AOLI: Adaptive Optics Lucky Imager

Diffraction limited imaging on large ground-based telescopes

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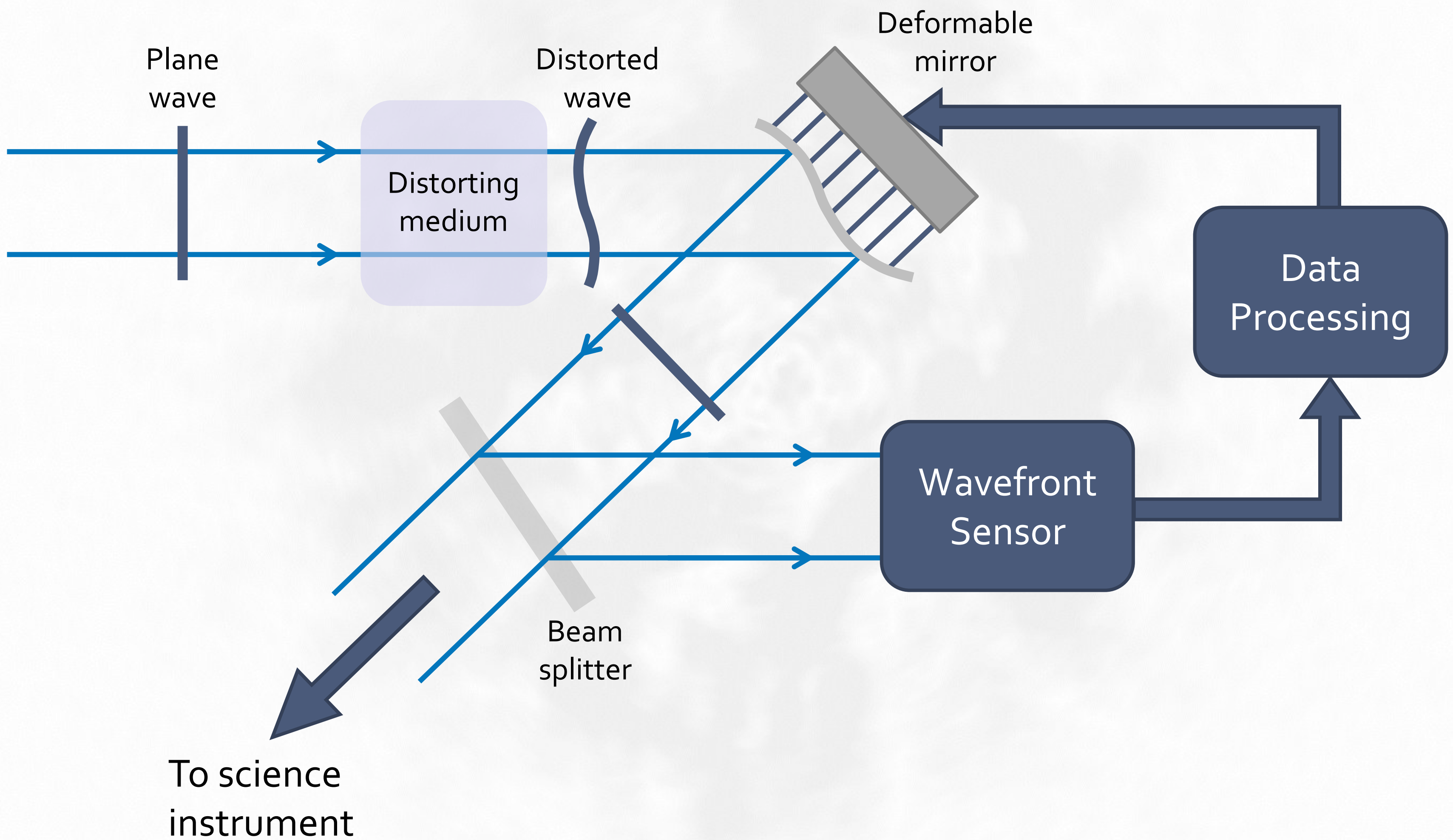
Outline

