Pixel Size Selection Criteria

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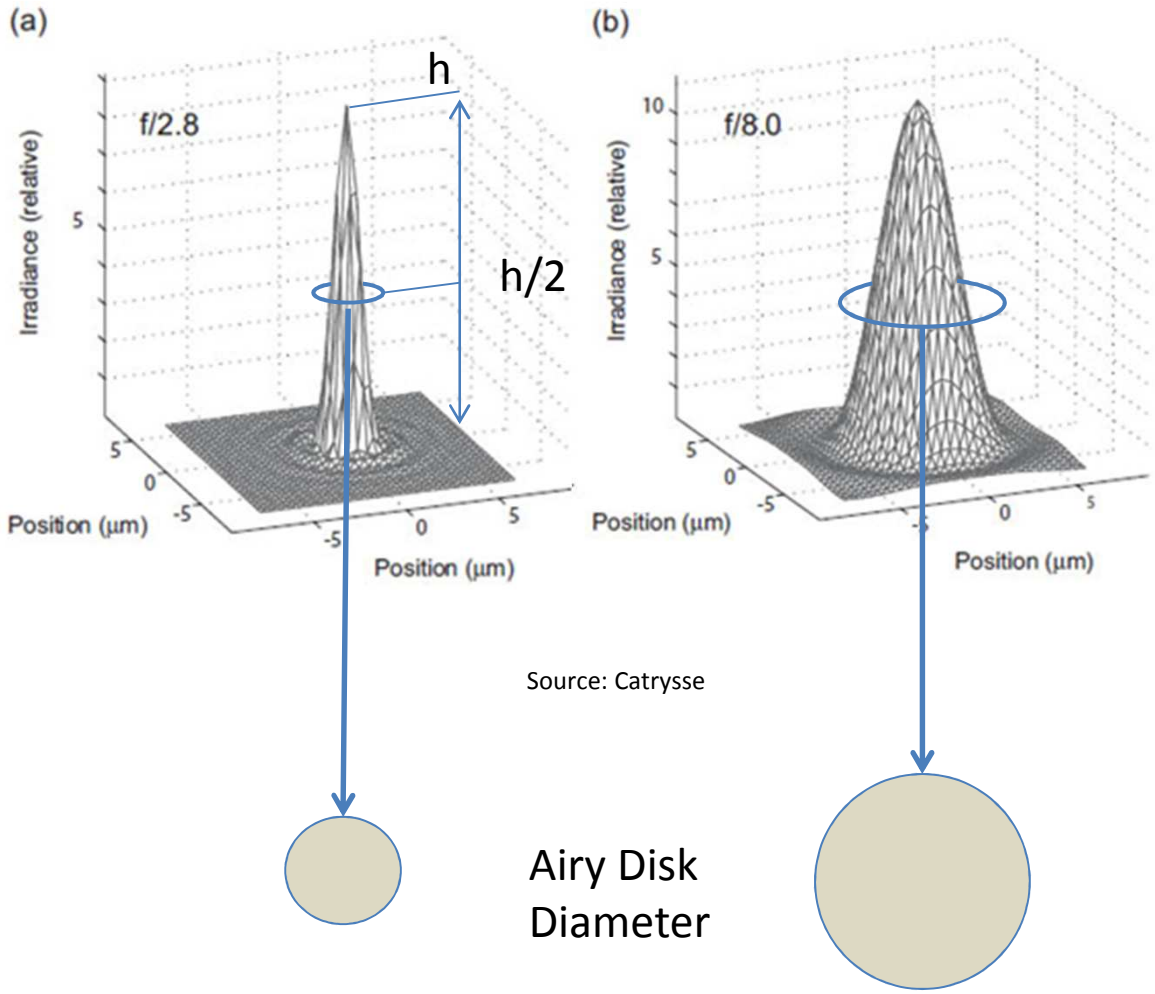
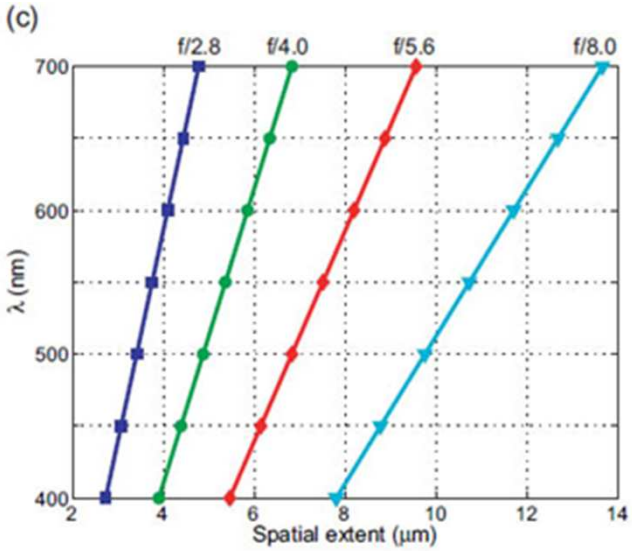
Pixel size considerations

