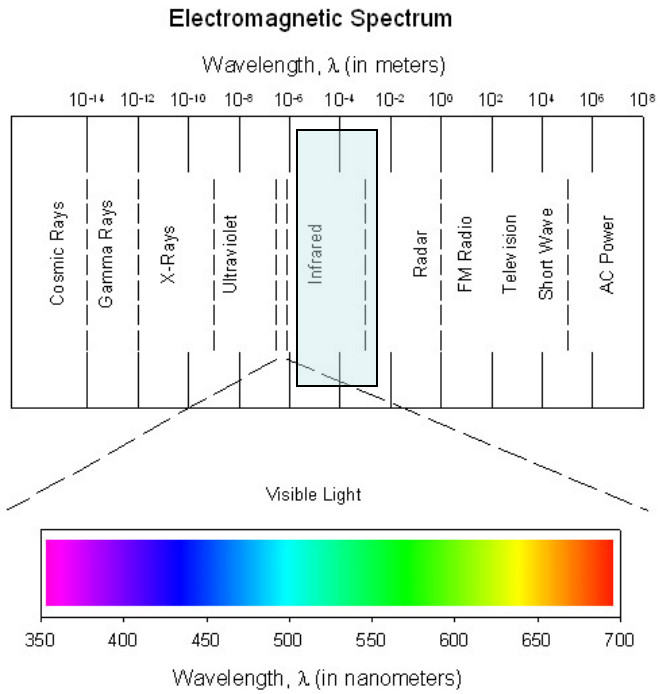
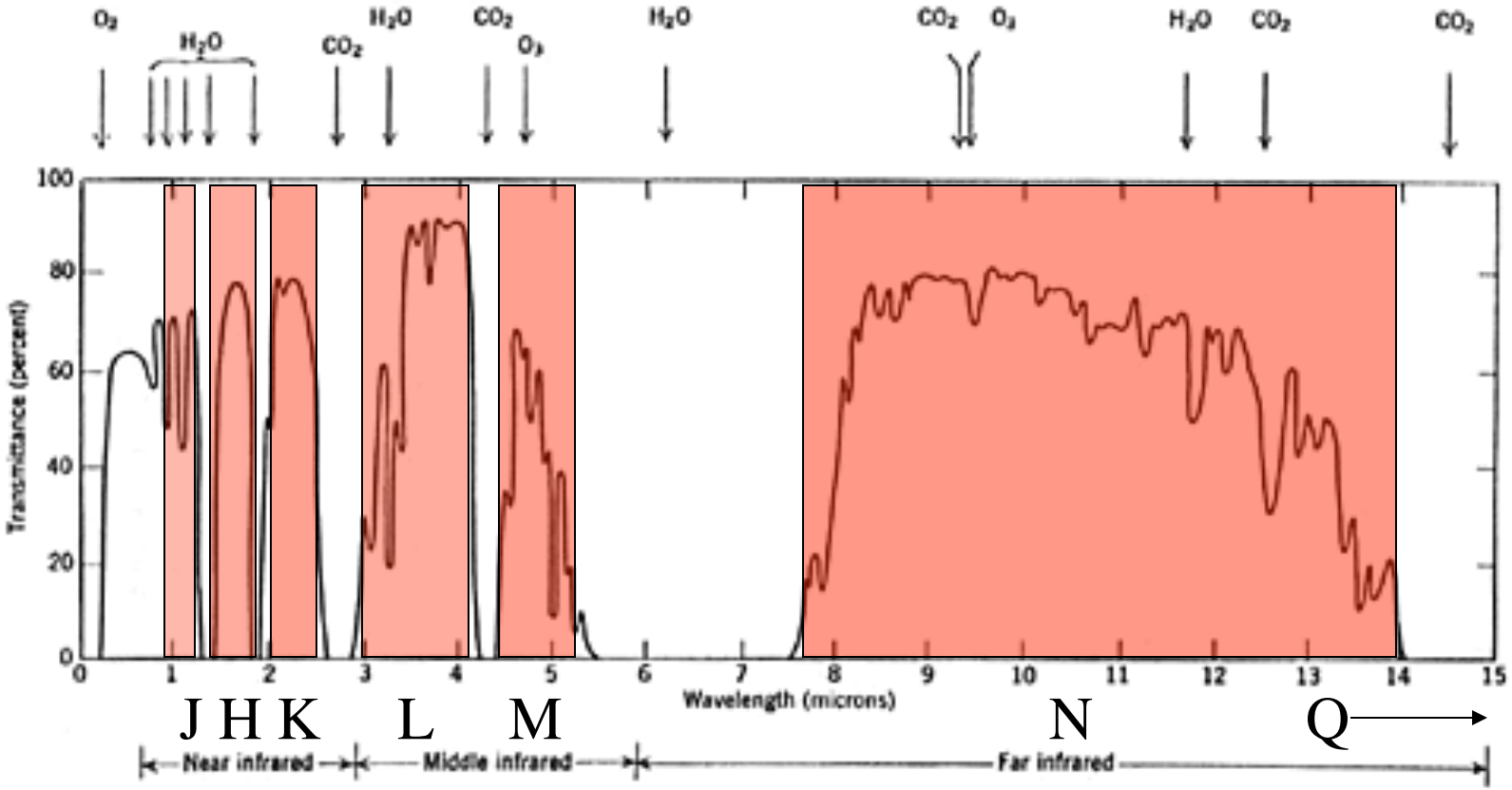
IR Astronomy

