Autocorrelation Techniques with Small Telescopes

Trying to beat the seeing in Eastern Kansas

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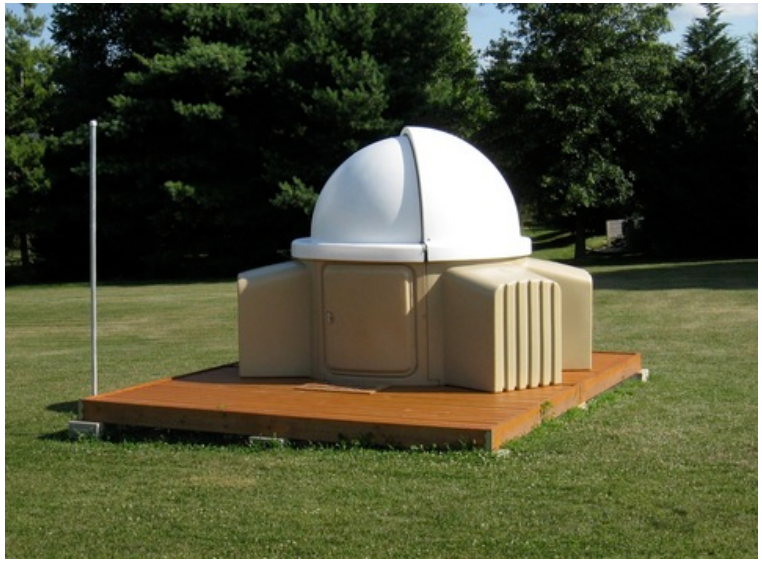
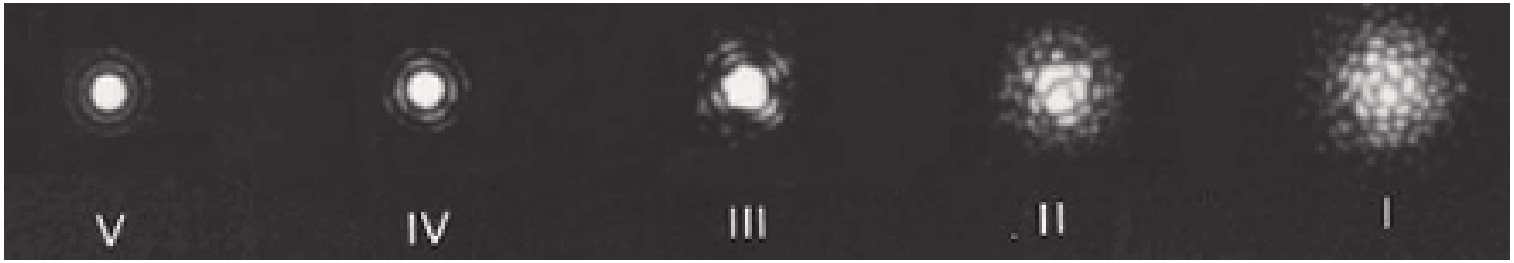
The Challenge

- Can we image astrophysically interesting pairs in less-than-perfect and even relatively poor nights of seeing with “average” amateur telescopes?



Objectives

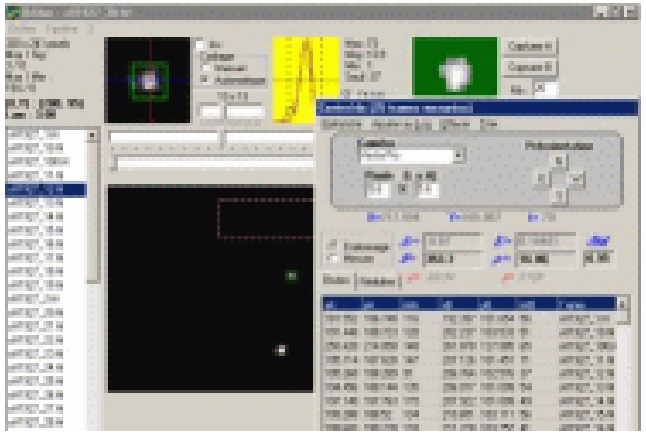
- Access autocorrelation data reduction techniques using a 204 mm telescope under less than ideal conditions.
- Compare the results to lucky imaging under the same conditions.
- For selected pairs, access accuracy using observed versus calculated (o-c) theta and rho



Stolen from Environment Canada

The Equipment

- Telescope: 204mm F22.5 Dall-Kirkham
- Mount: Losmandy G-11 GEM with DSC
- DMK21 video camera (640x480 pixels)
- 2x Orion shorty barlow for nominal F50
- REDUC software for data reduction



Methods - Imaging

- For each night's run
  - Establish plate scale and orientation
  - Integration times: 8 millisecond to 66 milliseconds
  - Four videos per double with 400 – 1000 frames per video.
  - Or (wide pairs) 100 – 400 frames at up to 1 second.
  - Convert avi files to bitmap images

Methods - Autocorrelation

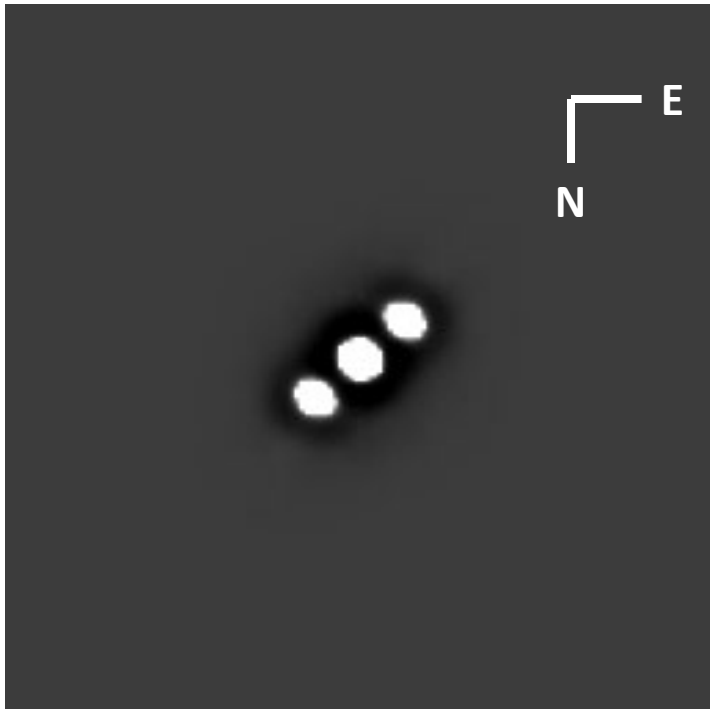
- REDUC v4.7 software (Losse, 2012)
- Autocorrelation
  - Autocorrelation with enhanced spectrum
  - Lowest correlogram of S1-S9
  - N=4 or N=5 measures

