Tests of novel wavefront reconstructors on sky with CANARY

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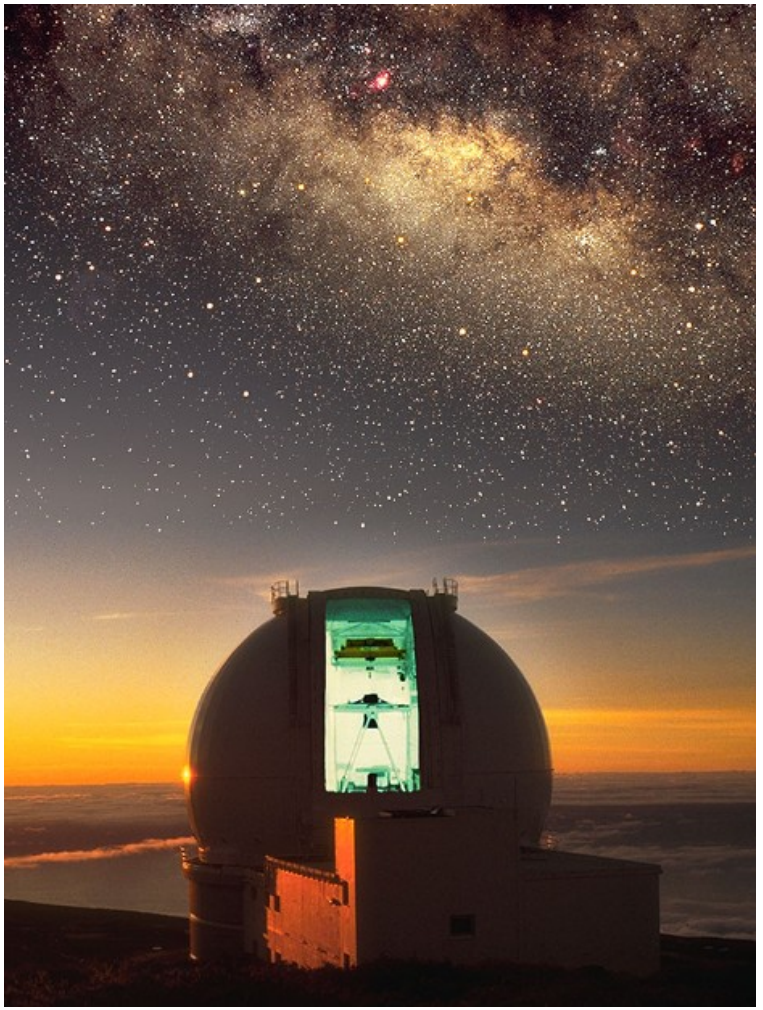
Real Time Control for Adaptive Optics
ESO, Garching, 4th - 5th Dec 2012

