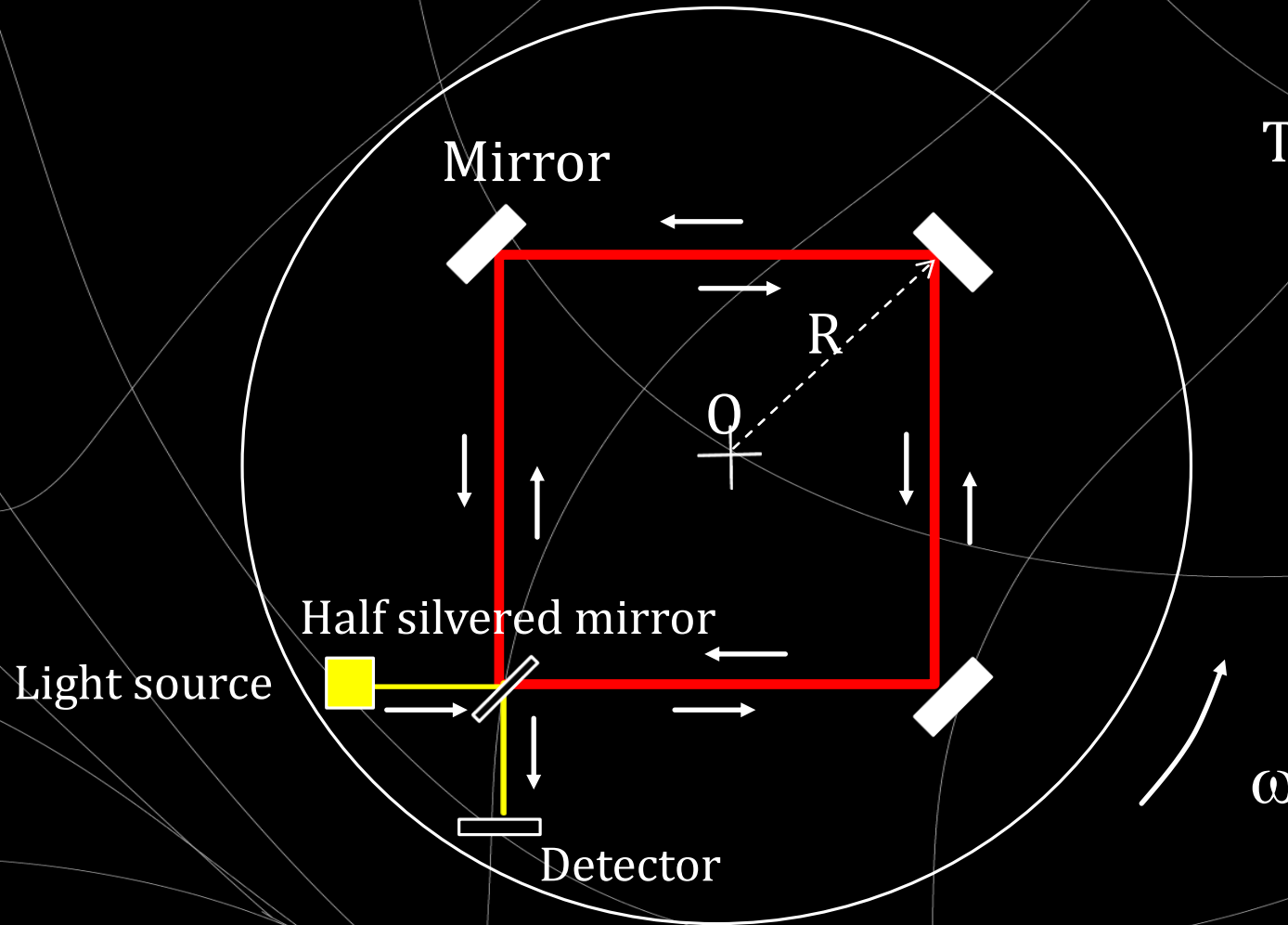




Inertial Sagnac effect and its relevance for accurate measurements using ring lasers

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Classical Sagnac and rotations



