Exploring the Low Wind Effect: Results from simulated, experimental and on-sky data

Carlos M. Correia, on behalf of **Masen Lamb**

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LAM
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DE MARSEILLE

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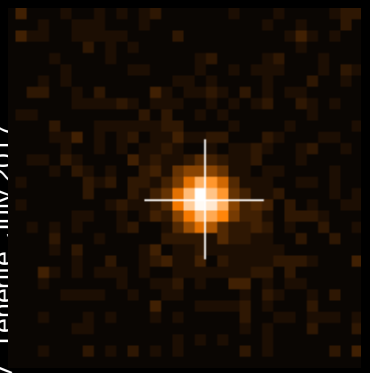
Initiative d'excellence Aix-Marseille

Discovery of low wind effect

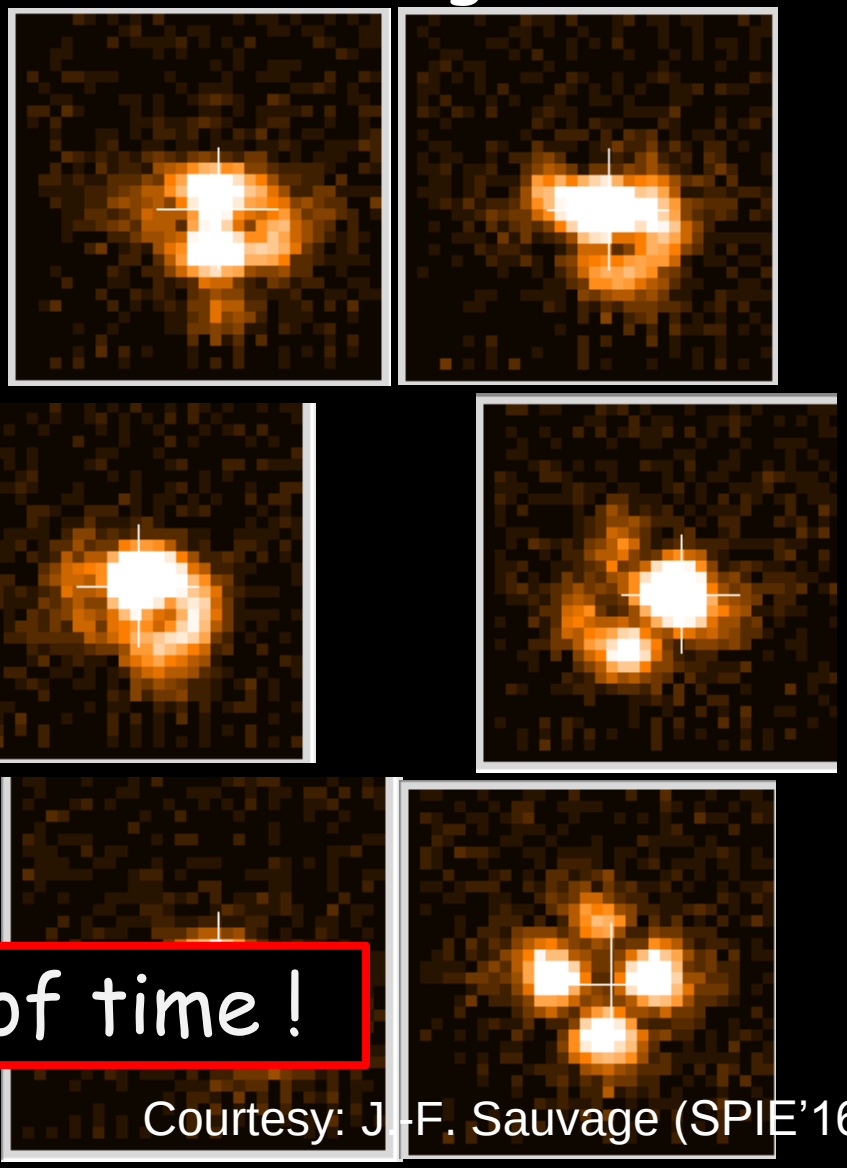
DTTS
H-band imager

No Effect



Typical Effect
"Mickey ears"

Strong cases

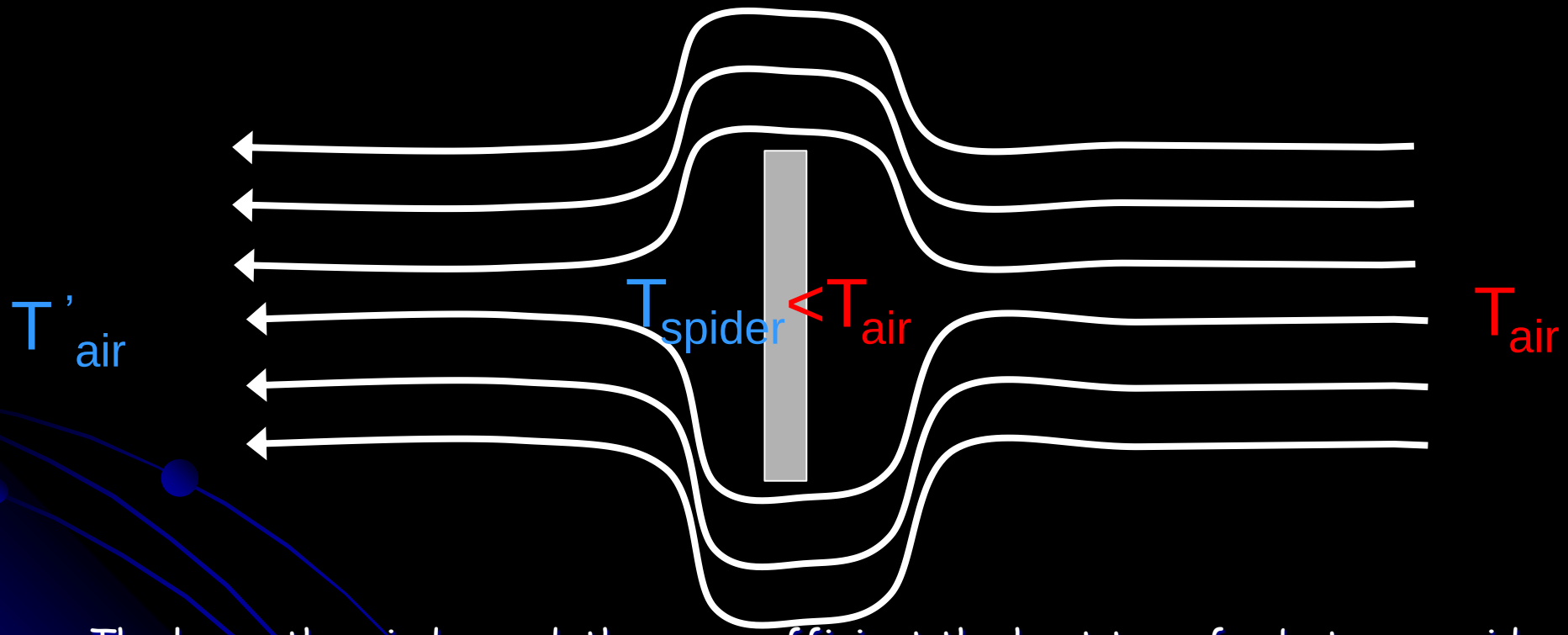


☹☹ affects 15-20% of time !

Courtesy: J.-F. Sauvage (SPIE'16)

Physical origin of the problem: heat exchange

- Scenario today: temperature difference around the spider



- The lower the wind speed, the more efficient the heat transfer between spider and air
- **1 degree difference, 1m height is enough to create 800nm OPD**
- Temperature measurement at Paranal, UT3
- ESO-validated (M. Brinkmann et al)

Courtesy: J.-F. Sauvage (SPIE'16)

Solutions ?

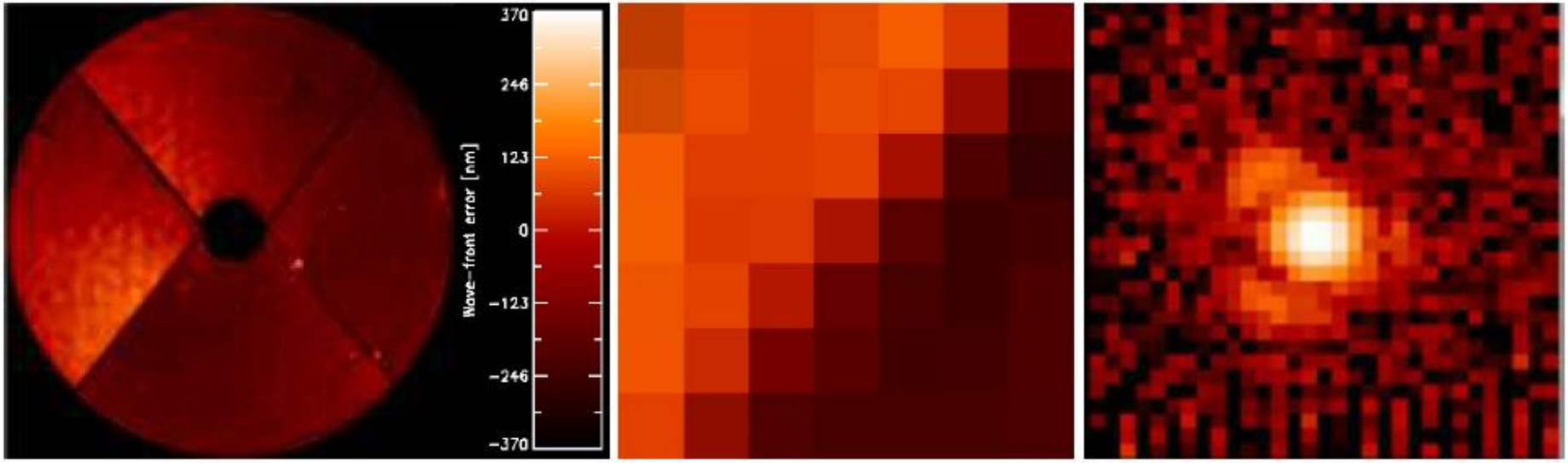
- Corrective actions:
  - Act on spider radiative transfer (ongoing)
    - Simple modification : radiative-friendly painting
    - Ideal solution for UV – VIS – NIR – IR ?
  - Monitor LWE during observation
    - Flag science data with a LWE-criterion => Sort science data according to LWE criterion
  - Precise measurement (focal-plane WFS ? Else ?)
    - DTTS ?
    - Zernike ?
  - Use XAO system to apply correction if needed ?
- Preemptive actions:
  - Act on local air flow inside telescope (windows…)
    - Increases wind speed at spider => Not ideal
  - Active spider temperature (to fit the air temperature)
    - Additionnal turbulence around spider ?
    - IR emissivity !
  - Modification of spider profile
    - Easier when telescope in design phase

