# IRACSIM: Simulating IRAC Data

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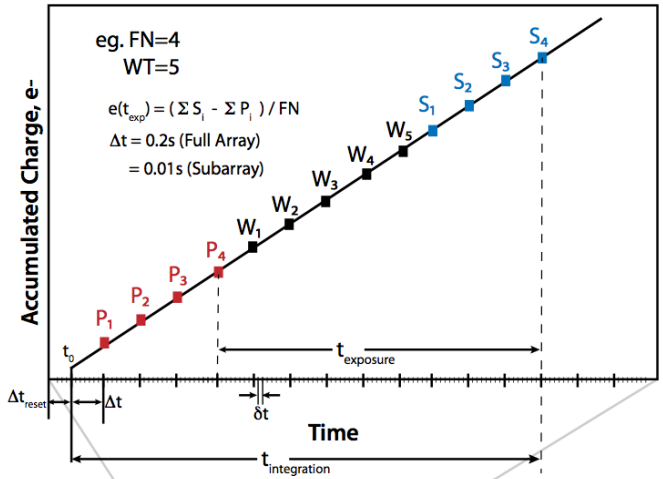
**(NOAO)**

# Components of a Data Simulator

## IRAC Photometry Model




Create vectors (**x,y,L**), sampled on intervals of δt.

For each DCE (save as data file):

For each SubFrame (1x 256 x 256 for Full Array, 64 x 32 x 32 for Subarray):

1) Produce PRF realizations at pixel $(i_p,j_p)$ covering the complete $t_{integration}$ -$t_0$ of the current integration (which starts at $t_0$),
$e(i_p,j_p,k) = e(\delta t) * L(t_k) * f_{PRF}[i_p,j_p,x(t_k),y(t_k)]$ ($f_{PRF}$ is normalized to 1.0 at the peak)

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2) For each Fowler Sample i, compute the Pedestal and Signal images by integrating the PRF realizations. Assume Δt is an integer multiple *n* of δt.
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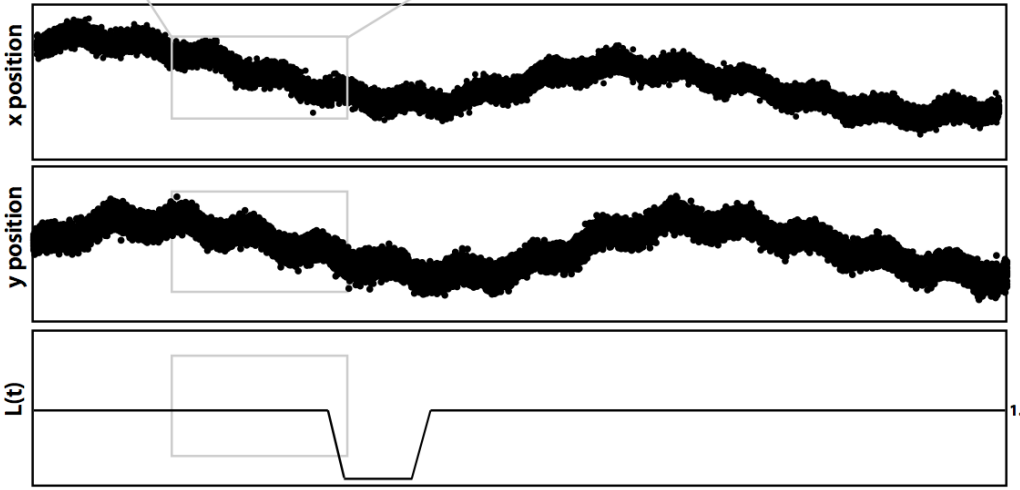


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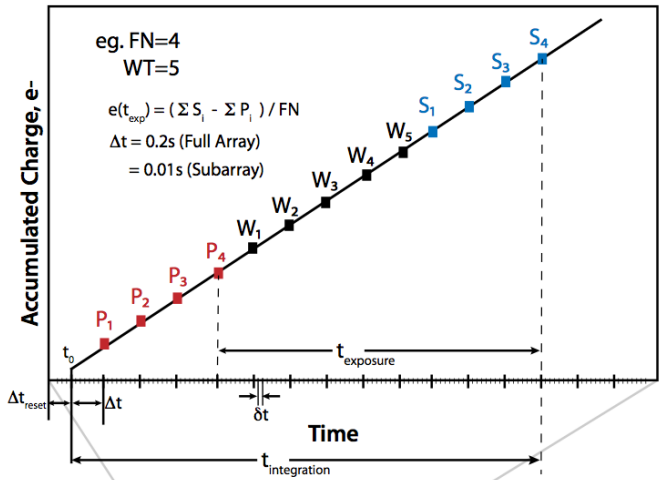


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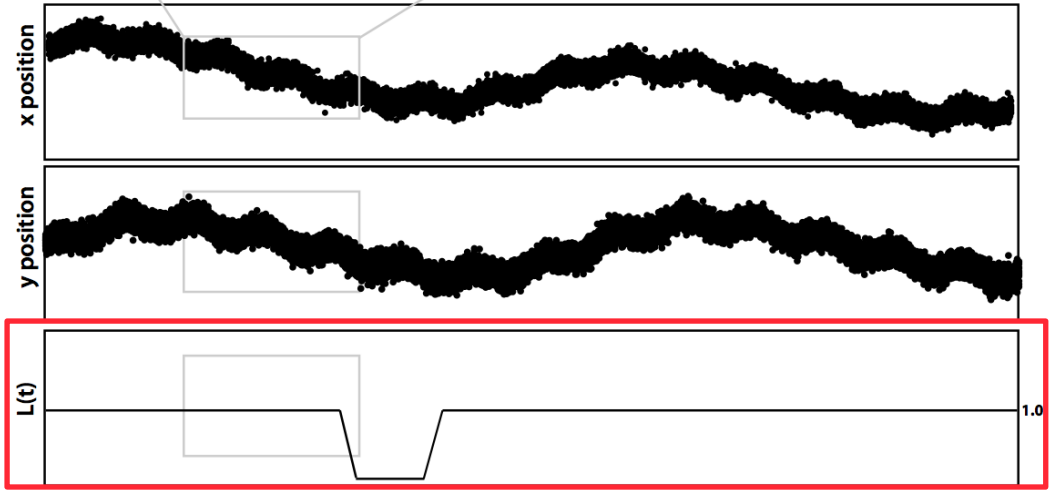


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- Source Variation

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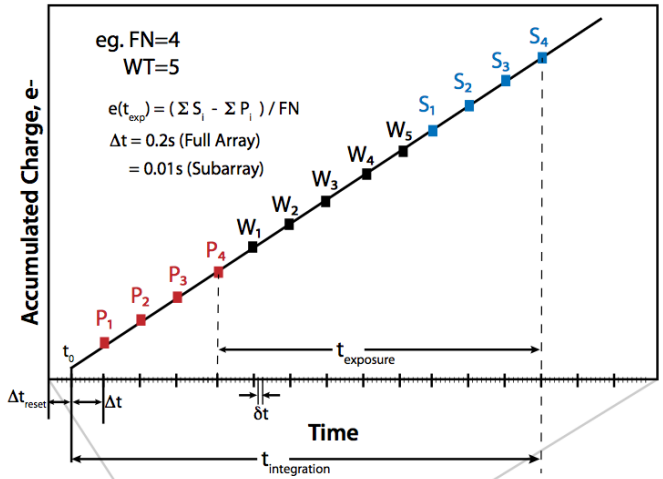


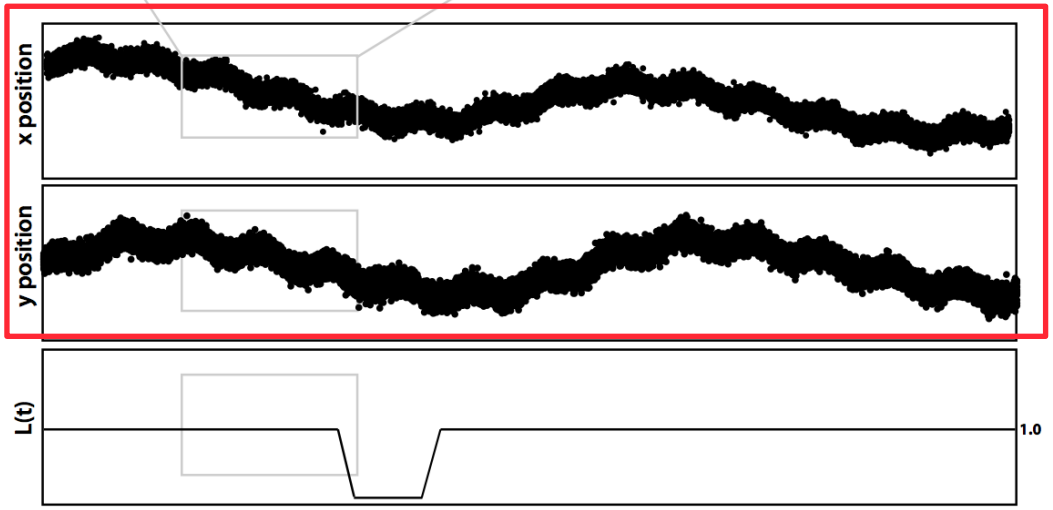


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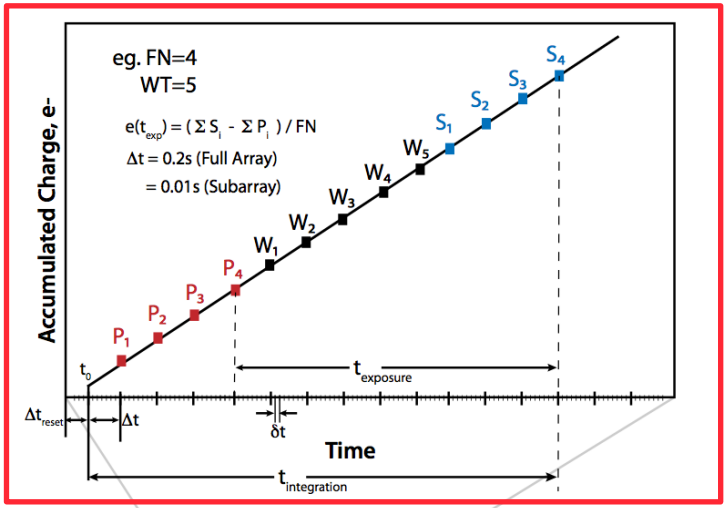