Typical time of flight difference

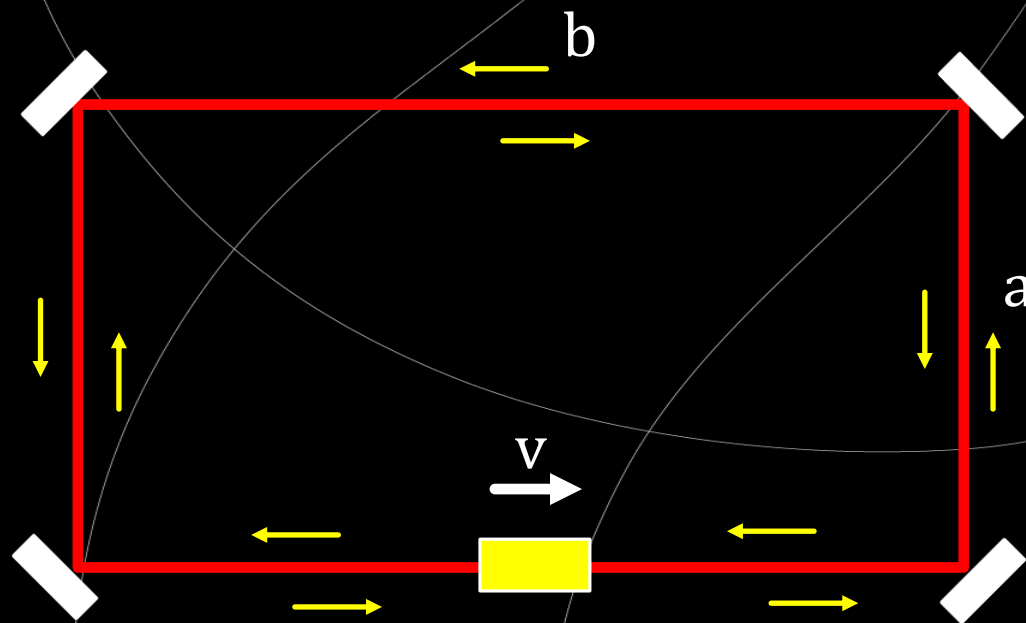
$$\Delta t = 4 \frac{A}{c^2} \hat{u}_n \cdot \vec{\omega} + O\left(\frac{\omega^3}{c^4}\right)$$

