

Application of adaptive optics in Space Debris tracking

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Australian Government
Department of Industry and Science

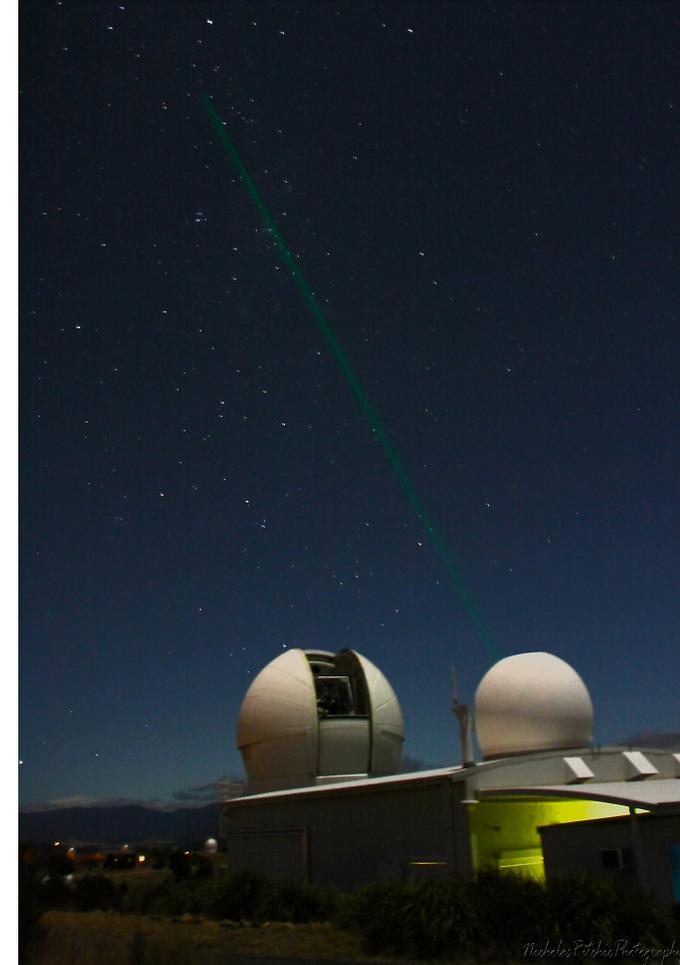
Business
Cooperative Research
Centres Programme

Satellite Tracking



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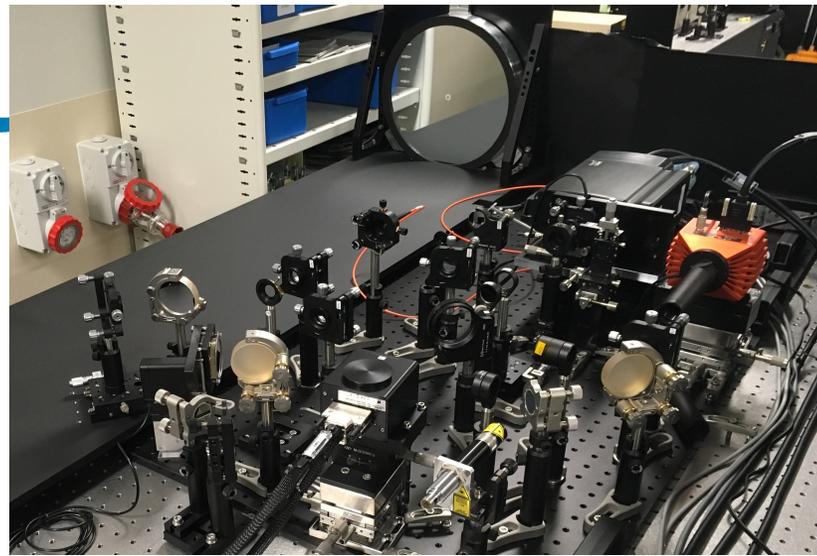
- Mount Stromlo home to EOS Space Systems laser ranging facility
- 1m for satellite laser ranging
- 1.8 m with high power laser for debris ranging
- RSAA is collaborating with EOS to develop AO enhanced debris ranging and satellite imaging systems



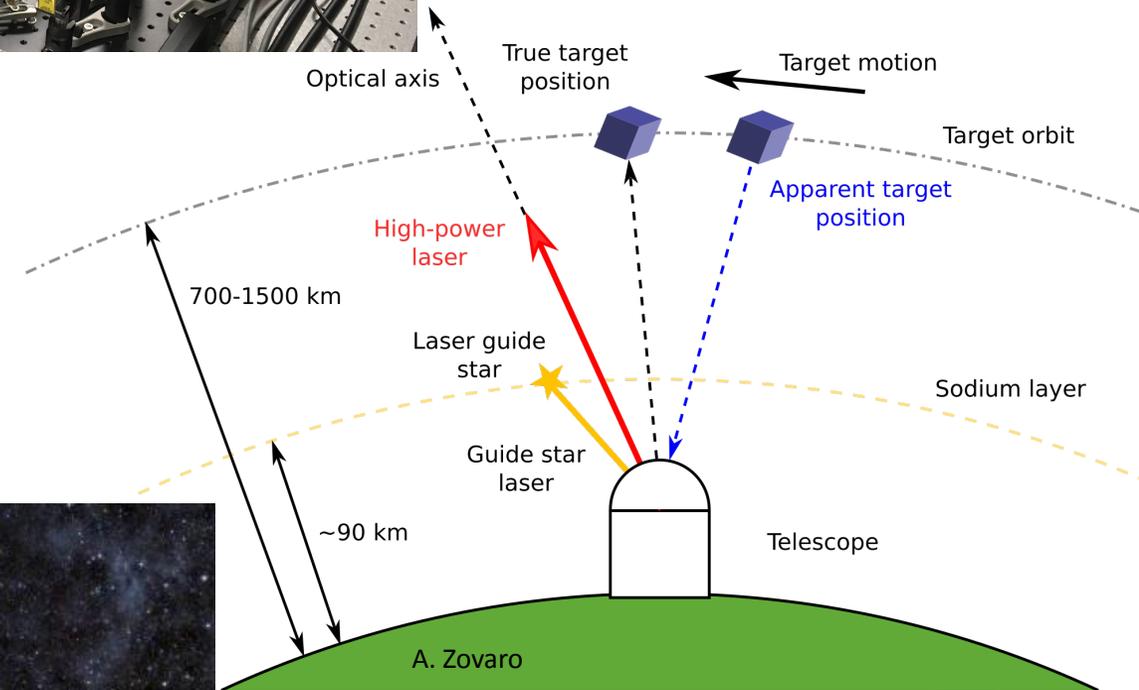
RSAA AO research



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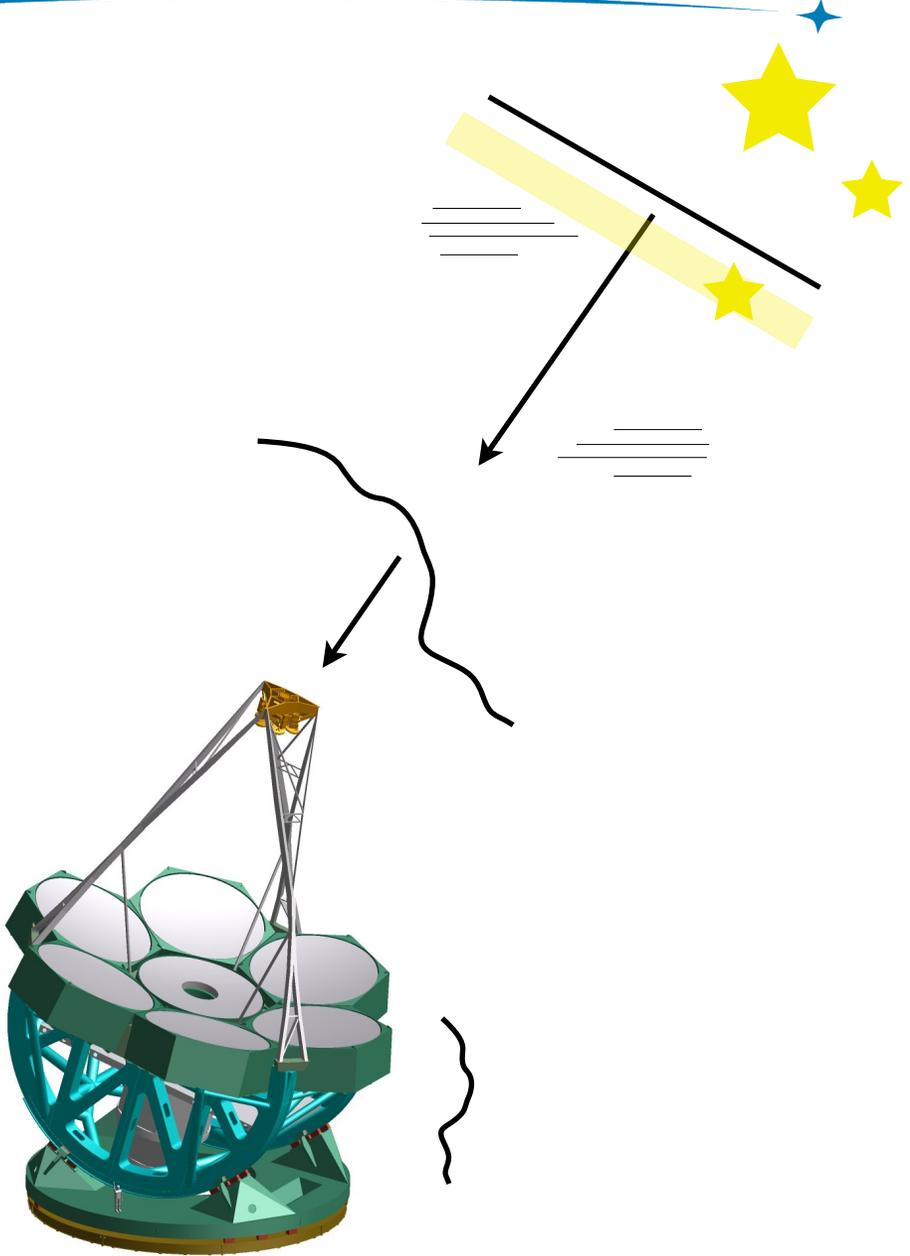
- 2016 deliverables:
 - AO for satellite imaging on 1 m telescope
 - Upgrade to Gemini south AO system
- SERC AO for satellite imaging:
 - Satellite imaging in LEO
 - GEO debris tracking
- SERC AO for remote manoeuvre:
 - 10 kW CW laser
 - Photon pressure to nudge object in orbit
- Other AO research
 - AO for laser communications
 - Compact AO systems
 - AO for GMT & first light instrument
 - Site atmospheric measurement
 - Detector characterisation



Adaptive Optics



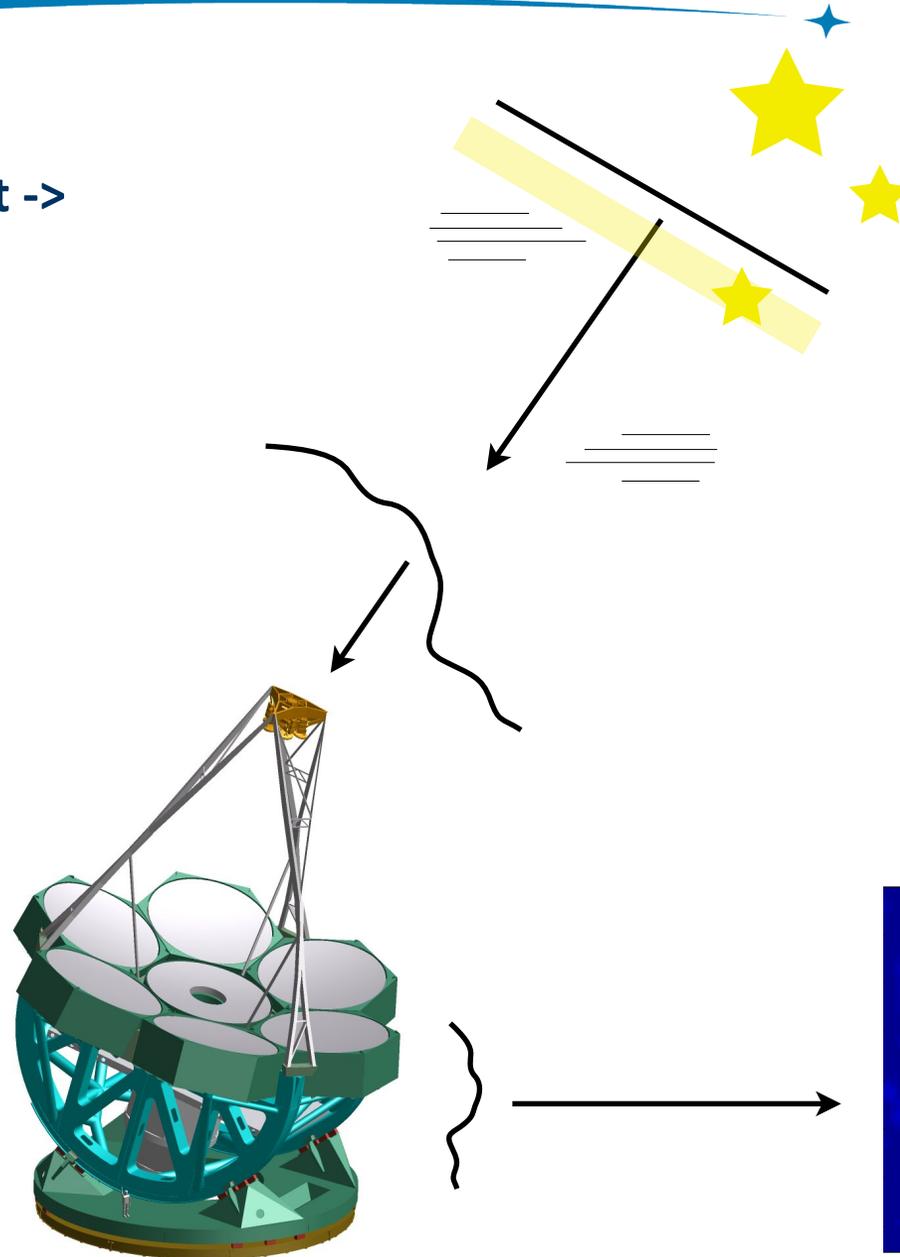
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Adaptive Optics



