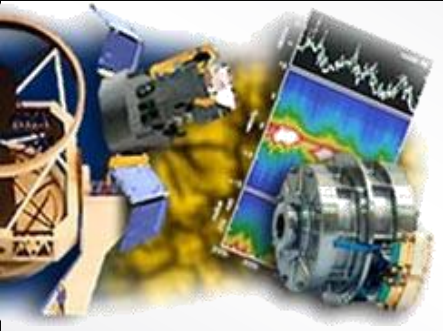

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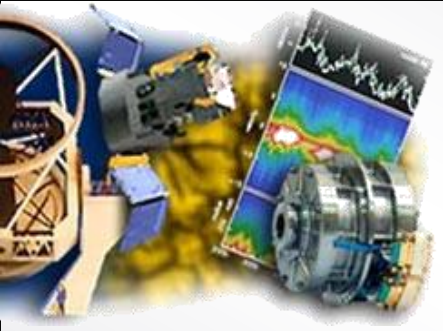
Non-common Path Aberration Compensation Using the NWIWM Method

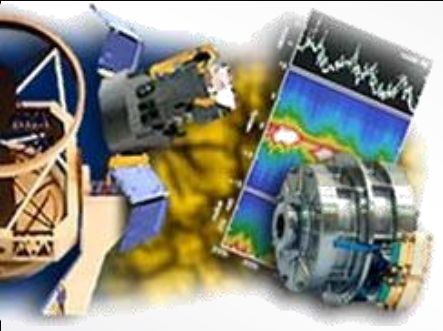
Luis Fernando Rodríguez Ramos

Javier López, Oscar Tubío, Carlos Colodro, Miguel Núñez, José Marco

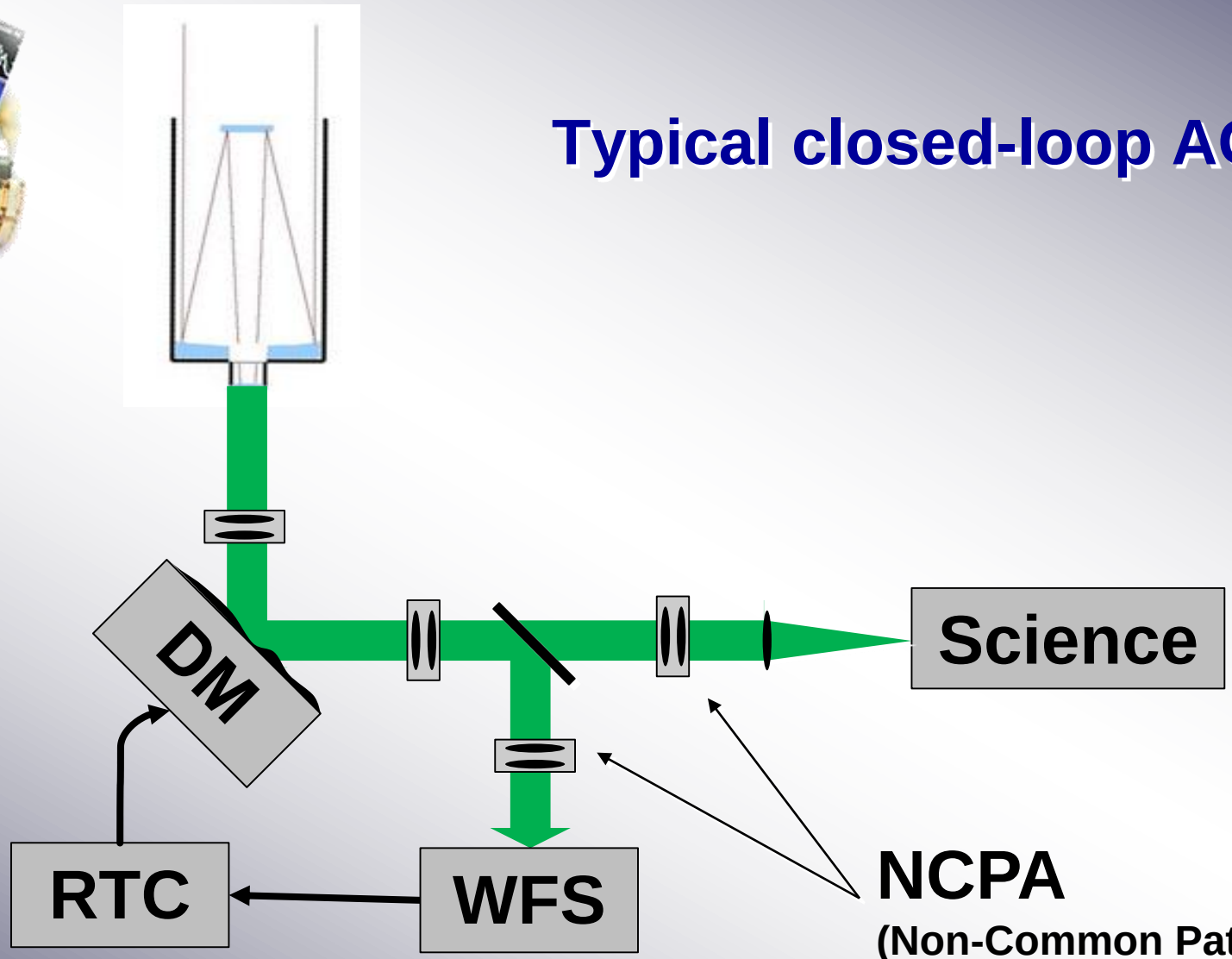


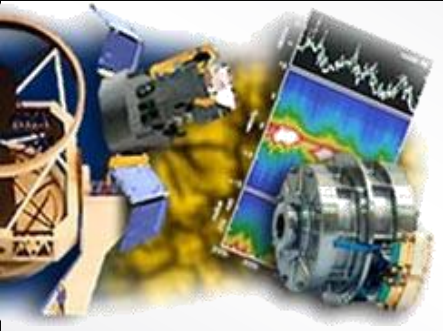
Contents

- Non-Common Path Aberrations (NCPA)
- NCPA compensation as an optimization problem
- Algorithm description
- Simulation results
- Laboratory tests
- Execution time estimation
- Future

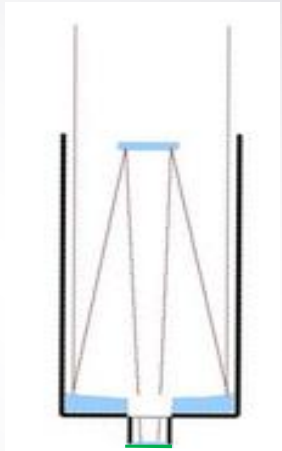


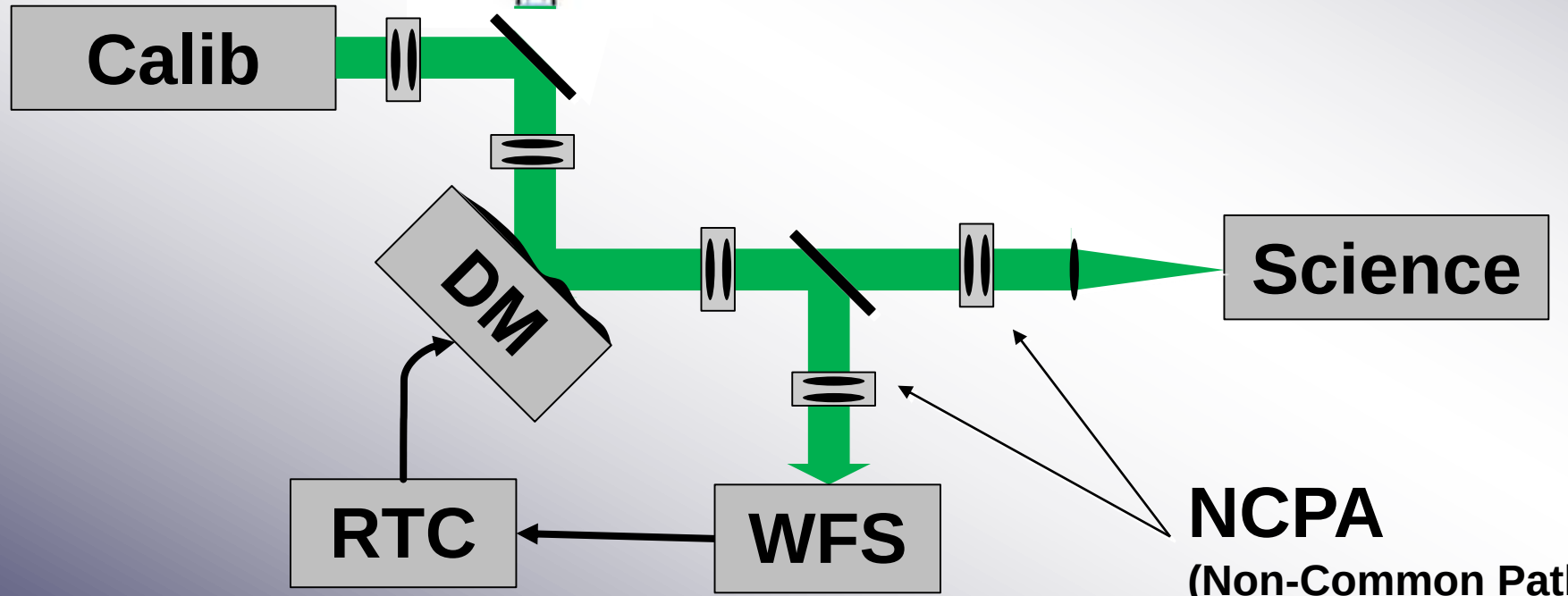
Typical closed-loop AO system layout





Closed-loop AO layout with calibration system





NCPA
(Non-Common Path Aberrations)