Durham University

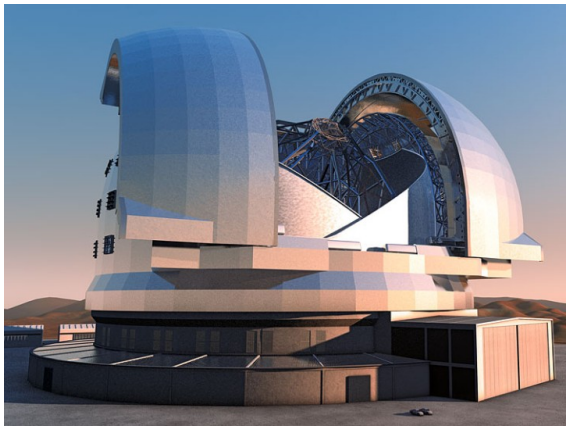
CANARY

OUTLOOK

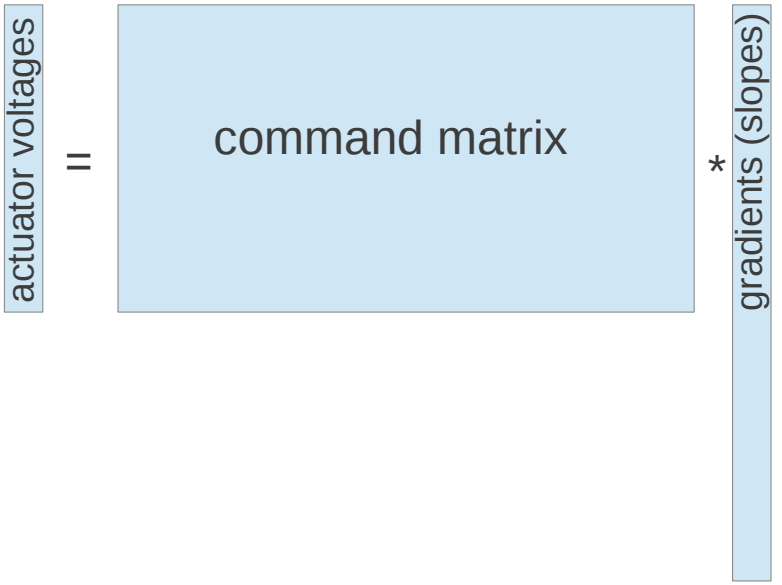
- RECONSTRUCTORS:
  - MVM
  - CuRe
  - DiCuRe
- WHT, CANARY, DARC
- MEASUREMENTS in 2012
- PLANS
- CONCLUSION

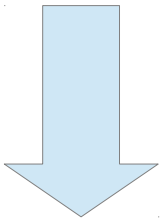


MVM



- obtain interaction matrix
- invert to get command matrix
- num. actuators x 2*num. subaps ==> N^2
- too slow for ELT - EPICS