- Motivation
- Adaptive Optics & Lucky Imaging
- The AOLI instrument
- Non-linear curvature wavefront sensor
- Current status & future work

Motivation

- Retirement of the Hubble Space Telescope
- There are no plans for a new optical space telescope
- Current ground based technologies cannot provide a solution individually on large telescopes

Adaptive Optics



Lucky Imaging

- Atmospheric turbulence is random
  - Times of relative 'calm' – of the order 100ms
  - The more turbulence you have, the smaller the chance of a period of calm
- If we image at times of calm, we get a sharp image
- Image at 20-25Hz using electron multiplying CCDs (EMCCDs)
- Post-process to rank image quality
- Combine the best images

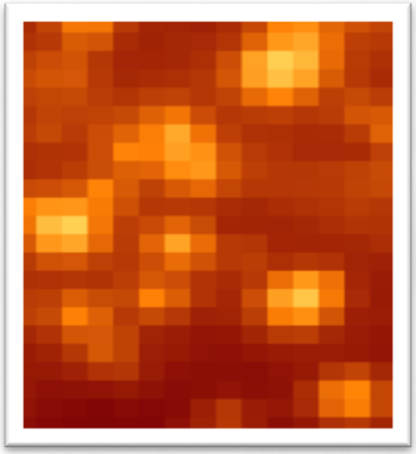
Adaptive Optics & Lucky Imaging

- AO currently is capable of diffraction limited imaging up to the near-IR
- Lucky Imaging can produce diffraction limited images in the optical on 2.5m telescopes

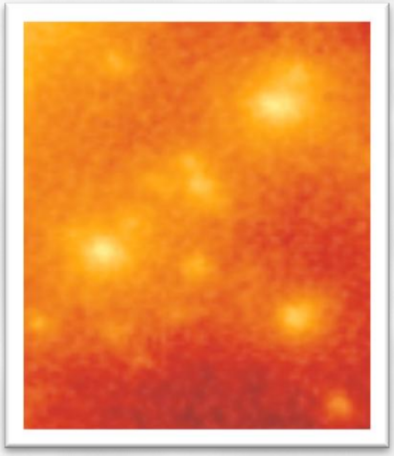
- Remove strongest atmospheric effects allows Lucky Imaging to work on larger telescopes

- Tried and tested!