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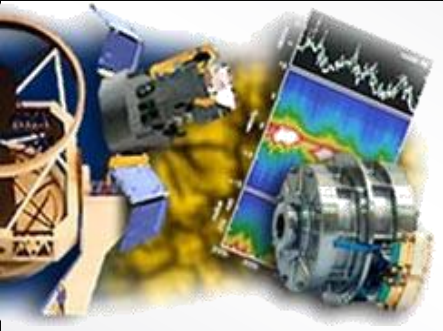
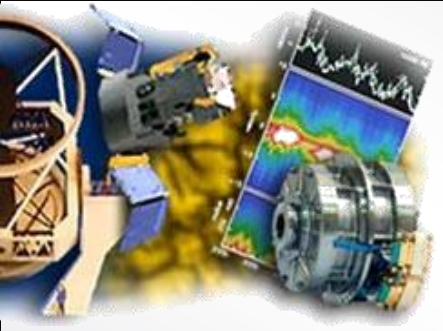


A number of [iterative] solutions…

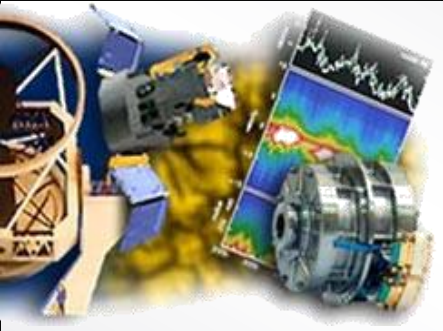
- Phase diversity
- Gerchberg–Saxton
- …

- Focal plane sharpening

  NWIWM: Noise Weighted Image Width Minimization

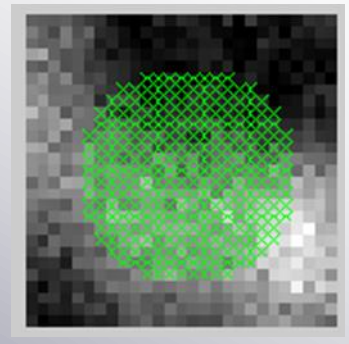


Fraction used by NWIWM



Maximizing the Encircled Energy (EE)

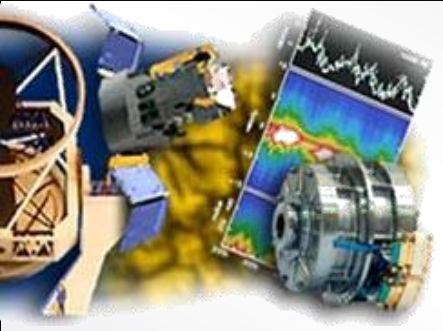
- Encircled energy, scalar function of all (N) actuators:



$$EE(a_1, a_2, \ldots a_N) = \sum_r p$$

p = pixel value
r = radius

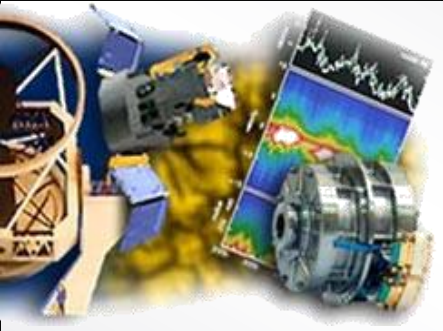
- …Extremely simple. More complex functions might also be used, like distance weighted, correlations, trying to exploit the a priori existing knowledge of the diffraction shape.



Some pre-processing always required:

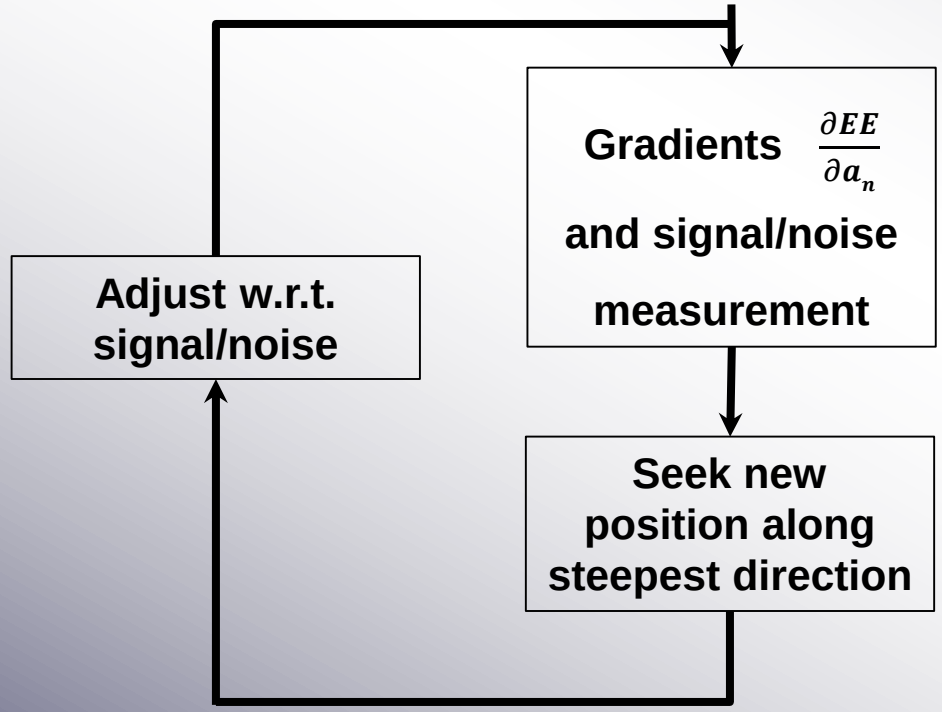
- Bias
- Flat
- Bad pixel removal
- (Threshold)
- …

- AVERAGING

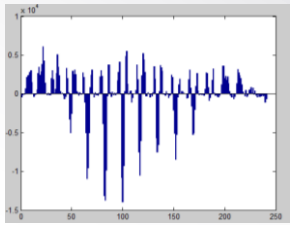


NWIWM Algorithm

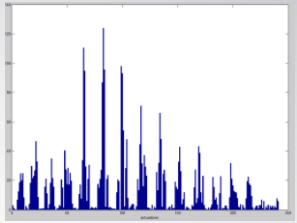
- **Keep it simple: "Steepest ascent to the EE peak"**