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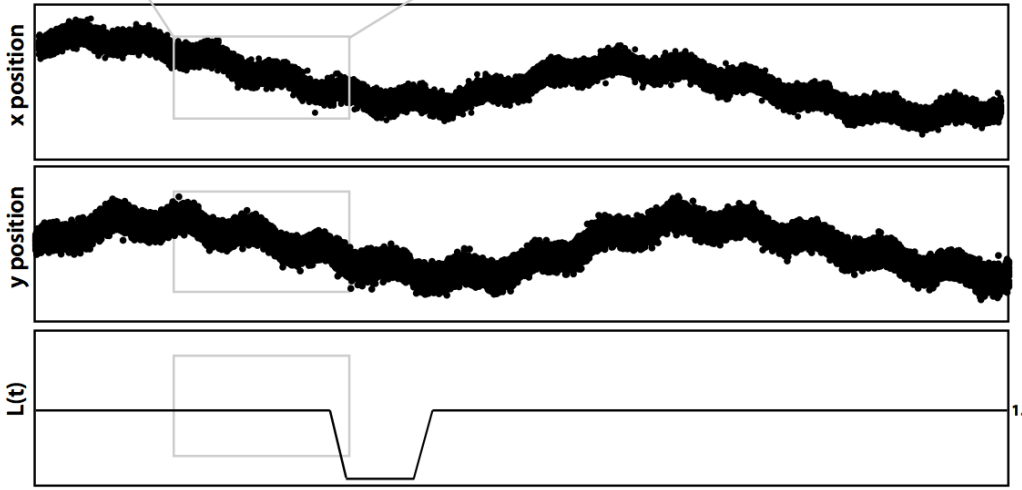


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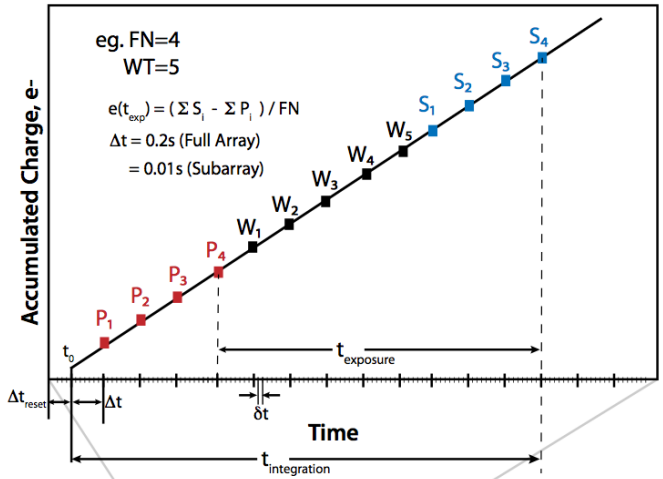


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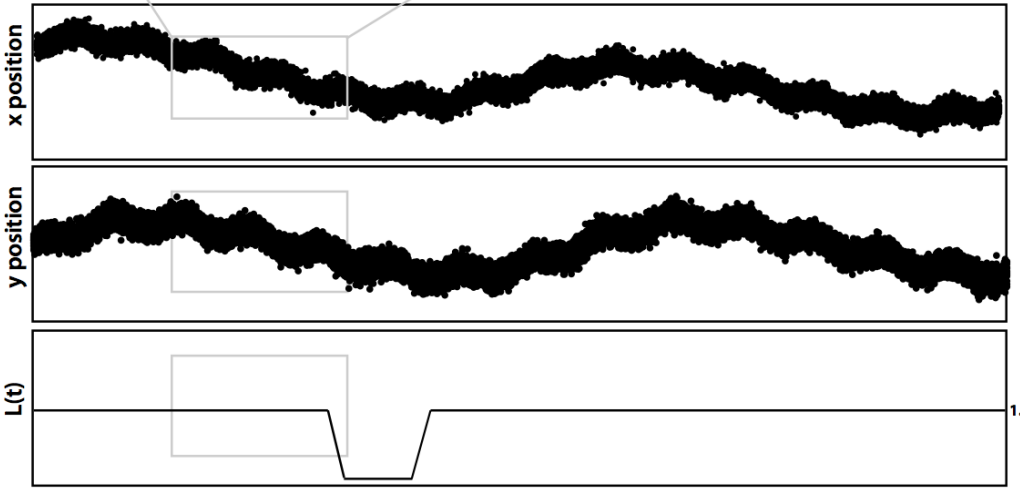


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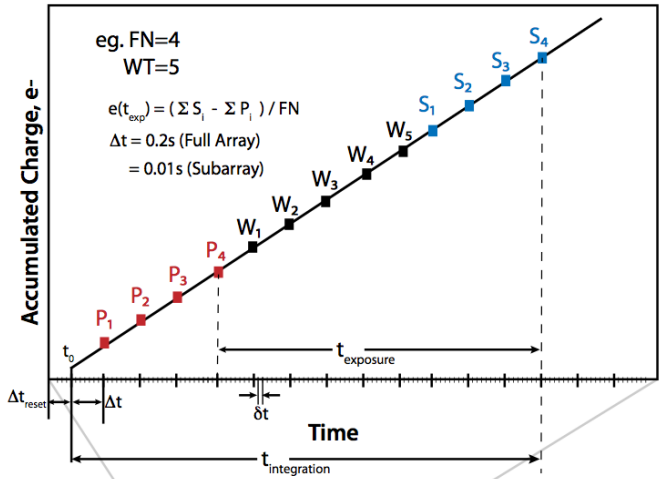


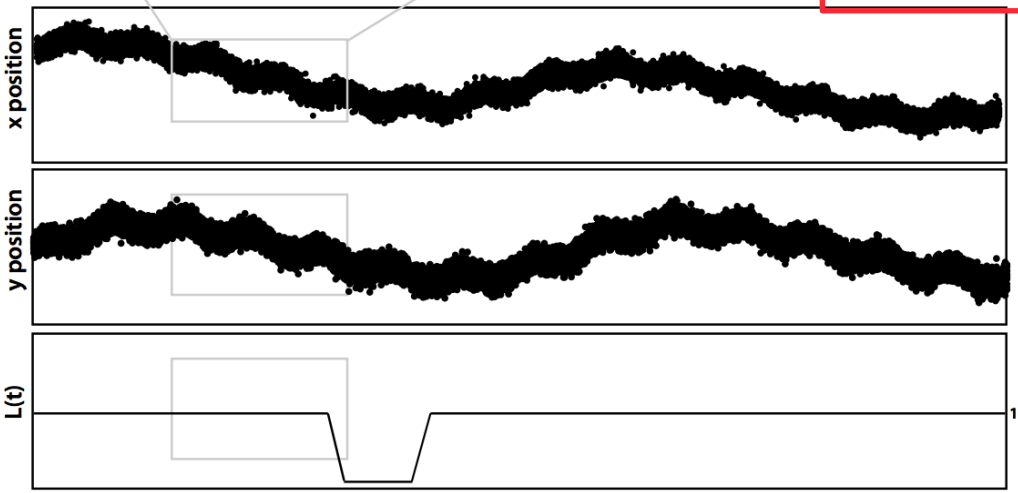


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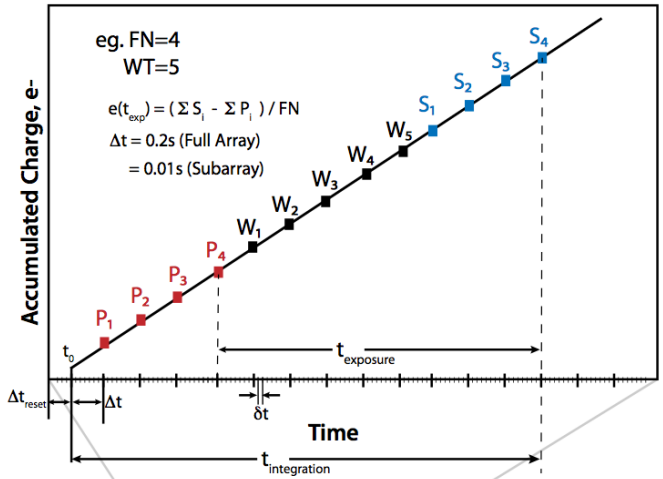


