STERG

SOLAR THERMAL ENERGY RESEARCH GROUP

Using Singular Value Decomposition to Obtain Multi-dimensional Gaussian Flux Distributions for Optical Modelling of Heliostats Images

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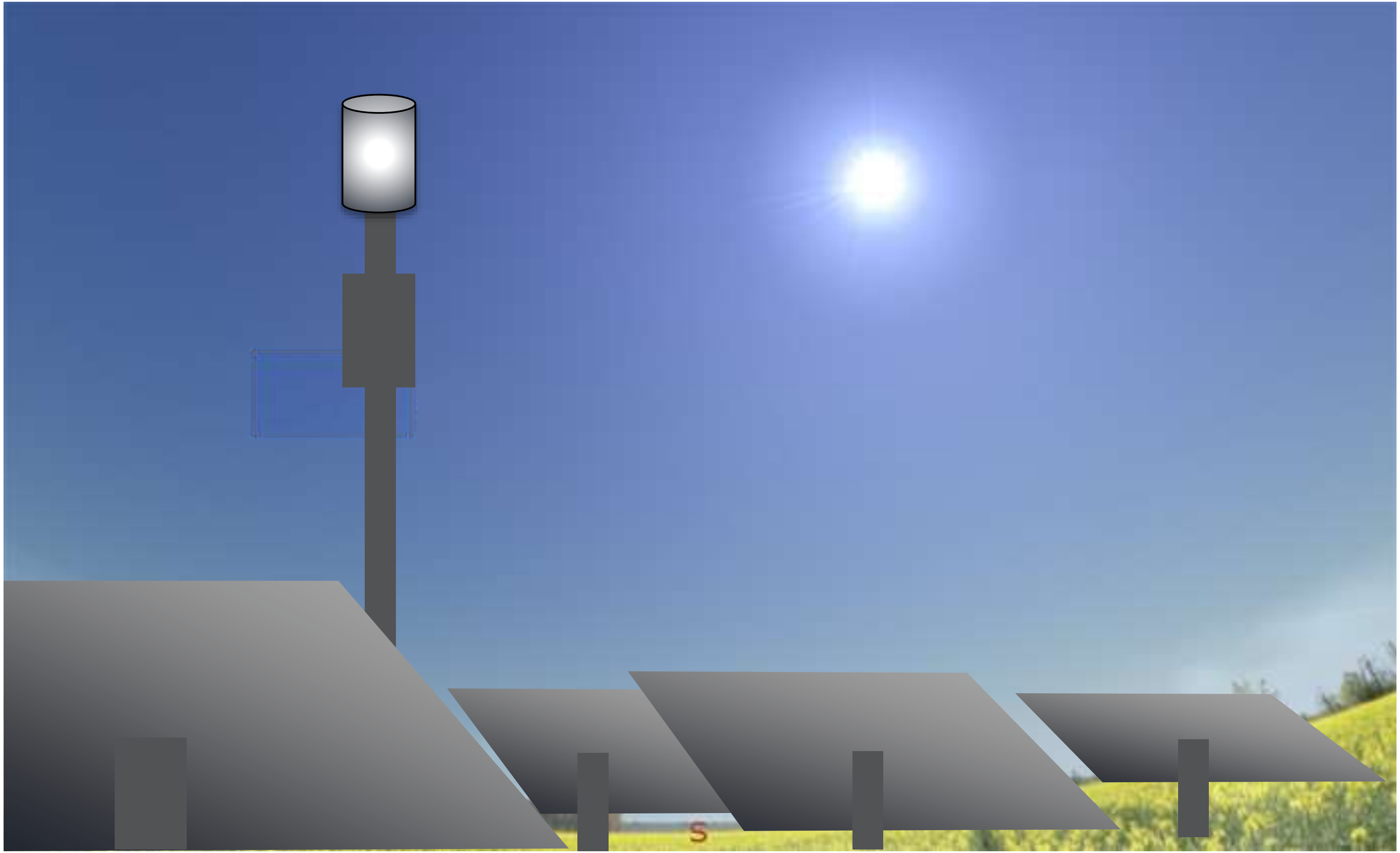
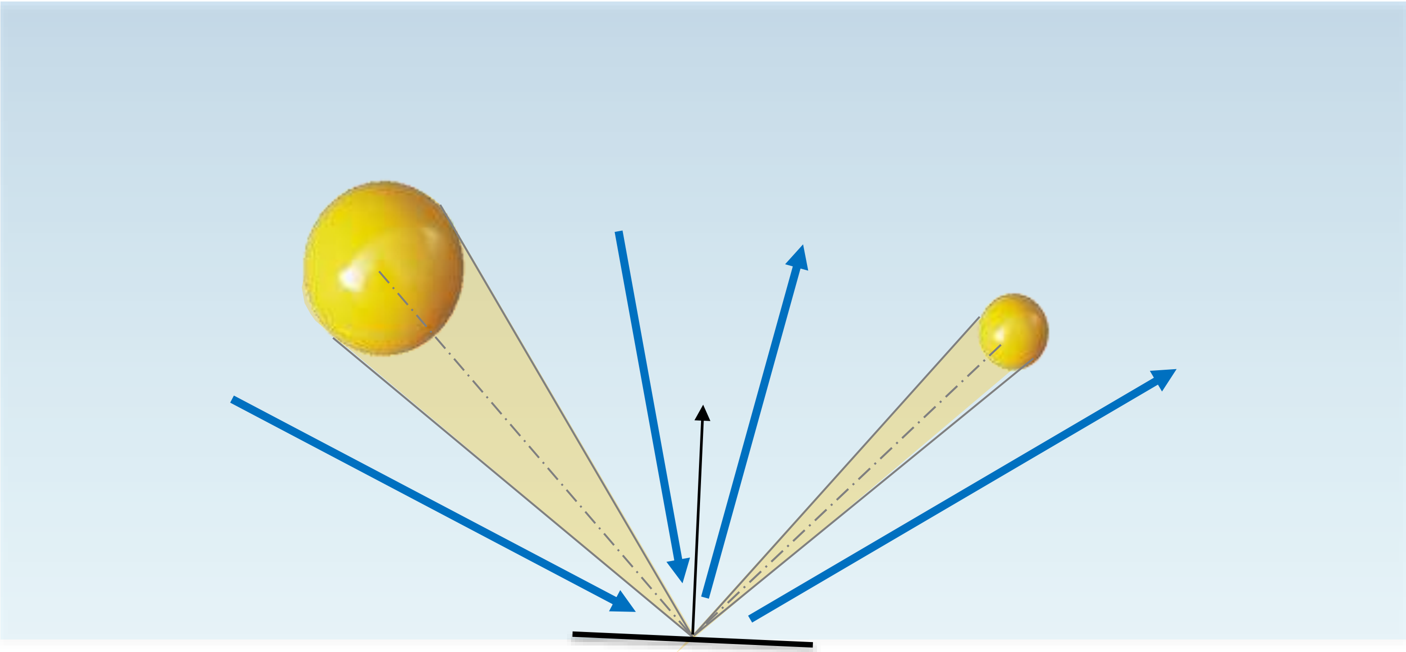
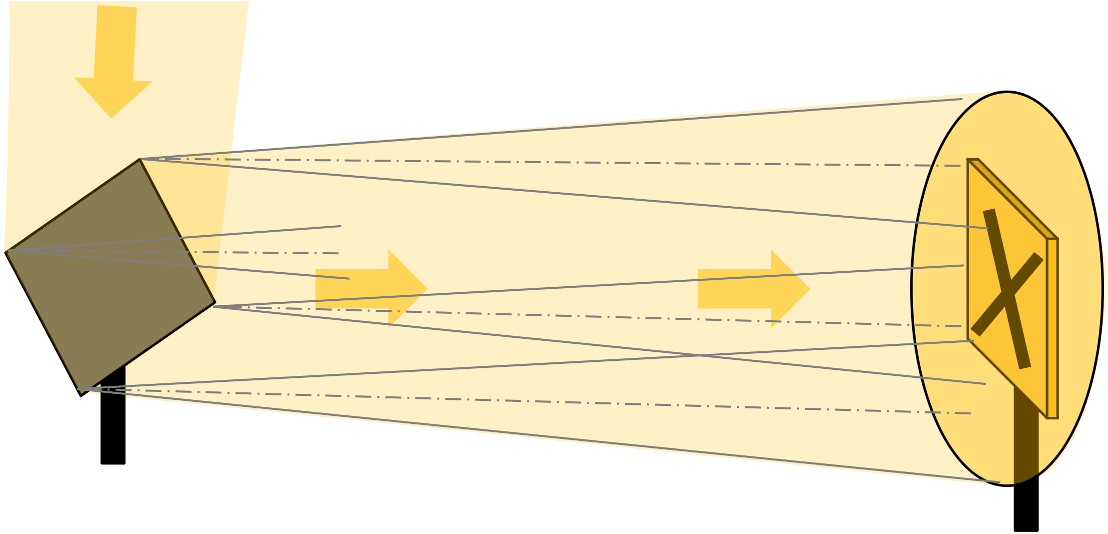