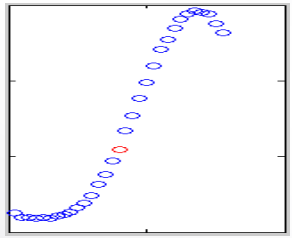


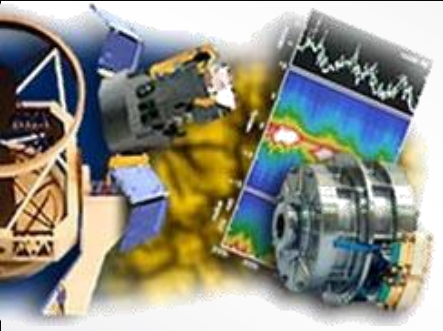
Grads



S/N

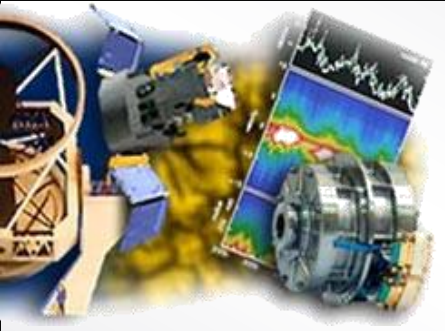






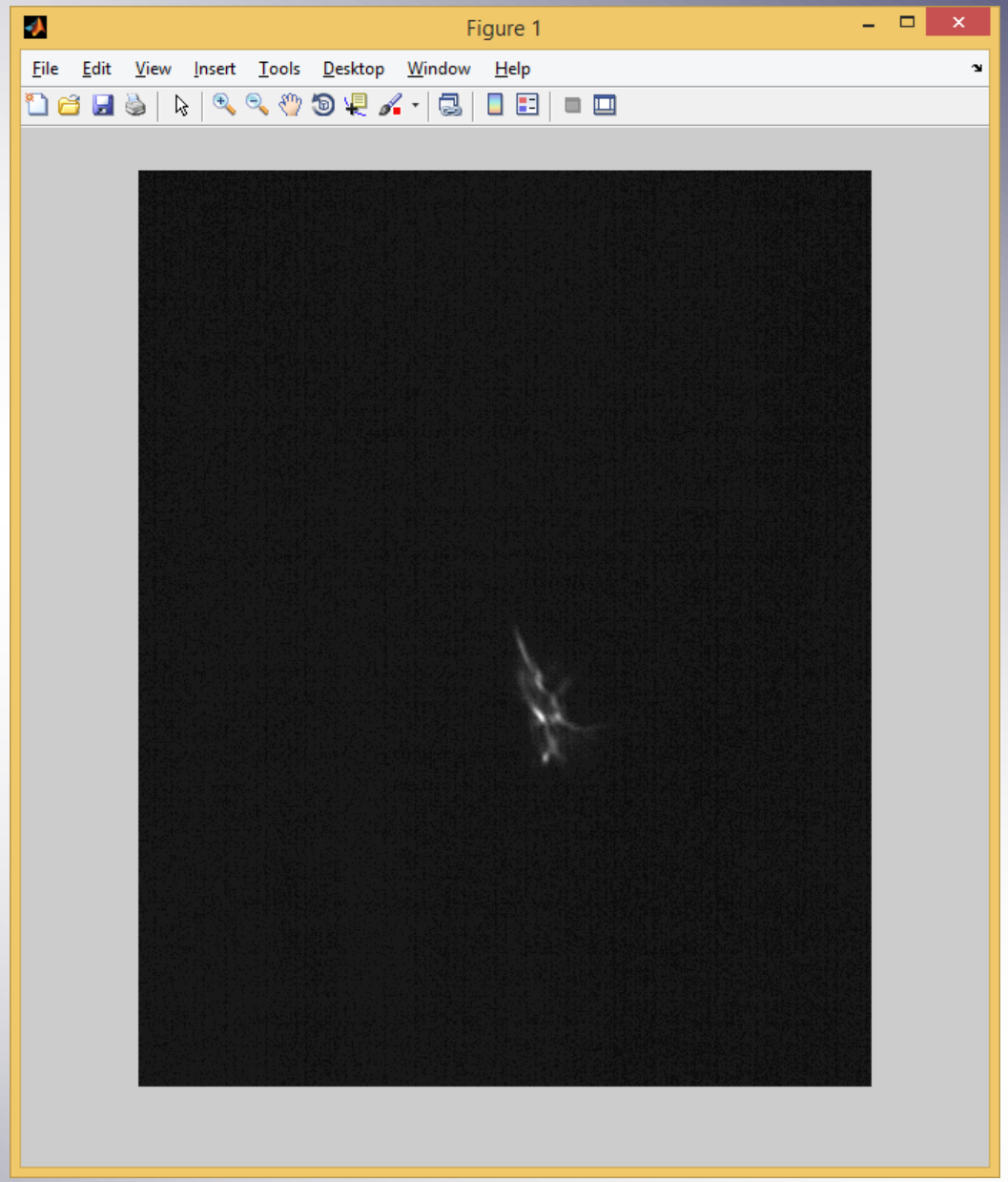
Key concepts

- Actuations for gradient measurement is adjusted using S/N values.
- New position is found using S/N information.
- No knowledge required about DM
- No WFS required



Real example:

Starting image
Zero actuation
AOLI Science Camera
(241 actuators DM)



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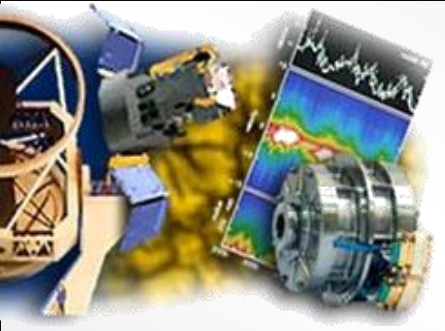
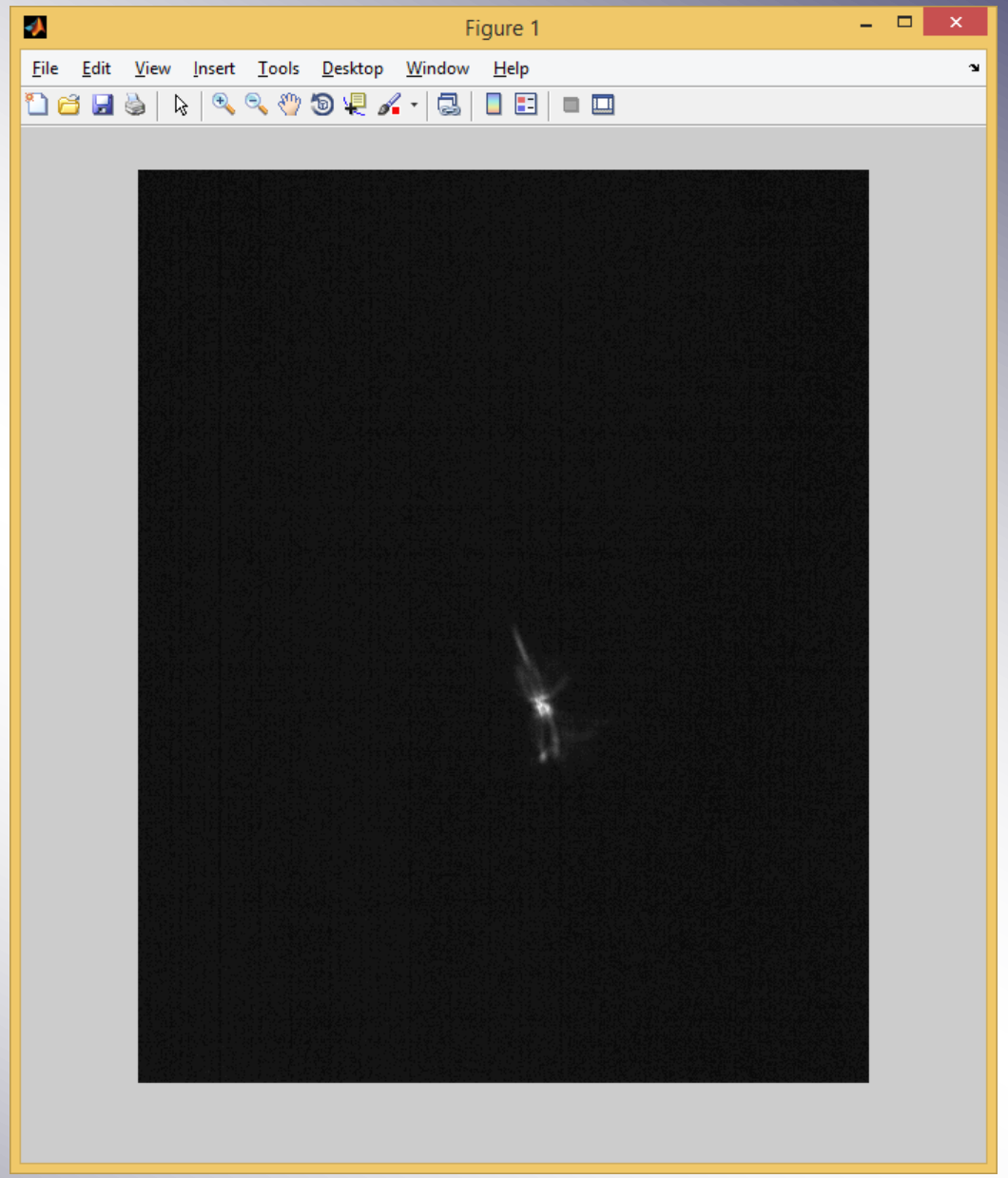


It=1



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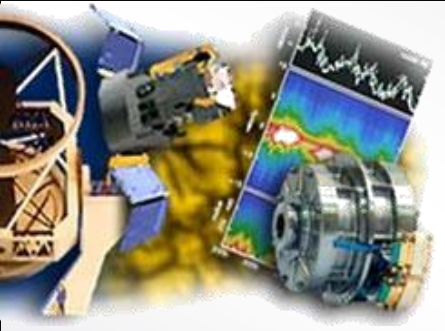

