Turbulence - Induced 2D Correlated Image Distortion
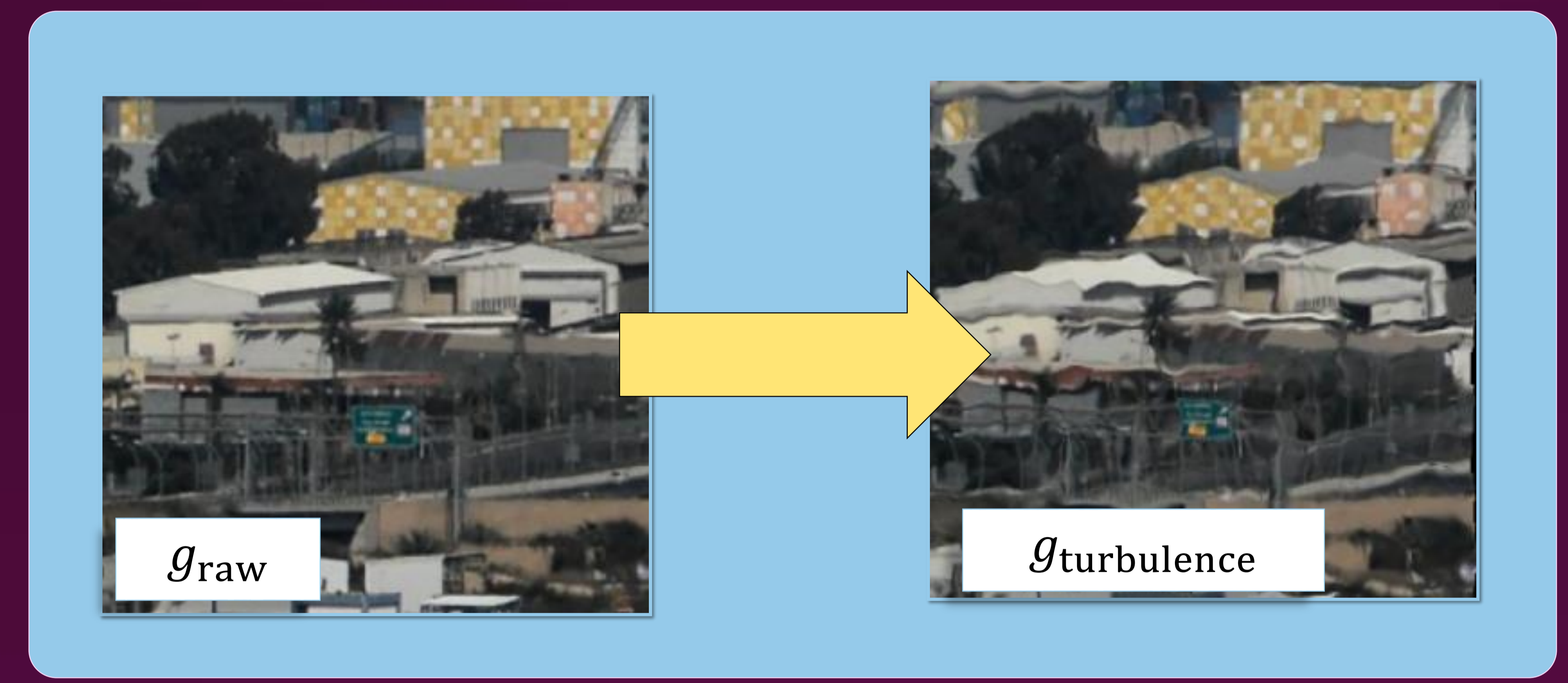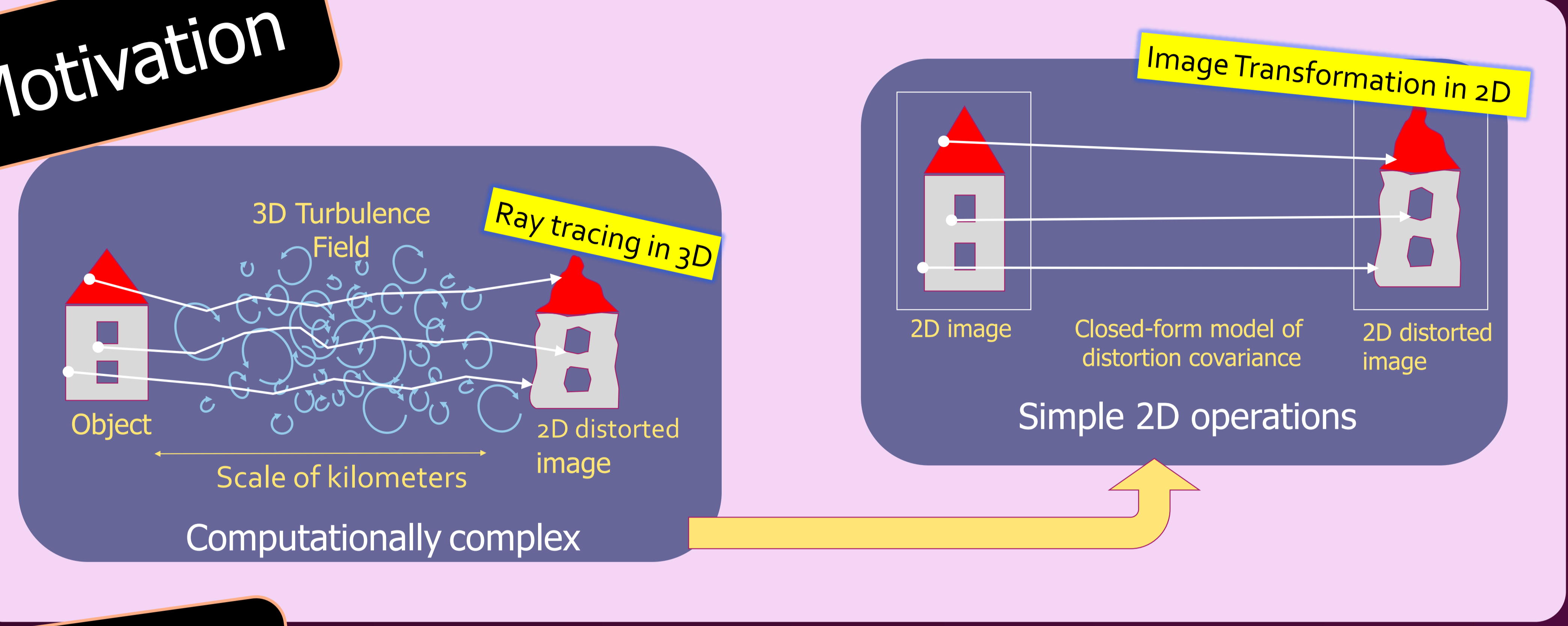
