

# Matching a camera to a telescope

By

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# Telescope

- Existing scope?
- Reducer?
- Buying? Consider a small refractor (ED80?)

# Which camera?

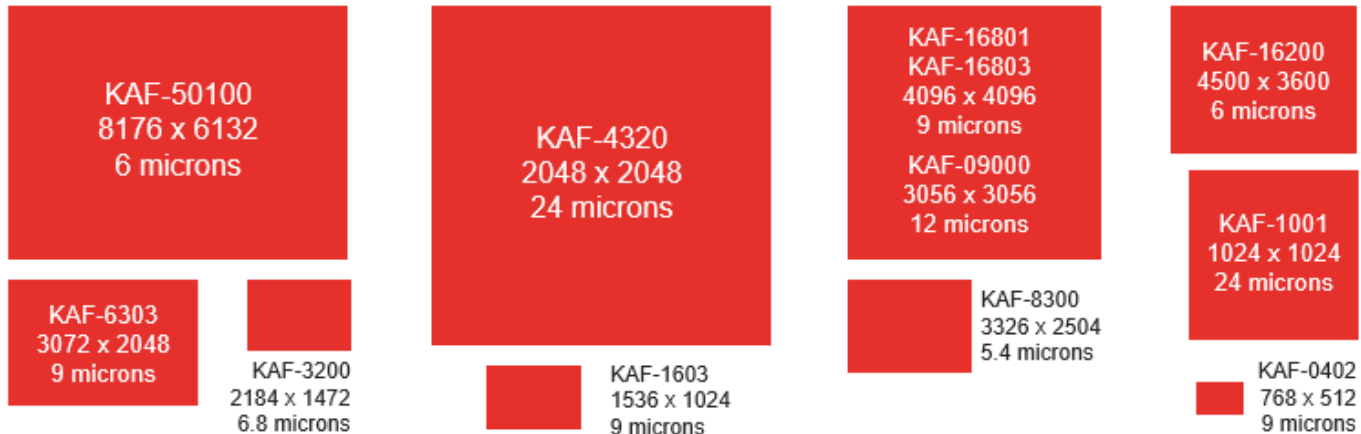
- Which sensor?
- Some sensors are used by multiple camera manufactures, e.g. KAF-8300

# Some camera sensors



[www.flicamera.com](http://www.flicamera.com)

## Full Frame Front-Illuminated CCDs



## Interline Transfer CCDs



# Field of view (FOV)

- FOV in degrees =  $57 \times \text{sensor diagonal in mm} / \text{focal length in mm}$
- E.g. 1600mm focal length with a KAF-8300 which has a sensor diagonal of 22.5mm