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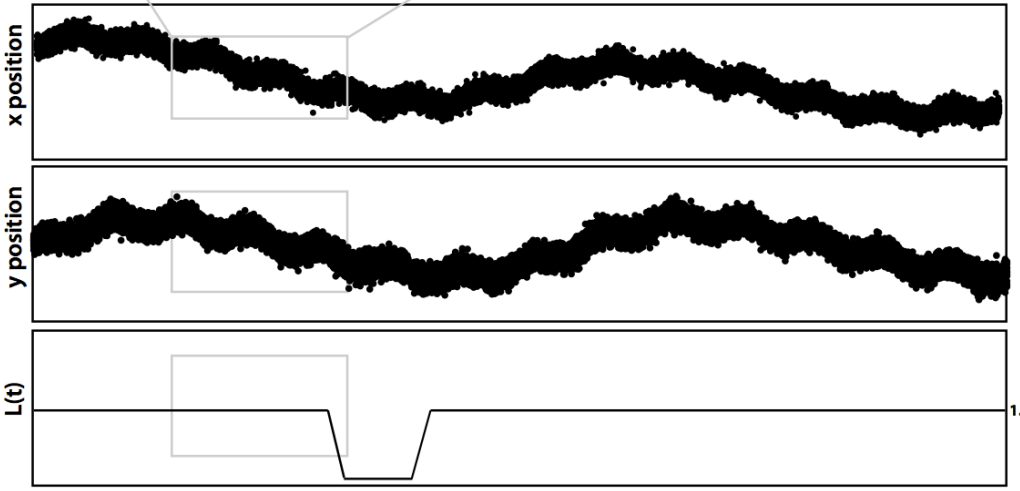


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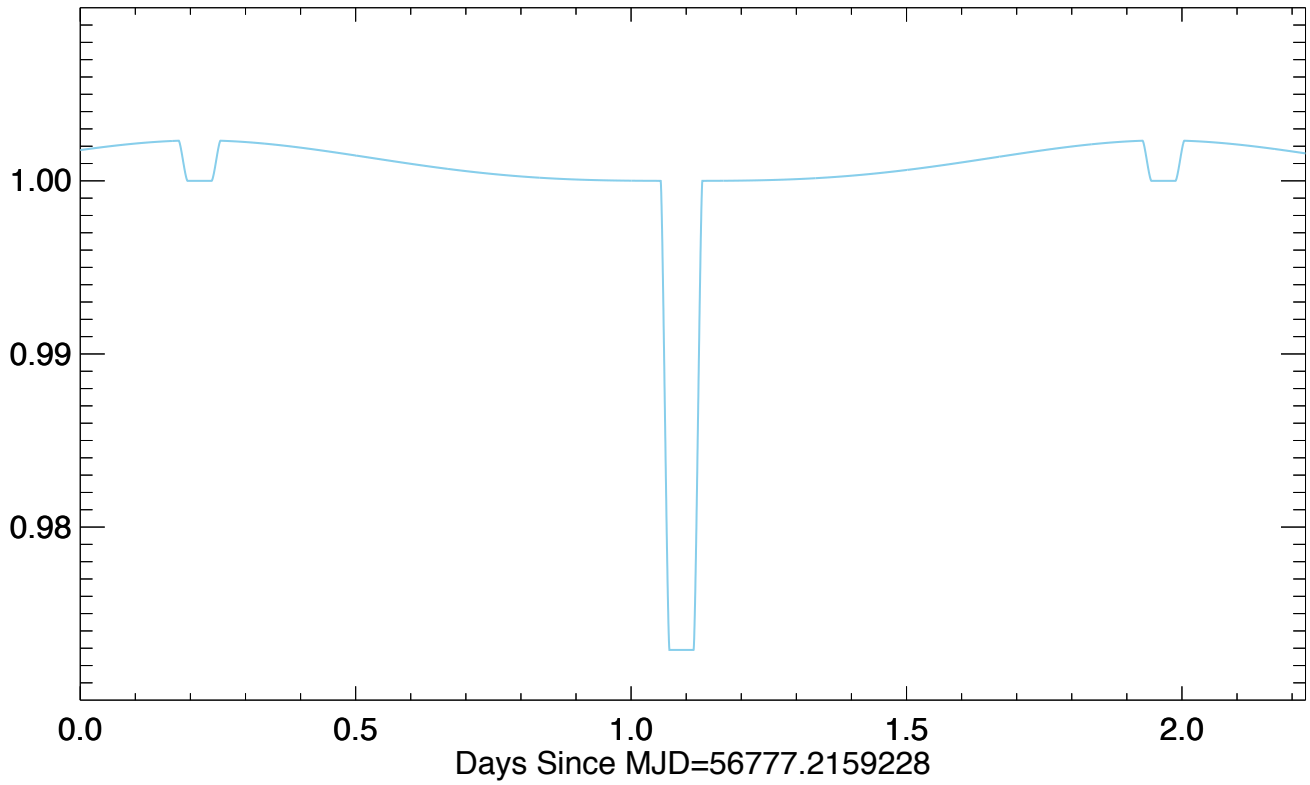
- Noise
- Calibration

# Source Brightness Variations

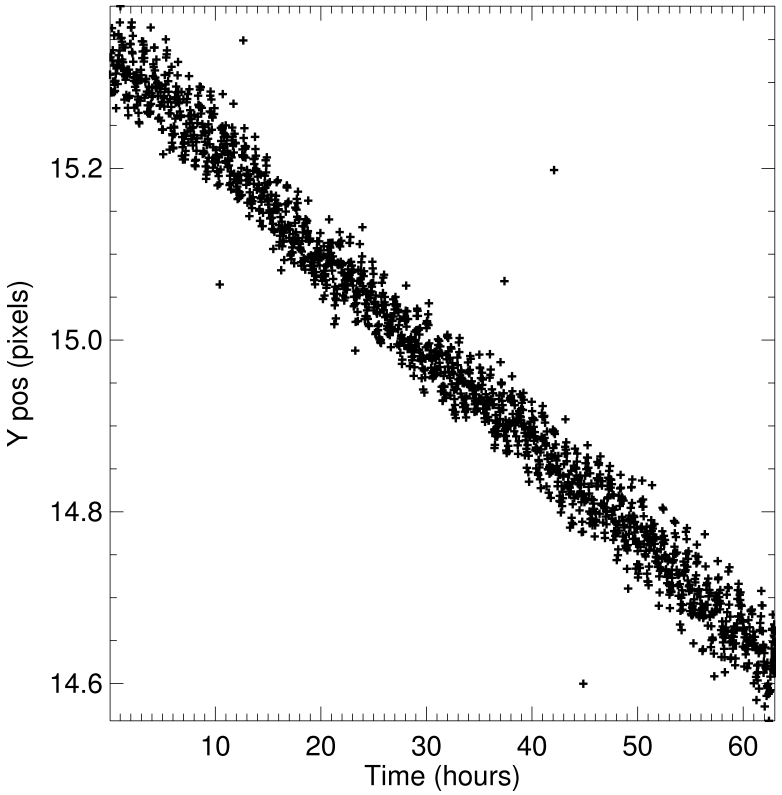
- Normalized brightness as a function of time expected (default = constant)
- Automatic download of Exoplanets.org database
- Adapted Mandel & Agol transit shape functions
- Phase curve for tidally locked blackbody Lambert sphere from Seager



# Pointing Model

- Empirical
- IRAC Detector-Based
- Include all known effects
- Most effects specified with an amplitude (vs time) and direction along the detector plane, resulting in projected X and Y pixel behavior
- Allow the user to adjust model parameters, or “turn off” an effect
- User can allow parameters to float and random values within reasonable ranges will be chosen

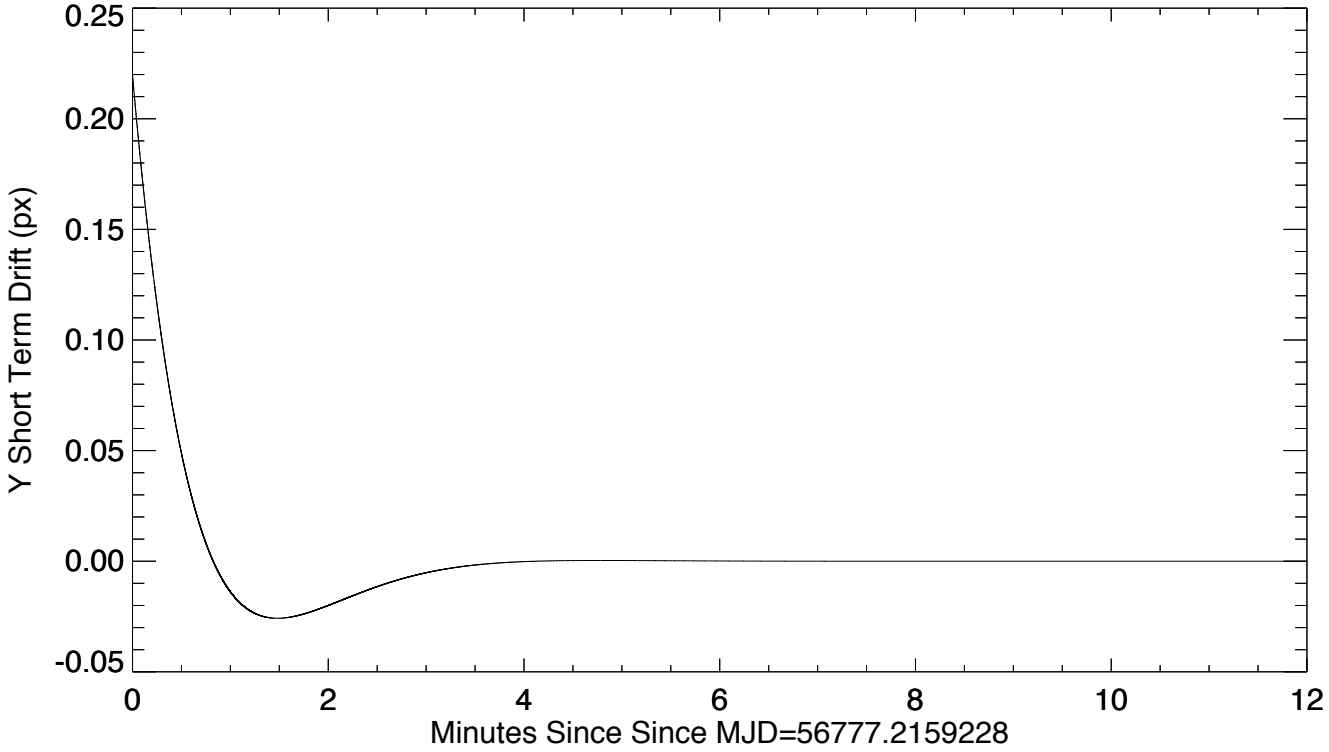
Centroid drift of staring mode observation of XO3