Inertial Sagnac

$$\ell = 2(a+b)$$

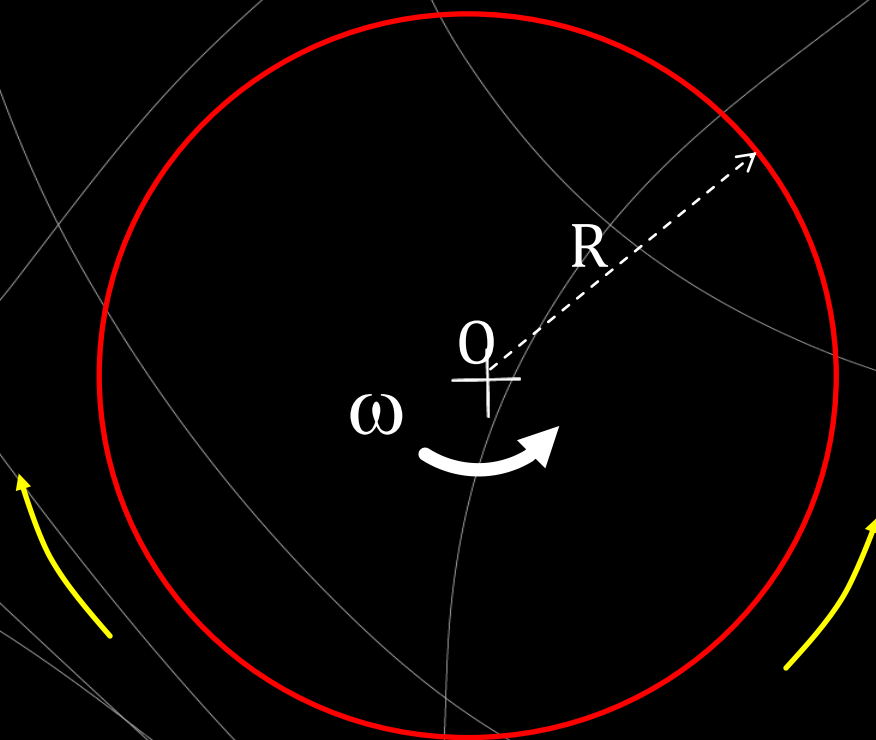
$$ct_+ = \ell + vt_+$$

$$ct_- = \ell - vt_-$$



$$\Delta t = 2 \frac{\ell v}{c^2} + O\left(\frac{v^3}{c^4}\right)$$

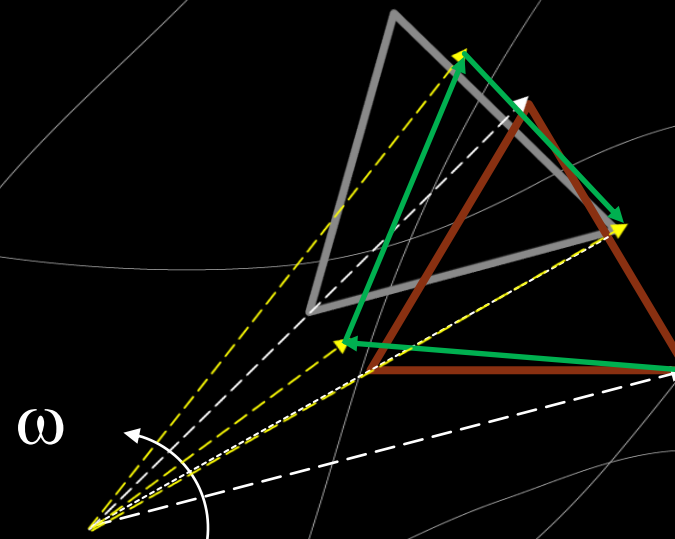
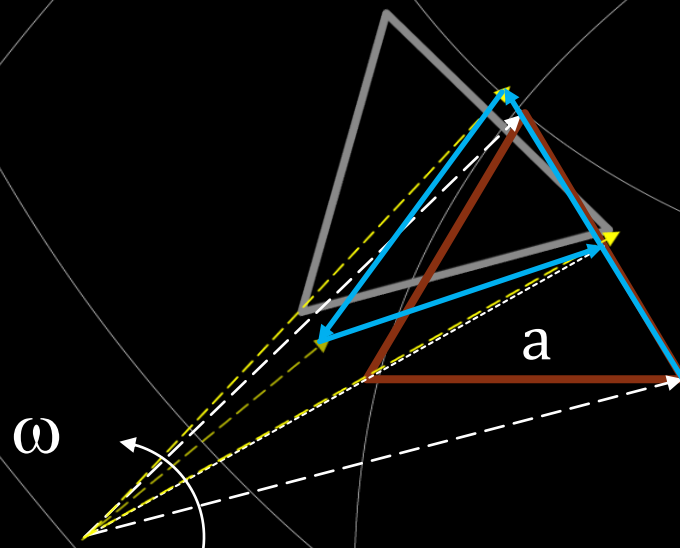
Rotational versus inertial



$$\begin{aligned}\Delta t &\cong 4 \frac{A}{c^2} \omega = 4 \frac{\pi R^2}{c^2} \omega \\ &= 2 \frac{2\pi R}{c^2} R \omega = 2 \frac{lv}{c^2}\end{aligned}$$

Rotating device

$$l = 3a$$



Beat frequency for the inertial Sagnac

$$\Delta t = t_+ - t_- = N(T_+ - T_-) = N \frac{f_- - f_+}{f_- f_+}$$

$$\cong \frac{\ell}{\lambda} \frac{\Delta f}{f^2} = \frac{\ell}{\lambda} \frac{\Delta f}{f^2} = \frac{\ell}{c} \frac{\Delta f}{f} \longrightarrow \frac{\ell}{c} \frac{\Delta f}{f} = 2 \frac{\ell v}{c^2} \longrightarrow \frac{\Delta f}{f} = 2 \frac{v}{c}$$

$$f_b = \frac{v}{c} f = \frac{v}{\lambda}$$

Orders of magnitude

$l \sim \text{meters}$

$v \sim \text{m/s}$

$f \sim 10^{14} \text{ Hz}$



$\Delta t \sim 10^{-16} \text{ s}$

$f_b \sim 10^6 \text{ Hz}$

Only measure so far: R. Wang, Y. Zheng, A. Yao, and D. Langley, *Phys. Lett. A* **312**, 7–10 (2003).

