

AN INTRODUCTION TO ITS POINTING DIFFICULTIES

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Master Student

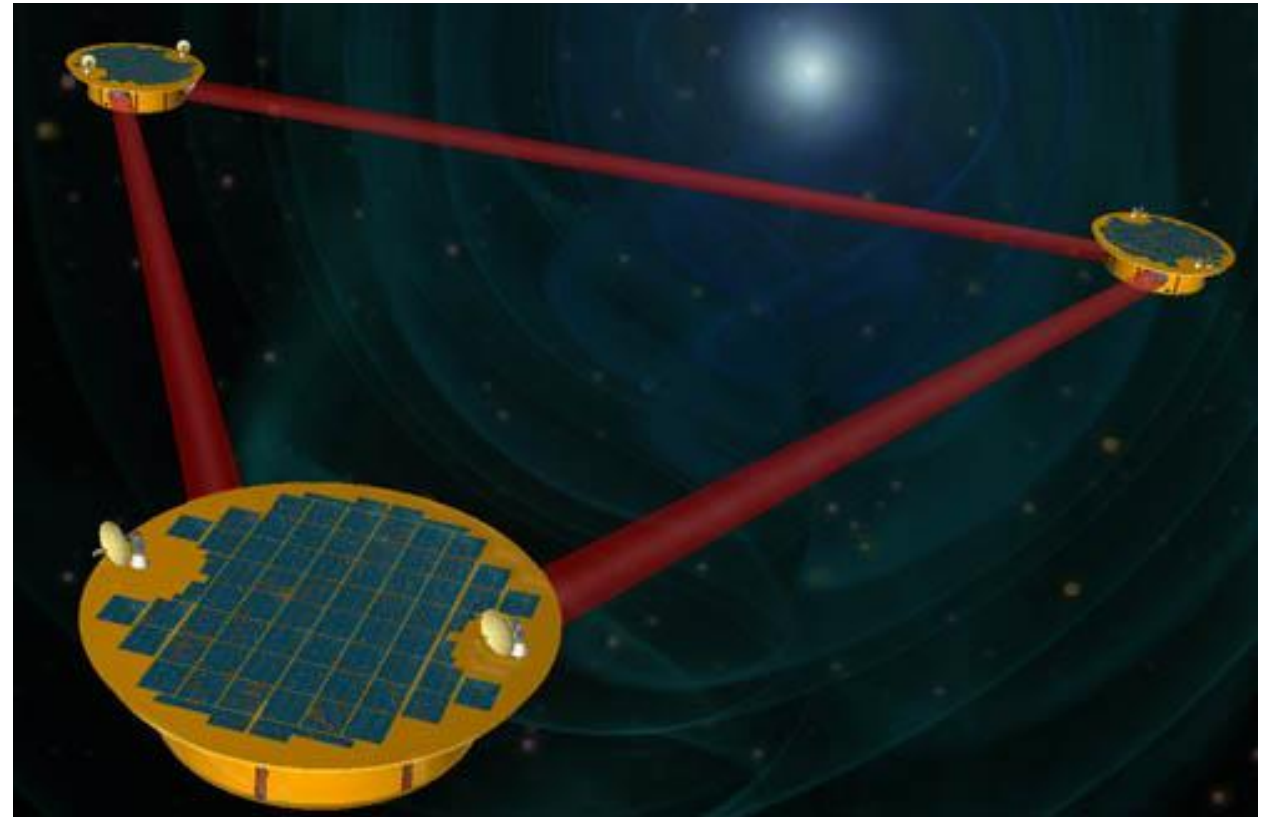
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Niels van Bakel (Nikhef)

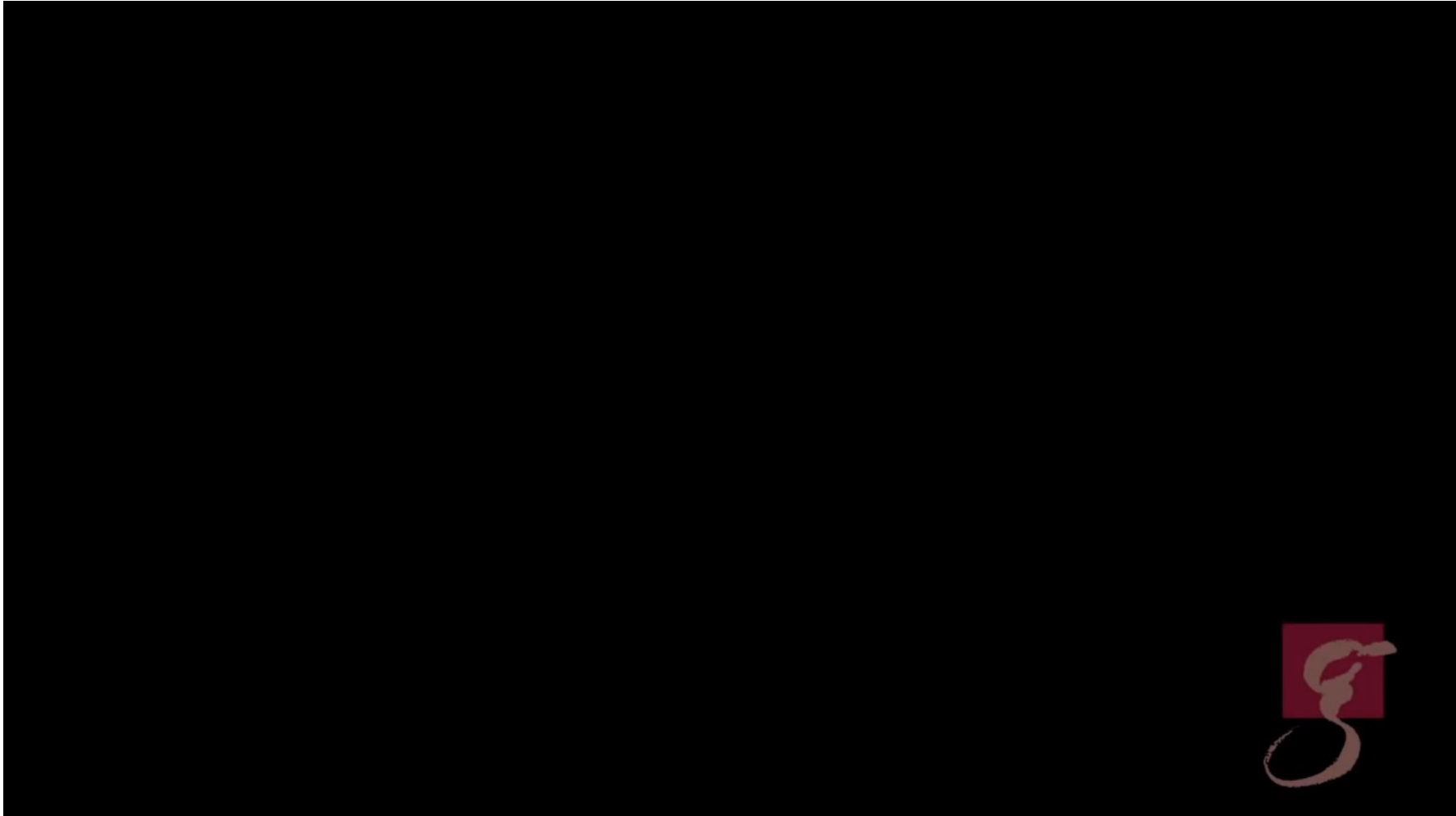
LISA

LISA

- Three spacecrafts
- $\approx 2.5 \cdot 10^9$ m arms
- Laser Interferometry
- No seismic noise