- Key issues are
  - matching the pixel size to the expected spot size from the optical system
    - Diffraction limited case is the smallest spot size, that's the limiting best case but is seldom encountered in terrestrial-based astrophotography
    - For terrestrial-based astrophotography "seeing" FWHM typically determines the spot size and is variable.
  - understanding the relationship among pixel size , optics and rate at which signal builds

Optics and the Airy Disk:
Focal ratio: Sets spot size for diffraction limited optics



Source: Catrysse



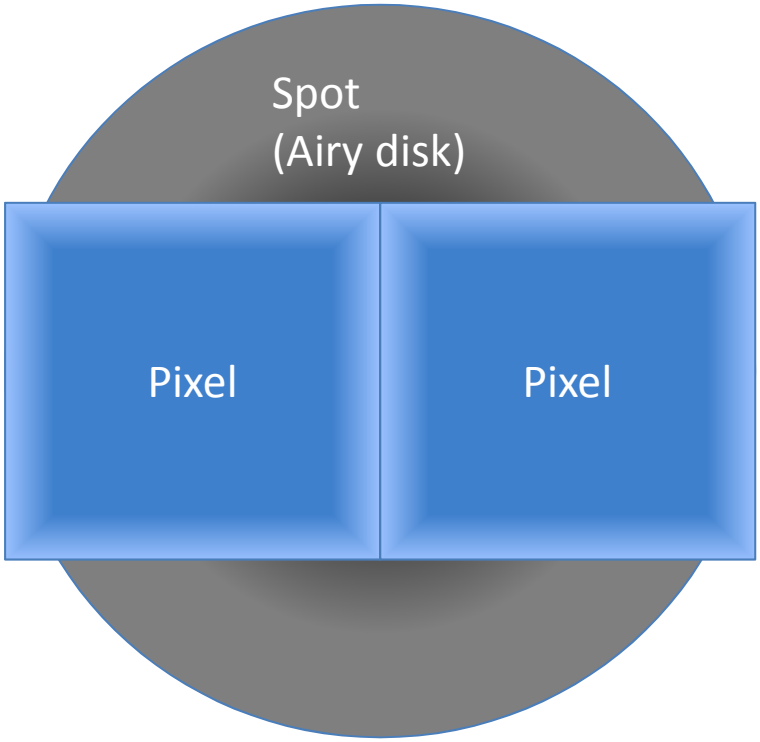
Airy Disk Diameter (microns)

Airy Disk Diameter

~3 microns, f/2.8

~10 microns, f/8.0

Nyquist Sampling of Airy Disk
Pixel Pitch: Sized to fit Airy Disk (spot):