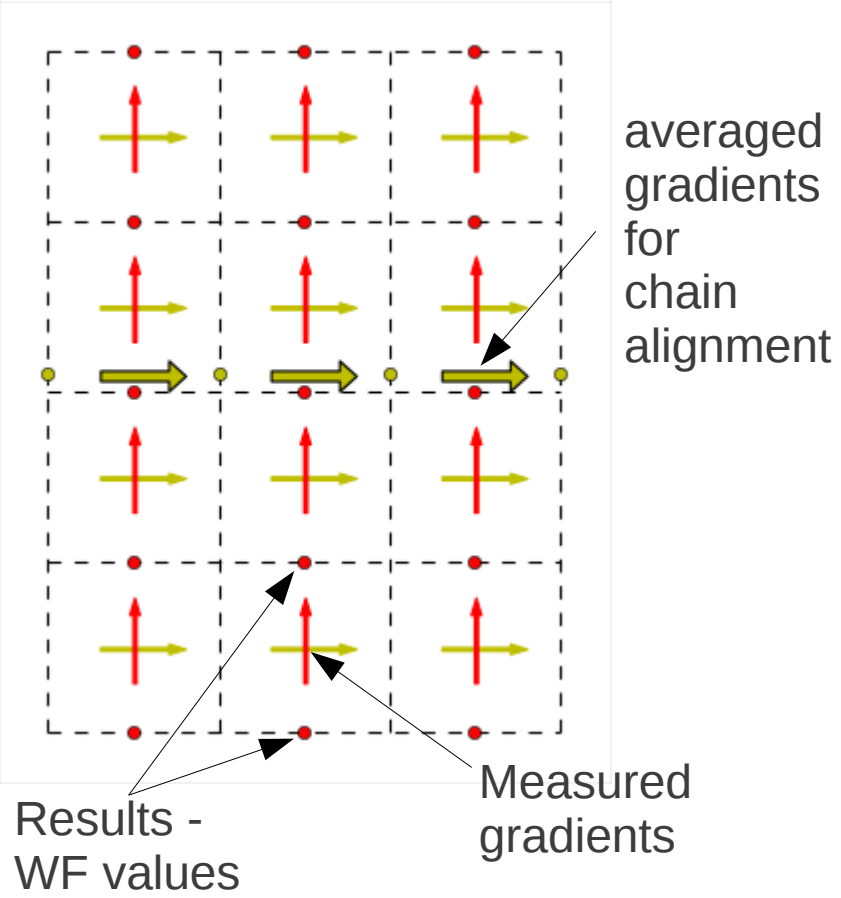




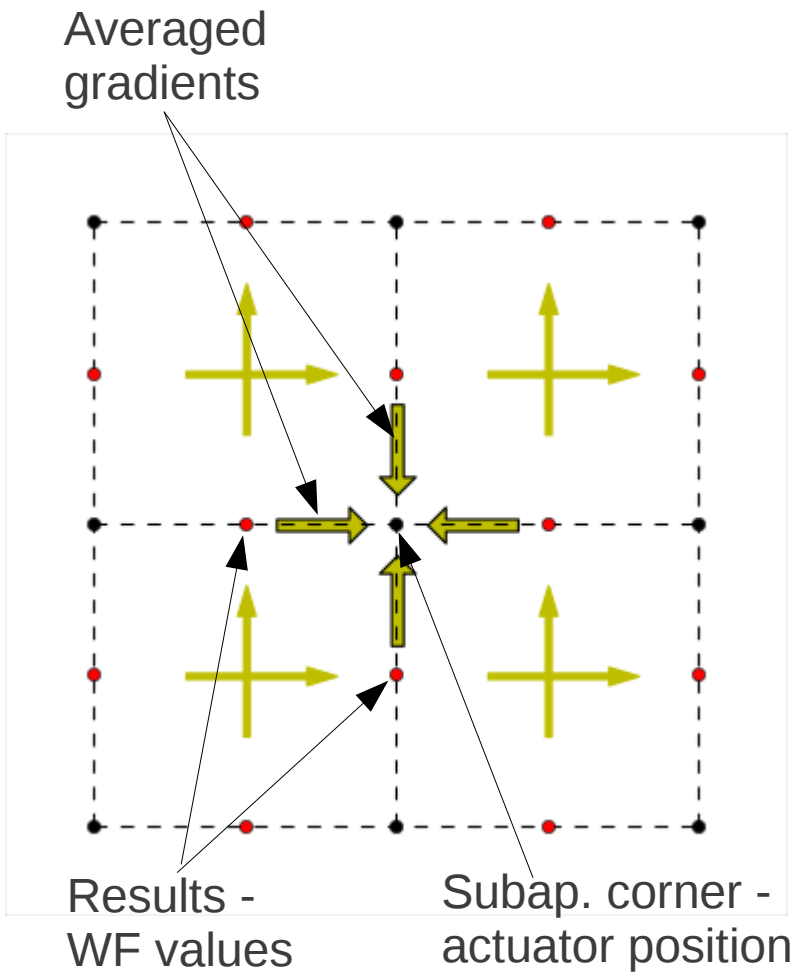
- investigate alternative solutions

Cumulative Reconstruction

- Talk from M. Rosensteiner
- direct algebraic reconstruction
- “integrate” gradients to get chains of **W**ave**F**ront values
- align the chains using a perpendicular chain obtained from average gradients



Cumulative Reconstruction

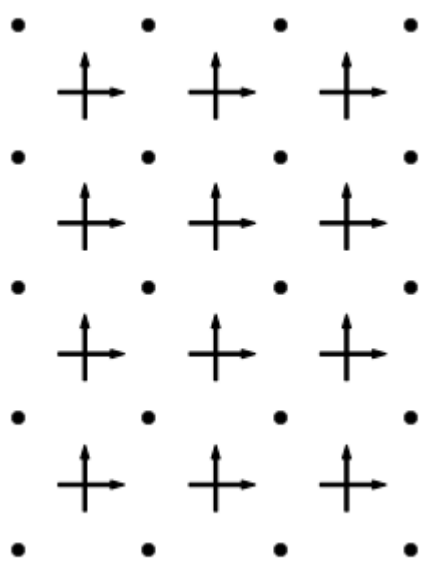


- Result: **W**ave**F**ront values in the middle of subaperture sides
- What one needs: values at subaperture corners
- Estimate it from the four surrounding points and *averaged* gradients