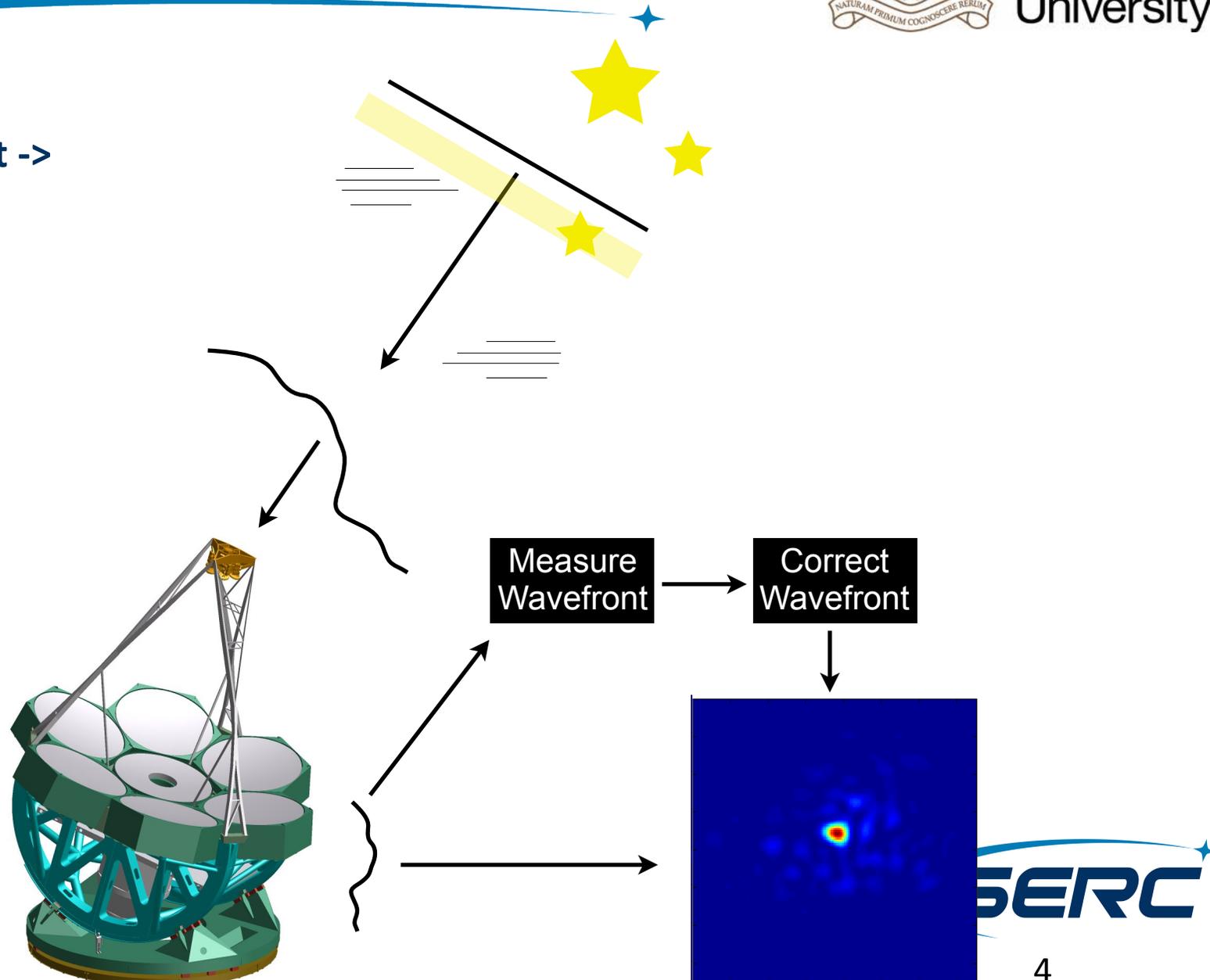
- Turbulent atmosphere distorts wavefront -> distorted image



Adaptive Optics



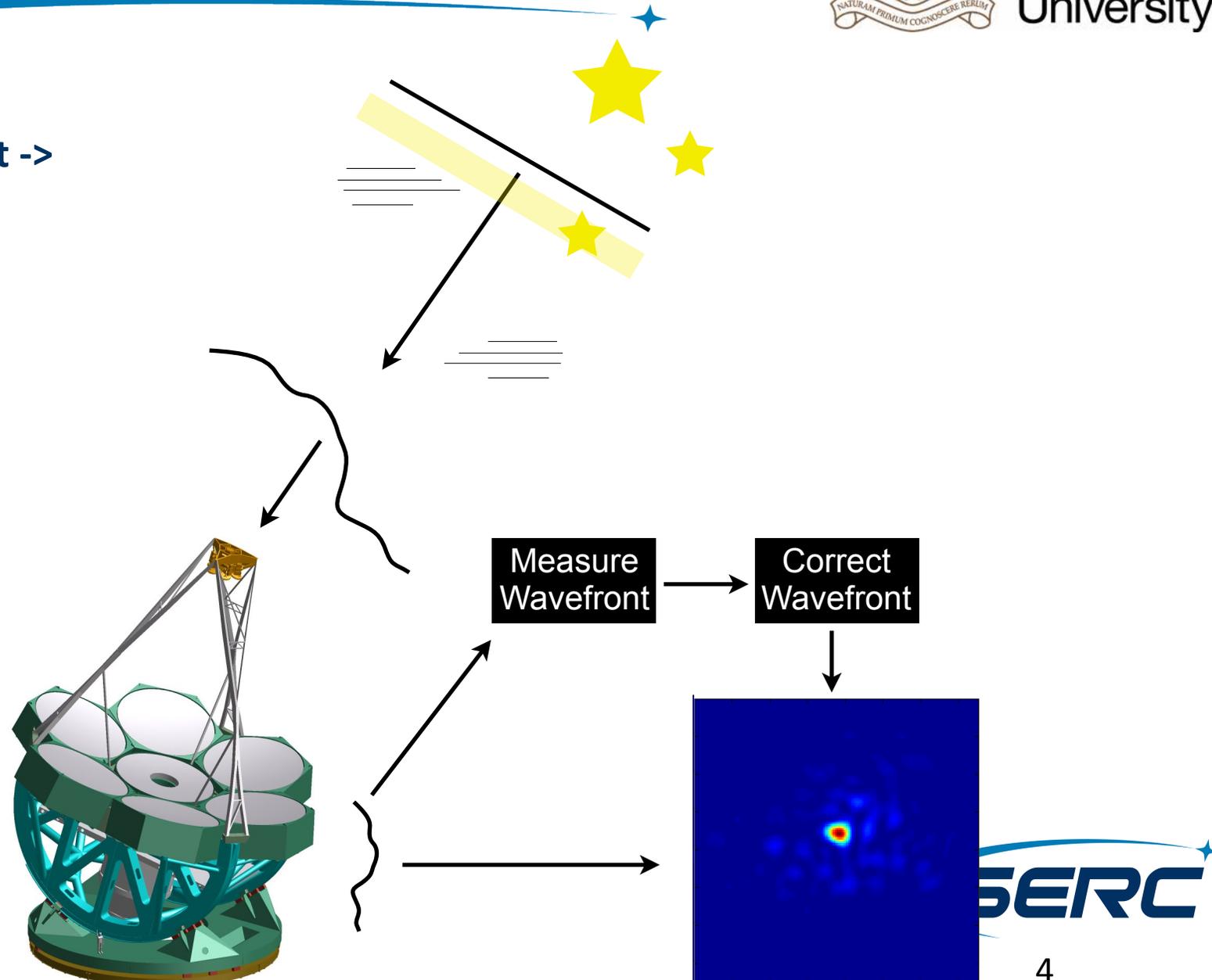
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- Adaptive optics measures and corrects wavefront distortions



Adaptive Optics

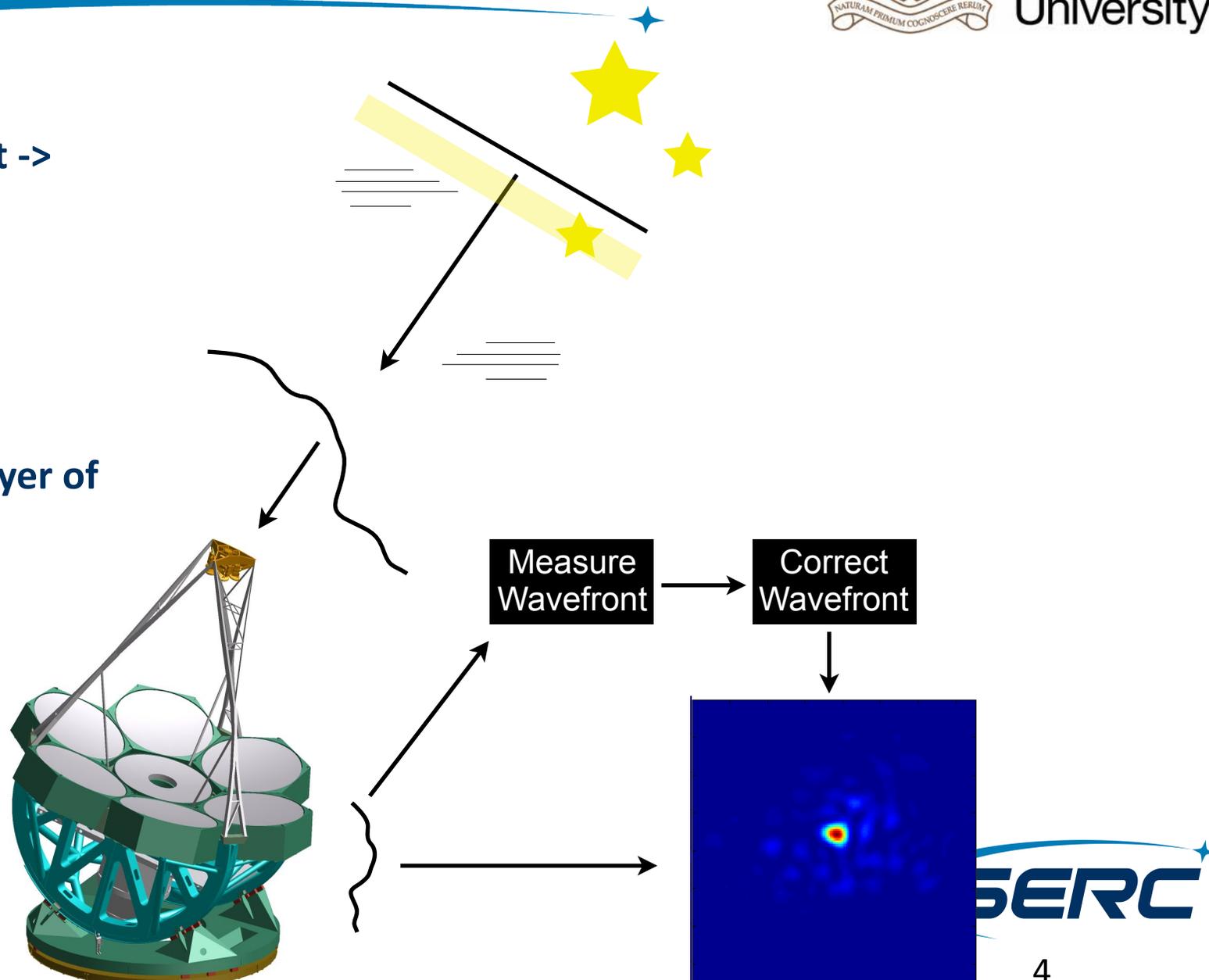


- Turbulent atmosphere distorts wavefront -> distorted image
- Adaptive optics measures and corrects wavefront distortions
- Requires a bright guide star to measure wavefront