Long term drift < 0.3 arcsec/day

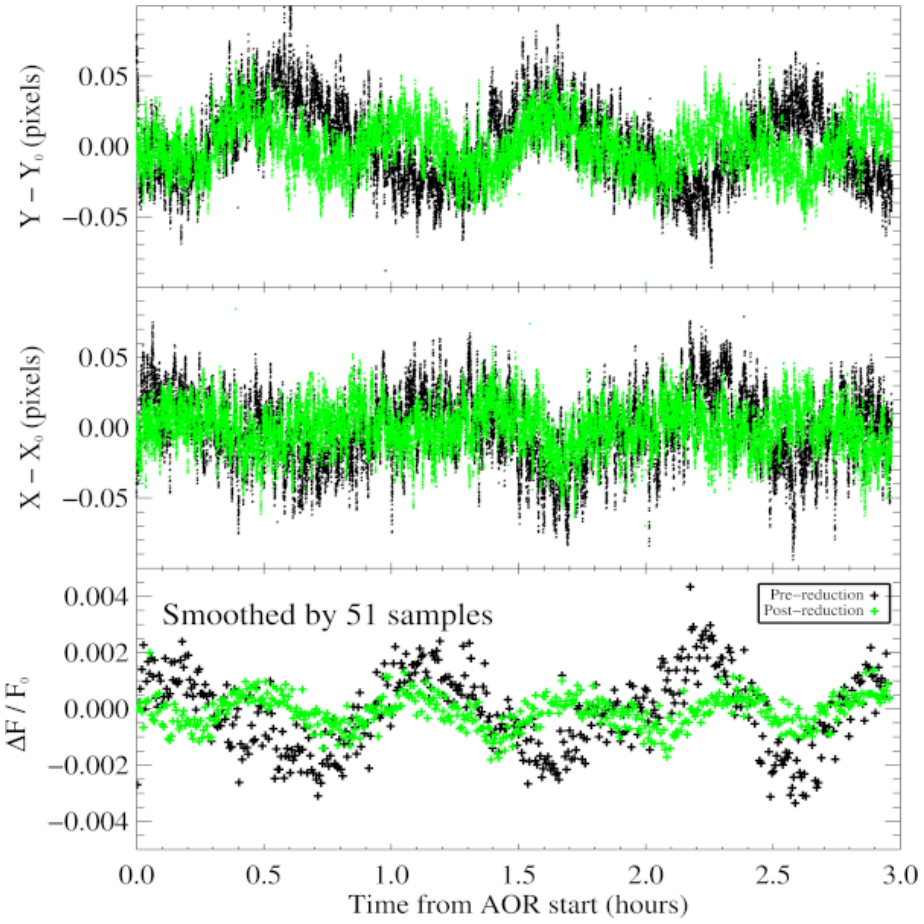
# Pointing Model: Short Term "Settling" Drift

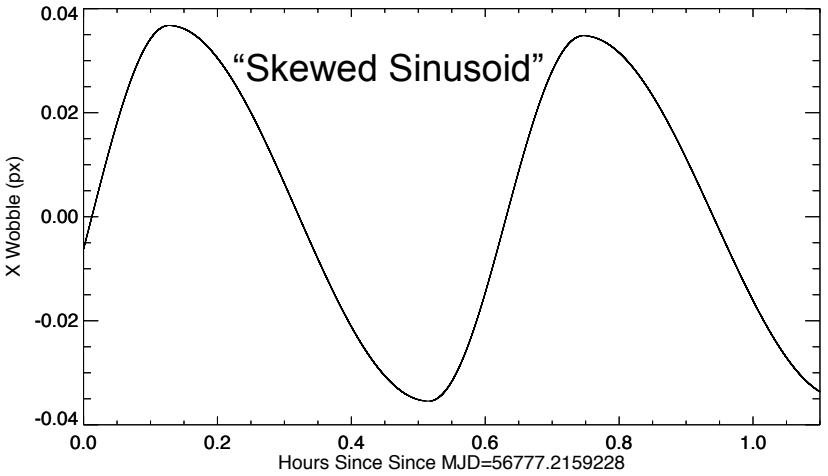
- Rapidly Decaying Sinusoid
- Decay can be positive or negative