$$\text{FOV} = 57 \times 22.5 / 1600 = 0.8 \text{ degrees}$$

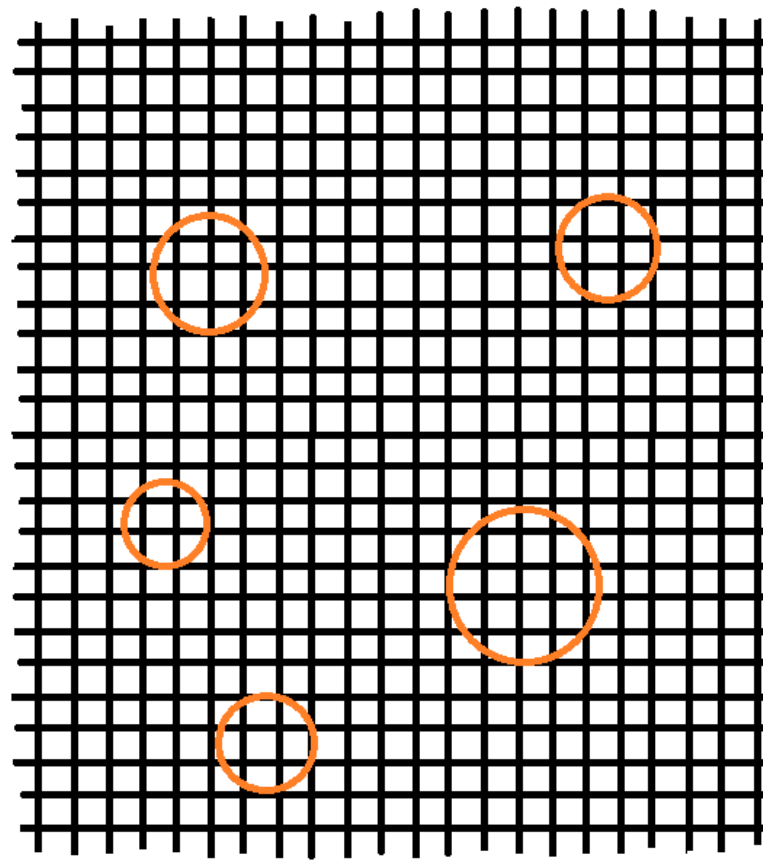
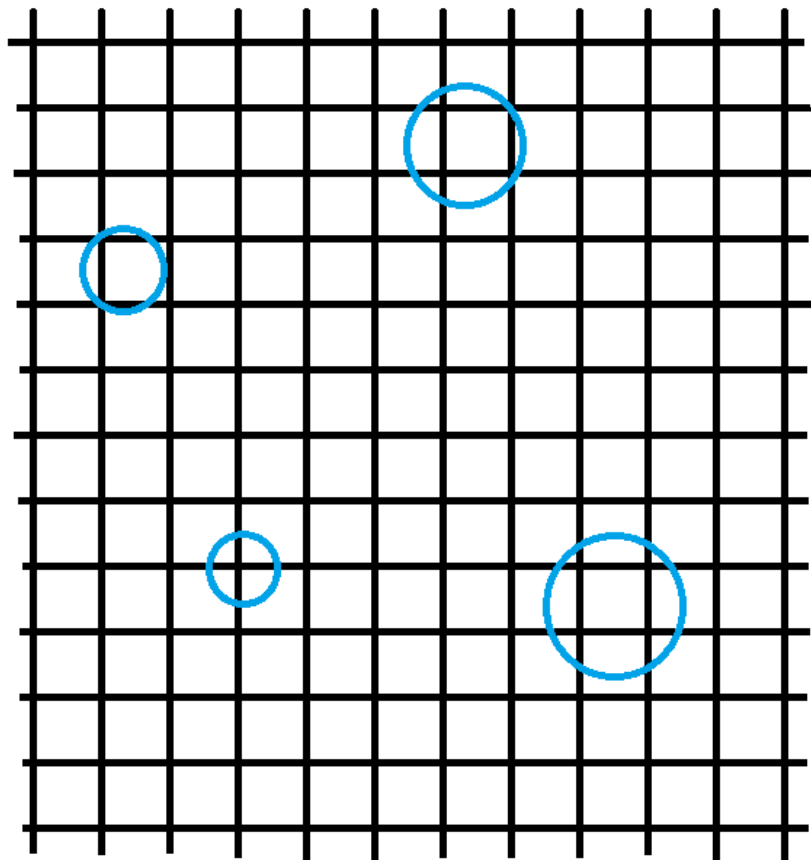
# Field of view

Target	Size
Southern Cross	7° x 5°
Andromeda Galaxy (M31)	3° x 1°
Large Magellanic Cloud	3° x 3°
Eta Carina Nebula	3° x 3°
Rosette Nebula	2° x 2°
Pleiades (M45)	1.5° x 1.5°
Lagoon Nebula (M8)	1° x 0.7°
Orion Nebula (M42)	45' x 45' (0.75° x 0.75°) [1° = 60']
Moon	30' x 30'
Eagle Nebula (M16)	20' x 20'
Southern Pinwheel Galaxy (M83)	12' x 12'
Great Barred Spiral Galaxy (NGC1365)	10' x 10'
Crab Nebula (M1)	8' x 4'

# FOV

FOV in degrees									
Focal len		Sensor diagonal (mm)							
(mm)	11	16	23	28	35	43	52	61	
400	1.57	2.28	3.28	3.99	4.99	6.13	7.41	8.69	
600	1.05	1.52	2.19	2.66	3.33	4.09	4.94	5.80	
800	0.78	1.14	1.64	2.00	2.49	3.06	3.71	4.35	
1000	0.63	0.91	1.31	1.60	2.00	2.45	2.96	3.48	
1200	0.52	0.76	1.09	1.33	1.66	2.04	2.47	2.90	
1400	0.45	0.65	0.94	1.14	1.43	1.75	2.12	2.48	
1600	0.39	0.57	0.82	1.00	1.25	1.53	1.85	2.17	
1800	0.35	0.51	0.73	0.89	1.11	1.36	1.65	1.93	
2000	0.31	0.46	0.66	0.80	1.00	1.23	1.48	1.74	
2500	0.25	0.36	0.52	0.64	0.80	0.98	1.19	1.39	
3000	0.21	0.30	0.44	0.53	0.67	0.82	0.99	1.16	
<b>Camera</b>	\$2K	\$3K	\$1.6K	\$2.4K	\$5.2K	\$7.5K	\$15K	\$23K	