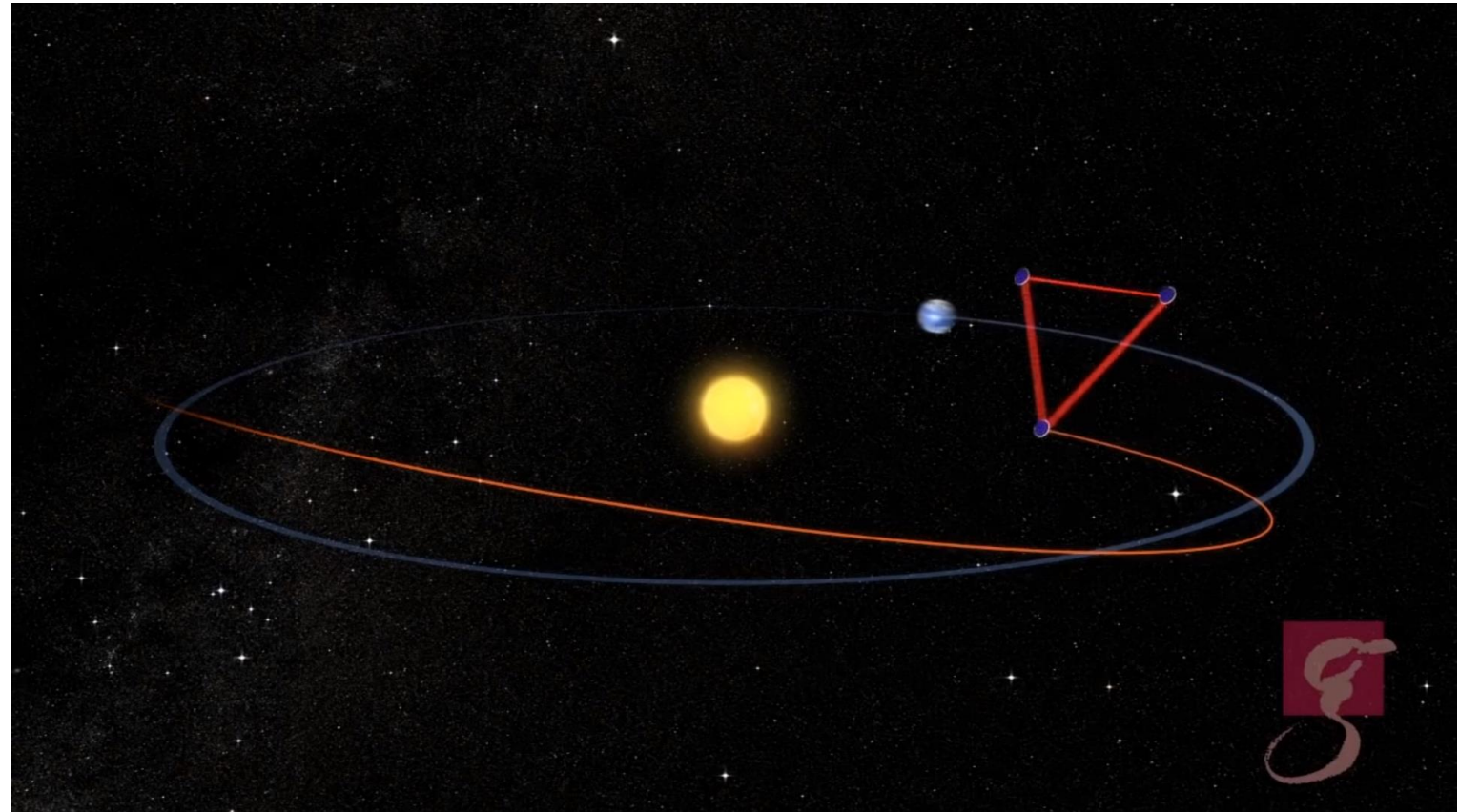
Orbit



Orbit

- Equilateral angle
- Constant length
- Tidal forces
- Inclination

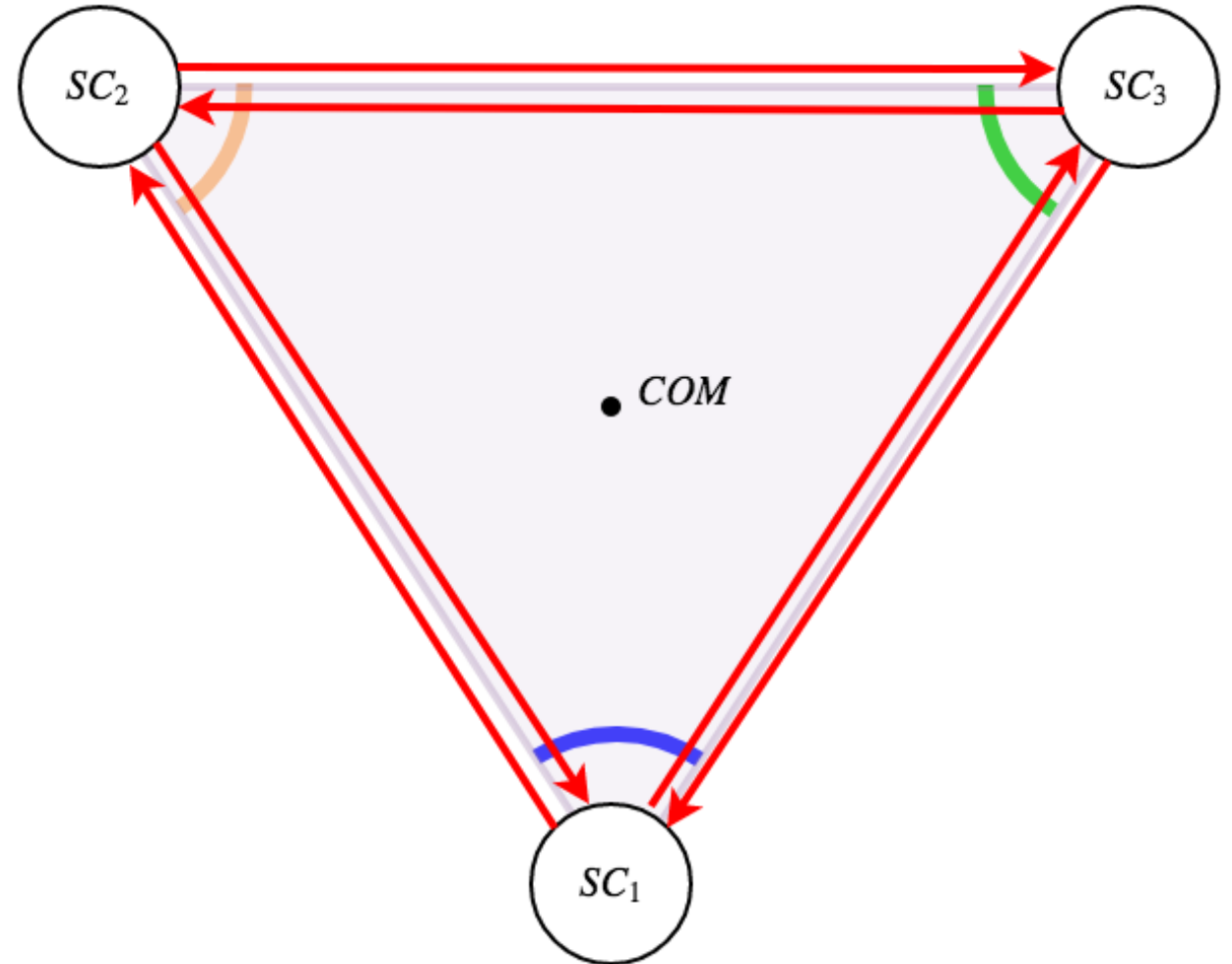
No “constant” triangle



Pointing

- Six laser links
- Pointing
 - Tilt
 - Offset
 - FOV

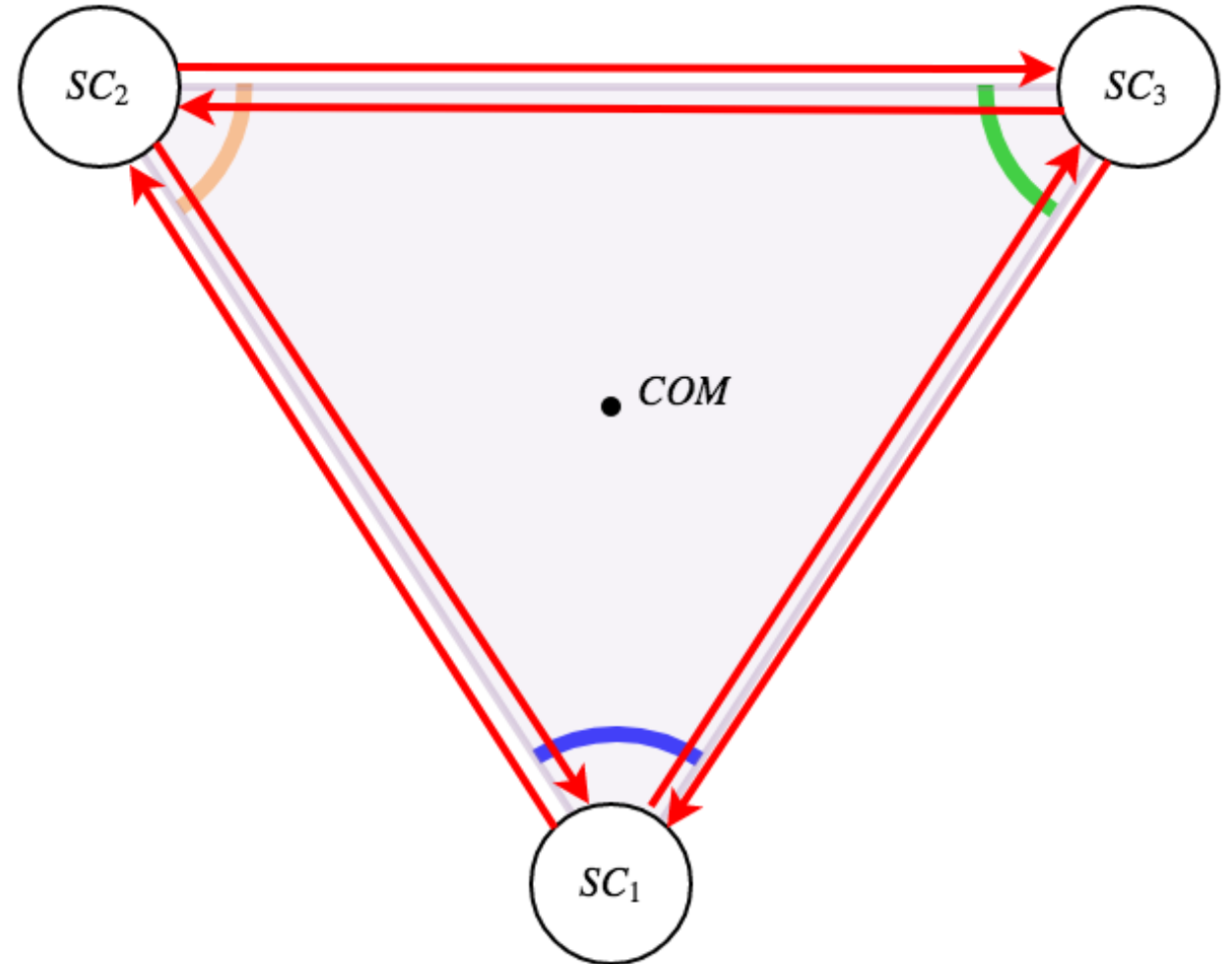
How to?



