Long baseline interferometry in the visible: Recent progress on FRIEND project

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CHARA Meeting – March 2016
Outline

- Short presentation of FRIEND prototype
- Coupling efficiency and limiting magnitude
- Instrumental visibility
- Closure phase
- Adaptive optics and injection
Short presentation of FRIEND prototype

\[ < |V|^2 > = \frac{< E_{HF} >}{\int_{\Delta\lambda} \kappa(\lambda) \int_{\Delta x} < P_1(\lambda, x) P_2(\lambda, x) > \, dx \, d\lambda} \]
Observations

2016-09-29
- E1E2W2
- $r_0 = 10 \text{ cm}$
- 1 Cal:
  - HD3360: $m_R = 3.74$
- 1 Sci:
  - HD5394: $m_R = 2.32$

2016-09-30
- E1W2W1
- $r_0 = 14 \text{ cm}$
- 3 Cal:
  - HD3360: $m_R = 3.74$
  - HD2905: $m_R = 4.02$
  - HD3240: $m_V = 5.076$
- 2 Sci:
  - HD5394: $m_R = 2.32$
  - HD11415: $m_R = 3.4$
Coupling efficiency and limiting magnitude

- Limiting magnitude defined by flux in photometric channels
Coupling efficiency and limit magnitude

- $r_0 = 14 \text{ cm } @ \text{ 550 nm} \Rightarrow \rho_{\text{expected}} = 2.6\%$
- Measured flux and magnitude
  - $t_{\text{CHARA}} = 1.7\%$
  - $t_{\text{FRIEND+OCAM}} = 31.5\%$

$\Rightarrow \rho_{\text{estimated}} = 2.8\% \text{ with } no \text{ adaptive optics}$
Coupling efficiency and limiting magnitude

- Limiting mag defined by photometric channels
- For faint stars, flux at 0 or less
- Photometric sorting: \( P_i > n \sigma_{dark} \), \( n = 1.5 \)

\[ \Rightarrow mag_{lim} = 4.1 \]

- \( \approx 20\sim25\% \) of frames

With:

\[ \rho = 2.6\% \]

No AO
Instrumental visibility

• Optimization : OPD rejection method (low spectral resolution)
Instrumental visibility

2016-09-29

Squared visibilities - E2W2 / FRIEND 23 = Base 1

Squared visibilities - E1E2 / FRIEND 12 = Base 2

Squared visibilities - E1W2 / FRIEND 13 = Base 3

2016-09-30

Squared visibilities - W2W1 / FRIEND 23 = Base 1

Squared visibilities - E1W2 / FRIEND 12 = Base 2

Squared visibilities - E1W1 / FRIEND 13 = Base 3
Instrumental visibility

- Stability of Base 1 on 09-29
- Determination of $V_{\text{instr}}$ stable with or without HD2905 (relative variation between fits < 1%)
- $V_{\text{instr}}$ does not seem night-dependent

<table>
<thead>
<tr>
<th></th>
<th>09-29</th>
<th>09-30</th>
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</thead>
<tbody>
<tr>
<td>Base 1</td>
<td>0.72 ± 0.05</td>
<td>0.82 ± 0.12</td>
</tr>
<tr>
<td>Base 2</td>
<td>0.62 ± 0.05</td>
<td>0.63 ± 0.05</td>
</tr>
<tr>
<td>Base 3</td>
<td>0.83 ± 0.06</td>
<td>0.73 ± 0.27</td>
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</tbody>
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Table 3: Estimation of $V_{\text{instr}}^2$ per base and per night.
Instrumental visibility

• Decrease on other bases: due to alignment drifts of pupils?
• Stability with respect to atmospheric condition:
  – No strong variation of the seeing during and between the nights
  – Systematic errors unseen?
  – Keep investigating
Closure phase

- Bispectrum: $B_{0,u,v} = B_{1,u,v} - \alpha \left( |C_u|^2 + |C_v|^2 + |C_{u,v}|^2 \right) + \beta N$

- $\alpha = \arg \min_{\alpha} \left( \text{Var} \left( B_g(B_{1,u,v}) \right) \right)$, $B_g =$ background

- Closure phase: $CP = \arctan \left( \frac{\Sigma \text{Im}}{\Sigma \text{Re}} \right)$

- $\sigma_\Sigma = \sqrt{N} \sigma_{bg}$, $\sigma_{CP}$ determined by Monte-Carlo
Closure phase

2016-09-29

2016-09-30
Closure phase

• 2016-09-29: \( \text{slope} = -0.01 \pm 0.01 \)

• 2016-09-30: \( \text{slope} = 0.16 \pm 0.06 \) with 1 cal
  \( \text{slope} = 0.14 \pm 0.06 \) with 2 cal

\[ \Rightarrow \text{Stability of } CP_{instr} \text{ with respect to the calibrators} \]

\[ \Rightarrow \text{Investigating on possible instrumental effects} \]
Adaptive optics and injection

Observations
(with T.Ten Brummelaar, M. Anderson, J. Sturmann, L. Sturmann, C. Farrington, N. Vargas, VEGA team)

2017-03-08

- S2
- \( r_0 = 7 \text{ cm} \)
- Target: Sirius
- AO modes:
  - Labao
  - Open loop
  - Labao + own TT
  - Fast TT

2017-03-10

- S1S2
- \( r_0 = 8 \text{ cm} \)
- Target: Procyon
- AO modes:
  - Labao
  - Open loop
Adaptive optics and injection

2017-03-08

\[ \langle \rho \rangle_{\text{open loop}} = 0.65\% \]

\[ r_0 = 7 \text{ cm} \Rightarrow \rho_{th} = 0.65\% \]

\[ \rho_{labao} = 0.76\% \Rightarrow \]

\[ r_{0,eq} = 7.43 \text{ cm} \]

2017-03-10

\[ r_0 = 8 \text{ cm} \Rightarrow \rho_{th} = 0.88\% \]

\[ \langle \rho \rangle_{S2,\text{open loop}} = 0.58\% \]

\[ \langle \rho \rangle_{S1,\text{open loop}} = 0.50\% \]
Conclusion and prospects

• Limiting magnitude: characterized and quantified
• Instrumental visibility:
  – Stable with respect to magnitude and night-dependent
  – Very sensitive to pupil drifts?
• Closure phase:
  – First measurements of CP quite accurate
  – Keep characterizing (magnitude, AO)
• AO and Injection:
  – AO improves a bit injection in FRIEND
  – Correlate FRIEND and AO data
• Martinod et al 2017 in prep.