S

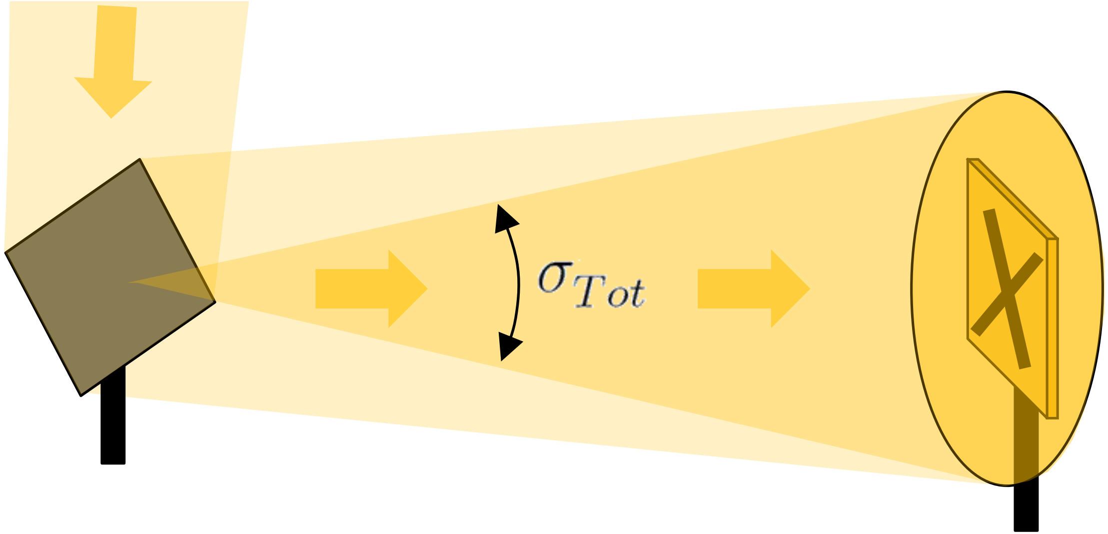
Snell's Law



Total Beam Dispersion Error

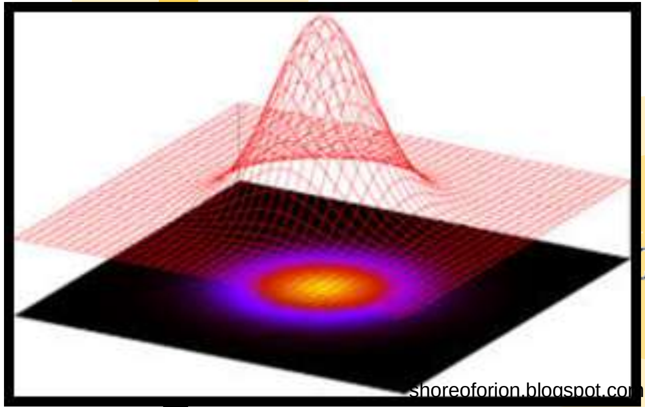


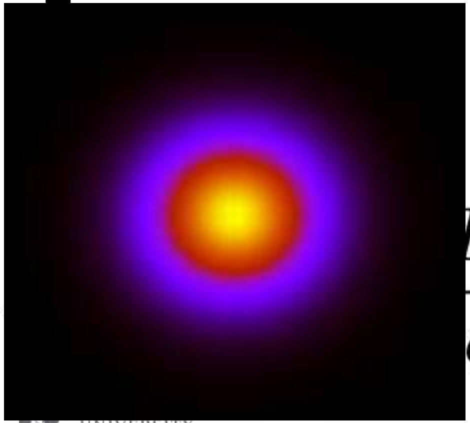
Total Beam Dispersion Error

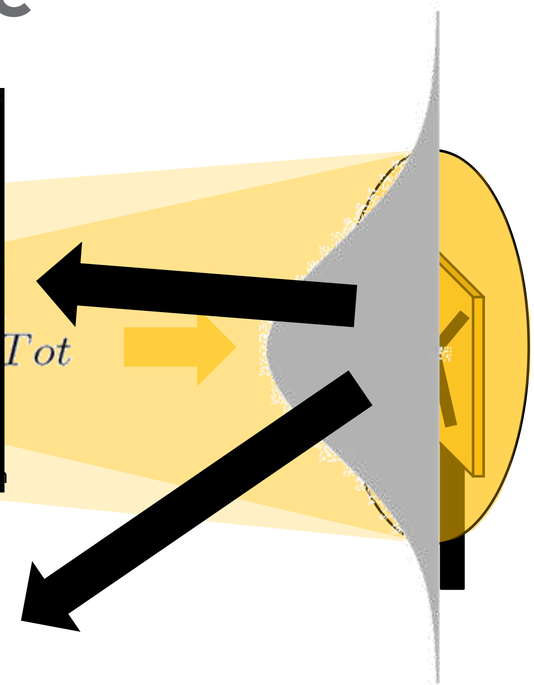