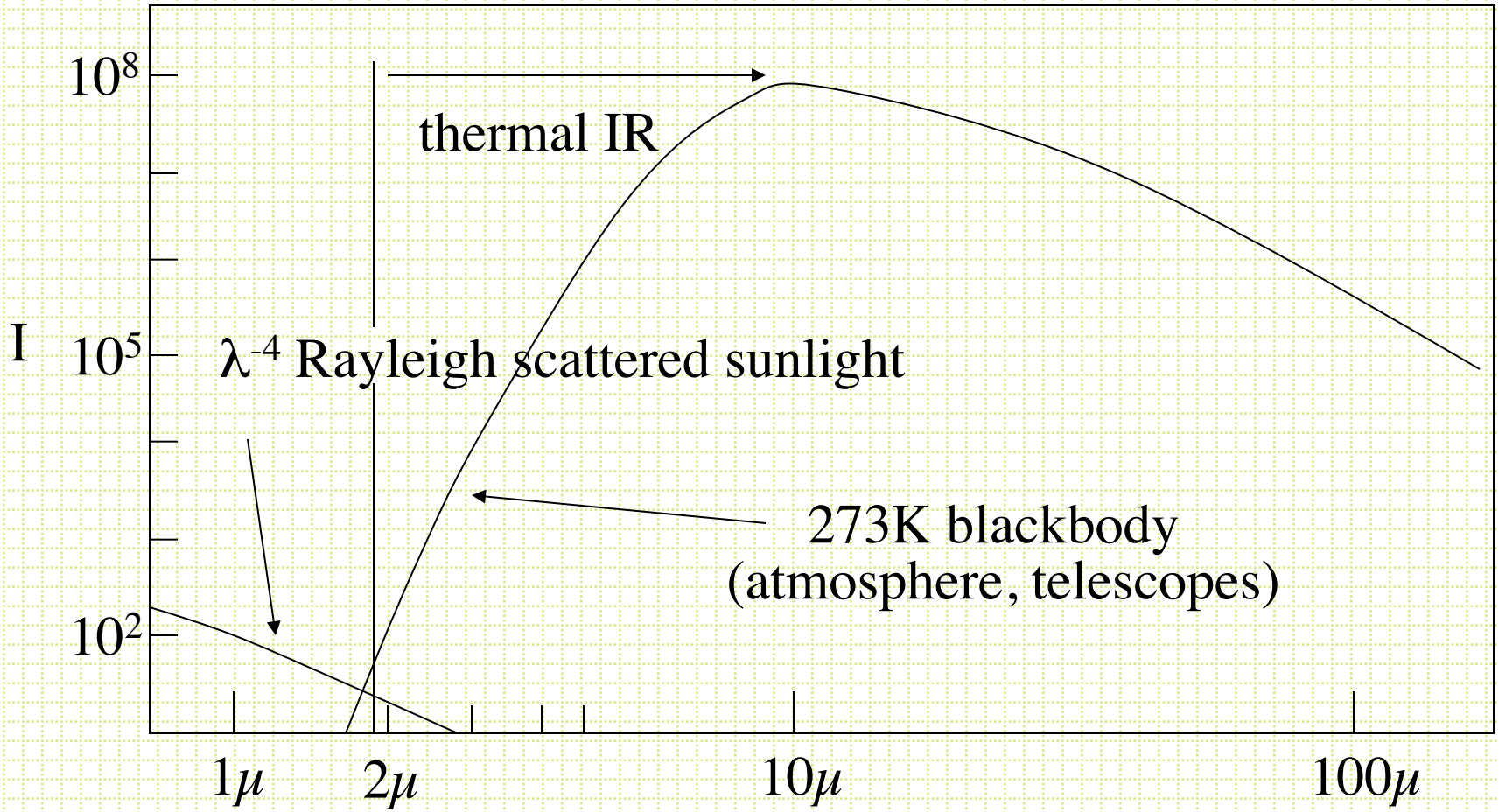
- Eye response goes to 0 at 7500Å
- Silicon bandgap energy of 1.1eV means a hard cutoff in CCD response at 1.1μ
- `near-IR': 1μ - 2.5μ
- `mid-IR': 2.5μ - 25μ
- `far-IR': 25μ - 350μ



