Simulations for CLASSIC++

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CLIMB

- H or K band
- Combines 2 (CLASSIC) or 3 (CLIMB) telescopes
- CLASSIC
  - Typical limiting magnitude: 7
  - Best limiting magnitude achieved: 8.5
- CLIMB
  - Typical limiting magnitude: 6
  - Best limiting magnitude achieved: 7
- Spectral resolution:
  - Broadband
  - $\lambda_0 = 1.673\ \mu m \qquad \Delta\lambda = 0.285\ \mu m$ (H band)

CLASSIC++

- Upgrade of CLASSIC/CLIMB for more sensitivity
- Funds for a new detector (e.g. C-Red 1)
- Is there a way to increase the SNR of the visibility even more?
- Let's do some simulations then
- 2 designs to test
  - Pupil plane with temporal encoding of the fringes
  - Image plane with spatial encoding of the fringes and spectral dispersion

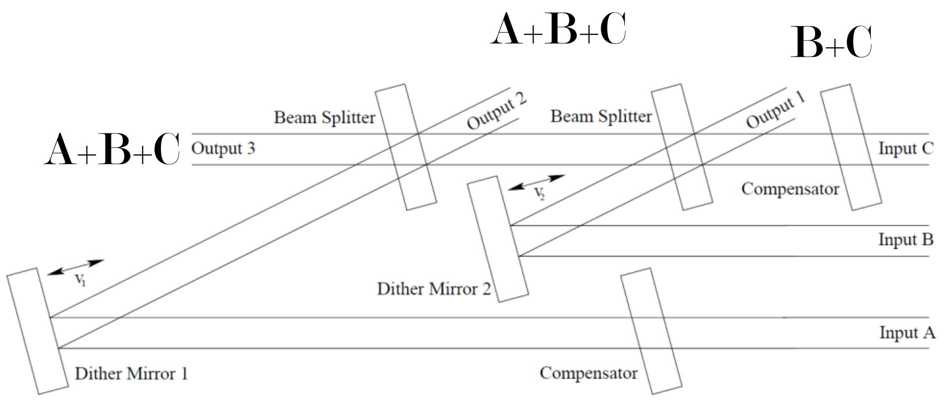
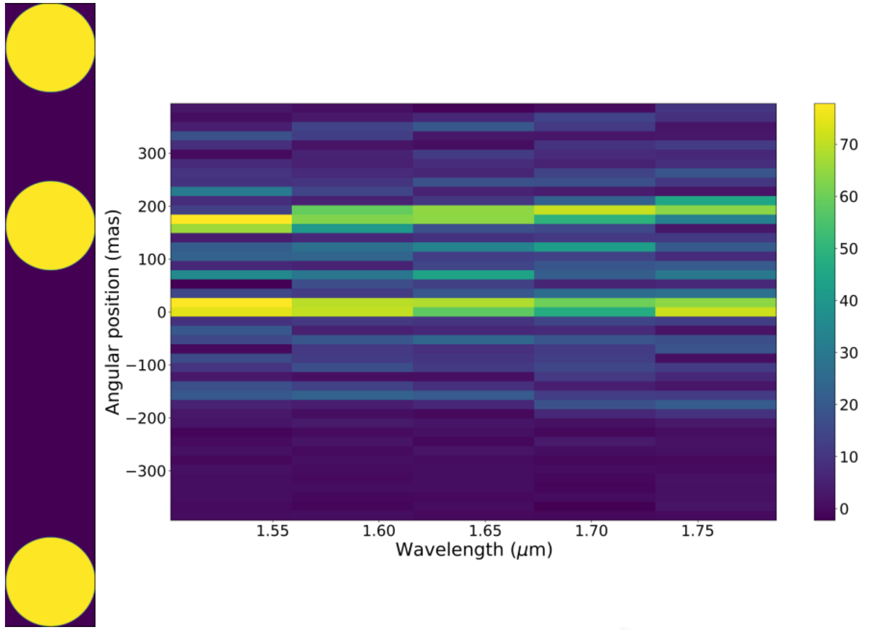


