Imaging Spectro-Polarimetry with Long Exposure Times

T. A. Waldmann
CASSDA Workshop, 18.02.2014
Motivation and approaches
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Short exposed images, 20ms exposure each, 15 frames / sec
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Long exposures: 420 ms exposure, 47 ms read out

Time
Motivation and approaches

- Short exposed images, 140ms exposure, 327 ms read-out

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Long-exposure PSF needed to deconvolve the frame!
Motivation and approaches

Short exposed images, 140ms exposure, 327 ms read-out

Long exposures: 420 ms exposure, 47 ms read out
Comparisons during this workshop

Short exposures: x ms exposure, y ms read-out

Long exposures: x ms exposure, y ms read out-out

Time
Comparisons during this workshop

- Short exposures: x ms exposure, y ms read out
- Long exposures: x ms exposure, y ms read out-out

Using averaged short exposures
Long-exposure PSF estimation

• Methods include, but are not limited to:
  - Use AO-telemetry data (e.g. Marino, 2007).
  - Use data from an additional imaging channel (e.g. Waldmann, 2011).
  - More sources available (e.g. Jollisant, 2004)…
PSF Estimation using an additional imaging channel
PSF Estimation

- PSF estimation is based on comparing the individual BB-images with a Speckle-Reconstruction of the BB-images.

- Photometry of Speckle-Reconstructions has been proven to be accurate (Wöger et al. 2008).
PSF Estimation

- Method introduced by Friedrich Wöger, 2007:
  - Iterative, regularized, constrained division in the Fourier-domain.
  - Gaussian shape of long exposure PSF.
  - PSF is non-negative.
  - MTF is limited by the MTF of the ideal telescope.
  - Division only if SNR exceeds a certain threshold.

- PIPE (Pipe Is a Psf Estimator):
  - Model PSF via wavefront phase at the telescope pupil.
  - Use simulated annealing to estimate a set of Zernikes that minimizes an error function.
  - Complete physical model of the PSF.
  - Slow.
  - No guarantee that the result is a (local, global, any…) minimum of the error function.
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Exemplary Results

- GFPI at VTT: Simulated long exposures (8*20 ms) and compared with MOMFBD and DSI.

![Image of simulated long exposures](image-url)
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**DSI**  
**MOMFBD 51**  
**SPLE 1e5**

**Comparable Noise Levels**
Exemplary Results

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<table>
<thead>
<tr>
<th>DSI</th>
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Increased Noise Level

Comparable Noise Levels

Increased Noise Level
Exemplary Results: Noise Levels

Stokes – V Continuum - DSI

Stokes – V Cont.- MOMFBD

Stokes – V Cont.- SPLE 1e5

Compute Standard Deviations for Stokes -Q, -U, -V.
## Exemplary Results: Noise Levels

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*Regarding the numbers shown here, please note the last slide of this presentation.*
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ALL IS WELL
PIPE-PSF Estimation: Flaws and Justifications

• **VTT pupil was modelled with Zernikes only (i.e. no secondary, no spider).**
  
  † No pupil images were available.
  † Pupil-arrays were small (64x64 to 128x128 Pixel).
  † Results compared well with the Wöger-Method.
  † Results compared well with Speckle-Deconvolution results.

• **Finally, only 25/(50) Zernikes were used.**
  
  † In simulations, no big difference between using 25 and up to 50 Zernikes was seen.
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We wanted to proof the concept, not optimize the details!
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  EASY : JUST DO IT !

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Two Possibilities:

a) Use code of Peter F. Perroni to estimate PSFs
b) Use more thorough model for a long exposure PSF
PIPE-PSF Estimation: How to do it better!

• **Work of Peter F. Perroni, 2013:**
  
  - Use GPUs instead of FPUs and a Cooperative Particle Swarm Optimization algorithm instead of simulated annealing.
  

• **More thorough model for a long exposure PSF:**
  
  - See, for example, the work of Jose Marino, 2007.
  - Other possibilities ?!
  
  - Note: if the statistics of the wavefront are used, a long exposure is an exposure in the order of $> 0.5$ seconds (cf. Marino, 2004).
Summary

- Spectro-Polarimetry with long exposure times can yield results close to the diffraction limit...
- ... at the lock point of the adaptive optics system...
- ..., i.e. size of field-of-view limited by anisoplanatism.
- SPLE using an additional imaging channel: proof-of-concept done...
- ... but methodology should be optimized ... 
- ... and possible advantages taken that have not been used up to now.
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• ... and possible advantages taken that have not been used up to now.
Some Comments

• Whatever PSFs you will use to deconvolve your data, deconvolution will enhance the contrast.

• Under- / Over-correction can lead to false deduction of physical parameters.

• Possible consistency checks:
  
  o Compare your results with independent findings (e.g. Sharmer et al, 2011).

  o Used a BB-Speckle-Reconstruction to estimate PSFs?
    > Check what happens when you deconvolve the raw BB-images (e.g. Waldmann, 2011).

  o Cross-check with other methods (e.g. this workshop, Waldmann, 2011; Marino, 2007).

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Final conclusion

if faster_cameras_available_nowadays then begin
    long_exposures=maybe_obsolete
endif else begin
    long_exposures=worthwhile_trying
endelse
Thank you for your attention.
Bibliography


* The noise levels of the Stokes parameters shown here are different than the numbers given in Waldmann, 2011. This is due to a re-computation of the demodulation matrix of the GFPI polarimeter. Please contact CASSDA team members for details.