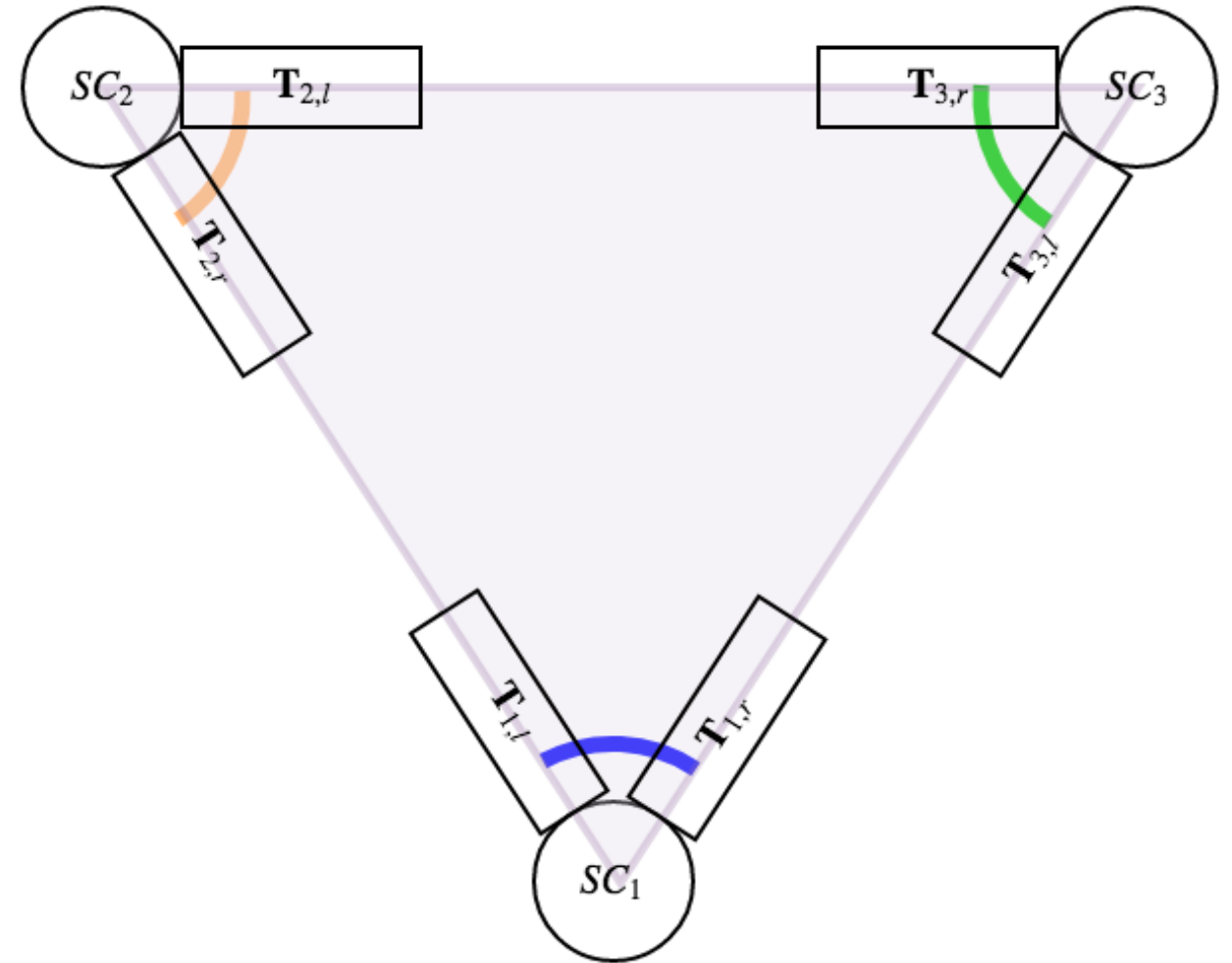
Content

- Breathing angle
- Point ahead angle
- How to compensate

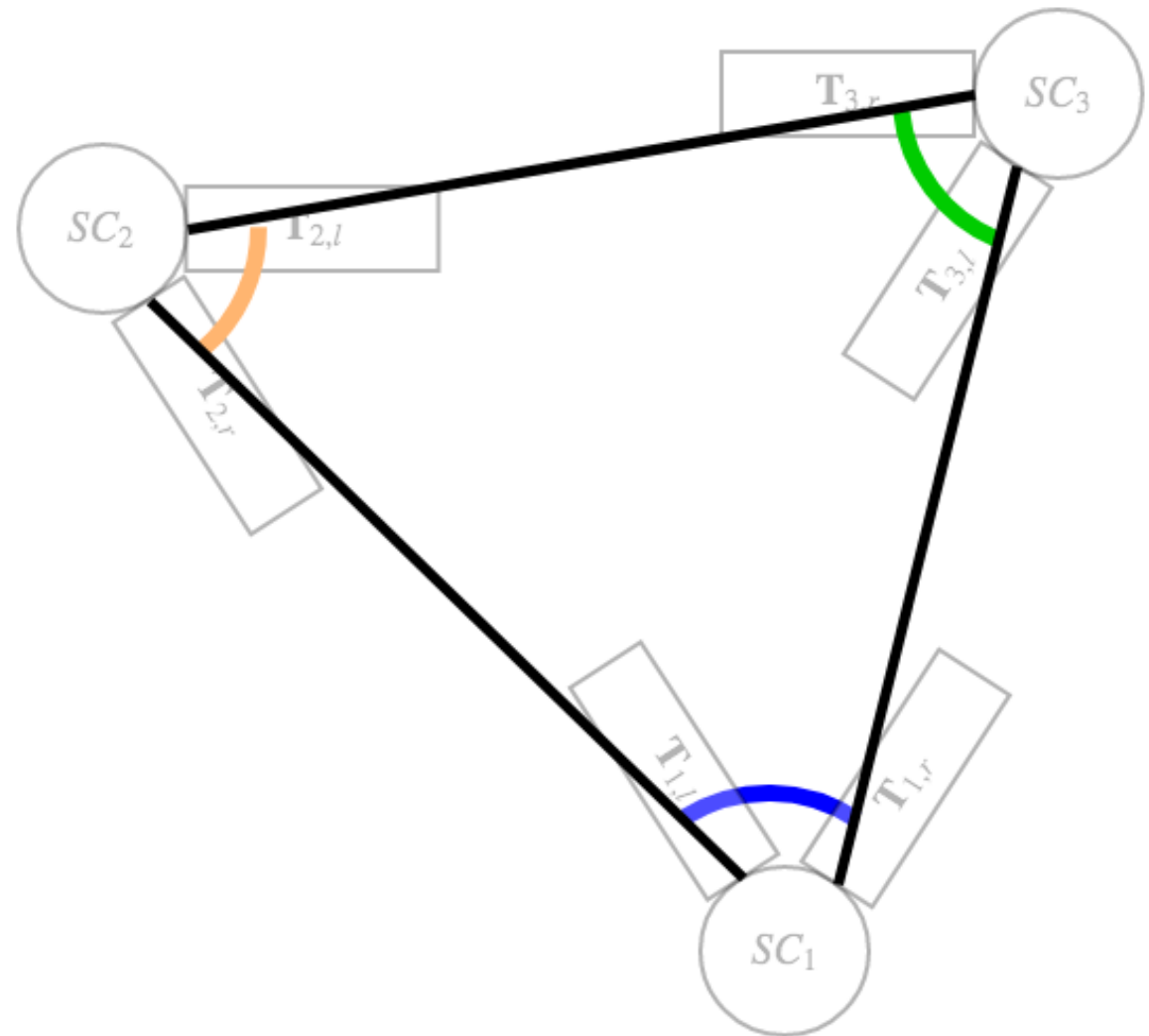
- My work



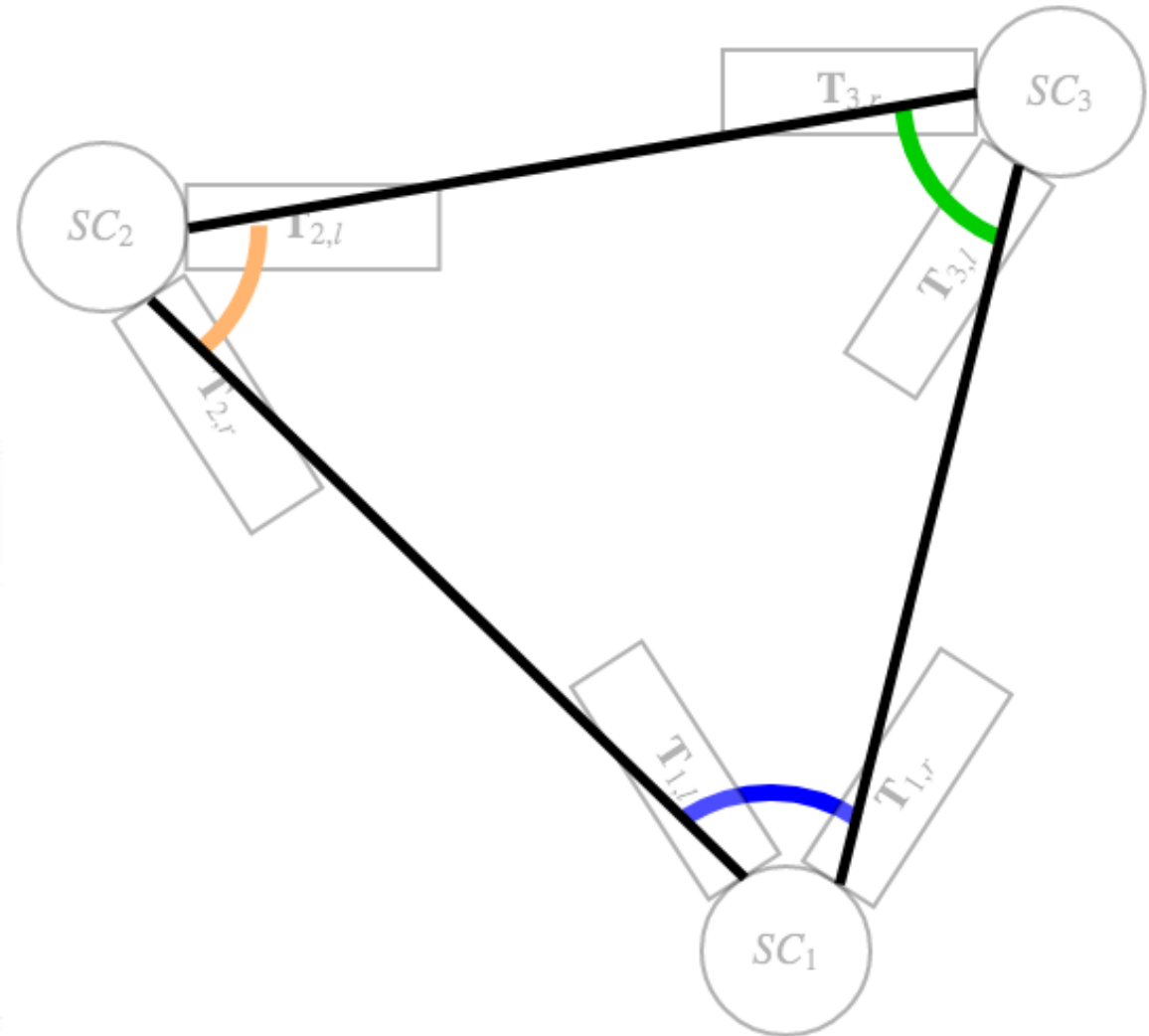
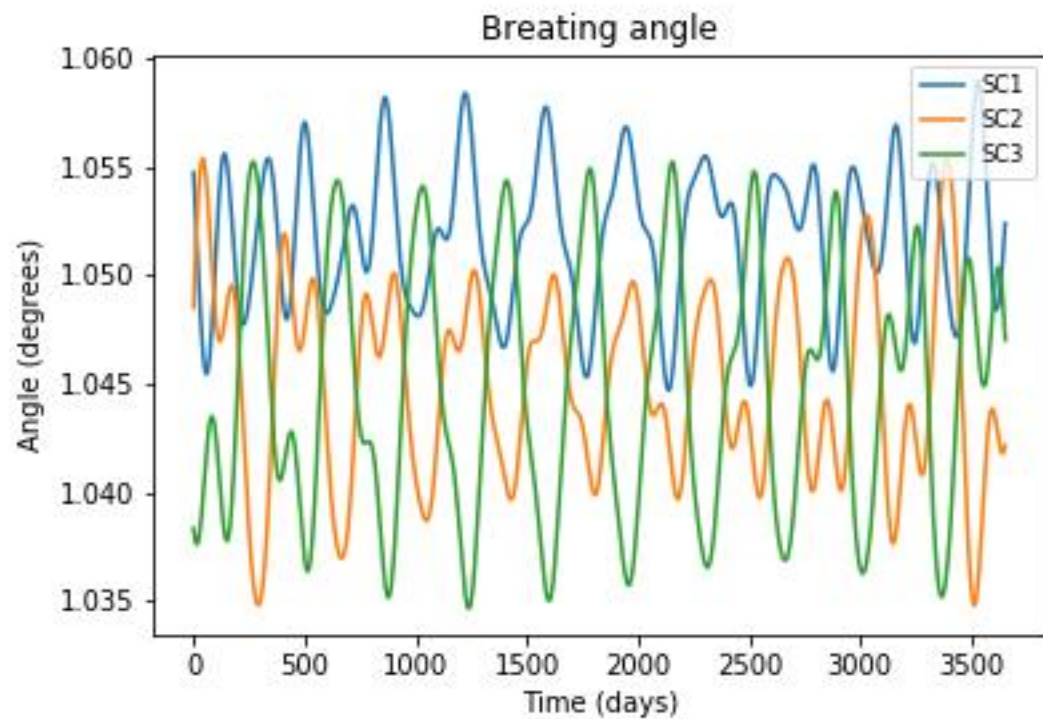
Breathing angle



Breathing angle



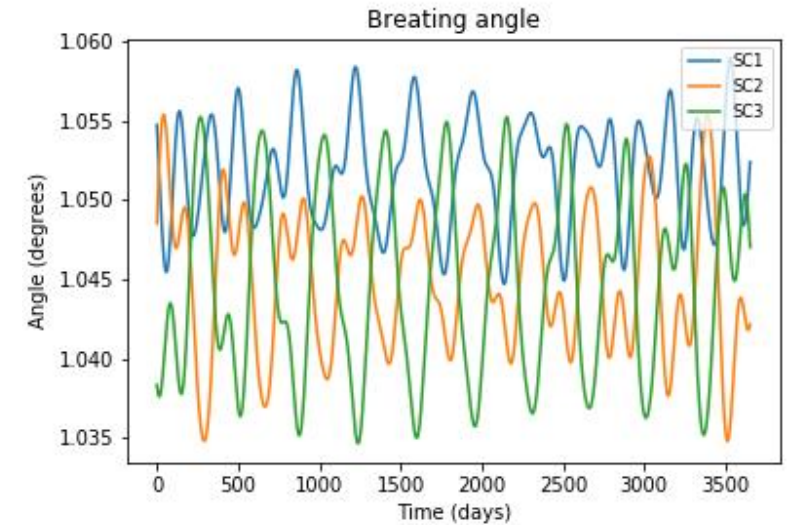
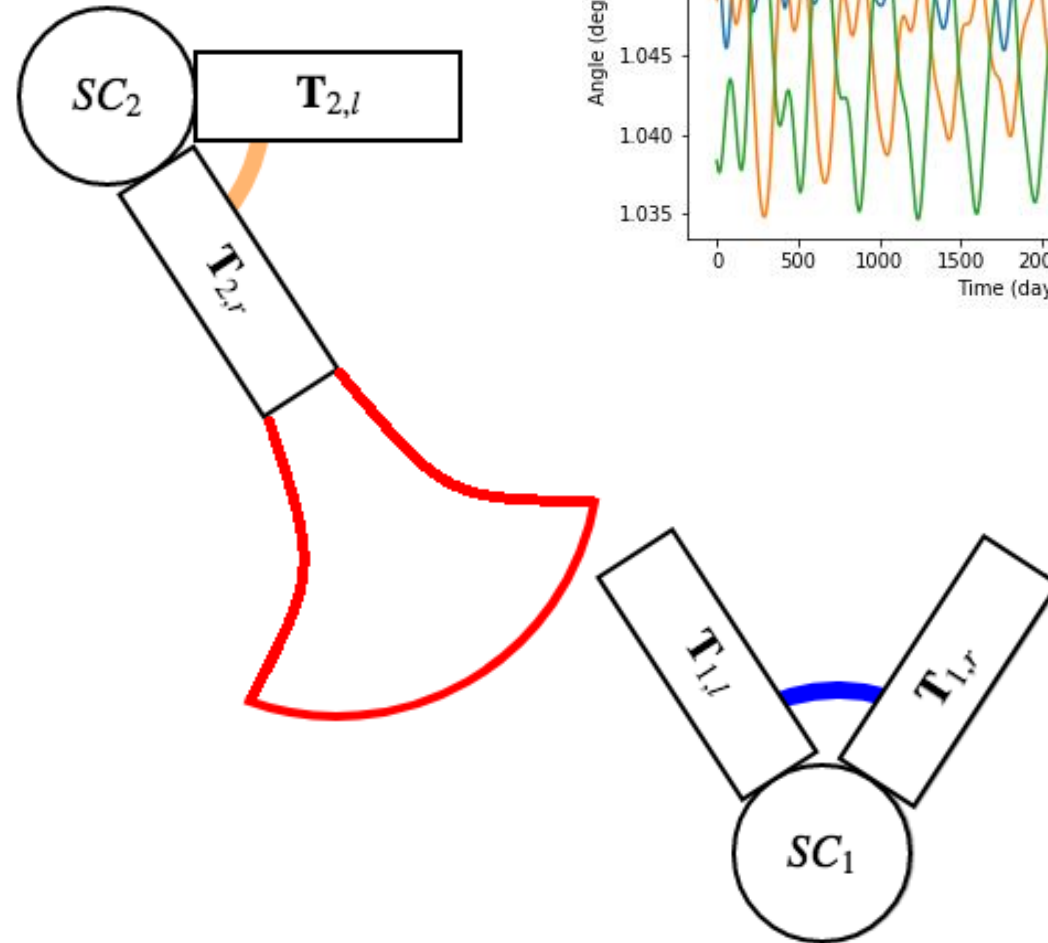
Breathing angle