Courtesy: J.-F. Sauvage (SPIE'16)

The Low Wind Effect

- Primary goal : Detect and Quantify amplitude of LWE during OP
- Secondary goal : measure LWE and handle with AO loop during OP

- Proposed scenario : use DTTS image (H band)
  - Always detected in visual inspection
  - DTTS close to coronagraph : direct link with image quality



Zelda measurement

>> M. N'diaye's talk

DTTS imager

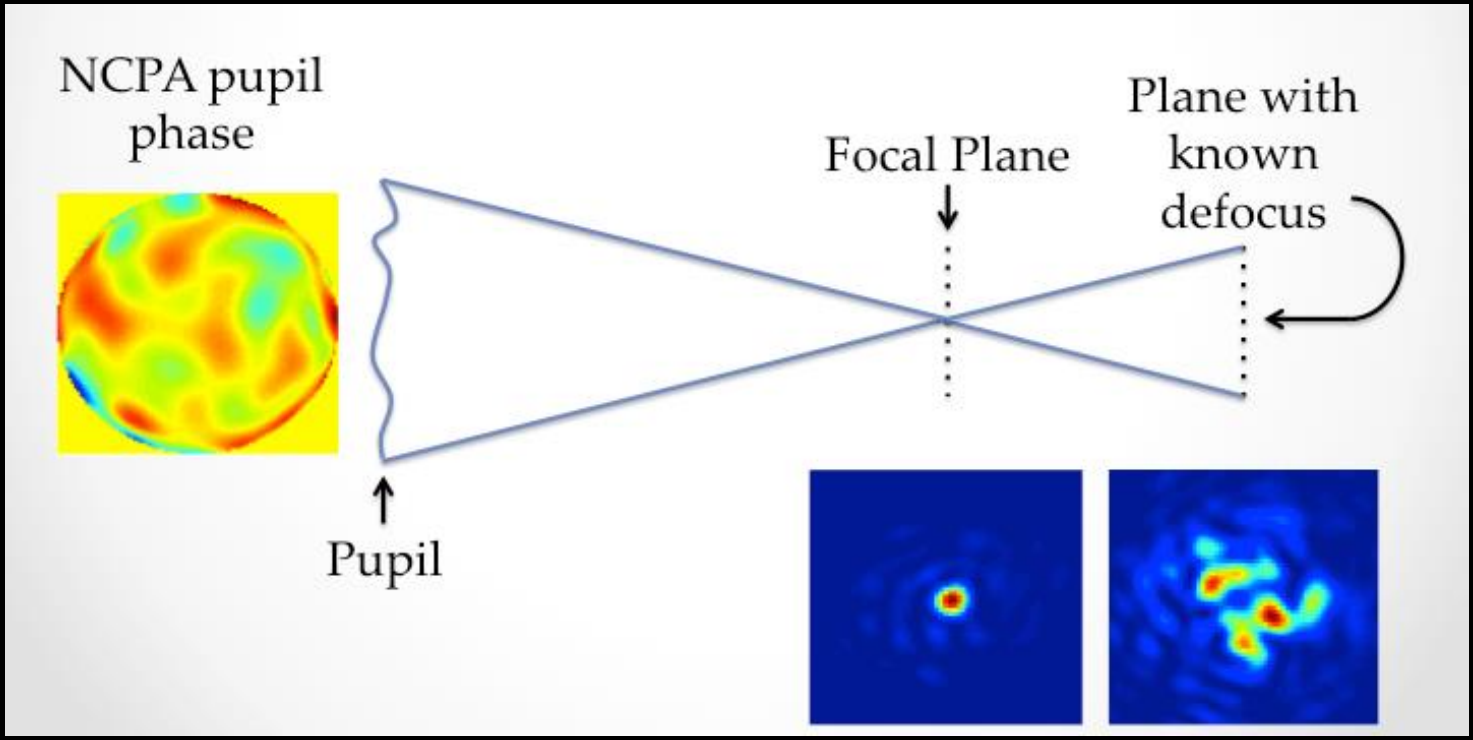
Masen Lamb et al,

Phase Diversity

- **Use the DTTS image "as-is" and estimate LWE-generated phase using phase diversity**

$$\emptyset = \emptyset_{LO} + \emptyset_{PTT}$$

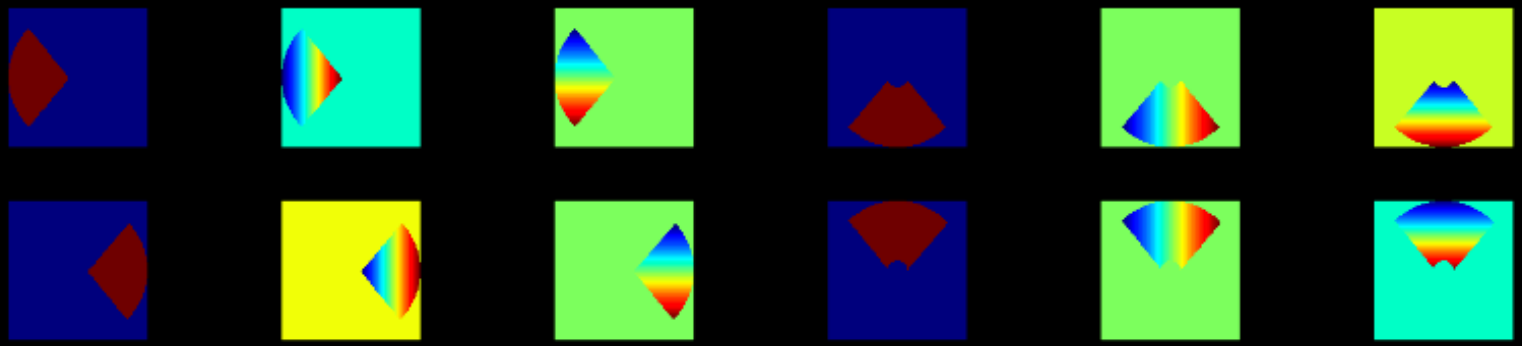
$$J(\emptyset_{PTT}) = \|i_{DTTS} - m(\emptyset_{PTT})\|^2$$