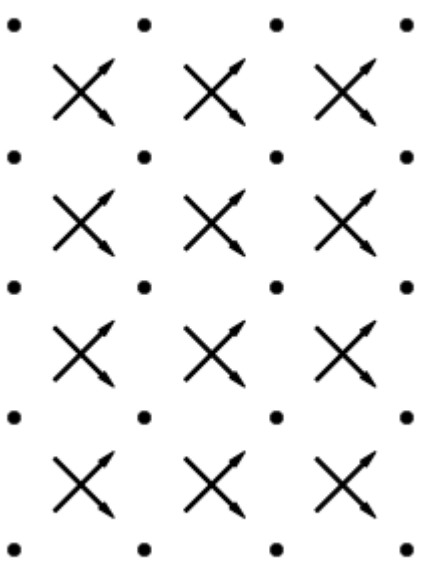
→ Loss of high spatial frequencies

Diagonal CuRe

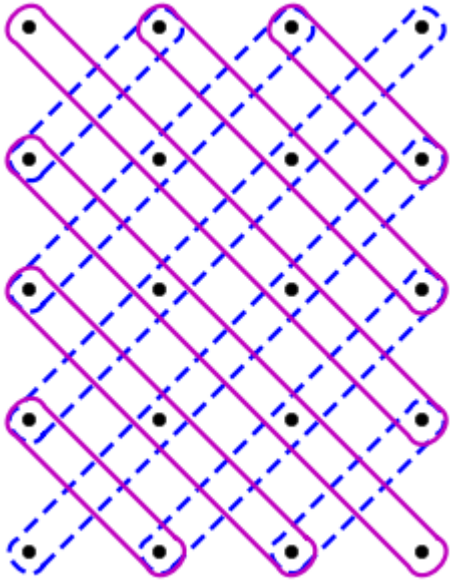
- Alternative approach (being developed in Durham):
  - (1) rotate gradients
  - (2) integrate diagonally



measured gradients



rotated gradients

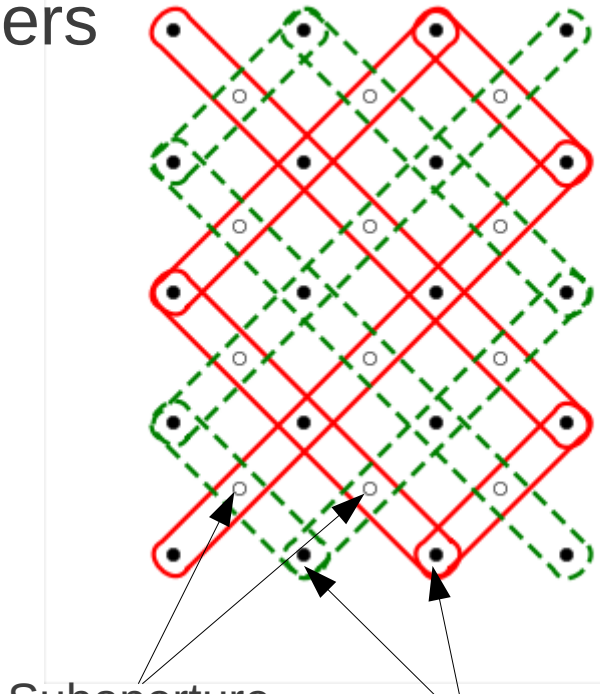


integrated chains

Diagonal CuRe

- To align the chains, require:
  - same value on subaperture corners

    AND
  - same value in the middle of the subapertures
- Ao + Bc = 0
  - o: vector of offsets (unknowns)
  - c: vector of chain elements
- Still in the development phase



Mapping matrix

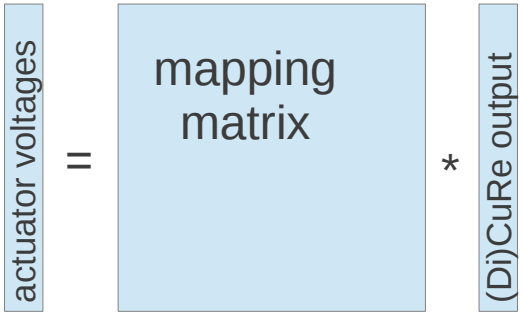
- CuRe/DiCuRe result: WF values at subaperture corners
- What you need: values at DM actuators positions
- Subaperture corners to actuators mapping matrix:

  (1) run CuRe/DiCuRe over columns of the interaction matrix => matrix A

  (2) invert matrix A ==> “mapping” matrix

  (3) to obtain actuator voltages, multiply the (Di)CuRe output vector with the mapping matrix.

