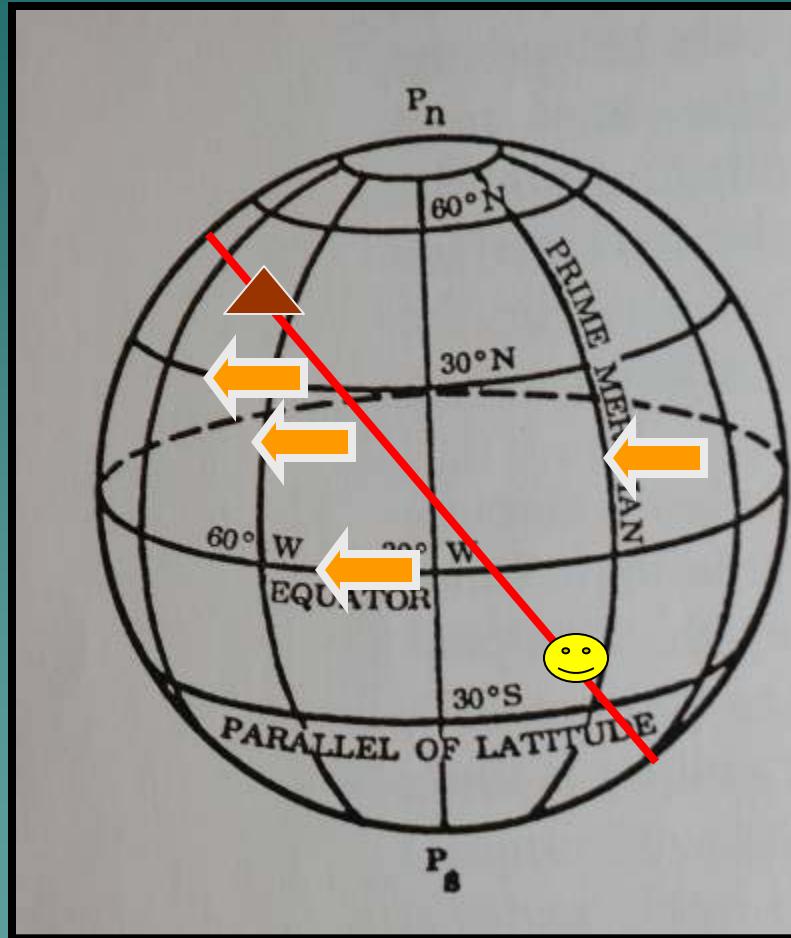


Celestial Navigation

Session II

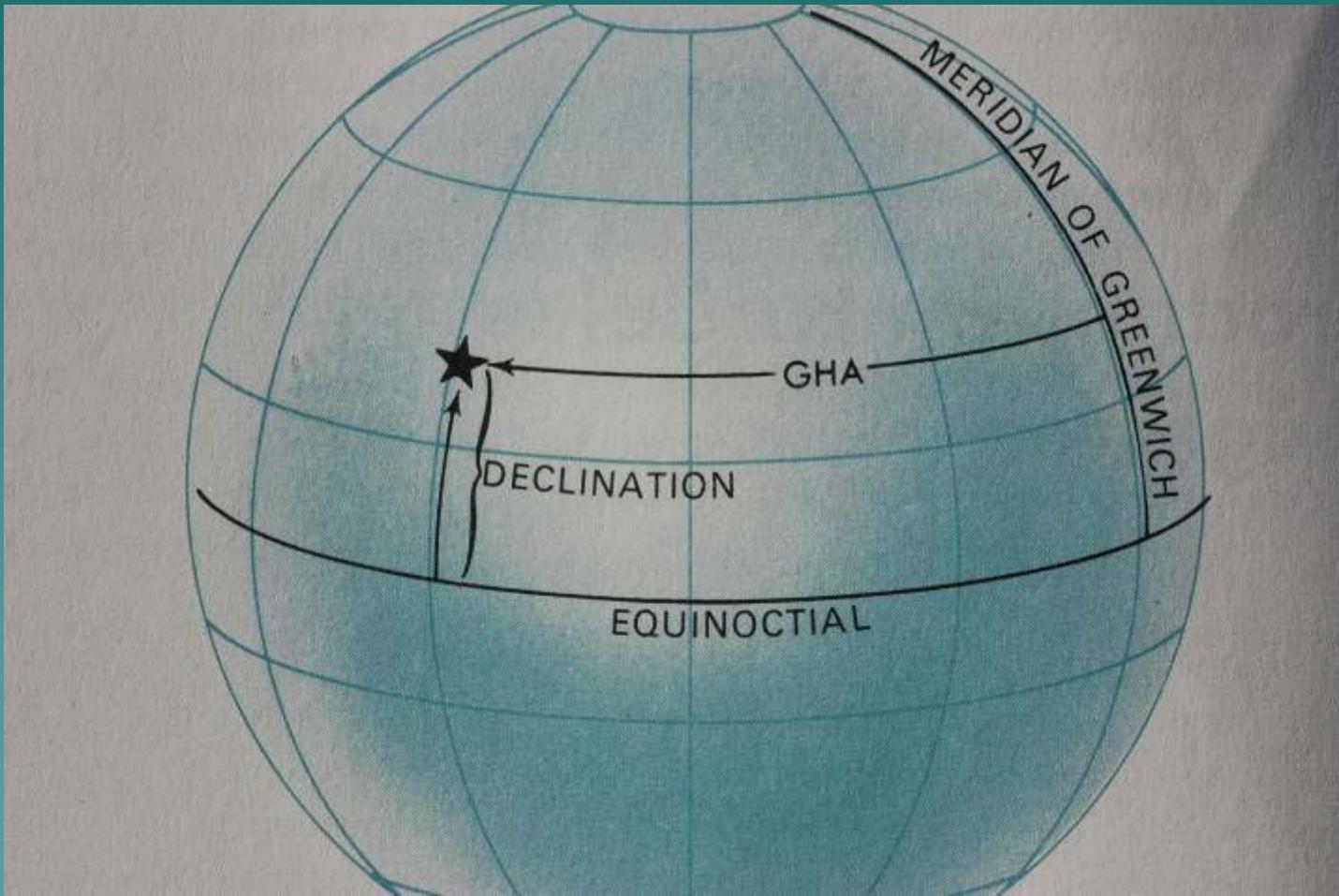
Presented by Ralph Naranjo

Circles and spheres

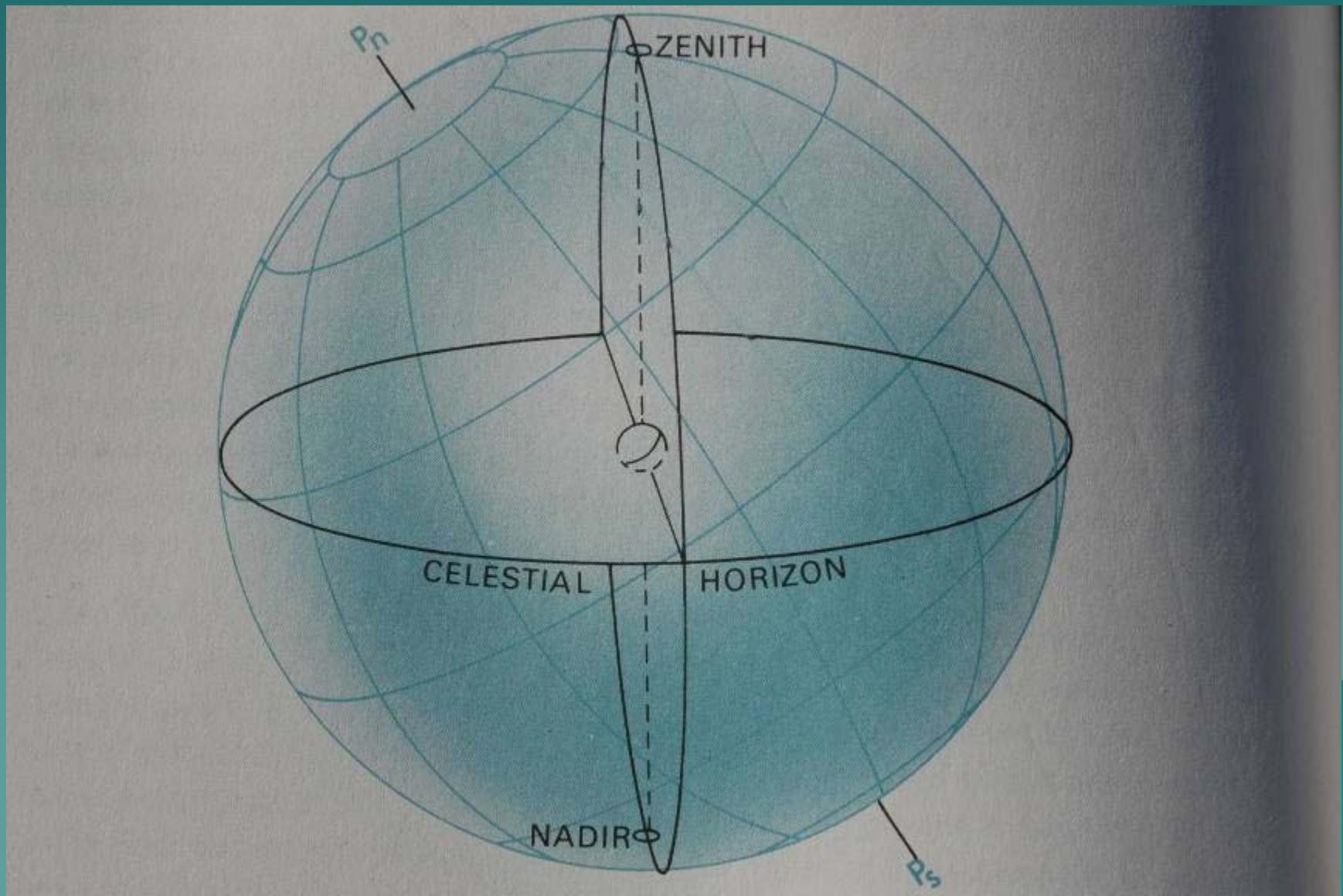


- ◆ Great circles
- ◆ Longitude
- ◆ Latitude
- ◆ Equator
- ◆ Parallels
- ◆ Obliquity of ecliptic

