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Development of a Single Star SCIDAR system for profiling atmospheric turbulence.

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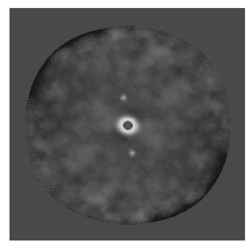
Binary Star SCIDAR – A Recap

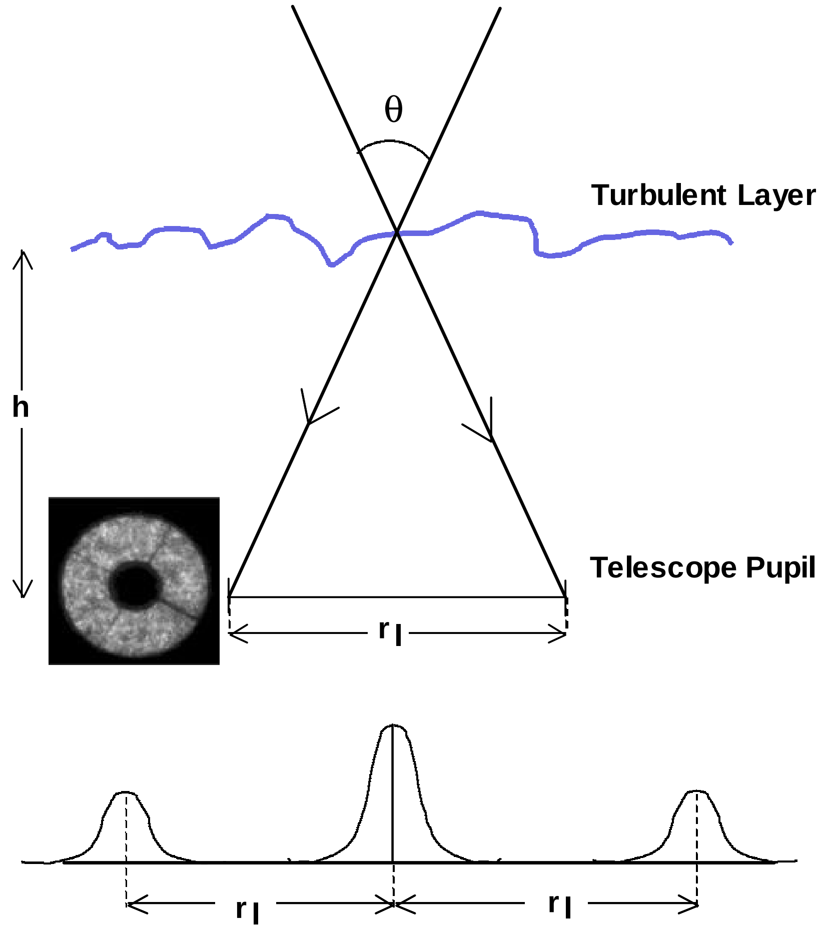
The average autocorrelation of a large number of short exposure telescope pupil images for the binary used to locate and quantify the strength of turbulence

$$c(r) = \left\langle \Delta I(\vec{x}+\vec{r})\,\Delta I(\vec{x}) \right\rangle$$

Solve the inverse problem

$C_n^2(h)$





A Problem: With the standard technique low altitude turbulence cannot be determined as the wave must propagate a distance (> 2km) for the scintillation to develop large enough level to be measured.

A Solution ⇒ Generalised SCIDAR (Fuchs, Tallon & Vernin): Adjust the conjugate plane to a distance below the telescope pupil.

