The Instrumental Effects on VLBI Polarization in Event Horizon Telescope Baselines

Michael Kosowsky[1,2]
Mentors: Vincent Fish[2], Rusen Lu[2]

[1]Brandeis University

[2]MIT Haystack Observatory

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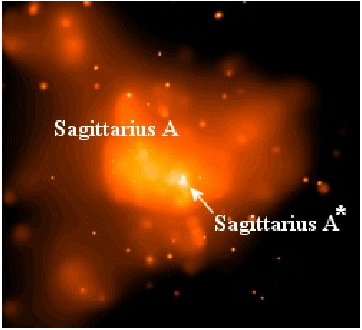
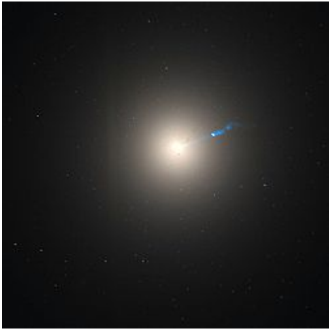
Targets

Sgr A*



M87



EHT Stations

CARMA

SMT

SMA

JCMT

EHT Telescopes

www.maps.google.com

VLBI Polarization

- We observe in 230 GHz (1.3 mm)
- Polarimetry teaches about B-fields in target sources
- Atmosphere is highly variable at 230 GHz - can't use absolute phases.

VLBI Polarization Equations

Parallel polarization ratio:

$$\frac{R_1 R_2^*}{L_1 L_2^*} = \frac{G_{1R}}{G_{1L}} \frac{G_{2R}^*}{G_{2L}^*} e^{2i(-\phi_1+\phi_2)}$$

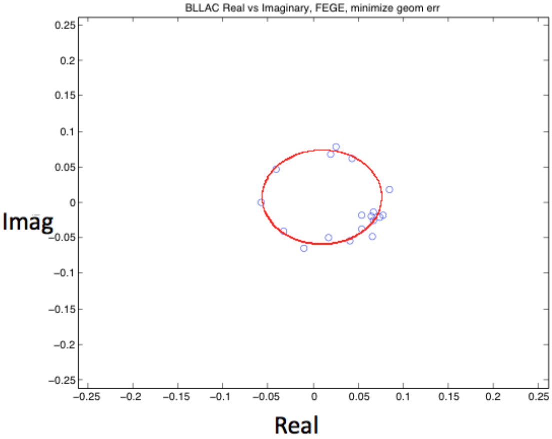
Cross-polarization ratio:

$$\frac{L_1 R_2^*}{R_1 R_2^*} = \frac{G_{1L}}{G_{1R}} \left[\frac{\tilde{P}_{21}^*}{\tilde{I}_{12}} e^{2i(\phi_1)} + D_{1L} + D_{2R}{}^* e^{2i(\phi_1-\phi_2)} \right]$$

Cyan are parallel hands.
Magenta are cross hands.
Green are antenna gains.
Violet are field rotation angles.
Orange are antenna polarization.
Red are source polarization.
Blue are source intensity.

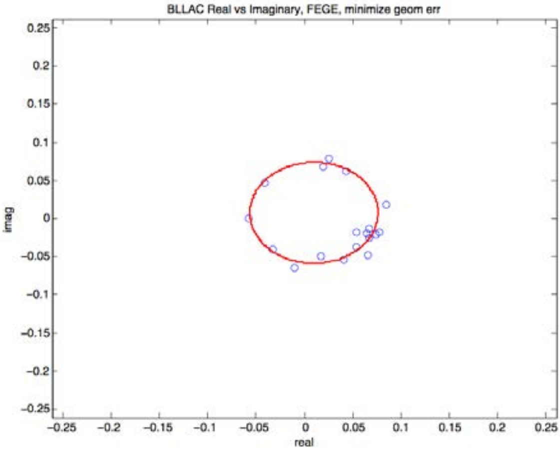
Roberts, Wardle, & Brown. 1994. ApJ., 472, 718

Circle Plots



$$\frac{L_1 R_2^*}{R_1 R_2^*} = \frac{G_{1L}}{G_{1R}} \left[\frac{\tilde{P}_{21}^*}{\tilde{I}_{12}} \; e^{i(2\phi_1)} + D_{1L} + D_{2R}^* \; e^{i(2\phi_1 - 2\phi_2)} \right]$$