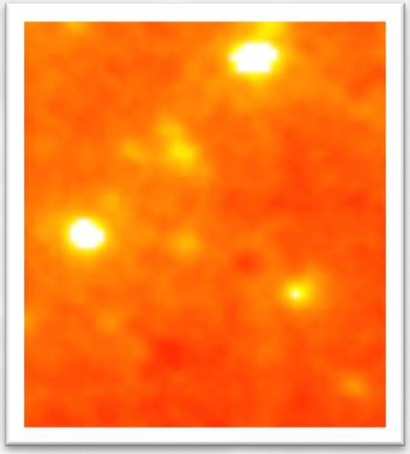
Adaptive Optics & Lucky Imaging



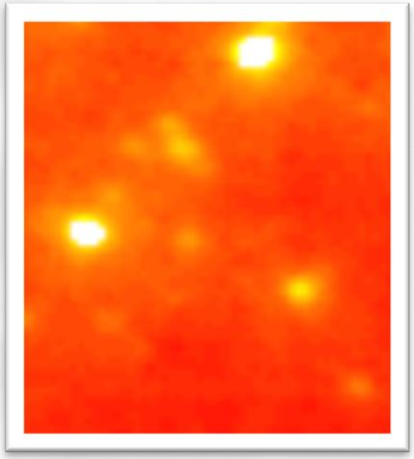
HST – ACS



Lucky – 10%



Fourier – 20%



Fourier – 50%

The Collaboration

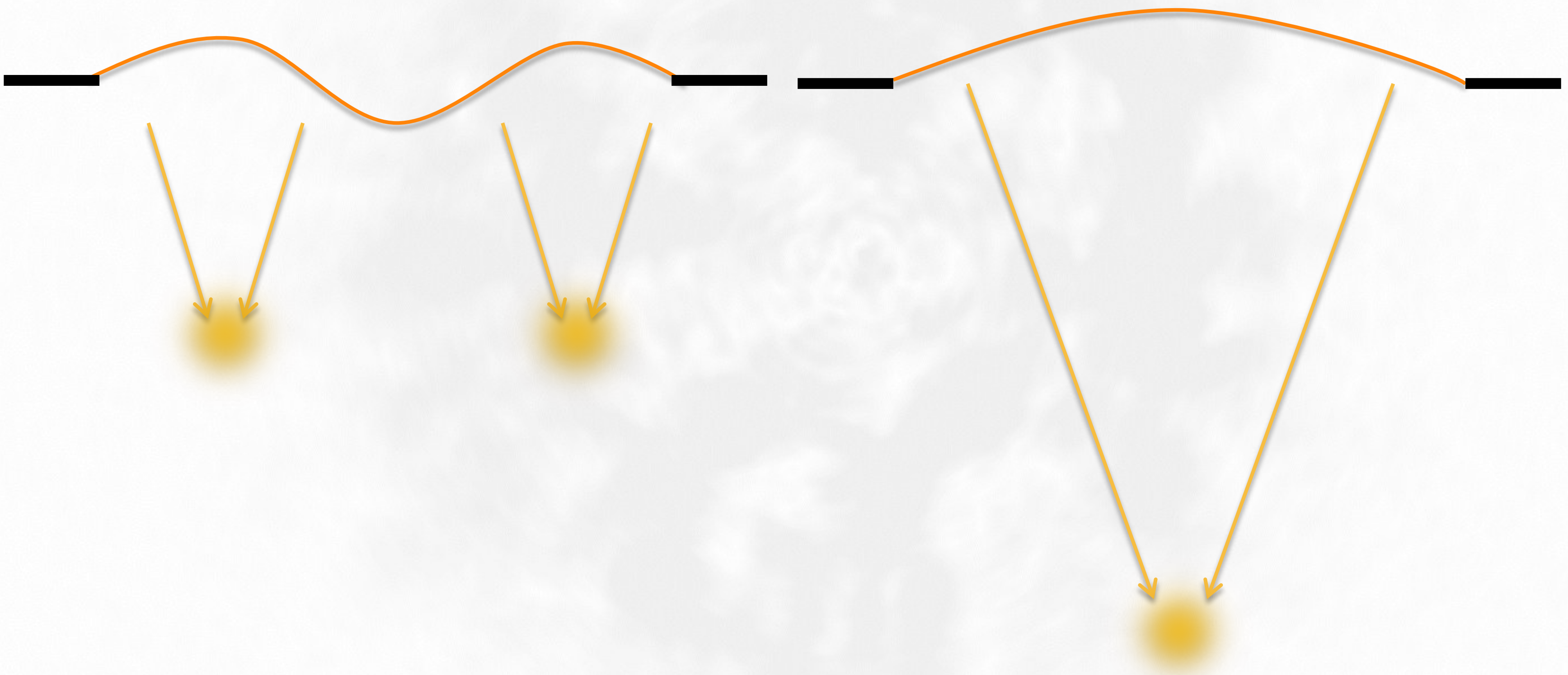
The Instrument

- Initially for the William Herschel Telescope
- Lucky Imaging based science instrument comprises:
  - 4 × 1024 square EMCCDs providing 2000×2000px imaging region
  - Pixel scale of 15 milliarcseconds in I-band
  - Resolution of 40 milliarcseconds
- AO component:
  - Alpao 97 actuator deformable mirror
  - Non-linear curvature wavefront sensor
    - Comprises 2 EMCCDs