550 nm test wavelength			
Pixel size (microns)	Optimum F#	Airy Diameter (microns)	Optical resolution LP/mm
0.75	1.12	1.5	667
0.9	1.34	1.8	556
1	1.49	2	500
1.1	1.64	2.2	455
1.25	1.86	2.5	400
1.4	2.09	2.8	357
1.5	2.24	3	333
1.75	2.61	3.5	286
2	2.98	4	250
2.25	3.35	4.5	222
2.5	3.73	5	200
2.75	4.10	5.5	182
3	4.47	6	167
3.5	5.22	7	143
4	5.96	8	125

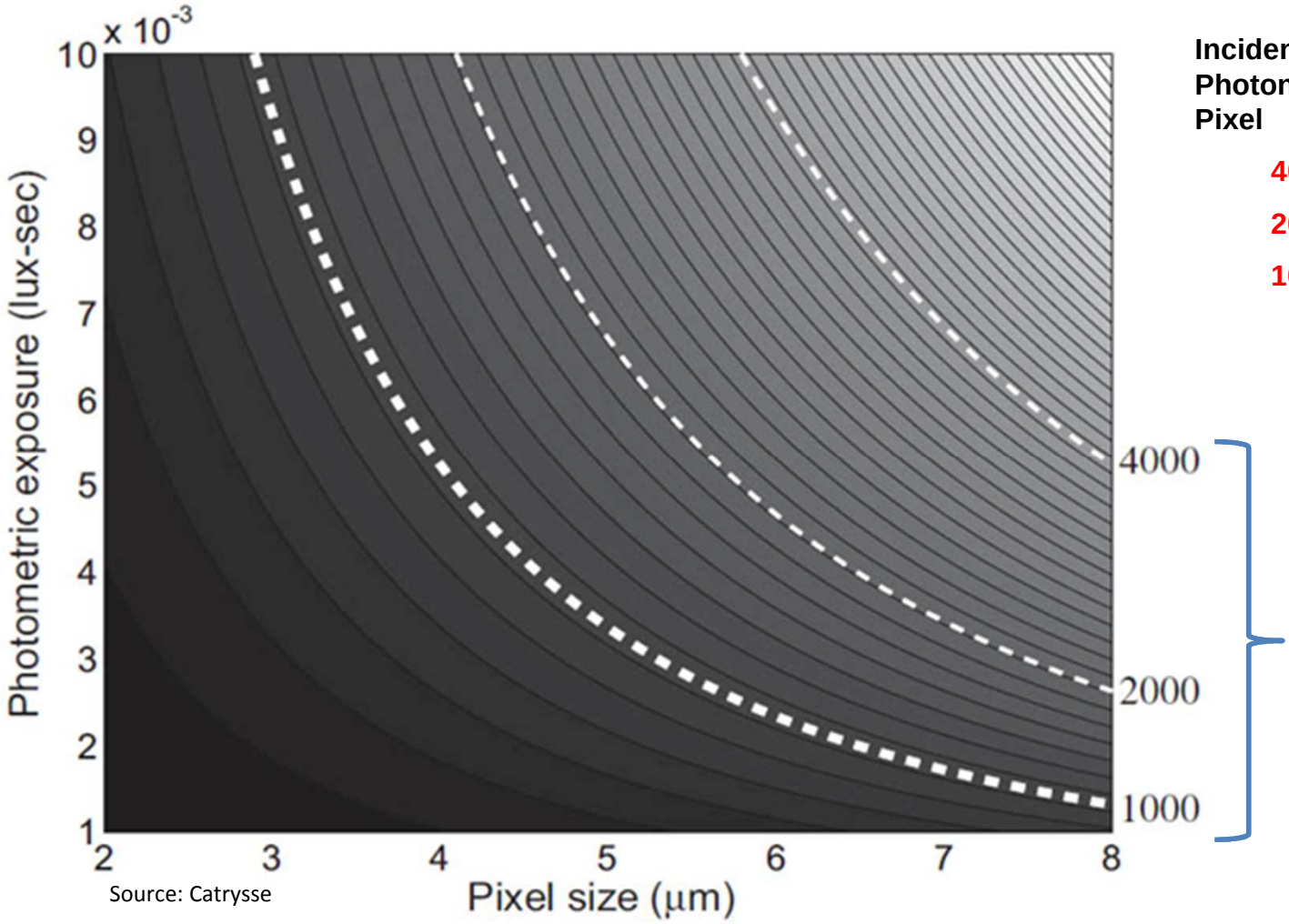
Nyquist Sampling Criteria:

$$Pixel\ size = 1.22\ * \lambda * F\#$$

- Exact Nyquist Sampling: 2 pixels to cover Airy Diameter (spot)

For Seeing-Limited spot size, the FWHM of the seeing sets the spot size and should still be covered by two pixels for proper sampling.

Pixel Geometry:
How many photons is your pixel receiving?

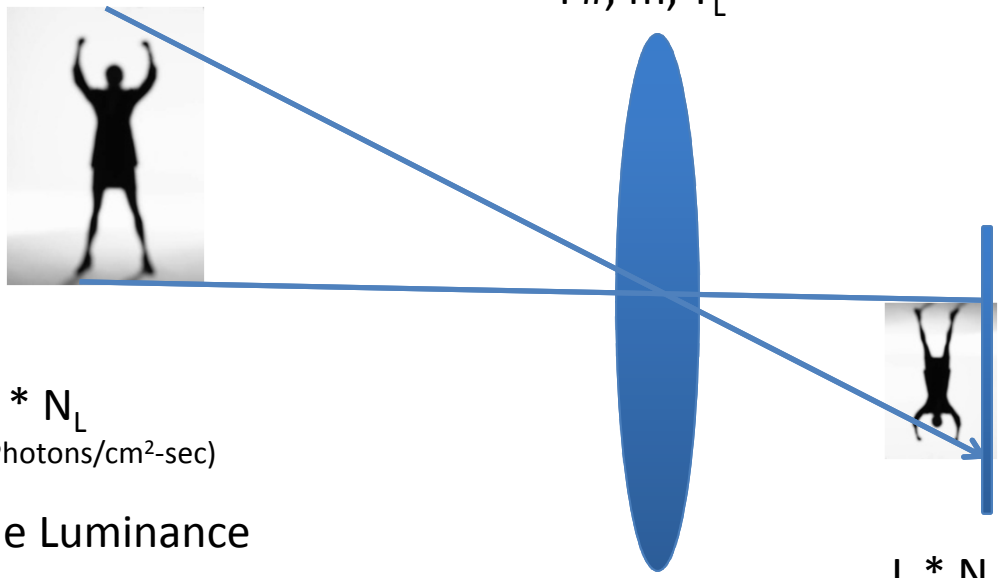


Source: Catrysse

Incident Photons/ Pixel	Maximum Theoretical SNR*
4000	63.25
2000	44.72
1000	31.62

*occurs when:
QE= 100%
Noise = 1e-

Delivering photons to the sensor: the impact of Imaging Lens F# and magnification



m = magnification
= 2*pixel_size*F#/Focal_length
T_L = Transmission of Optics
N_L= photons/cm^2-sec/lux
L=Luminance level (lux)

$L * N_L$
(Photons/cm^2-sec)