Methods – Lucky Imaging

- REDUC v4.7
- Sort on Max signal
- Pick best 10-25% based on file size (larger % for wide bright pairs with good images)
- Stack and measure stacked image
- N= 4-5 total measures
- Save data to REDUC

F50 - 00550+2338STF 73AB

36 And, 6th mag, Dm 0.4

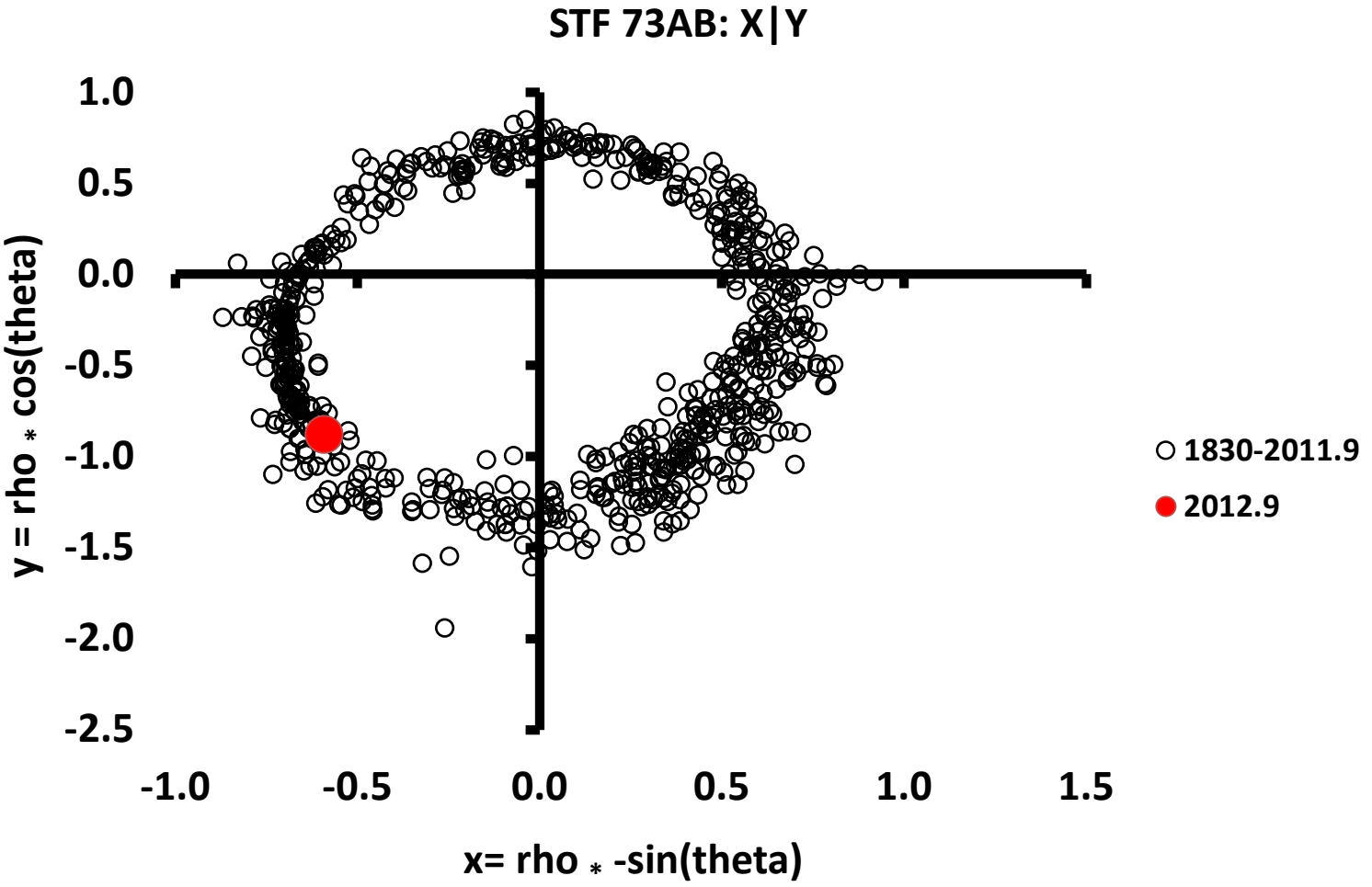


S5 correlogram
Best 500 of 1000
16 milliseconds
Nominal F50
Seeing 3

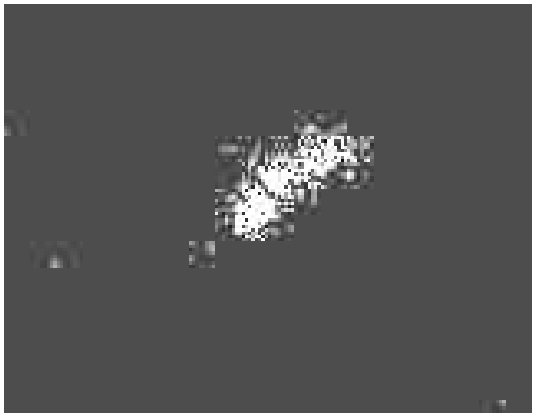
2012.953 - Autocorrelation
PA = 326.1° ± 0.6
Sep = 1.06” ± 0.03”
o-c -0°7/-0"03
Muterspaugh et al., 2010