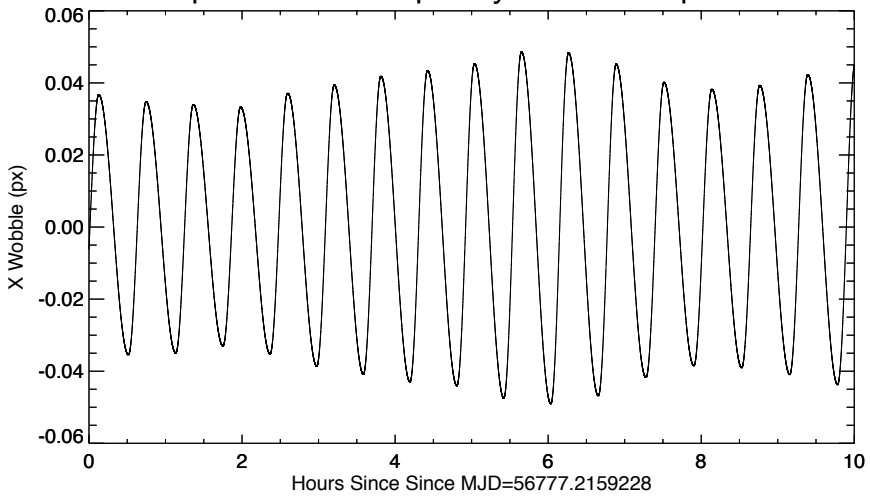
# Pointing Model: Heater Wobble

Photometry of HD 158460
Pre (black) and Post (green) heater change

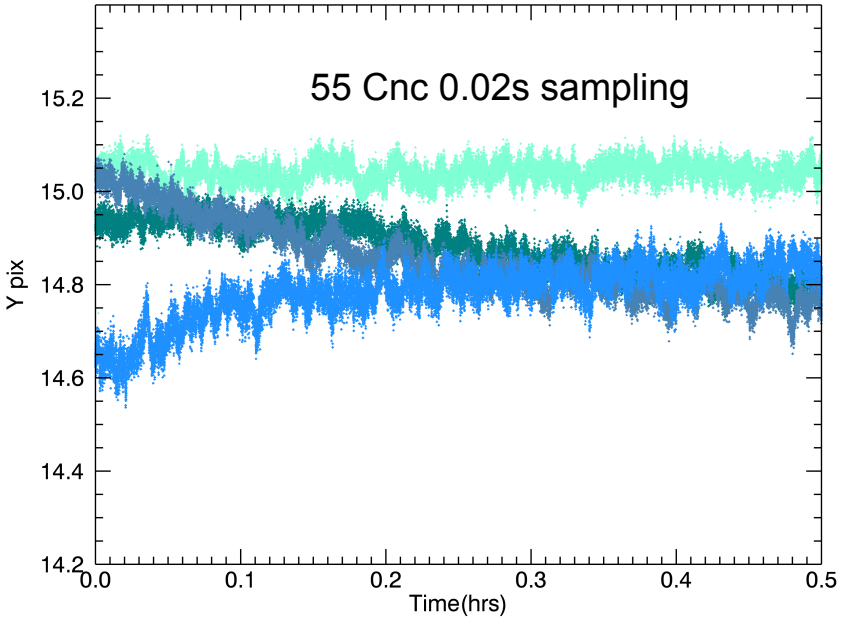


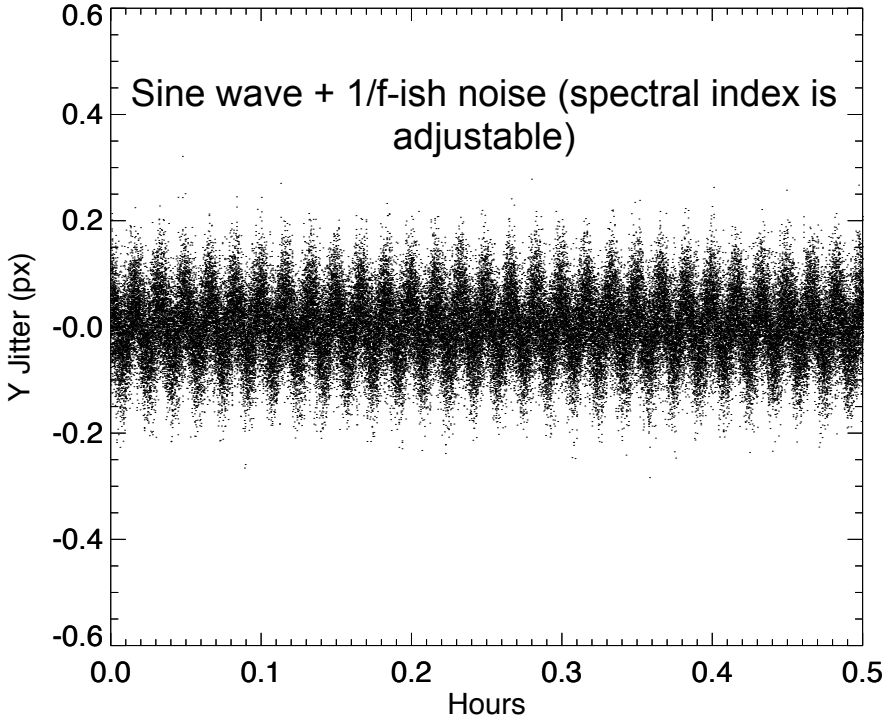




Amplitude and Frequency variations optional



# Pointing Model: High Frequency "Jitter"

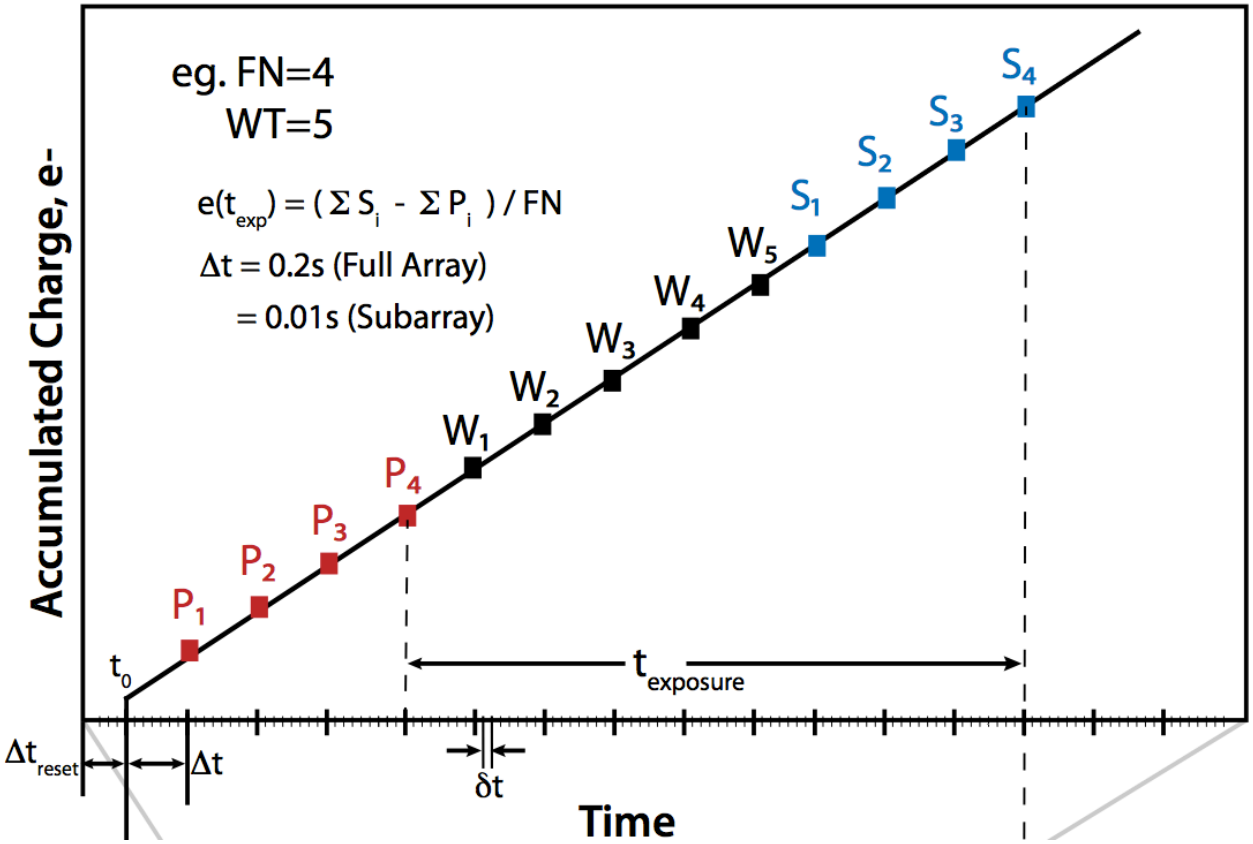



- Fluctuations faster than the Pointing Control System can react

# Simulating IRAC Integration

- Pointing model is sampled every 1ms
- IRAC PRF is realized (e/ms/px) for every (x,y) offset in the pointing model
- Array is “read” by integrating the 1 ms images to make Fowler samples



# Simulator Inputs

- Position(s) of one or more sources
- Date & Time of observation
- Source flux density (ies)
- Source light curve
- AOR-type observational parameters (channel, frametime, number of repeats, Full or Subarray)
- Pointing model parameters

# Simulator Outputs

- BCD image files
- Uncertainty files
- Can produce results in DN or electrons
- Realistic Fits header (should fool your software)
- Header lists average x,y position over integration from pointing model

```
SIMPLE  =                    T / Written by IDL:  Thu May 15 15:57:58 2014
BITPIX  =                  -32 / Number of bits per data pixel
NAXIS   =                    3 / Number of data axes
NAXIS1  =                   32 /
NAXIS2  =                   32 /
NAXIS3  =                   64 /
DATE    = '2014-04-29'         / Creation UTC (CCCC-MM-DD) date of FITS header
COMMENT FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT and Astrophysics', volume 376, page 359; bibcode 2001A&A...376..359H
COMMENT
COMMENT ******************THESE ARE SIMULATED DATA******************
COMMENT
ORIGIN  = 'Spitzer Science Center (FAKE DATA)' /Organization generating this FIT
TELESCOP= 'Spitzer (FAKE DATA)' /SPITZER Space Telescope
INSTRUME= 'IRAC (FAKE DATA)'   /SPITZER Space Telescope instrument ID
CHNLNUM =                    2 /1 digit instrument channel number
EXPTYPE = 'sci     '           /Exposure Type
REQTYPE = 'AOR     '           /Request type (AOR, IER, or SER)
AOT_TYPE= 'IracMapPC'          /Observation template type
AORLABEL= 'WASP52_sim_ch2'     /AOR Label
FOVID   =                   77 /Field of View ID
FOVNAME = 'IRAC_Center_of_4.5umSub-Array' /Field of View Name

        / TIME AND EXPOSURE INFORMATION

DATE_OBS= '2014-04-30T05:10:55.731' /Date & time (UTC) at DCE start
MJD_OBS =       56777.2159228 /[days] MJD in UTC at DCE start (,JD-2400000.5)
HMJD_OBS=       56777.2159228 /[days] Corresponding Helioc. Mod. Julian Date
BMJD_OBS=       56777.2159228 /[days] Solar System Barycenter Mod. Julian Date
SCLK_OBS=      1083301855.73 /[sec] SCLK time (since 1/1/1980) at DCE start
AORTIME =            2.00000 /[sec] Frameset selected in IRAC AOT
SAMPTIME=          0.0100000 /[sec] Sample integration time
FRAMTIME=            2.00000 /[sec] Time spent integrating (whole array)
COMMENT Photons in Well = Flux[photons/sec/pixel] * FRAMTIME
EXPTIME =       1.92000000000 /[sec] Effective integration time per pixel
COMMENT DN per pixel = Flux[photons/sec/pixel] / GAIN * EXPTIME
AINTBEG =       21833809.2939 /[Secs since IRAC turn-on] Time of integ. start
ATIMEEND=       21833937.7959 /[Secs since IRAC turn-on] Time of integ. end
AFOWLNUM=                    8 /Fowler number
AWAITPER=                  184 /[0.01 sec] Wait period
AREADMOD=                    1 /Full (0) or subarray (1)
HDR_MODE=                    F /DCE taken in High Dynamic Range mode

        / TARGET AND POINTING INFORMATION

OBJECT  = 'WASP-52 b'          /Target Name
CRVAL1  =       348.494767764 /[deg] RA at CRPIX1,CRPIX2 (using ptg model)
CRVAL2  =       8.76141566878 /[deg] DEC at CRPIX1,CRPIX2 (using ptg model)
RA_HMS  = '23h13m58.7s'        /[hh:mm:ss.s] CRVAL1 as sexagesimal
DEC_HMS = '008d45m41s'         /[dd:mm:ss] CRVAL2 as sexagesimal
RADESYS = 'ICRS    '           /International Celestial Reference System
EQUINOX =             2000.00 /Equinox for ICRS celestial coord. sys.
CD1_1   =  -0.000337893987308 /CD matrix element
CD1_2   =       0.00000000000 /CD matrix element
CD2_1   =       0.00000000000 /CD matrix element
CD2_2   =   0.000337737990775 /CD matrix element
CTYPE1  = 'RA---TAN-SIP'       /RA---TAN with distortion in pixel space
CTYPE2  = 'DEC--TAN-SIP'       /DEC--TAN with distortion in pixel space
CRPIX1  =             16.5000 /Reference pixel along axis 1
CRPIX2  =             16.5000 /Reference pixel along axis 2
PXSCAL1 =      -1.21641835431 /[arcsec/pix] Scale for axis 1 at CRPIX1,CRPIX2
```