Fig. 2. Schematic of the optical layout of the CLIMB beam combiner



Specifications of the simulations

- Operates in H band
- Photometric model and throughput: $N_{ph} = 10189\ 10^{-\frac{mag}{1.071}}$ (Empirical model for CLASSIC)
- Field of view
  - Pupil plane: 0.78”/pixel (like CLASSIC)
  - Image plane: width of one Airy disk at the shortest wavelength
- Camera: C-Red One
  - Characteristics based on experiments carried on MIRC-X and datasheet
- Atmosphere
  - Kolmogorov phase mask (XAOSIM, F. Martinache)

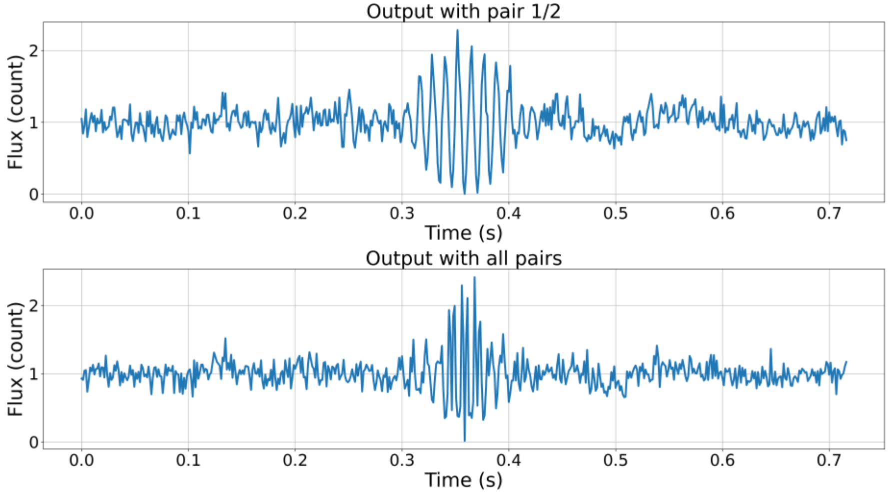
Specifications of the simulations

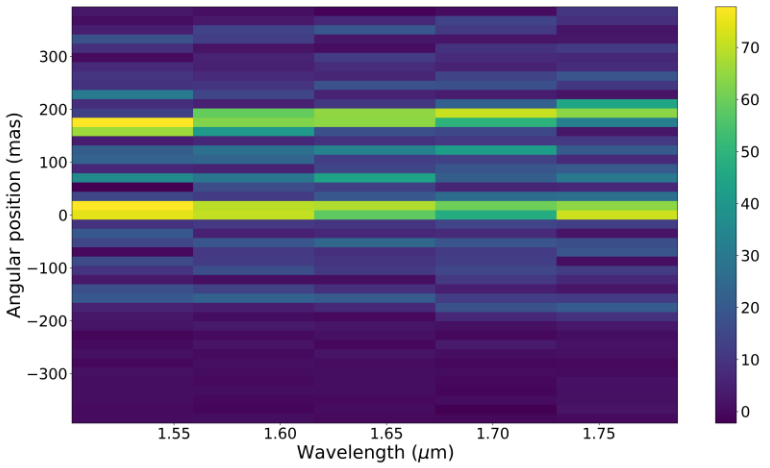
- Pupil plane design
  - Fringe encoding frequencies: $f_0, 2f_0, 3f_0$, $f_0 = \frac{750}{9} = 83.3$ Hz
  - Sample time of 1.33 ms (=1/750)
  - No spectral dispersion
  - $N_{AP} = \frac{9L}{\lambda} =$ **538** samples for scan length $L = 100\ \mu m$, in H band (3 pixels per "fastest" fringe)
  - One full scan done in 0.72 seconds
  - Fringe packet is $20\ \mu m$ so only 20% of the scanning time is spent in the fringes
- Image plane design
  - Fringe encoding: 2D-4D-6D

    Leads to 5, 10 and 15 fringes → 45 pixels to sample the fringes (3px/fringe)
  - Sample time = 12 ms ($1/f_0$)
  - Spectral dispersion $R = \frac{L}{2\lambda_0} = 30$, Spectral channel width of 56 nm → 5 pixels across H band
  - Total number of pixels for one sample: **225** pixels
  - Integration time = 0.72 s ie integration of 60 samples.
  - Reduction of RON by $\sqrt{60}$.