$$\sigma_{Tot}^2 = \sigma_{sun}^2 + \sigma_{astigmatism}^2 + \sigma_{BQ}^2$$

Gaussian Flux Image







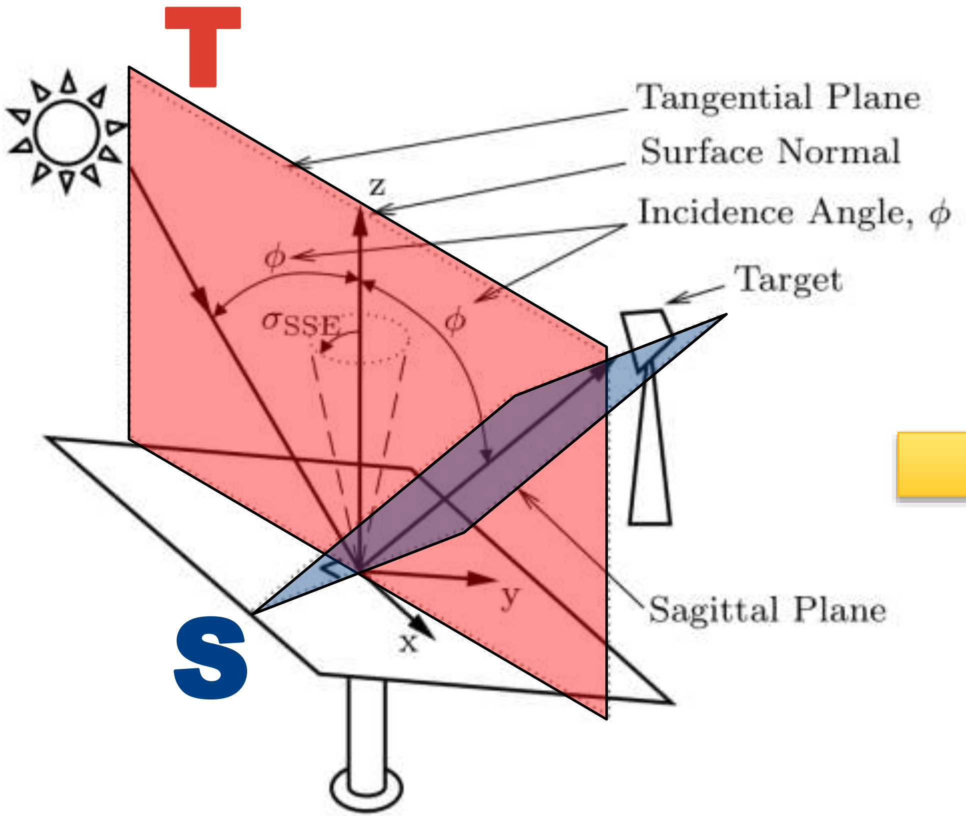
$$\frac{P_h}{\sigma_{Tot}^2} \exp\left(\frac{-r^2}{2\sigma_{Tot}^2}\right)$$