Breathing angle

Adjust telescopes

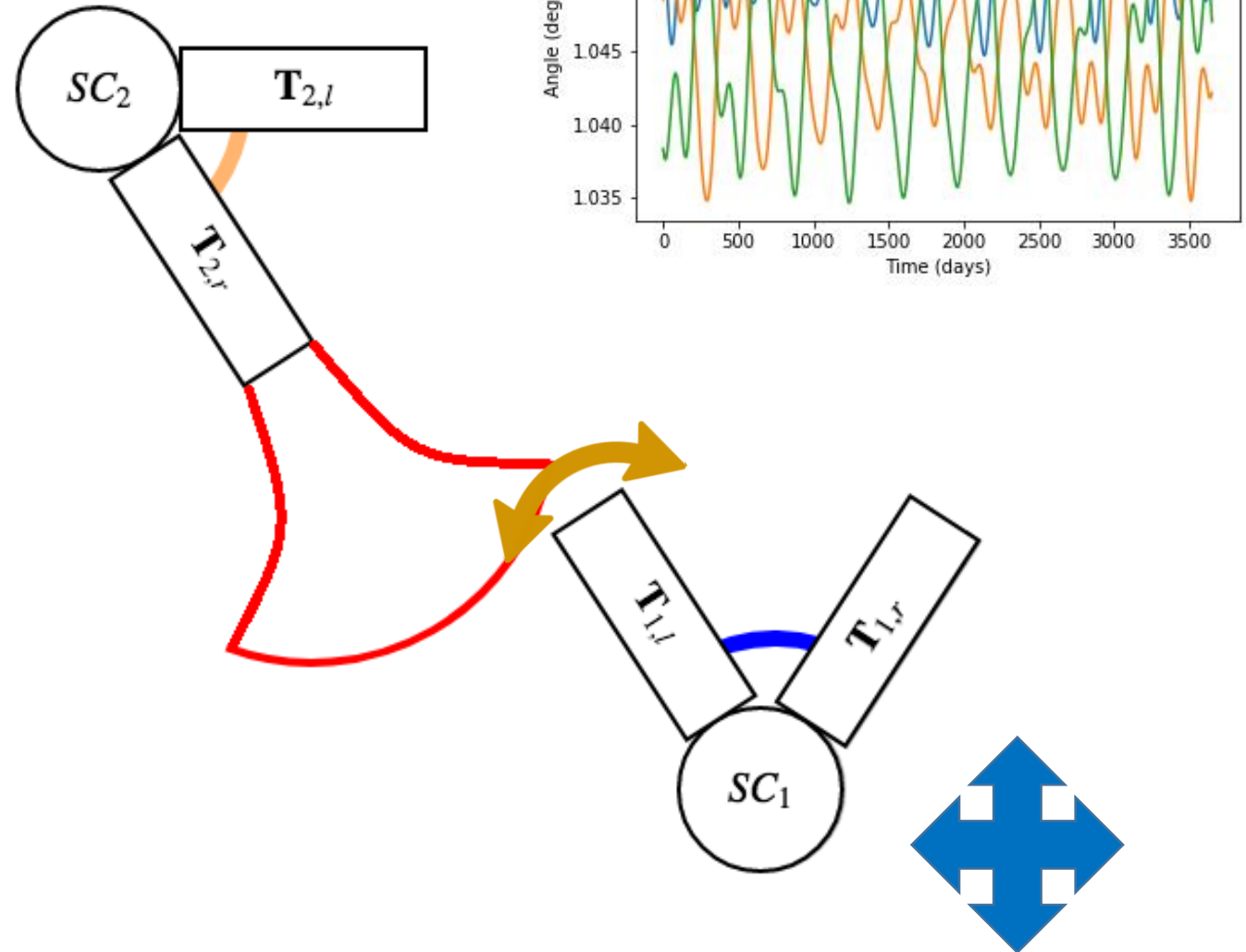
- Optical Assembly Tracking Mechanism (OATM)



Breathing angle

Adjust telescopes

- Optical Assembly Tracking Mechanism (OATM)
 - Micronewton thrusters
 - Optical assembly

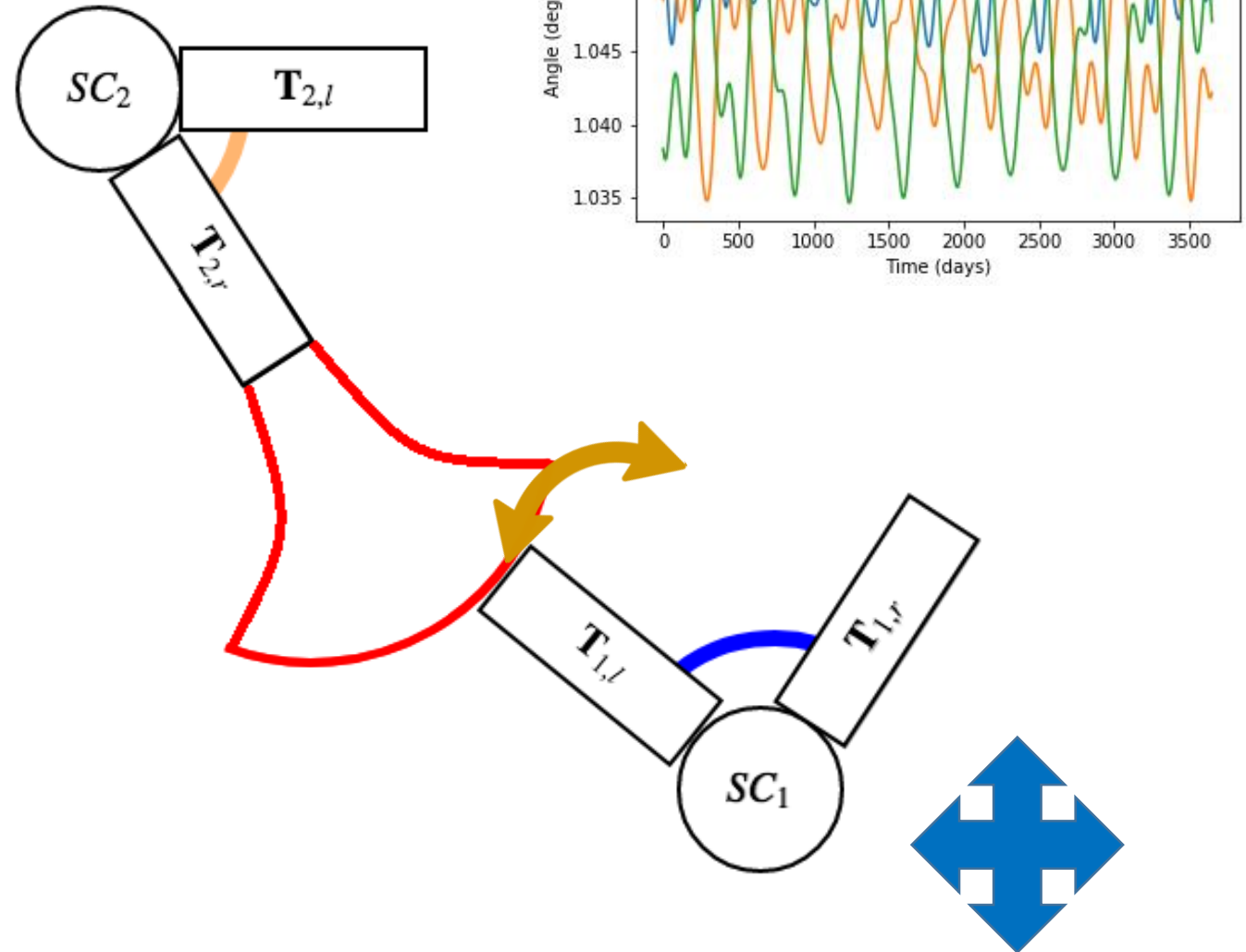


Breathing angle

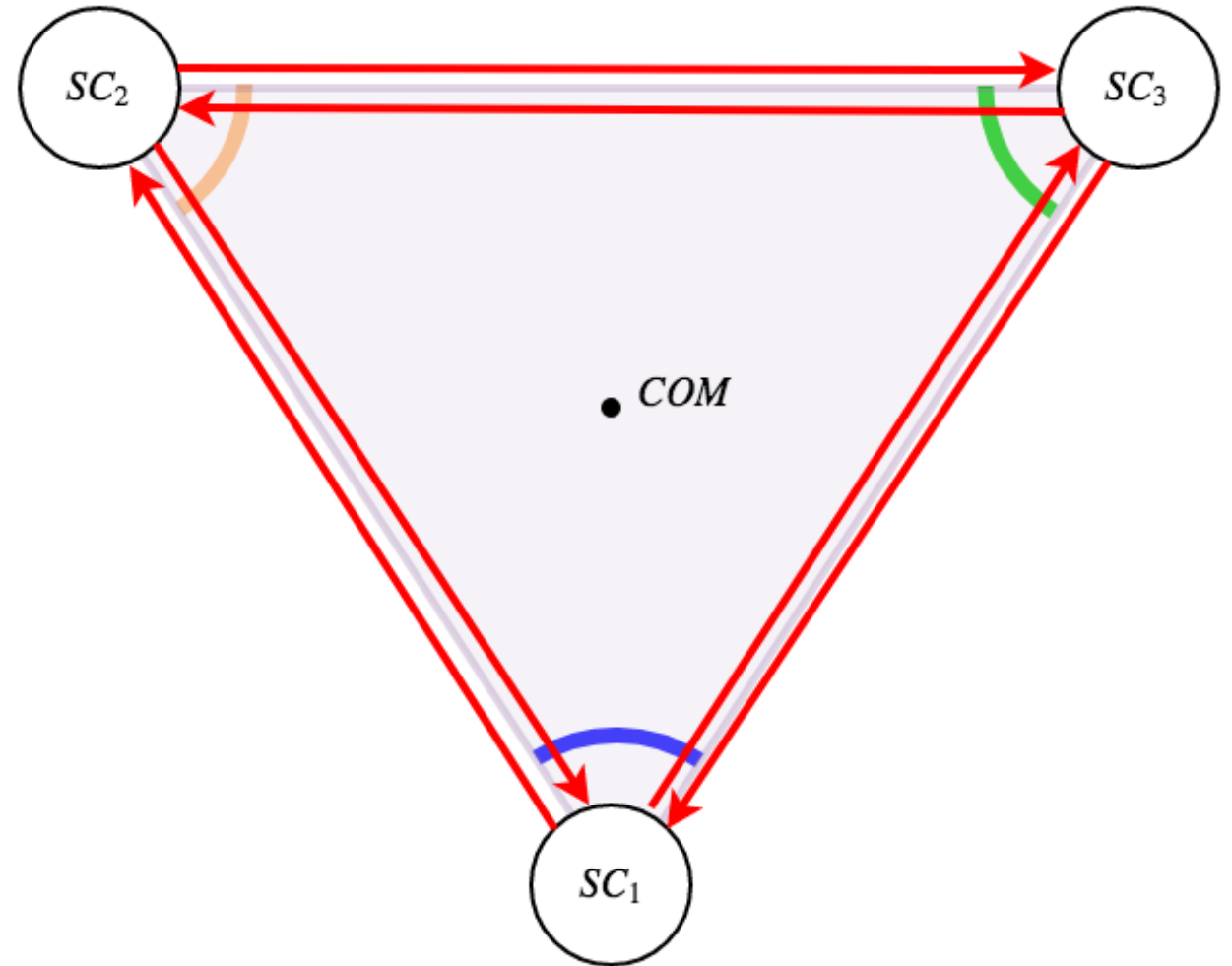
Adjust telescopes

- Optical Assembly Tracking Mechanism (OATM)
 - Micronewton thrusters
 - Optical assembly

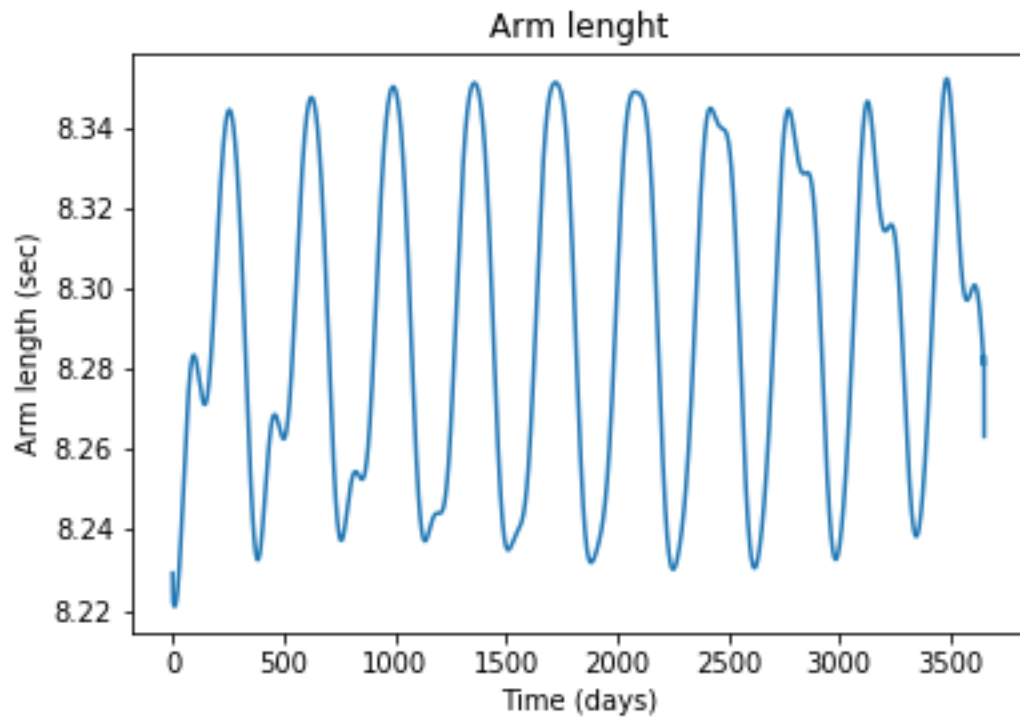
Otherwise outside FOV
($=8 \mu rad$)