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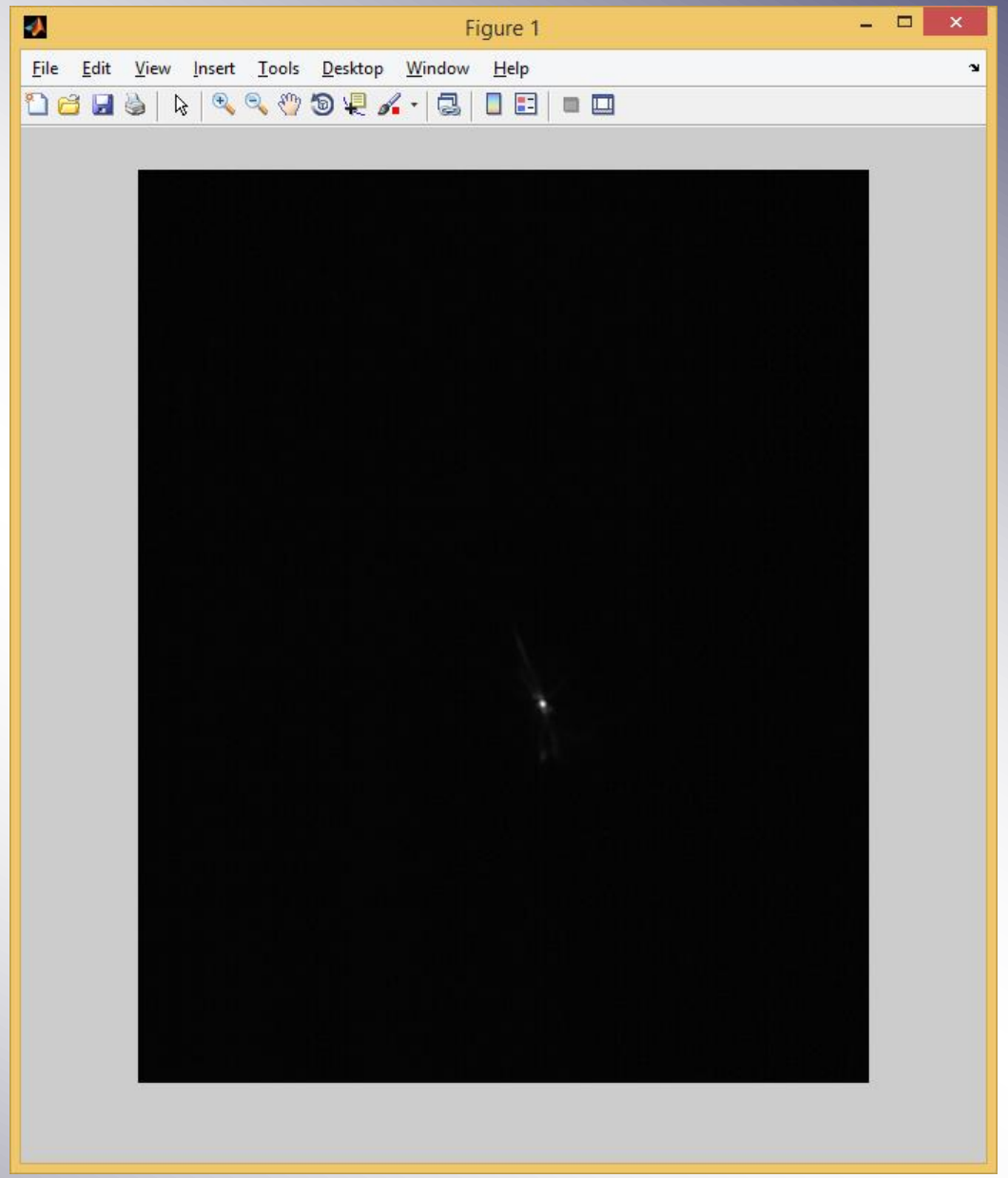

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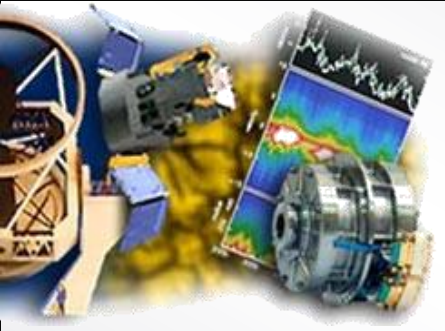

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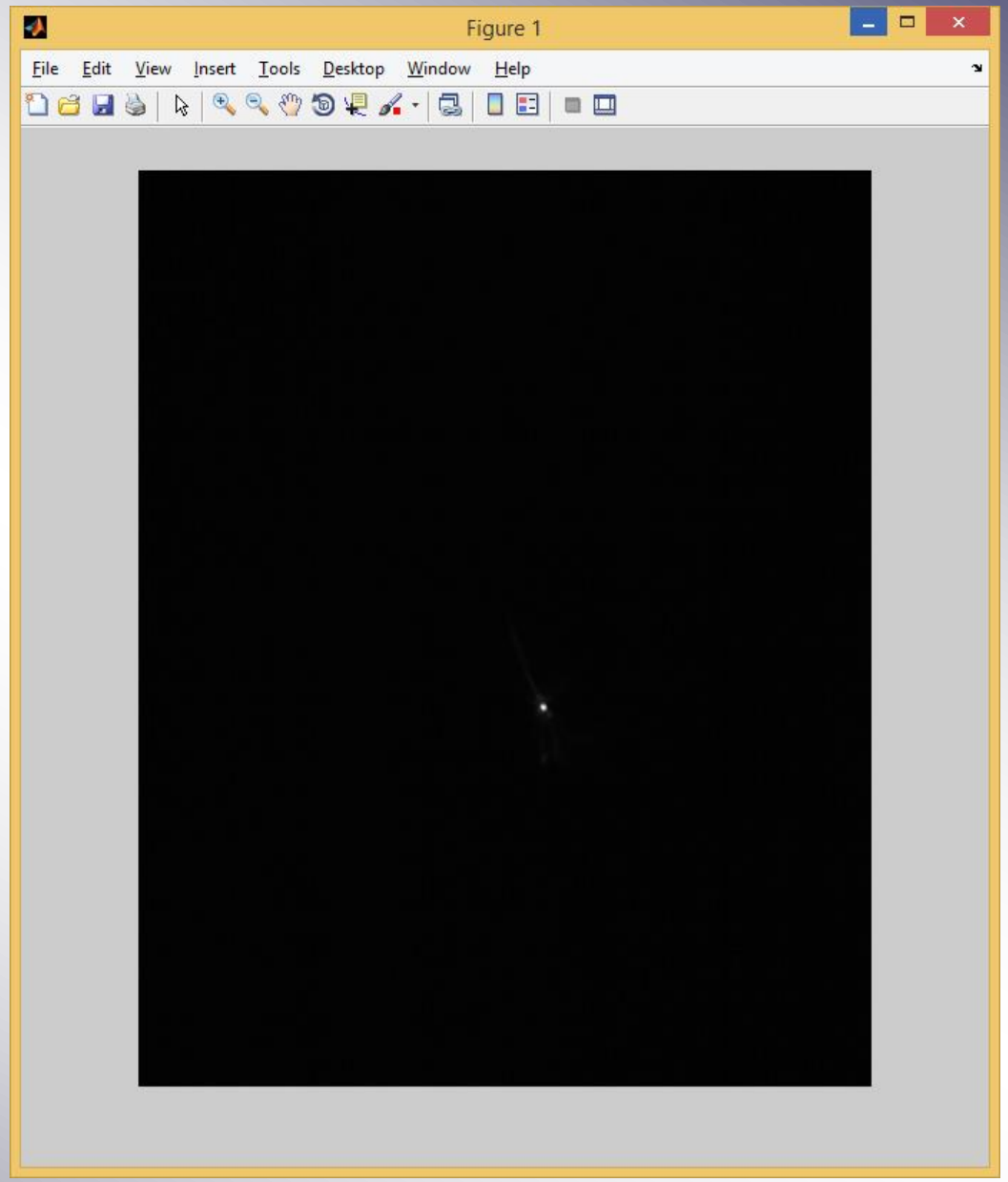