Basics of Single Star SCIDAR

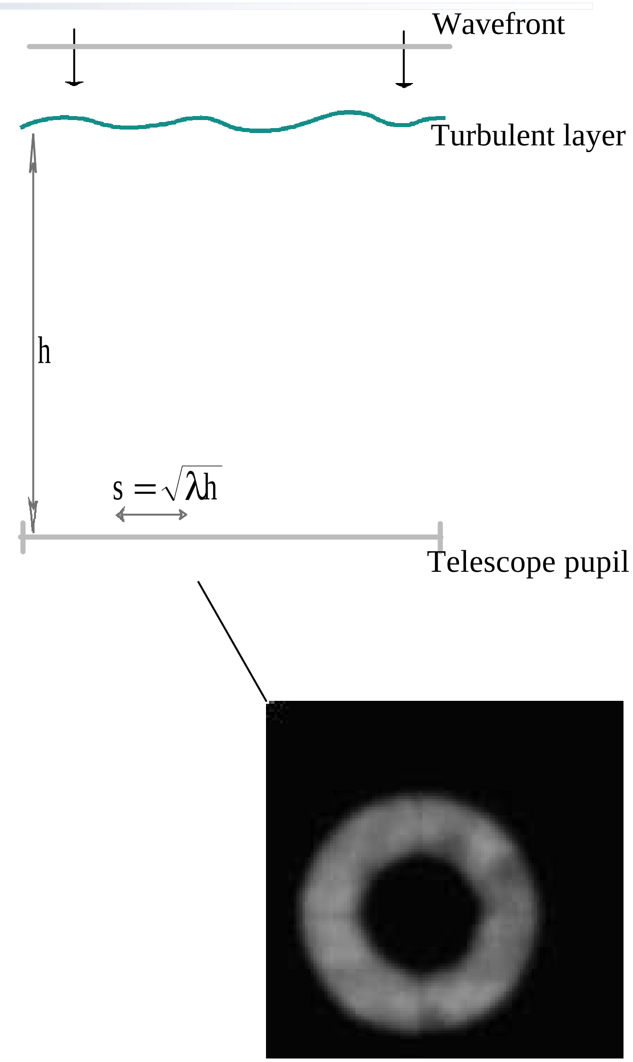
- Autocorrelation of scintillation pattern at pupil is again used to probe the strength of the atmospheric turbulence.

  ⇒ **Need to retrieve $C_n^2(h)$ from the central autocorrelation peak.**

  No triangulation to help us.

- Technique gives lower height resolution and a poorer fix on **$C_n^2(h)$** than binary star SCIDAR but does promise larger sky coverage

- To aid **$C_n^2(h)$** calculation:
  - Employ generalised SCIDAR to aid in assessing turbulence near ground.
  - Image different pupil heights in atmosphere to eliminate their contribution to the imaged pattern.

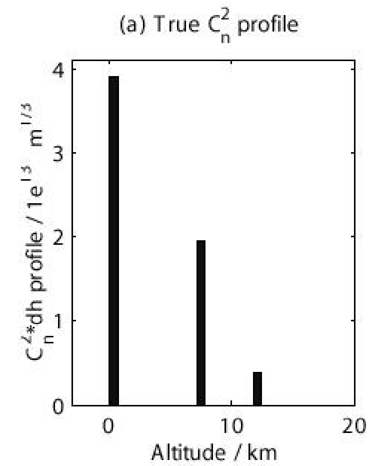


Feasibility of SSS + Data Processing & Problems

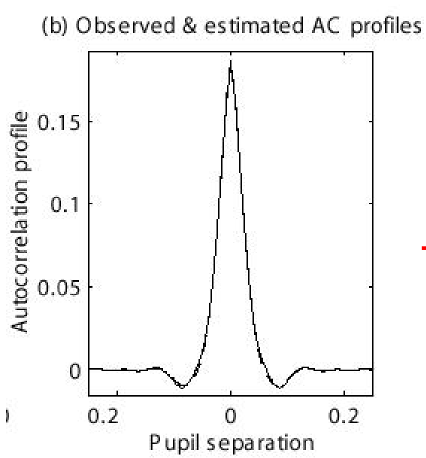
- The inverse problem - The average covariance, ***c(r)***, can be described by the matrix equation ***c(r)*** = **T(r,h)** $\mathbf{C_n^2(h)}$

  where ***c(r)*** is the covariance function
  T(r,h) is the T matrix and
  $\mathbf{C_n^2(h)}$ is the required profile.

- Studies based on simulated scintillation patterns have demonstrated the feasibility of the technique (Klückers. unpublished work, Johnston, R. Ph.D thesis).



In addition to the low signal to noise inherent in the ***c(r)*** data, calculating $\mathbf{C_n^2(h)}$ is complicated by the complex form of the T matrix .



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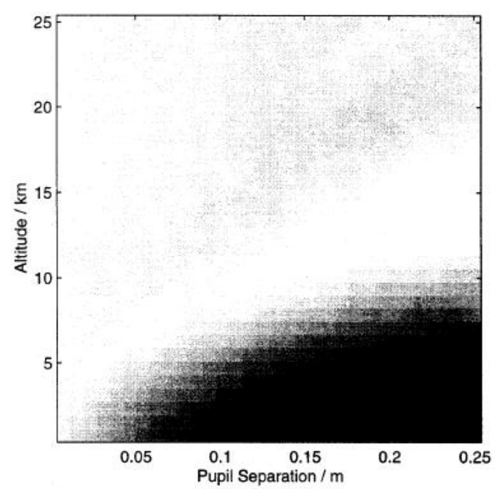
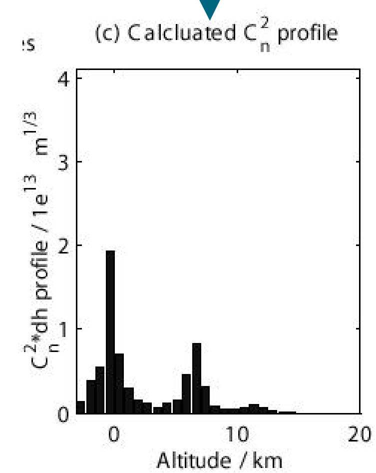