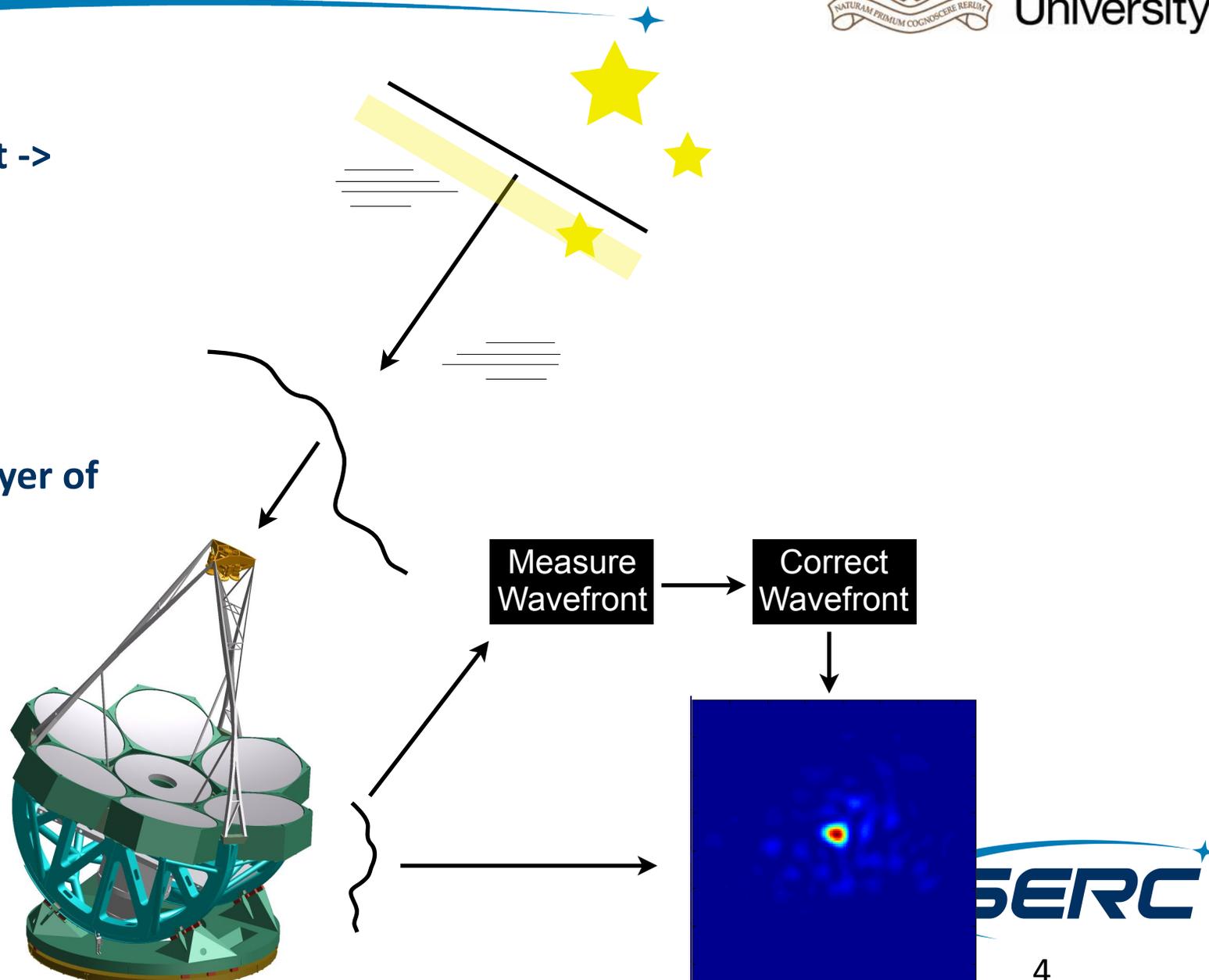
Adaptive Optics

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- Adaptive optics measures and corrects wavefront distortions
- Requires a bright guide star to measure wavefront
- Artificial guide star: illuminate Sodium layer of atmosphere (~90 km altitude)

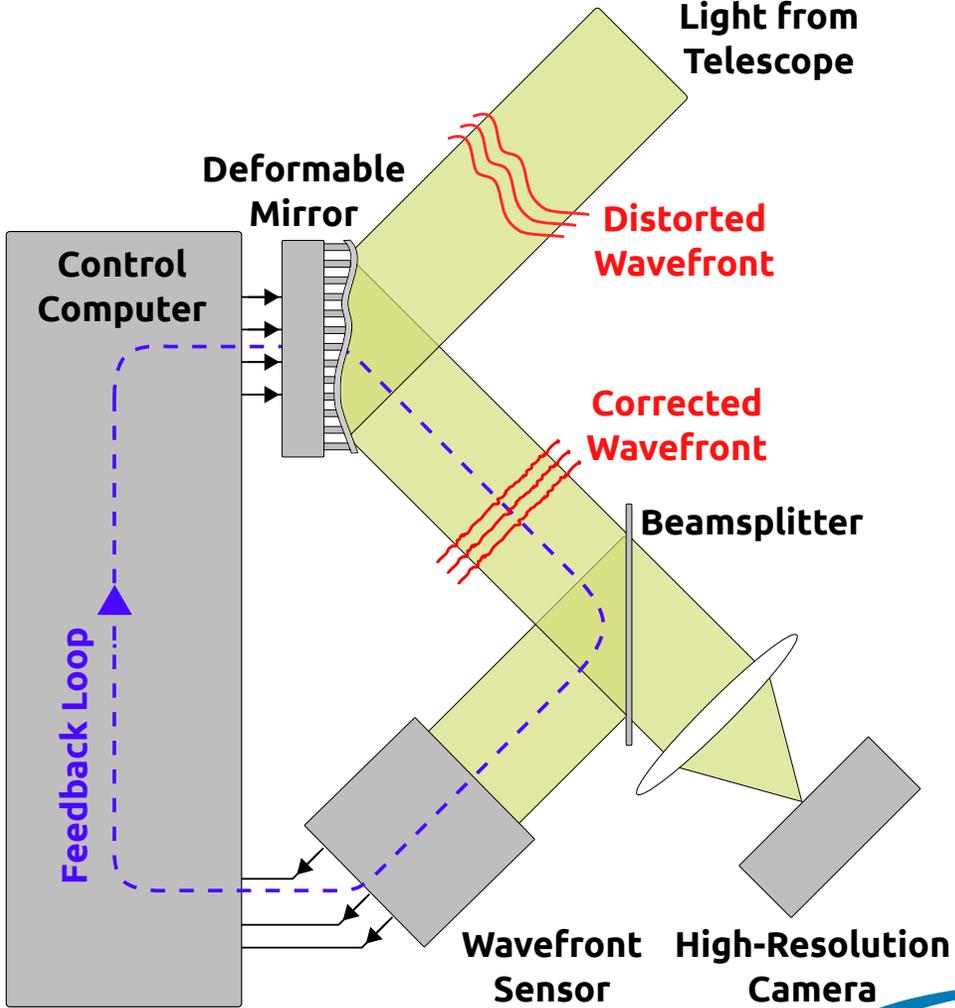


Adaptive Optics

- Turbulent atmosphere distorts wavefront -> distorted image
- Adaptive optics measures and corrects wavefront distortions
- Requires a bright guide star to measure wavefront
- Artificial guide star: illuminate Sodium layer of atmosphere (~90 km altitude)
- AO correction only applies very close to guide star



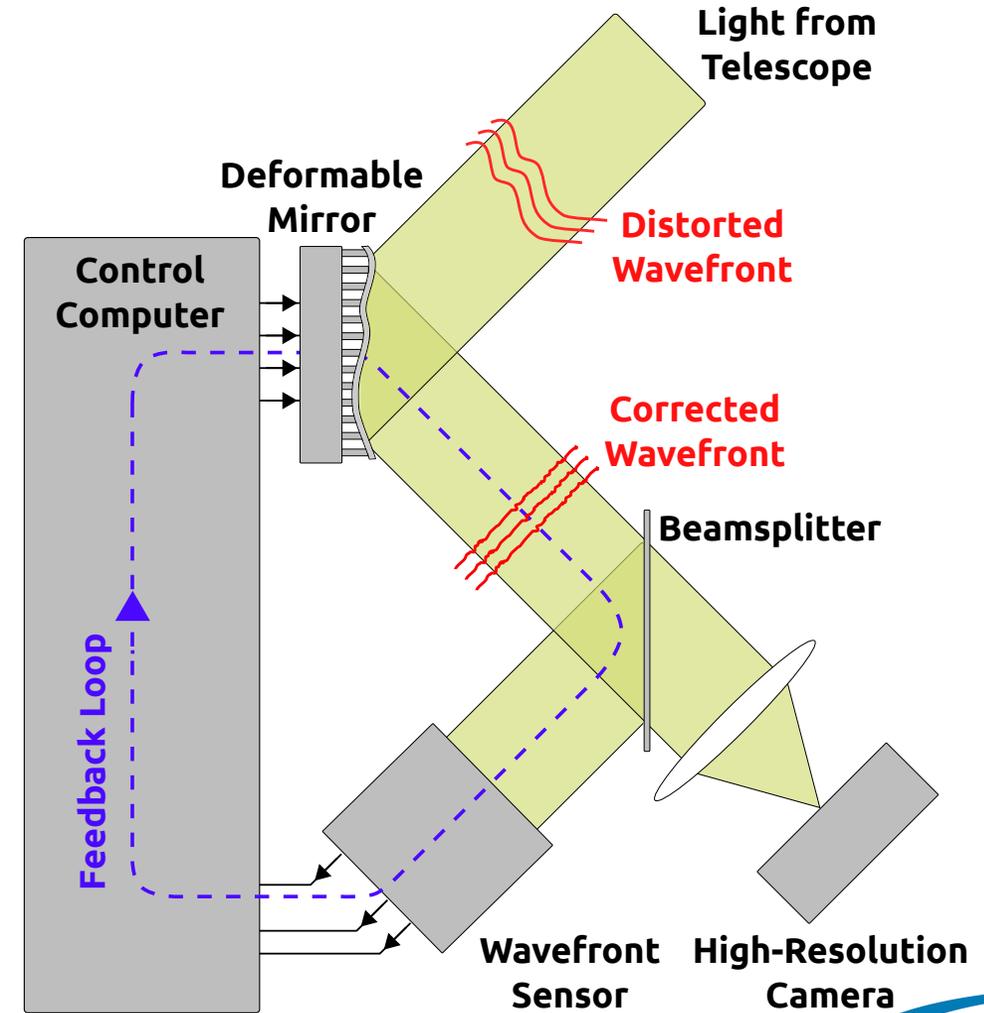
Adaptive Optics: Control system



Adaptive Optics: Control system



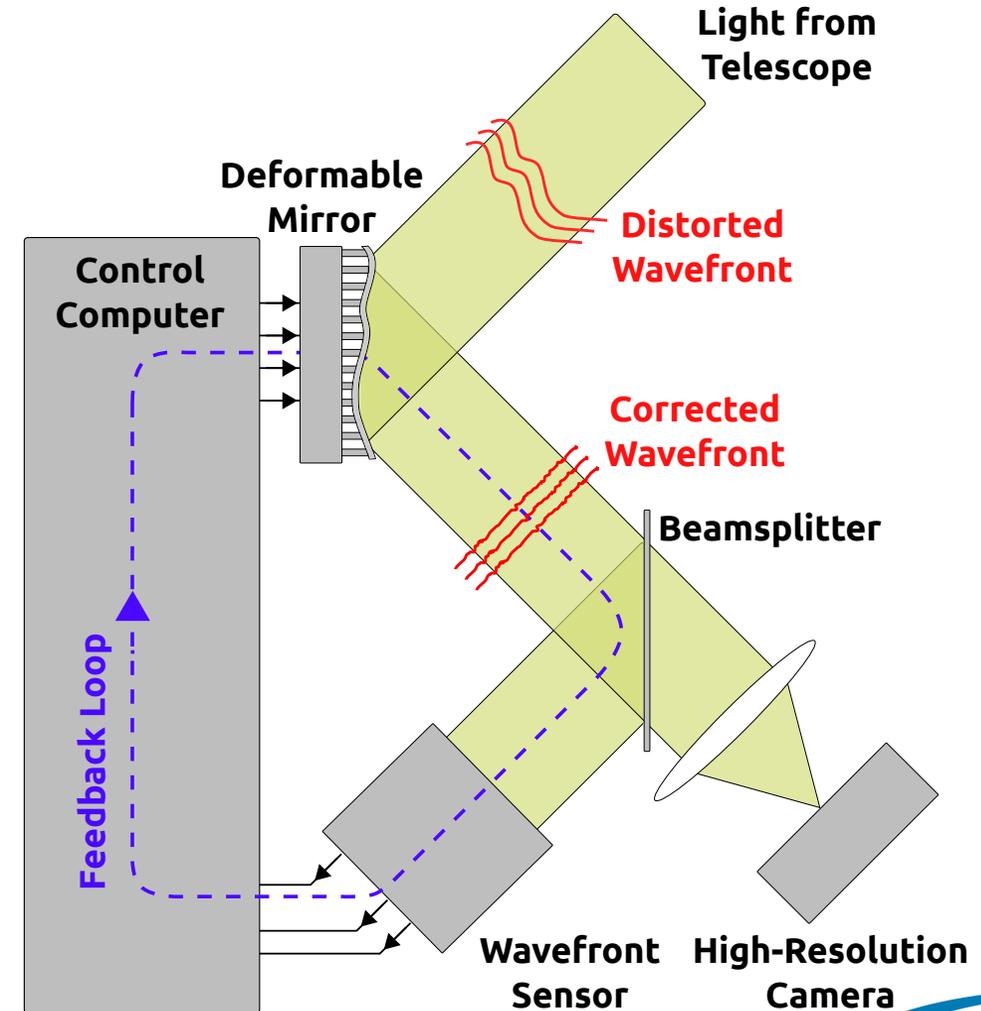
- Deformable mirror
 - Reflective face sheet deformed
 - Corrects wavefront