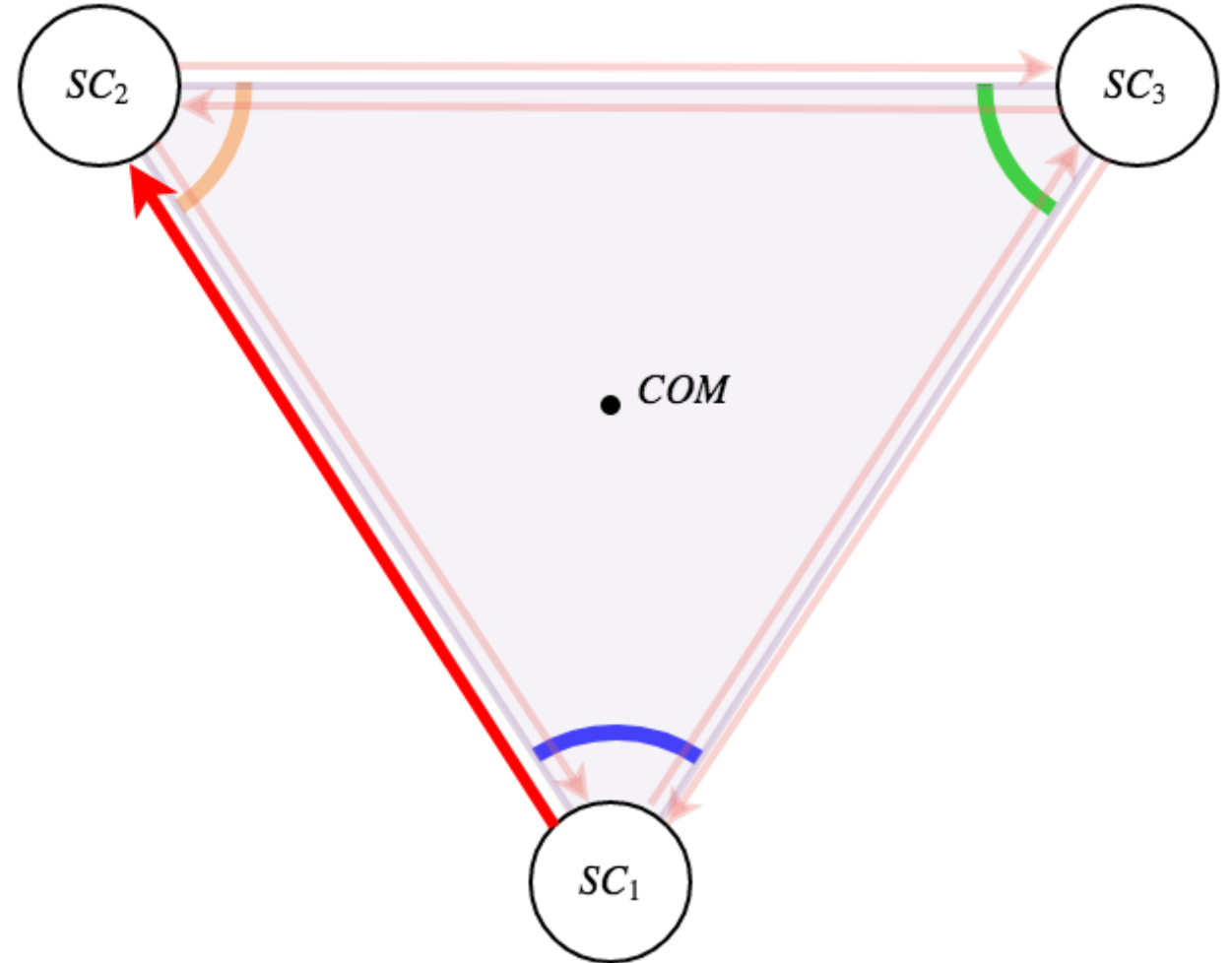
Six Laser Links



Six Laser Links



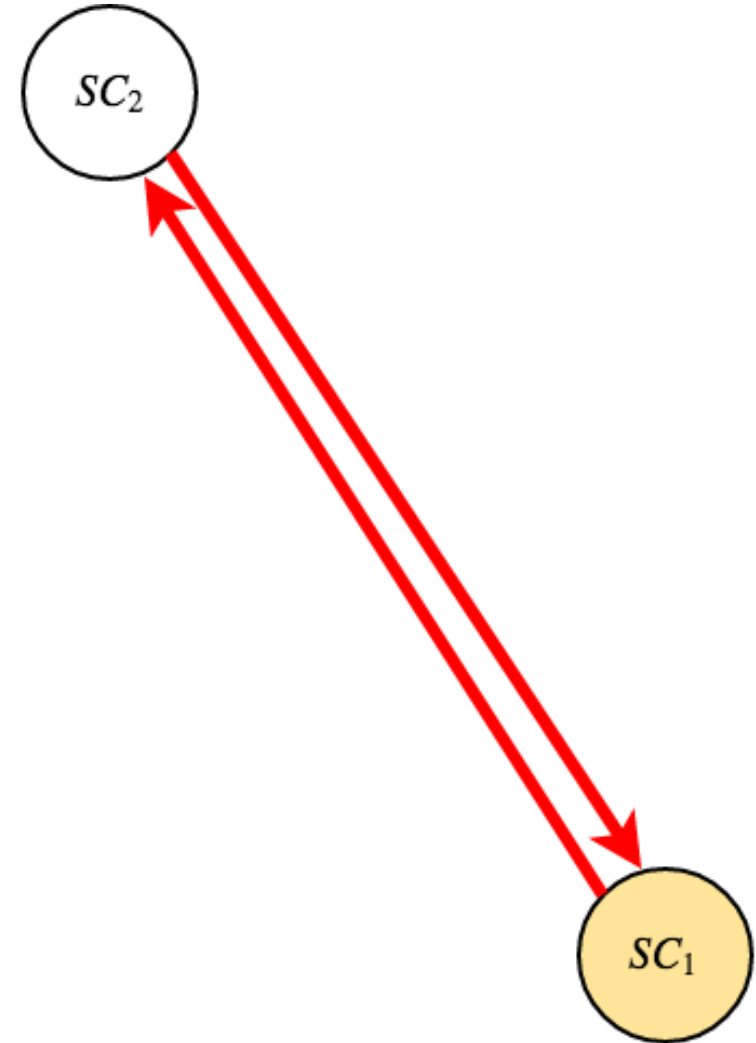
- Time delay



Laser Link

Varying arm lengths and angles:

- Signal
- Pointing



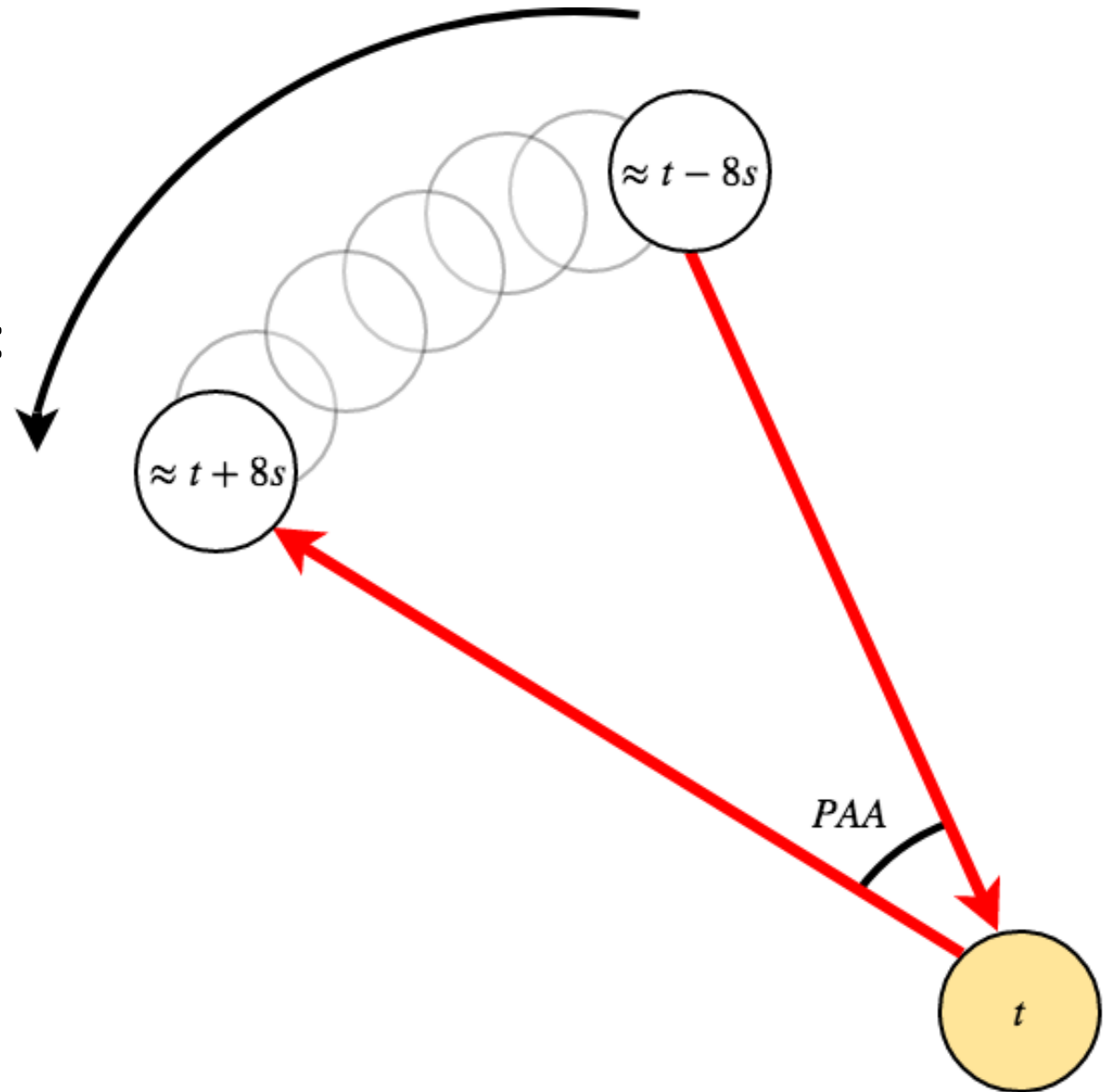
Laser Link

Varying arm lengths and angles:

- Signal
- Pointing

→ Point Ahead Angle (PAA)

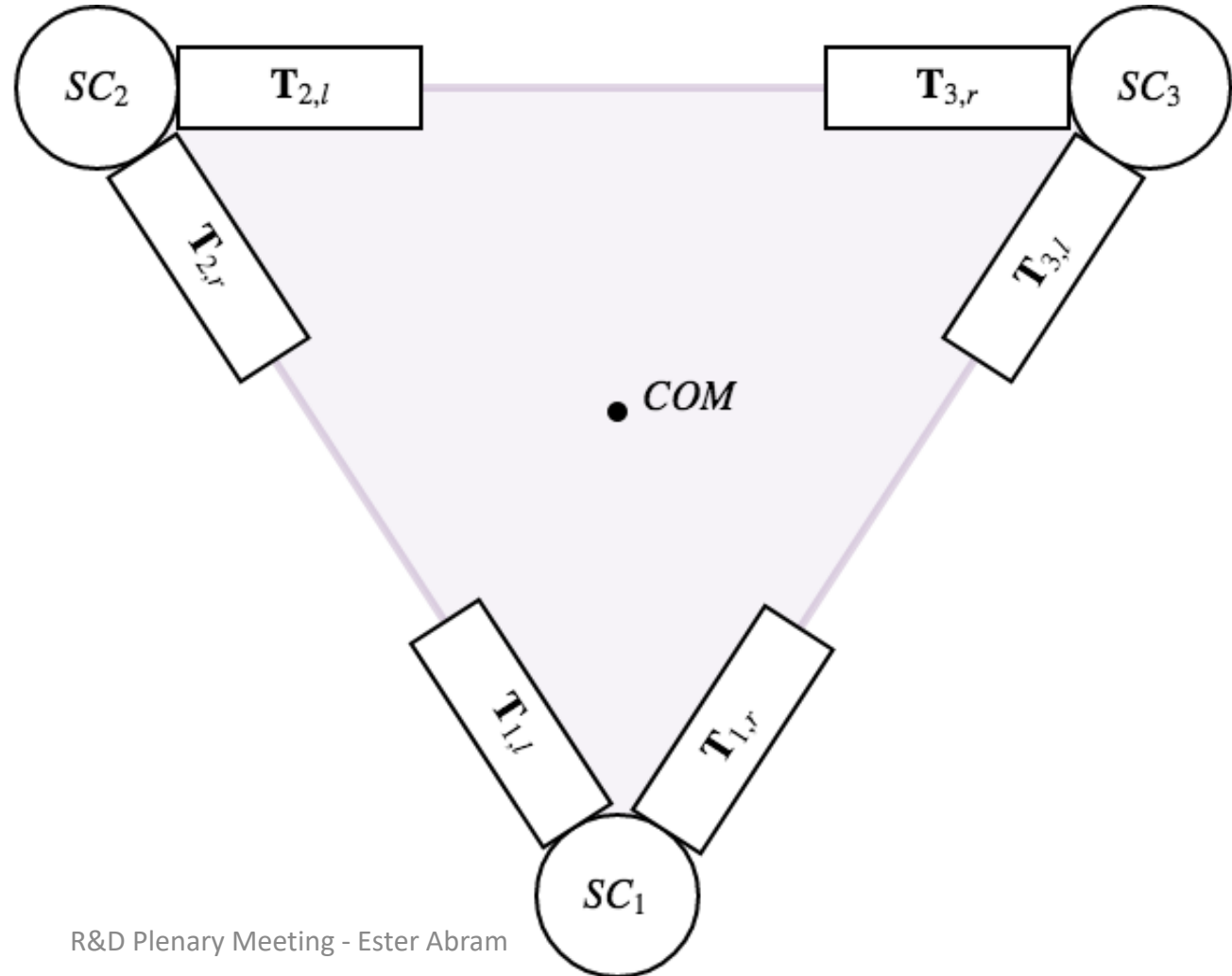
Otherwise you will 'miss'