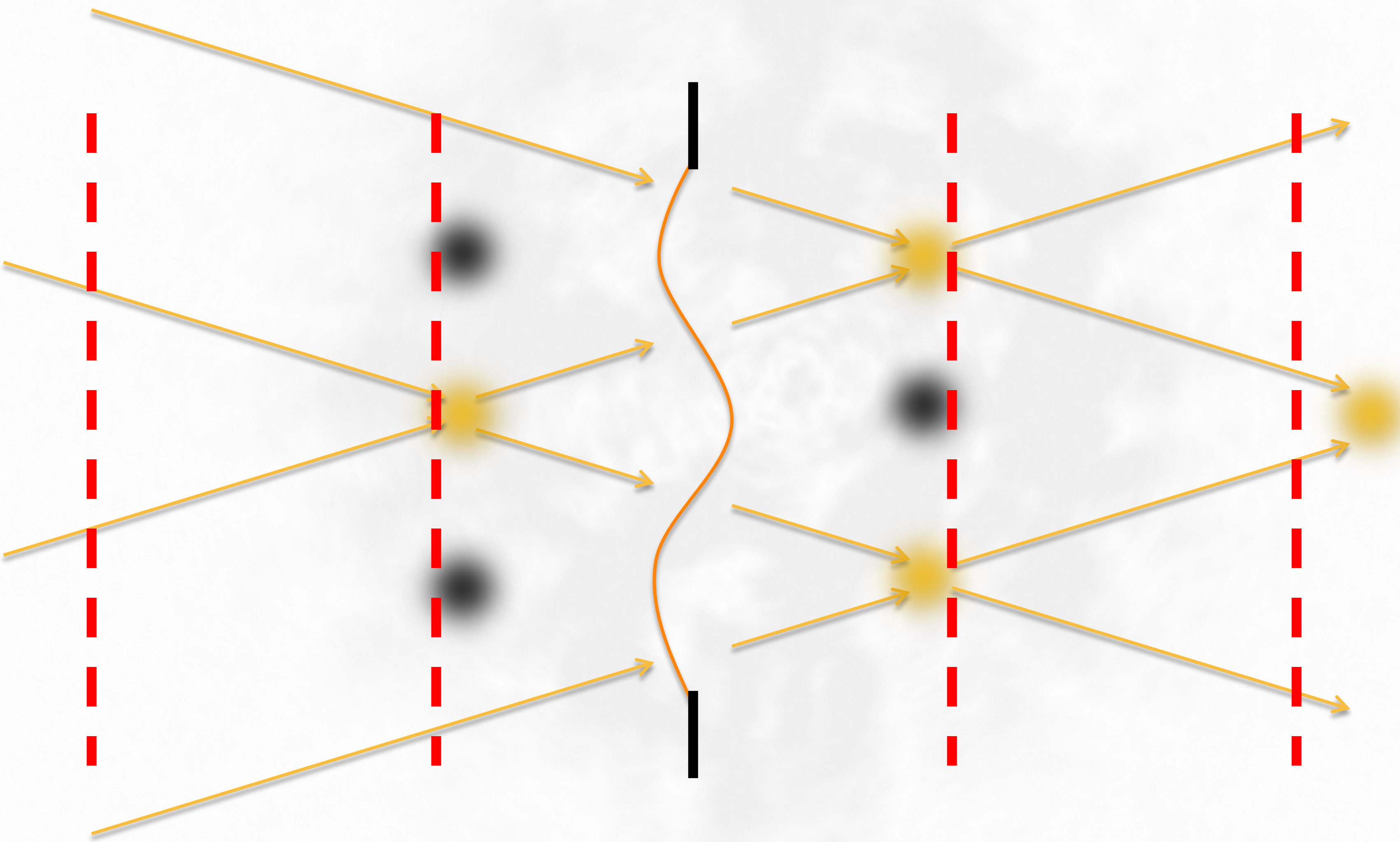
Curvature Wavefront Sensing

High order distortion

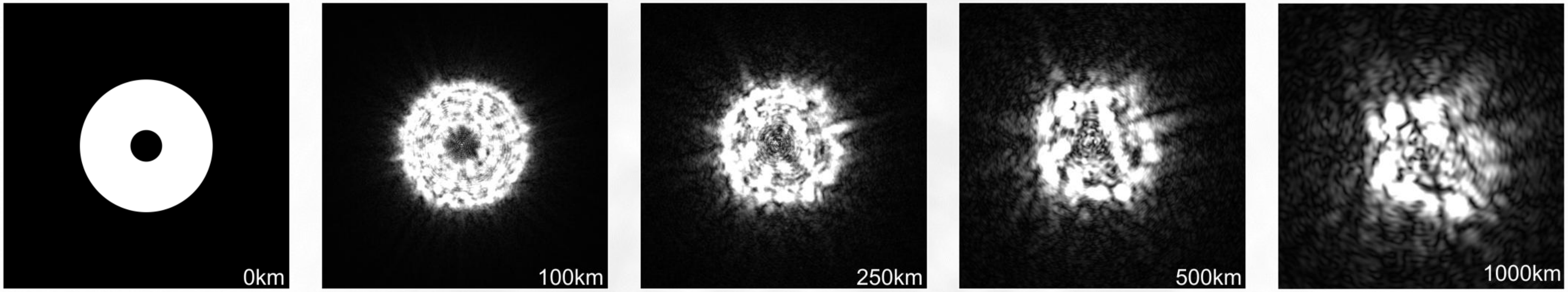