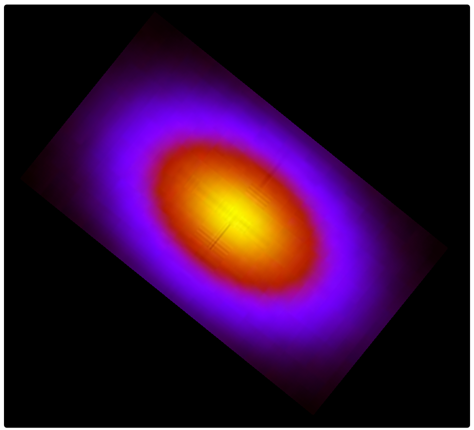
Total Beam Dispersion Error

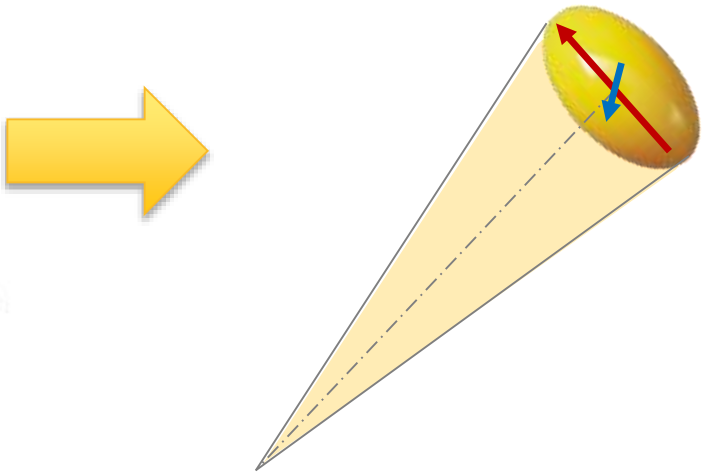
Components:

- Sun Shape (circular)
- Astigmatism (not circular)
- Surface Slope Error (not circular)
- Specularity Error (circular)

Elliptical Image







Axial Convolution

	Tangential	Sagittal
Sun-shape $\sigma_{sun}{}^2$	$\sigma_{sun}{}^2$	$\sigma_{sun}{}^2$
Astigmatism $\sigma_{ast}{}^2$	$\frac{\left(D\left\lvert\frac{d}{f}-\cos\varphi\right\rvert\right)^2}{32d^2}$	$\frac{\left(D\left\lvert\frac{d}{f}\cos\varphi-1\right\rvert\right)^2}{32d^2}$
SSE $\sigma_{bq}{}^2$	$4\,\sigma_{SSE}{}^2$	$(1+\cos^2\varphi)^2\,\sigma_{SSE}{}^2$

There are 2 unknowns

Applications?

