Study of scattering points on LIGO mirrors

Lamar Glover, Riccardo DeSalvo (Cal State LA)
Bill Kells (LIGO/Cal Tech), Innocenzo Pinto (Unisannio)

LIGO-G1501385

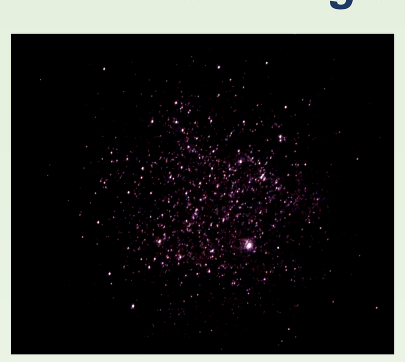
INTRODUCTION

Light scatterers on the surface of the dielectric mirrors of Gravitational Wave detectors are responsible for a large fraction of the stored beam light losses, and limit the sensitivity and range of detection of observations. Spatial and amplitude distribution studies of these scatterers on LIGO mirrors are attempted in an effort to identify common characteristics of the scattering points. Measurements were made in situ by Bill Kells and on samples by Josh Smith at Cal State Fullerton and the Syracuse group. At Cal State Los Angeles, we are having a second look at the scattering points.

METHODS

1. Isolate individual scatterers using astronomical algorithms for stars in galaxies.
2. Extract amplitude and position of each scatterer.
3. Extract the light beam position and profile to determine the illumination power on each location.
4. Re-normalize the amplitude of each scatterer (dividing by the illumination power) to extract actual scattering power of each point.

Initializing the analysis software

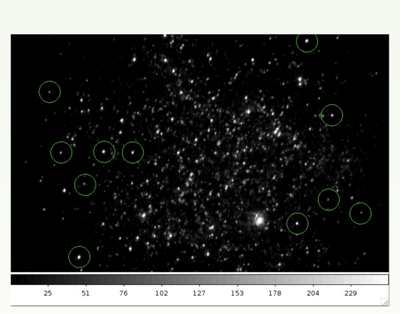


Left: Original Photo from LIGO

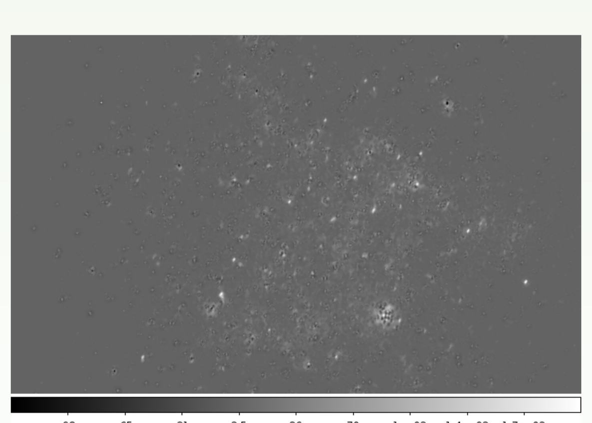
Right: Original Photo in ds9 imaging program: (point sources marked with green circles were used to construct point spread template)

Utilizing the "daophot" package in the IRAF software bundle, the original photo was analyzed in order to determine the coordinates and magnitudes of the light point sources within the image.

Identifying & Subtracting Scatterers



Left: Original Photo in "ds9" Imaging Program



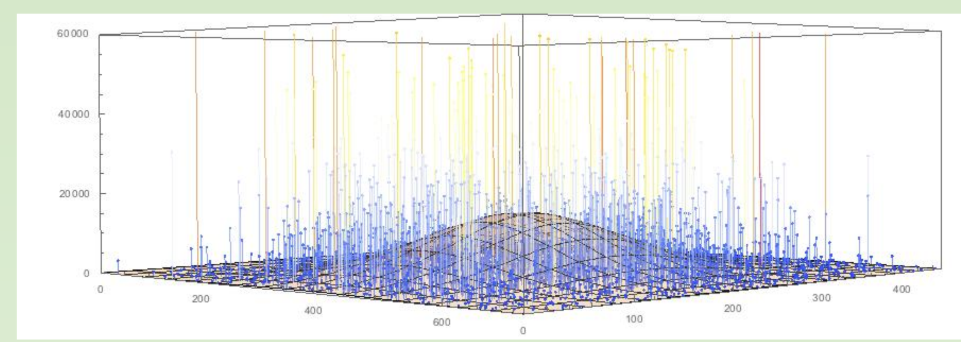
Right: Resulting Photo from first run of "daophot" package

By extracting the bright point sources, a gray background becomes obvious.