Low order distortion



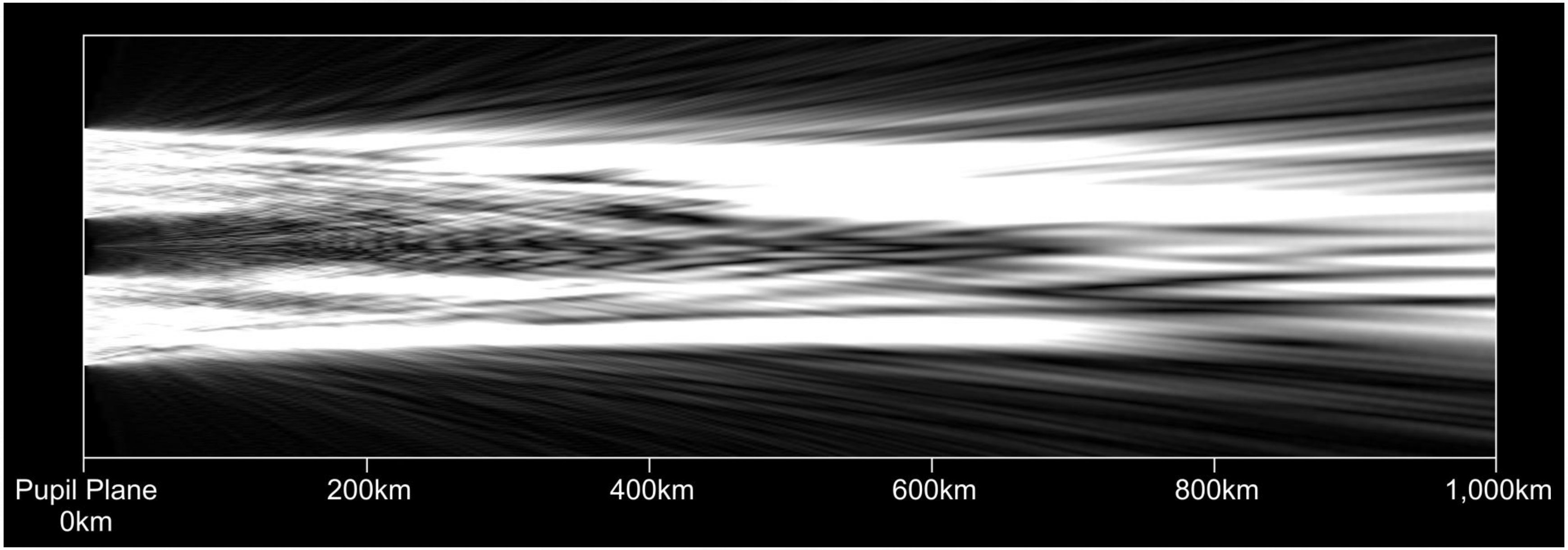
Curvature Wavefront Sensing



Non-Linear Curvature Wavefront Sensing