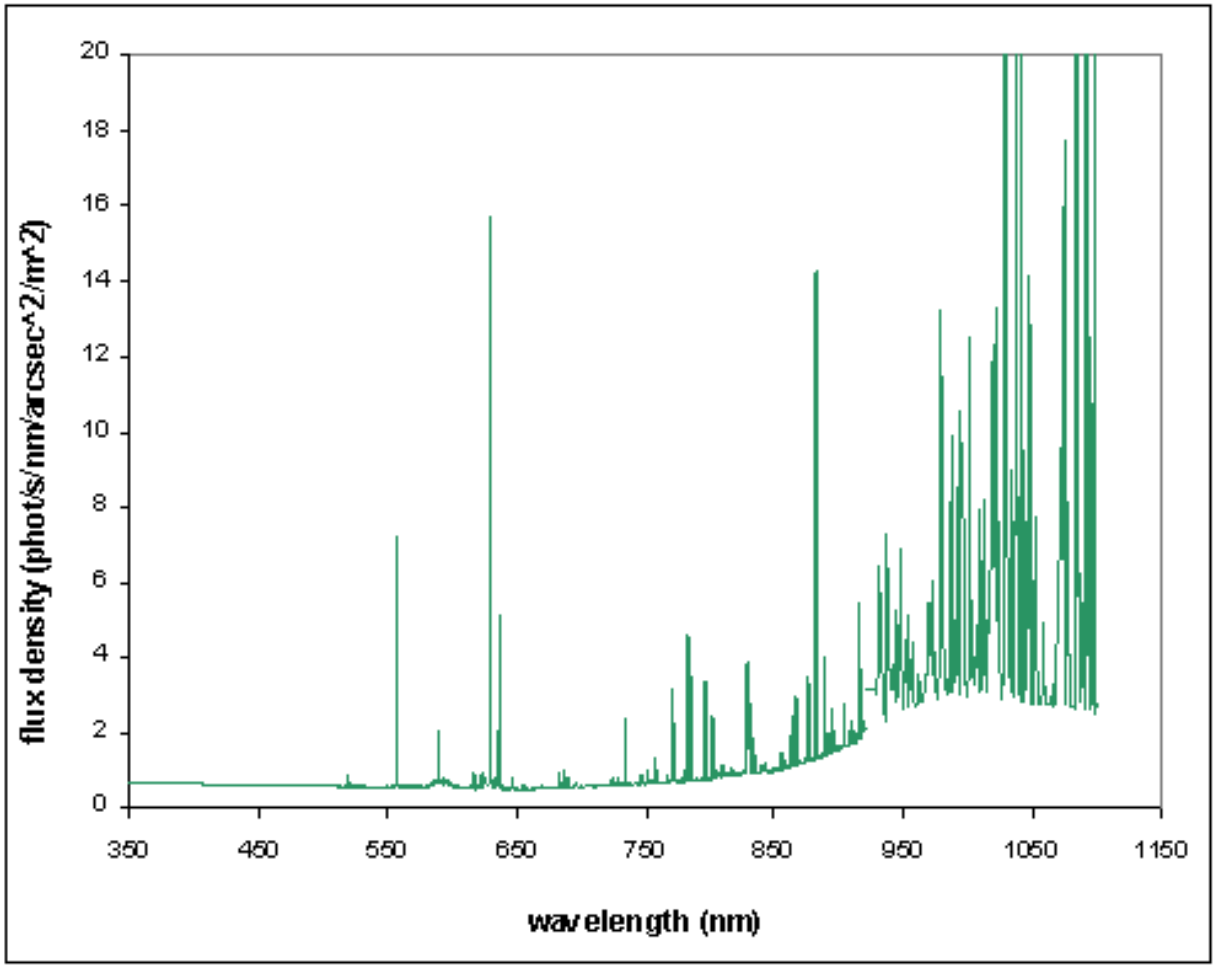
Atmospheric Windows

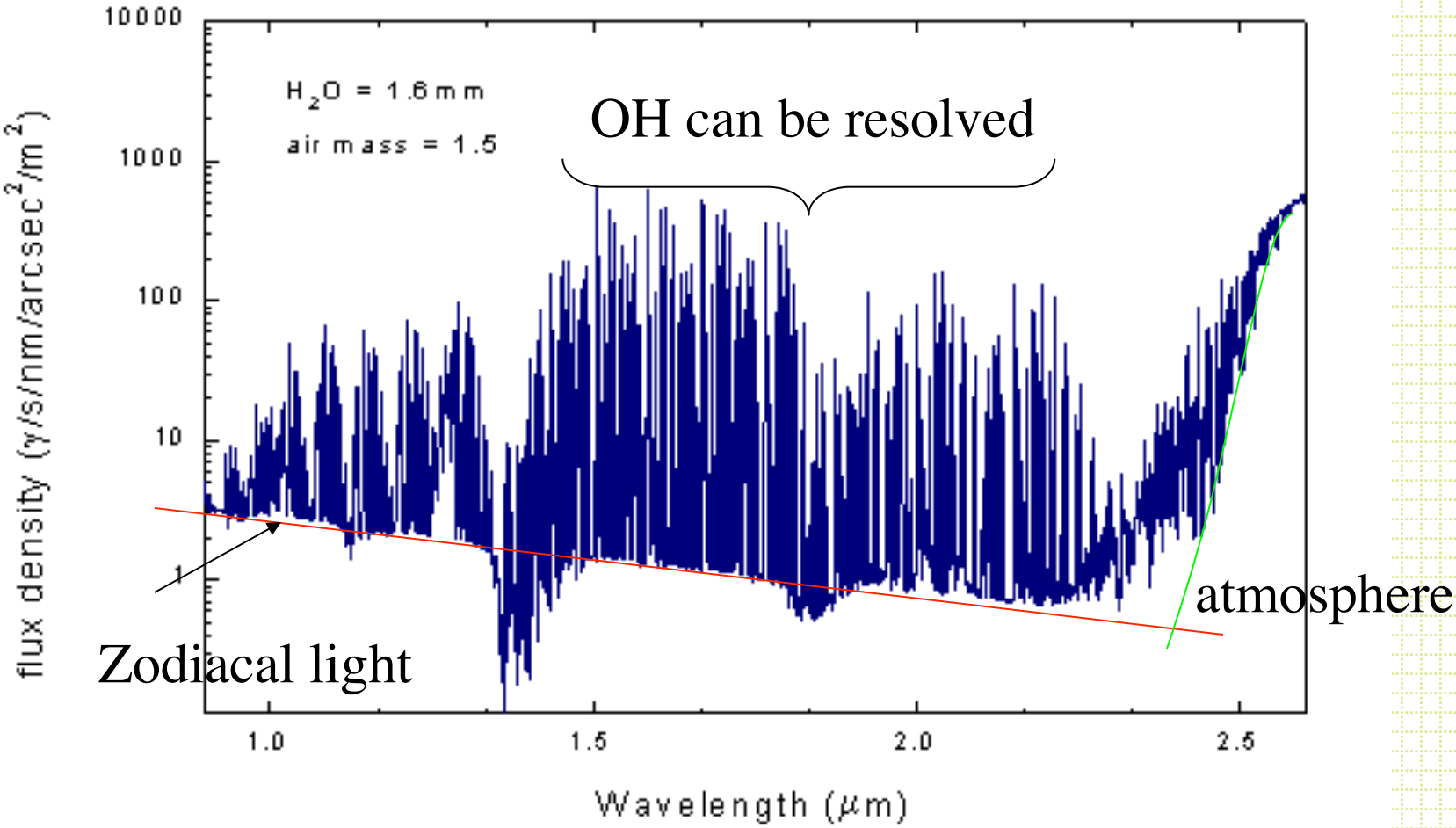


Backgrounds

