ΜΗΧΑΝΙΣΜΟΣ ΑΝΤΙΚΥΘΗΡΩΝ

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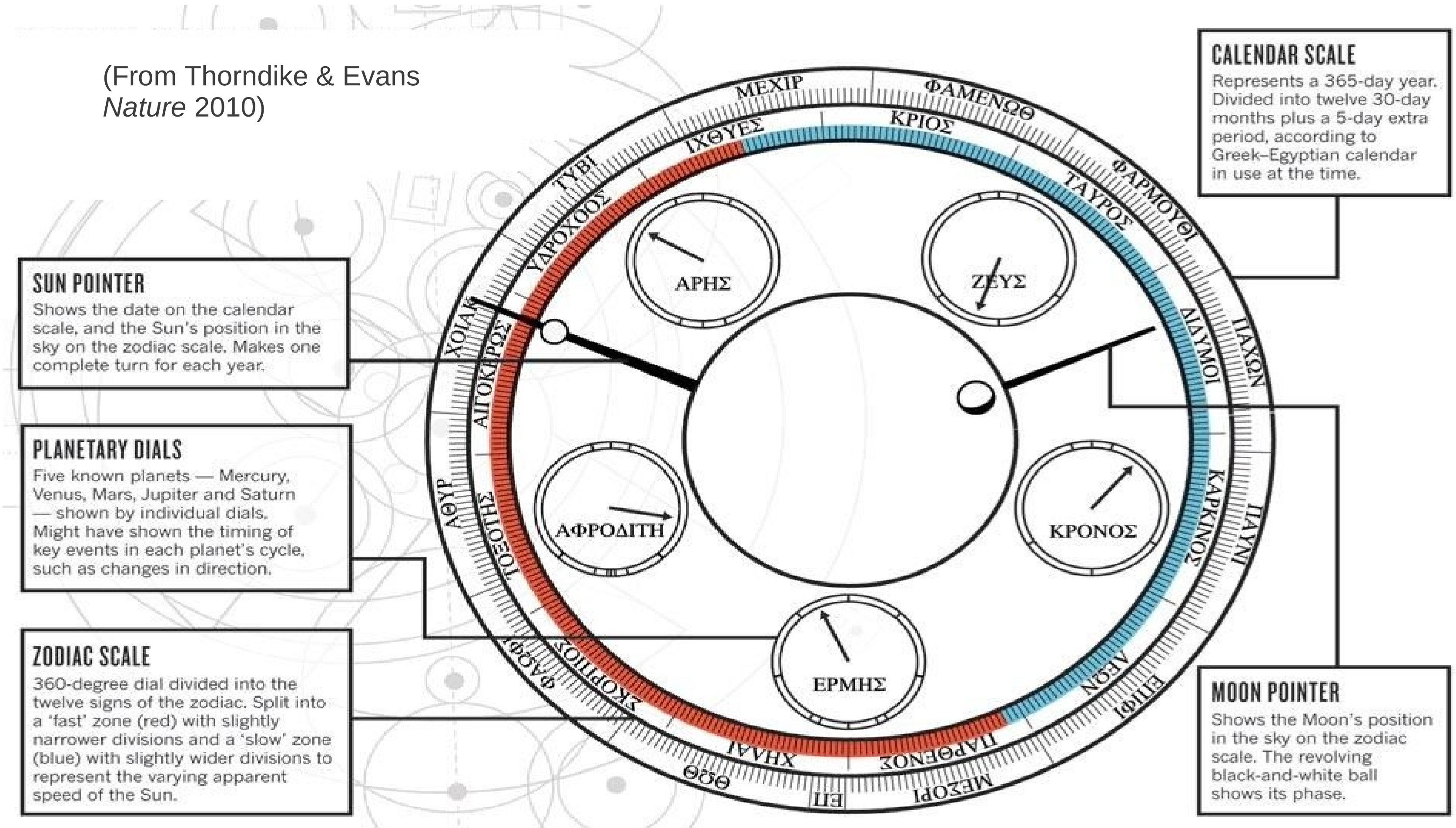
(From Thorndike & Evans *Nature* 2010)