R. Wang, Y. Zheng, and A. Yao, *Phys. Rev. Lett.* **93**, 143901-1-3 (2004).

Rotation plus vibration

$$f_b \cong \left(2 \frac{A}{cl} \omega \hat{u}_a \cdot \hat{u}_n + \frac{v}{c} \right) f$$

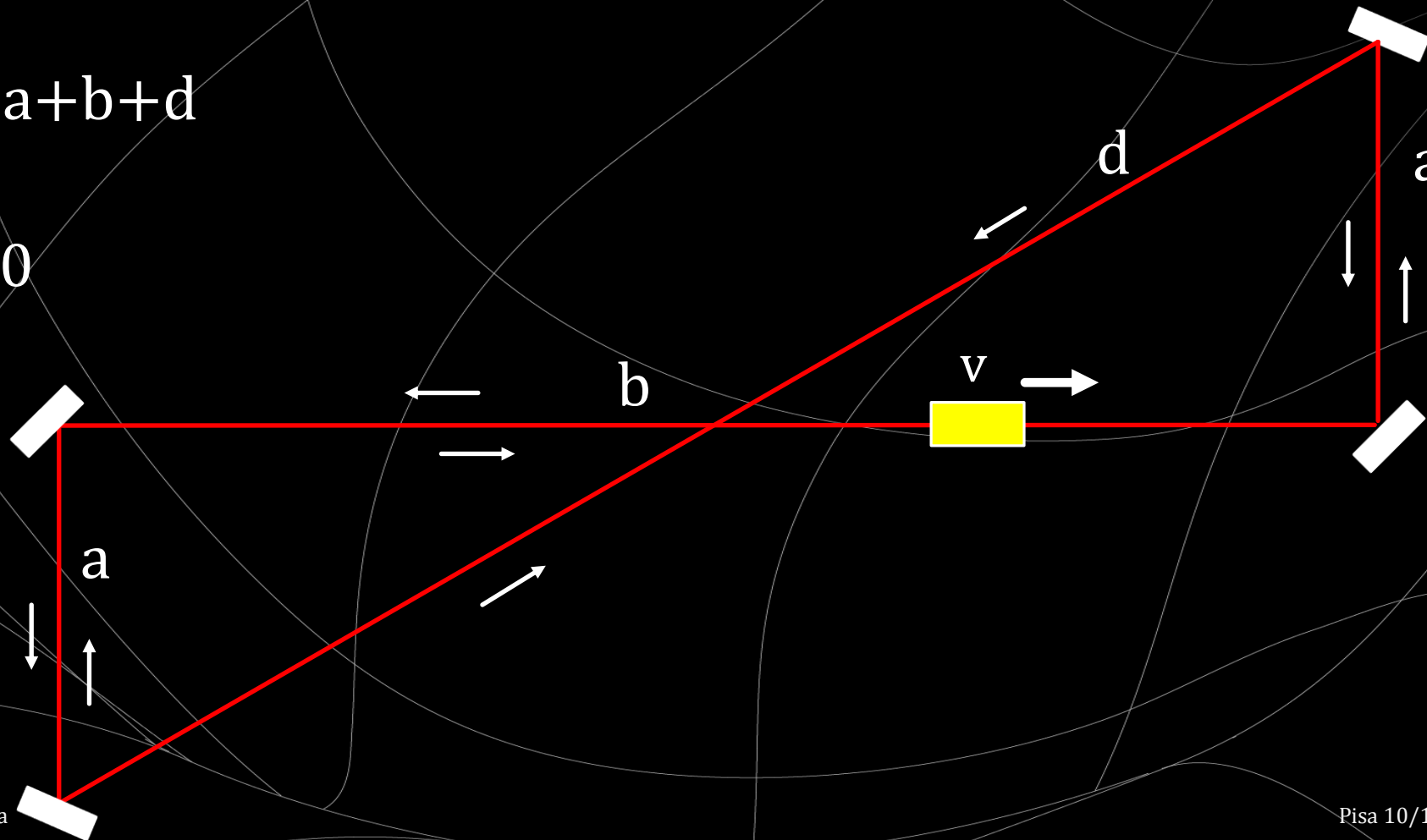
Accelerometer