Work in optimising the inverse calculation is currently in progress

System Specifications

Requirements

- A short exposure time is required to freeze the scintillation pattern (< ms).
- High frame rate (large number of frames) for adequate signal to noise in the average covariance signals (~100 Hz).
- High gain/sensitivity for good “sky coverage”.
- Able to transfer quickly between target pupil heights in imaging scintillation patterns.

- Real time output
  - Real time covariance output
  - Real time **$C_n^2(h)$** profile for final instrument.
- Remote operation and alignment.
- Portability

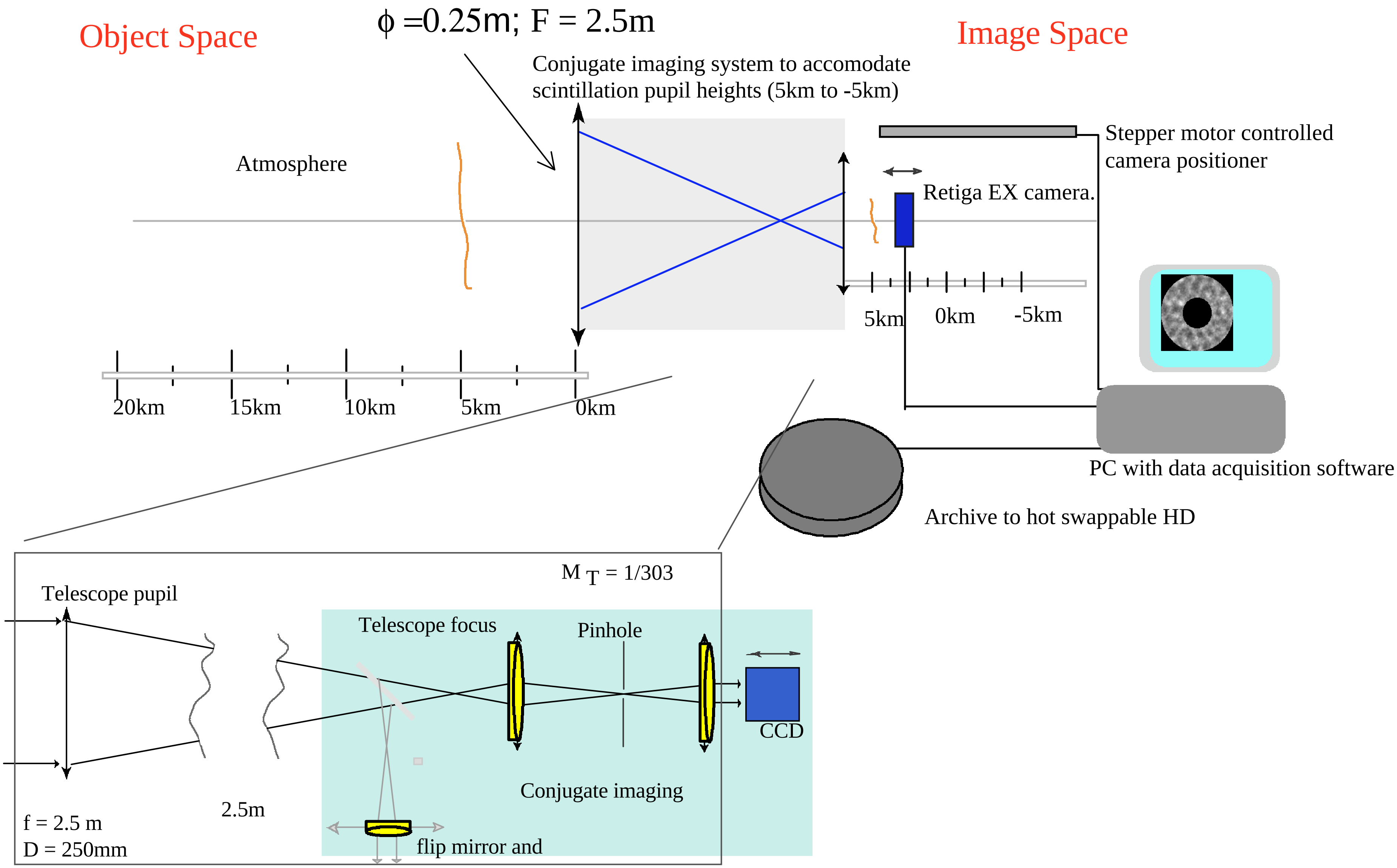
System Specifications

•Camera used = Retiga EX. [ROI = 128^2 area. 8/ 12 bit ADU: Exposure time 40μs - 1ms. Frame rate of 100fps at best.