Point Ahead Angle (PAA)

Due to relative velocity:

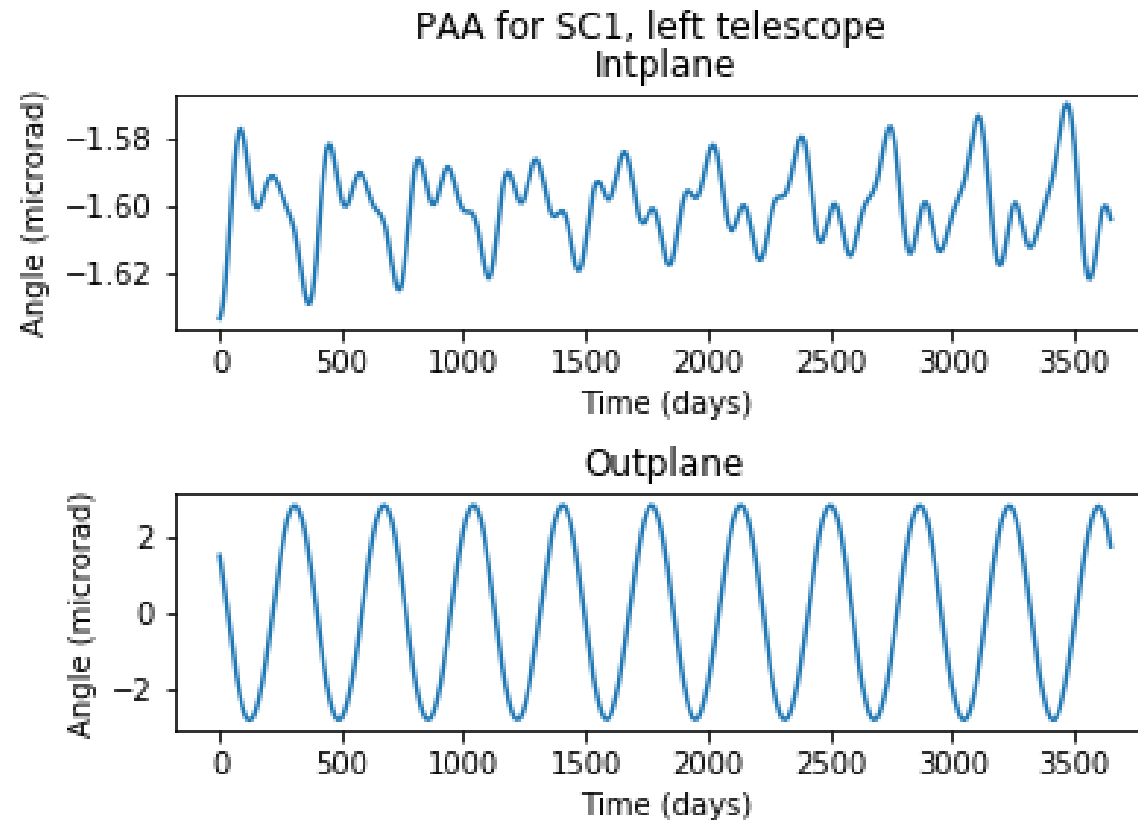
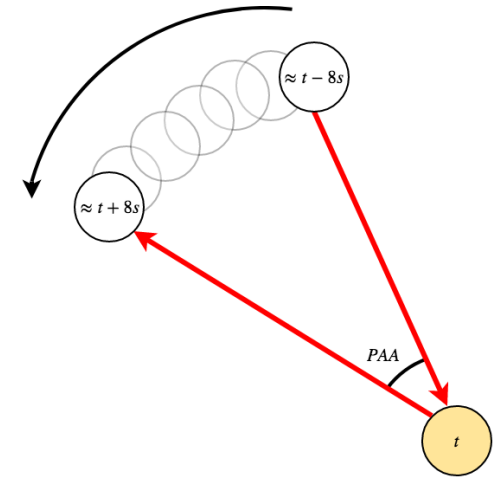
- “Inplane” and
“Outplane” PAA



Point Ahead Angle (PAA)

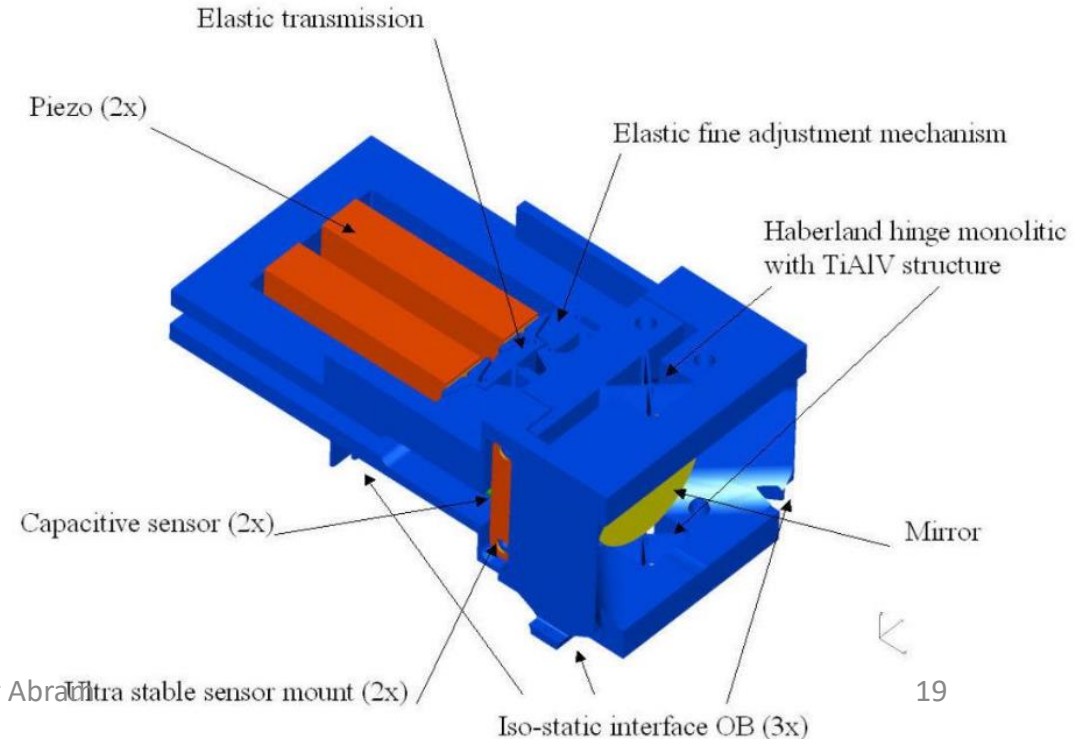
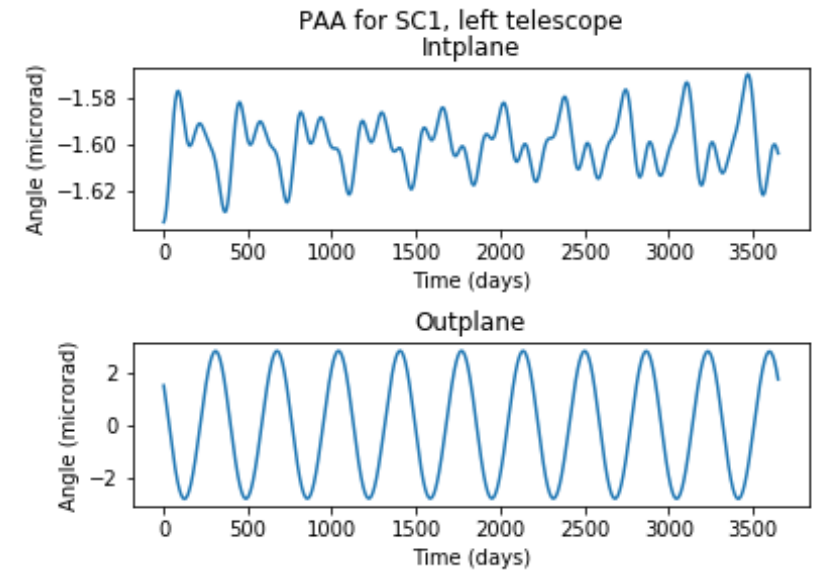
Due to relative velocity:

- “Inplane” PAA
 - Telescope
- “Outplane” PAA
 - PAAM



PAA Outplane

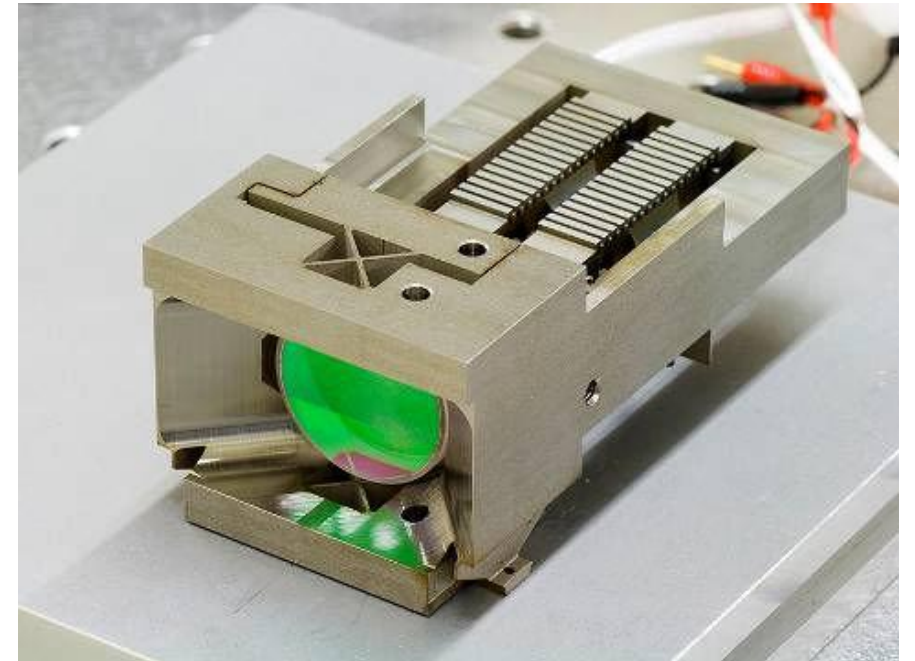
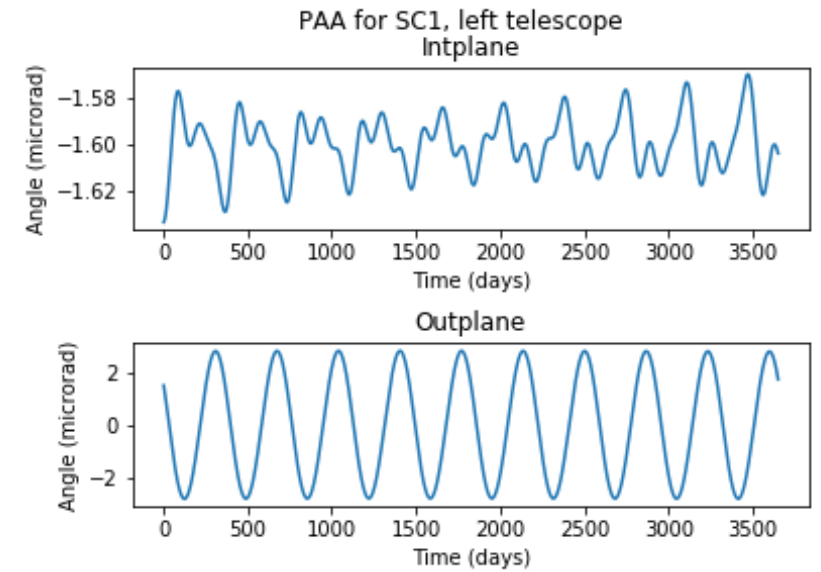
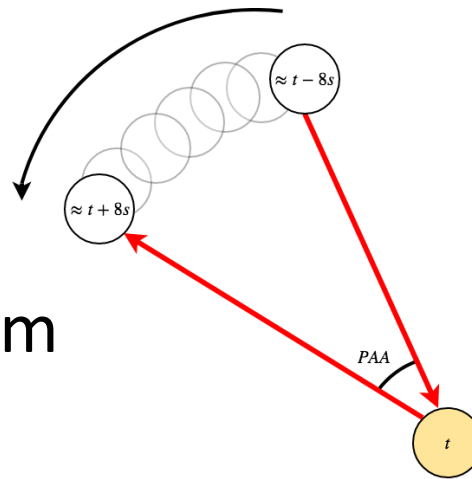
- Point ahead angle mechanism (PAAM)
- Two piezo stacks
 - Dynamic control
- High precision