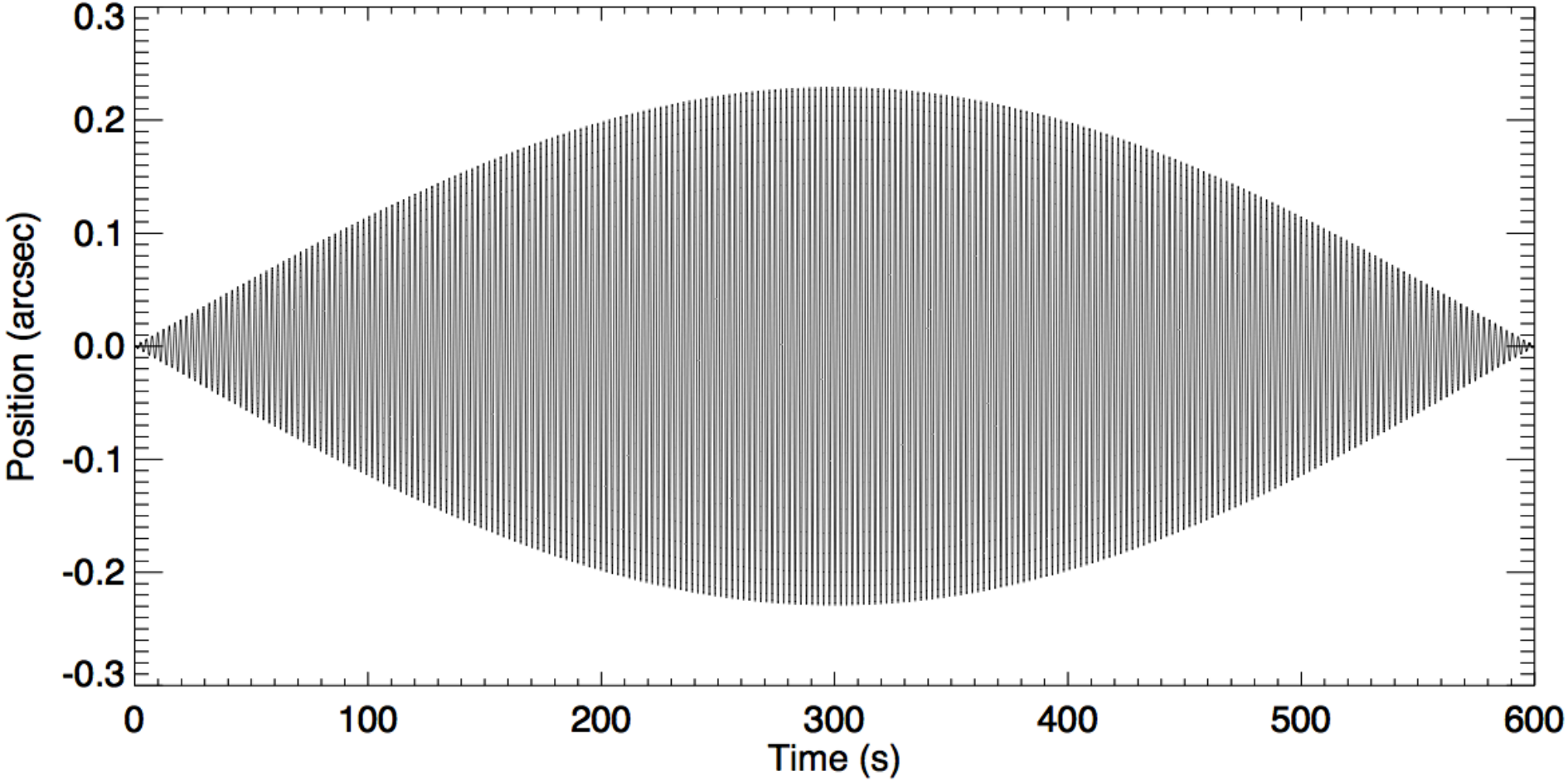
# Simulator Outputs

```
        / SIMULATION INFORMATION

CLOCAT  =          15.3082349651 /X Position of Star 0 (simulated, average)
CLOCAT  =          15.0917280049 /Y Position of Star 0 (simulated, average)
CYMEAN01= '(15.337853,15.309308)' /(X,Y) Position of Star 0 on subframe 1
CYMEAN02= '(15.338775,15.291182)' /(X,Y) Position of Star 0 on subframe 2
CYMEAN03= '(15.326275,15.266002)' /(X,Y) Position of Star 0 on subframe 3
CYMEAN04= '(15.328428,15.250069)' /(X,Y) Position of Star 0 on subframe 4
CYMEAN05= '(15.304004,15.228810)' /(X,Y) Position of Star 0 on subframe 5
CYMEAN06= '(15.322533,15.215123)' /(X,Y) Position of Star 0 on subframe 6
CYMEAN07= '(15.292161,15.181839)' /(X,Y) Position of Star 0 on subframe 7
CYMEAN08= '(15.313308,15.156205)' /(X,Y) Position of Star 0 on subframe 8
```

# Noise Pixel Spikes: High Frequency Ringing?

- Attempt to replicate spikes in Noise Pixels
- Position oscillates faster than the per-frame integration
- Image is smeared, centroid is maintained



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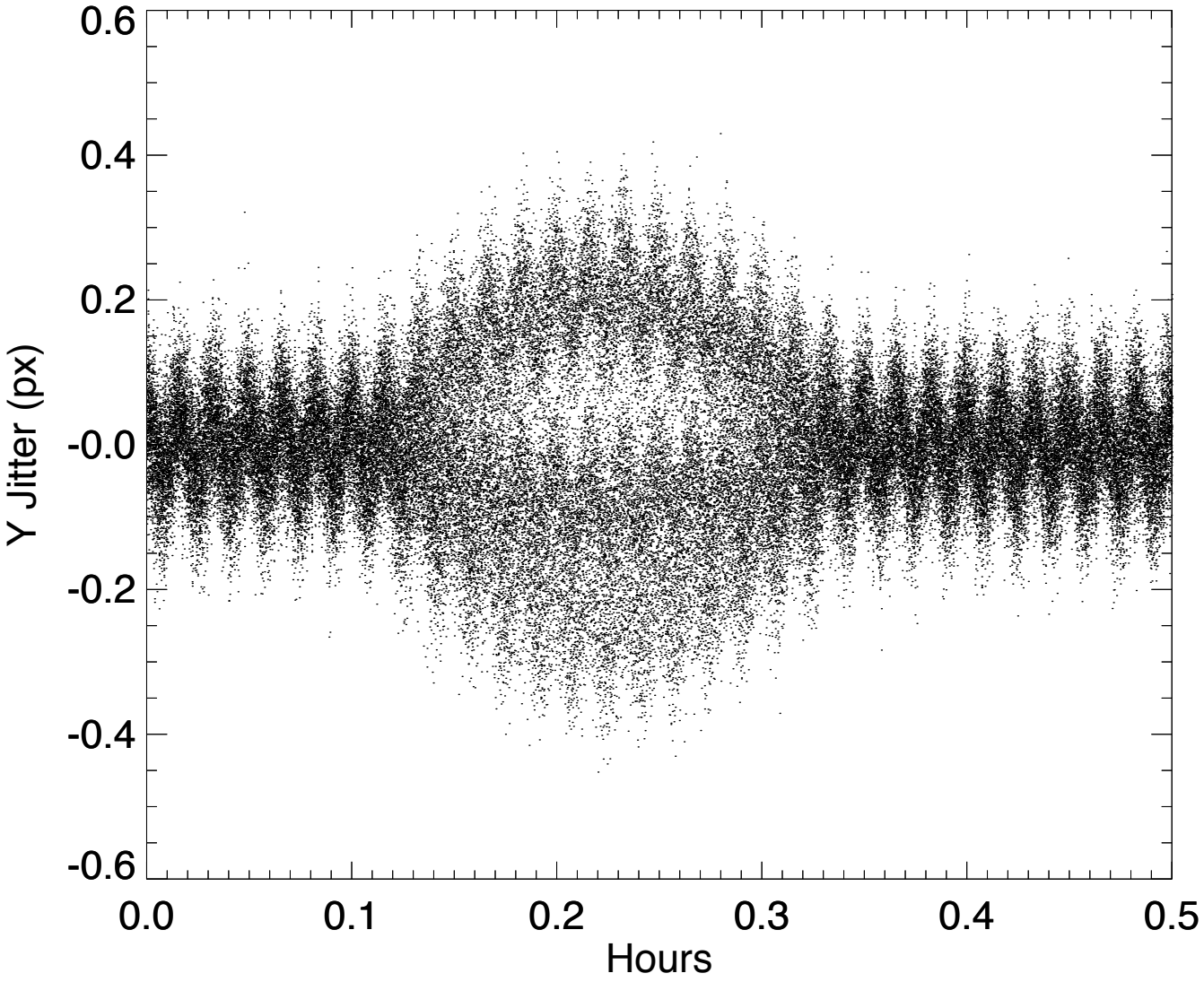