Adaptive Optics: Control system



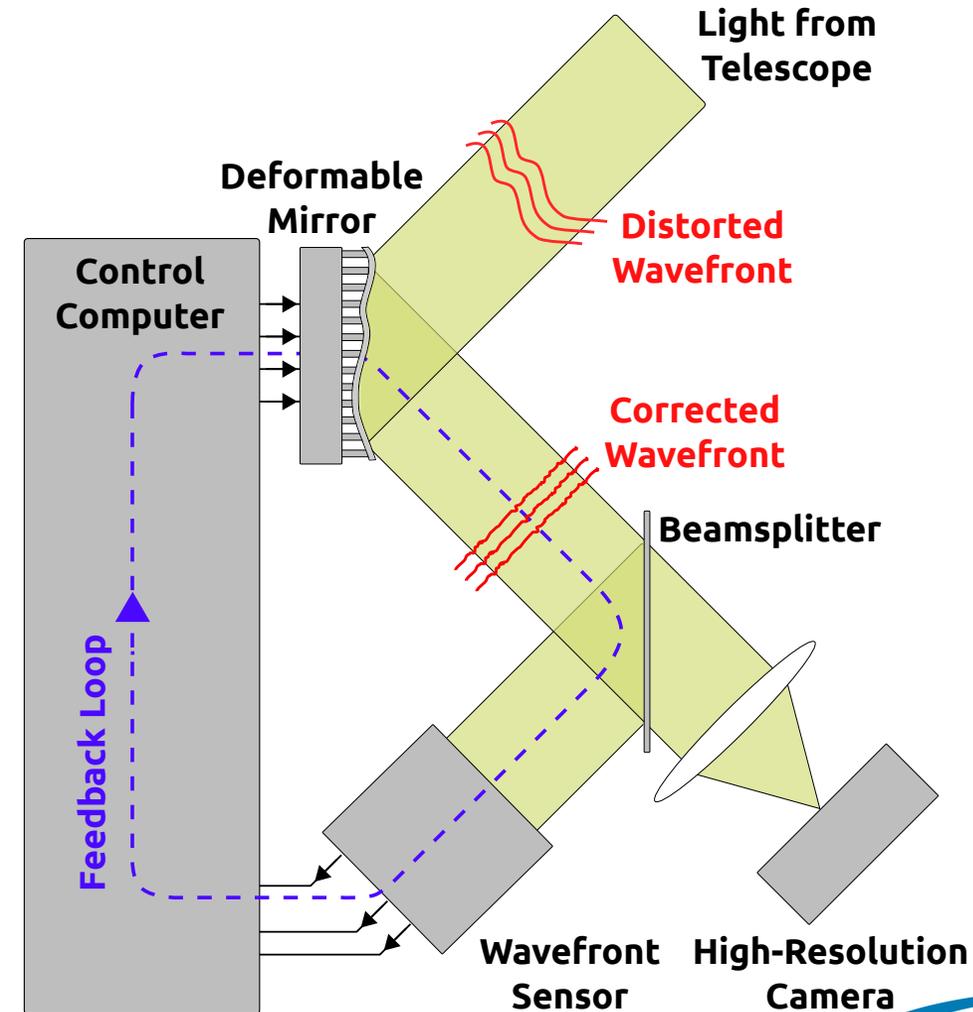
- Deformable mirror
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- Wavefront sensor
 - Measures turbulent wavefront
 - Needs a guide star
 - Shack-Hartmann, pyramid, shearing interferometer, focal plane...



Adaptive Optics: Control system



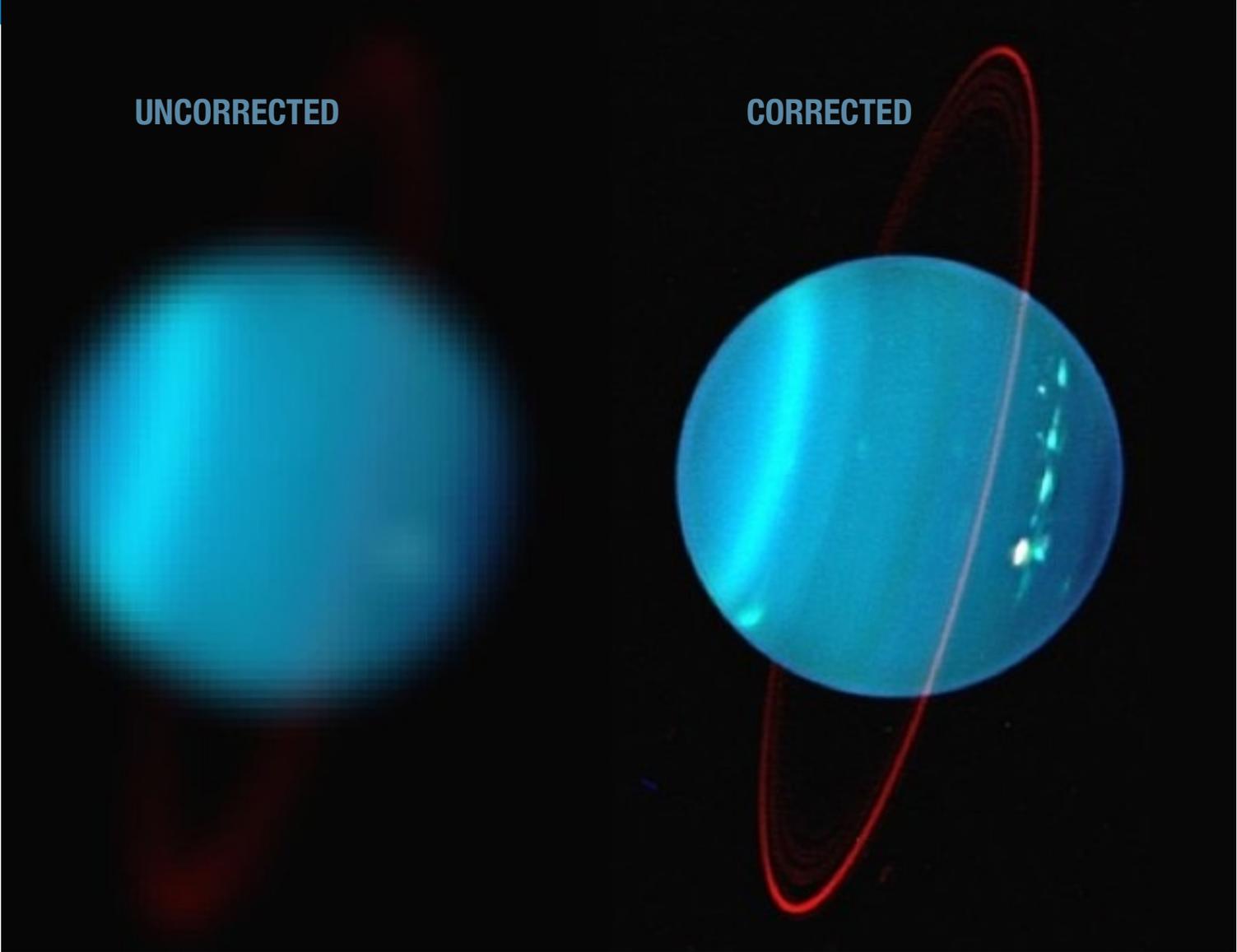
- Deformable mirror
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 - Measures turbulent wavefront
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- Control system deforms mirror to compensate
 - Corrected wavefront measured again
 - -> Closed loop AO system



Adaptive Optics: Astronomy



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URANUS
∅ 4"
KECK II
NEAR IR

Credit Keck Observatory

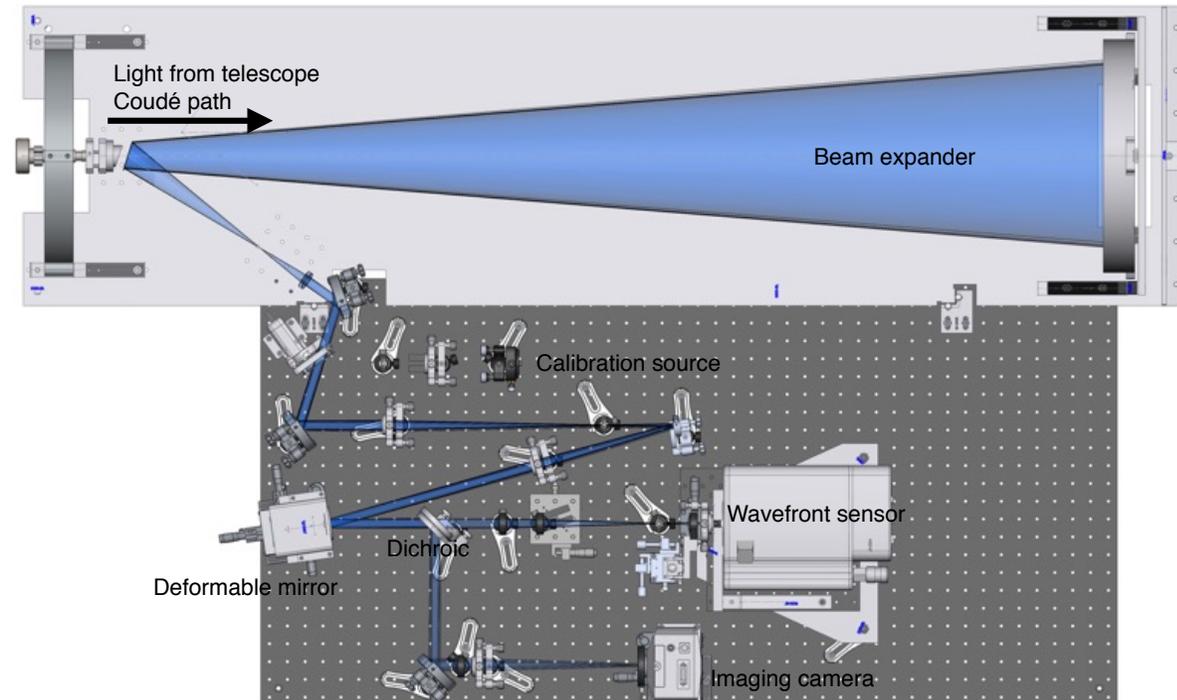
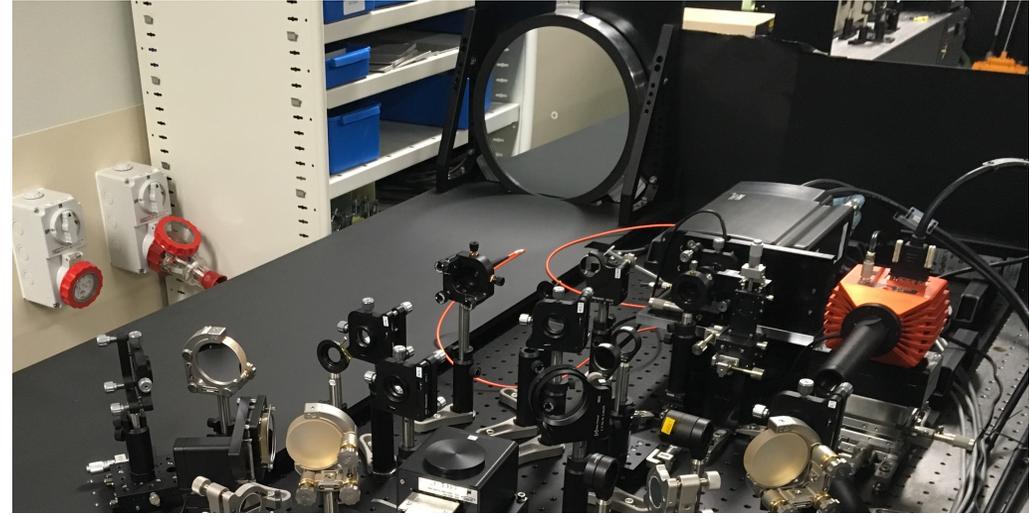