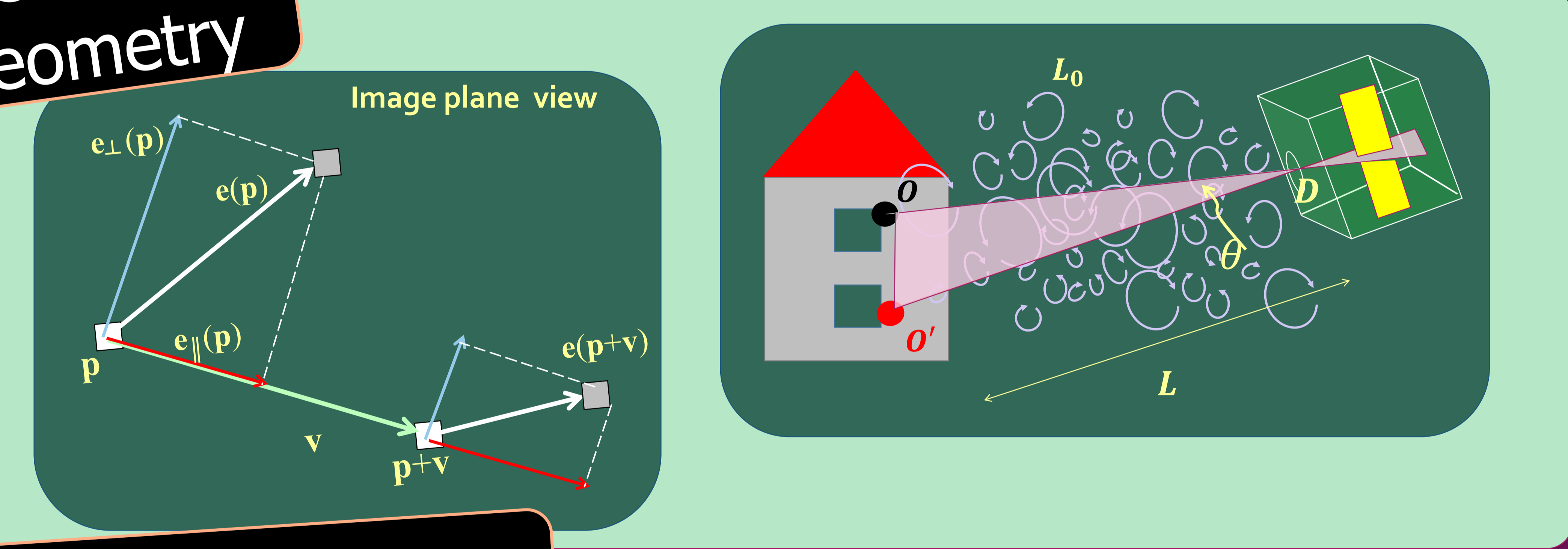**Armin Schwartzman**   **Marina Alterman**   **Rotem Zamir**   **Yoav Y. Schechner**