DATA & ANALYSIS

First run of "daophot" software resulted in the detection of 3,131 separate points with x & y coordinates as well as having varying magnitude.

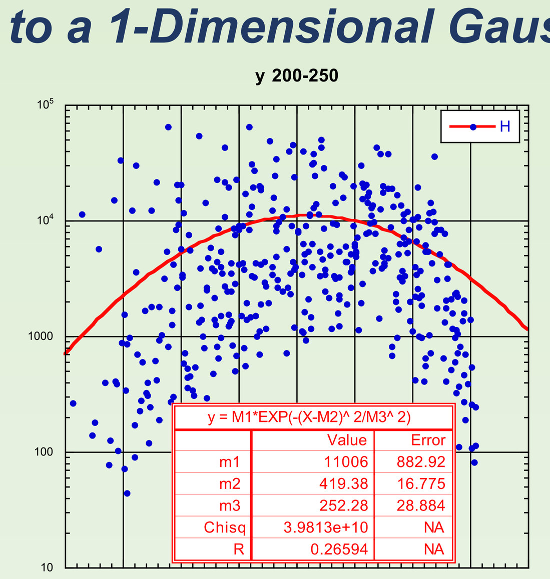
Attempting a 2-Dimensional Gaussian Fitting

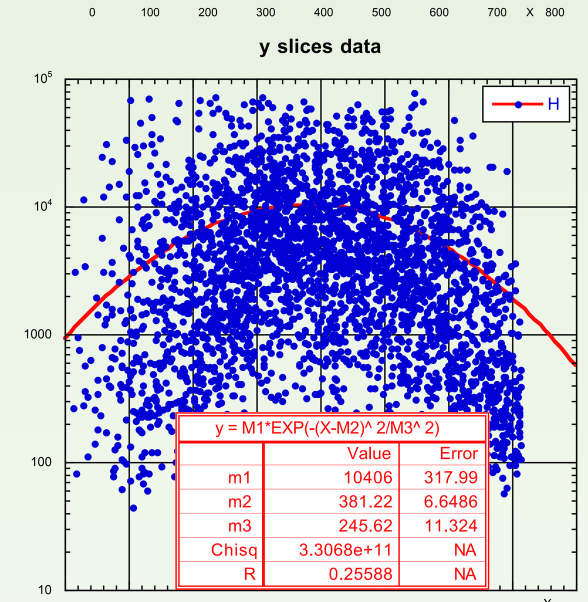


$$f(x,y) = A * \exp\left(-\left(\frac{(x-\mu_x)}{2\sigma_x^2} + \frac{(Y-\mu_Y)}{2\sigma_Y^2}\right)\right)$$

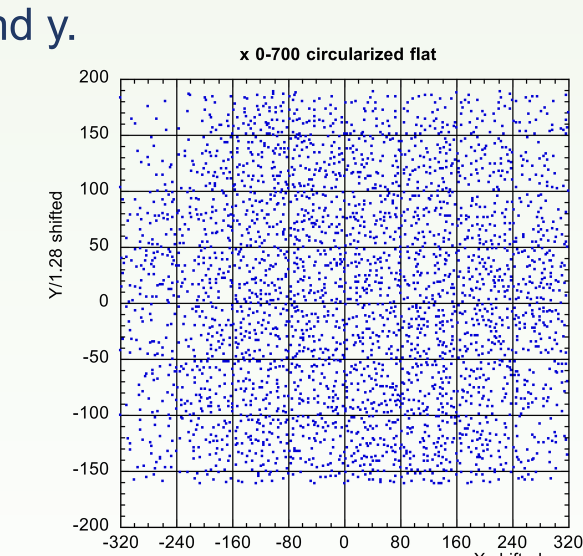
Data analysis was unable to produce a meaningful best-fit due to high noise levels in the data.