- Computationally intensive: N^2
  - make it sparse by setting 70%, 80%, 90% of elements to 0
- Alternative: find the actuator positions by fitting, then interpolate



MVM vs. CuRe and DiCuRe

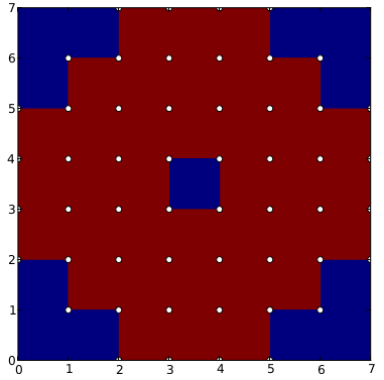
- Number of operations required:
  - MVM: $2*N^2$
  - CuRe: $12*N$
  - DiCuRe: $20*N$, with noise reduction $N^{3/2}$
- For the presented measurements the speed was not measured.

WHT:

William Herschel Telescope
ORM, La Palma, Canary Islands

CANARY:

- An on-sky MOAO demonstrator
- For these tests:
  - SCAO mode, 7x7 subapertures, 36 illuminated
  - closed loop
  - used the telescope simulator



DARC: Durham AO RTC

- CANARY uses DARC for real-time control
- Modular: to implement CuRe or DiCuRe, no changes to DARC needed, just provide the new reconstruction module
- This implementation of CuRe and DiCuRe:
  - no parallelisation
  - reconstruction begins when all the slopes are available

September and October 2012 runs

- September 2012:
  - CuRe and DiCuRe tests on bench and on sky (bad seeing)
  - both work stably in a closed loop
- October 2012:
  - CuRe unchanged
  - DiCuRe enhanced, but introduced a bug causing instability.
  - Bench test and on sky (excellent seeing)