Motivation

3D Turbulence Field

Ray tracing in 3D

Object

2D distorted image

Scale of kilometers

Computationally complex

Image Transformation in 2D

2D image

Closed-form model of distortion covariance

2D distorted image

Simple 2D operations

g_{raw}

$g_{\text{turbulence}}$

Distortion Geometry

Image plane view

$e_\perp(p)$

$e(p)$

$e_\parallel(p)$

p

v

$p+v$

$e(p+v)$

L_0

O

D

O'

L
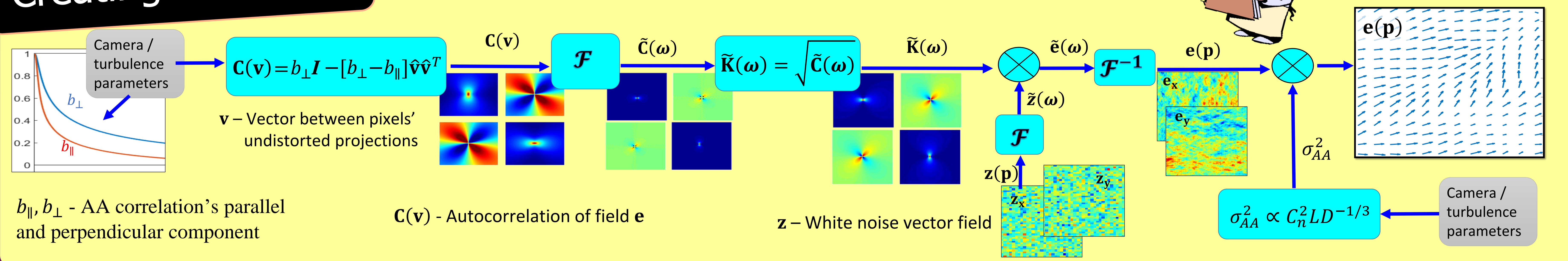
- **Render image distortions consistent with the theory**
- **Create 2D random correlated distortion vector fields**
- **The correlations depend on the distortion directions relative to the orientation of all object-pairs**
- **By-pass 3D numerical calculations and ray-tracing**
- **Using correlation functions and Fourier transforms**

Creating Distortion

Camera / turbulence parameters

$b_\perp$

$b_\parallel$

$$\mathbf{C}(\mathbf{v}) = b_\perp \mathbf{I} - [b_\perp - b_\parallel]\hat{\mathbf{v}}\hat{\mathbf{v}}^T$$

v – Vector between pixels' undistorted projections

$b_\parallel, b_\perp$ - AA correlation's parallel and perpendicular component

$\mathbf{C}(\mathbf{v})$ - Autocorrelation of field **e**

$\mathbf{C}(\mathbf{v})$

$\mathcal{F}$

$\tilde{\mathbf{C}}(\boldsymbol{\omega})$

$$\widetilde{\mathbf{K}}(\boldsymbol{\omega}) = \sqrt{\tilde{\mathbf{C}}(\boldsymbol{\omega})}$$

$\widetilde{\mathbf{K}}(\boldsymbol{\omega})$

$\tilde{\mathbf{z}}(\boldsymbol{\omega})$

$\mathcal{F}$

$\mathbf{z}(\mathbf{p})$

$\mathbf{z}_x$ $\mathbf{z}_y$

z – White noise vector field

$\tilde{\mathbf{e}}(\boldsymbol{\omega})$

$\mathcal{F}^{-1}$

$\mathbf{e}(\mathbf{p})$

$\mathbf{e}_x$

$\mathbf{e}_y$

$\mathbf{e}(\mathbf{p})$

σ_{AA}^2

$$\sigma_{AA}^2 \propto C_n^2 L D^{-1/3}$$

Camera / turbulence parameters

recipe

UC San Diego

Hybrid Imaging Lab

Northwestern University

Technion - Israel Ins. Technology