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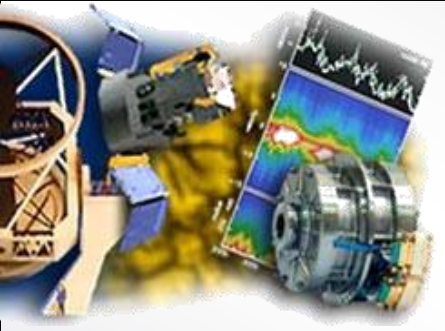
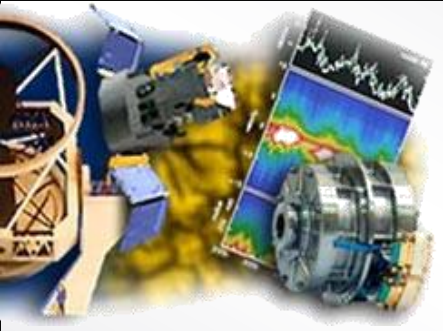
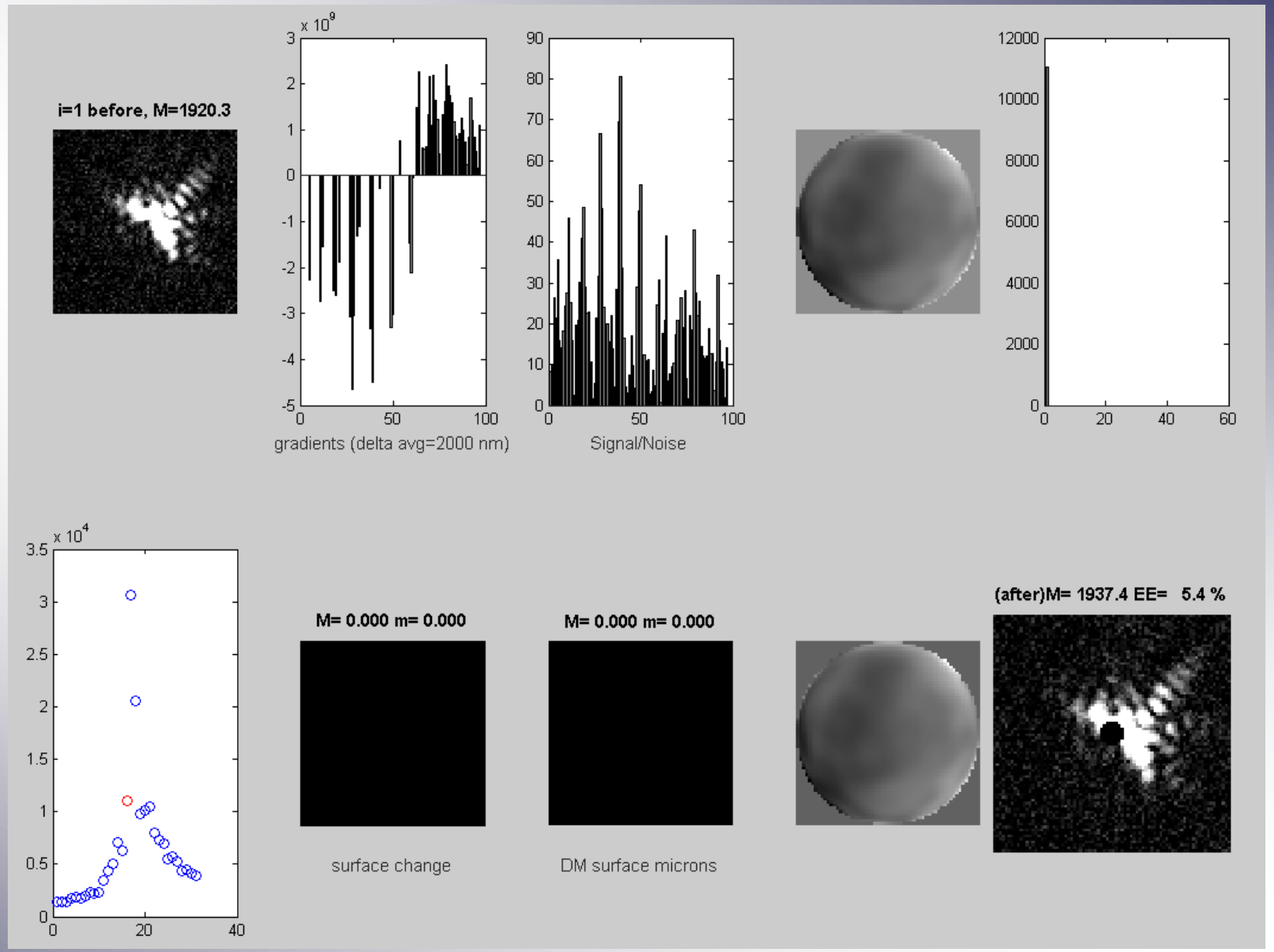


Simulation results

- **OOMAO (C. Correia, R. Conan)**
  - MATLAB based
  - Object oriented
  - Open source
  - Easy to use

- **Main parameters**
  - 97 actuators
  - Readout noise = 20 e^-
  - NCPA 200 Zernikes
  - Random amplitudes related to order number
  - Starting delta = 2 microns
  - EE radius = 4 pixels
  - Averages = 9
  - Target S/N = 3





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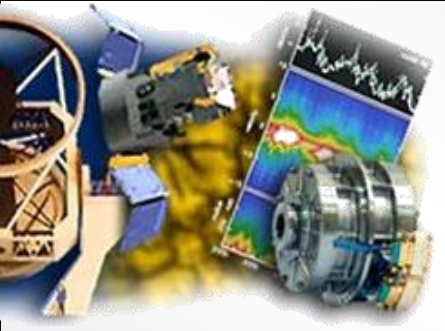

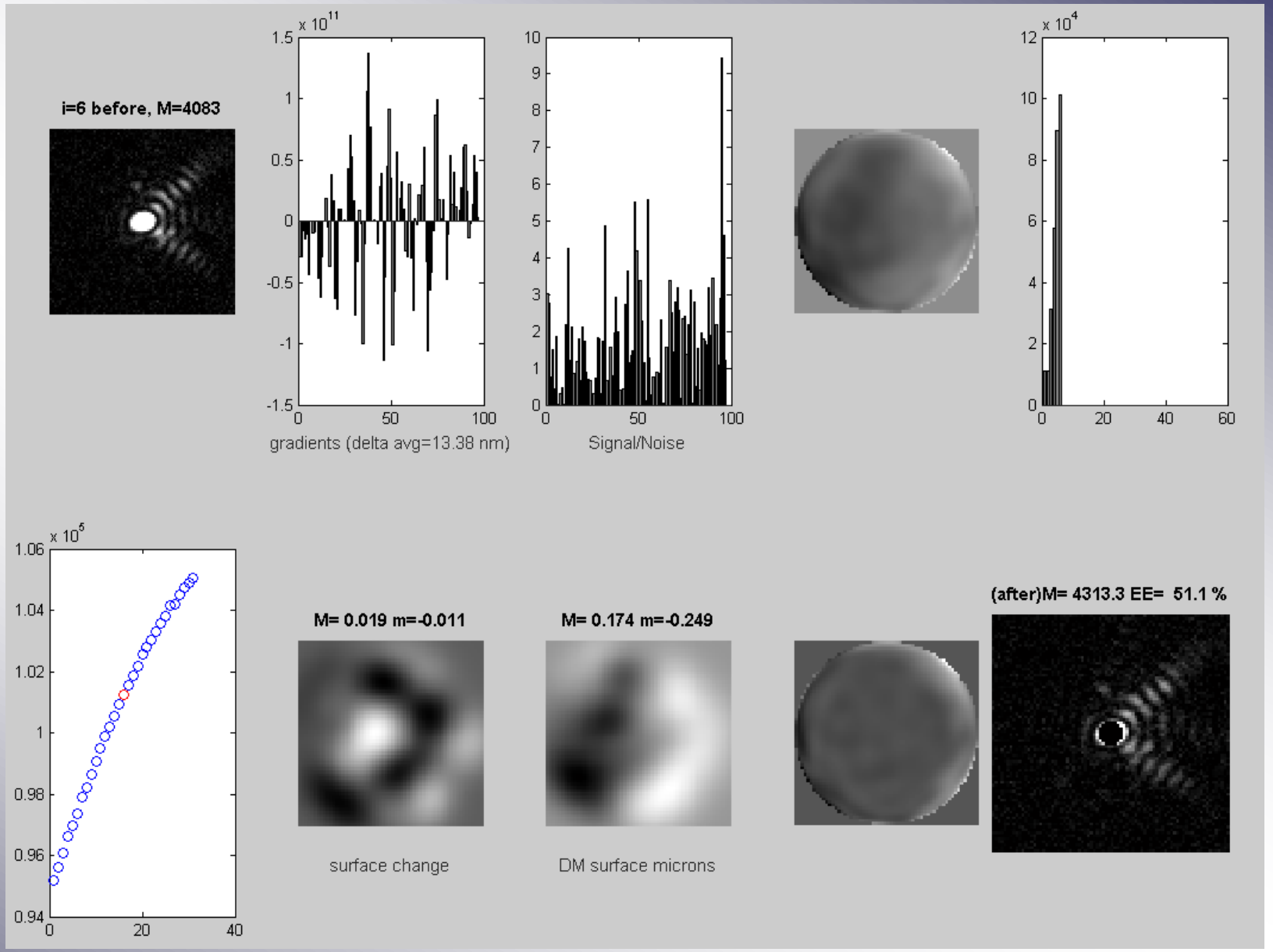

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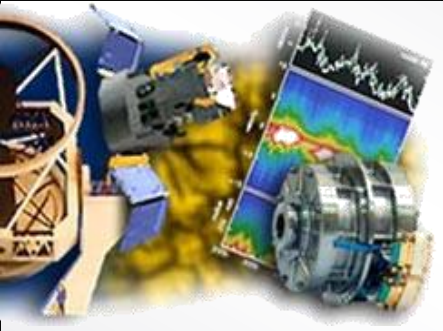