Bench tests

- Test on the bench, gain = 0.3

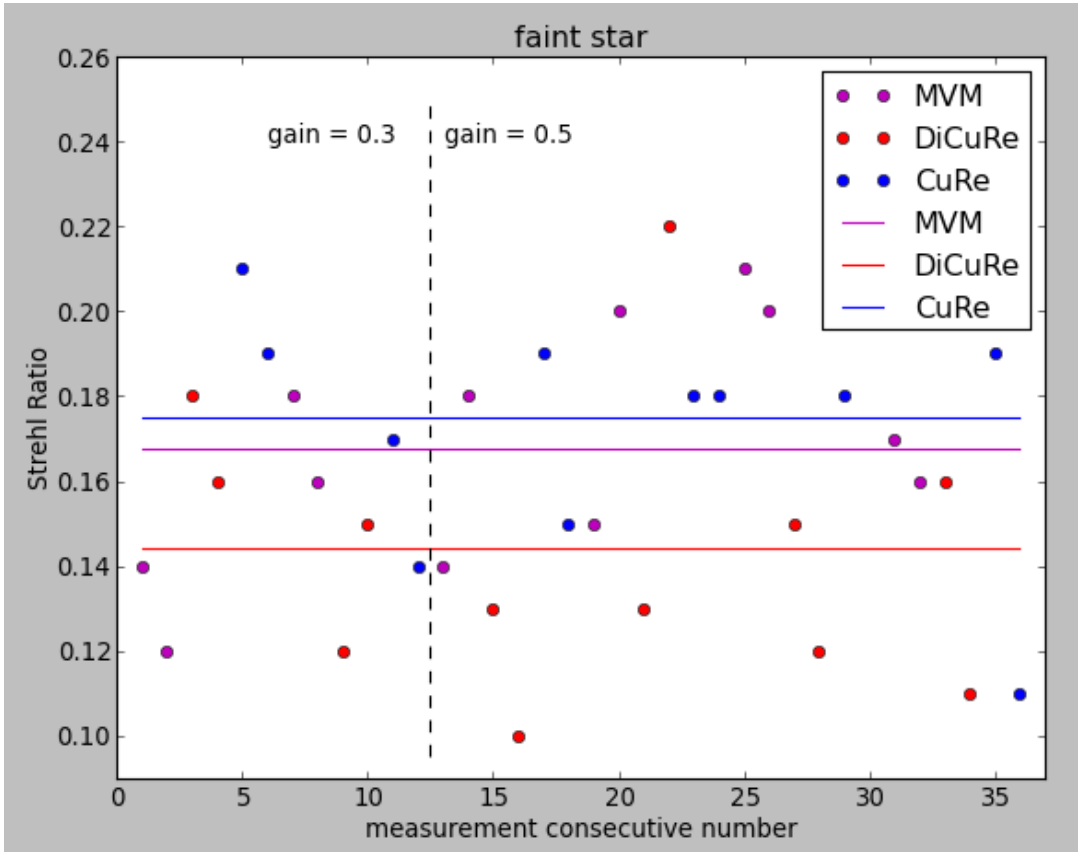
Reconstructor	Measured Strehl ratios	average Strehl r.
MVM	0.22, 0.22, 0.22, 0.22, 0.22	0.220
DiCuRe	0.21, 0.22, 0.21, 0.22, 0.21	0.214
CuRe	0.23, 0.24, 0.22, 0.23, 0.24	0.232

- Test sparsity of the “mapping matrix” (subaperture corners to actuators):

DiCuRe (different conditions then the table above):