Epicyclic Gear Train

External Central Gear: $R_a = R_c + R_p$

$v_p = v_a + v_{pa}$, $\omega_c R_c = \omega_a R_a - \omega_p R_p$

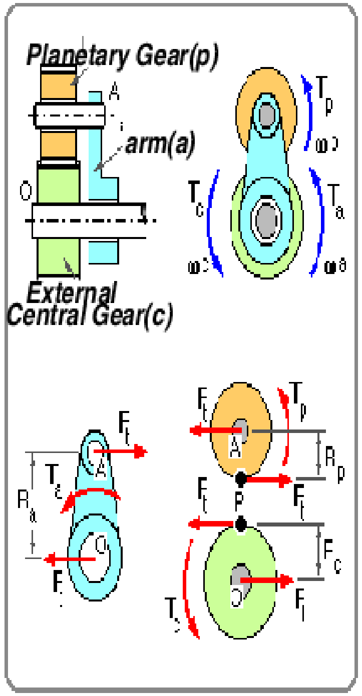
$F_\tau = -\frac{\tau_c}{R_c} = -\frac{\tau_p}{R_p} = \frac{\tau_a}{R_a}$

Internal Central Gear: $R_a = R_c - R_p$

$v_p = v_a + v_{pa}$, $\omega_c R_c = \omega_a R_a + \omega_p R_p$

$F_\tau = -\frac{\tau_c}{R_c} = \frac{\tau_p}{R_p} = \frac{\tau_a}{R_a}$

Tooth Number Ratio: $\frac{Z_c}{Z_p} = \frac{R_c}{R_p}$



3 Component Element: $(\omega_c - \omega_a)Z_c + (\omega_p - \omega_a)Z_p = 0$ (1)

$\frac{\tau_c}{Z_c} = \frac{\tau_p}{Z_p} = -\frac{\tau_a}{Z_c + Z_p}$ (2) (negative Z_c for Internal Gear)

Net External Torque: $\Sigma\tau = \tau_c + \tau_p + \tau_a$

$\tau_c(1 + \frac{Z_p}{Z_c} - \frac{(Z_c+Z_p)}{Z_c}) = 0$

Total External Power: $\Sigma P = \omega_c\tau_c + \omega_p\tau_p + \omega_a\tau_a$

$\tau_c(\omega_c + \omega_p\frac{Z_p}{Z_c} - \omega_a\frac{Z_c+Z_p}{Z_c}) = \tau_c\frac{(\omega_c-\omega_a)Z_c+(\omega_p-\omega_a)Z_p}{Z_c} = 0$

First Element: External Sun Gear and Planet 2

Second Element: Planet 3 and Internal Gear 4

1-2-arm:

$(\omega_1 - \omega_a)Z_1 + (\omega_2 - \omega_a)Z_2 = 0$ **from (1)**

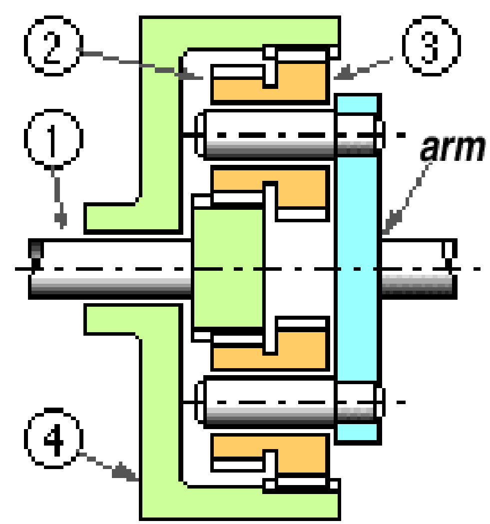
$\frac{\tau_1}{Z_1} = \frac{\tau_2}{Z_2} = -\frac{\tau_{a2}}{Z_1+Z_2}$ **from (2)**

3-4-arm:

$(\omega_4 - \omega_a)(-Z_4) + (\omega_3 - \omega_a)Z_3 = 0$

$\frac{\tau_4}{-Z_4} = \frac{\tau_3}{Z_3} = -\frac{\tau_{a3}}{-Z_4+Z_3}$ **(internal central gear)**

Planets 2,3 Coupled:



$\omega_3 = \omega_2$

$\tau_3 = -\tau_2$

$\tau_a = \tau_{a2} + \tau_{a3}$

Thus $\frac{\omega_1-\omega_a}{\omega_4-\omega_a} = \sigma_0$,

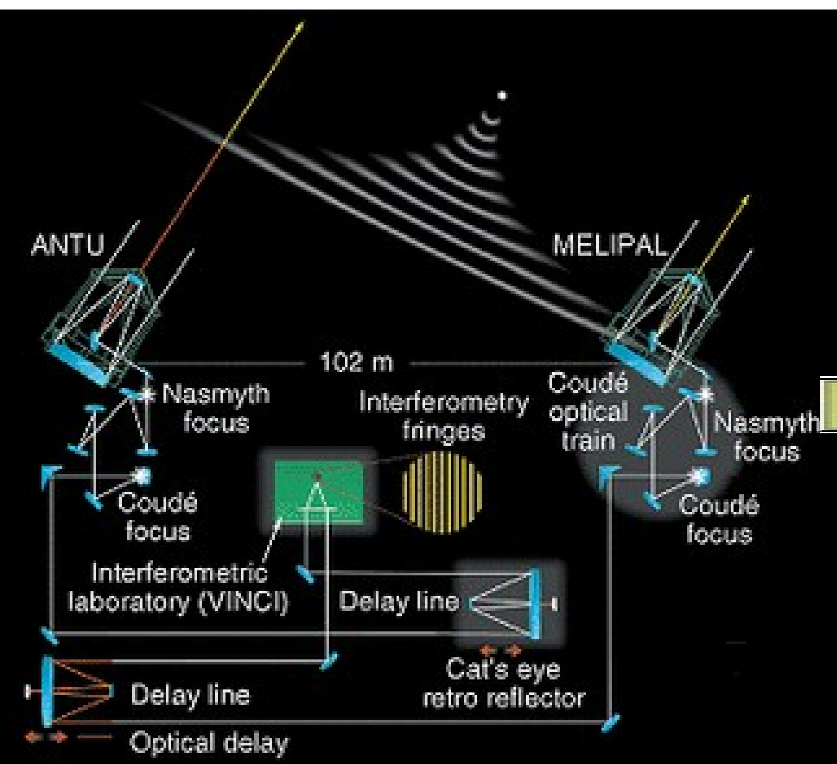
$\tau_1 = -\frac{\tau_4}{\sigma_0} = \frac{\tau_a}{\sigma_0 - 1}$,

where $\sigma_0 = -\frac{Z_2Z_4}{Z_1Z_3}$ **= basic speed ratio =** $\frac{\omega_1}{\omega_4}|_{\omega_a=0}$

Differential devices have other applications, from analog computers to μarcsec astrometry and imaging, nm laser metrology...

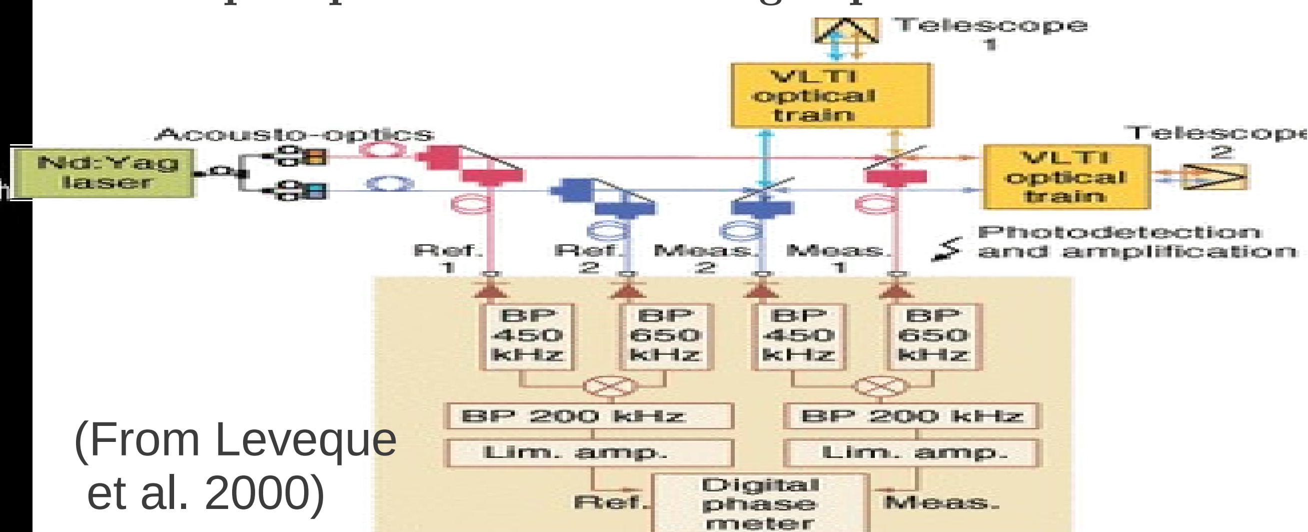
Tracking Differential Delay

- Measure Group Delay with varying baseline, source position, atmosphere
- Complex Visibility whose argument is varying phase is a function of this delay
- Phase referenced to calibrator by differential delay
- Phase referenced to target at different frequency
- Multical optimization, correlation techniques
- e.g. zenith path delay error → systematic delay difference $\Delta\tau$(cal-tar)
- ATCA, EVLA, GMRT, WRST, VLBA, ALMA, SKA...



- Measure instrumental optical path fluctuations
- e.g. heterodyne Michelson interferometers in tandem

→ coupled path observed through optical train



(From Leveque et al. 2000)

Αλλη μια φαση!