PAA Outplane

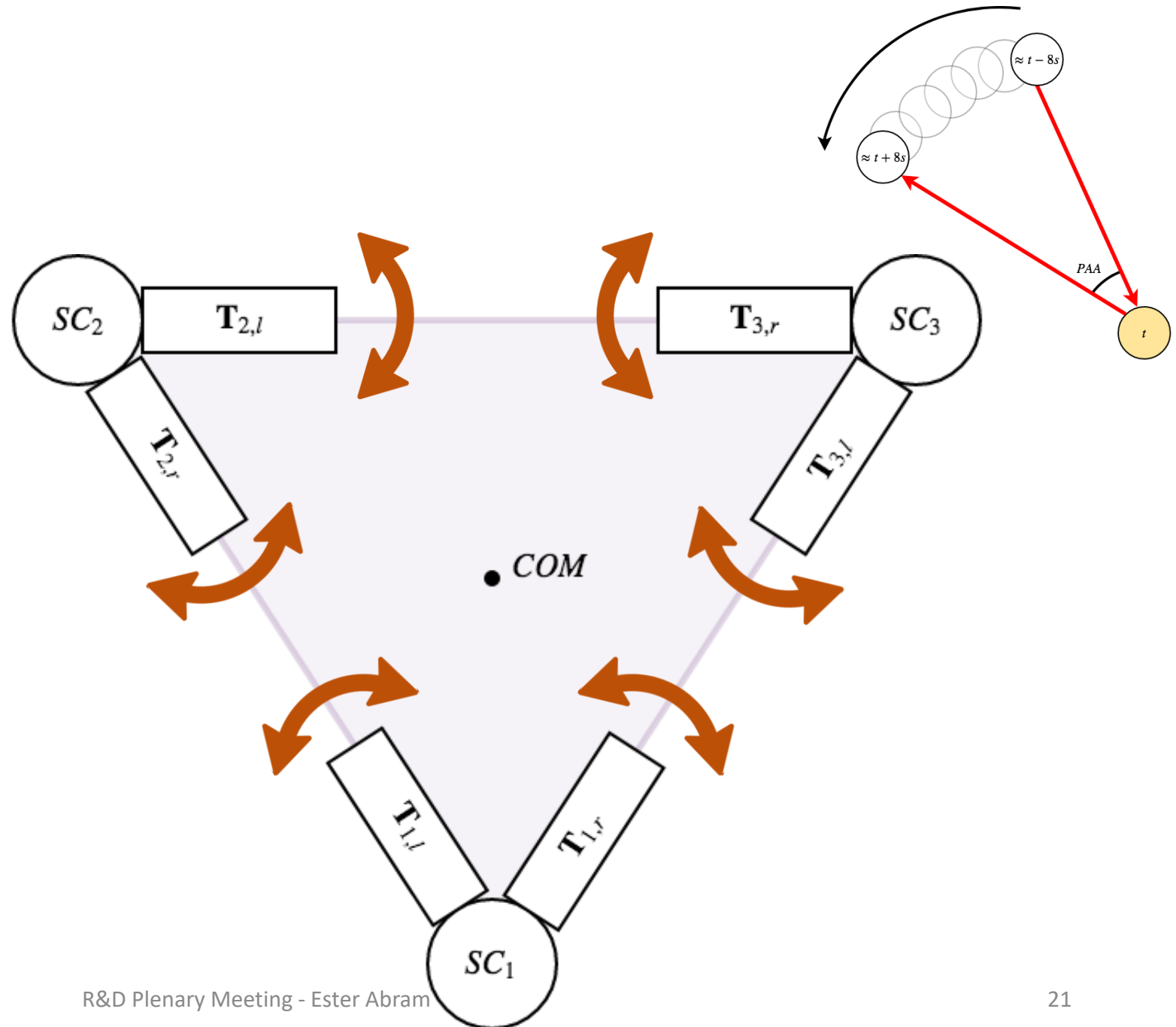
- Point ahead angle mechanism (PAAM)
- Two piezo stacks
 - Dynamic control
- High precision

The PAAM will send the transmitted beam under an angle with the received beam



PAA Inplane

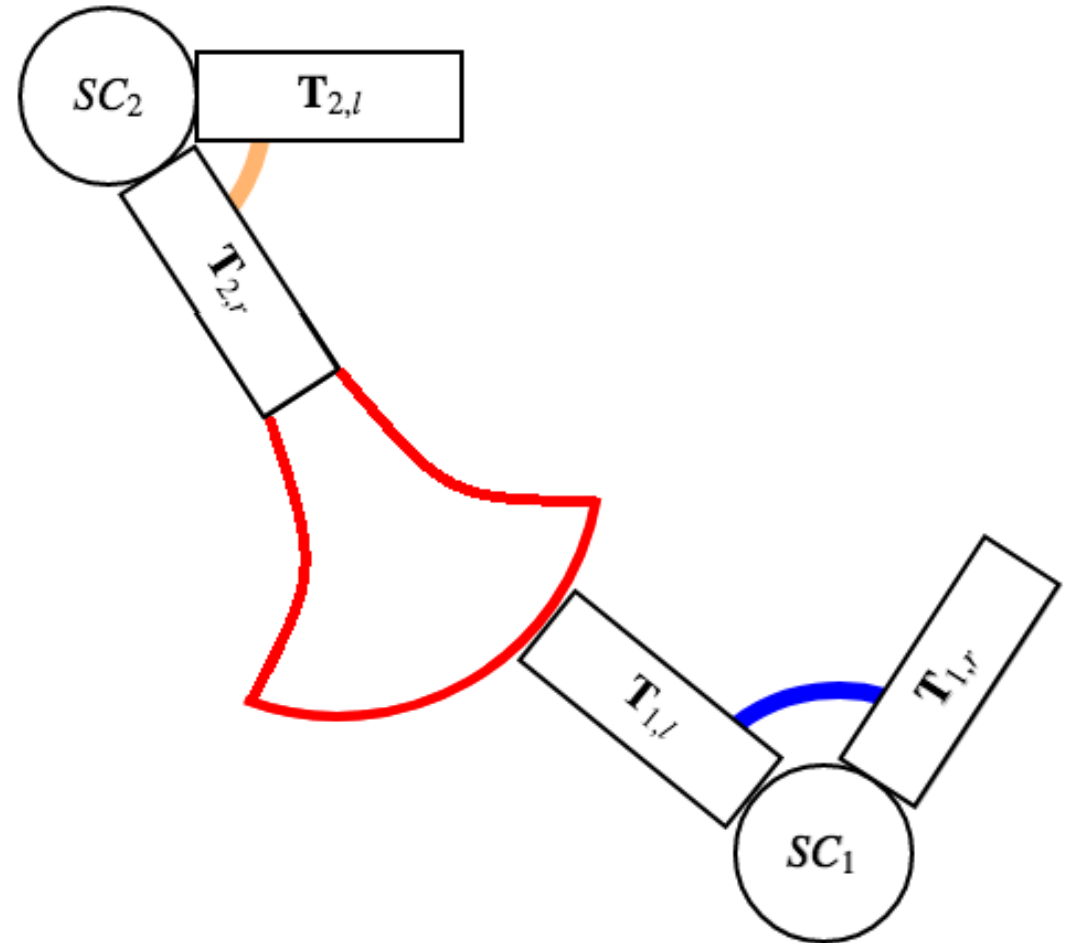
Control telescopes:



PAA Inplane

Control telescope:

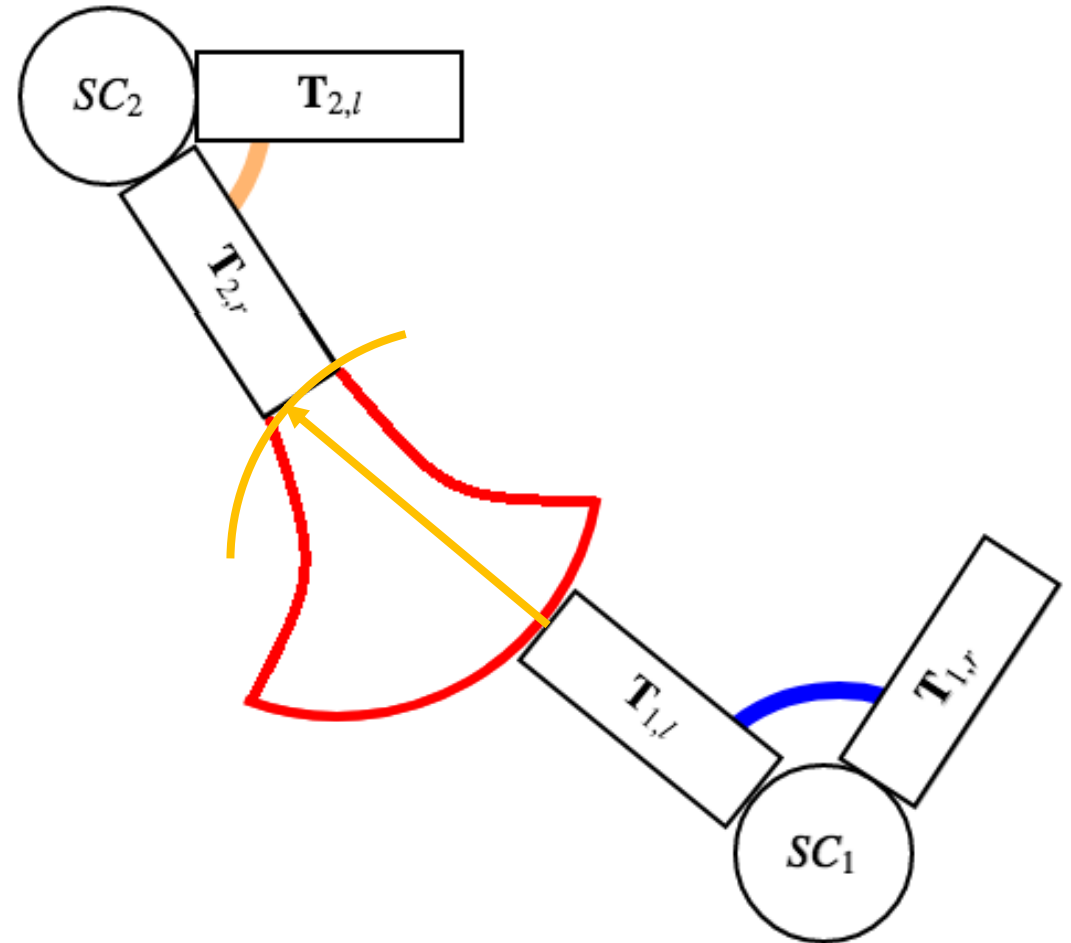
- It will receive the incoming beam 'straight'



PAA Inplane

Control telescope:

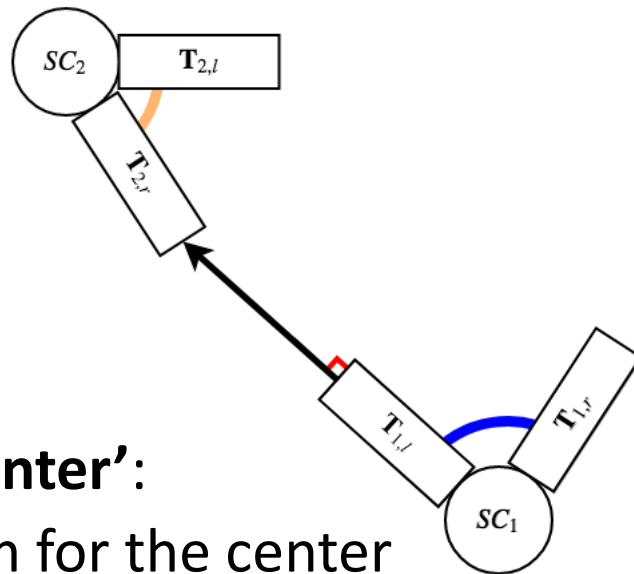
- It will receive the incoming beam 'straight'
- Affects outgoing beam
- Not dynamic control
- Heavy (noise)