KASI AO



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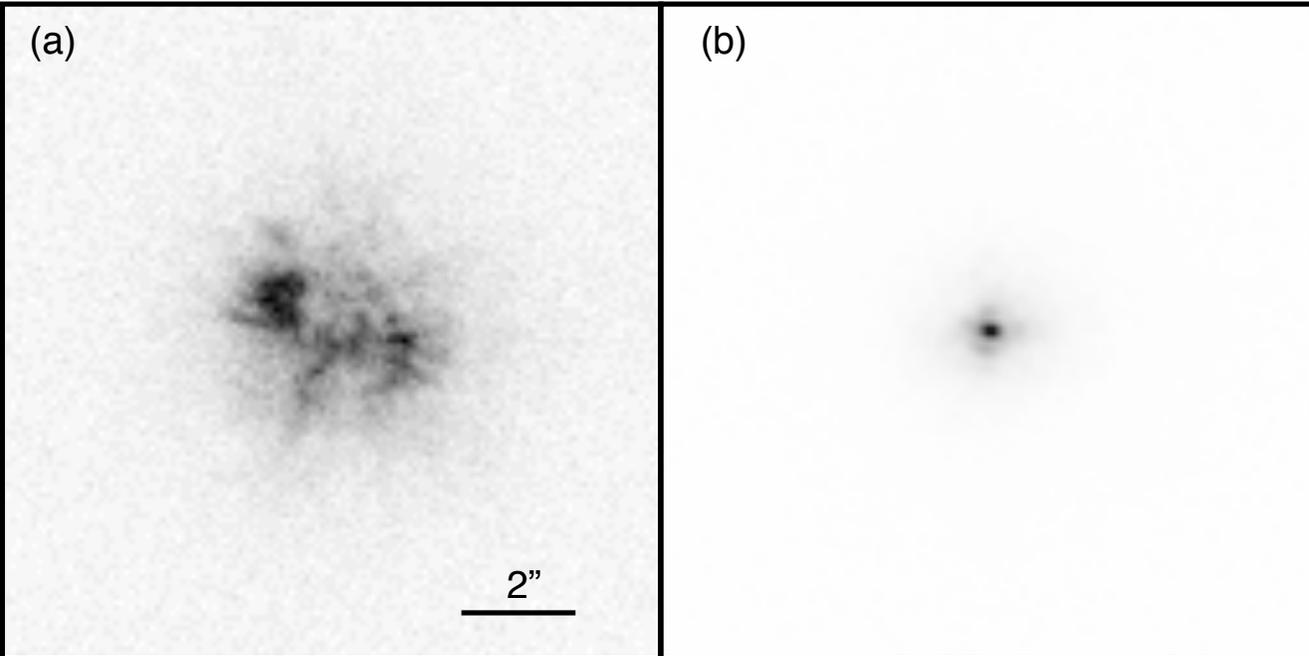
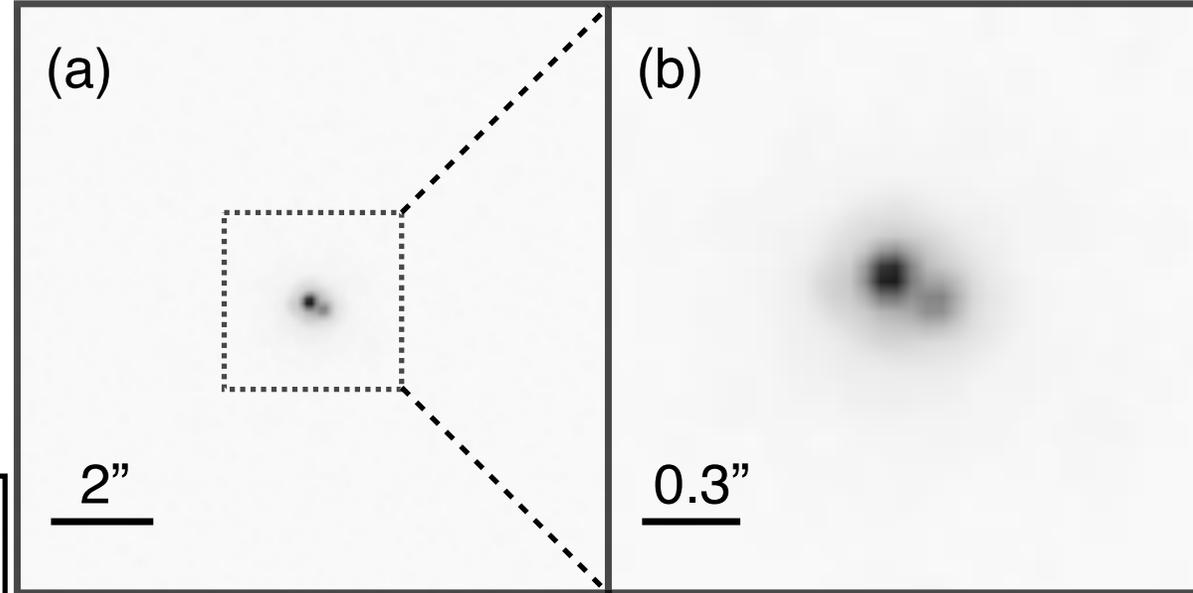
- AO system for 1 m telescope
- Korean Astronomy and Space Institute (KASI)
- Designed to image satellites in orbit
- Resolution of 0.18 arcsec (~ 90 cm @ 1000 km)
- Shack-Hartmann wavefront sensor 450-800 nm
- Imaging camera 800-900 nm
- AO loop runs at up to 2 kHz
- Imaging camera captures images at up to 60 Hz
- Image rotation and tip-tilt removed in post processing

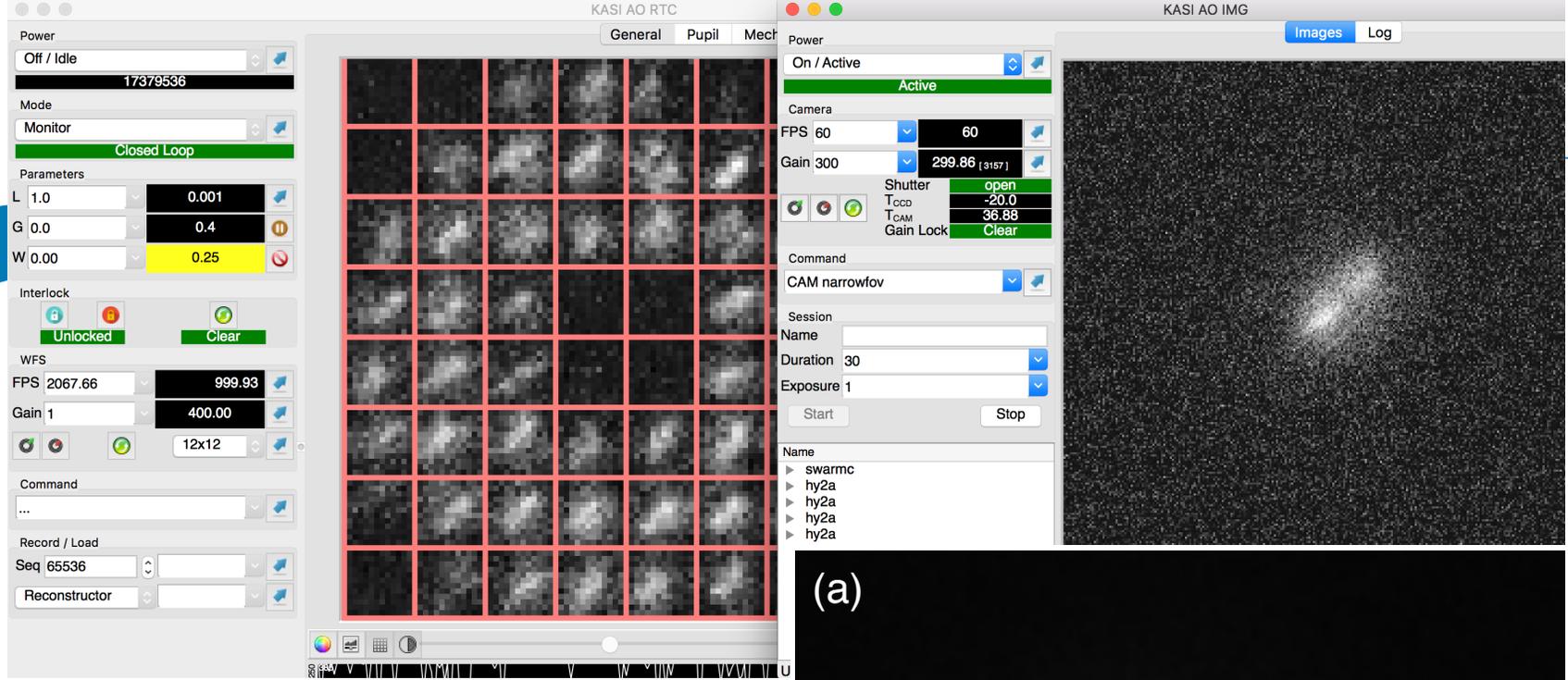


First on-sky results: stars

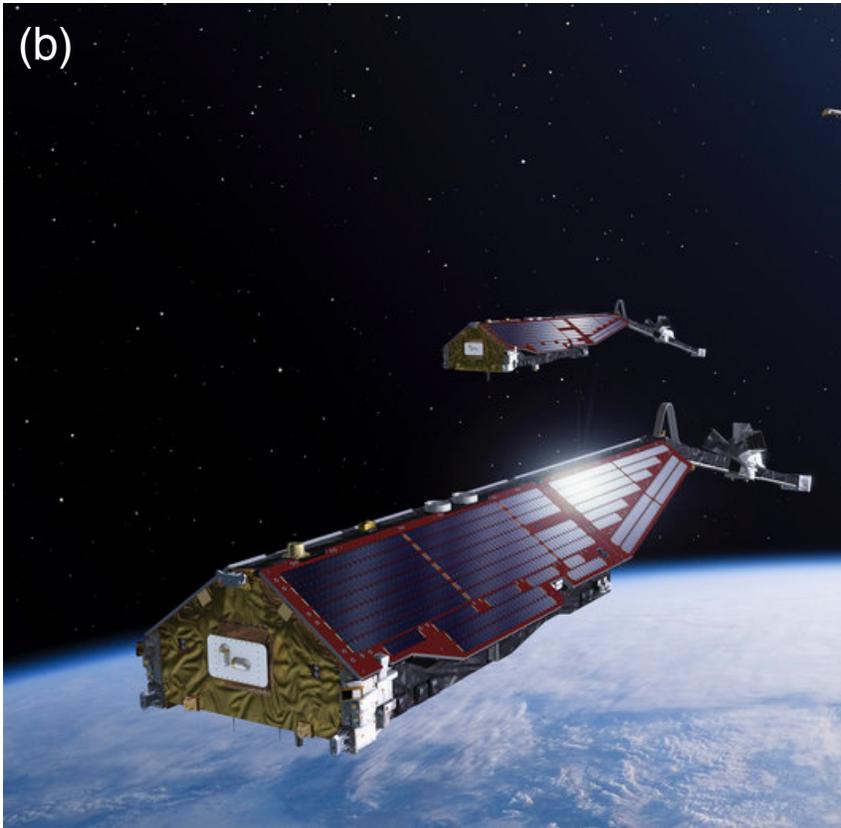
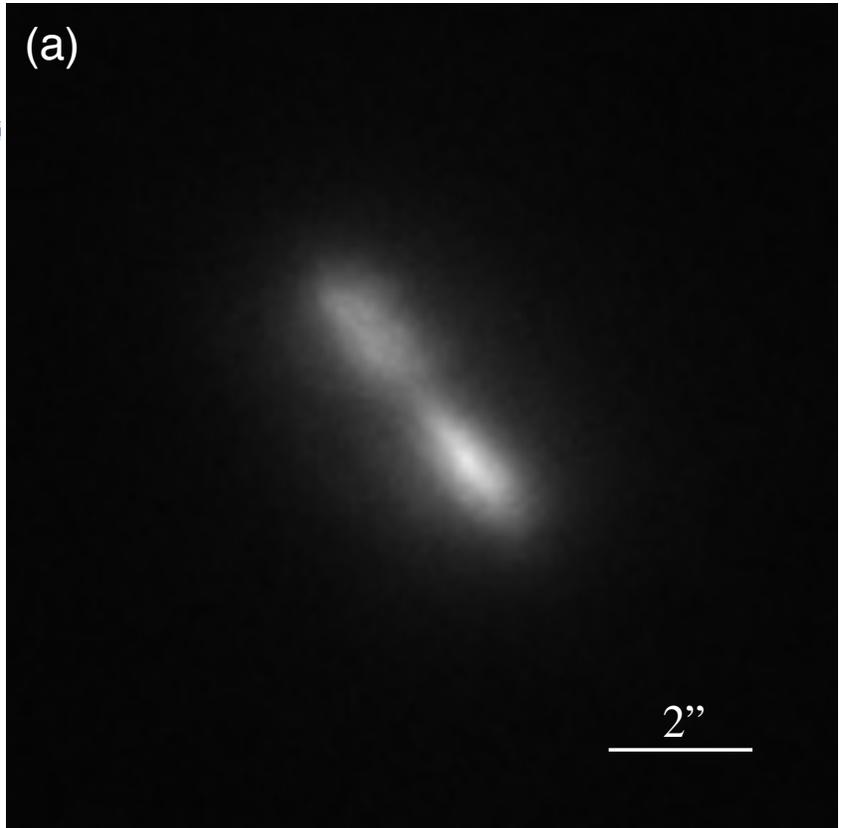