•PC controlled imaging of target heights via stepper motor assembly.

•Acquisition and control software runs on a Pentium 4 machine and implements real time base level image processing and archiveing of data onto USB 2.0 hard disk.

The Current System.



The Telescope

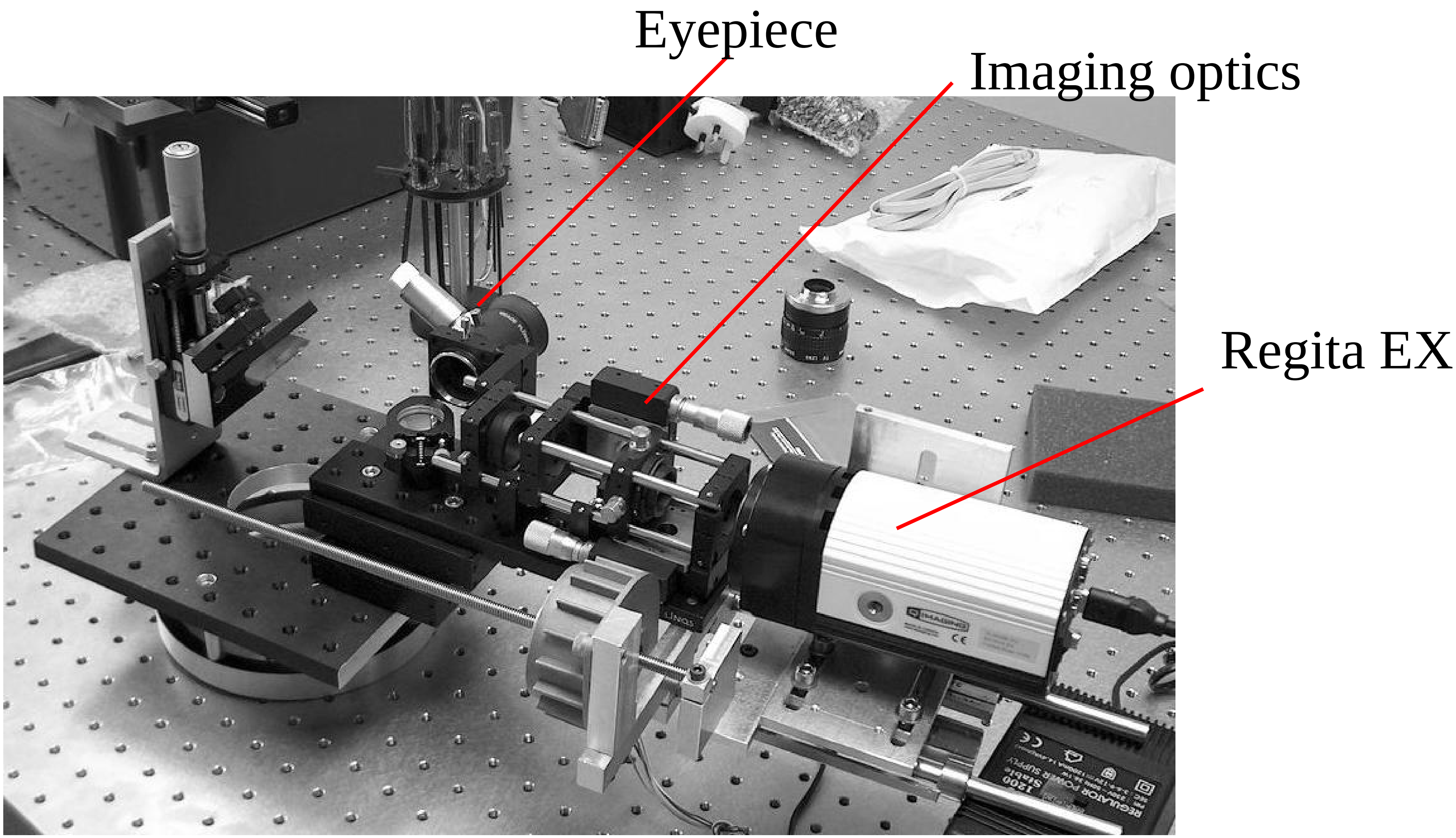
System Specifications

•Diffraction limited optics.