$$\dot{v} = \frac{\dot{f}_b}{f} c$$

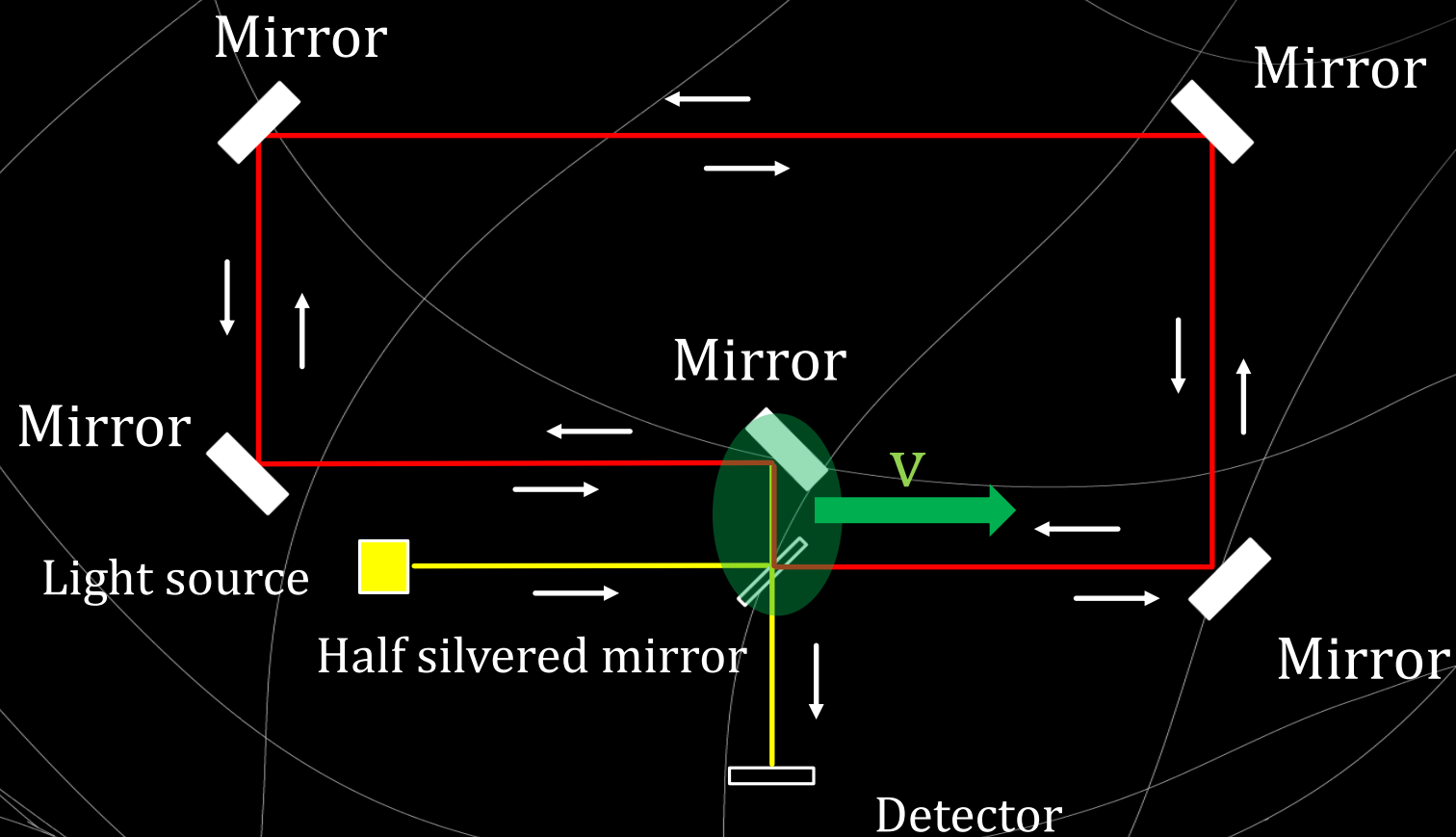
Rotation free configuration

$$\ell = 2a + b + d$$

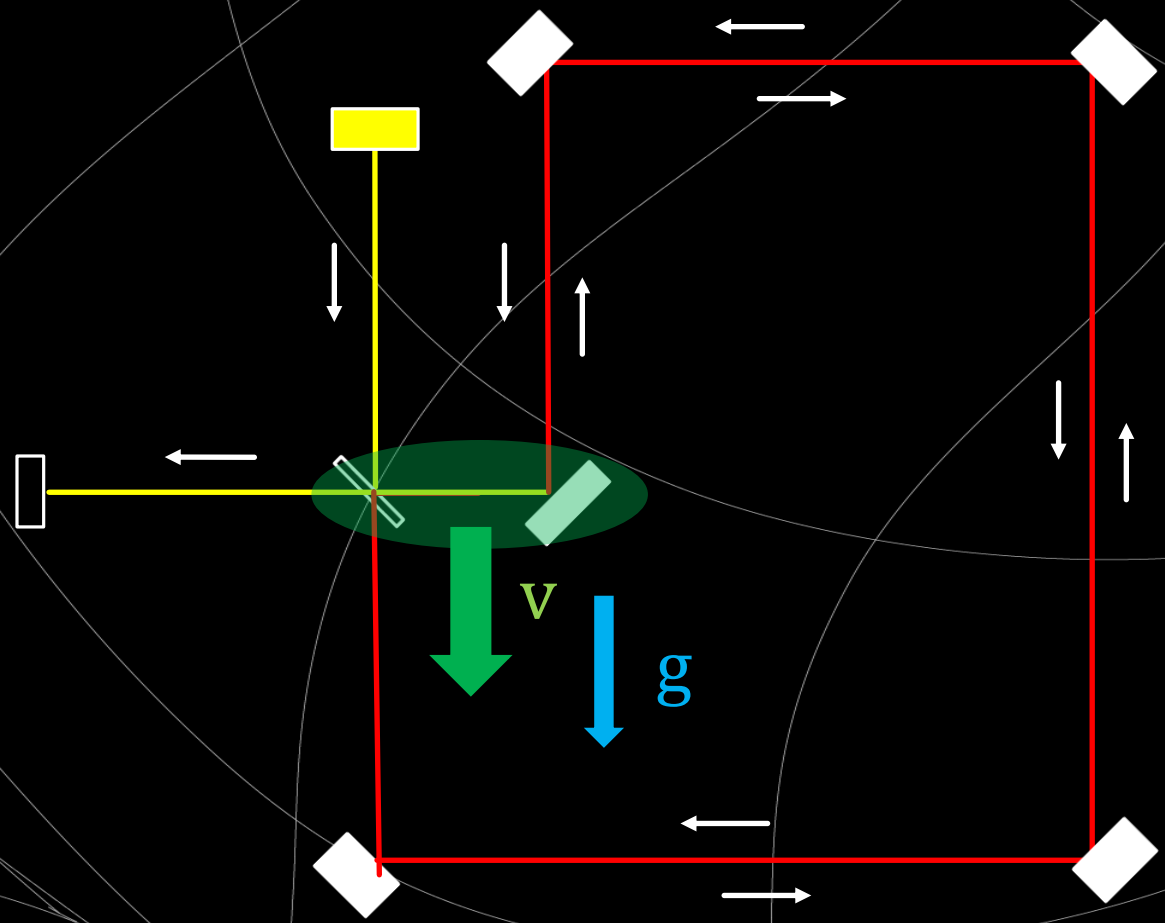
$$A_{\text{tot}} = 0$$



Can we make an experiment?



Gravimeter?



References

- A. Tartaglia, ML. Ruggiero, *Am. J. Phys.*, **83**, 427 (2015)
- ML Ruggiero, A. Tartaglia, *Eur. Phys. J. Plus*, **130**, 90 (2015)
- ML Ruggiero, A. Tartaglia, *Eur. Phys. J. Plus*, **129**, 126 (2014)
- A. Tartaglia, *Gen. Rel. Grav.*, **32**, 1745 (2000)