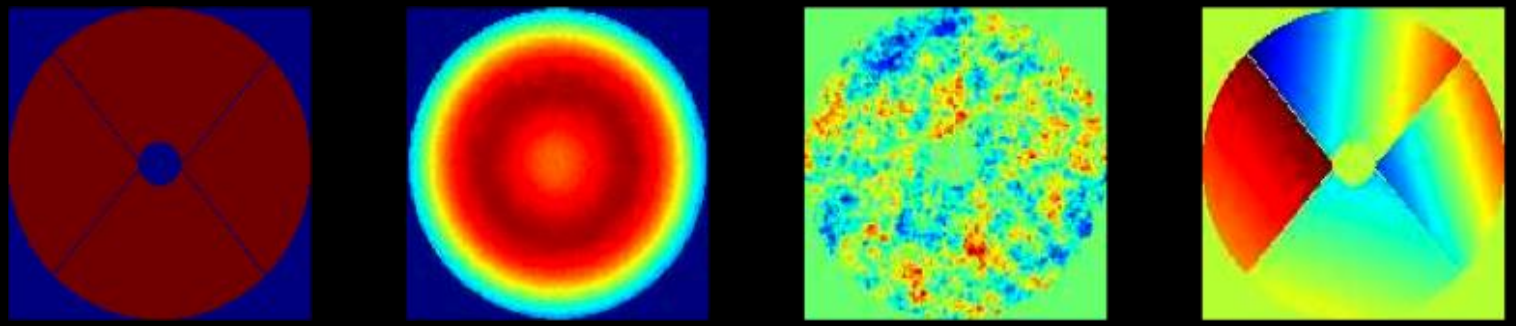


Lamb et al, JATIS 2017

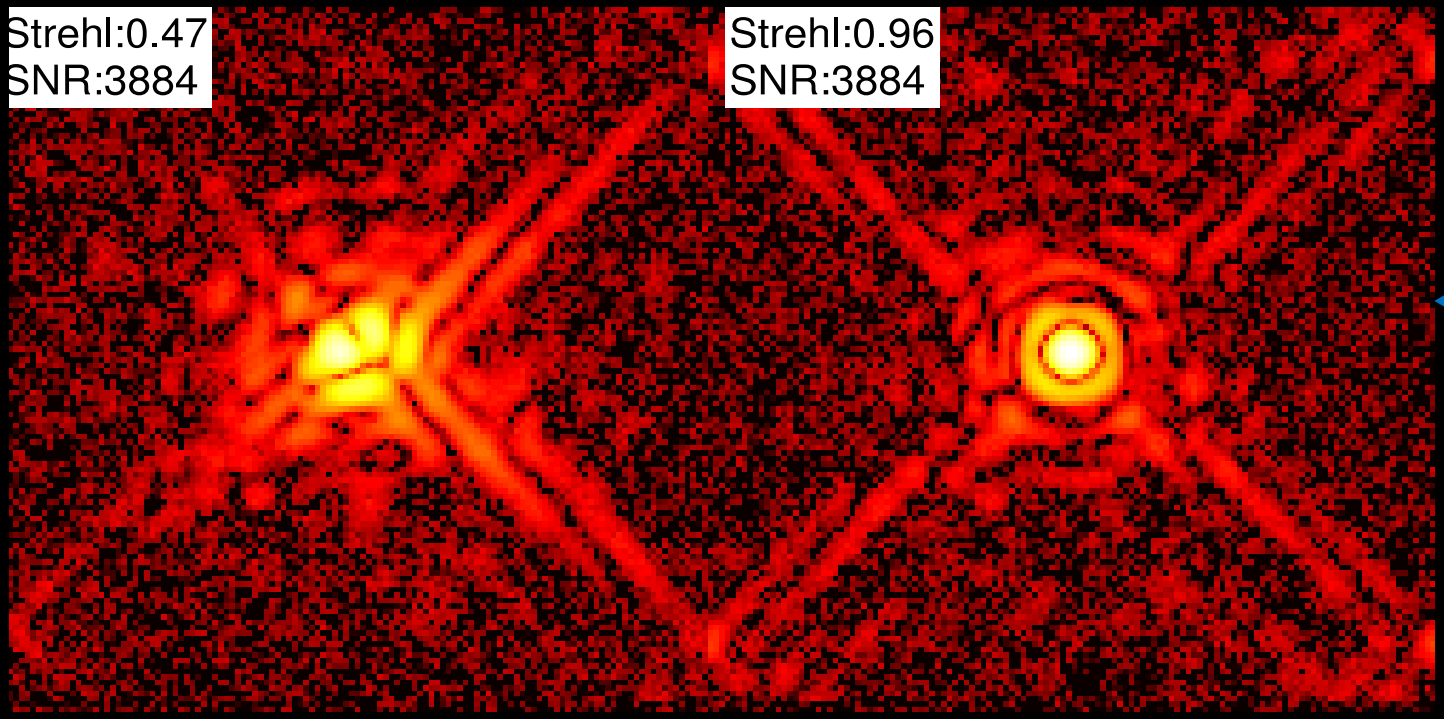
Simulation

- Use combination of disk-harmonics and LWE-specific basis (piston-tip-tilt) over each petal





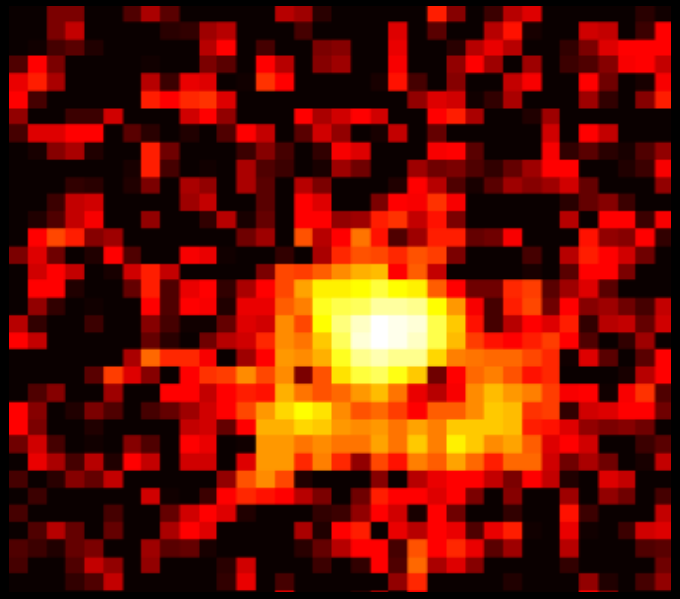
VLT pupil	Apodisation	NCPA (~40nm)	LWE

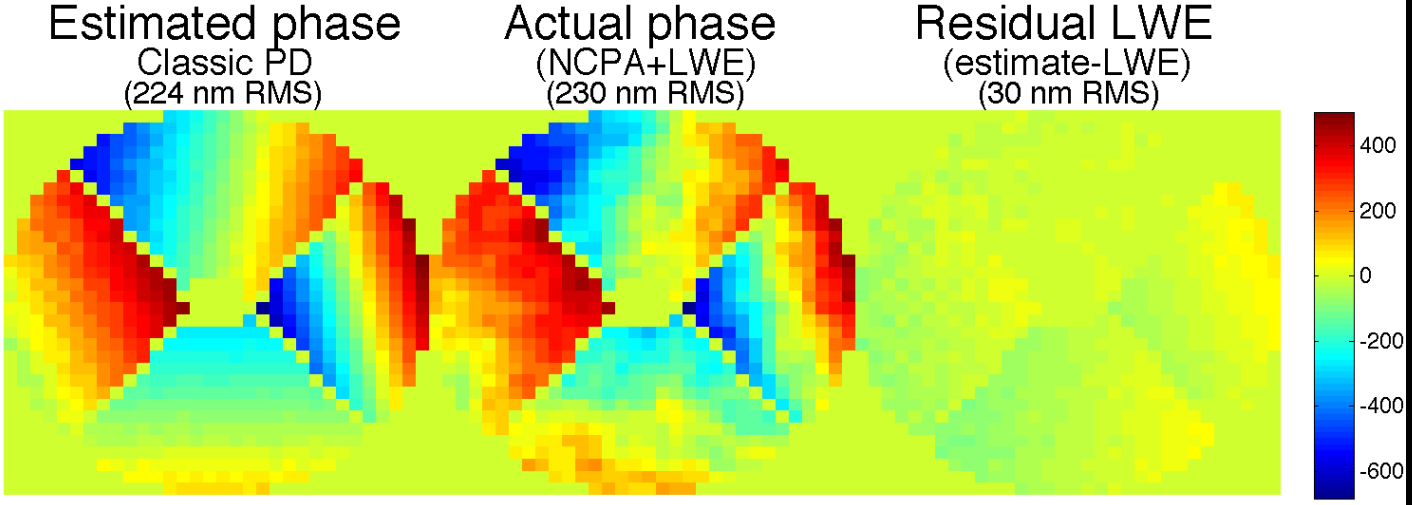


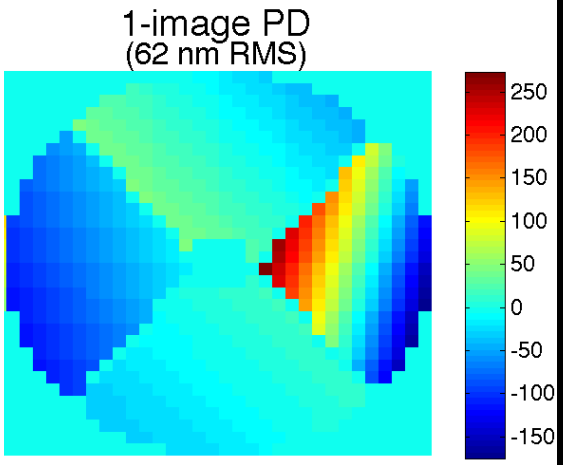
‘Classic PD’
(2 images, obj. estimation

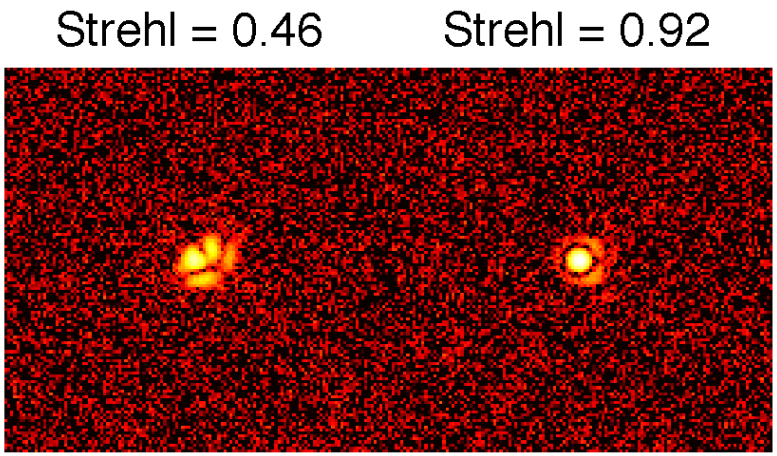
What about using a single image?