Doing the simulations

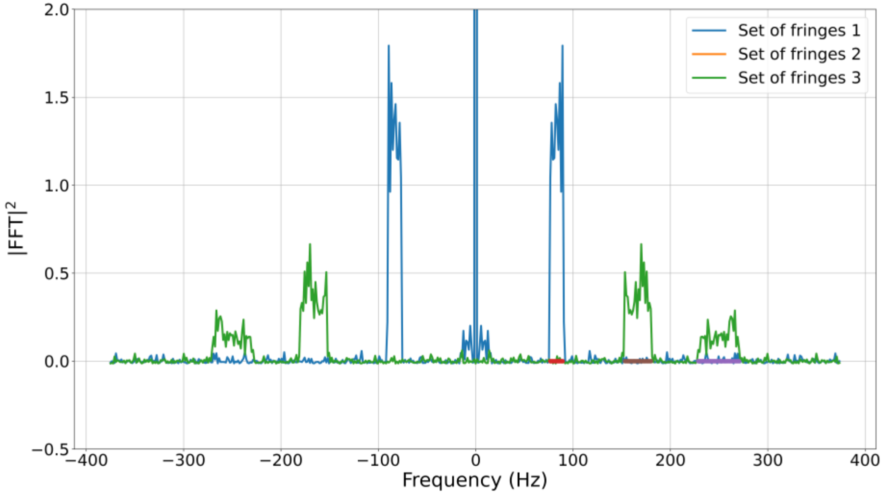
- Pupil plane: generating the scan, extracting visibility and SNR based on CLASSIC pipeline
- Image plane: incoherent integration, extraction of fringe peak and SNR based on FRIEND pipeline

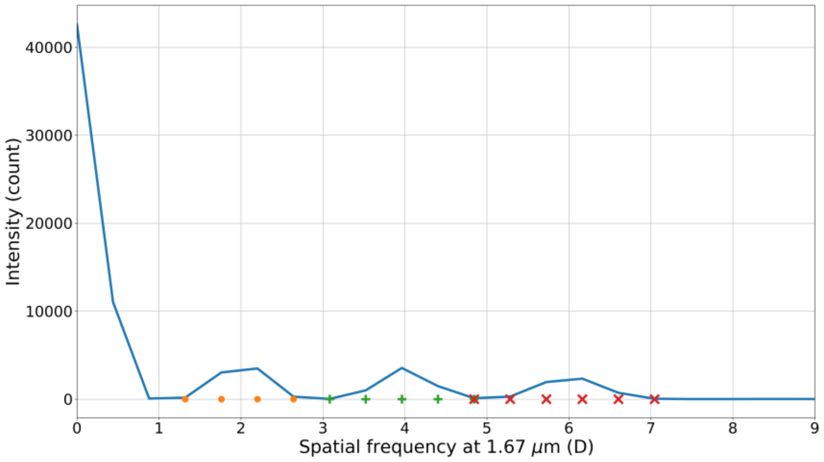




Pupil plane (↑Scan / ↓DSP)

Image plane (↑Scan / ↓DSP)

