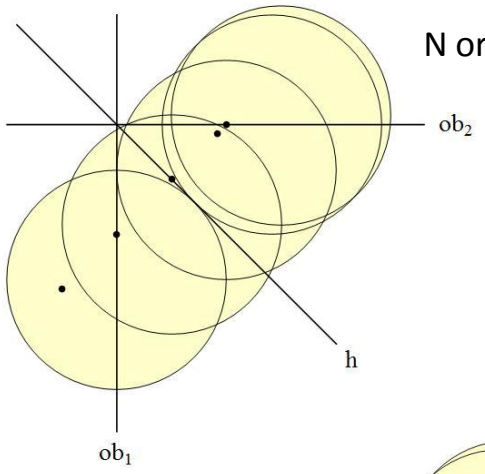
We observe a good overall agreement of reconstructed observations

Butterfly diagram for sunspots



Experiments with position of wires

	N	S	
le bord du ⊙ al horiare	12:39:58	13:01:58	
le grande tache al oblique	12:40:22	13:02:07	
la grande tache al horiare	12:41:21	13:03:21	(+1)
le bord du ⊙ al horiare	12:42:09	13:04:09	(+1)
le grande tache al oblique	12:42:22	13:04:30	

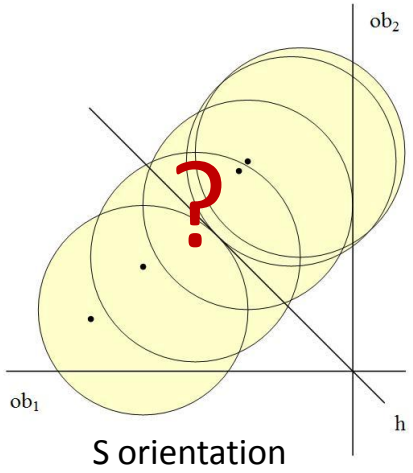


Expressions became more complicated and orientation of wires is essential:

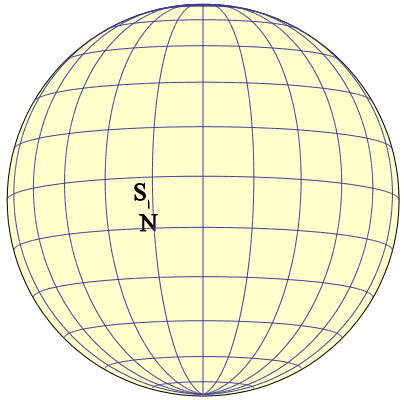
Let d be equal to $bh_2 - bh_1$, then

$$x = \frac{1}{2}\left(\frac{bh_2 - sh}{d} + 1 - \frac{sh - bh_1}{d}\right)$$

$$y = 1 - \frac{1}{2}\left(\frac{so_1 - sh}{d} + \frac{sh - so_2}{d}\right)$$



We obtained similar coordinates for sunspot measured twice: relative to N and relative to S orientation of wires



Incomplete notes are not lost

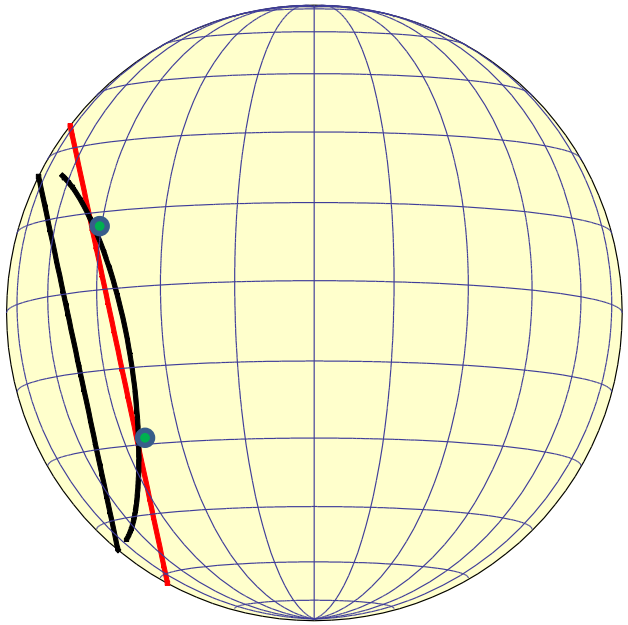
Some measures are incomplete for reconstruction

le bord du ⊙ h	11:51:10	13:19:25
tache h	11:53:12	13:21:18
le bord du ⊙ h	11:53:27	13:21:42

Differential rotation can be exploited to localize position

$$\Omega(B) = 14.551 - 2.87 \sin^2 B - 0.986$$

Series of such observations will remove the ambiguity



Wolf's numbers

We observe some deviations from g/s numbers given in Wolf's table

yyyy	mm	dd	time	L_0	B_0	CMD	Long	Lat	g/s	Wolf g/s
1795	02	12	11:40	215.0	-6.8	10.8	225.8	10.7	1 1	2 -
1795	03	04	12:50	311.0	-7.2	-17.1 -31.2	293.9 279.8	-7.8 1.4	2 2	2 5
1795	07	05	9:25	336.5	3.7	52.7 -51.7	29.2 284.8	-5.7 6.3	2 2	2 3
1796	07	11	7:15	258.3	4.3	26.8 -48.9 -52.6	285.1 209.4 205.7	5.7 13.3 13.4	2 3	2 3
1796	07	13	6:20	232.3	4.5	-39.2	193.1	0.5	1 1	1 1
1796	07	16	7:25	192.1	4.8	-5.0	187.1	11.7	1 1	1 5
1796	07	19	7:45	152.2	5.0	3.3	155.5	12.9	1 1	1 2
1796	07	20	7:30	139.1	5.1	17.5	156.6	11.5	1 1	1 1
1796	07	24	7:05	86.4	5.5	-53.4	33.0	-5.9	1 1	1 1
1796	07	30	8:00	6.5	5.9	-25.8 -4.6	32.3 1.9	-6.9 -5.2	2 2	2 2
1796	09	02	7:55	277.2	7.2	-54.7 -54.3 -45.5 -51.7	222.5 222.9 231.7 225.5	11.0 13.7 -13.2 14.7	3 4	2 7
1796	11	13	12:05	45.1	2.6	7.1	52.2	5.9	1 1	1 9
1798	12	20	15:05	0.7	-2.0	3.3	4.0	7.7	1 1	1 1
1798	12	21	14:55	347.7	-2.1	17.6	5.3	4.6	1 1	1 1

Conclusion

- We suppose to understand a way sunspots were measured
- Excellent accuracy of observations was achieved with simple method
- Most of disagreements in positions can be explained by natural mistakes during making notes
- Incomplete observations are not hopeless for reconstruction
- Further investigation of Flaugergues archive can be done in a systematic way

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- We suppose to understand a way sunspots were measured
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Thank you for your attention!