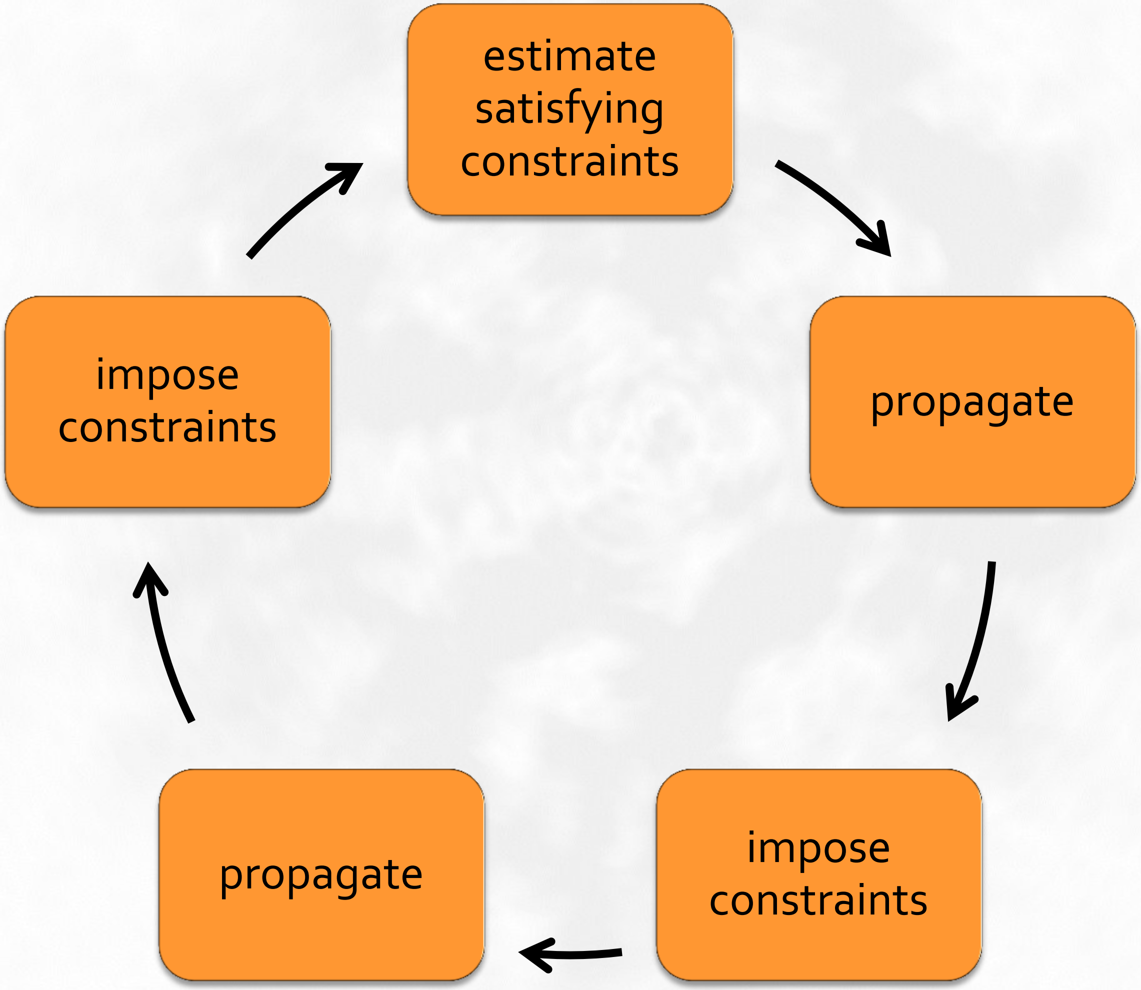
Simulations at 650nm for a 4.2m telescope with 1m central obscuration



