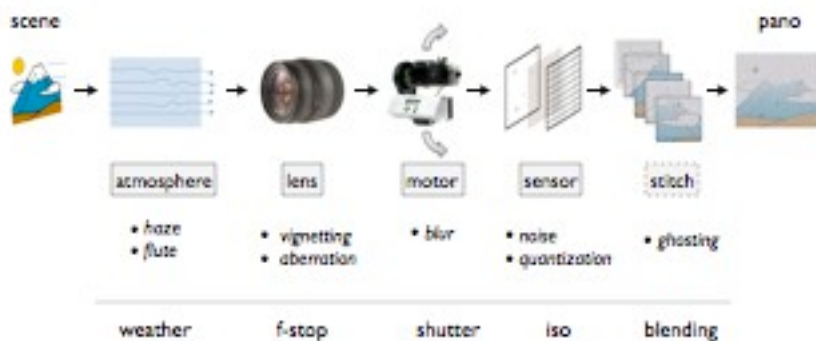


Assembling Gigapixel Panoramas

Luiz Velho
IMPA

The Real Scenario

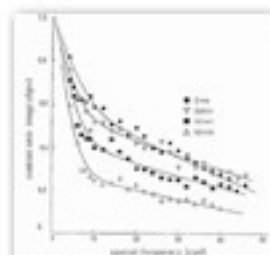
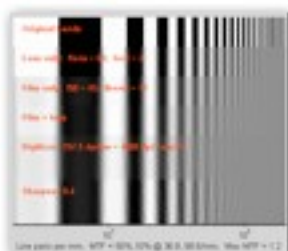
- Complete Pipeline



MTF

- System MTF

- Lens + Sensor + etc.. + (Human Eye)

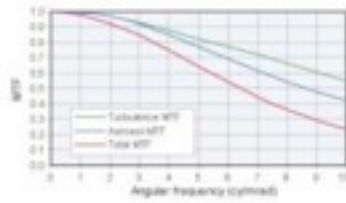


Atmospheric Limitations

- Turbulence (*Heat*)

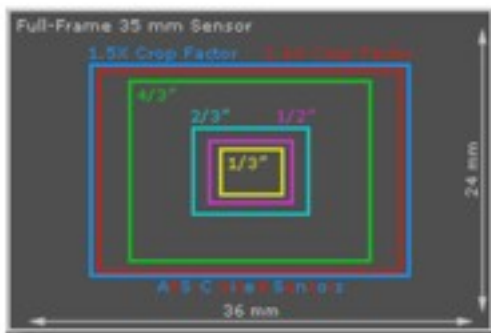


- Aerosols (*Distance*)



M65 Summer atmospheric MTF for a 5.5km horizontal path

Sensor Formats



- FX - Full Frame
- DX - Digital Camera

Lens MTF Parameters

- Sagittal / Meridional Patterns

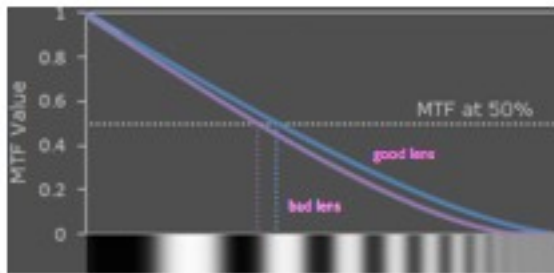


- Distance from Image Center



Lens Performance

- the good and the bad ;-)



► MTF-50

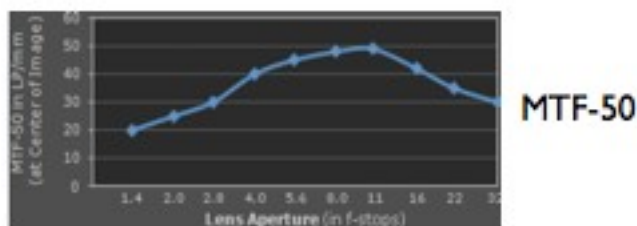
- sharpness perception

Aperture x Pixel Size

- Optimal Aperture



The Sweet Spot

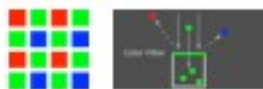


- Why ?

- Large Apertures (light aberrations) **
- Small Apertures (diffraction effect)

Sensor Resolution

- Bayer Pattern



- Demosaicing



original

sensor

- Moire Artifacts



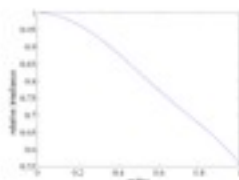
Lens Vignetting

- *Radial Falloff*



- 4 types:

- Natural
- Pixel
- Optical
- Mechanical



Vignetting Correction

- Venice panorama



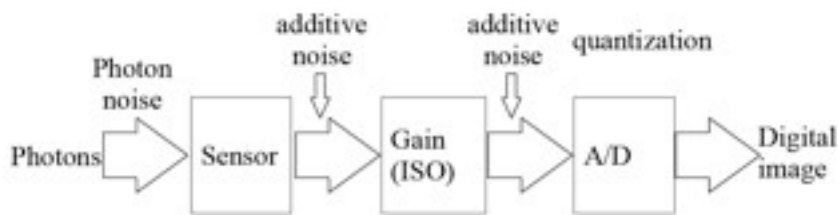
Motion Blur

- Object Movement
- Camera Motion



► De-blurring...

The Camera Sensor



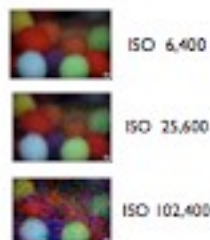
- Noise
- Quantization

Sensor Noise

- ISO / Sensor Size

ISO	100	200	400	800
Red Channel				
Green Channel				
Blue Channel				
Camera Grade	Professional	Prosumer	Prosumer	Prosumer
Camera Type	SLR	SLR	Compact	Compact
Pixel Size	Large	Large	Small	Small
ISO	100	200	400	800

Canon EOS-1D Mark IV



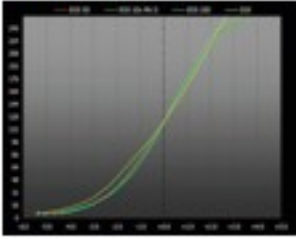
- Long Exposure
- Other Factors

► Noise Reduction...



Sensor Quantization

- Response Curve



- Analog - Digital (8 to 14 bits)



Camera Processing

- Photosites (photons to electrons)
- ISO (amplification)
- A/D (quantization) ----- RAW
- Demosaicing
- [denoising]
- [color conversion]
- Response Curve
- Gamma Encoding
- JPEG

Stitching

- Alignment
 - Projective Transformation
- Blending
 - Linear
 - Multiband
 - GraphCut
 - Poisson



The Future

- Terapixel Imaging Systems
- Metalens
- Super-resolution

The End ?