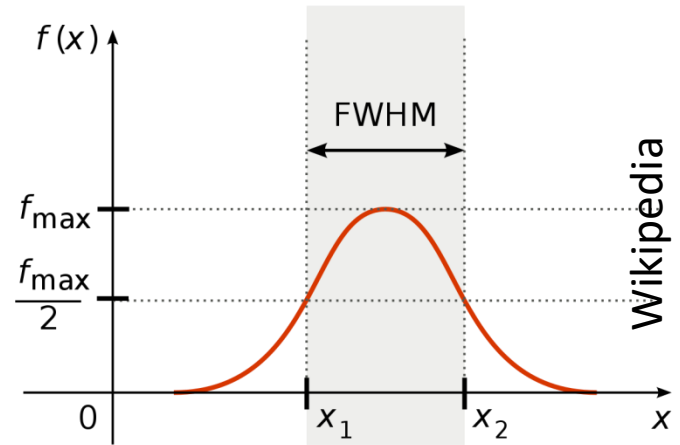
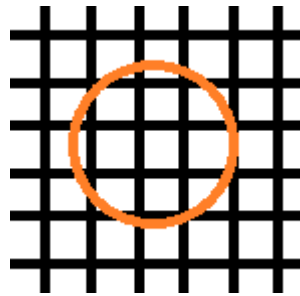
# Image scale





# Pixel size

- Ideally FWHM =  
3.3 x pixel size



- Ideal pixel size = focal length (mm)  
x seeing (arcsecs)  
/ 206.3 / 3.3

# Pixel size

Ideal pixel size (um)			
Focal len (mm)	Seeing (arcsecs)		
	1	2	3
400	0.6	1.2	1.8
600	0.9	1.8	2.6
800	1.2	2.4	3.5
1000	1.5	2.9	4.4
1200	1.8	3.5	5.3
1400	2.1	4.1	6.2
1600	2.4	4.7	7.1
1800	2.6	5.3	7.9
2000	2.9	5.9	8.8
2500	3.7	7.3	11.0
3000	4.4	8.8	13.2

too small

Typical values: 4, 5, 6, 9, 12 um

# Pixel size

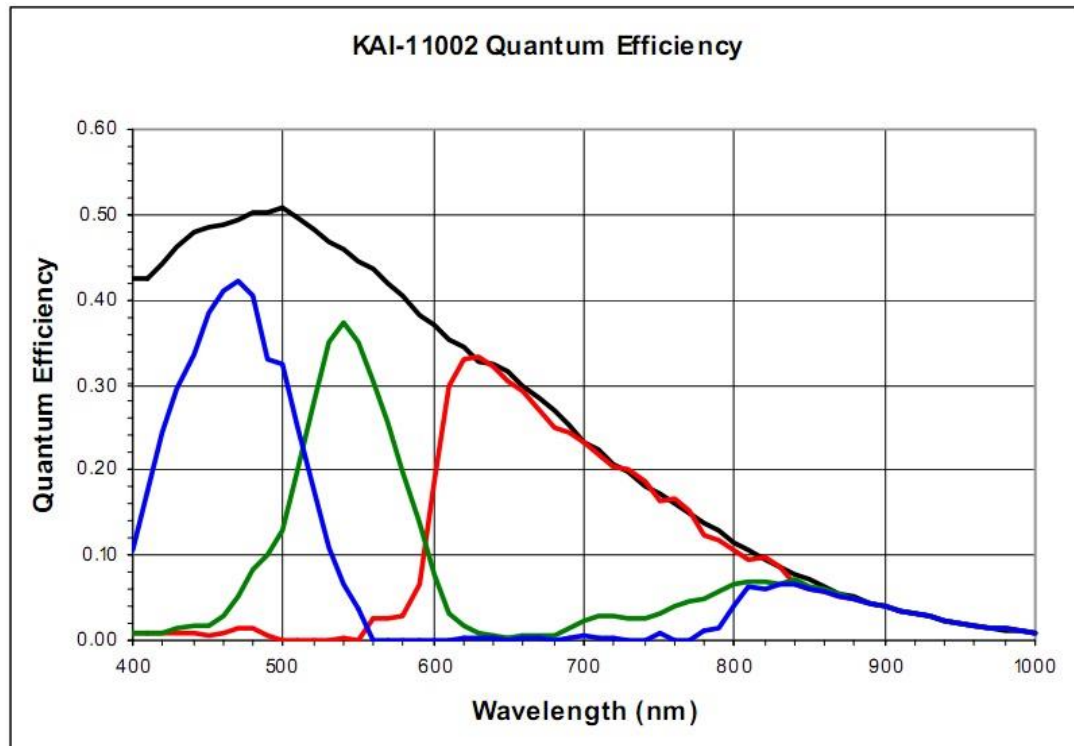
- Below ideal: over-sampling  
pixel not collecting as much light
- Above ideal: under-sampling  
stars not round
- For mild under-sampling, see drizzling
- Wide-field imaging (large FOV): 2 – 4 x ideal OK