Reducing to a 1-Dimensional Gaussian Plot



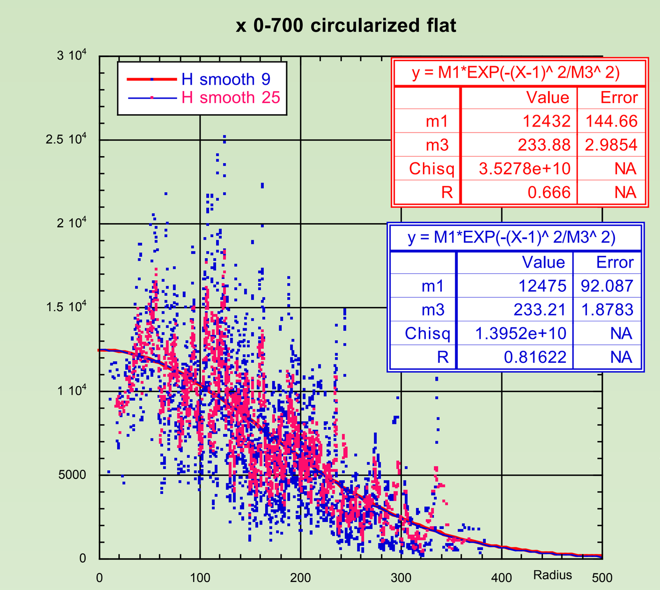


We cut data into slices along the x and y axis and fit each slice with a 1D Gaussian to find a beam center and its widths in x and y.



The image was shifted and rescaled to correct for the rectangular shape of the CCD, equalizing the widths of the beam along the x and y axis.

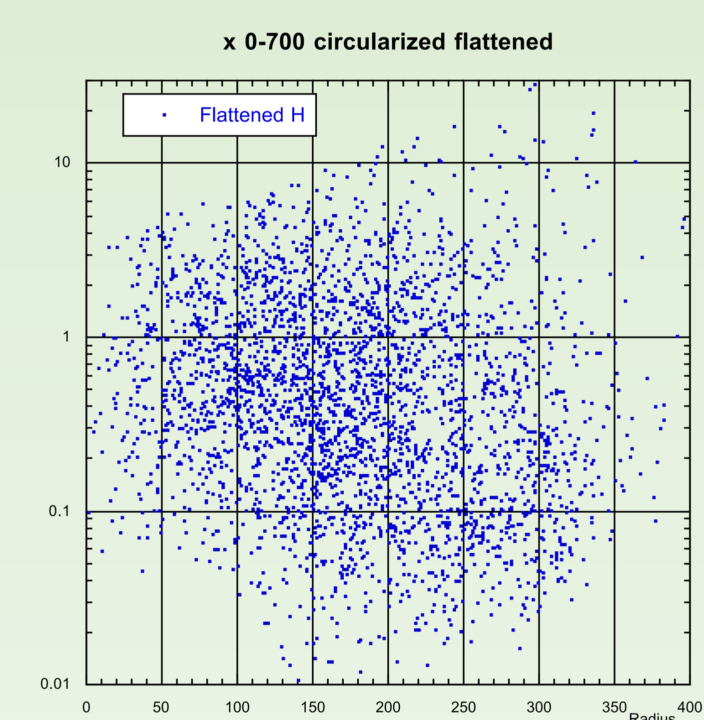
Fitting Radial Profile



$$f(r) = A * \exp\left(-\left(\frac{(r-\mu)}{2\sigma^2}\right)\right)$$

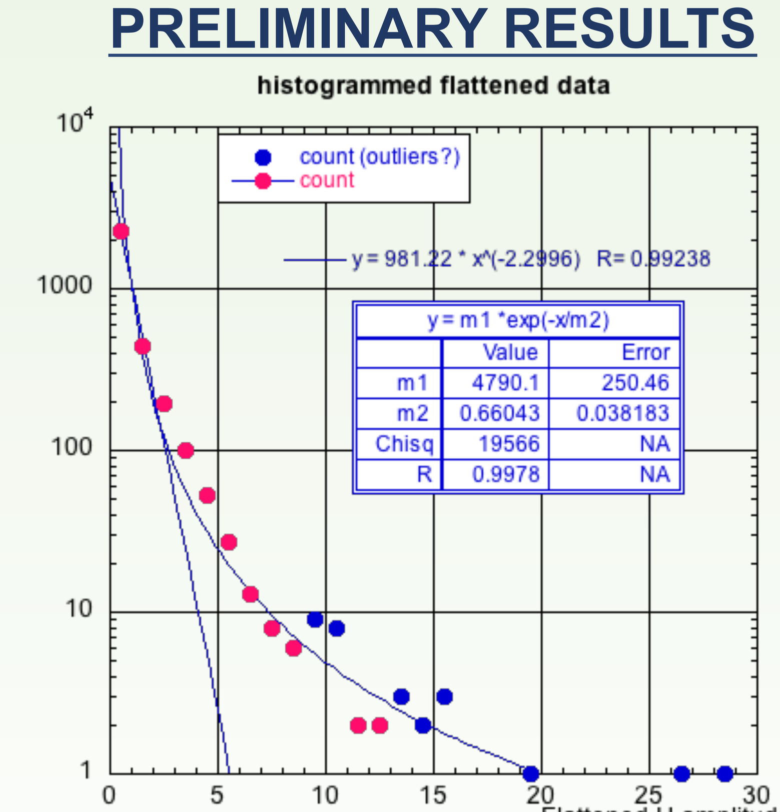
Once the beam has been circularized (equalize x and y widths) and centered around (0,0), Radial distance of each point is calculated. To find the re-normalization function, data is fit with f(r).