4th Interferometric Catalog
Prieur et al. 2010.05
o-c -0°6/-0"004
Mason et al. 2009.652
o-c -0°6/-0"02

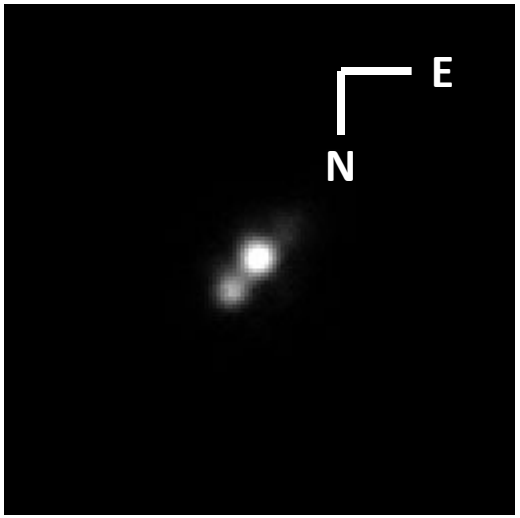
00550+2338STF 73AB Relative Motion



00550+2338STF 73AB: Lucky Imaging



1 of 1000 frames, 16 ms, F50



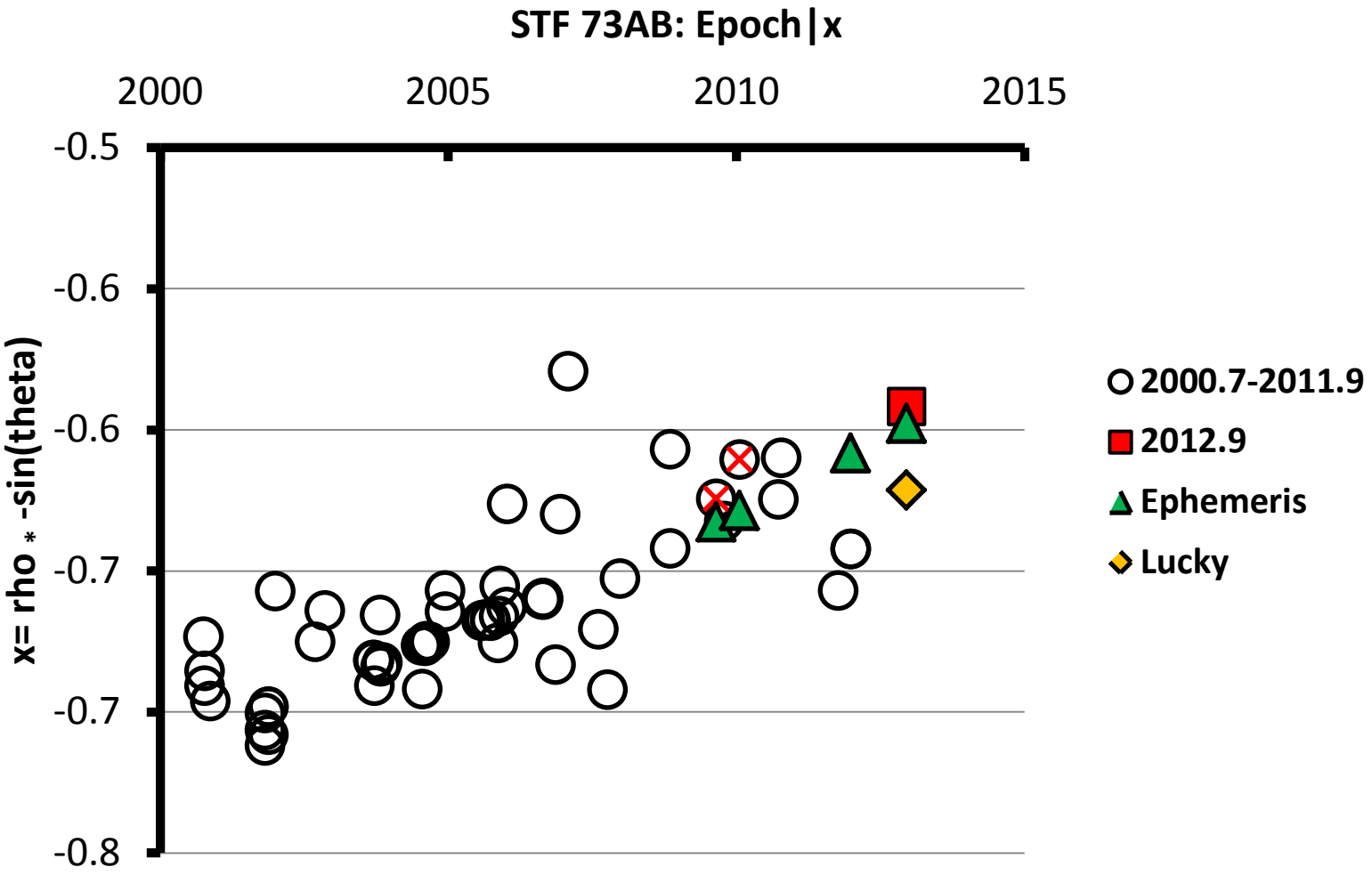
Stack of best 100 frames