# Image scale

- Image scale is in arcsecs per pixel
- Image scale =  $206.3 \times \text{pixel size (microns)} / \text{focal length (mm)}$
- Rough guidelines based on the 3.3 factor:
  - Seeing of 3 arcsecs: image scale 0.8 to 1.1
  - Seeing of 2 arcsecs: image scale 0.5 to 0.9

# Quantum efficiency

- % of photons converted to electrons
- Typically around 50 – 80% for maximum



# Full well

- Number of electrons to saturate a pixel
- Typically 20,000 – 100,000 electrons
- Bigger is better – more dynamic range
- But ...

# Read noise

- On read-out of a pixel value
- Typically 1 – 13 electrons
- Smaller is better, especially for faint objects

# Dynamic range

- Full well / read noise [ db = 20 log (fw/rn) ]
- Measure of number of distinct pixel values
- Bigger is better

• Camera:	ZWO 1600	FLI 16803
Full well:	20,000	100,000
Read noise:	1.2	10
Dynamic	16,667	10,000
db	84	80



# Light gathering

- Pixel gathering light:
  - Area of the pixel
  - Quantum efficiency
- Sensitivity index = pixel size <sup>2</sup> x QE

# Some cameras

OTA focal length (mm)	1000					
Make	ZWO	ZWO	ZWO	SBIG	Atik	FLI
Model	1600	ASI 294	071	STF-8300	11000C	PL16803
Chip		Sony	Sony	Truesense	Truesense	Truesense
		IMX294	IMX071	KAF-8300	KAI-11002M	KAF-16803
CCD/CMOS	CMOS	CMOS	CMOS	CCD	CCD	CCD
Pixel size	3.8	4.63	4.78	5.4	9	9
Image scale (arc sec/pixel)	0.78	0.95	0.98	1.11	1.85	1.85
Width (pixels)	4656	4144	4944	3326	4008	4096
Height (pixels)	3520	2822	3284	2504	2672	4096
Aspect ratio	1.32	1.47	1.51	1.33	1.50	1.00
Diagonal (mm)	22.2	23.2	28.4	22.5	43.4	52.1
FOV diagonal (arc mins)	75.9	79.4	97.0	76.9	148.3	178.3
FOV width (arc mins)	60.5	65.6	80.8	61.4	123.4	126.1
FOV height (arc mins)	45.7	44.7	53.7	46.2	82.2	126.1
Quantum efficiency (%)	60	78	55	57	50	60
Sensitivity index	866	1672	1257	1662	4050	4860
Full well	20000	63700	46000	25500	60000	100000
Read noise	1.2	1.2	3.3	9.3	13	10
Dynamic range	16667	53083	13939	2742	4615	10000
Dynamic range db	84	94	83	69	73	80
Price	\$2,049	\$1,599	\$2,399	\$2,999	\$7,499	\$15,299
\$ / mm of diagonal	\$92	\$69	\$85	\$133	\$173	\$293

# Other

- Colour / mono
- Binning
- Back focus distance
- Focuser
- Don't obscure edges of sensor
- ADC 12, 14, 16 bits
- Cooling below ambient
- Blooming / anti-blooming
- Residual bulk image (full frame)
- Integrated guide camera (SBIG)