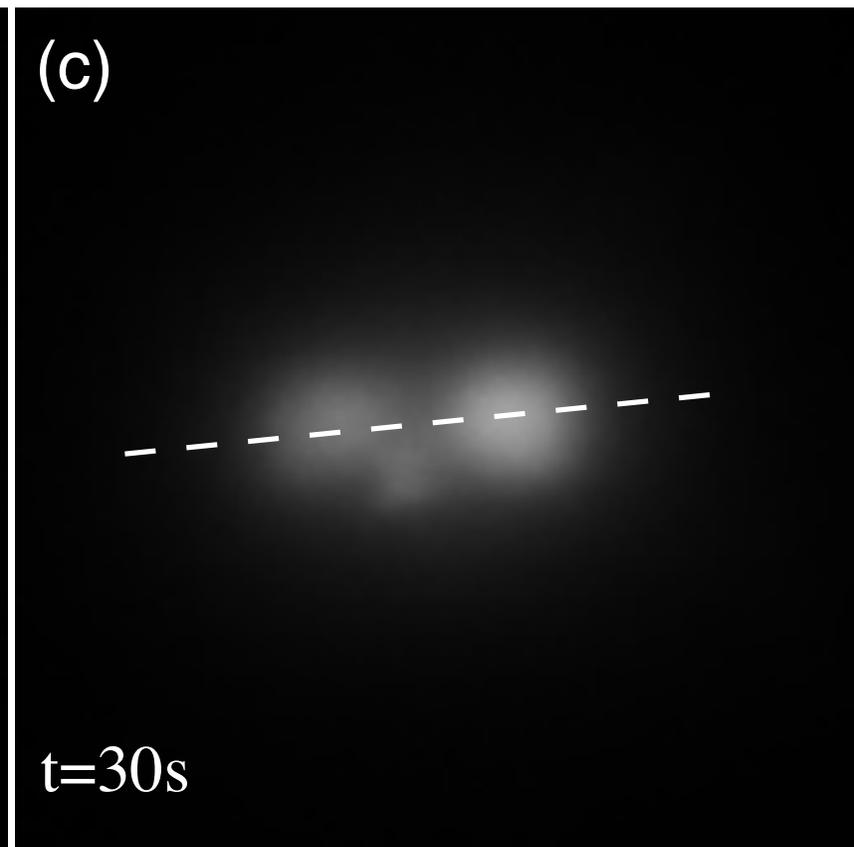
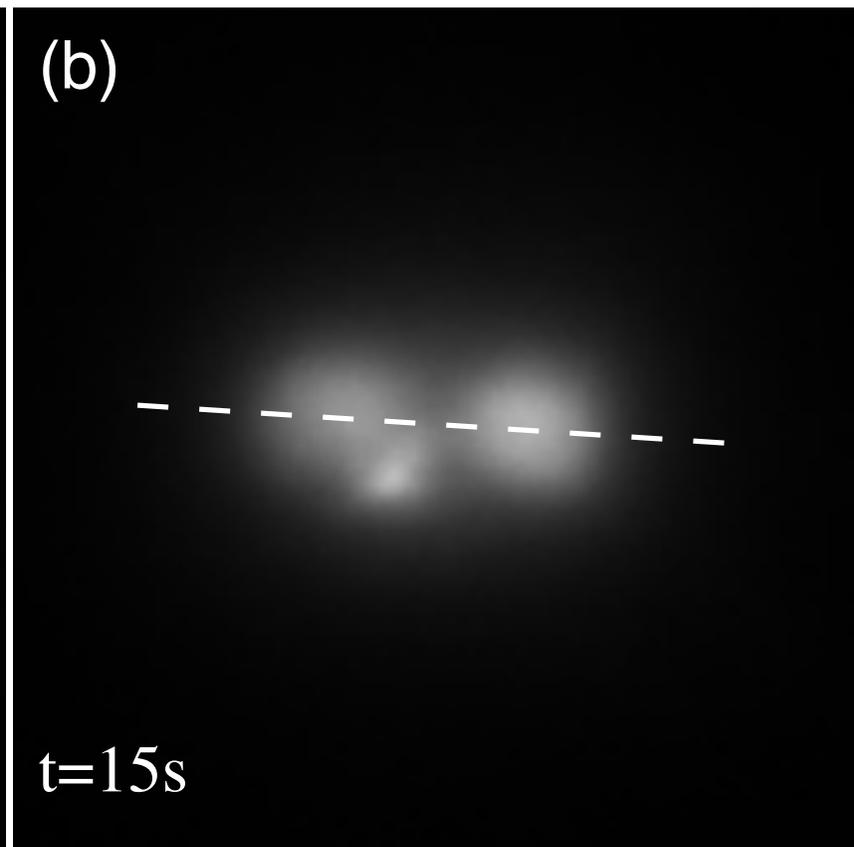
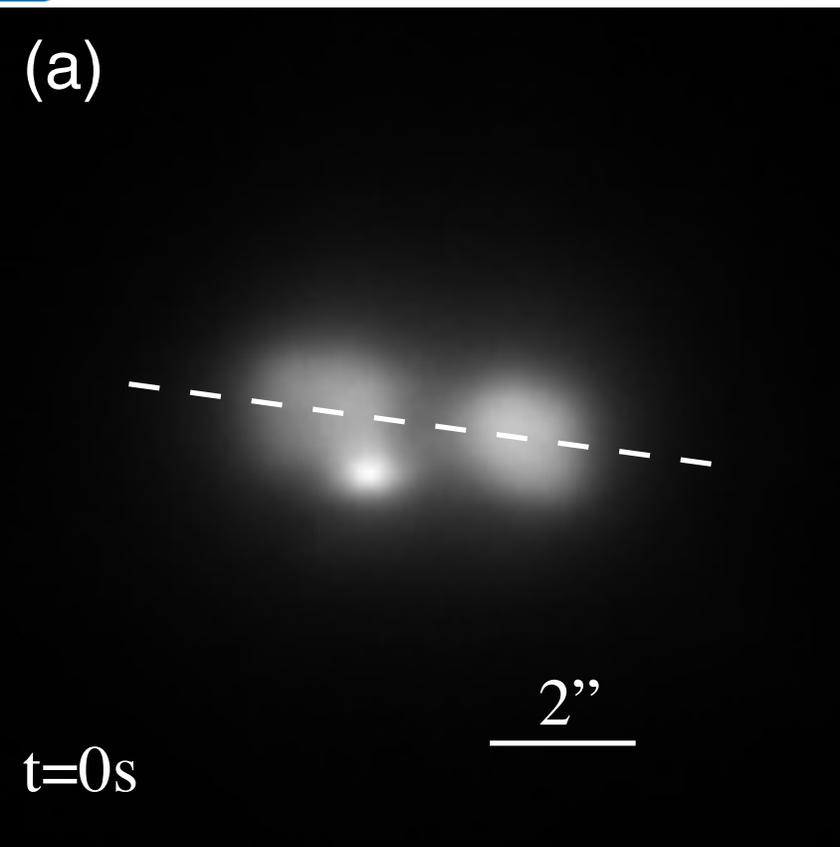
- Good correction on bright objects
 - first Airy ring visible
- Resolved double star with separation of $\sim 0.3''$
- Resolved several large satellites





Swarm -C
FWHM size 1.2 x 9 m





Resurs-DK1

Current development: AO Systems for SSA



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- AO for satellite imaging
 - Updated system design
 - 1.8 m telescope gives ~2x resolution
 - Ability to operate in natural or laser guide star modes
 - Resolve features of 50 cm @ 1000 km

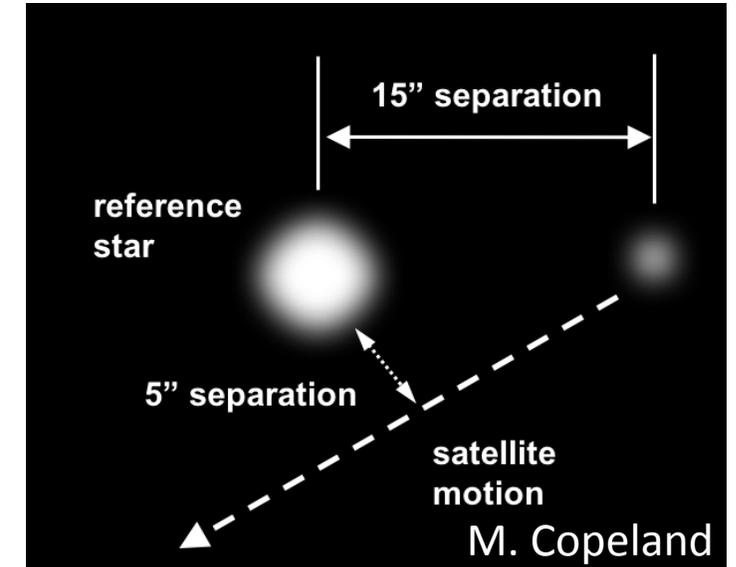


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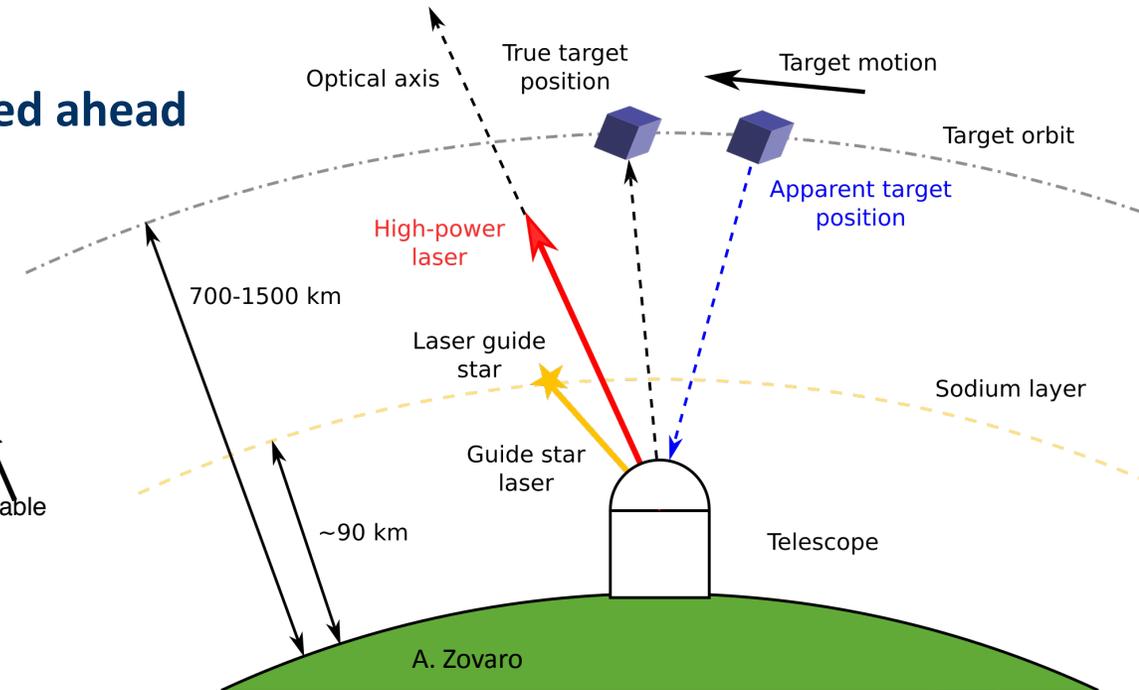
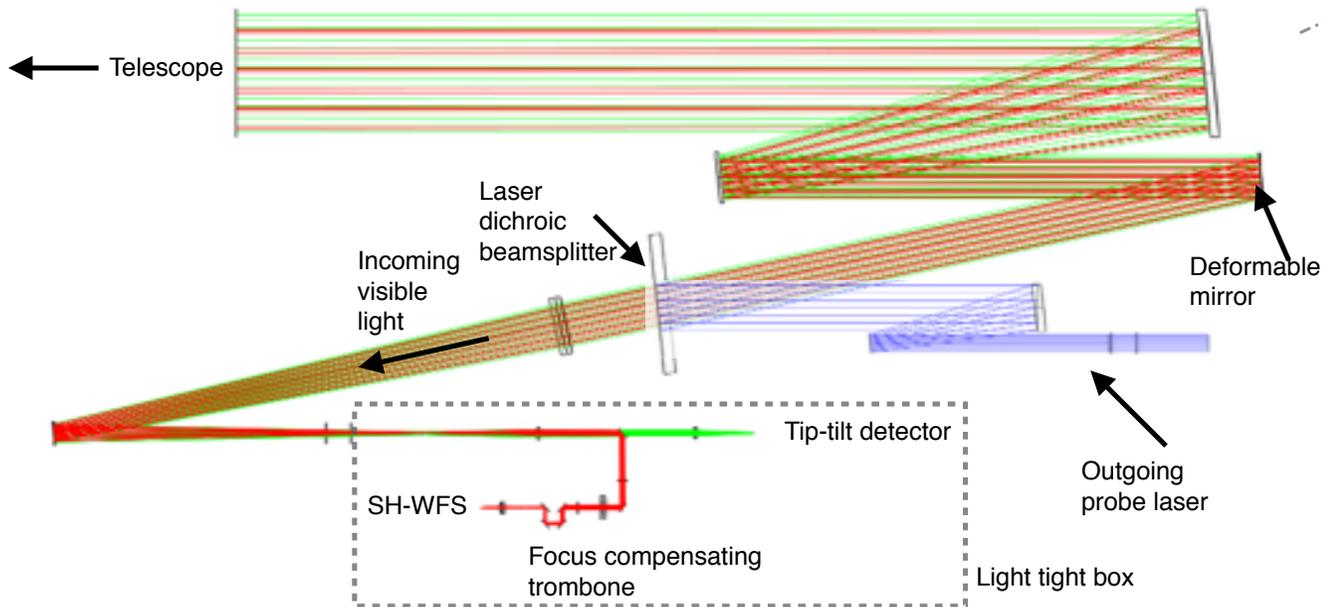
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 - Resolve features of 50 cm @ 1000 km
- GEO tracking
 - Unique method of using Gaia astrometric catalogue with AO
 - AO reduces size of star and object, and stabilises differential image motion
 - Positional measurement accuracy of <math>< 2\text{ m}</math> @ GEO for magnitude 15 object (approx. 1 m^2)



Adaptive Optics for Laser Ranging & Photon pressure

- Use a higher power laser to track uncooperative targets
- Adaptive optics corrects atmospheric turbulence to reduce the beam size on sky
- AO provides higher photon density required to track smaller uncooperative targets
- System requires laser guide star - which also needs to be pointed ahead
- 10's kW CW laser for remote manoeuvre



Conclusion



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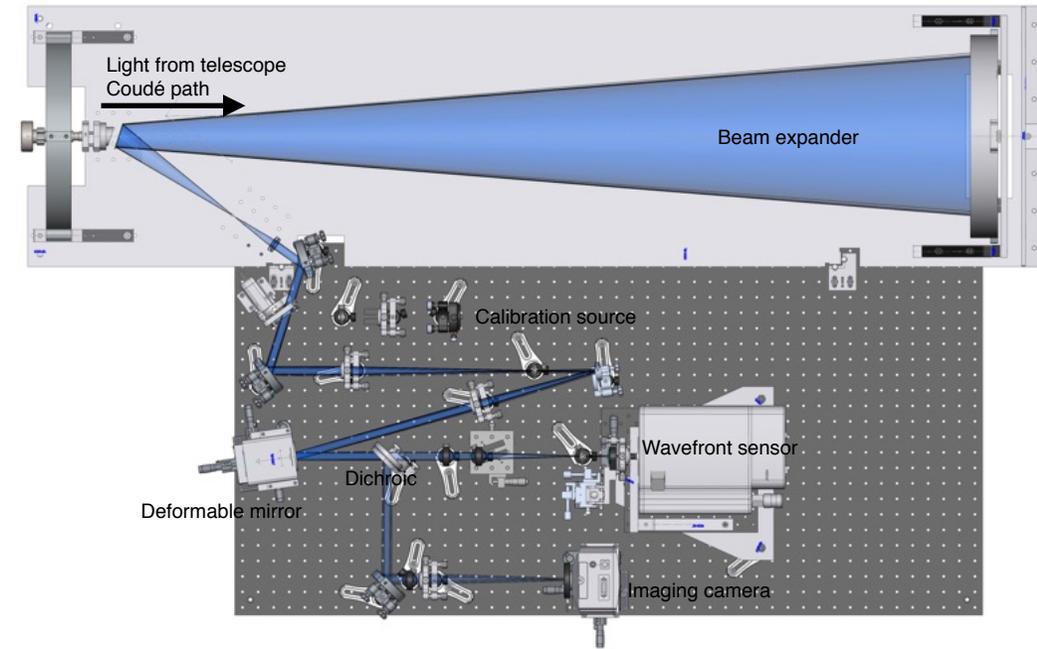