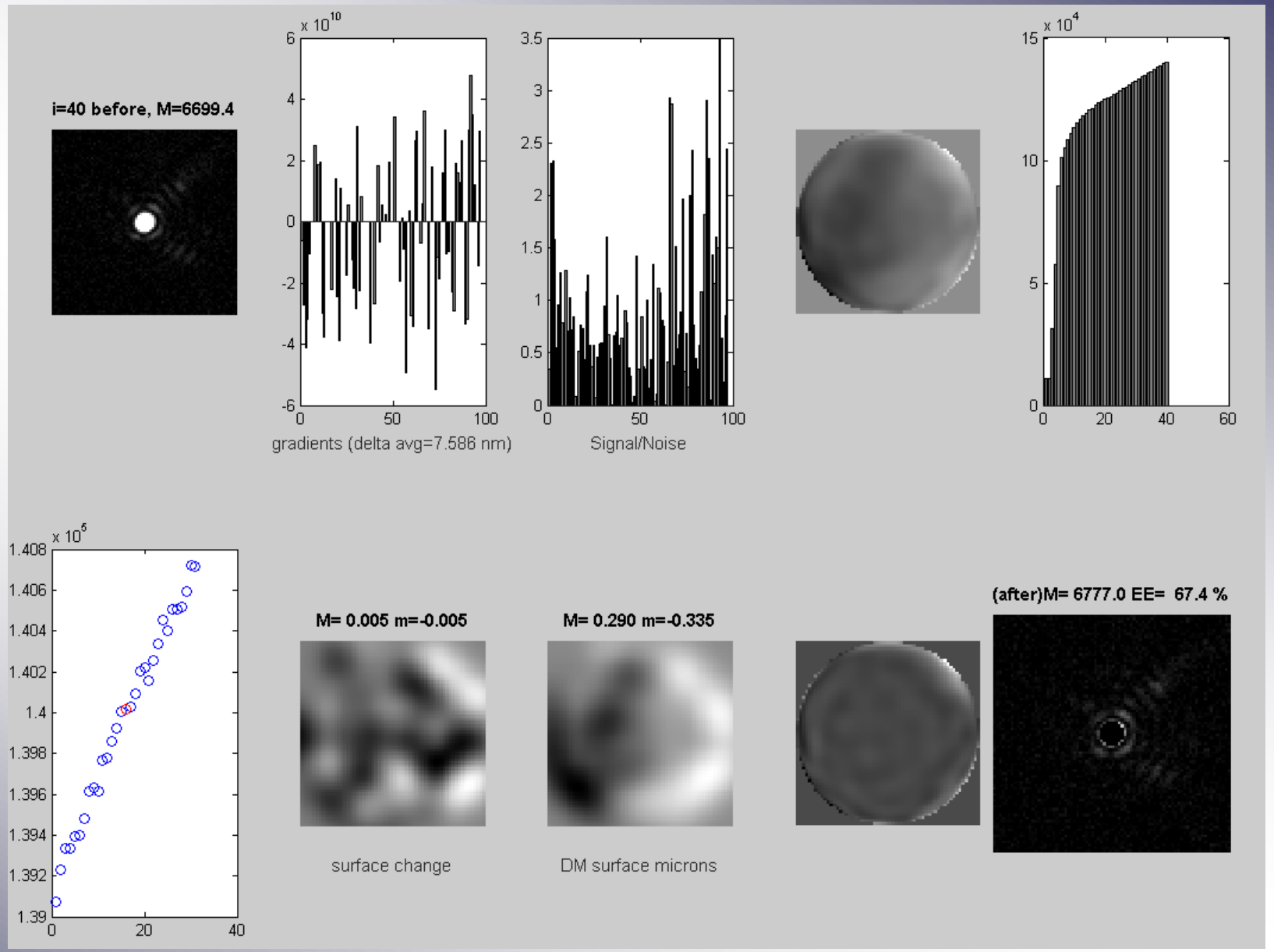

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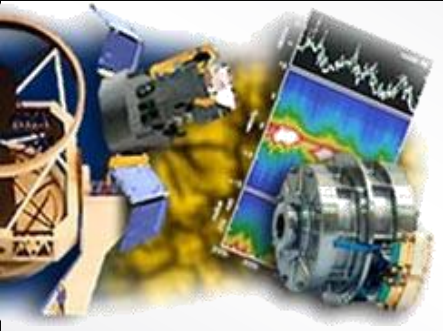
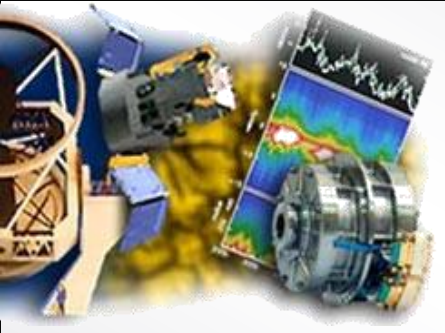
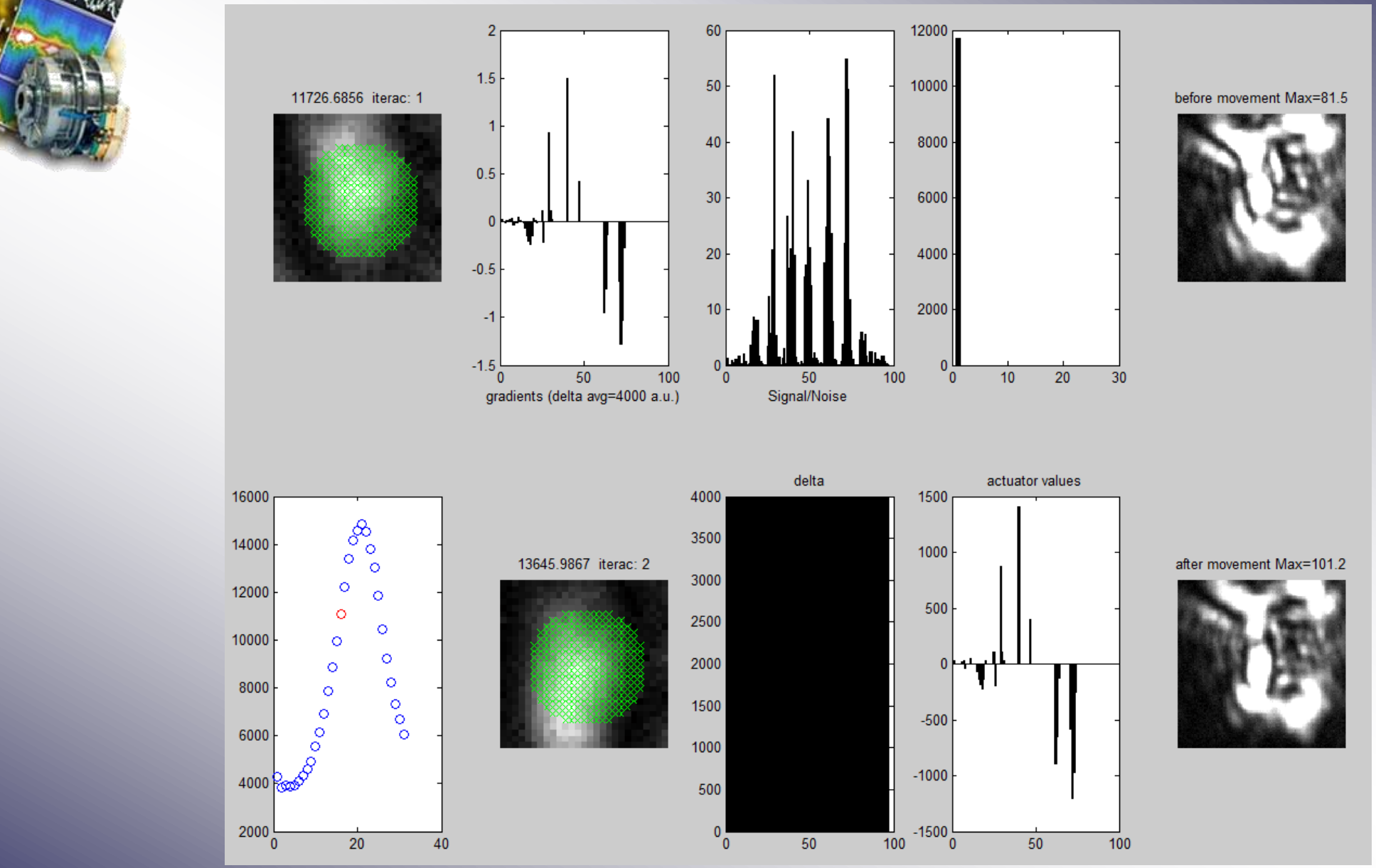