Reconstruction Algorithm

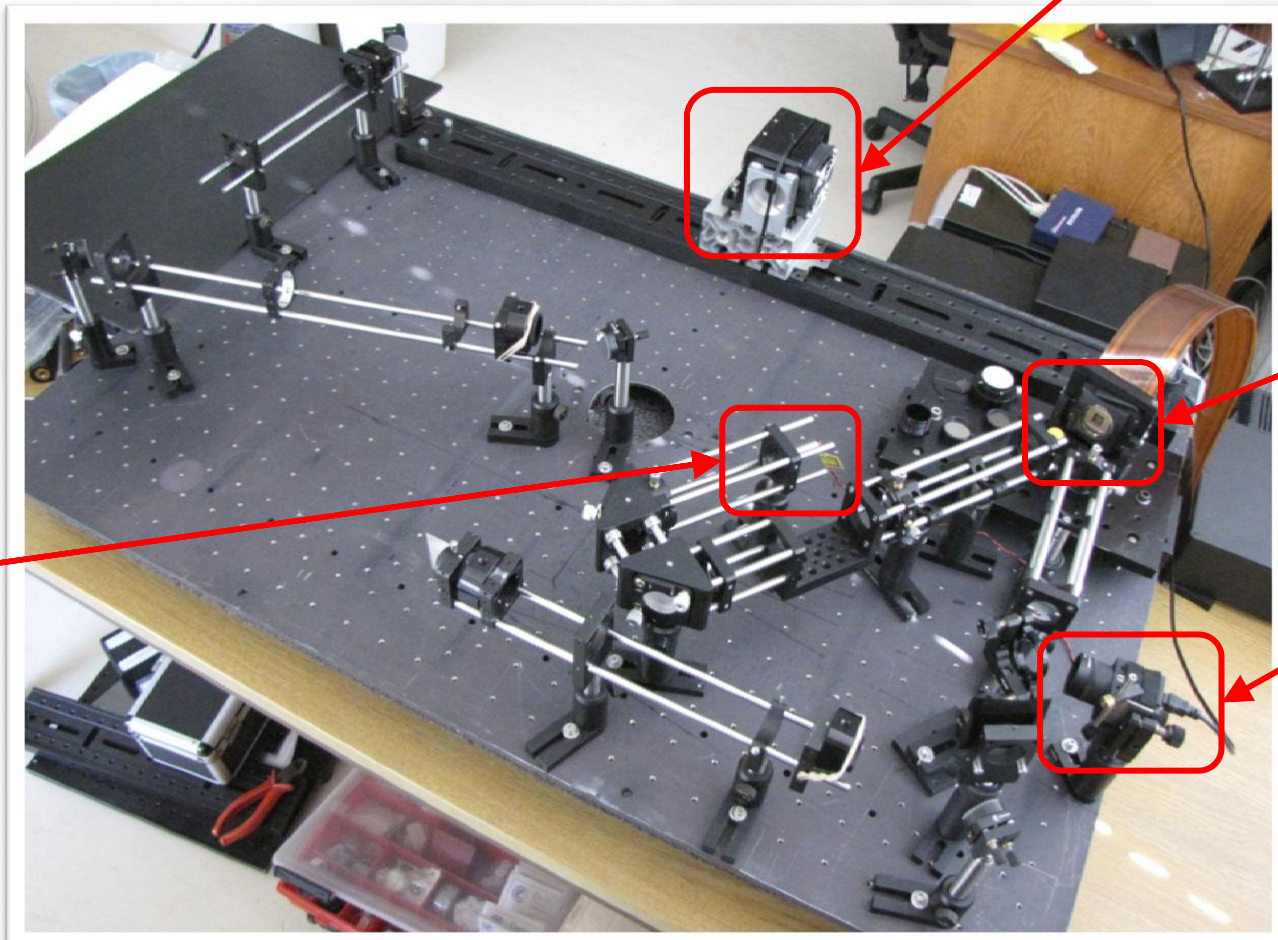
- We want to reconstruct the phase in the pupil plane
- All we can measure is the intensity away from the pupil
- Non-linear problem ⇒ iterative method
- Based on Gerchberg-Saxton algorithm
  - Further work by Fienup

Reconstruction Algorithm



Laboratory Setup

CCD Camera



Deformable Mirror

Light Source

SHWFS

Current Status & Future Work

- Reconstruction algorithm successfully working on simulated data
- Laboratory setup being used to investigate:
  - Effects of chromaticity
  - Low photon numbers
  - Optimal plane location
  - Reconstruction with real data
- Algorithm speed up
- Aim to have first version on sky in late 2013