Conclusion



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- ANU developing AO systems for SSA, including laser ranging

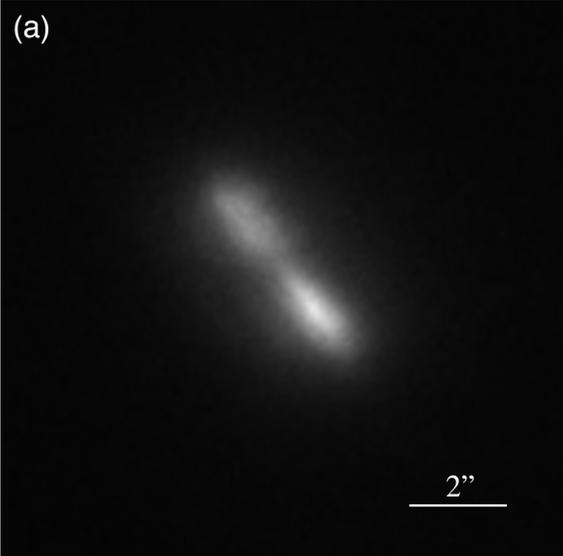
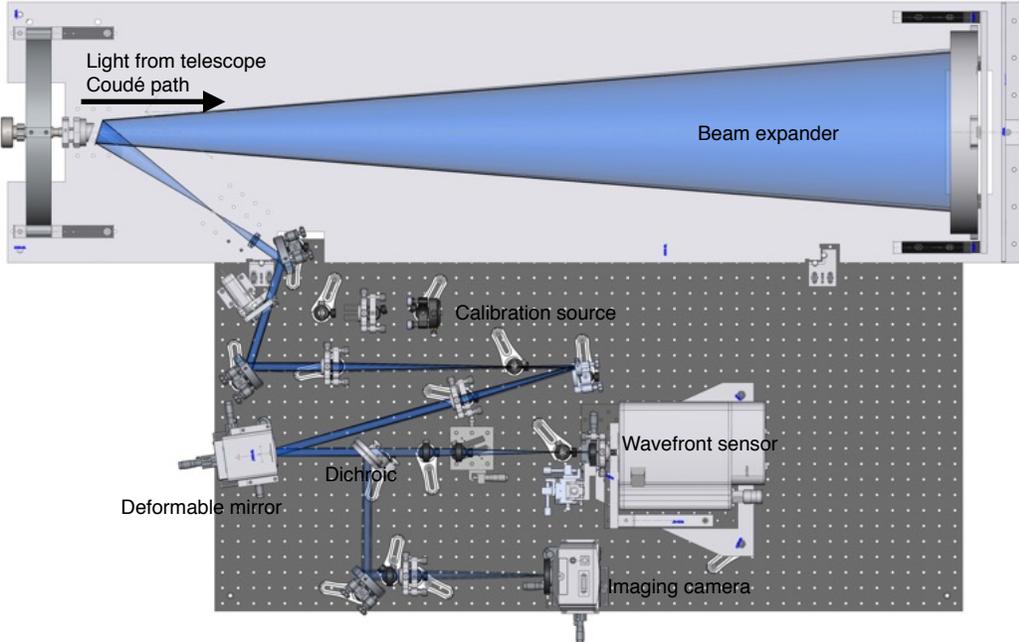


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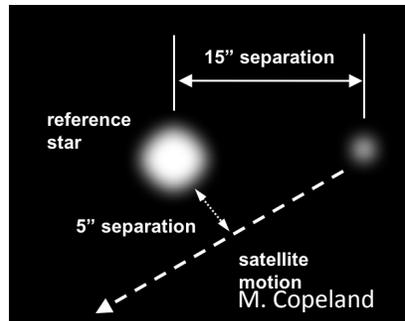
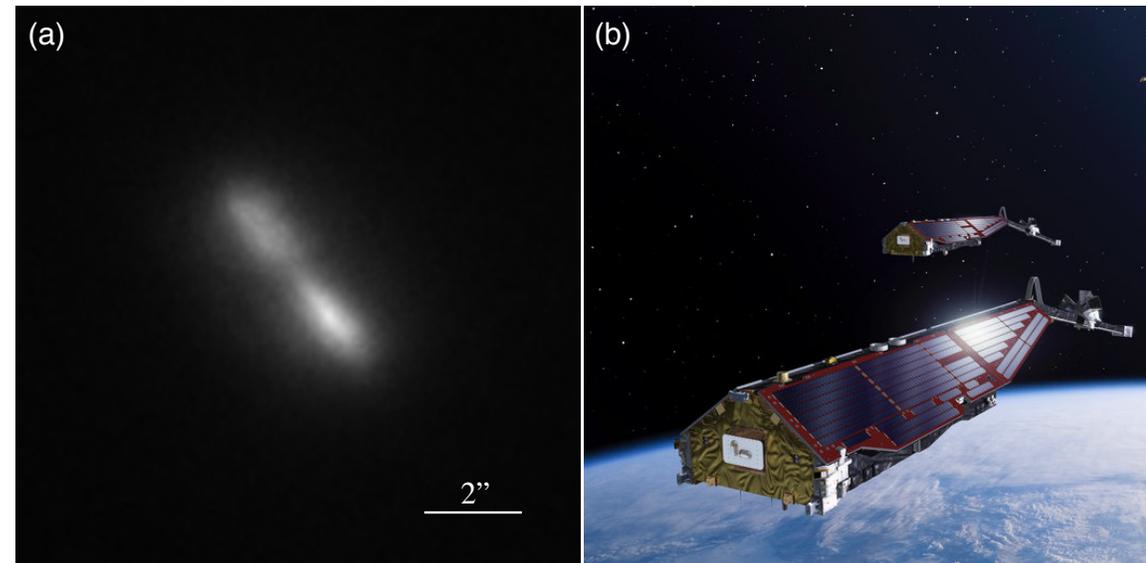
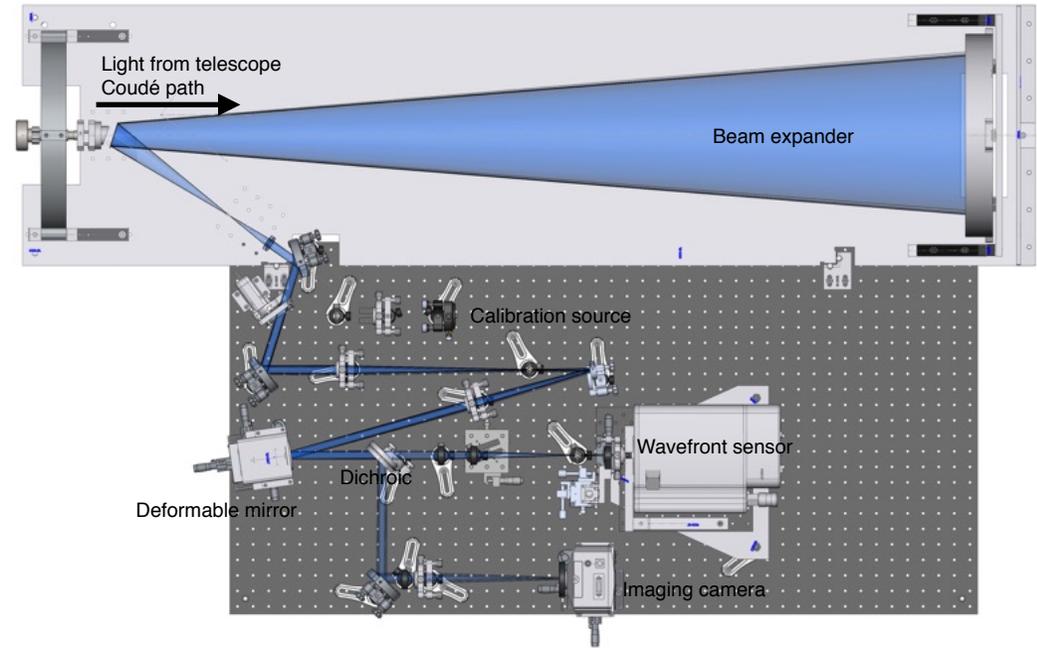
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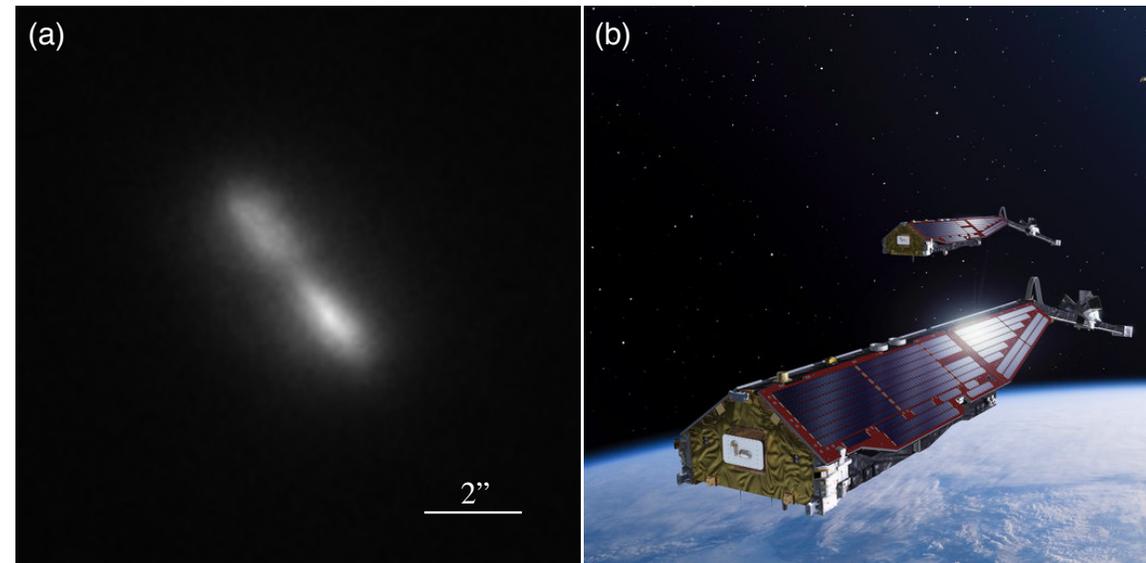
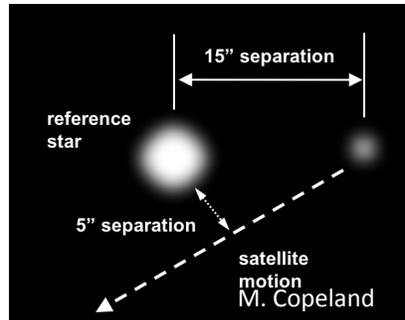
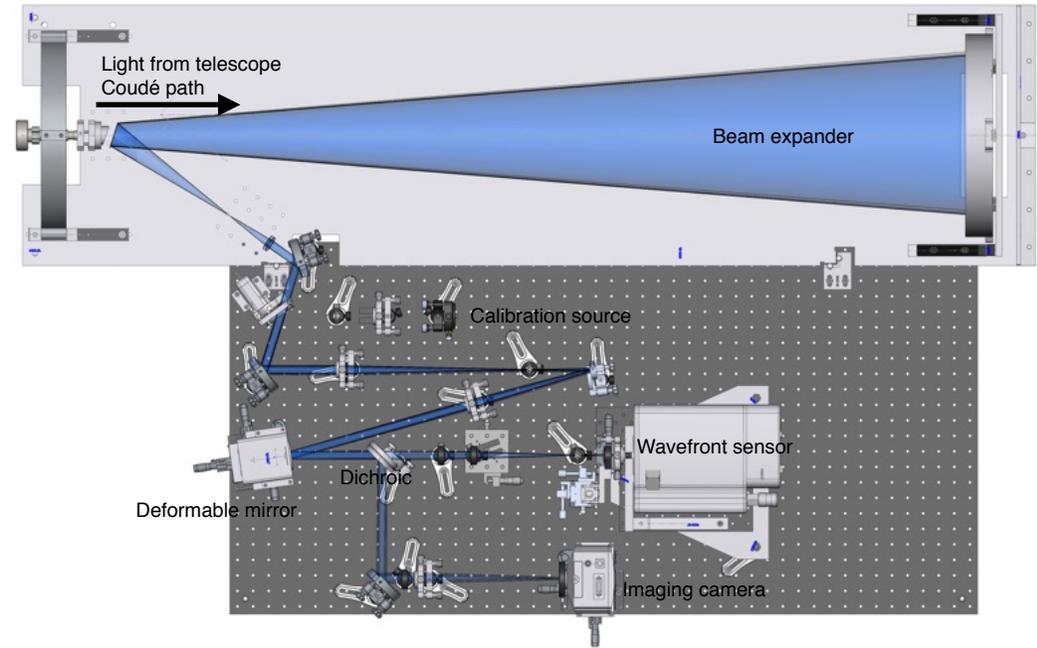
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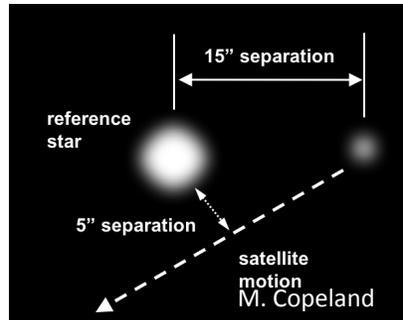
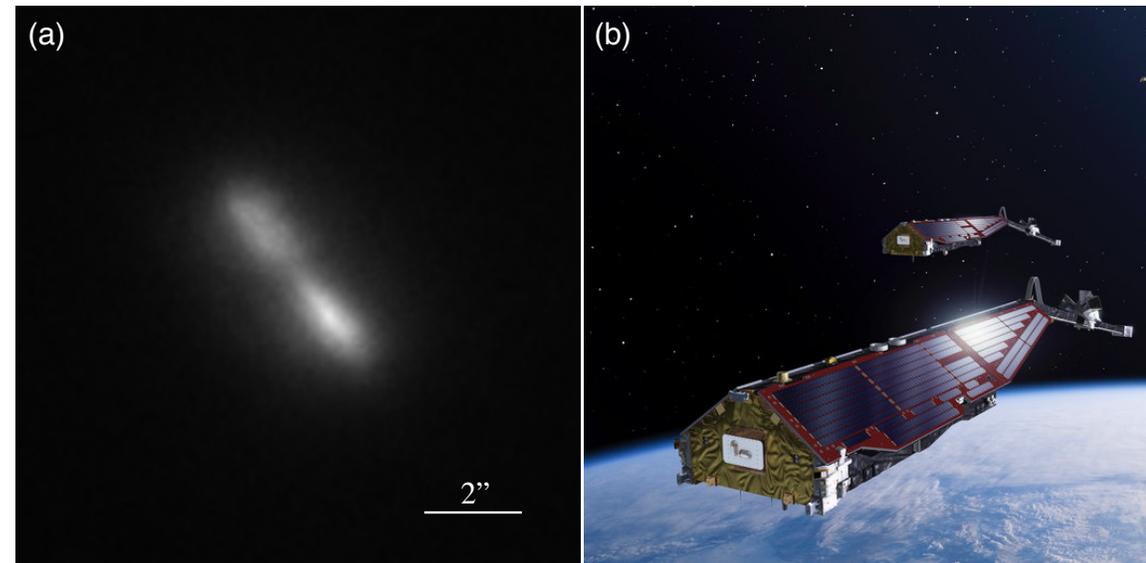
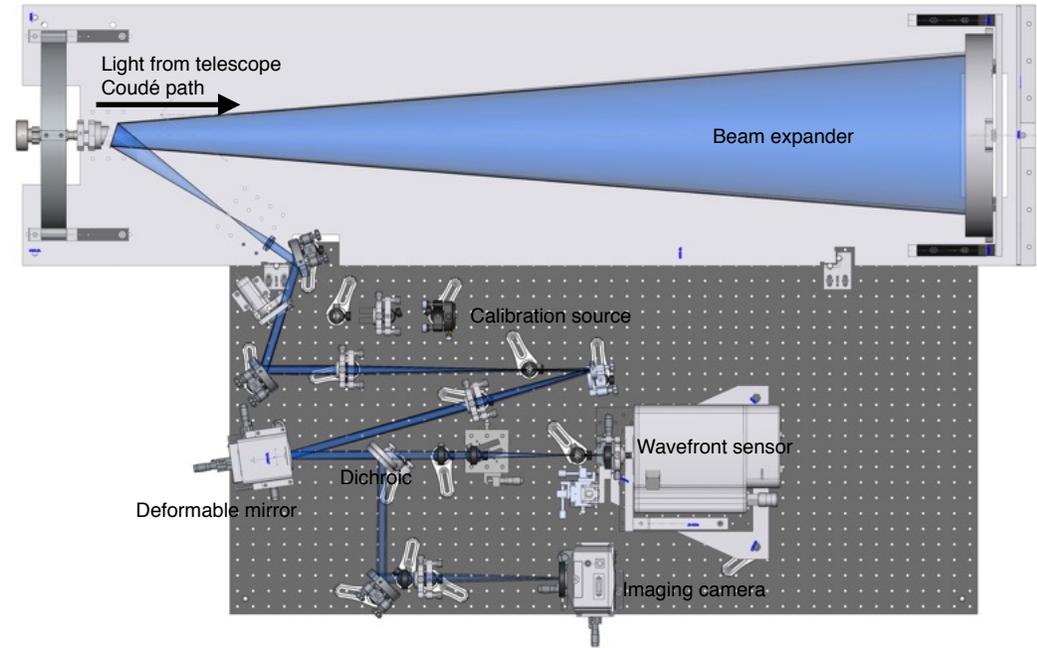
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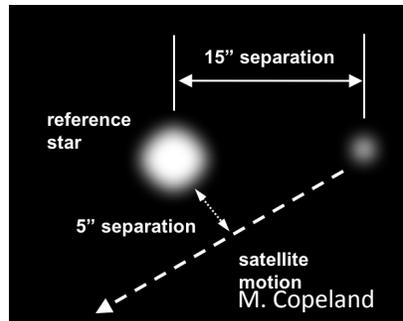
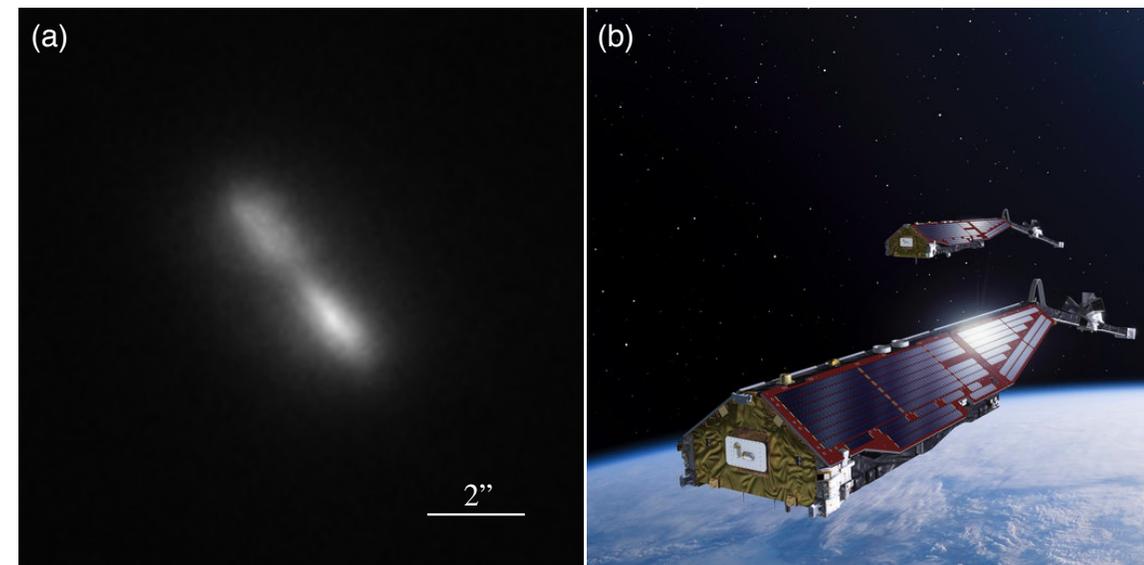
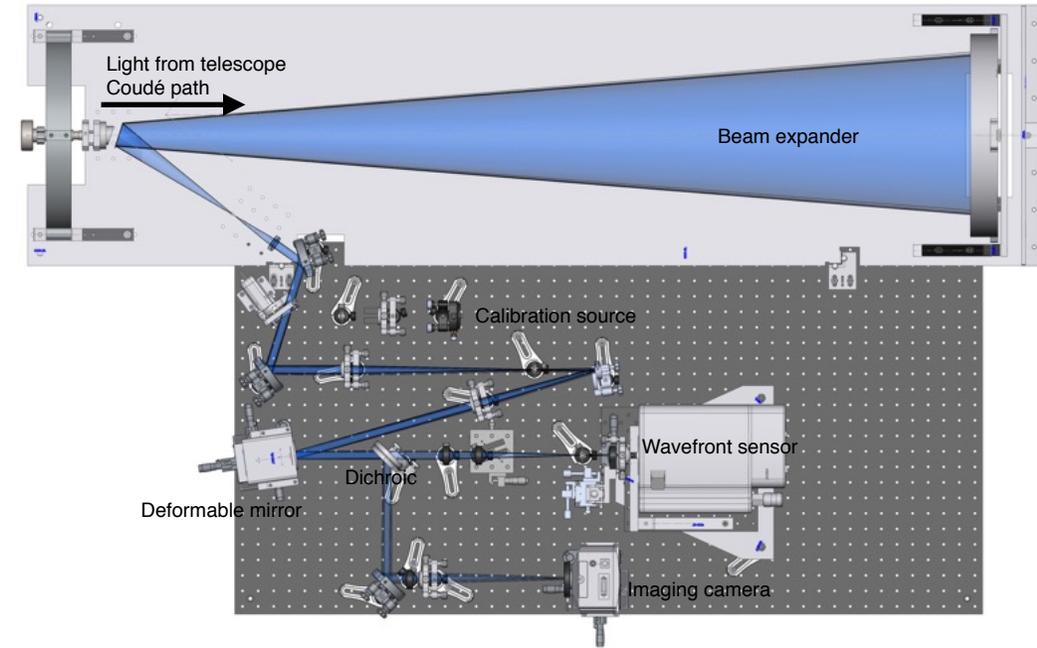
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 - Peak flux increased by 10x