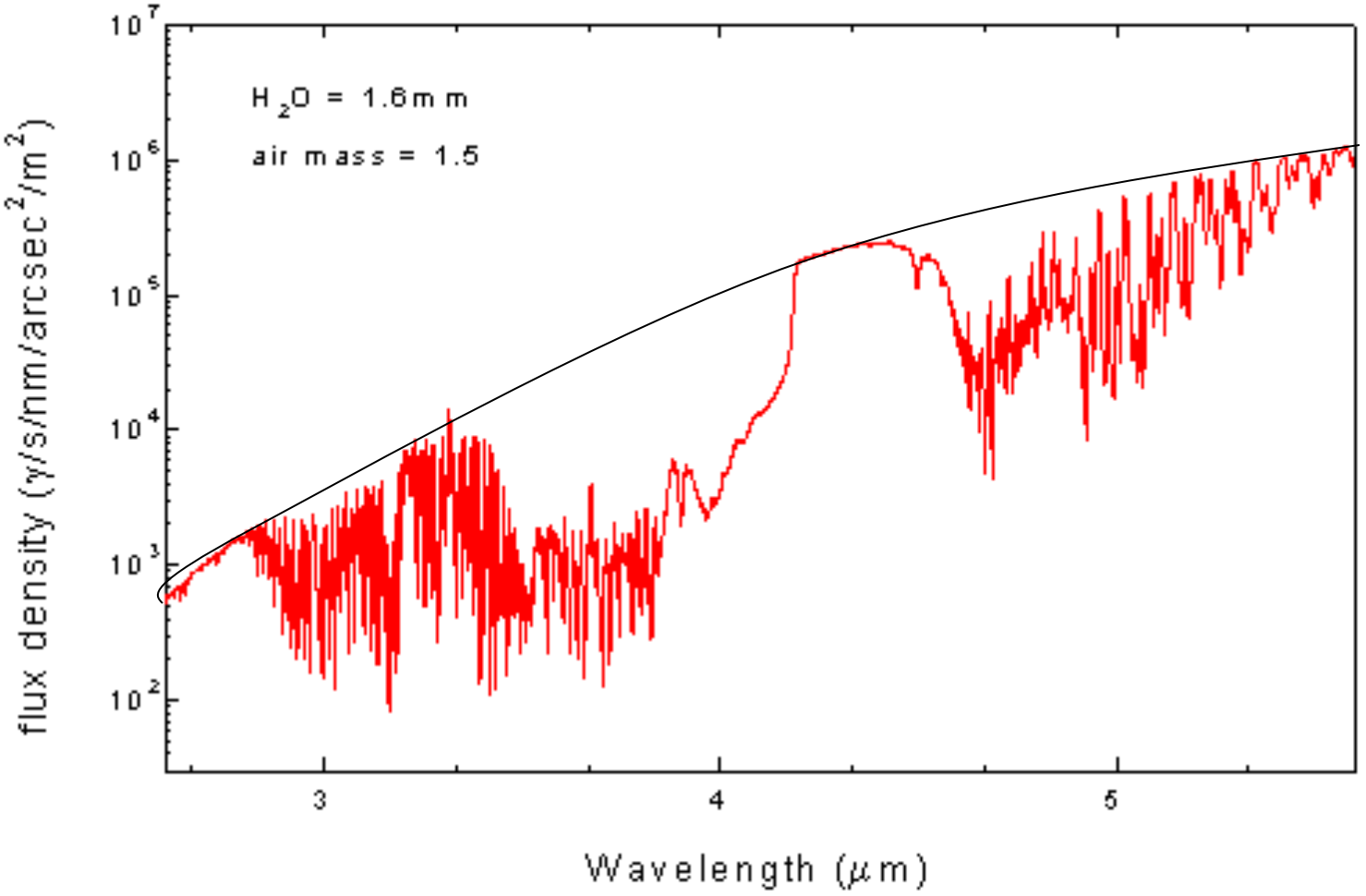


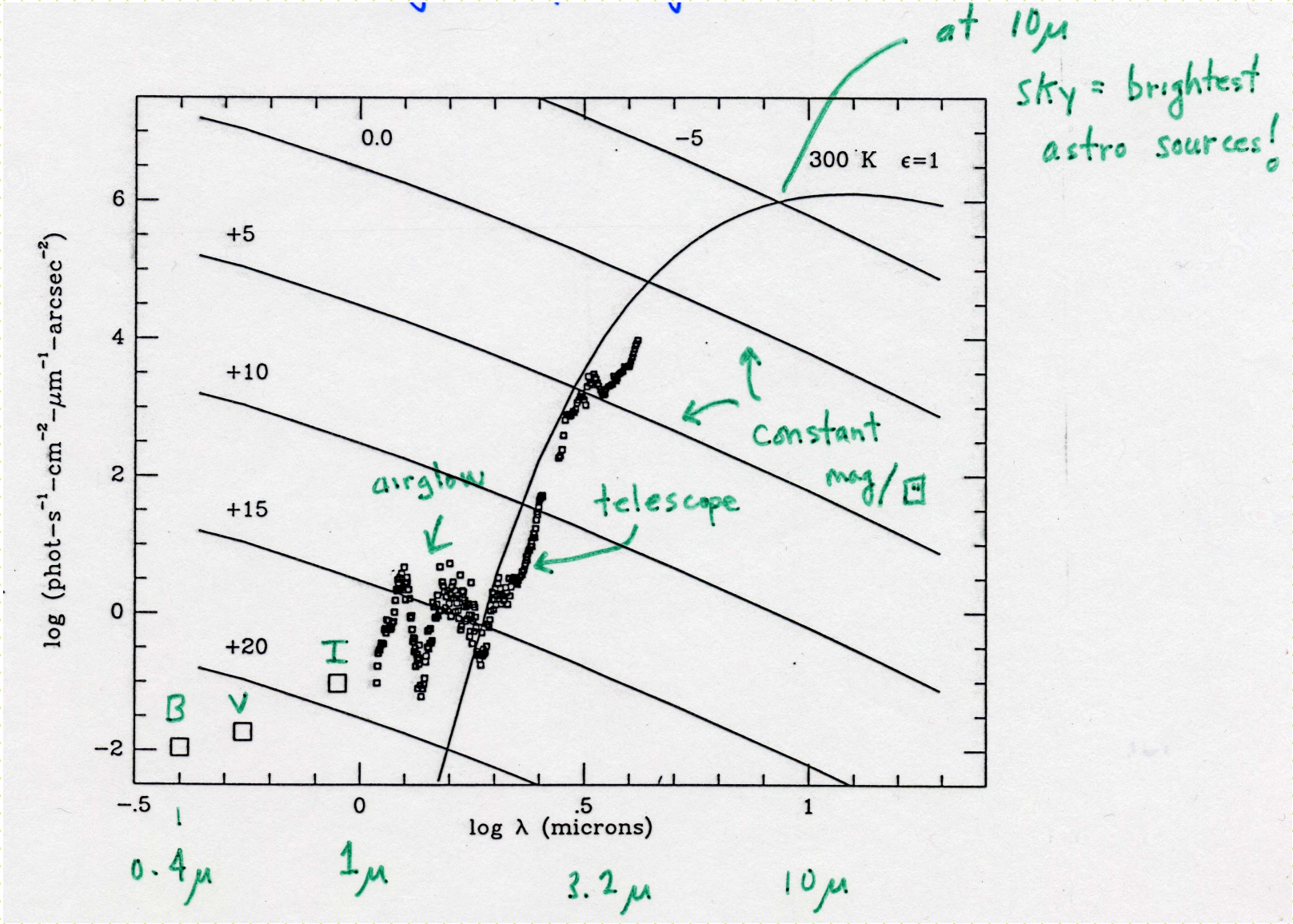
Backgrounds

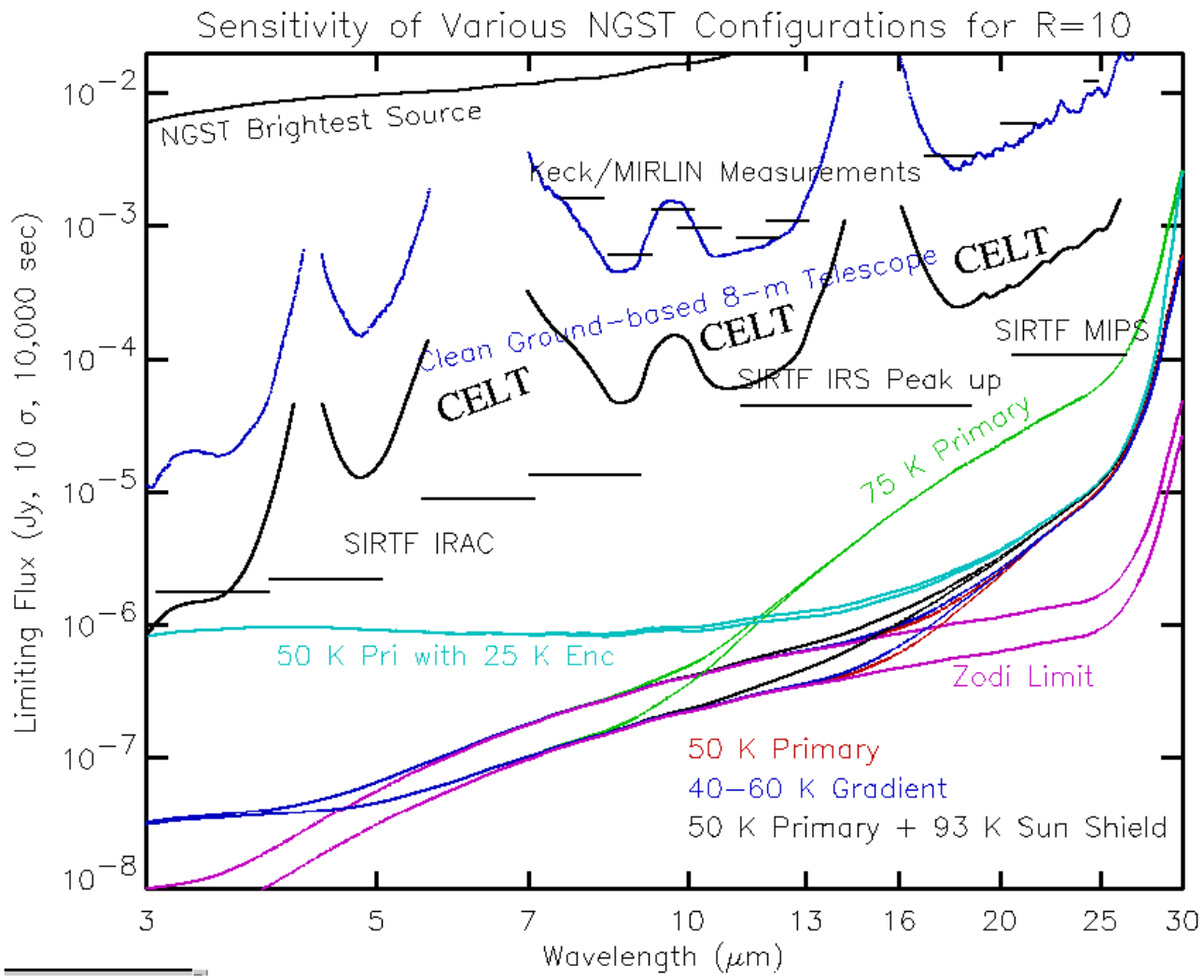



10000
1000
100
10
1
H_2O = 1.6 mm
air mass = 1.5
OH can be resolved
flux density (γ/s/nm/arcsec^2/m^2)
Zodiacal light
atmosphere
1.0
1.5
2.0
2.5
Wavelength (μm)

Note vertical scales on plots!




at 10μ
sky = brightest
astro sources!
0.0
−5
300 K ε=1
+5
+10
+15
+20
constant
mag/□"
airglow
telescope
B
V
I
log (phot-s⁻¹-cm⁻²-μm⁻¹-arcsec⁻²)
log λ (microns)
−.5
0
.5
1
6
4
2
0
−2
0.4μ
1μ
3.2μ
10μ