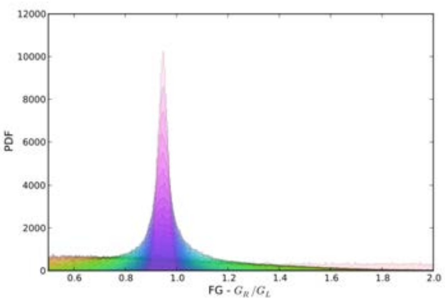
Circle Plots



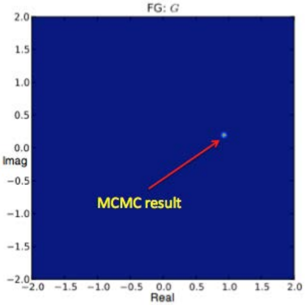
$$\frac{L_1 R_2^*}{R_1 R_2^*} = \frac{G_{1L}}{G_{1R}} \left[\frac{\tilde{P}_{21}^*}{\tilde{I}_{12}} \, e^{i(2\phi_1)} + (D_{1L} + D_{2R}^*) \right]$$

MCMC Simulations - CARMA-CARMA

Phased CARMA R/L gain amplitude

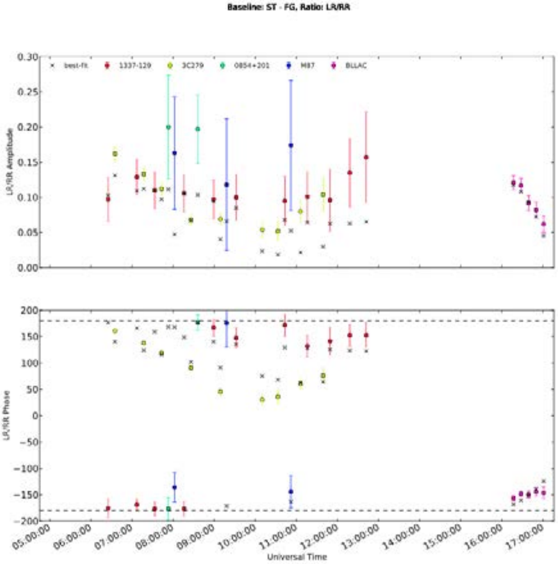


Phased CARMA R/L complex gain



Reduced $\chi^2 = 1.596$

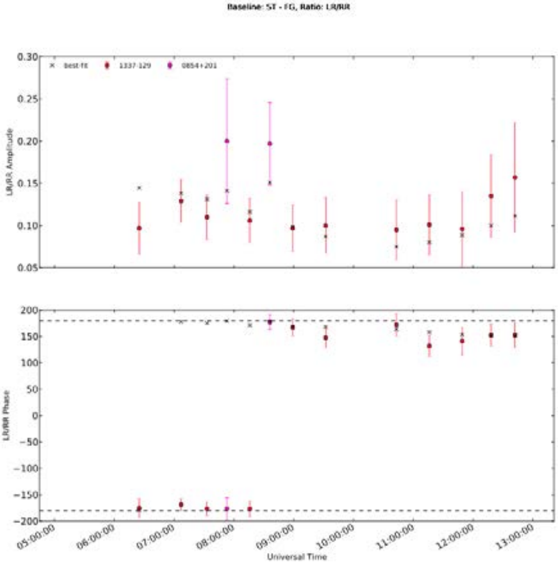
MCMC Simulations - SMT-CARMA



Reduced $\chi^2 = 4.743$

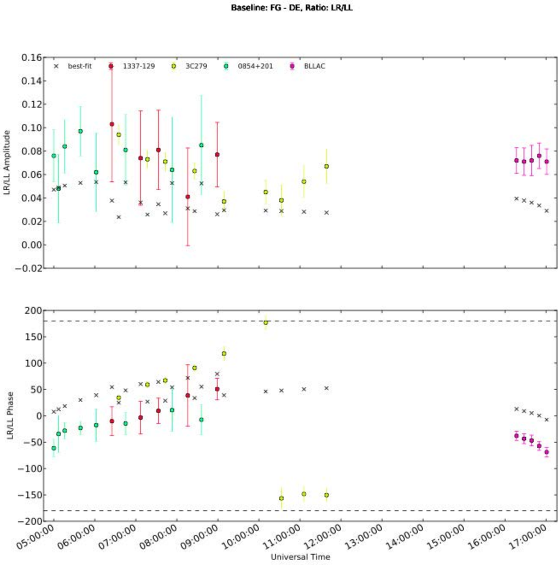
Clearly, 3C279 doesn't fit.