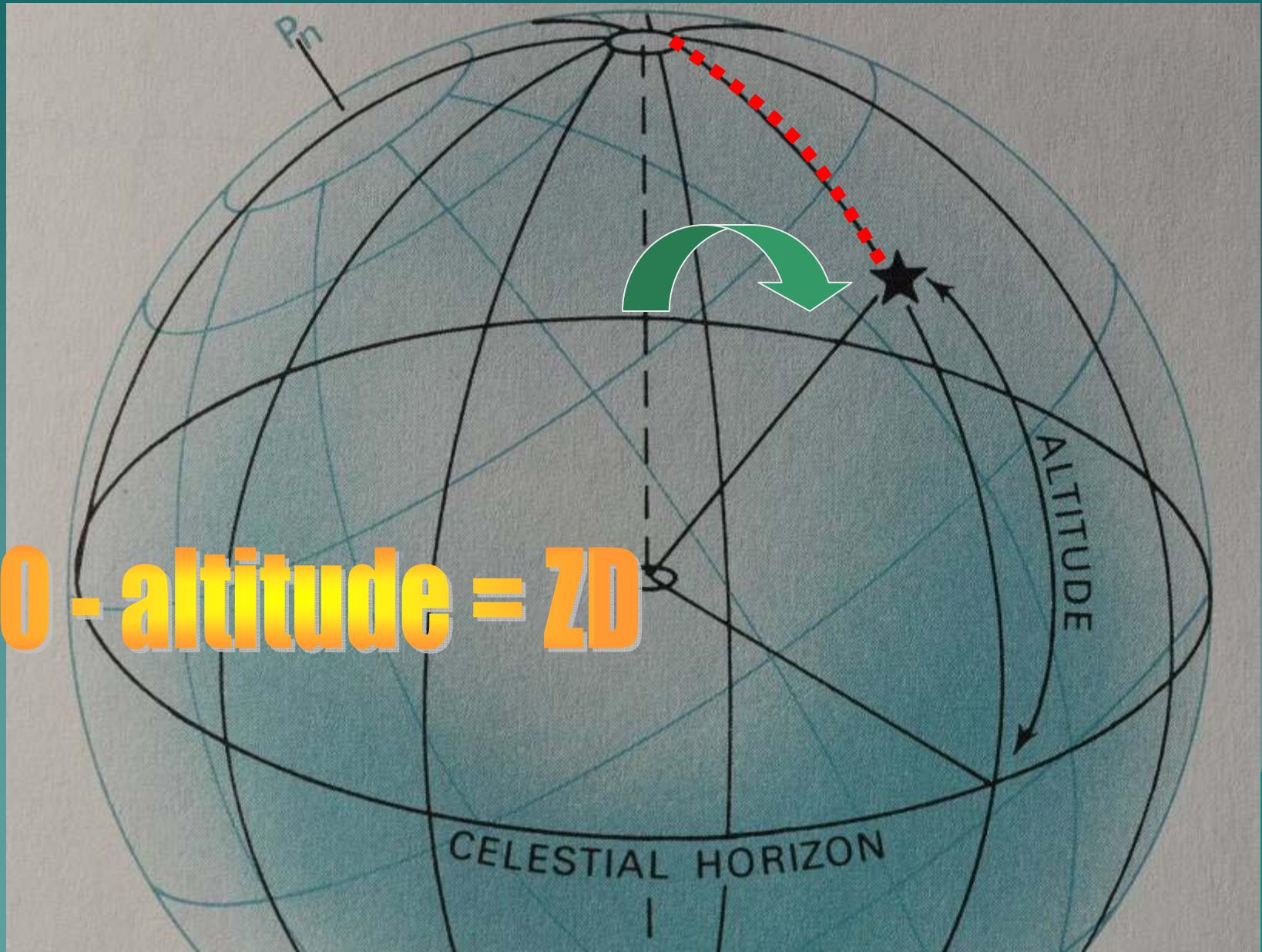
Coordinates on the Celestial Sphere



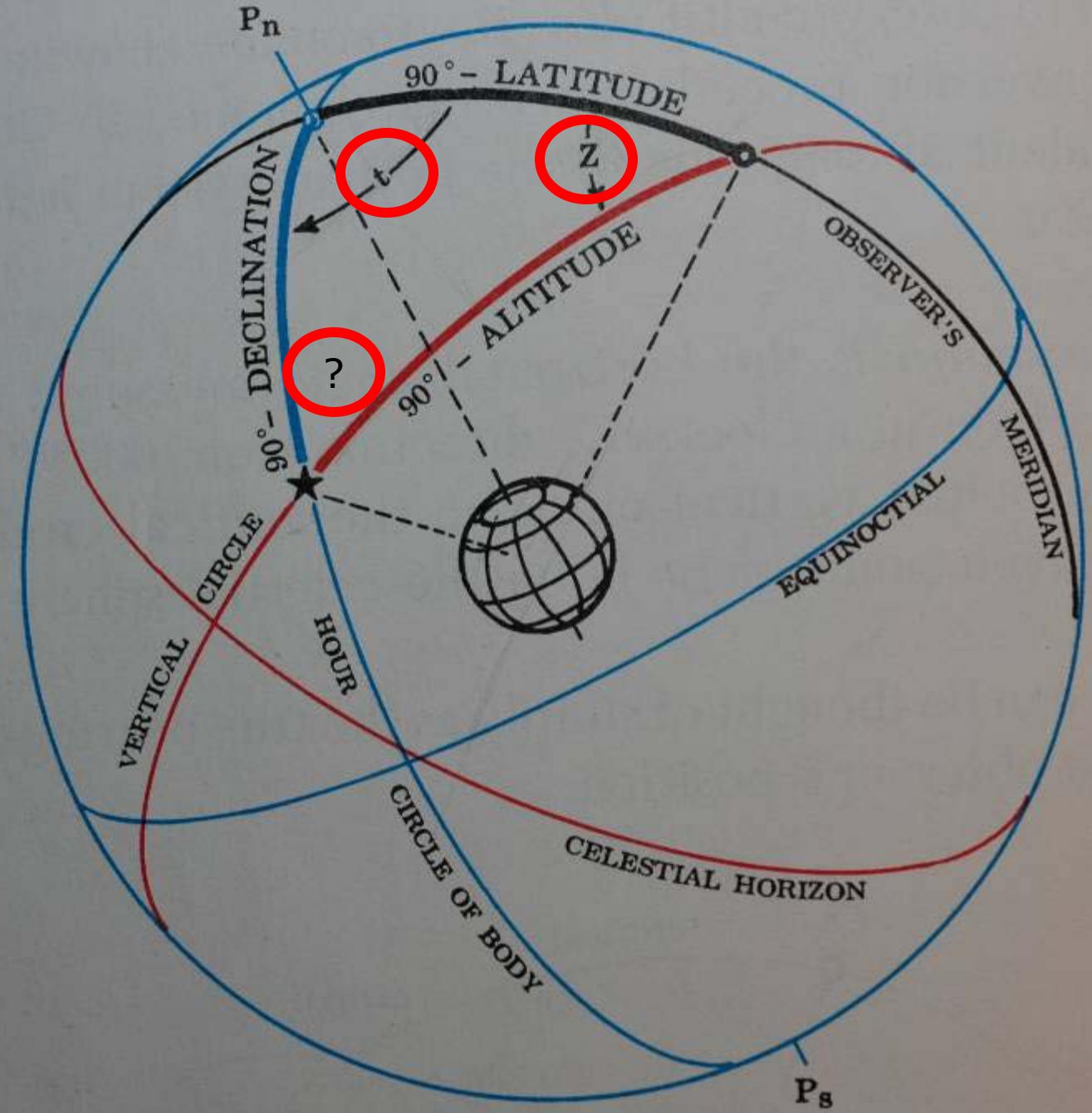
The third sphere



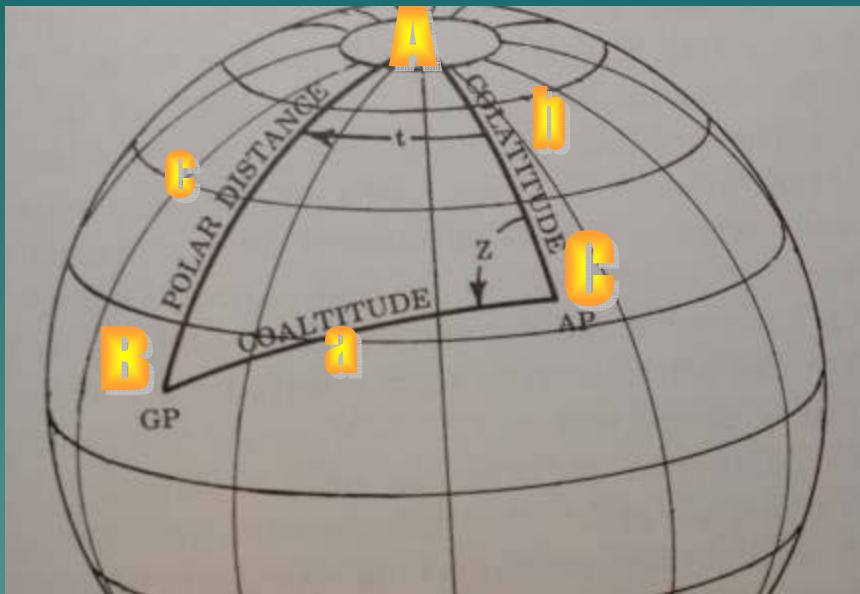
Measuring altitude



Celestial triangle



Solving the navigational triangle



- ◆ Spherical trig
- ◆ Sight reduction tables
- ◆ Calculator
- ◆ Computer program