Sparsity	Strehl
1.0	0.23
0.3	0.22
0.2	0.21
0.1	0.13

On sky test: faint star

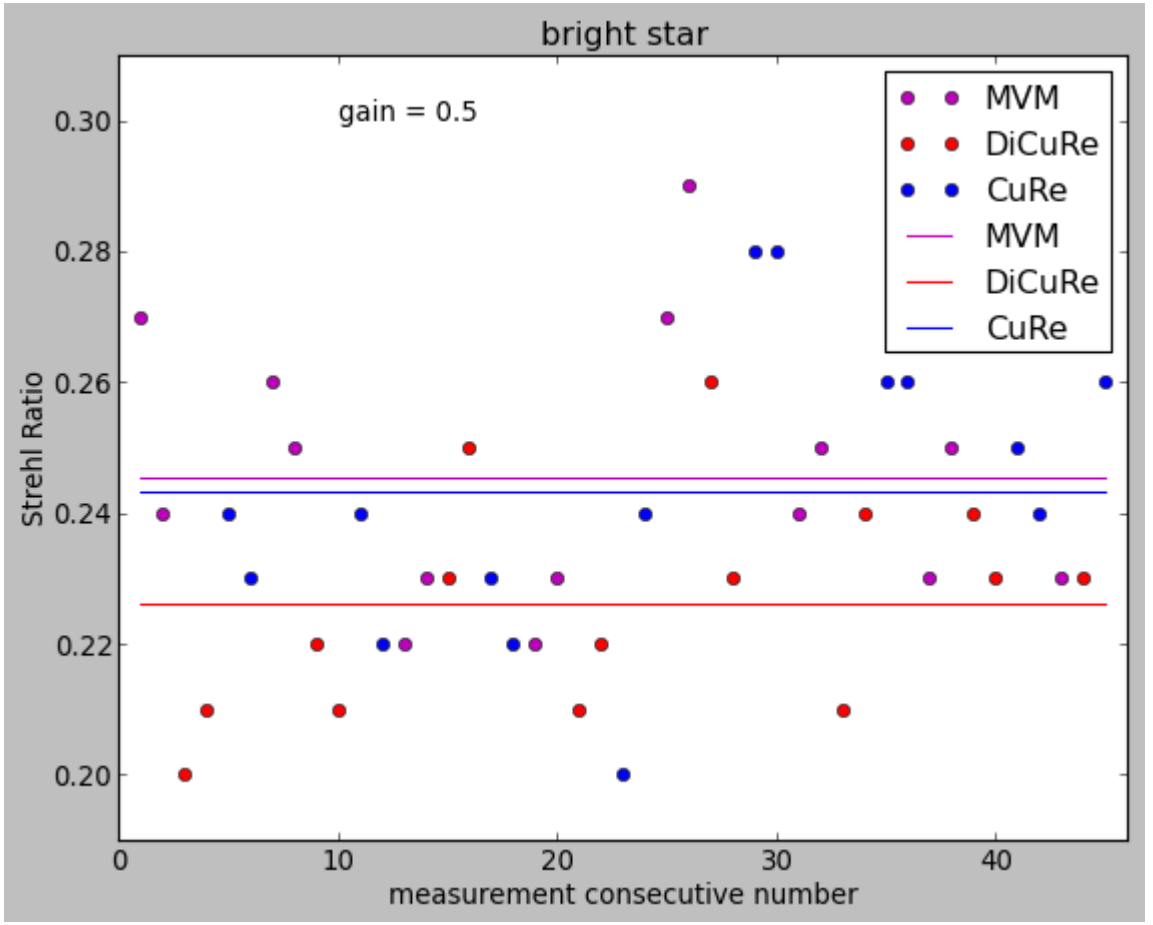


- Strehl ratio vs. time

Recon-structor	Number of measured points	average Strehl ratio
MVM	12	0.168
DiCuRe	12	0.144
CuRe	12	0.175

- Why CuRe looks better than MVM?
  - command matrix for MVM - non-optimal conditioning?
  - too low gain
- Why is DiCuRe worse than CuRe? Because under development:
  - chain alignment: two sets of chains, causing waffle
  - a bug