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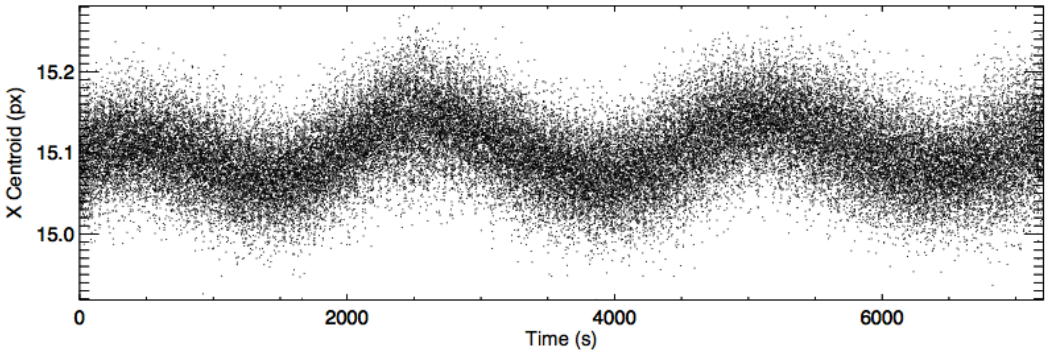
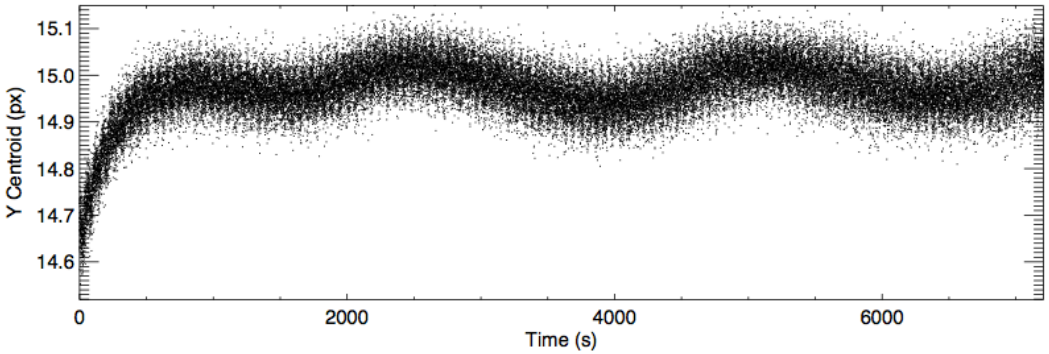
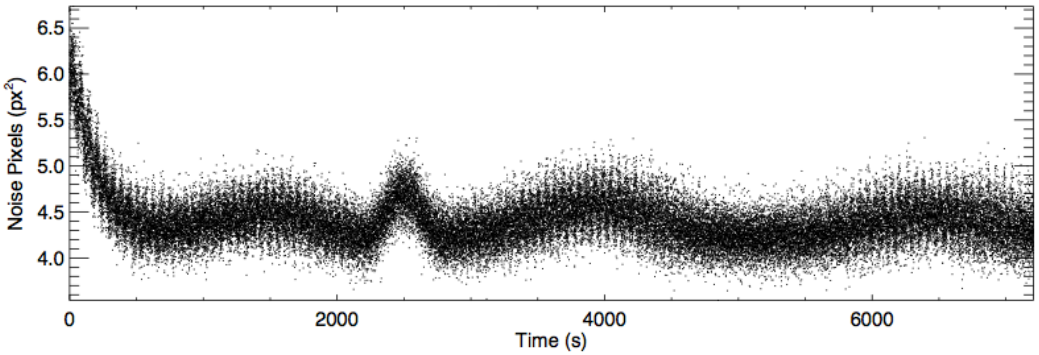
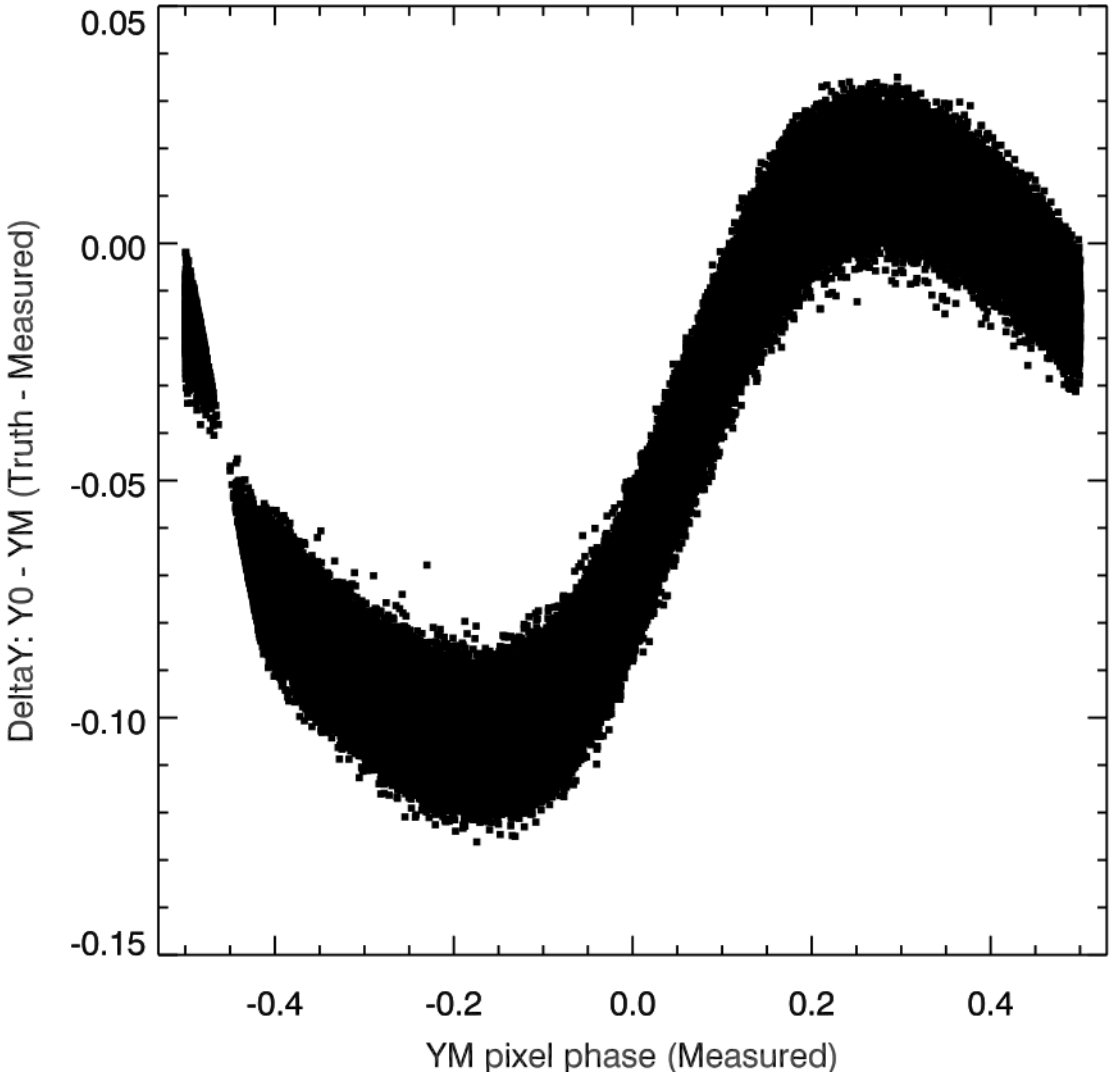


# Measuring Bias in Centroid Methods

- Work done by Ken Mighell (NOAO)
- Simulate point sources on a grid of subpixel positions
- Turn off pointing model
- Measure Error between input source position and moment centroid
- Separable in X and Y
- Repeatable
- Correction derived from mean at each pixel phase