$$\cos a = \cos b \cos c + \sin b \sin c \cos A$$

$$\cos C = \frac{\cos c - \cos a \cos b}{\sin a \sin b}$$

The evolution of the sextant



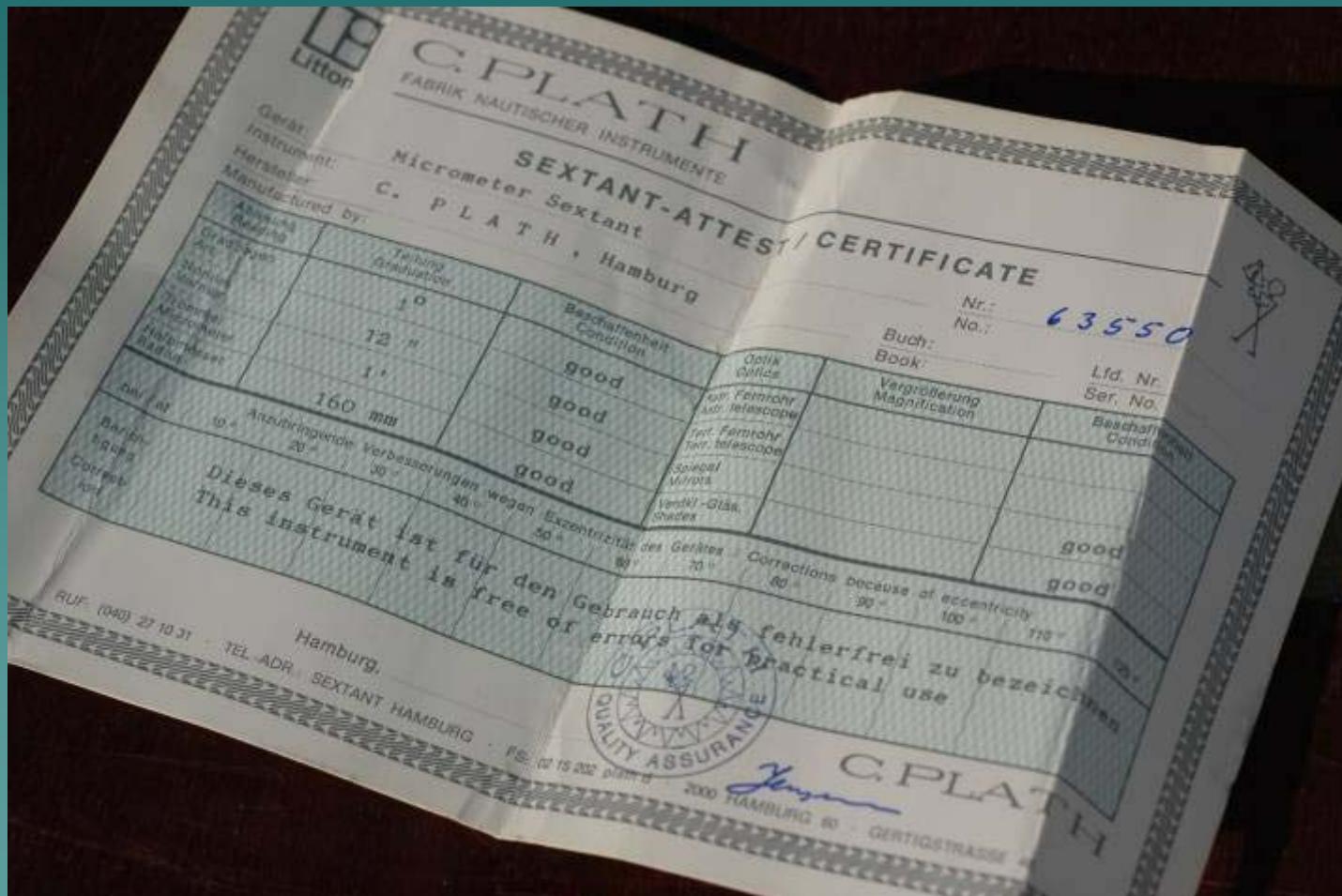
A sextant and its case



Momentary perch



Instrument history



Parallel Optics



Horizon mirror



Index arm mirror



Horizon and index filters

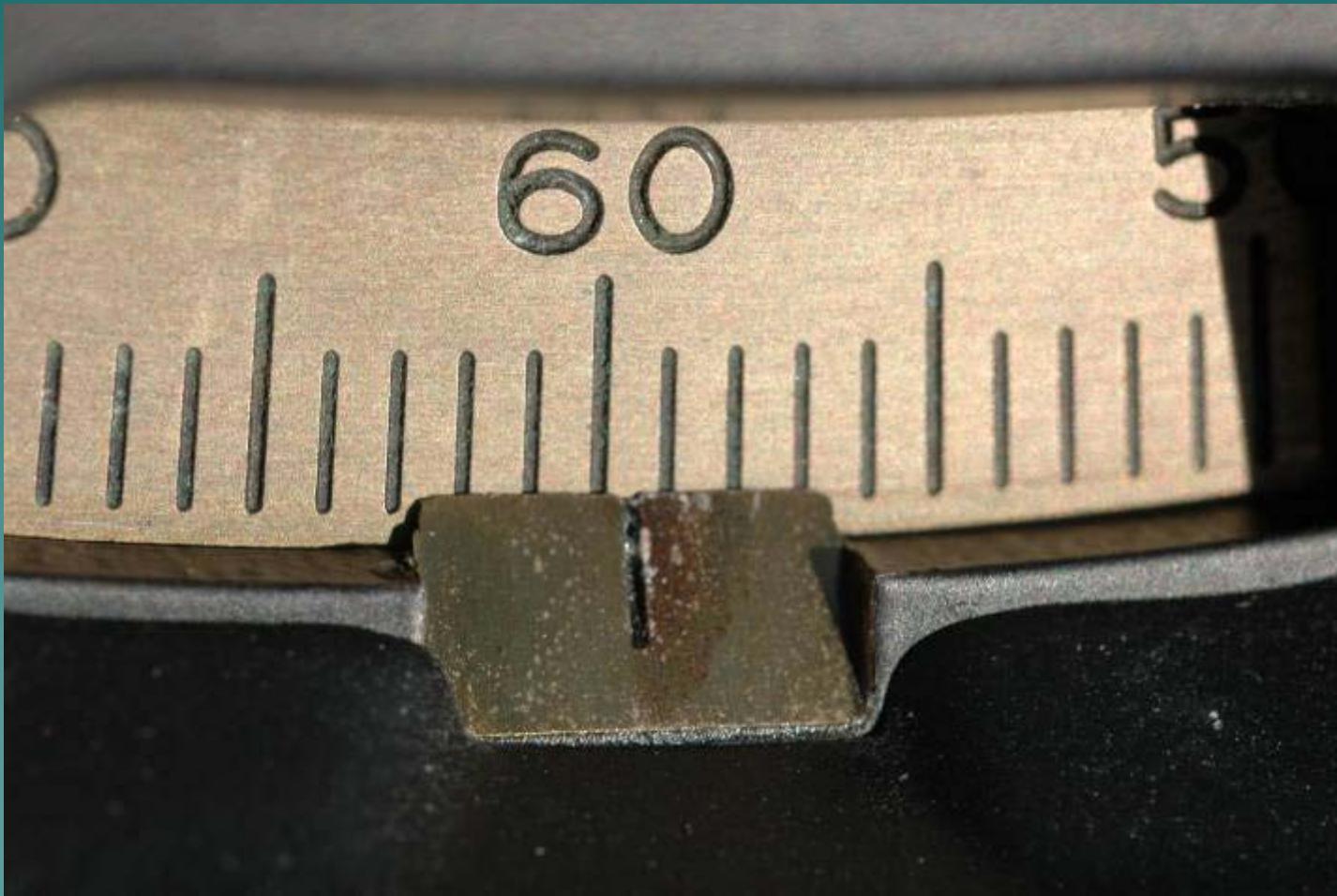




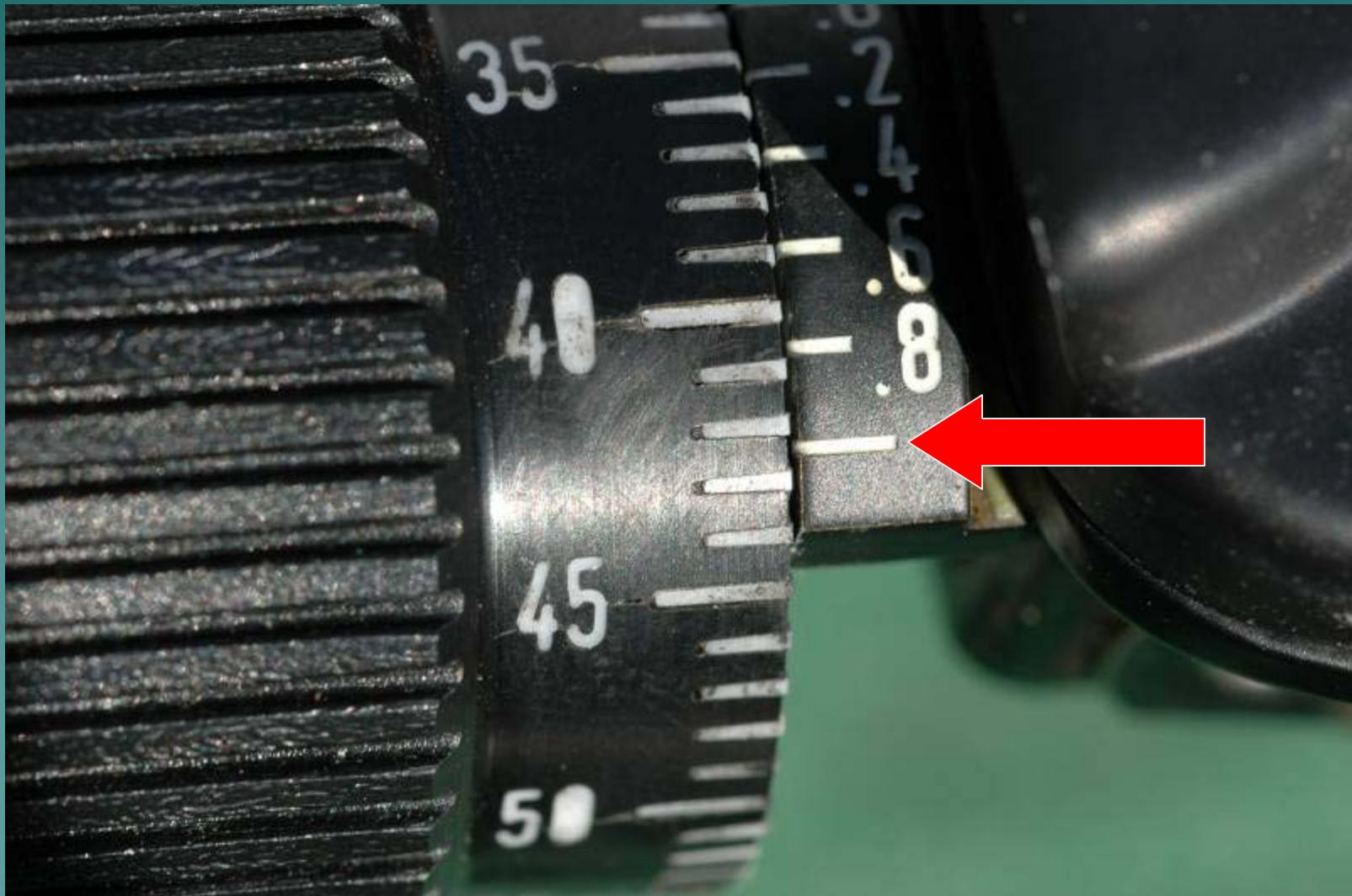
Precise gear to micrometer relationship