- A) Predict the flux distribution

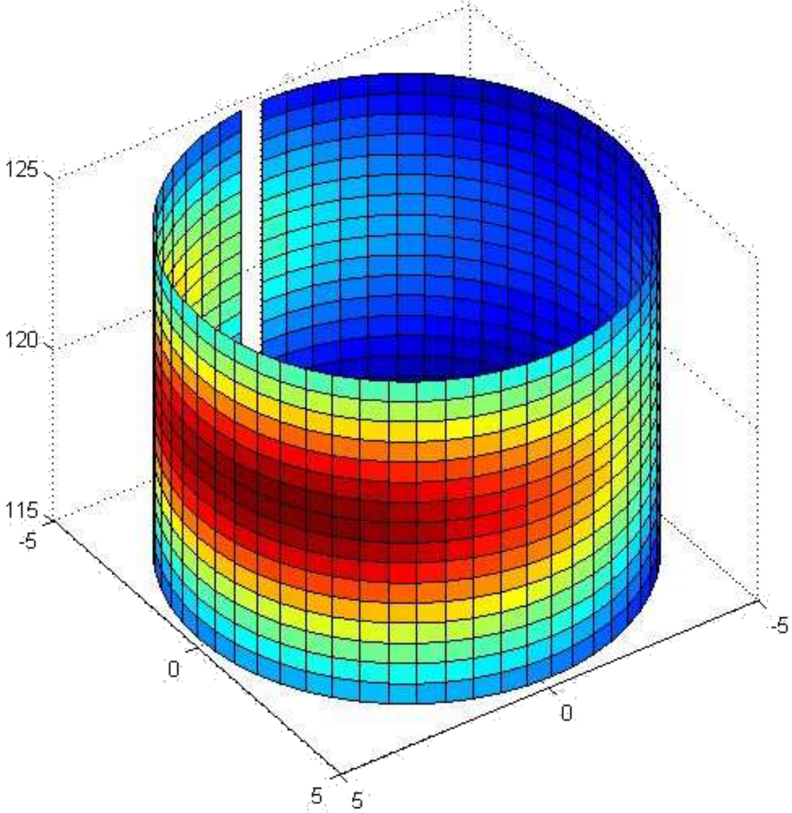
OR

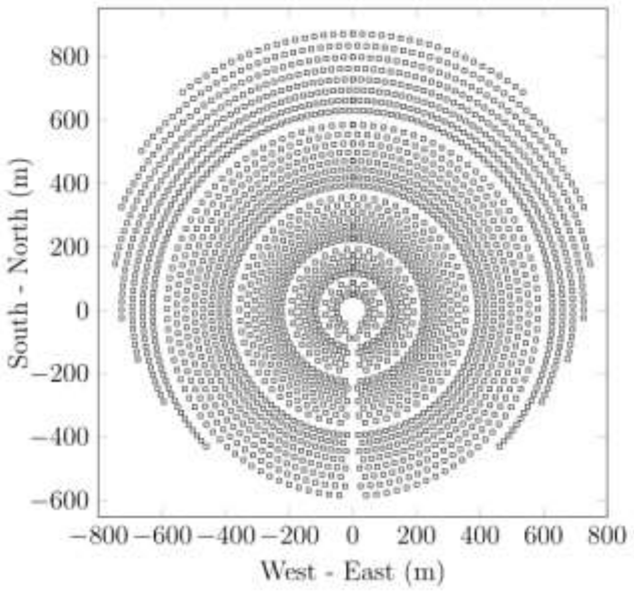
- B) From the flux distribution determine optical variables

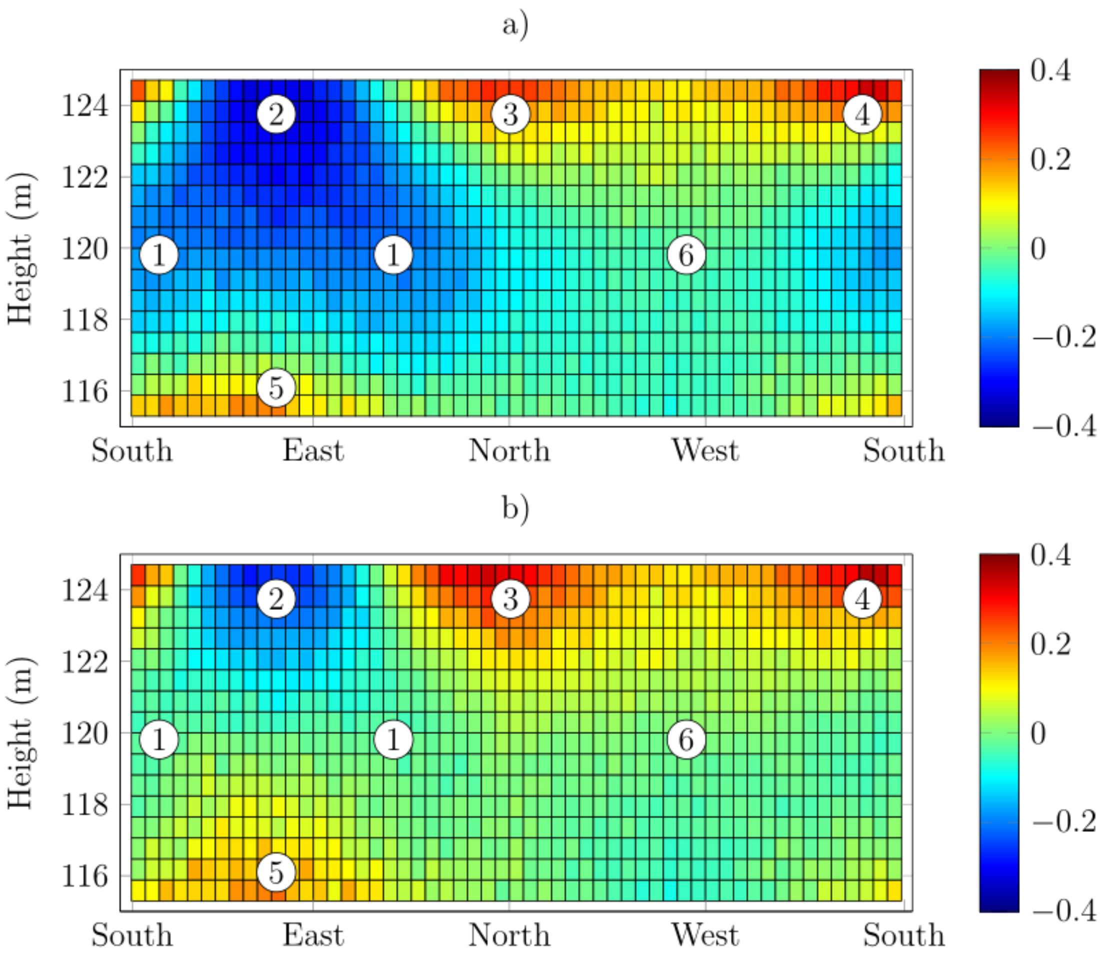
(Monterreal, 2013)