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- AO on return signal
 - Couple return pulse into single mode fibre receiver
 - May allow more advanced timing mechanisms such as digital interferometry

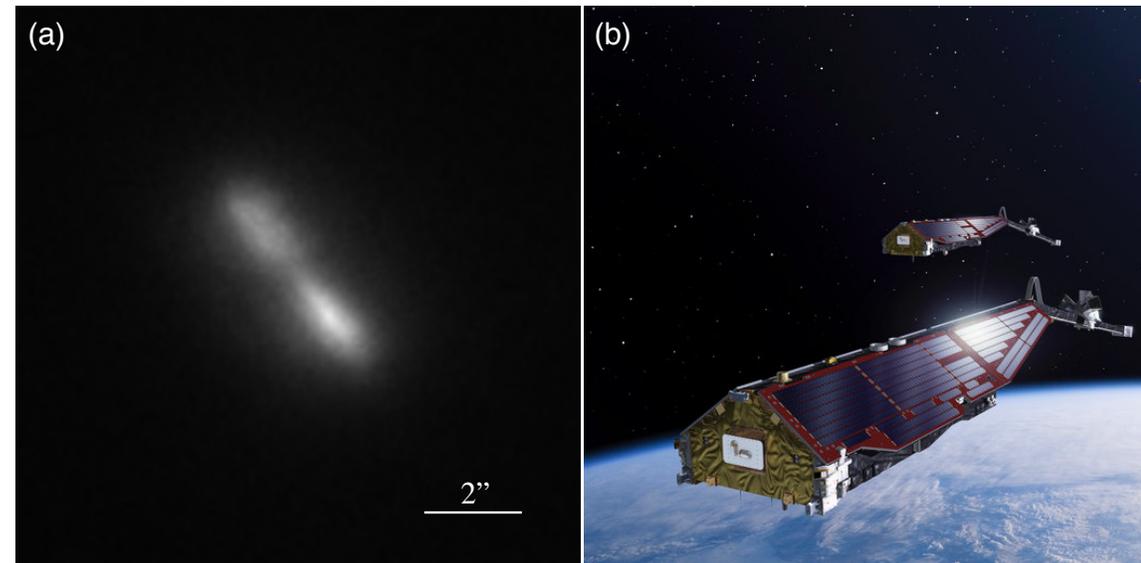
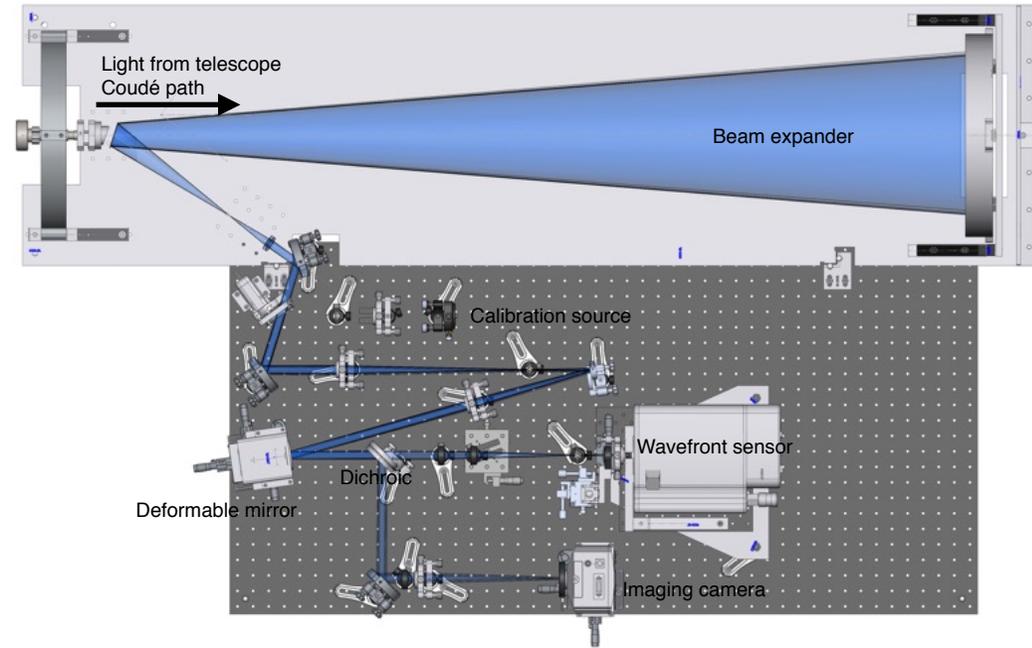


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