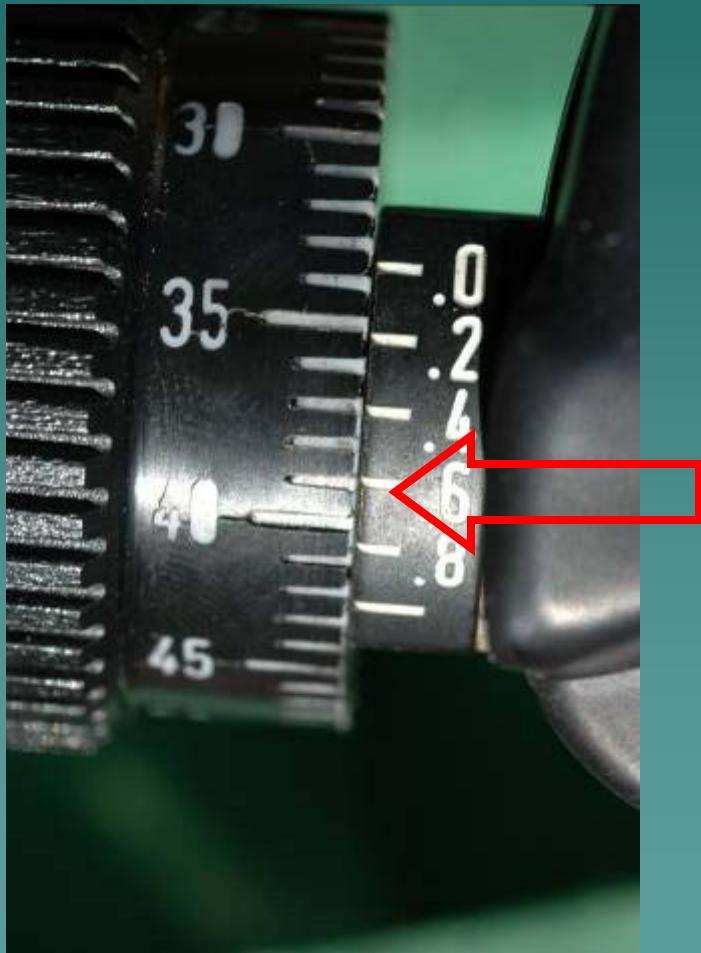


Read lower whole degree



Minute scale on drum





- ◆ Match up the best aligned decimal mark on the micrometer scale

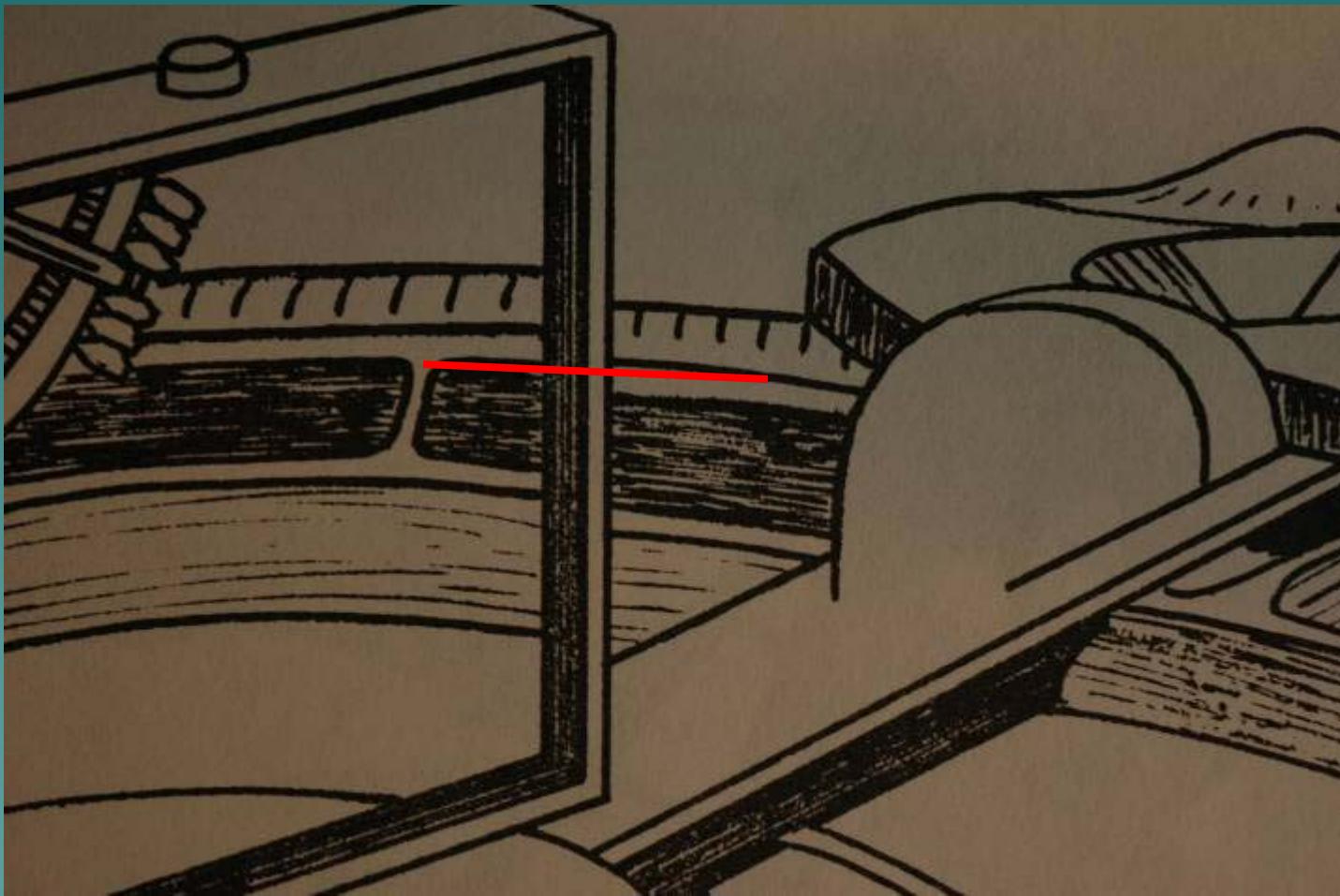
Index and horizon filters



Index mirror alignment



Index mirror not aligned correctly

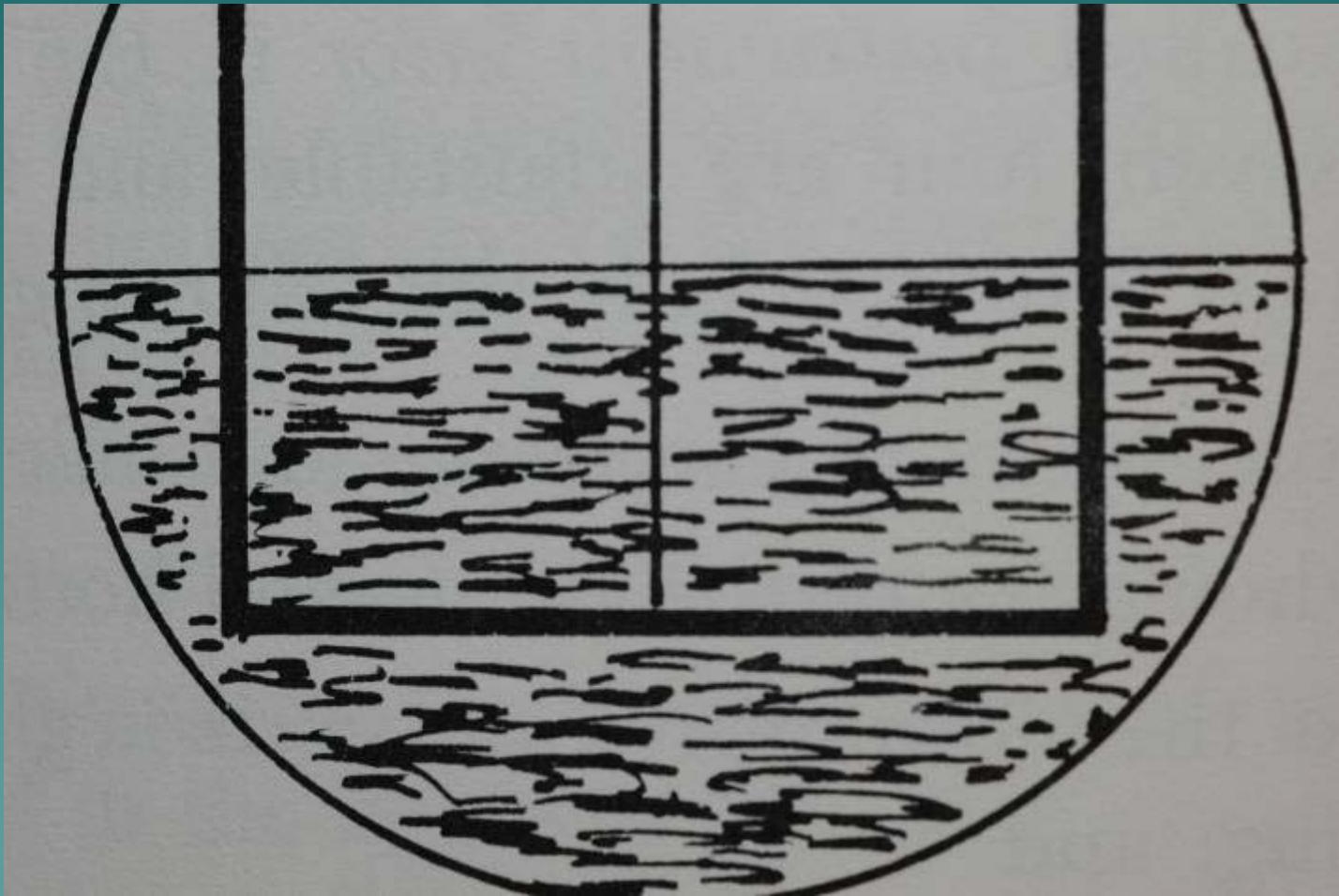


Set index to 0°0'

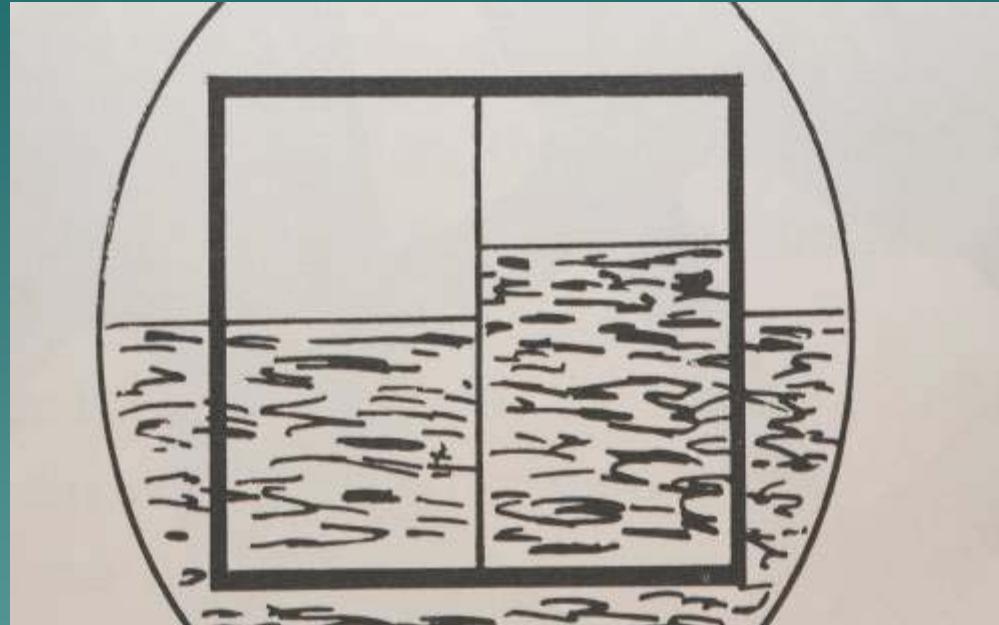


- ◆ Measure index correction by first viewing the horizon with the above settings