Laboratory Results

- **EDiFiSE (Equalized and Diffraction-limited field spectrograph experiment)**
  - **Prototype for AO + fibre optic equalised IFU + spectrograph**
  - **97 actuators ALPAO DM + Physik Instrumente Tip-tilt mirror**
  - **500 frames/second, 16x16 SH WFS (*not used for NWIWM*)**
  - **FPGA-based RTC controller (*only used to command DM*)**
  - **PULNIX 6740 science camera simulator, 7.4 µm pixel**
  - **Narrow band I filter**





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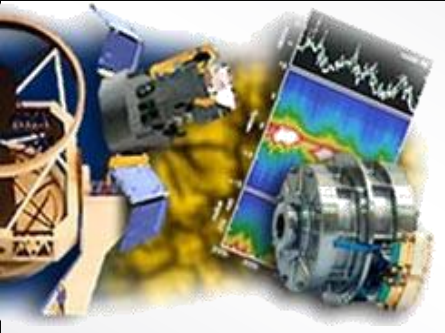

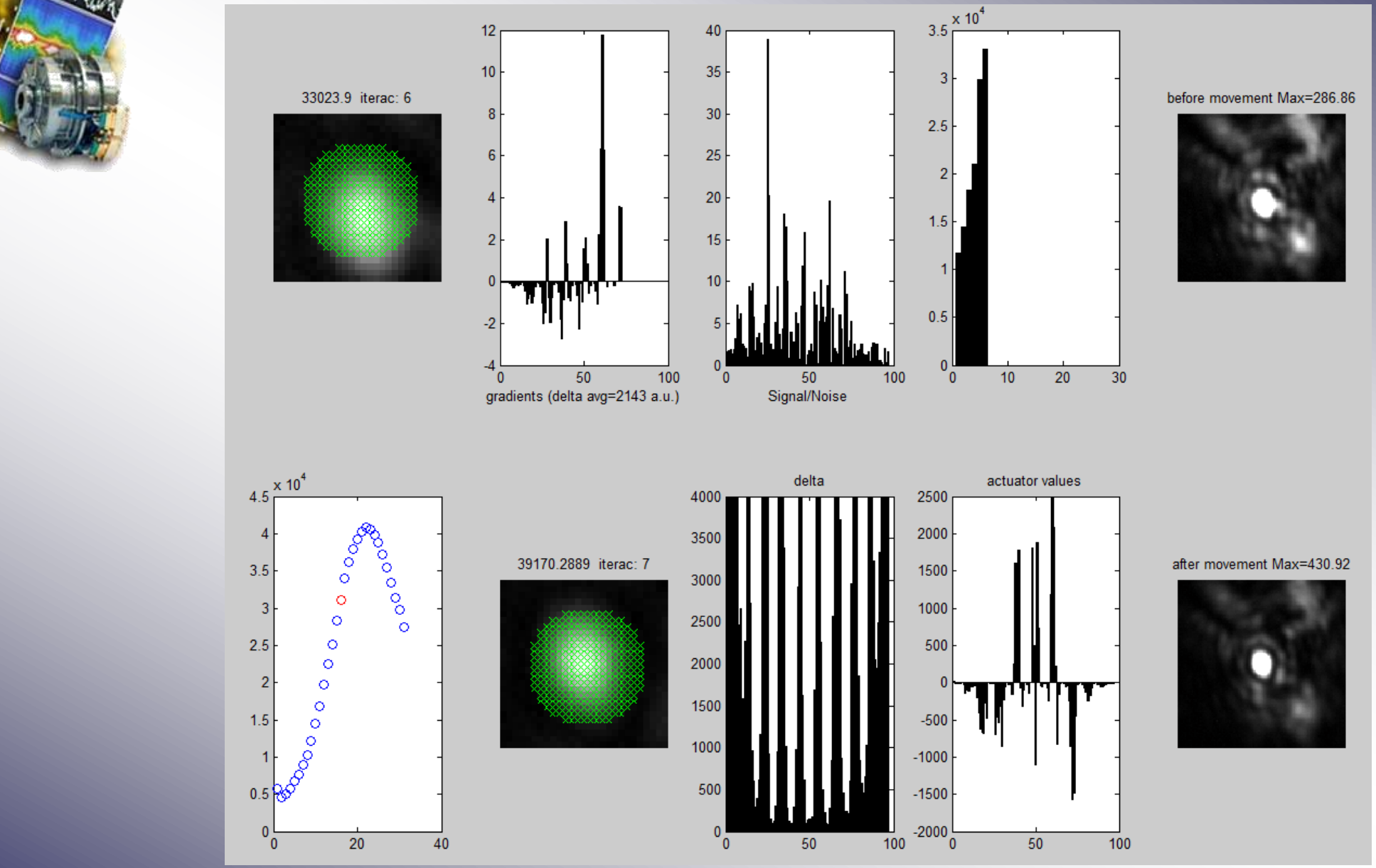

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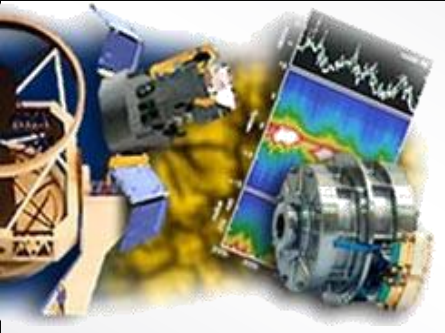