2012.953 F50
Quadplex
"Surface" N=5
PA = 324.4° ± 0.7
Sep = 1.05" ± 0.02"

o-c -2°37/-0"02

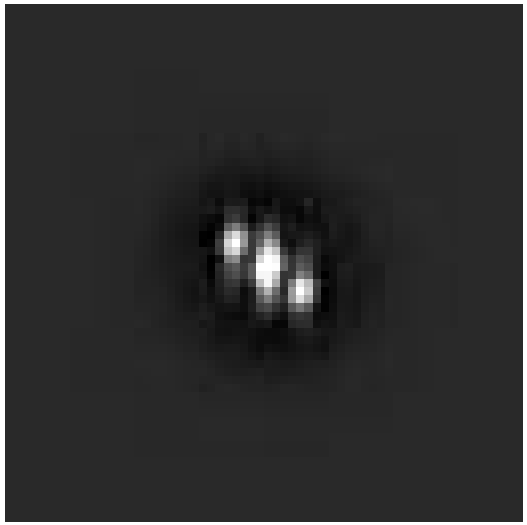
Muterspaugh et al., 2010

00550+2338STF 73AB
Recent Observations

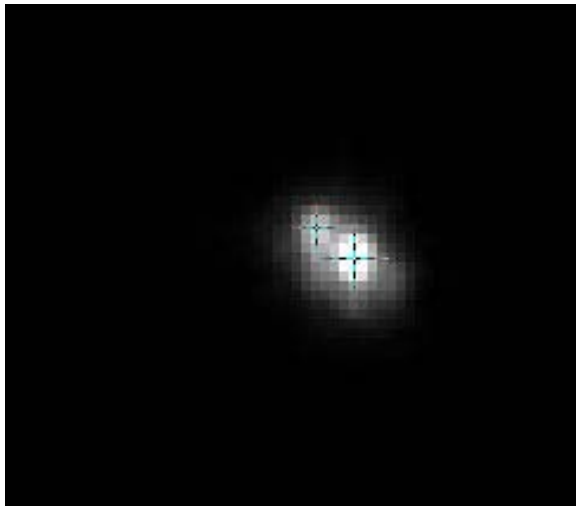


15038+4739STF1909

44 Boo, 5th&6th mag, Dm 1