No index correction required

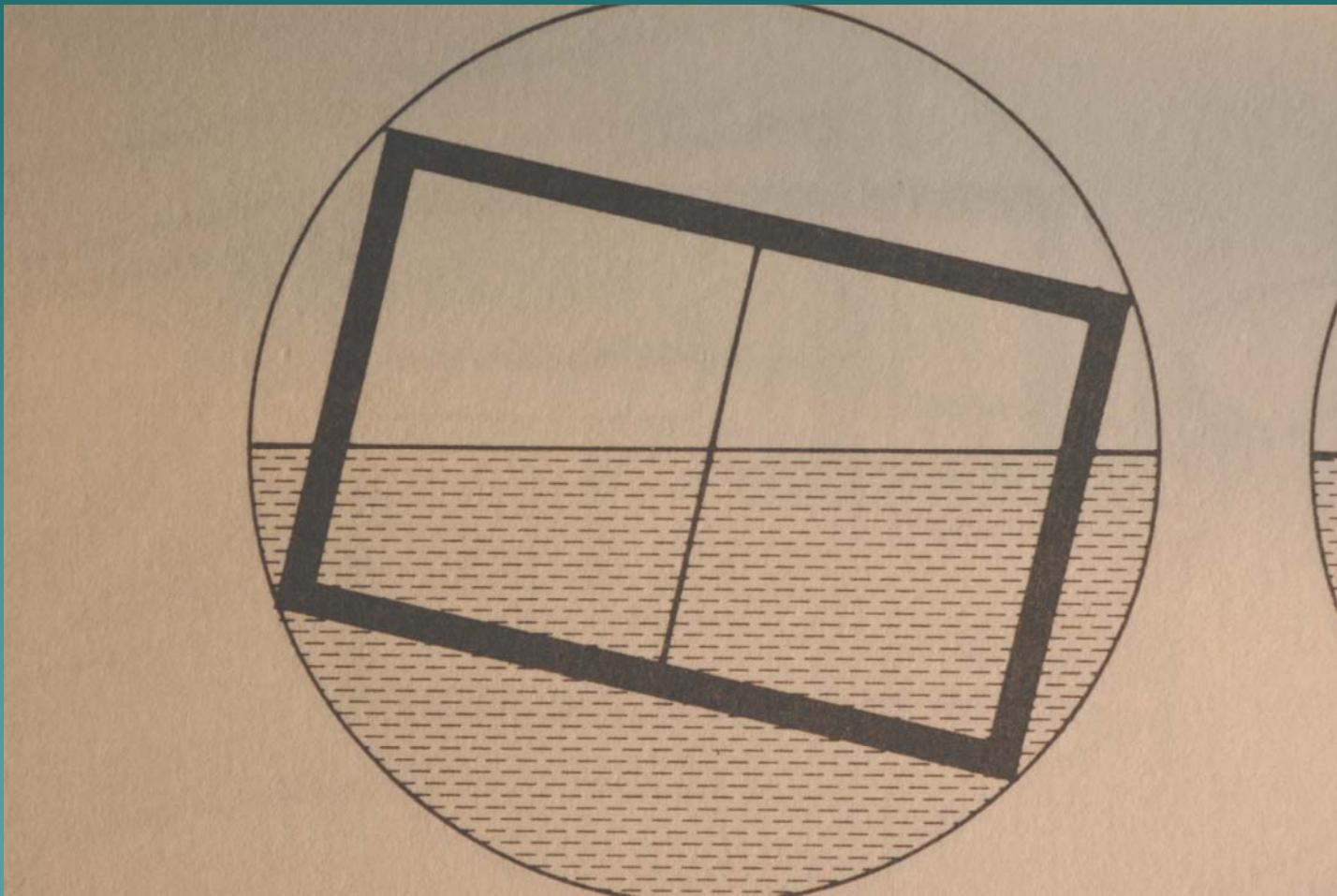


Index correction needed

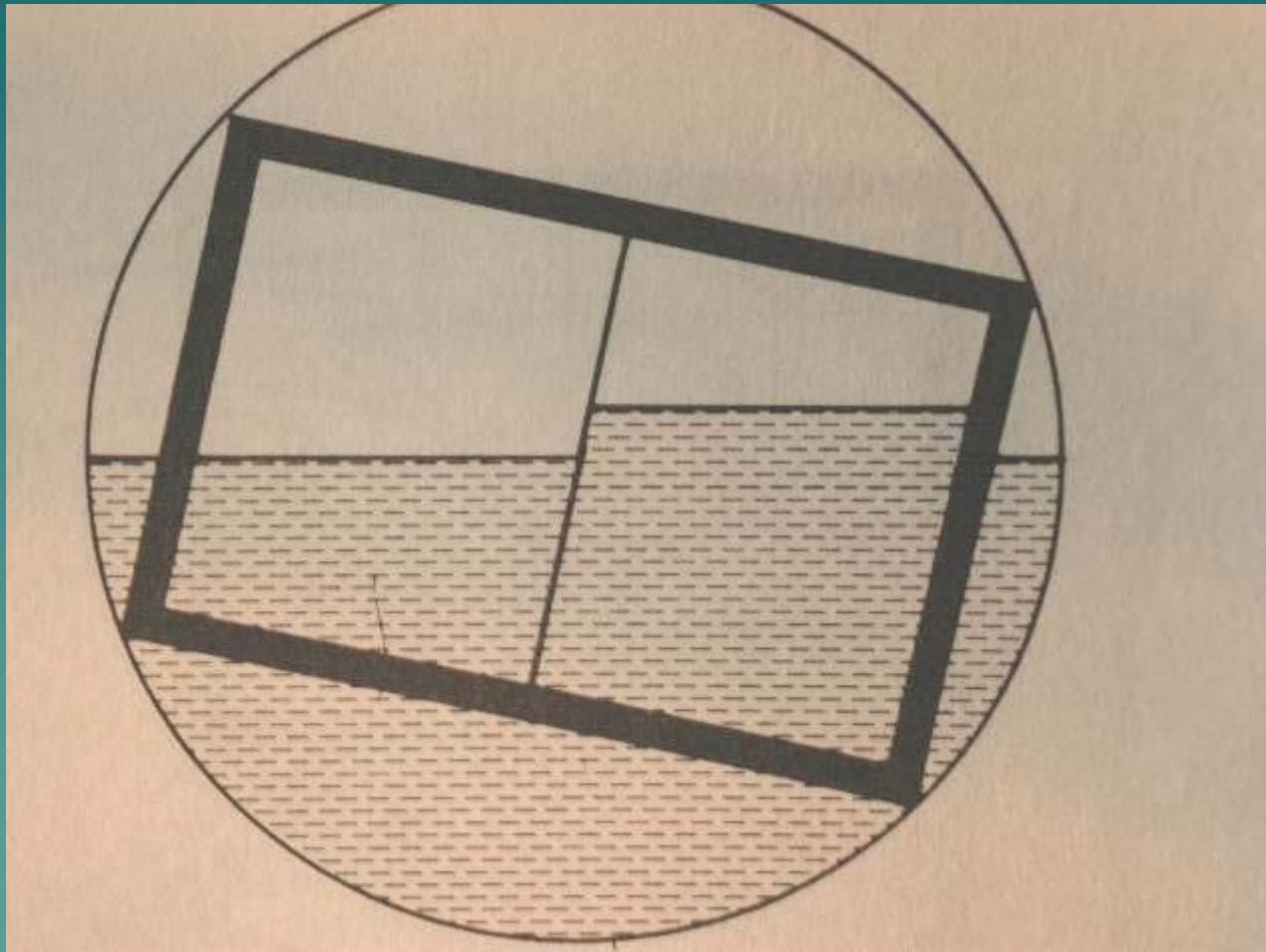


- ◆ Turn micrometer dial to level horizon
- ◆ Record setting as IC factor
- ◆ On-it's-off - - off-it's-on

Additional alignment tests



Horizon and index mirrors are not parallel



In your hand or in the case



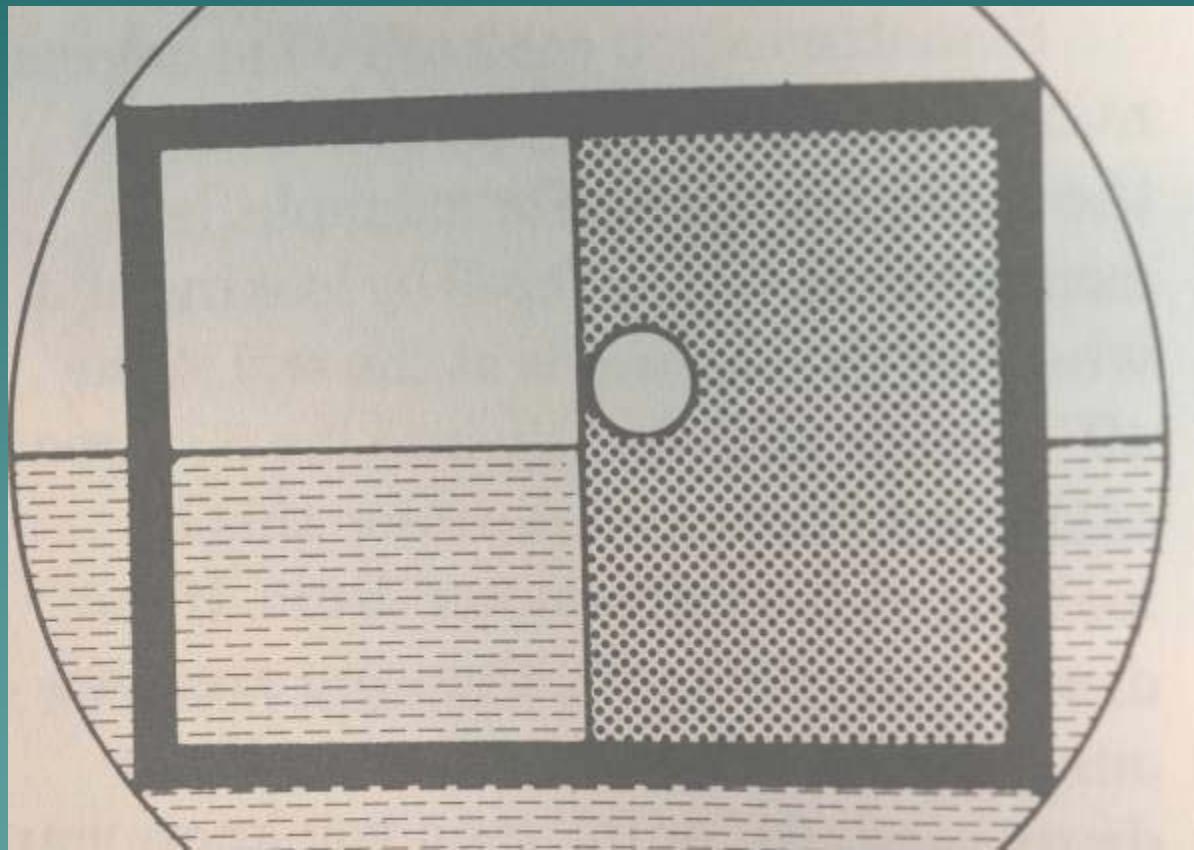
Rock sextant side-to-side



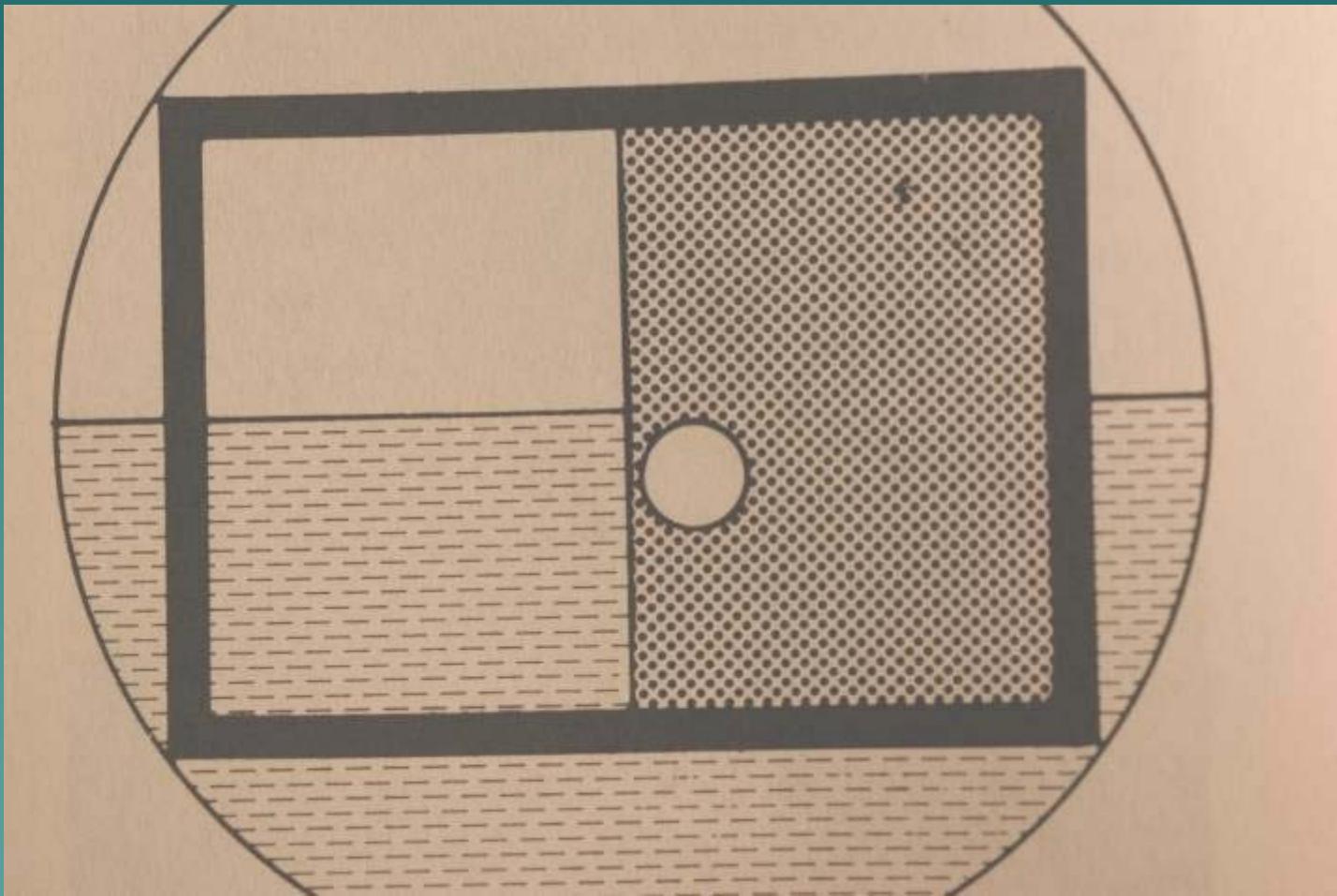
Hs in degrees minutes tenths

43° 24.3'