20 nm RMS focus
(actual DTTS data)



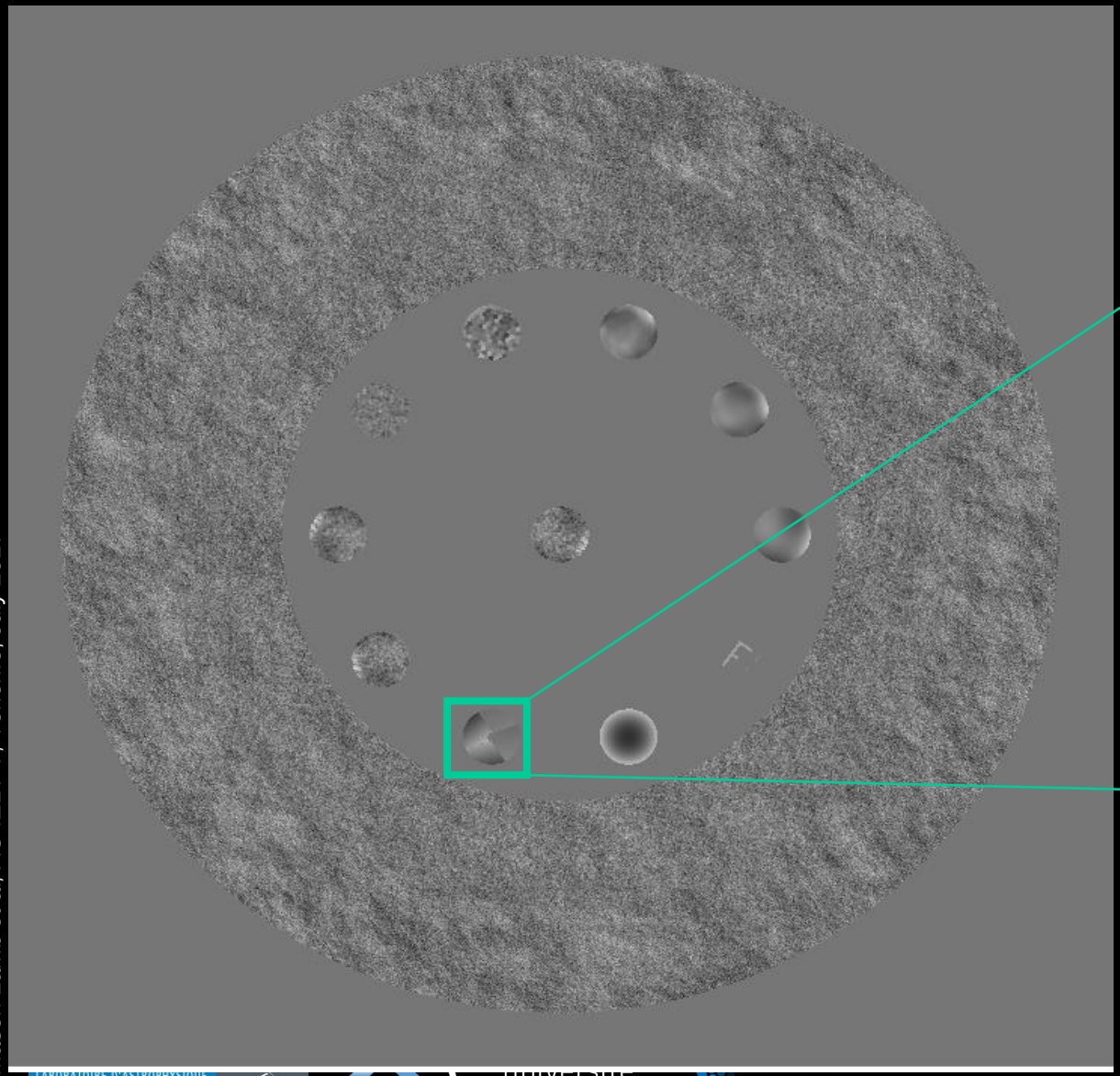

Estimated phase
Classic PD
(224 nm RMS)
Actual phase
(NCPA+LWE)
(230 nm RMS)
Residual LWE
(estimate-LWE)
(30 nm RMS)
400
200
0
-200
-400
-600

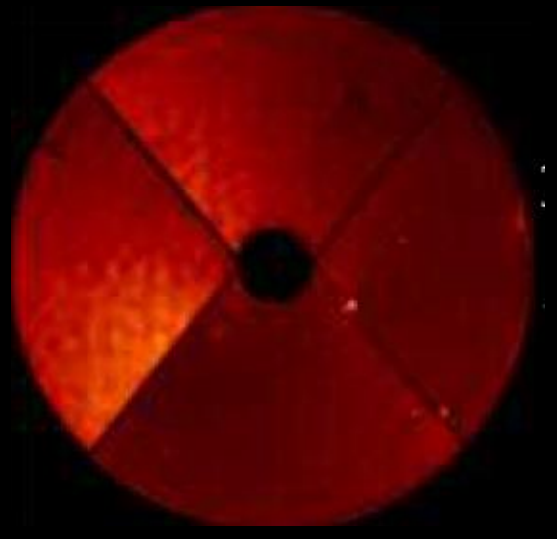

1-image PD
(62 nm RMS)
250
200
150
100
50
0
-50
-100
-150

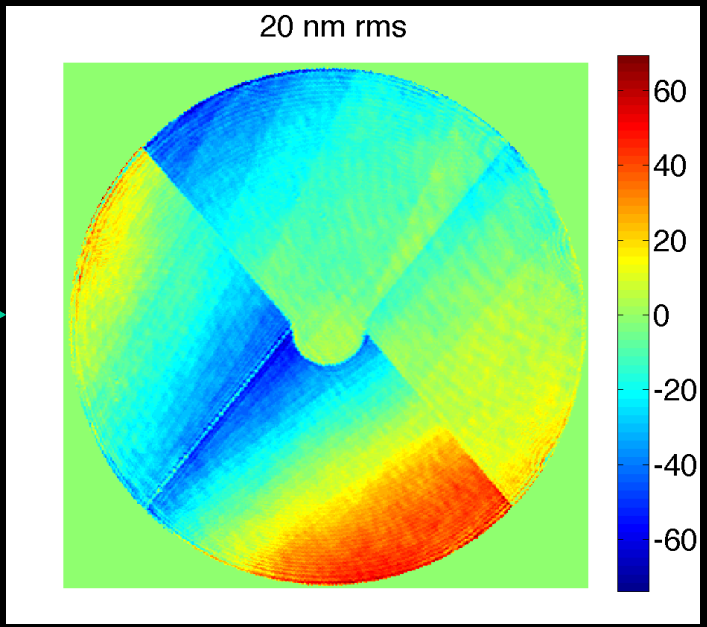

Strehl = 0.46
Strehl = 0.92

Works well in simulation…

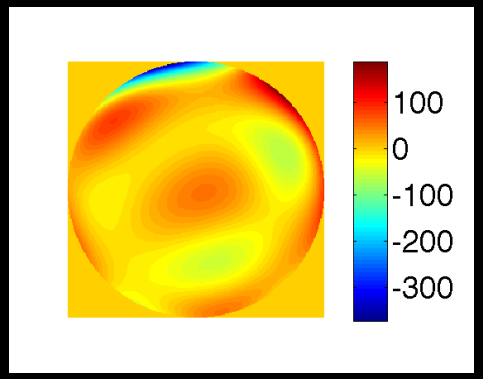
- … but also on the MITHIC bench @ LAM!