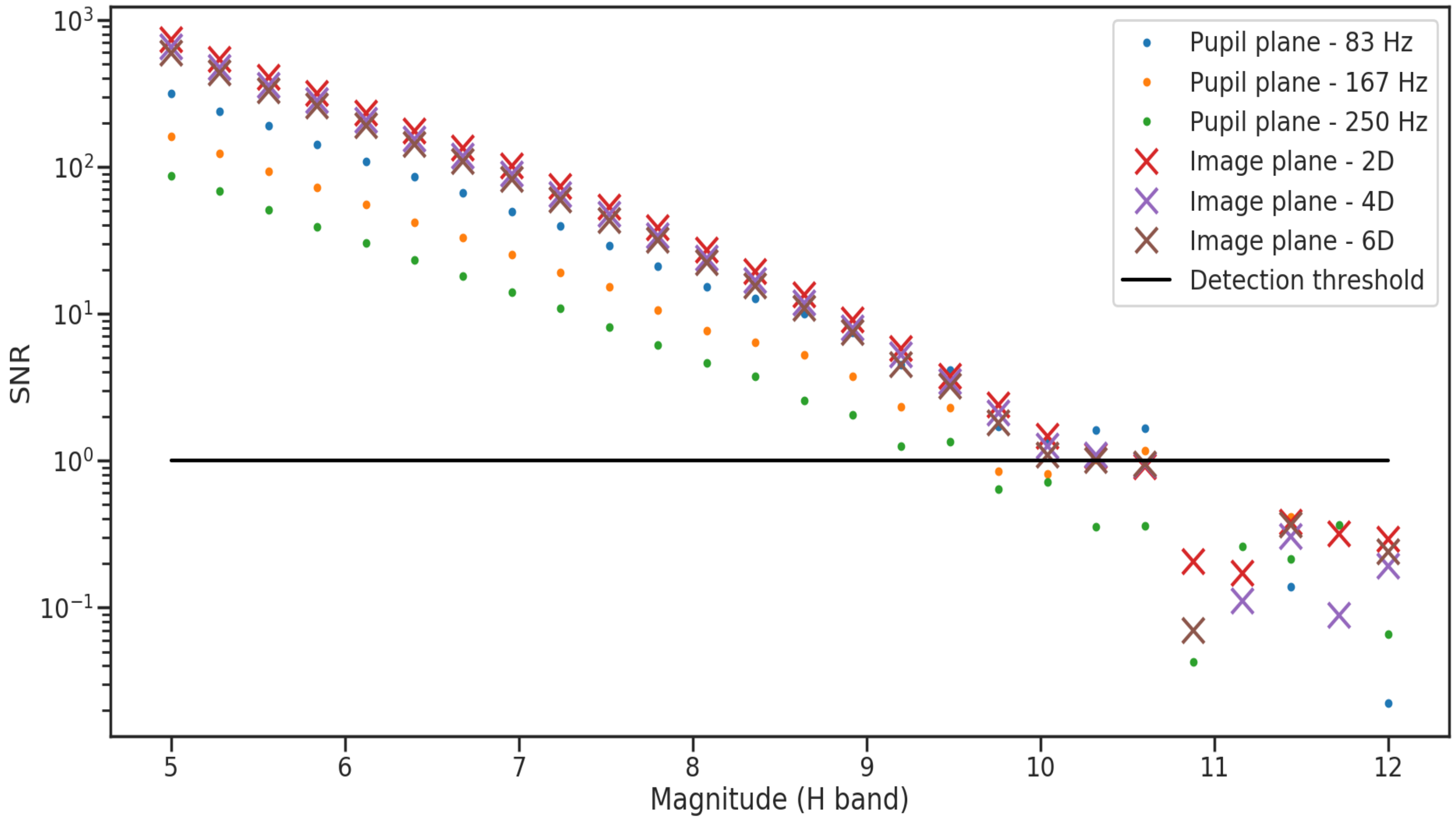




Results

- Pupil plane
  - Lower limiting magnitude (Hmag=9.2)
  - Not same SNR on the baselines
  - Hardly scalable to more baselines
  - Fewer changes in the optical layout
  - Low risk
- Image plane
  - Higher limiting magnitude (Hmag = 10)
  - Consistent SNR on all baselines
  - Looking at fringes all the time
  - Scalable to more baselines
  - New optical layout
  - Risker than pupil plane

- Image plane chosen (cf Peter Tuthill's talk about the design)



ANNEX: Simulating Atmospheric Turbulence

- Creation of atmospheric turbulence
  - Kolmogorov mask for phase turbulence
  - Independent phase mask per pupil
  - Translation of phase mask during time of the observation (masks large enough to avoid wrapping)
  - Parameters:
    - Reproduce a visibility of 0.75 in K band
    - $r_0 = 3.35$ cm and wind speed $v = 15$ m/s
- Adapted from XAOsim tools (F. Martinache)