Telescope Alignment and Wavefront Sensing

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Atlanta 2011
Wavefront Evaluation at CHARA

• 2001-2010  Wavefront is computed from its Laplacian (Roddier)

• 2010  Wavefront is computed from its gradient (Shack-Hartmann Sensor)

not for alignment

better for alignment
**Optical Setup**

**WFS**
OKO Standard Config. #1
Hexagonal array
127 lenses, 0.3 mm pitch
F=18 mm.

CCD

40 mm collimator

Green filter

focal plane

Beam splitter

25 mm eyepiece

LED

Reticle

Projector

FrontSurfer

Wavefront expanded into Zernike polynomials
**CALIBRATION**

9.922 μm

9.907 μm

**TAS**

PINHOLE SOURCE, TAS OBJECTIVE

- Strehl = 0.95
- RMS = 17 nm
- P – V = 152 nm

PINHOLE SOURCE, TAS COMPLETE

- Strehl = 0.92
- RMS = 22 nm
- P – V = 196 nm

50x452ms EXPOSURE OF VEGA

- Strehl = 0.89
- RMS = 27 nm
- P – V = 237 nm

**ZERNIKES [nm]**

E1

- 1000 x 10ms exposures of Vega

- 540 nm
- 1600 nm
- 2200 nm

**WAVEFRONT MAP**

Strehl = 0.35
RMS = 78 nm
P – V = 558 nm

ZERNIKES [nm]

- $Z_5 = -28$
- $Z_6 = -2$
- $Z_7 = -7$
- $Z_8 = 1$
- $Z_9 = -8$
- $Z_{10} = 11$
- $Z_{11} = 31$

Strehl = 0.89
Strehl = 0.94

ZERNIKES [nm]

- $Z_5 = 58$
- $Z_6 = -141$
- $Z_7 = -114$
- $Z_8 = -5$
- $Z_9 = 0$
- $Z_{10} = -66$
- $Z_{11} = 90$

contours in nm
E2
9/17/2010

1000 x 10ms exposures of Vega

<table>
<thead>
<tr>
<th>WAVEFRONT MAP</th>
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<tbody>
<tr>
<td>contours in nm</td>
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Strehl = 0.14
RMS = 95nm
P – V = 606nm

ZERNIKES [nm]

\[
Z_5 = 55 \\
Z_6 = -41 \\
Z_7 = -154 \\
Z_8 = 53 \\
Z_9 = -158 \\
Z_{10} = -166 \\
Z_{11} = 149
\]

S1
9/23/2010

1000 x 10ms exposures of Vega

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Strehl = 0.02
RMS = 231nm
P – V = 1211nm

ZERNIKES [nm]

\[
Z_5 = 568 \\
Z_6 = -226 \\
Z_7 = -307 \\
Z_8 = 27 \\
Z_9 = 14 \\
Z_{10} = 40 \\
Z_{11} = 147
\]
TWEAKING ALGORITHM
BASED ON SIMULATIONS

center star in WFS

WFS: \( Z_5, \ldots, Z_{11} \)

\[
\sqrt{Z_7^2 + Z_8^2} \leq \varepsilon_{\text{coma}}
\]

\( \text{Y} \)

\[
\sqrt{Z_5^2 + Z_6^2} \leq \varepsilon_{\text{ast}}
\]

\( \text{Y} \)

focus

\( \text{N} \)

tilt M2

re-center star by tilting the telescope

\( \text{N} \)

tilt M1

re-center star by tilting M2

\( \text{N} \)

tilt M2

re-center star by tilting the telescope

focus
ORTHOGONAL AZ-EL ADJUSTMENT AT M2 BUT NOT AT M1

SOFTWARE

DIAL INDICATOR

ACTUATOR

EL
AZ
02-03-2011

P-V=1340 nm
RMS=270 nm

02-12-2011

P-V=318 nm
RMS=50 nm

W1

<table>
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<th>02/03/11 [nm]</th>
<th>02/12/11 [nm]</th>
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<tr>
<td>Z₅</td>
<td>540</td>
<td>27</td>
</tr>
<tr>
<td>Z₆</td>
<td>570</td>
<td>145</td>
</tr>
<tr>
<td>Z₇</td>
<td>-175</td>
<td>-41</td>
</tr>
<tr>
<td>Z₈</td>
<td>196</td>
<td>-40</td>
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ASYMMETRIC PUPIL
MONTE CARLO SIMULATION

SOLUTION 1

SOLUTION 2

TWO SOLUTIONS AT A GIVEN M1, M2 LATERAL DISPLACEMENT
FUTURE PLANS: TESTING M1 IN SITU

WHAT IS THIS?

FOCUS INACCESSIBLE
FINDING THE VERTEX OF M1

M1 is F/2.5

VERY SENSITIVE TO MISALIGNMENT

COMA

CCD CAMERA
SIMULATED PRIME FOCUS IMAGES

OFF-AXIS

ON-AXIS
COMA FREE TILTING OF M2

SPHERICAL BEARING AT THE FOCAL POINT

ACTUATORS

M2
ODDS & ENDS

• COUDE-BOX COVER

• HUMIDITY-TEMPERATURE SENSORS IN THE DOMES

![Graph showing temperature changes over time](image-url)