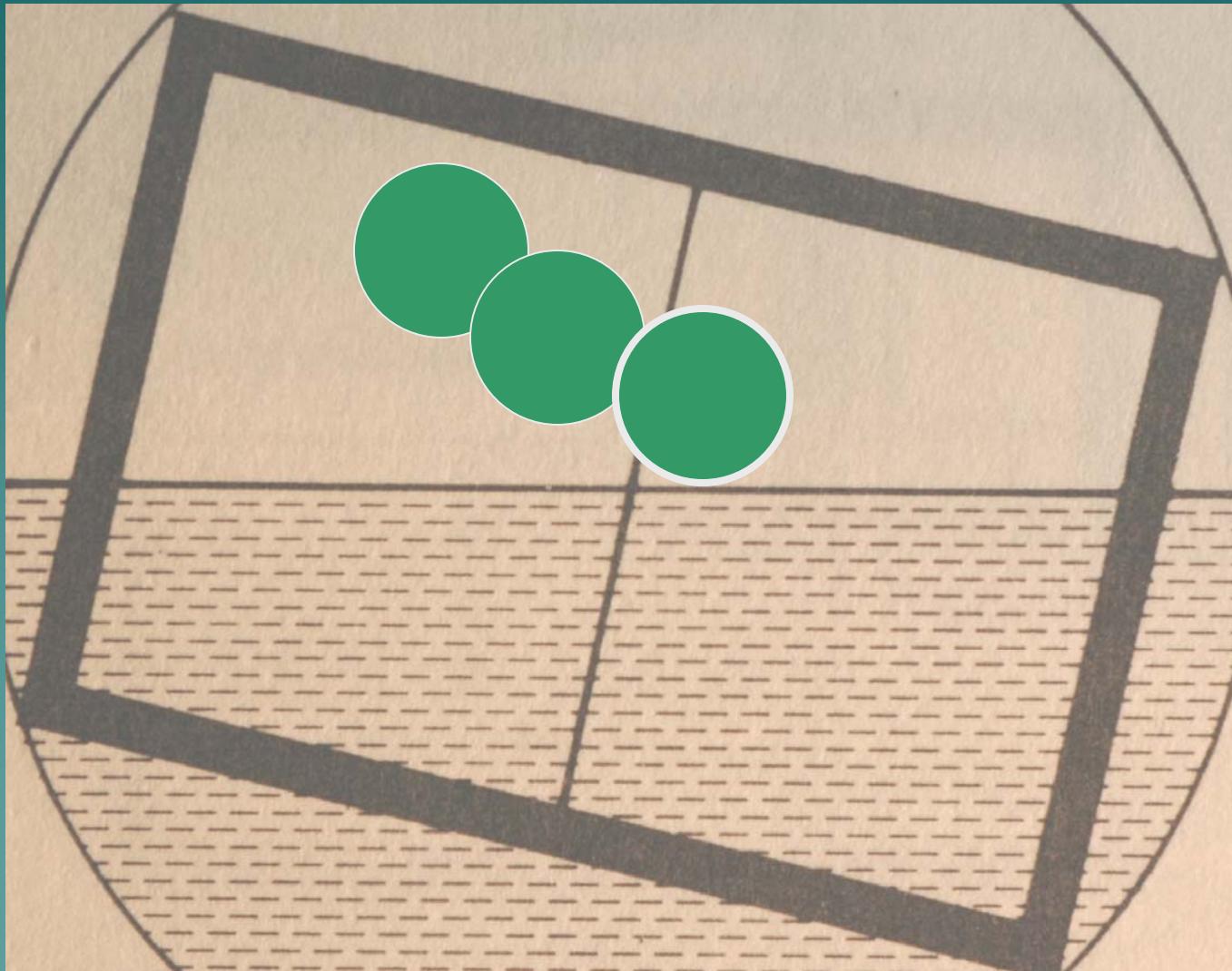
Touch lower limb to surface



Bring upper limb to surface



Rock the sextant

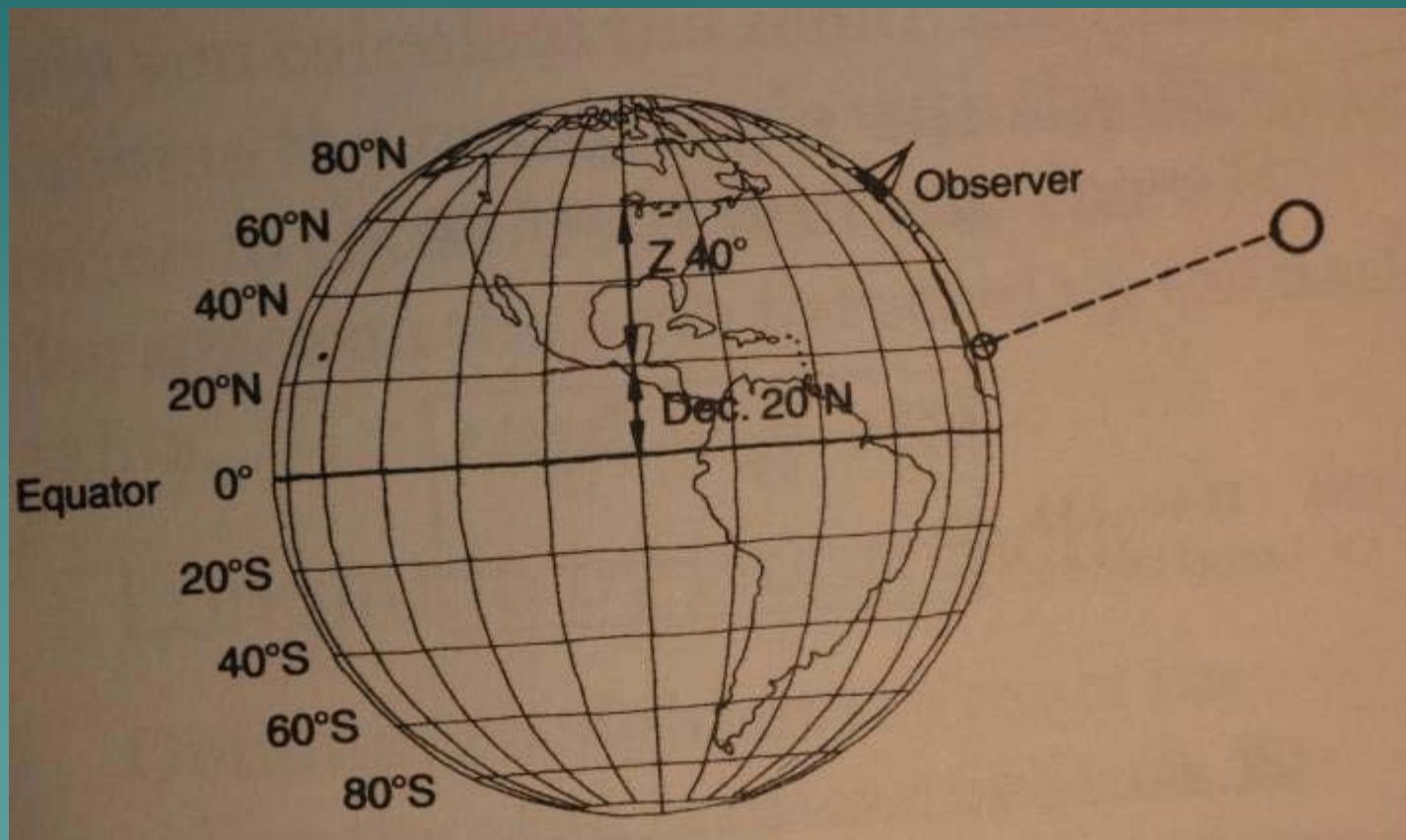


Time

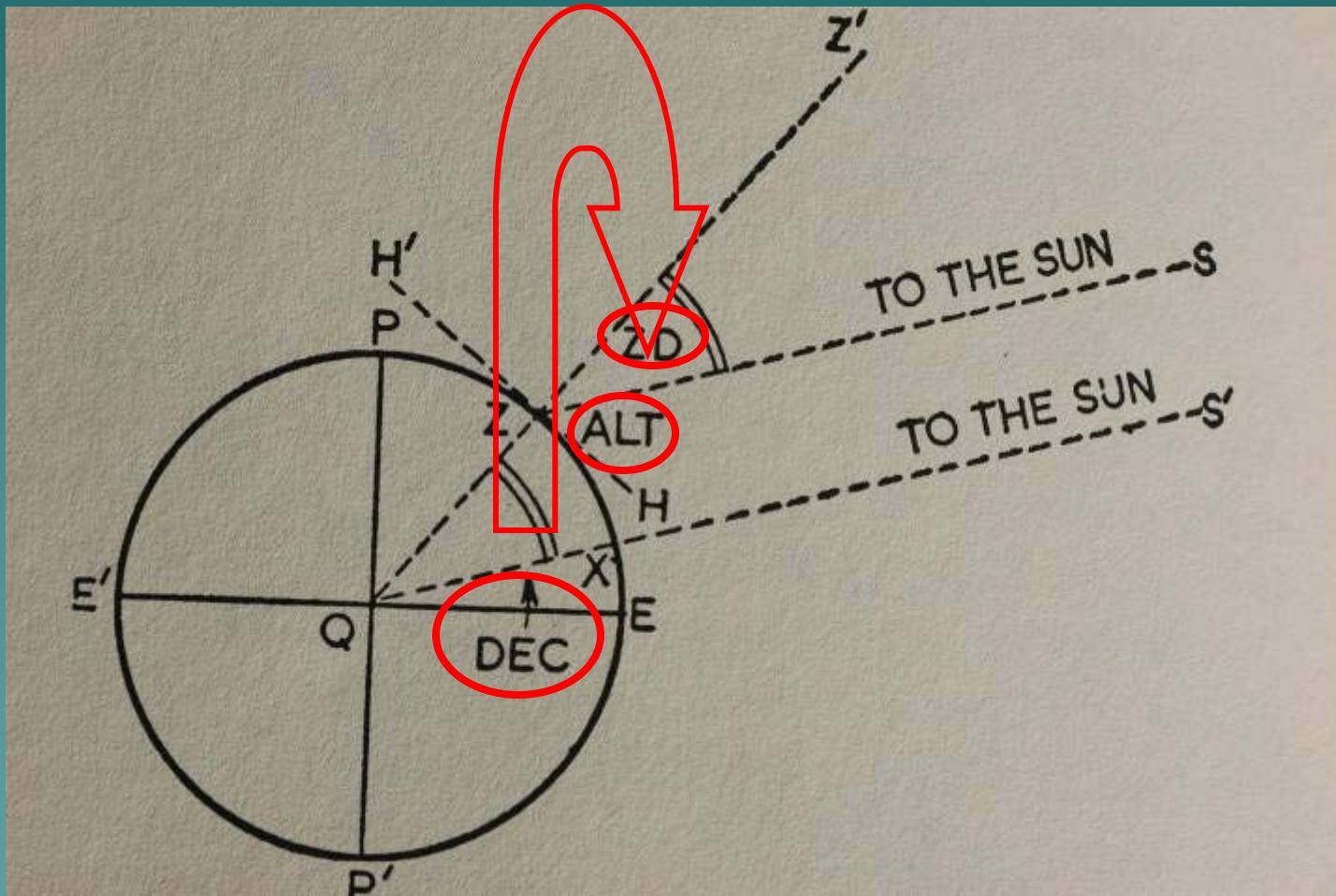
- ◆ GMT set watch (check with WWV)
- ◆ Concept of mean time (sun v. clock)
- ◆ Equation of time