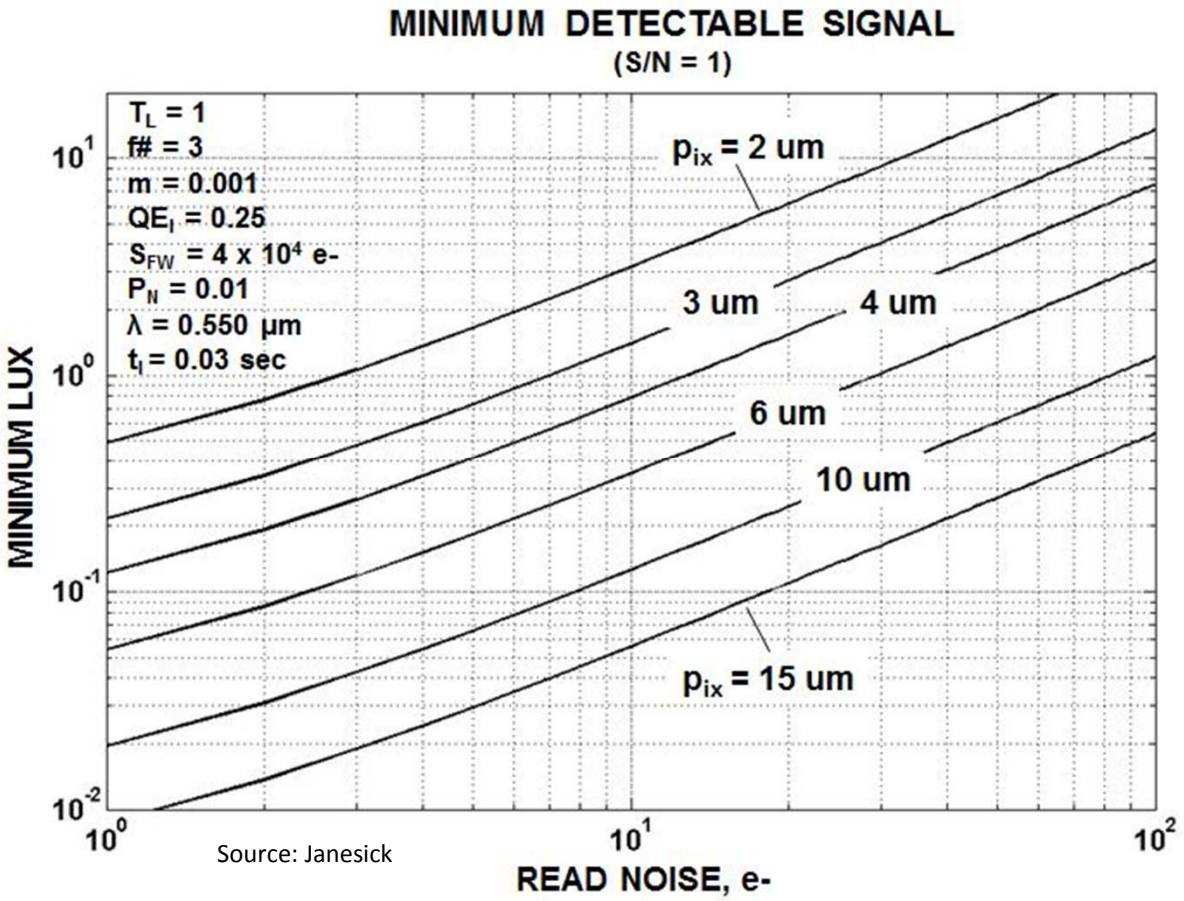
Scene Luminance

$L * N_L \dfrac{T_L}{4*F\#^2*(1+m)^2}$ (Photons/cm2-sec)

Incident Luminance at Sensor

How much does the lens spread the light flux? (magnification)

Sensitivity vs Pixel size considering system noise impact



Source: Janesick

100% optical transmission
f/3 optics
Lens magnification of 0.001*
QE = 25%
Full well = 40Ke-
PRNU = 1%
550nm wavelength
Exposure time = 30msec

* For magnification of 0.001, something that is 10 mm tall will fill a 10 micron pixel
ie: a lens that makes a 10 x 10 meter FOV fill a 1000 x 1000 pixel sensor with 10 micron pixel size

F#, system noise impact

100% optical transmission
4 micron pixel
Lens magnification of 0.001
QE = 25%
Full well = 40Ke-
PRNU = 1%
550nm wavelength
Exposure time = 30msec