•Autoguiding to take up slack in telescope tracking.

Autoguider camera also used to locate target star.

Main Instrument



Initial Aims – Mark 1 System

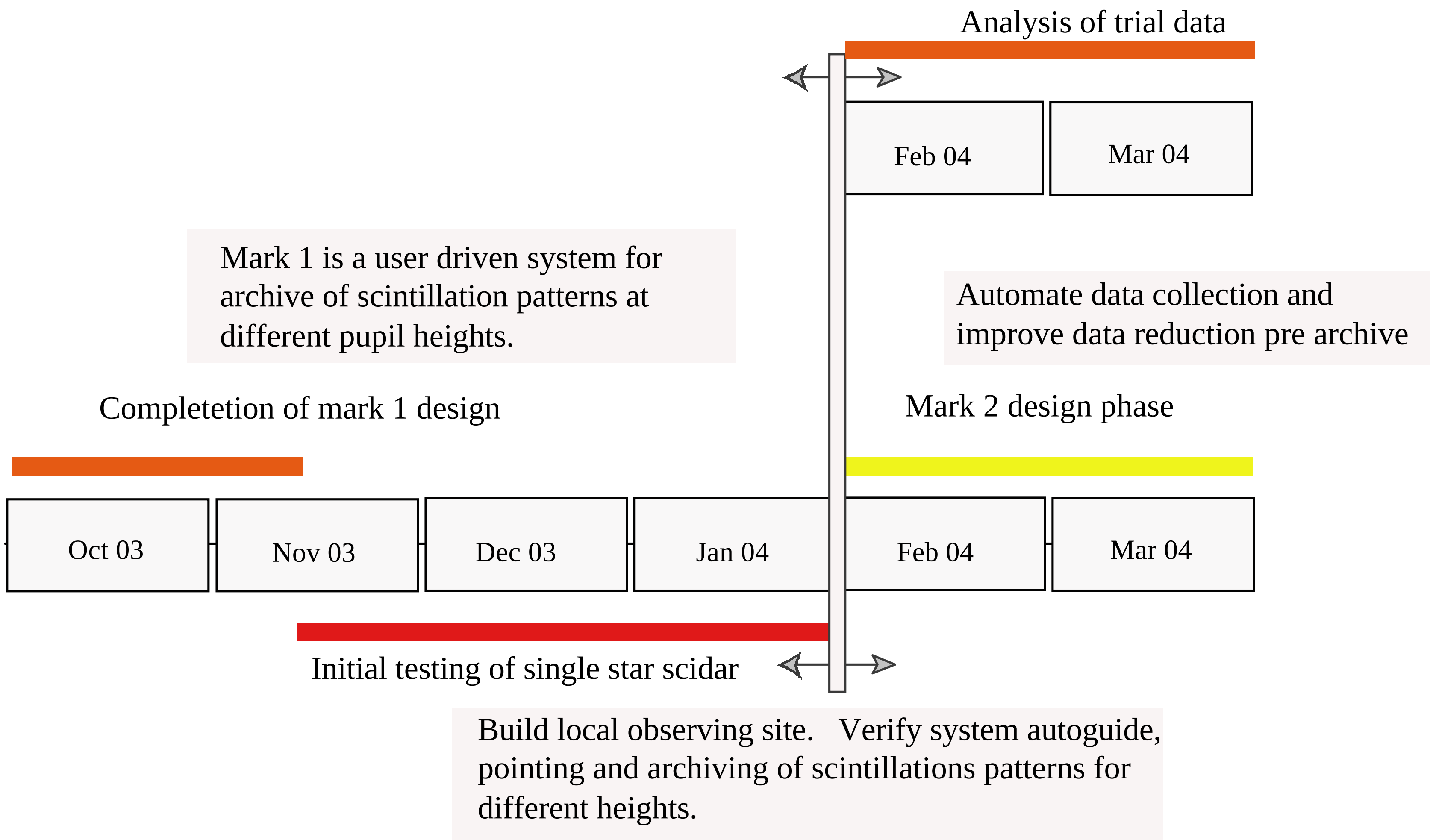
- Perform basic image processing on frames and archive for offline analysis.

- Enable user controlled configuration of target pupil plane.

  From an analysis standpoint see if we can wash out contributions to the pupil pattern.

- Verify tracking of scope and orders of magnitude of sources that can be studied with current system.

Research time line



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