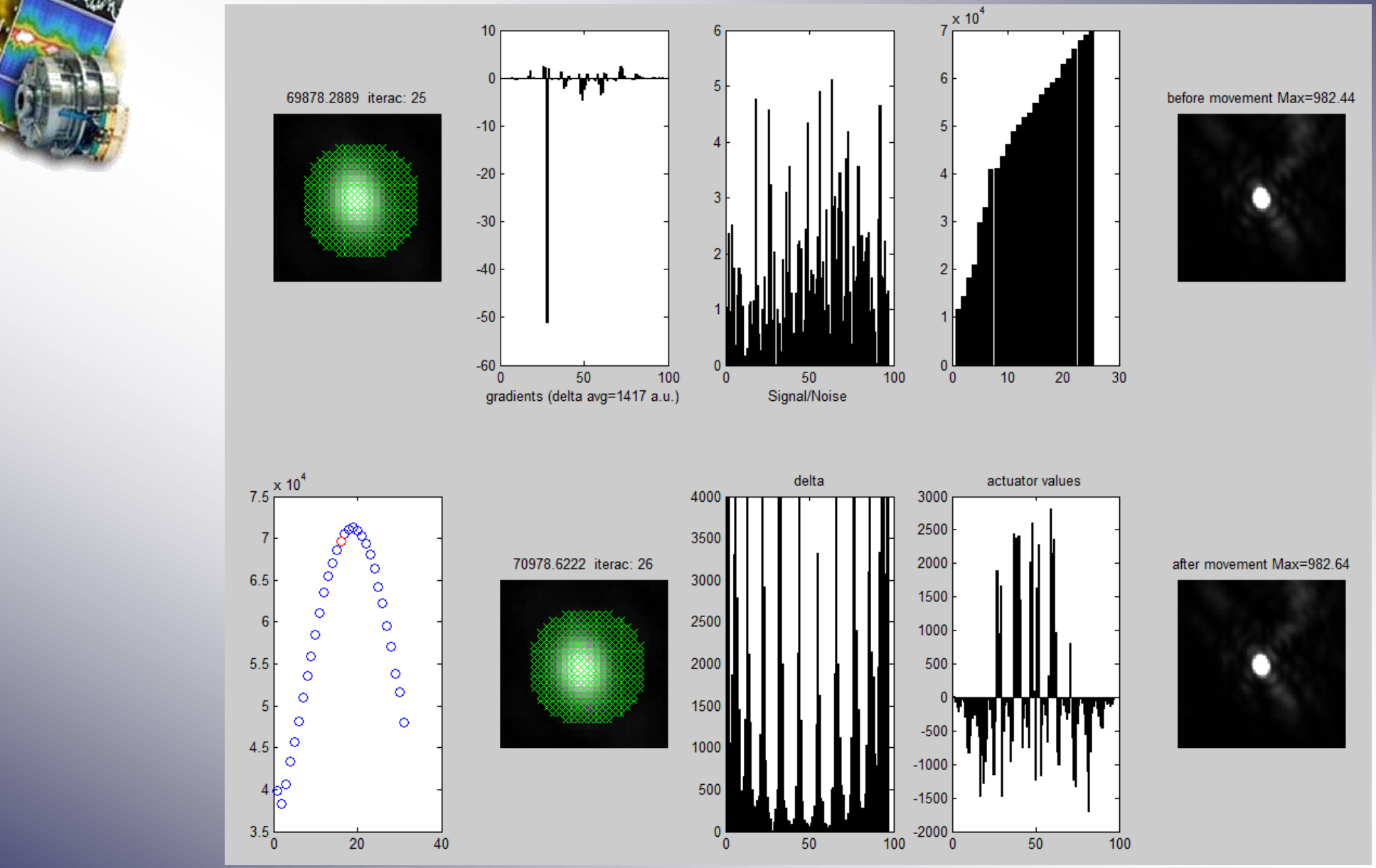

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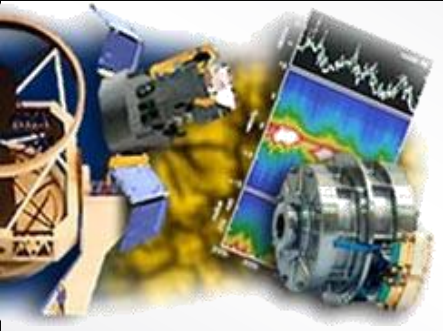
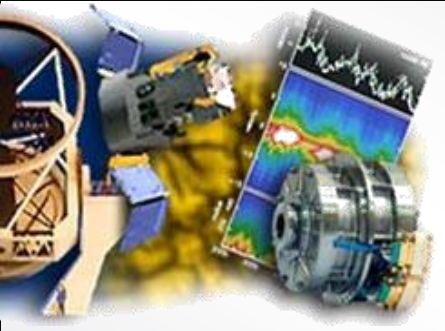


After 25 iterations:

➢ Main drawbacks:

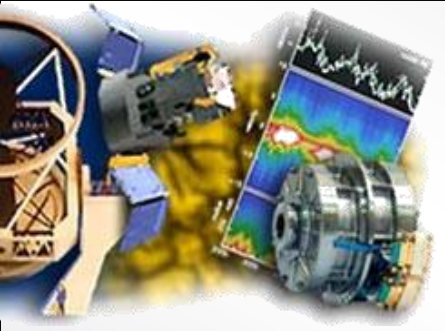
- Convergence slows near the peak
- Detector dynamic range
- Total measuring time



Execution time estimation for:

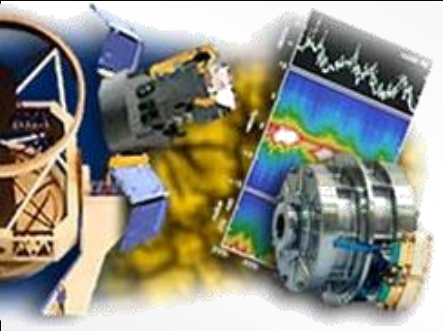
. 40 iterations
. 9 averages
. 3 exposures for DM stabilization
. 500 images/sec

	OGS	WHT	GTC	ELT
size (m)	1	4,2	10	39
Estimated Number of actuators	97	241	373	5000
Exposures per iteration	2733	6189	9357	120405
Total (secs)	219	495	749	9632
Total (mins)	4	8	12	161

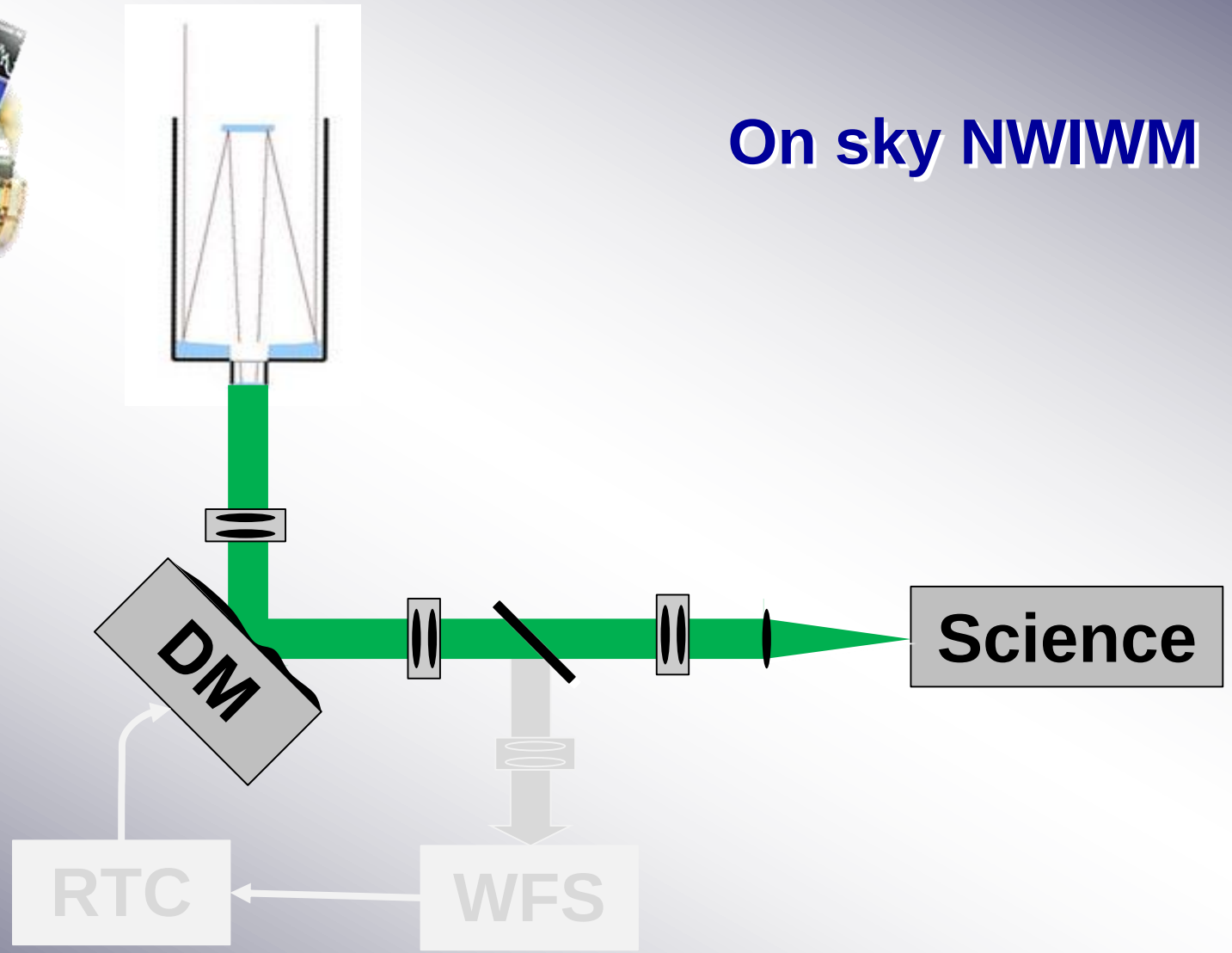


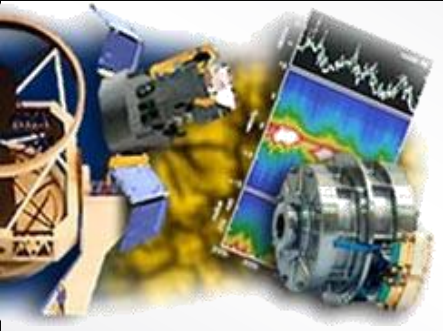
Future

- **Extended simulations.**
  - Target S/N, seek length, number of actuators…
- **Algorithm improvement.**
  - Conjugated gradients, correlation, distance weighted energy,…
- **Comparison with other algorithms**
  - Phase diversity…
- **Extended laboratory tests**
  - Possible use in EDIFISE, AOLI, GTCAO…others?
- **On sky NWIWM**
  - Directly using bright stars to evaluate PSF, by Lucky Imaging, Speckle Reconstruction,…



On sky NWIWM





Thanks!