2012.953: F22.5, 8ms, S1 correlogram

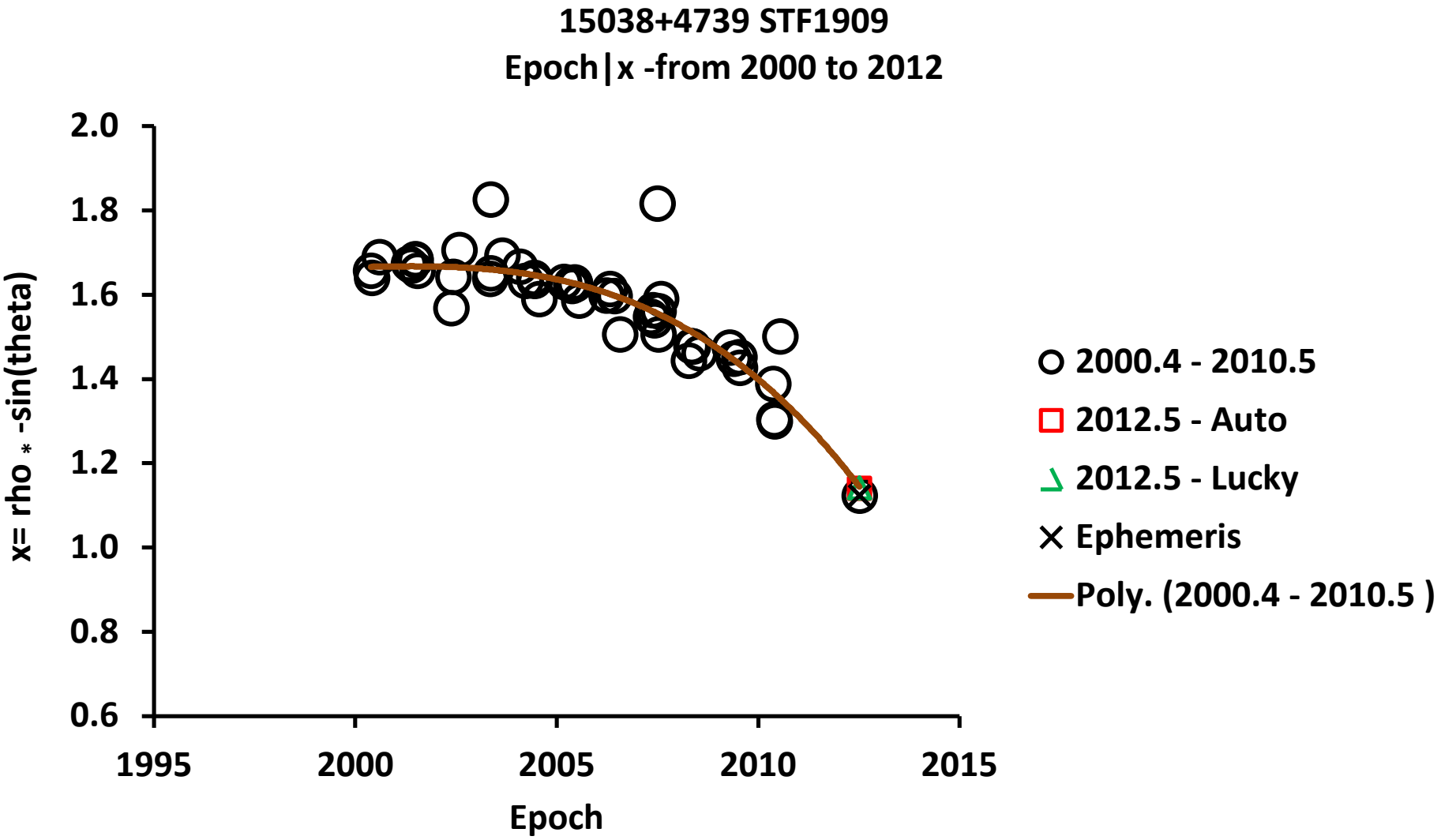


2012.953: F22.5, 8ms, 40 stacked

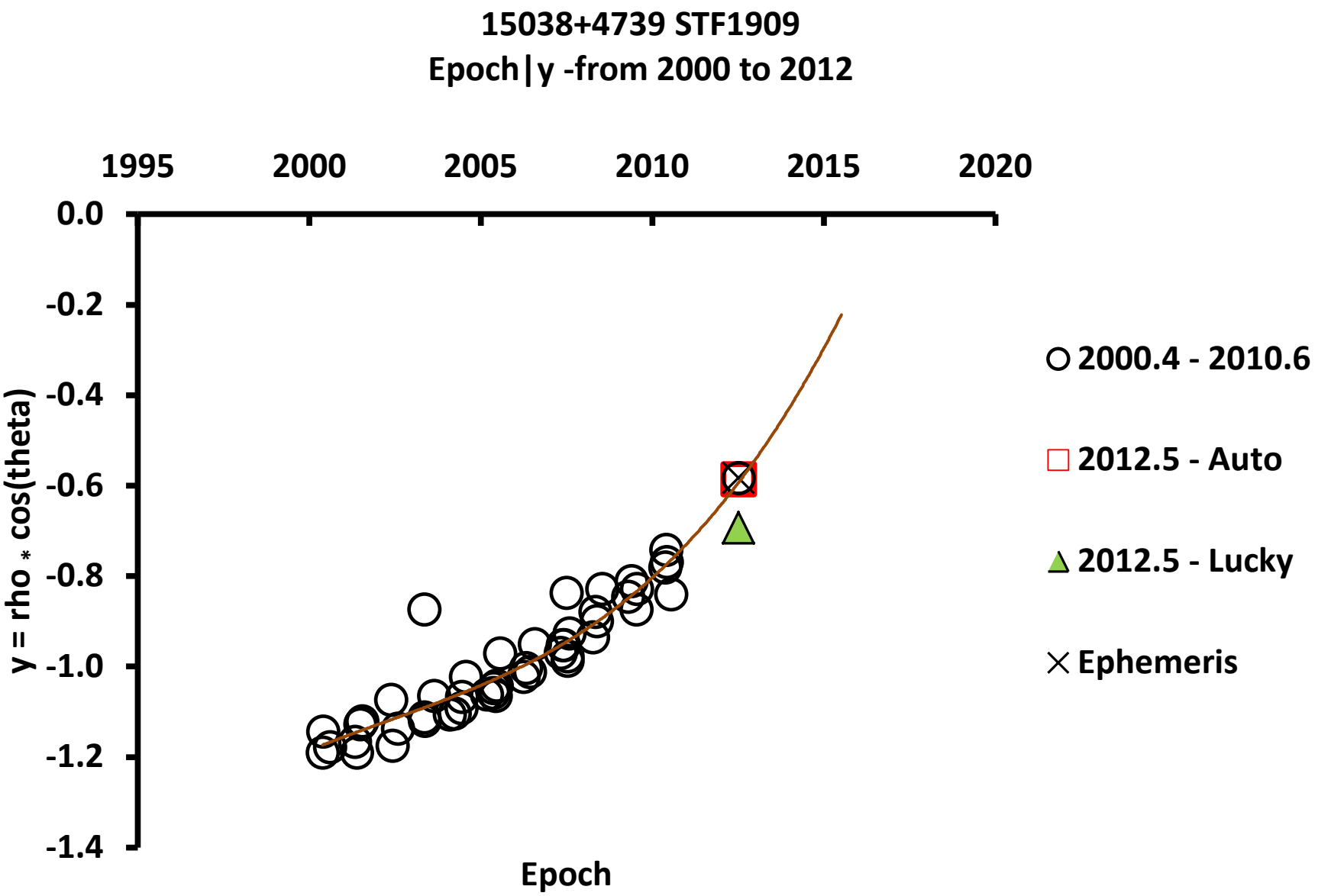
Autocorrelation 400
N = 4
PA = 62.7° ±0.13
Sep = 1.282±0.004
o-c -0°4/0”04

Lucky 40/400
Quadplex - “Surface” N=4
PA = 61.3°±1.56
Sep = 1.297” ± 0.03”
o-c -1°21/0”03