A) Predict the flux distribution

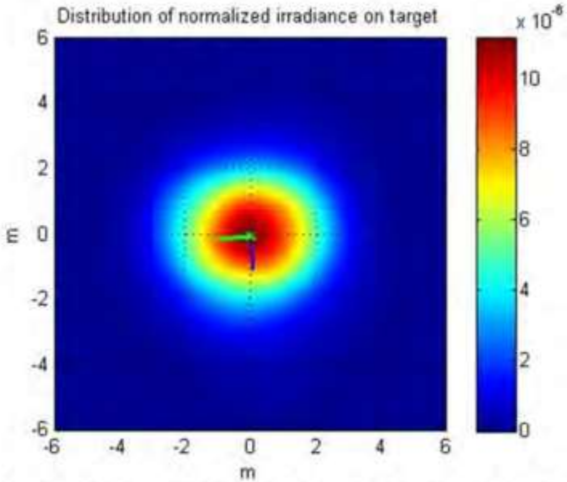
- Speed vs accuracy…
- Now project elliptical images onto complex surfaces at high computational efficiency

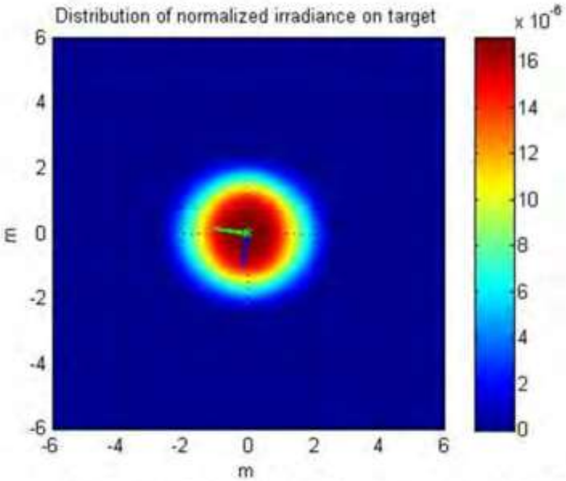



800
600
400
200
0
−200
−400
−600
South - North (m)
−800 −600 −400 −200 0 200 400 600 800
West - East (m)


a)
Height (m)
124
122
120
118
116
2
3
4
1
1
6
5
South
East
North
West
South
0.4
0.2
0
−0.2
−0.4
b)
Height (m)
124
122
120
118
116
2
3
4
1
1
6
5
South
East
North
West
South
0.4
0.2
0
−0.2
−0.4

B) Determine optical variables





STATISTICS ANALYSIS OF REAL IMAGE:

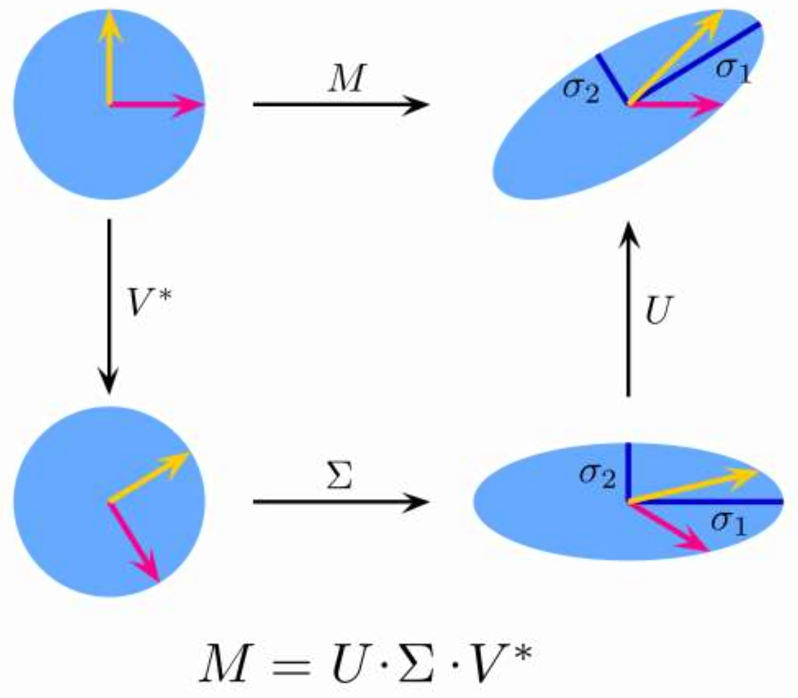
Image centroid = (-0.16,-0.35) m
Image peak = (-0.18,-0.29) m
90-Percent Image Radius = 3.407 m
Horizontal (1σ) radius μ_X = 1.601 m
Vertical (1σ) radius μ_Y = 1.566 m
Major (1σ) radius μ_U = 1.601 m
Minor (1σ) radius μ_V = 1.566 m
Ellipticity = 1.02
Ellipticity direction = 3.72 deg

STATISTICS ANALYSIS OF IDEAL IMAGE:

Image centroid = (0.00, 0.00) m
Image peak = (0.00, 0.00) m
90-Percent Image Radius = 2.158 m
Horizontal (1σ) radius μ_X = 1.124 m
Vertical (1σ) radius μ_Y = 1.071 m
Major (1σ) radius μ_U = 1.126 m
Minor (1σ) radius μ_V = 1.070 m
Ellipticity = 1.05
Ellipticity direction = -9.04 deg

(Monterreal, 2013)

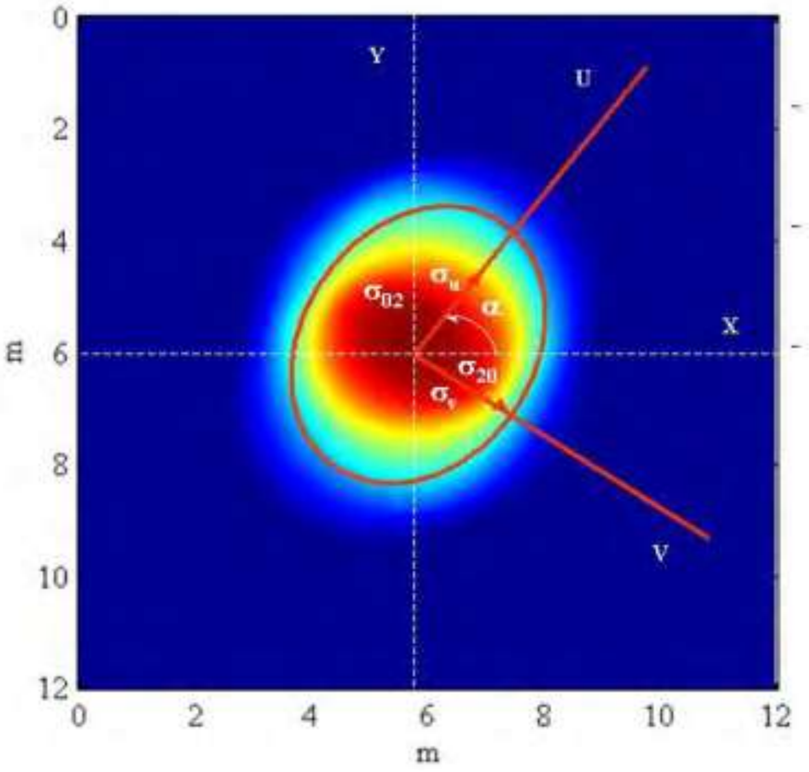
Singular Variable Decomposition



Singular Variable Decomposition

- Statistical analysis yields:
  - Ellipse major axis
  - Ellipse minor axis

  - Which results in 2 simultaneous equations!



(Monterreal, 2013)

Singular Variable Decomposition

- Enables us to link the effects canting and supporting structure on image quality
- Can be automated by incorporating it into the calibration process

Further Work

Conclusions

- SVD is useful for both heliostat image prediction and analysis
- Particular applications are in aim-point optimisation where realtime flux prediction is required

ACKNOWLEDGEMENTS:

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