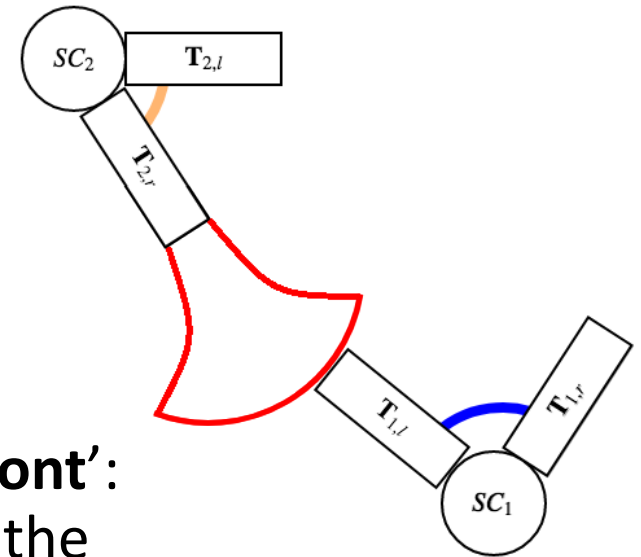
My work

Find a/the best way to point

- Different strategies:



‘Center’:
Aim for the center
of the telescope

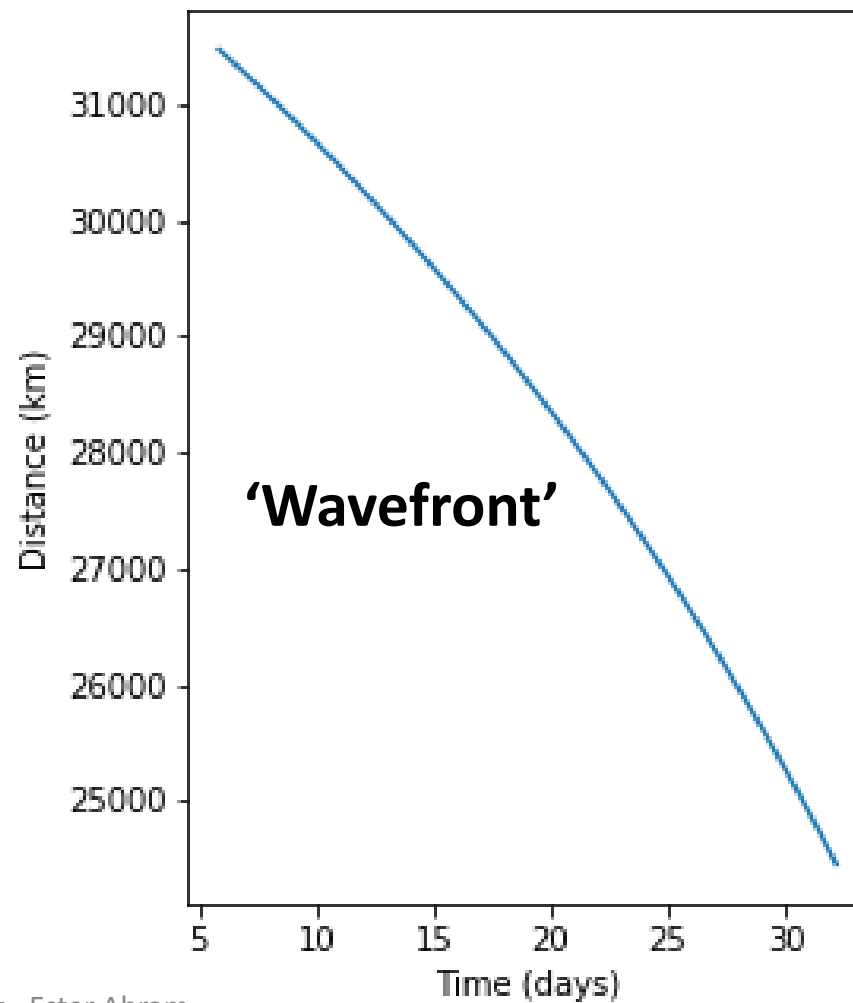
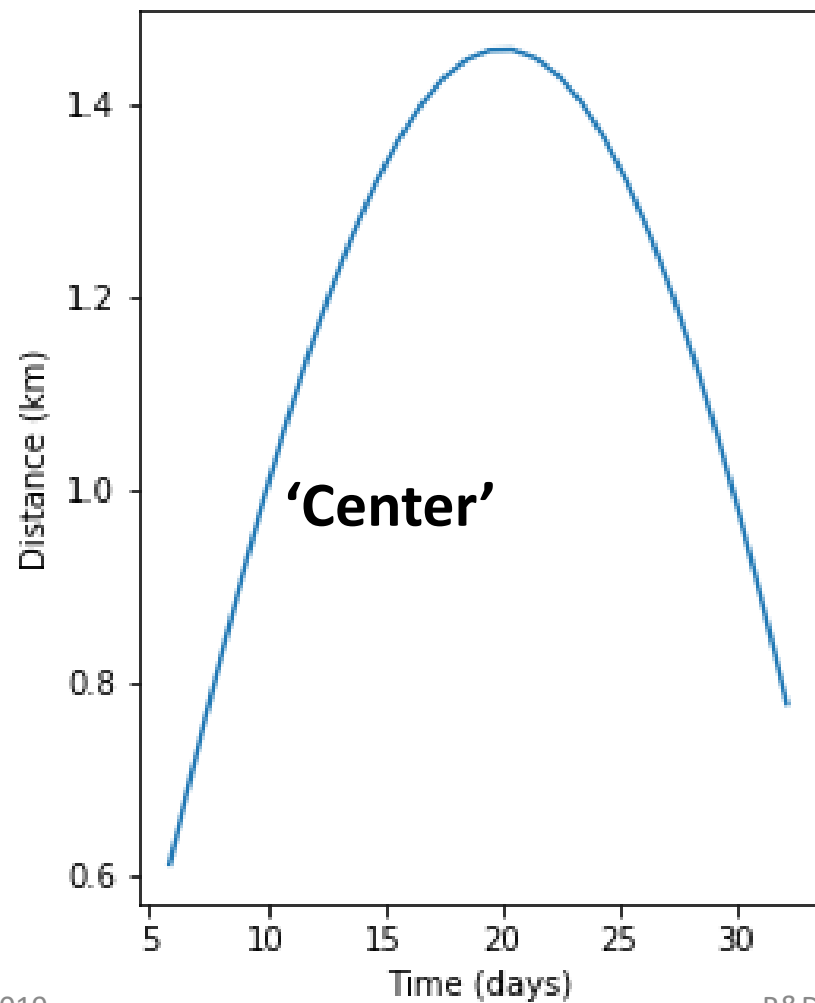


‘Wavefront’:
Receive the
incoming beam
straight

r mean

tele: full control, center, PAAM: full control, center
Iteration: 1

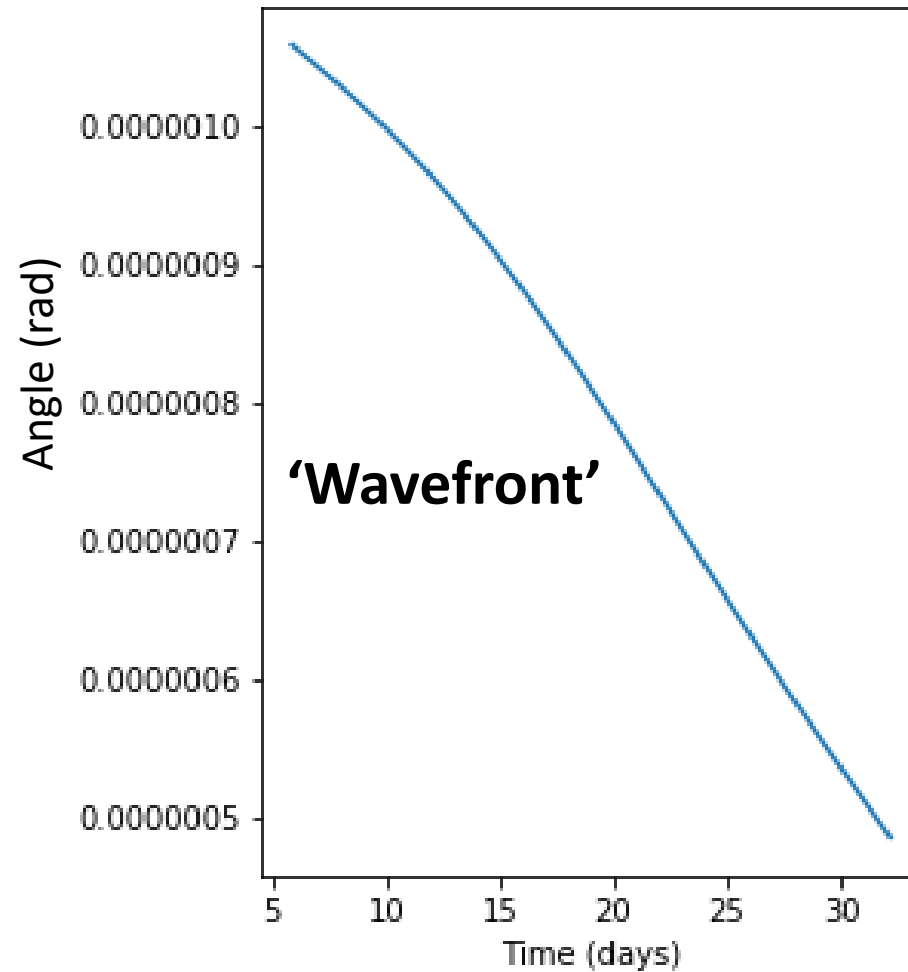
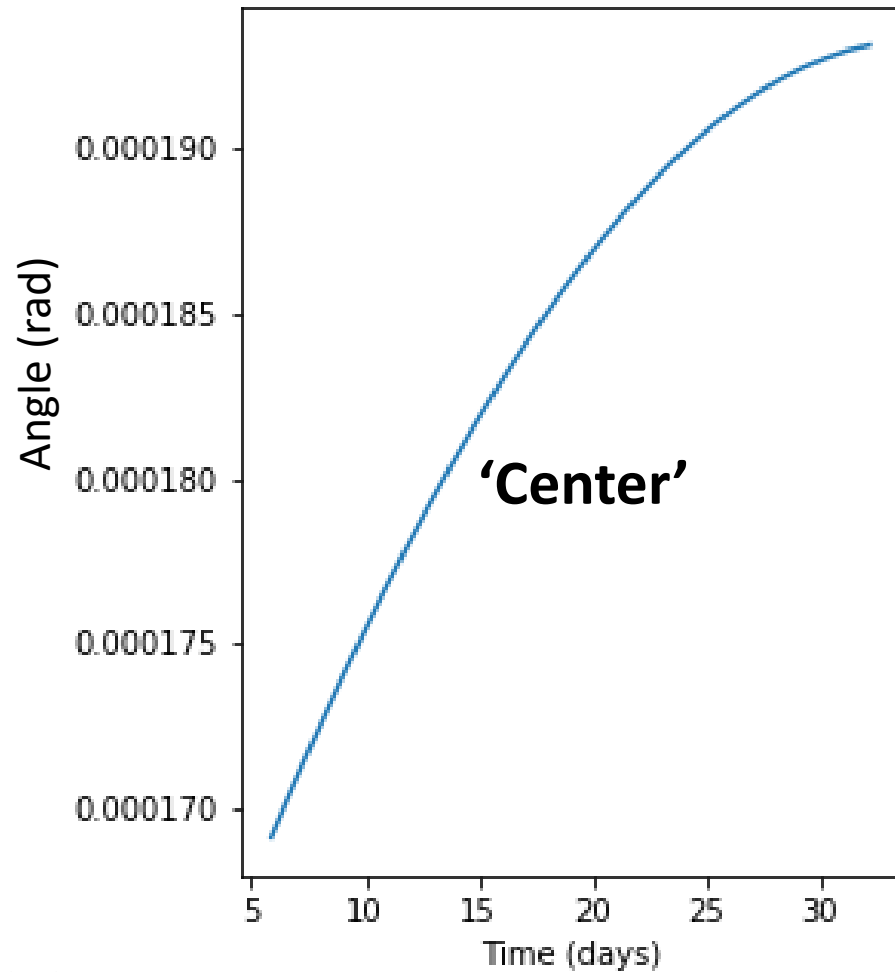
tele: full control, wavefront, PAAM: full control, wavefront
Iteration: 1



tilt mean

tele: full control, center, PAAM: full control, center
Iteration: 1

tele: full control, wavefront, PAAM: full control, wavefront
Iteration: 1



My work

Find a/the best way to point

- Different strategies:
 - ‘Center’
 - ‘Wavefront’
- Different methods:
 - ‘No control’
 - ‘Full control’
 - ‘Step and stare’ (SS)



My work - Goal

- Good and fast simulation and calculations
- Reliable

- Optimized pointing
 - How to control the PAAM
 - How to control the telescope

- Add additional inplane PAAM?



Sources

- <http://www.astronomy.com/news/2018/11/looking-ahead-to-the-lisa-gravitational-wave-detector>
- https://www.researchgate.net/figure/Realization-of-the-Point-Ahead-Angle-Mechanism-The-mirror-is-glued-to-a-monolithical_fig4_321192271