MCMC Simulations - SMT-CARMA, Only Good Sources



Reduced $\chi^2 = 1.599$

Checking MCMC Consistency



Reduced $\chi^2 = 17.571$ Clearly, the points do not fit.

Conclusions

- MCMC works well as a fitting tool for our data
- We have good estimates for the gains and D-terms of the CARMA and SMT stations

Future Work for MCMC

- Include HI stations
- Reverse fit - assume D-terms to find source polarization
- Baseline-dependent source polarization
- Look at data over time
- Global fit of everything

Acknowledgements

- NSF
- Vincent Fish and Rusen Lu
- Sheperd Doeleman
- Kazunori Akayama
- The EHT Group
- Phil Erickson, K.T. Paul and Heidi Johnson

CARMA-CARMA MCMC Results

Parameter	Value
G_{1R}/G_{1L}	1.0288
$\Psi_{1R} - \Psi_{1L}$	11.6052°
G_{2R}/G_{2L}	0.9398
$\Psi_{2R} - \Psi_{2L}$	-167.2085°
$\lvert D_{1R} + D_{2L}^*\rvert$	0.0283
$\phi(D_{1R} + D_{2L}^*)$	3.6562°
$\lvert D_{1L} + D_{2R}^*\rvert$	0.0260
$\phi(D_{1L} + D_{2R}^*)$	179.8692°

SMT-CARMA MCMC Results

Phased CARMA	Value
G_R/G_L	0.9979
$\Psi_R - \Psi_L$	11.9603°
D_R amp	0.0397
D_R phase	60.9276°
D_L amp	0.0130
D_L phase	117.1770°

Phased CARMA	Value
G_R/G_L amp	1.0122
$\Psi_R - \Psi_L$	8.9545°
D_R amp	0.0509
D_R phase	120.0533°
D_L amp	0.0502
$D_L$phase	-4.7177°

Comp. CARMA	Value
G_R/G_L	0.9668
$\Psi_R - \Psi_L$	-166.7028°
D_R amp	0.0215
D_R phase	147.7472°
D_L amp	0.0334
D_L phase	74.6544°

Comp. CARMA	Value
G_R/G_L amp	0.9606
$\Psi_R - \Psi_L$	-169.5825°
D_R amp	0.0874
D_R phase	-170.2907°
D_L amp	0.0764
D_L phase	33.4524°

SMT	Value
G_R/G_L	1.0133
$\Psi_R - \Psi_L$	104.1871°
D_R amp	0.0684
D_R phase	50.6288°
D_L amp	0.1049
D_L phase	102.3045°

SMT	Value
G_R/G_L amp	0.9914
$\Psi_R - \Psi_L$	102.1956°
D_R amp	0.1478
D_R phase	87.0353°
D_L amp	0.1573
D_L phase	107.4904°

VLBI Polarization Equations

$$\frac{R_1 R_2^*}{L_1 L_2^*} = \frac{G_{1R}}{G_{1L}} \frac{G_{2R}^*}{G_{2L}^*} e^{2i(-\phi_1+\phi_2)}$$

$$\frac{L_1 R_2^*}{R_1 R_2^*} = \frac{G_{1L}}{G_{1R}} \left[\frac{\tilde{P}_{21}^*}{\tilde{I}_{12}} e^{i(2\phi_1)} + D_{1L} + D_{2R}^* e^{i(2\phi_1 - 2\phi_2)} \right]$$

$$\frac{L_1 R_2^*}{L_1 L_2^*} = \frac{G_{2R}^*}{G_{2L}^*} \left[\frac{\tilde{P}_{21}^*}{\tilde{I}_{12}} e^{i(2\phi_2)} + D_{1L} e^{i(-2\phi_1 + 2\phi_2)} + D_{2R}^* \right]$$

$$\frac{R_1 L_2^*}{L_1 L_2^*} = \frac{G_{1R}}{G_{1L}} \left[\frac{\tilde{P}_{12}}{\tilde{I}_{12}} e^{i(-2\phi_1)} + D_{1R} + D_{2L}^* e^{i(-2\phi_1 + 2\phi_2)} \right]$$

$$\frac{R_1 L_2^*}{R_1 R_2^*} = \frac{G_{2L}^*}{G_{2R}^*} \left[\frac{\tilde{P}_{12}}{\tilde{I}_{12}} e^{i(-2\phi_2)} + D_{1R} e^{i(2\phi_1 - 2\phi_2)} + D_{2L}^* \right]$$