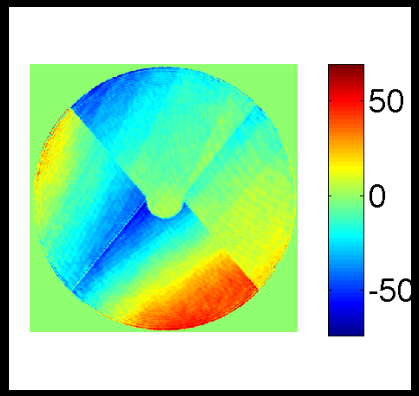




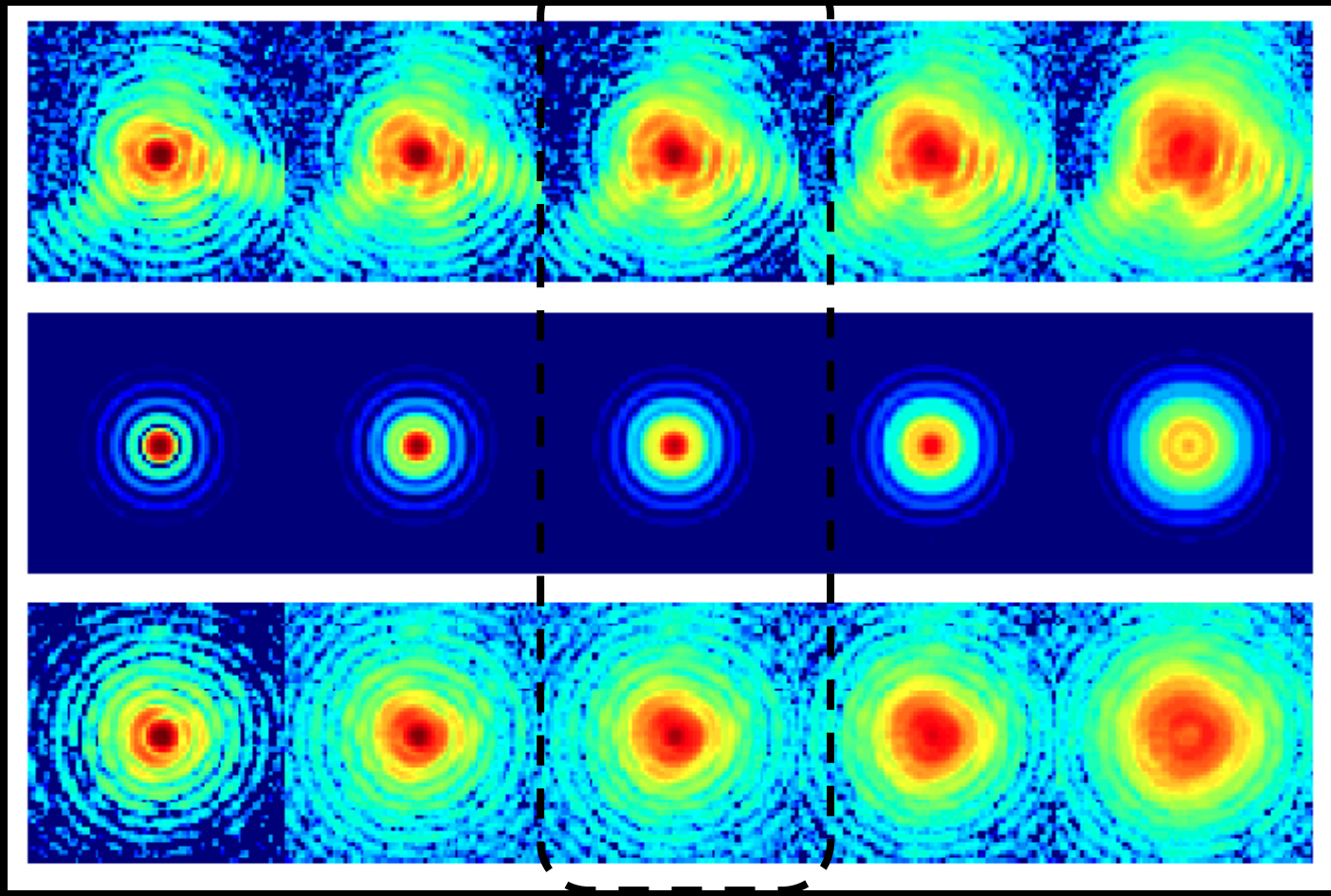
MITHIC bench data



(SLM)

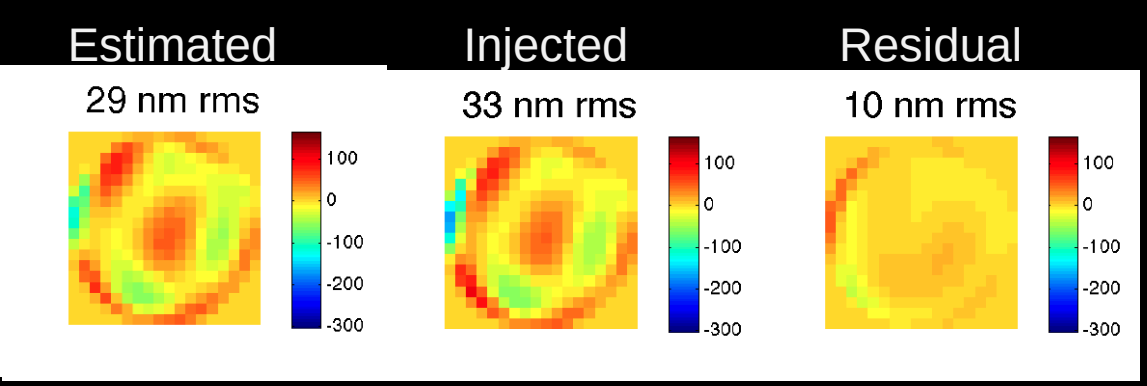


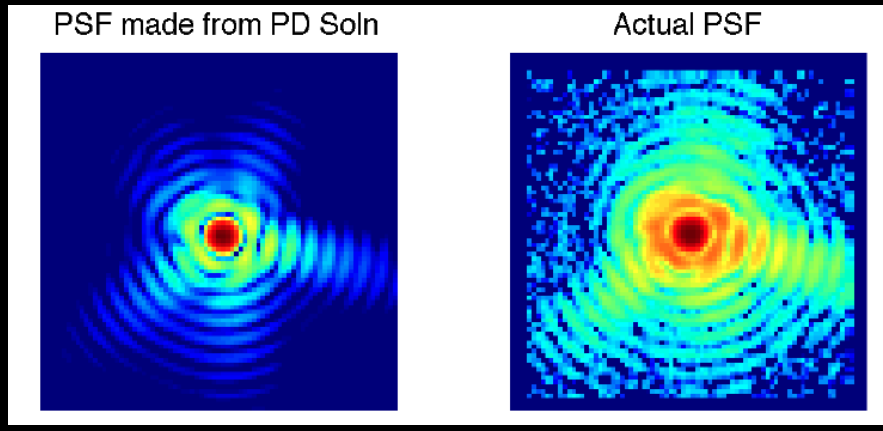
(PS)

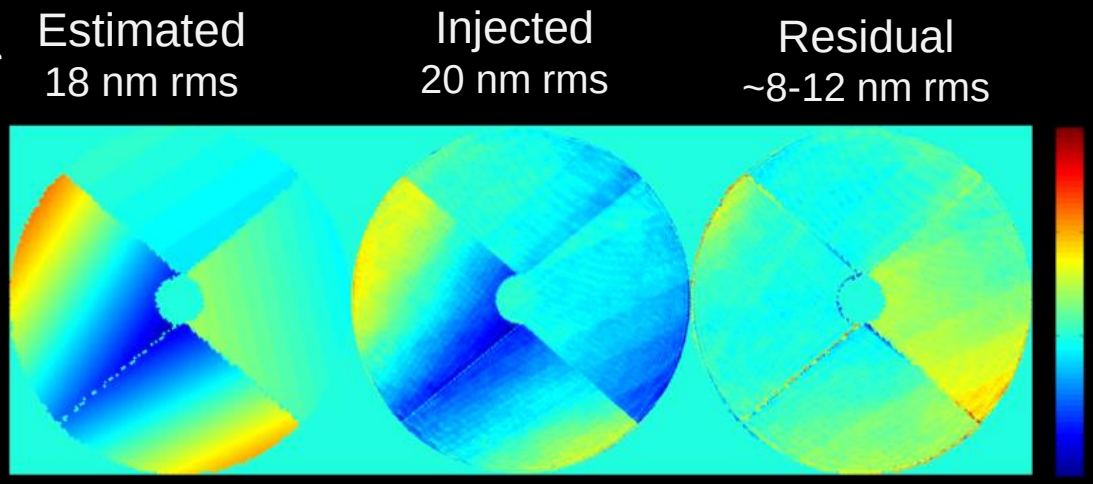


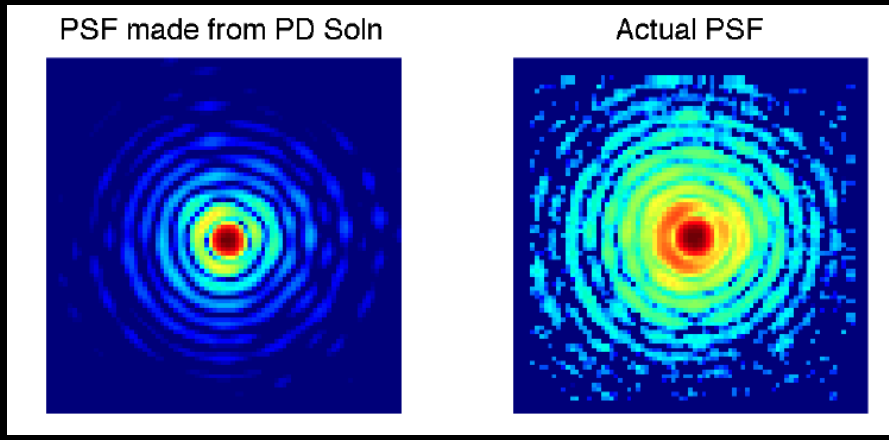
Parallel, independent development using Fast&Furious algorithm by M.J. Wilby et al, in prep.

single image PD validation



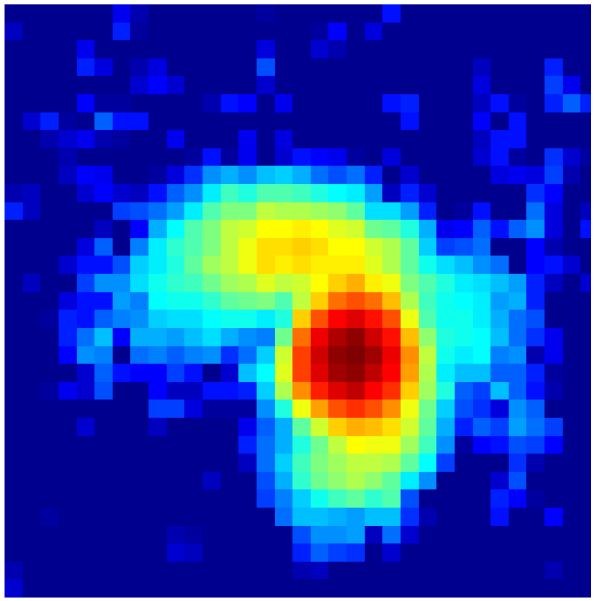
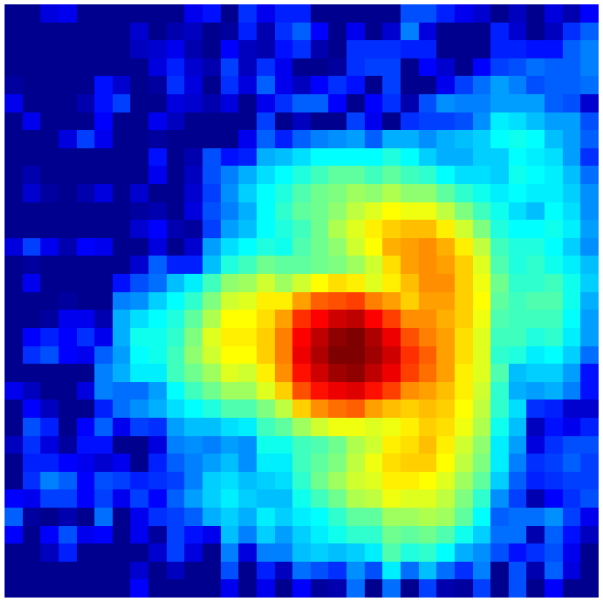
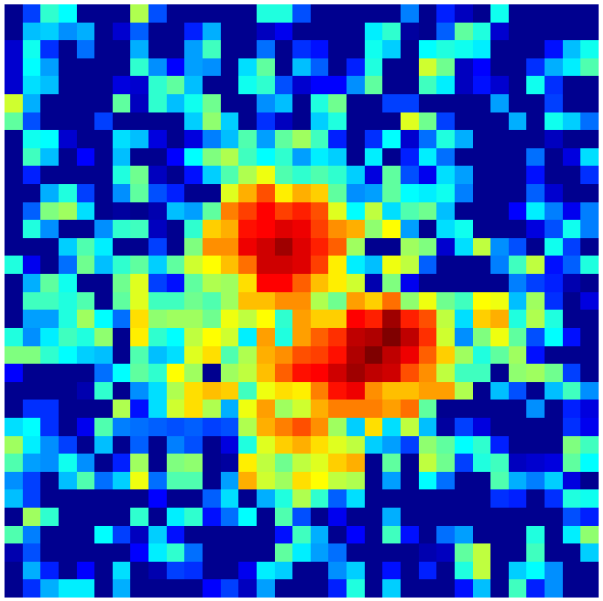