Local Apparent Noon



Light rays assumed parallel



Noon sight

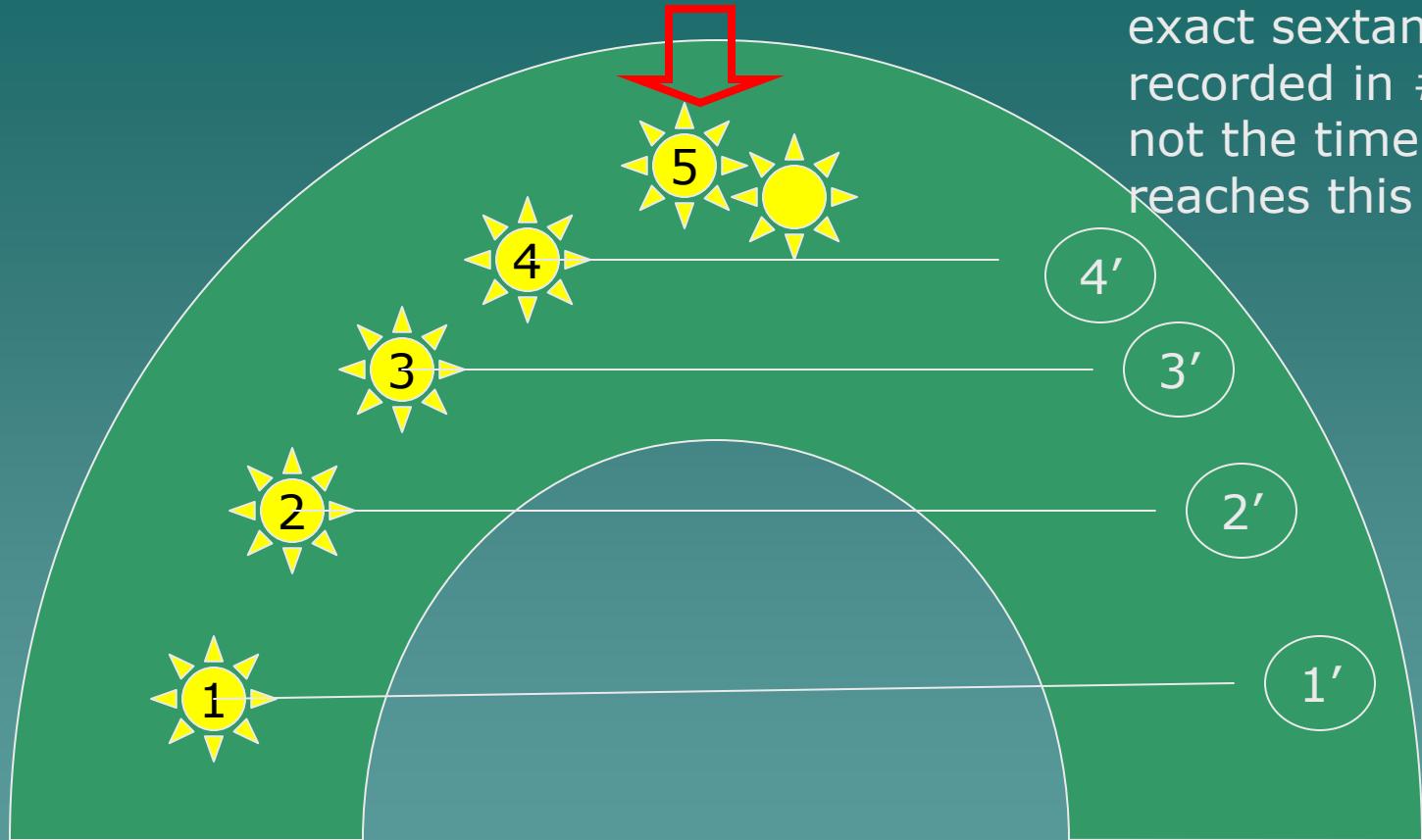
- ◆ Meridian transit
- ◆ Longitude = GHA (western hemisphere)
- ◆ Estimate LAN



time

1page table

Noon Sight



Set sextant to the exact sextant angle recorded in #4 and not the time the sun reaches this point

Shoot at approximate 3min intervals

sight	Rising angle	Setting angle
5	21:43:52 XXXX	
4	21:40:15 YYYY	21:46:45 YYYY
3	21:36:45 VVVV	21:50:15 VVVV
2	21:33:12 WWWW	21:53:45 WWWW
1	21:30:10 UUUU	21:56:49 UUUU



Example: The Longitude Calculation

Longitude: 2 June

$$\begin{array}{r} 21 \text{ h } 43 \text{ m } 30 \text{ s} \\ - 12 \text{ h } 00 \text{ m } 00 \text{ s} \\ \hline 09 \text{ h } 43 \text{ m } 30 \text{ s} \end{array} \quad \begin{array}{l} \text{GMT of local noon (from observation above)} \\ \text{Greenwich noon} \end{array}$$

$$\begin{array}{r} \\ \times \\ \hline \\ \times \\ \hline \\ \div \\ \hline \\ + \\ \hline \end{array} \quad \begin{array}{l} 583 \\ 15 \\ 8752.5 \text{ m} \\ 60 \\ 145^\circ 52'.5 \text{ W} \\ 33'.0 \text{ W} \\ 146^\circ 25'.5 \text{ W} \end{array}$$

**1hr clock - 15° of longitude
1min clock = $15'$ of longitude**

Minutes of arc (nautical miles) from Greenwich
Minutes/degree conversion
Longitude position of mean sun
Equation of time for 2 June (from student tables)
Longitude of observer

Example: The Latitude Calculation Latitude: 2 June

Step One: Finding corrected altitude of the sun.

hs	84° 56'	Lower limb observation (your sextant reading at local noon)
- IC	5'	Index correction
	84° 51'	
- DIP	3'	Height of eye correction (see Fig. 8)
	84° 48'	
+ \odot	16'	Semi-diameter correction
Ho	85° 04'	Corrected altitude

Step Two: Applying the above formula for latitude

	89° 60'	Altitude of the sun at G.P. ($89° 60' = 90°$)
- Ho	85° 04'	Corrected altitude of the sun (from "Step One" above)
	4° 56'	Distance from the sun's G.P.
+ \odot	22° 08'	N Declination of the sun, north of the equator on June 2 (from student tables)
	27° 04'	N Latitude of observer

Item General Data

1. Name of Body

2. Limb (Upper/
Lower)

3. Date (G)

4. Watch Time (G)

5. Watch Error
(+ if slow - if fast)6. GMT (six
digits)7. DR Latitude
(N/S)8. DR Longitude
(E/W)

SUN
Lower
3 June 83

Hrs	Min	Sec
20	43	59
	-	-
20	43	59

Deg	Mins	Tenths
42	18	N
71	36	W

Sextant Corrections

—general

9. Sextant
Reading (Hs)10. Instrument
Corr. (+ or -)11. Index Cor-
rection (+ or -)12. Dip Correction
for 10 feet -)13. Total (Items 9-12)
is Apparent
Altitude (Ha).

Deg	Mins	Tenths
36	49	6
		→ →
	-1	4
	-3	1
36	45	1

from inside front/
back covers of
Almanac

14. Altitude Cor-
rection (+ or -)

15. Venus, Mars
only, add'l correction (+ or -)

16. Moon only, Corr.
for daily page HP: _____ (+)

17. Moon only, if
upper limb -30°

18. Non-Standard
conditions only,
add'l Corr.

19. Total (Items
13-18) is Observed
Altitude (Ho)

	+ 14	7
36	59	8

GHA—from Nautical Almanac

DAILY PAGES

20. GHA of body,
whole hours

• "v" value, planets
moon, + unless
shown otherwise

"v"



Deg	Mins	Tenths
120	29	3
10	59	8
131	29	1

YELLOW PAGES

21. Increments, (+)
minutes and secs.,
from sun/planets or
moon column.

22. Moon, planets,
"v" correction for "v"
value above, use
same sign

23. Total GHA
(items 20-21 & 22)
• if over 360°
subtract 360°

Declination—From Nautical Almanac

DAILY PAGES

24. Declination,
whole hour, (N/S)

- "d" value, (+ if Dec. increasing, - if Dec. decreasing)

YELLOW PAGES

25. "d" correction
for "d" value above,
use same sign

26. Total Decli-
nation (items 24-25)
(N/S)

	Deg	Mins	Tenths	
"d"	22	19	1	N
+ 0.3				
	+ 0	2		
	22	19	3	N

Assumed latitude

Assumed longitude

- ◆ DR $42^{\circ} 18'N$ - $71^{\circ} 36'W$
- ◆ GHA $131^{\circ} \underline{29.1'}$
- ◆ Dec $22^{\circ} 19.3'N$



- ◆ aL $42^{\circ}N$ $a\lambda$ $71^{\circ} 29.1'W$
- ◆ LHA 60°

Sight reduction table HO 249

- ◆ Dec Inc +or-d
 - ◆ Hc (Tab Alt)
 - ◆ Dec corr'n
 - ◆ Hc (Comp Alt)
 - ◆ Ho (Obs Alt)
 - ◆ Intercept
 - ◆ Z to ZN