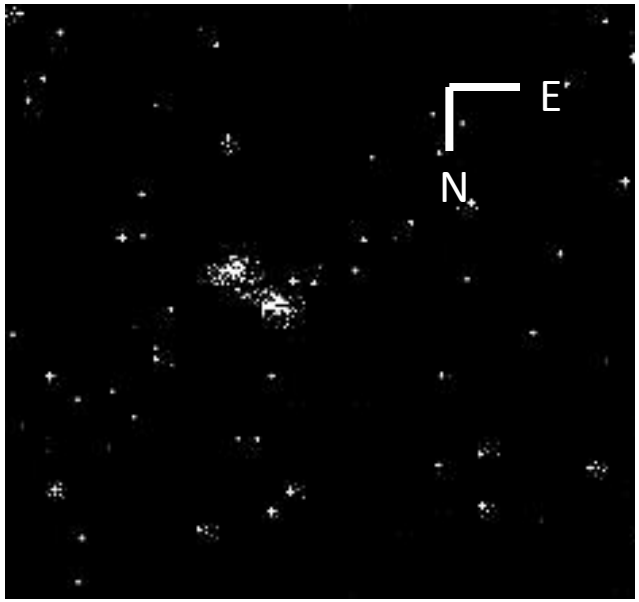
History versus O-C



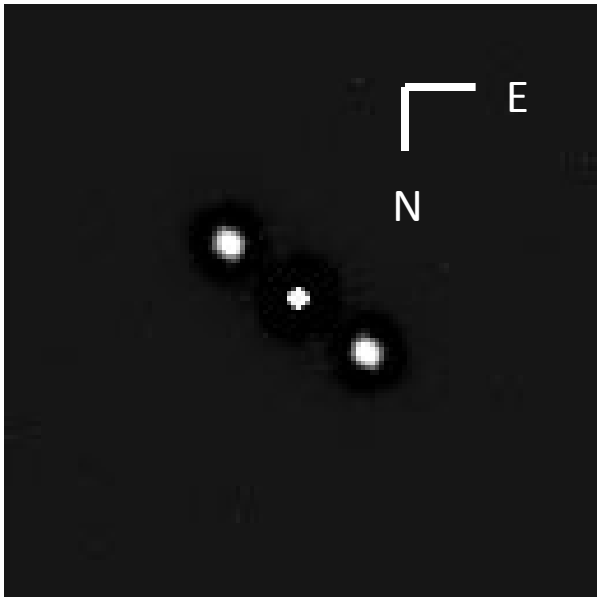
History versus O-C



What if you have no Model? 03401+3407STF 425