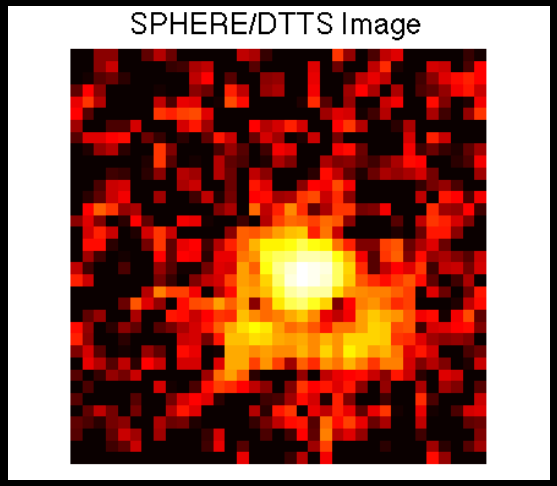
... and with on-sky data

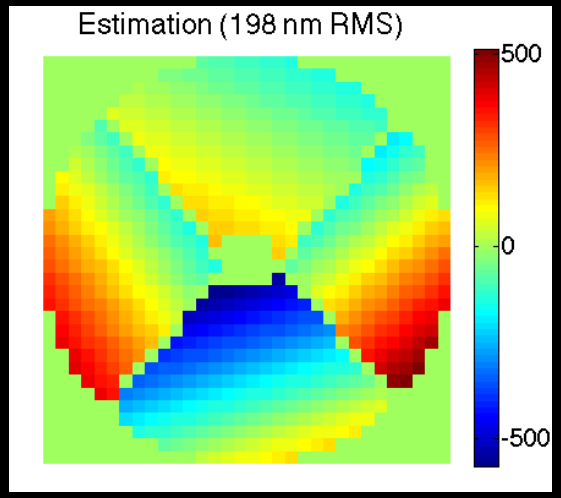
- DTTS data taken during a strong LWE night in 2016
- Want to use PD w/ natural 20 nm RMS focus to monitor LWE

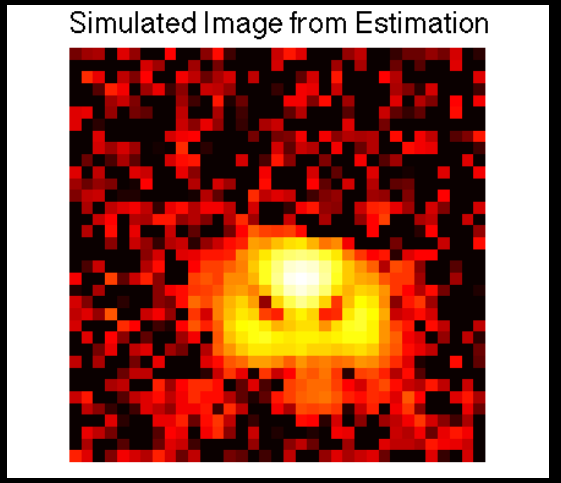




3 different images taken at different points in the night showing the LWE

Image reconstruction:







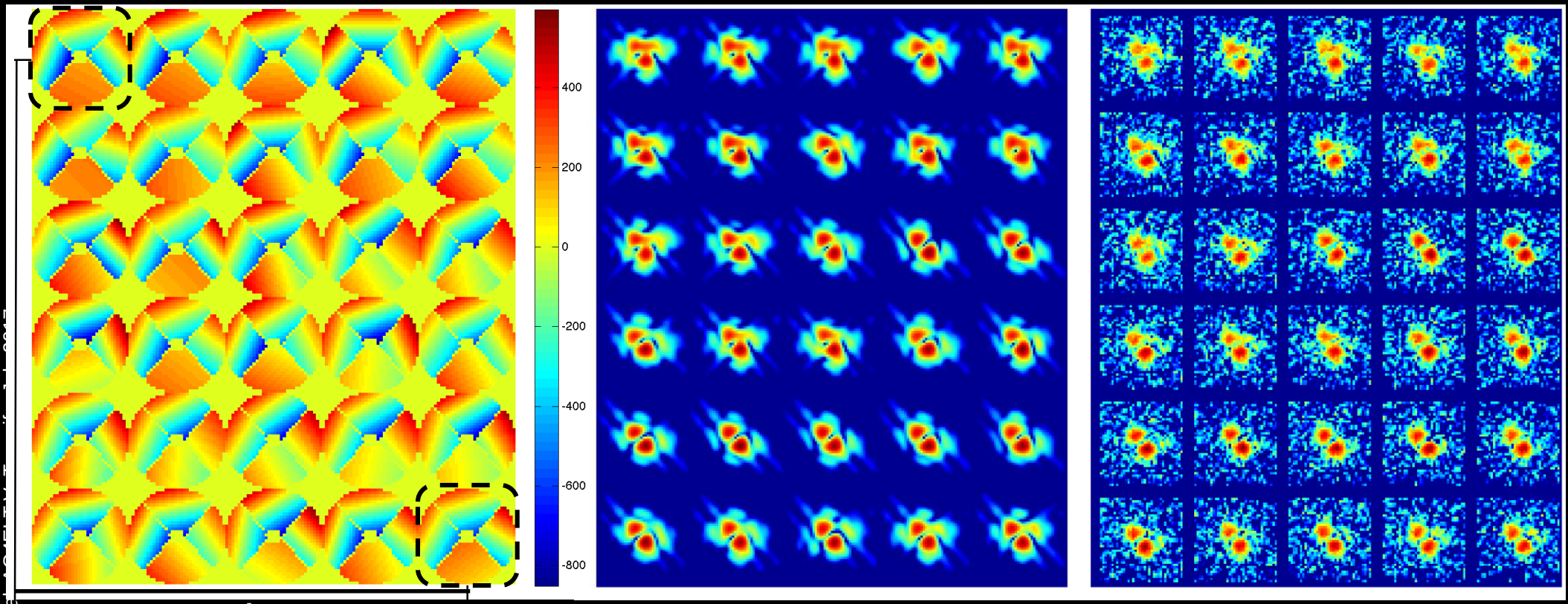
LWE ‘Monitor’

- **DTTS data can ‘monitor’ LWE when looking @ PV WFE**
- **Useful tool to assess strength of LWE on a given night**

- **Consider two scenarios:**
  - Evolution over **one minute**
  - Evolution over **one hour**

One minute of LWE evolution

- Some (but not huge) variation over 1 min!