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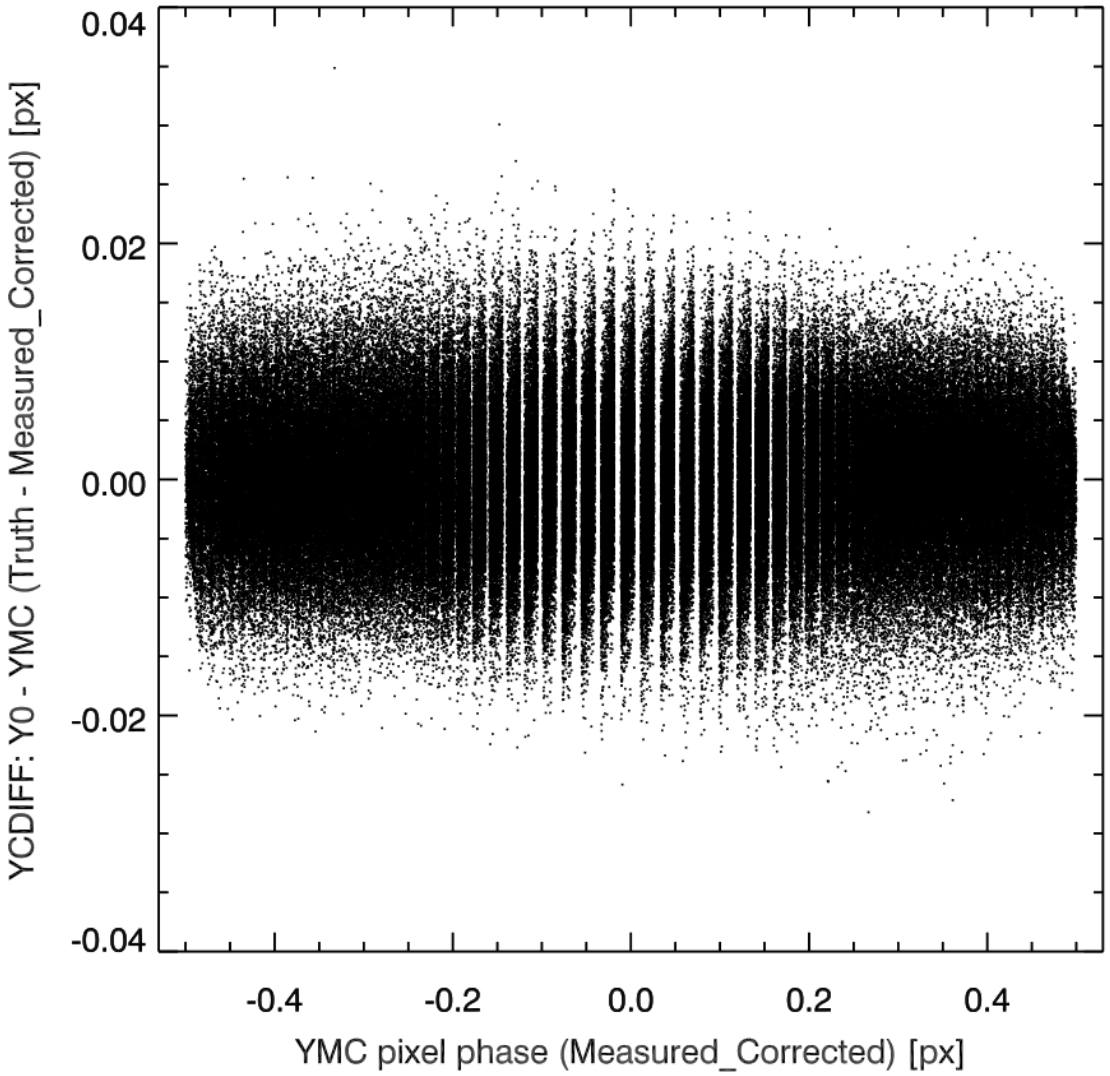
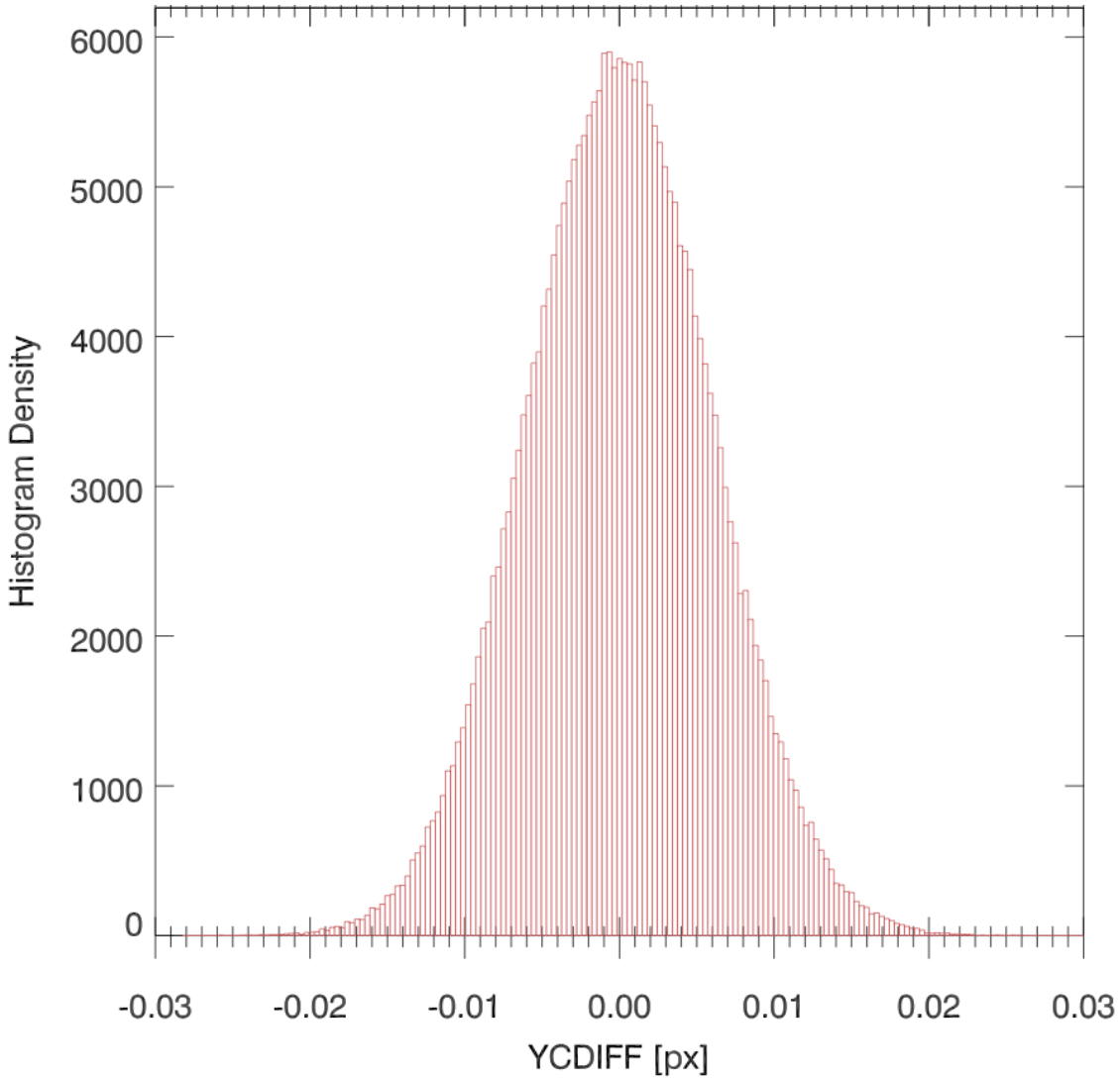


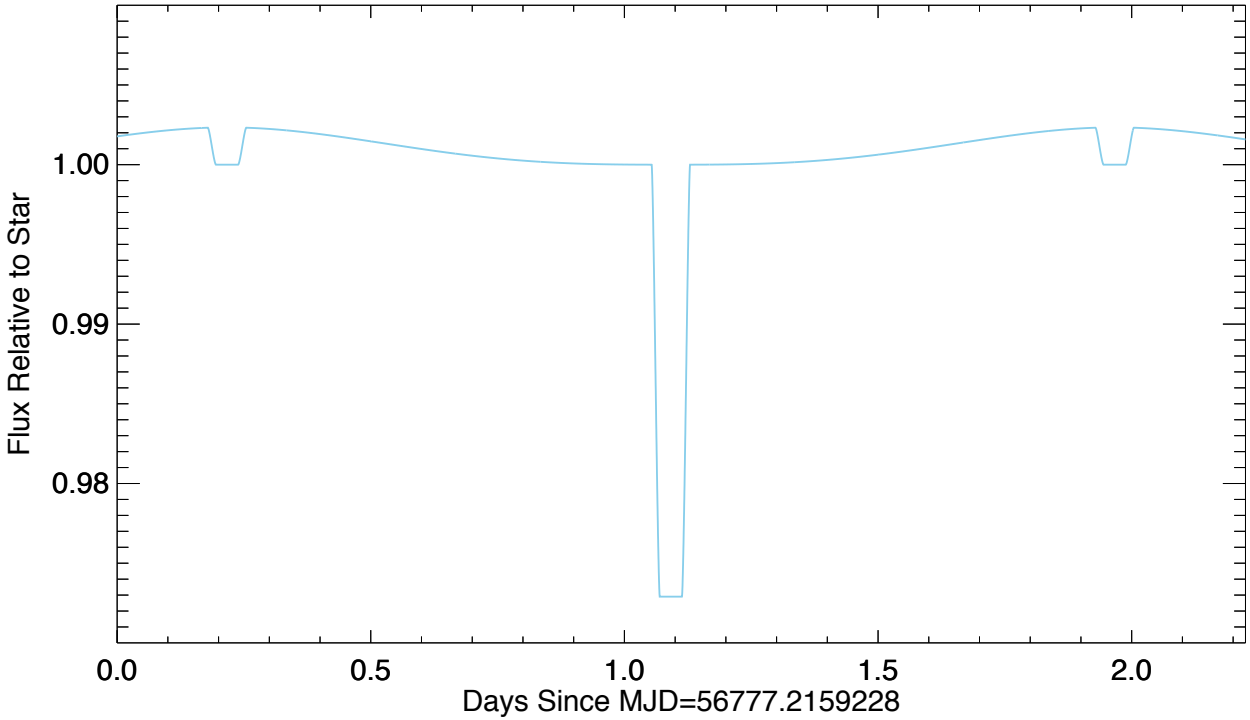
# Measuring Bias in Centroid Methods

- Moment centroiding can be used for ~0.01 arcsecond astrometry!



# Creating the Data Challenge Dataset

- WASP-52 chosen(not too long, detectable transit and eclipse)
- Observations “broken up” into 12hr AORs
- Reposition using PCRS Peakup at the beginning of each AOR (0.1px repeatability)
- 30-min Pre-AOR run to allow for short term drift



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- Reposition using PCRS Peakup at the beginning of each AOR (0.1px repeatability)
- 30-min Pre-AOR run to allow for short term drift
- Noise Pixel bumps added to trip people up.