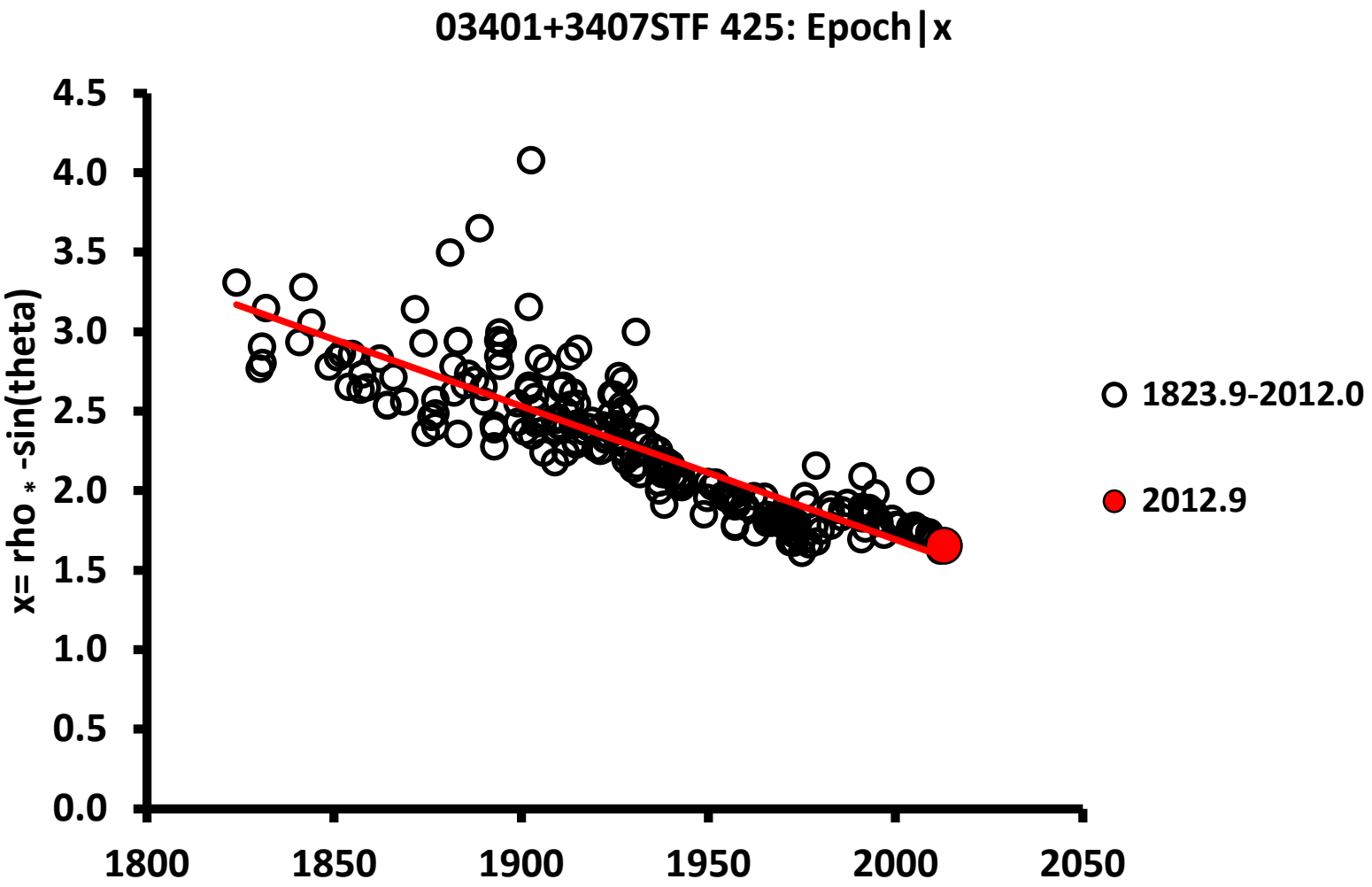
Best single of 1000 33ms



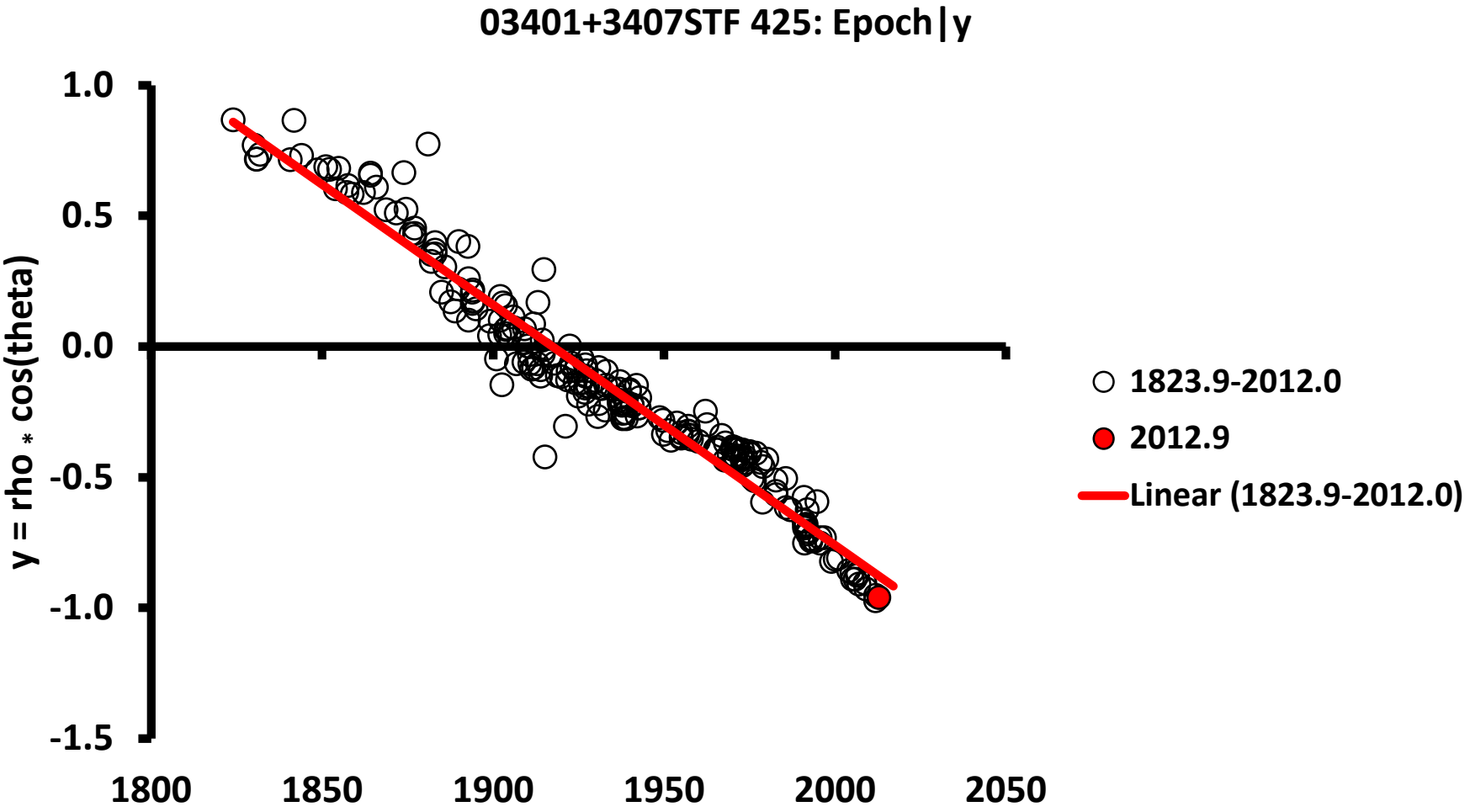
S3 correlogram

F50 - 2012.9274 59.9±0.7° 1.91±0.03”