Δ P-V WFE ~ 100 nm

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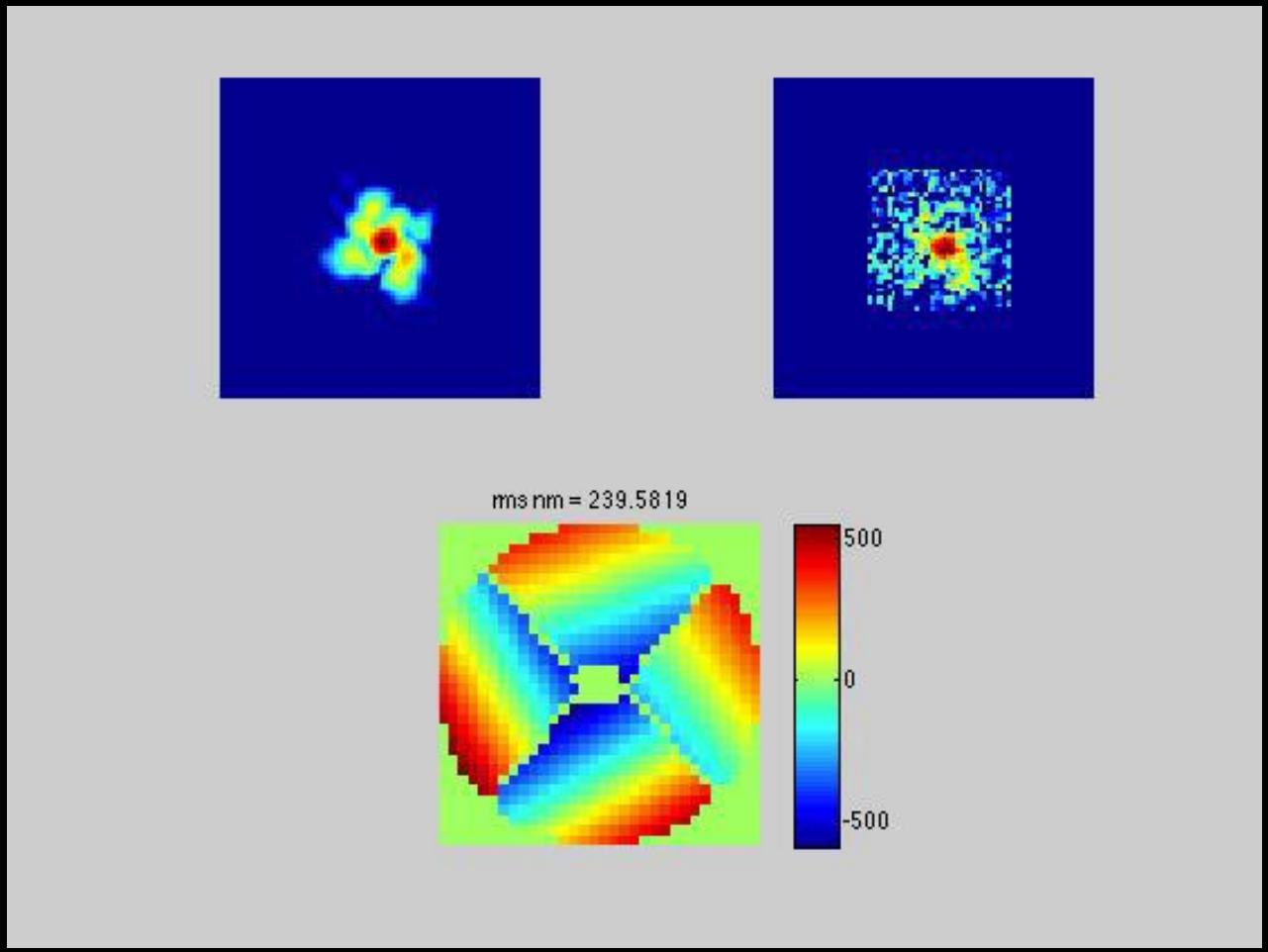
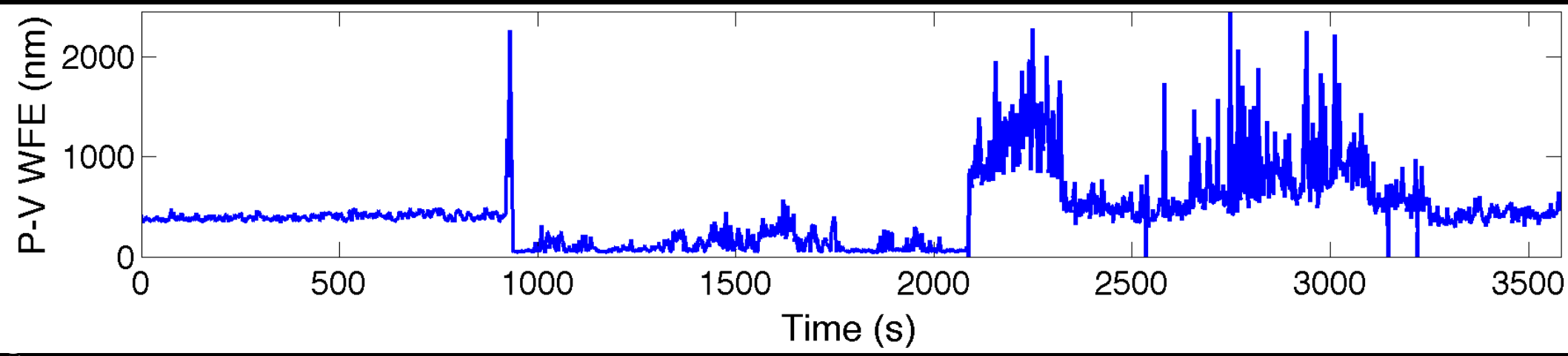
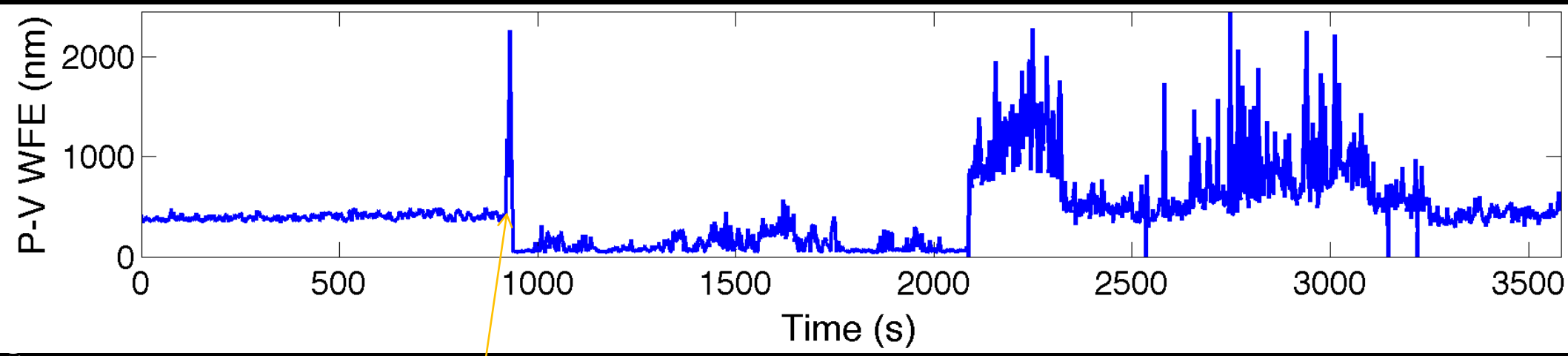
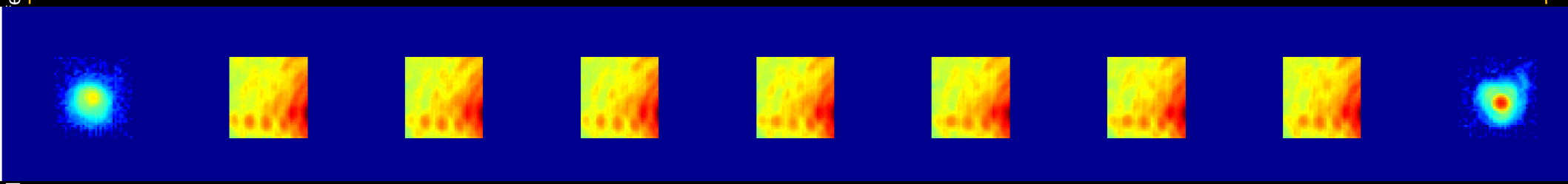

rms nm = 239.5819
500
0
-500

One hour of LWE evolution



One hour of LWE evolution





e, July 2

Masen Lamb et al

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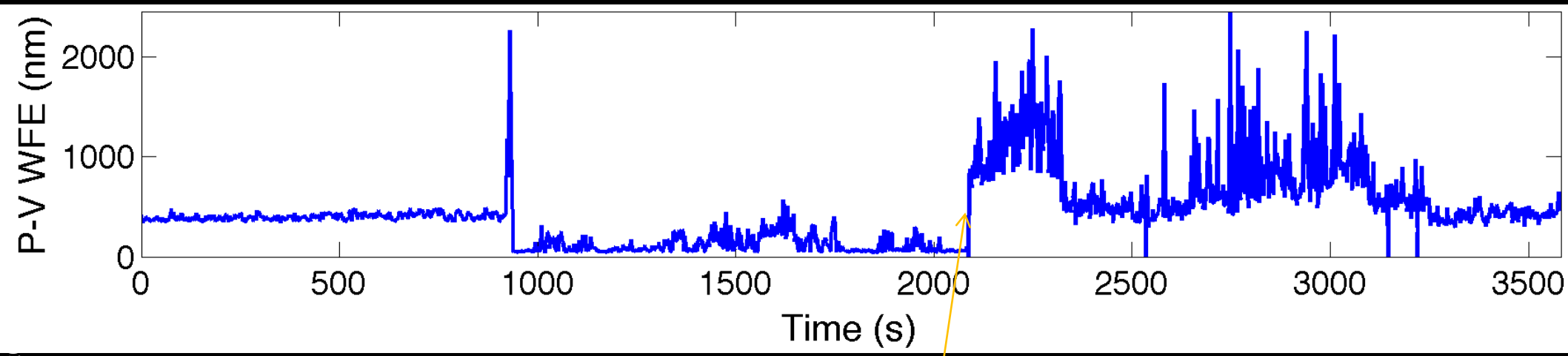