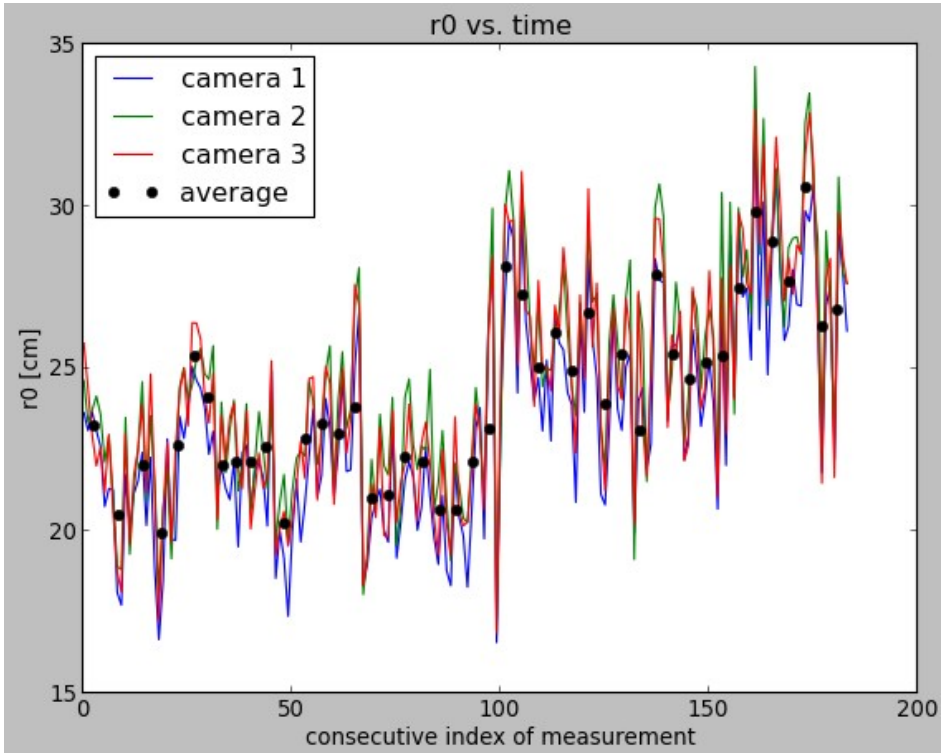
On sky test: bright star

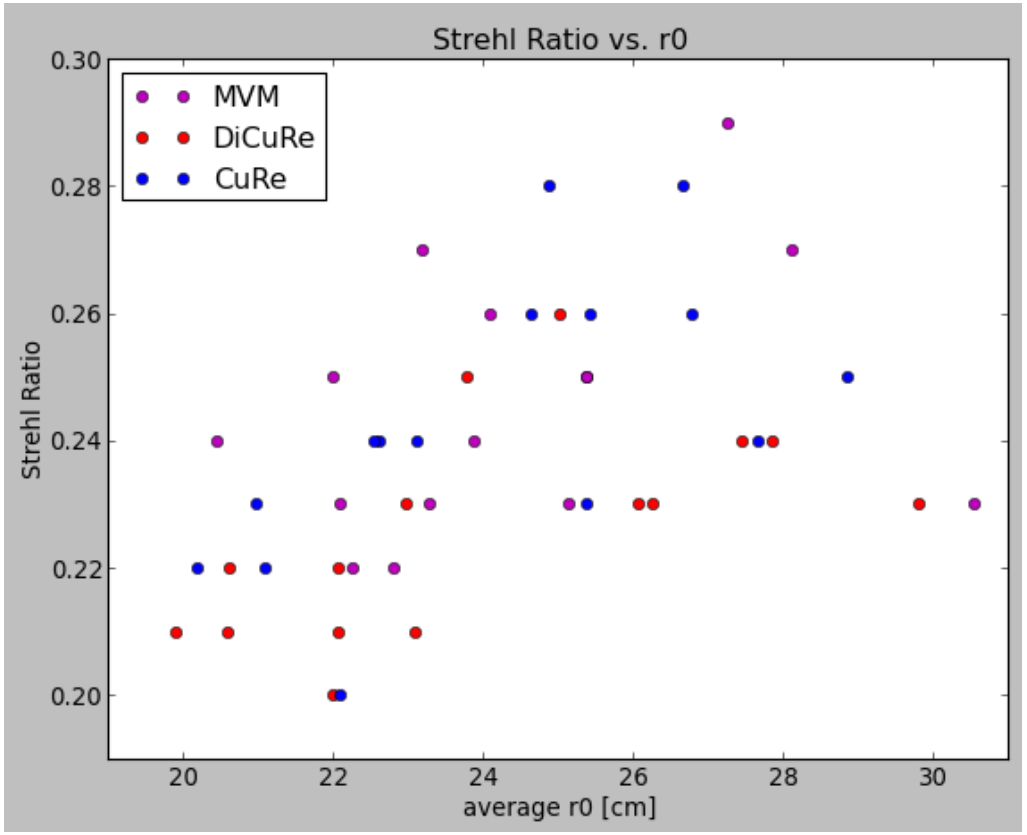


Recon-structor	Number of measured points	average Strehl ratio
MVM	15	0.245
DiCuRe	15	0.226
CuRe	15	0.243

- Strehl ratio vs. time

On sky test - bright star





- r0 vs. time
- Strehl ratio vs. r0

Future plans

- Finalise DiCuRe
- Use Durham AO RTC with Durham AO Simulation Package:
  - further tests and optimisations of DiCuRe
  - CuRe and DiCuRe - subaperture corners to actuators mapping:
    - sparsity of the mapping matrix
    - alternative methods (e.g. interpolation)

Summary

- CuRe and DiCuRe tested on the bench and on sky: run stably in a closed loop.
- DiCuRe still in the development phase.

- Strehl ratios:
  - CuRe comparable to MVM
  - DiCuRe 10-15% worse
- Timing: no attempts to compare the speed
- THANKS:
  - Matthias Rosensteiner, Andreas Obereder
  - Ali Bharmal, Alastair Basden, Tim Morris