Accessing o-c in Absence of Model

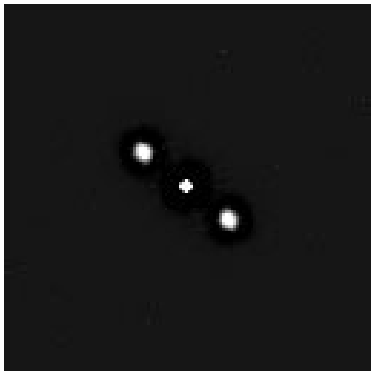


Accessing o-c in Absence of Model

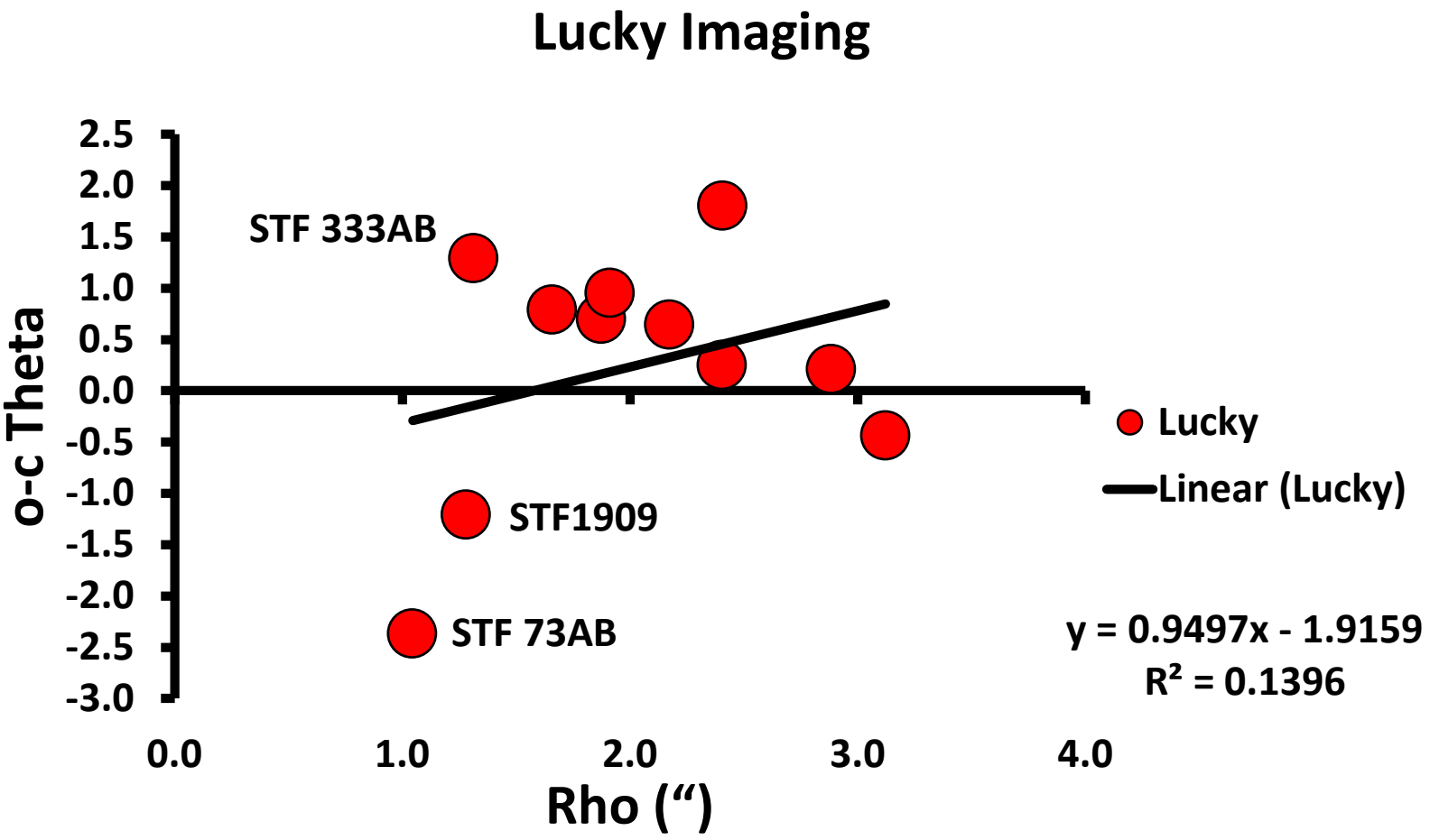


Assessing o-c in Absence of Model

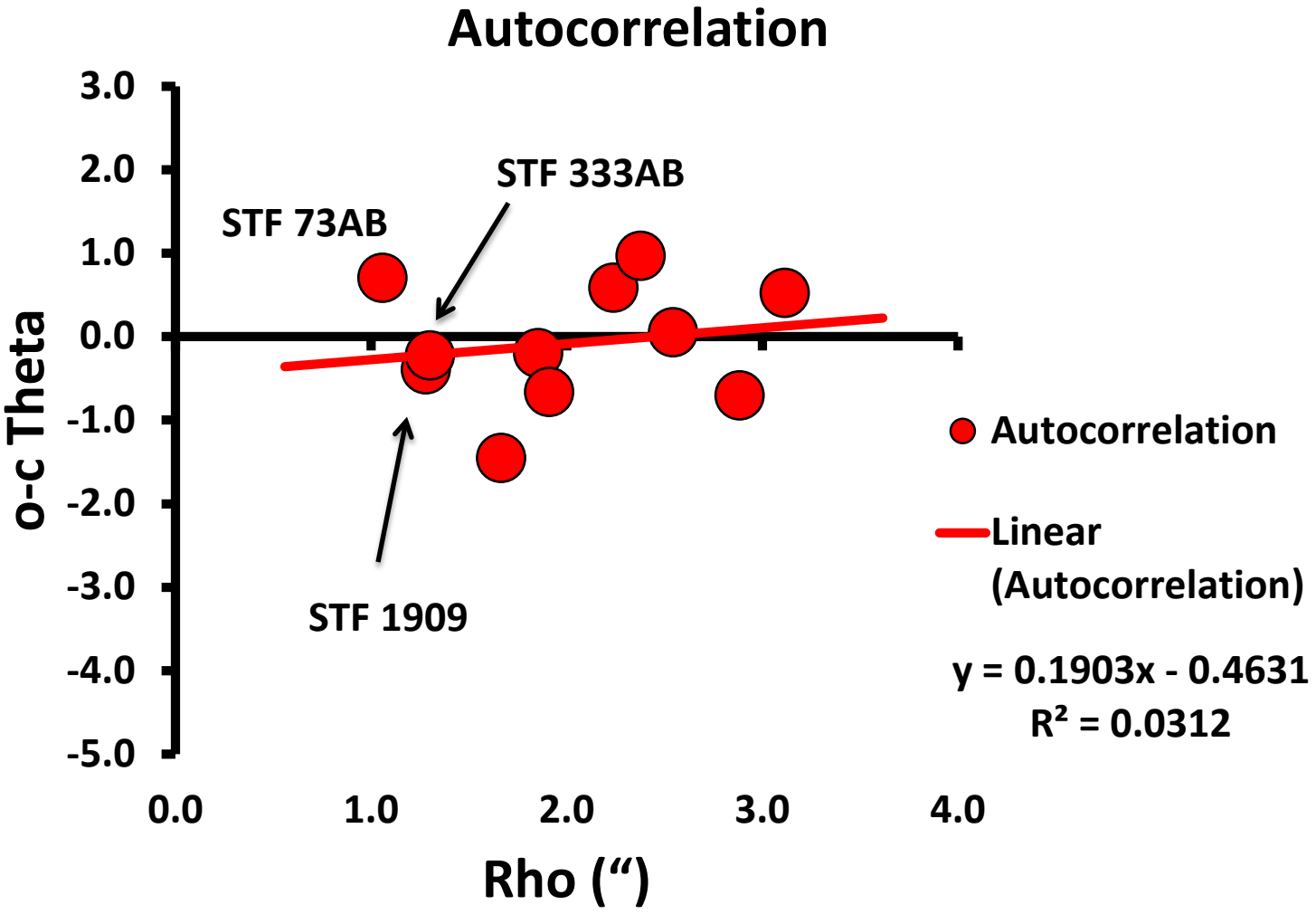
- Regress x and y-values including your measure on Epoch. (“true” regression - Epoch without error)
- Predicted x- and y-values = “Calculated”
- Measured values = “Observed”
- Convert predicted x- and y-values to “calculated” theta and rho
- Calculate o-c
- Example: STF 425 o-c (autocorrelation)
  - Theta 0°67
  - Rho 0”03



Rho|o-c Theta at F22.5 & F50



Rho|o-c Theta at F22.5 & F50



Conclusions

- Autocorrelation seems to work well with pixels in the apparent absence of speckles even under adverse conditions with small telescopes and modest cameras.
- For well resolved doubles autocorrelation and lucky imaging seem equally accurate up to at least 1.5-2” separation although measurement scatter is greater with lucky imaging as implemented by me in REDUC.
- Autocorrelation seems superior to lucky imaging under adverse conditions and doubles <1.5”.

Acknowledgements

- Florent Losse for much advice on REDUC.
- Brian Mason and Bill Hartkopf (USNO) for honoring my many requests for data.
- Bob Royce for producing a truly exceptional set of Dall-Kirkham optics.
- Russ Genet for hours of talking “REDUC.”
- All the organizers who have made this conference a success.