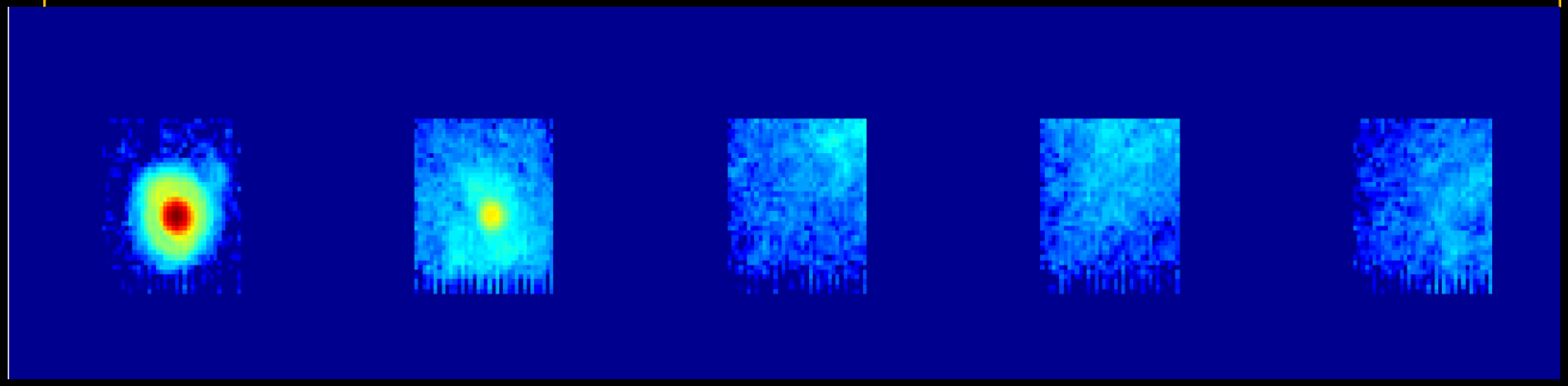

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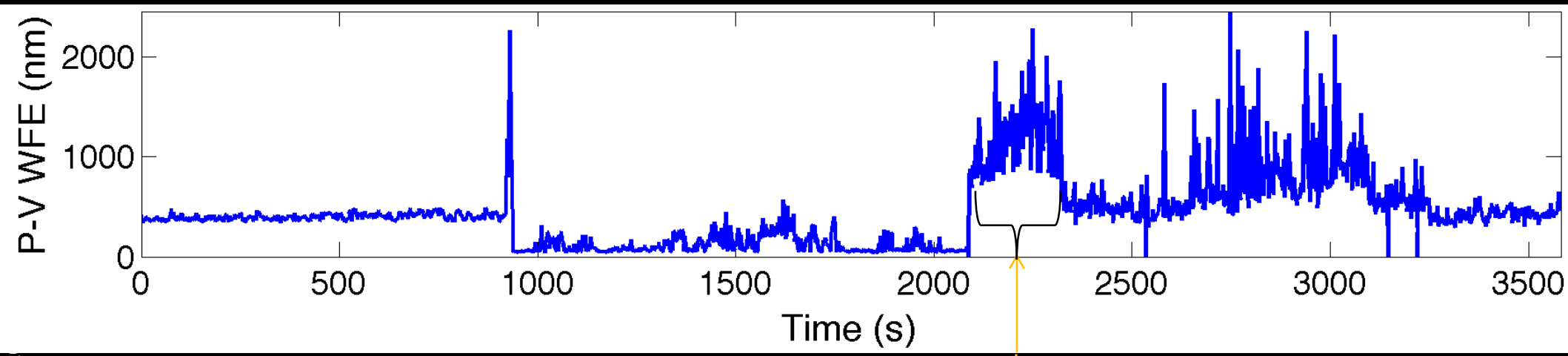

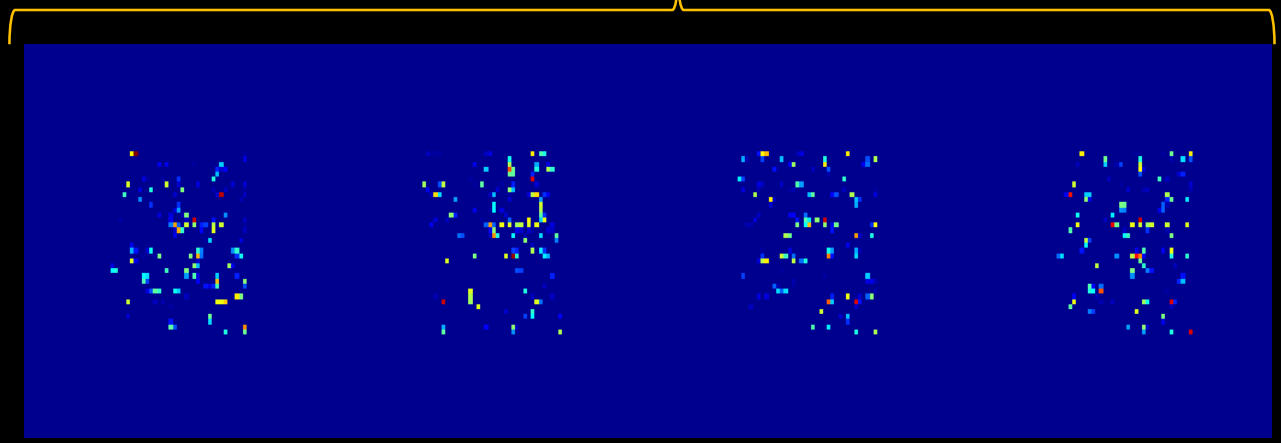

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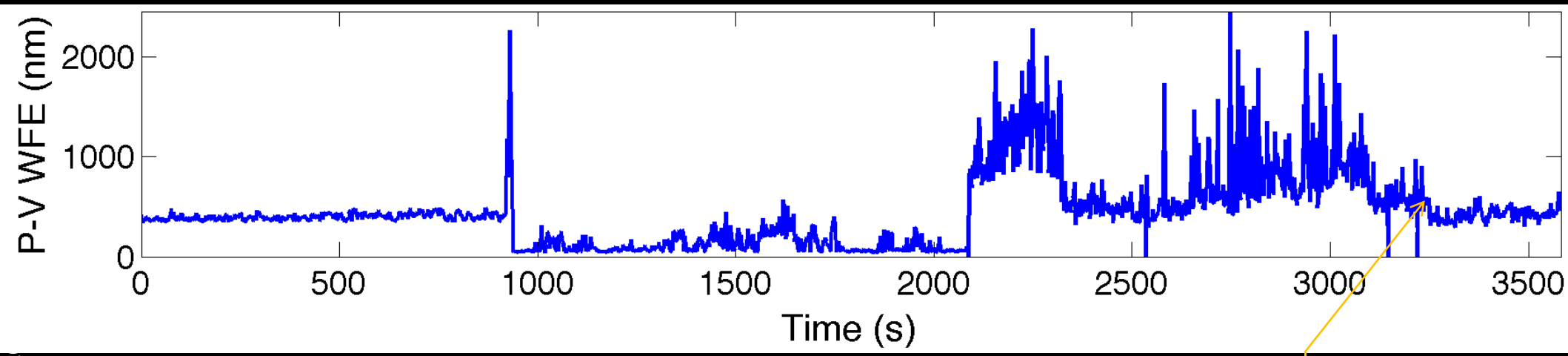

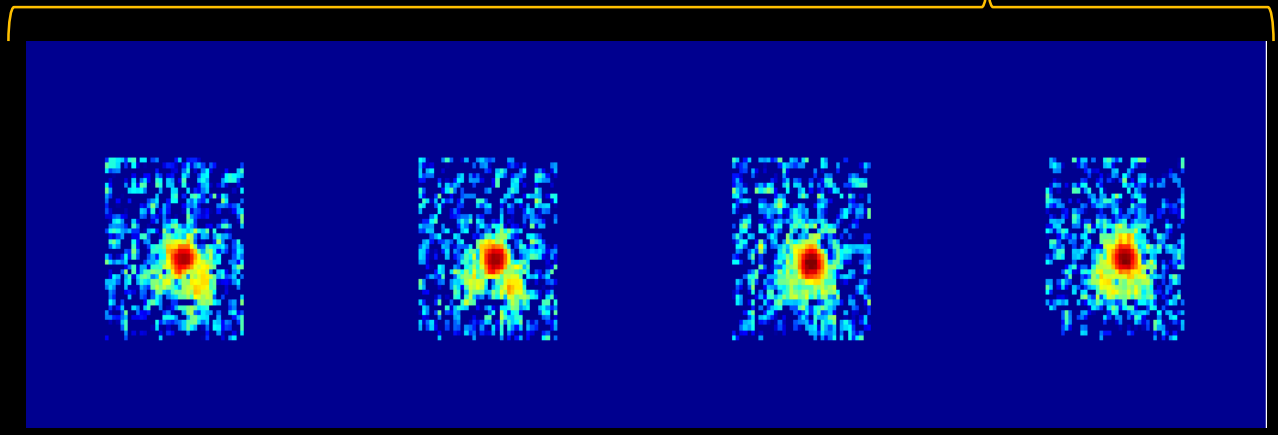

Conclusions

- **Simulation:**
  - LWE estimated with ‘classic’ PD to within 30 nm RMS
  - Single image w/ DTTS focus to within 60 nm RMS

- **Bench:**
  - LWE phase screen estimated to within 12 nm RMS w/ single defocussed image (*aka phase diverse phase retrieval*)
- **On-Sky:**
  - DTTS images w/ LWE estimated w/ natural DTTS focus to ‘monitor’ the LWE
  - LWE evolution over scales of minutes is not large (i.e. Δ~100 nm PV)
  - LWE evolution over scale of one hour shows significant variation
  - If the LWE is controlled every 6 seconds or so it could constrain the DTTS such that it would never lose centroiding

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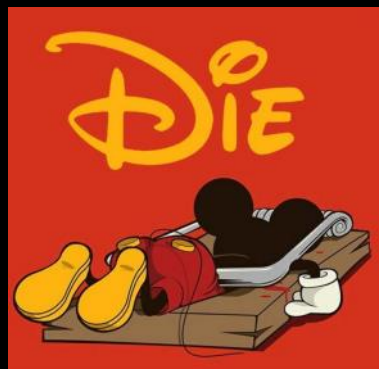

Thank you.

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All the simulations and analysis done with the object-oriented MATLAB AO simulator (OOMAO) freely available from https://github.com/cmcorreia/LAM-Public