1 DECLINATION (0° - 14°) CONTRARY NAME TO LATITUDE

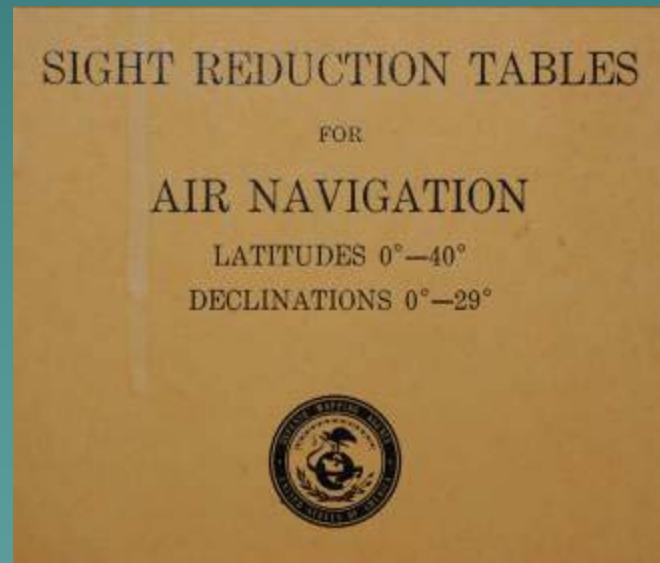
HO 249

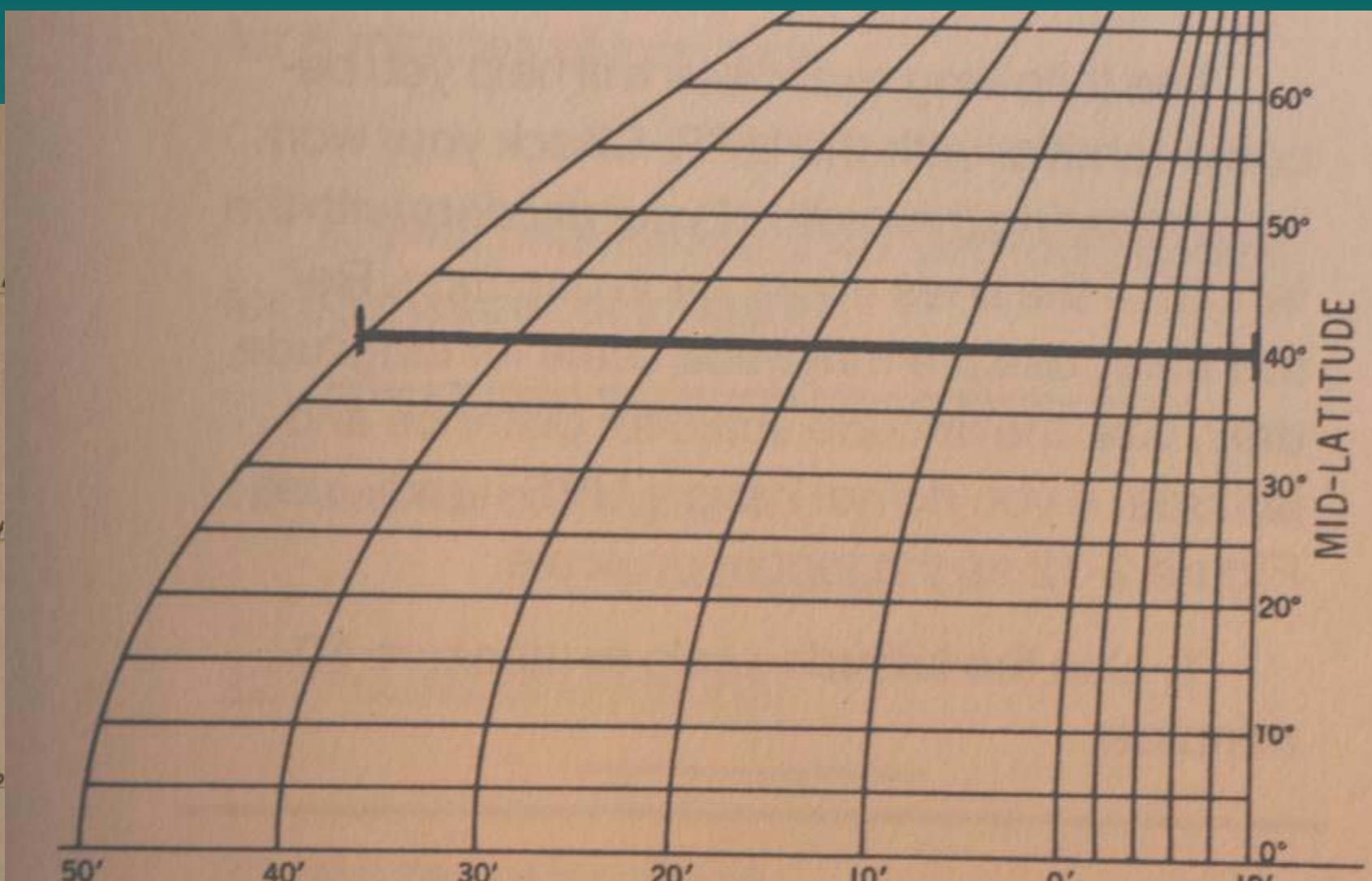
LAT 50°

27°			28°			29°			LHA	LAT 50°
h	d	Z	Hc	d	Z	Hc	d	Z		
00	+60	180	68 00	+60	180	69 00	+60	180	360	
59	60	178	67 59	60	178	68 59	60	178	359	
57	60	175	67 57	60	175	68 57	60	175	358	
53	60	173	67 53	60	173	68 53	59	173	357	
48	59	171	67 47	60	171	68 47	59	170	356	
41	+59	169	67 40	+60	168	68 40	+59	168	355	
43	59	167	67 32	59	166	68 31	59	166	354	
43	59	164	67 22	58	164	68 20	59	163	353	
42	58	162	67 10	59	162	68 09	58	161	352	
49	58	160	66 57	58	159	67 55	58	159	351	

Exit table with

- ◆ Zn azimuth (true bearing to body)
- ◆ Intercept (offset distance of the LOP)
- ◆ DR
- ◆ AP



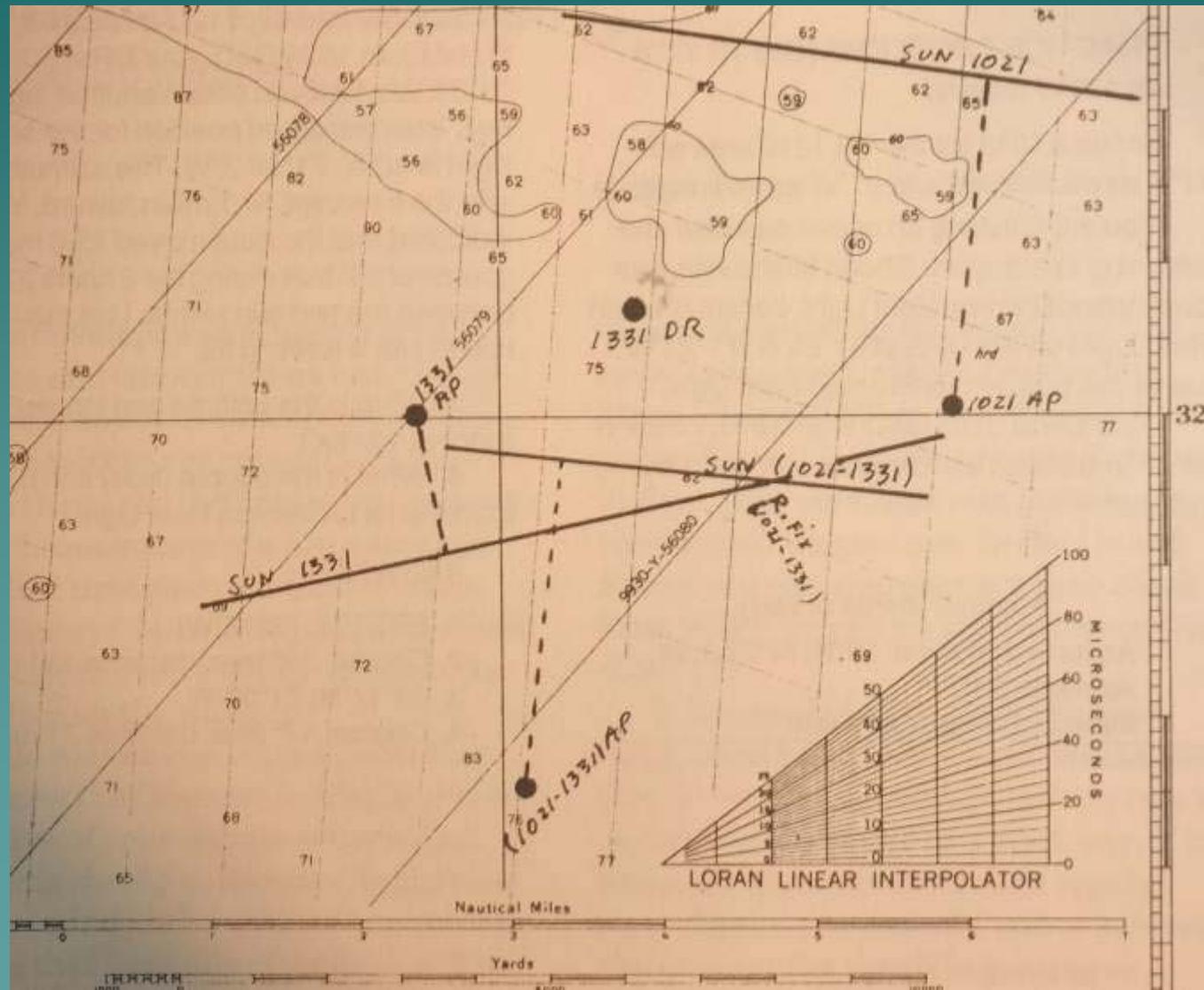


39°N

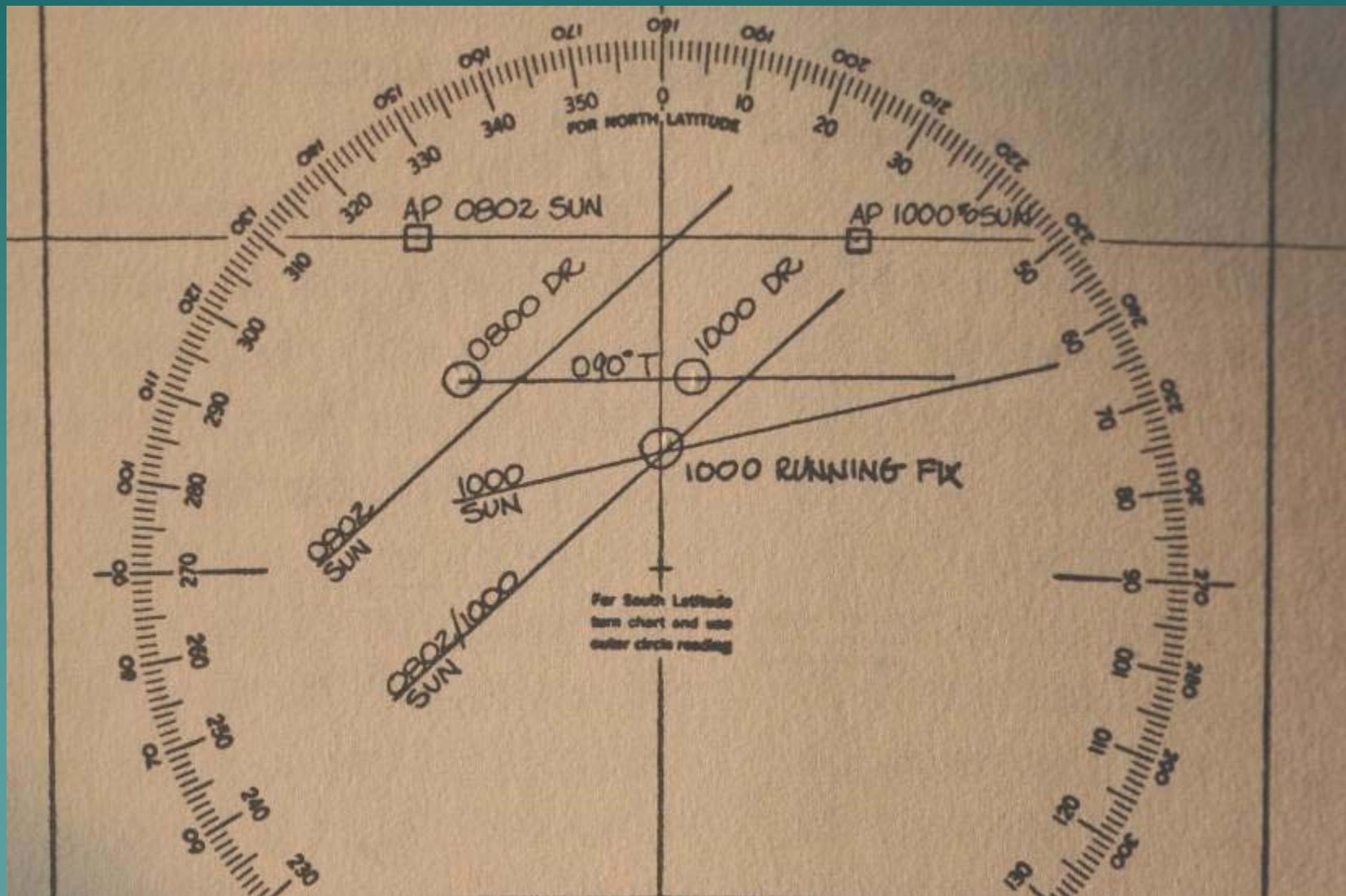
23°W



Plot directly on a chart



Advancing a line of position





tool v. instrument rule