Cross Check



After re-normalizing, the slope has disappeared. There is more spread at high r as expected since re-normalization entails dividing by a smaller number.

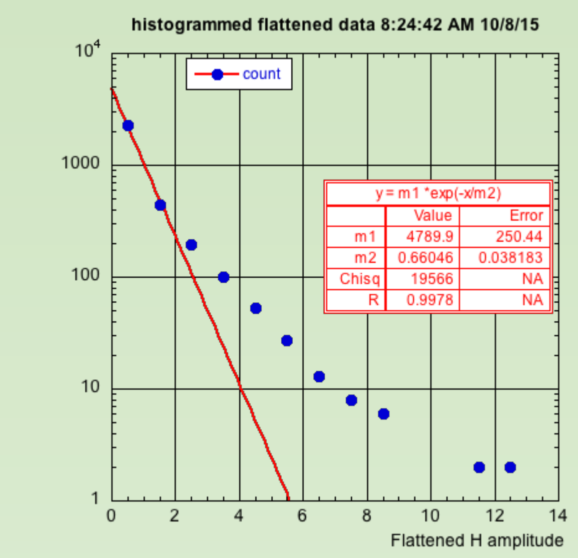
PRELIMINARY RESULTS



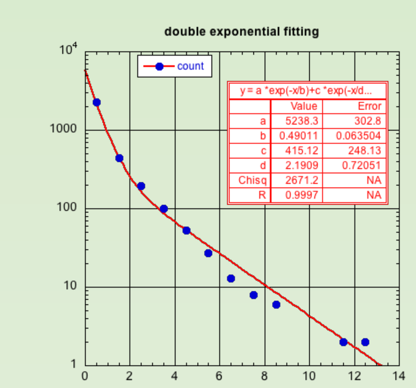
Re-normalization of beam was performed using circumferential average of amplitudes. Small number of outliers (blue):

- Could simply be dirt
- To be identified by manual inspection

NEXT STEPS



$$a \cdot e^{-r/b}$$



$$a \cdot e^{-r/b} + c \cdot e^{-r/d}$$

The next area of focus in this study is to investigate spatial distribution with the goal of isolating and excising abnormal scatterers. In the graphs above, points suspected of being associated with abnormal scatterers were manually removed from analysis instead of being properly corrected. This was done in order to determine if outliers potentially correlate with dirt clusters.

One can also observe a clear excess from exponential distribution as noted in the graphs above. The next steps in the study will include comparing our data with the expected power distribution from the attenuation through the depth of the coating structure.

CHALLENGES

Due to the fact that:

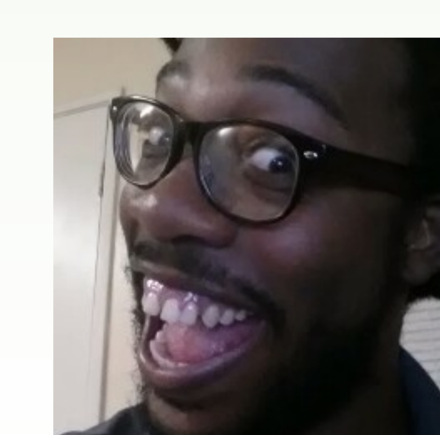
1. a commercial Rectangular Color CCD camera was used for 1064 nm IR light
2. optics with anti-reflex and dichroic lenses are optimized for visible not IR
3. and IR is filtered/attenuated to optimize for visible rendering,

the resulting image is not as accurate as desired due to low, possibly non uniform, IR detection efficiency. Evidence of this may be the scattering of IR light and the haze or grey halo observed from the analyzed photo. There also may be issues with the internal conversion of RGB image and distortion from the large angle associated with the viewing port.

CONTACT

For questions, comments, suggestions and more, please contact:

Lamar Glover
Graduate Student
Dept. of Physics and Astronomy
Cal State Los Angeles
lglover3@calstatela.edu



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