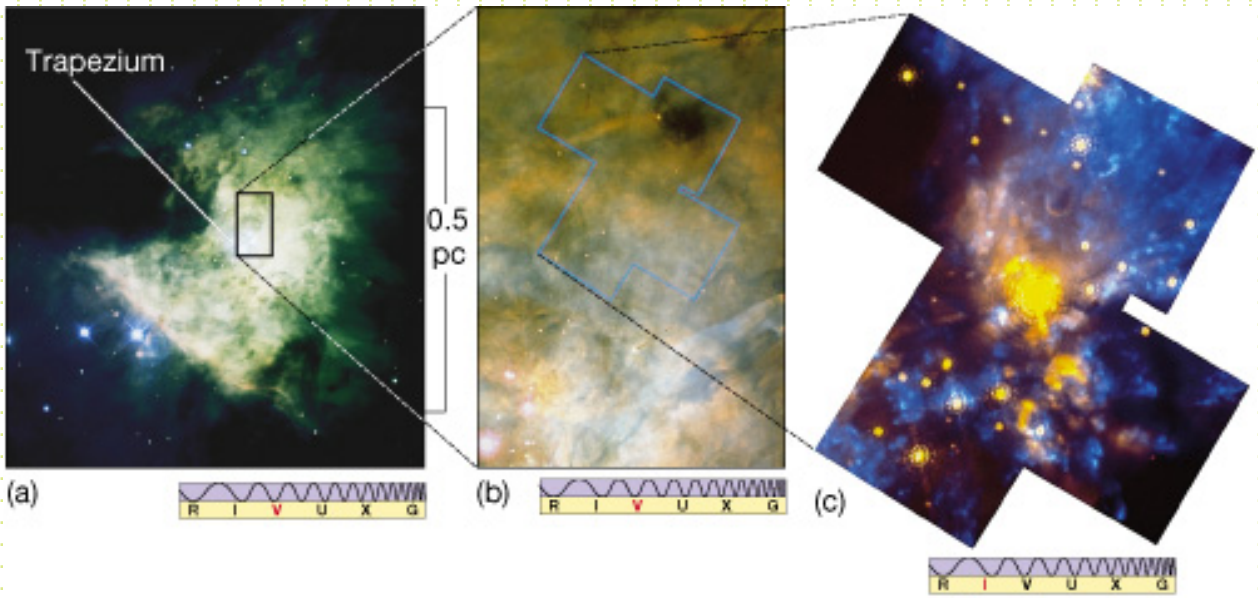

Sensitivity of Various NGST Configurations for R=10
Limiting Flux (Jy, 10 σ, 10,000 sec)
Wavelength (μm)
NGST Brightest Source
Keck/MIRLIN Measurements
Clean Ground-based 8-m Telescope
CELT
CELT
CELT
SIRTF MIPS
SIRTF IRS Peak up
SIRTF IRAC
75 K Primary
50 K Pri with 25 K Enc
Zodi Limit
50 K Primary
40–60 K Gradient
50 K Primary + 93 K Sun Shield

Why IR?

- Galactic dust extinction law:

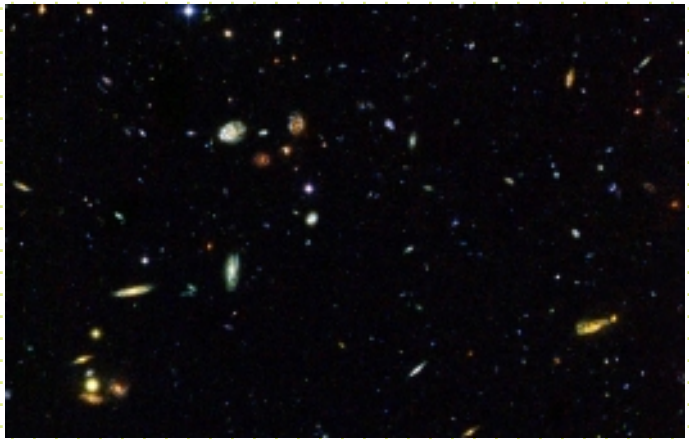
$$k_{2.2\mu} \sim 0.1 k_{0.5\mu}$$

- Cool stuff: $\lambda_{peak}(\text{planck}) = 2898/T\ (\mu)$
  - Cool stars emitted energy peak ~ 1μ
  - Giant planets ~ 6-15μ
  - Dust re-radiation ~ 20-200μ



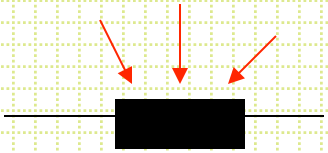
High-z Universe

- $\lambda = \lambda_0(1+z)$
- @z=1.8 Ca H&K `break' redshifted to J band
- @z=8 L



Detectors

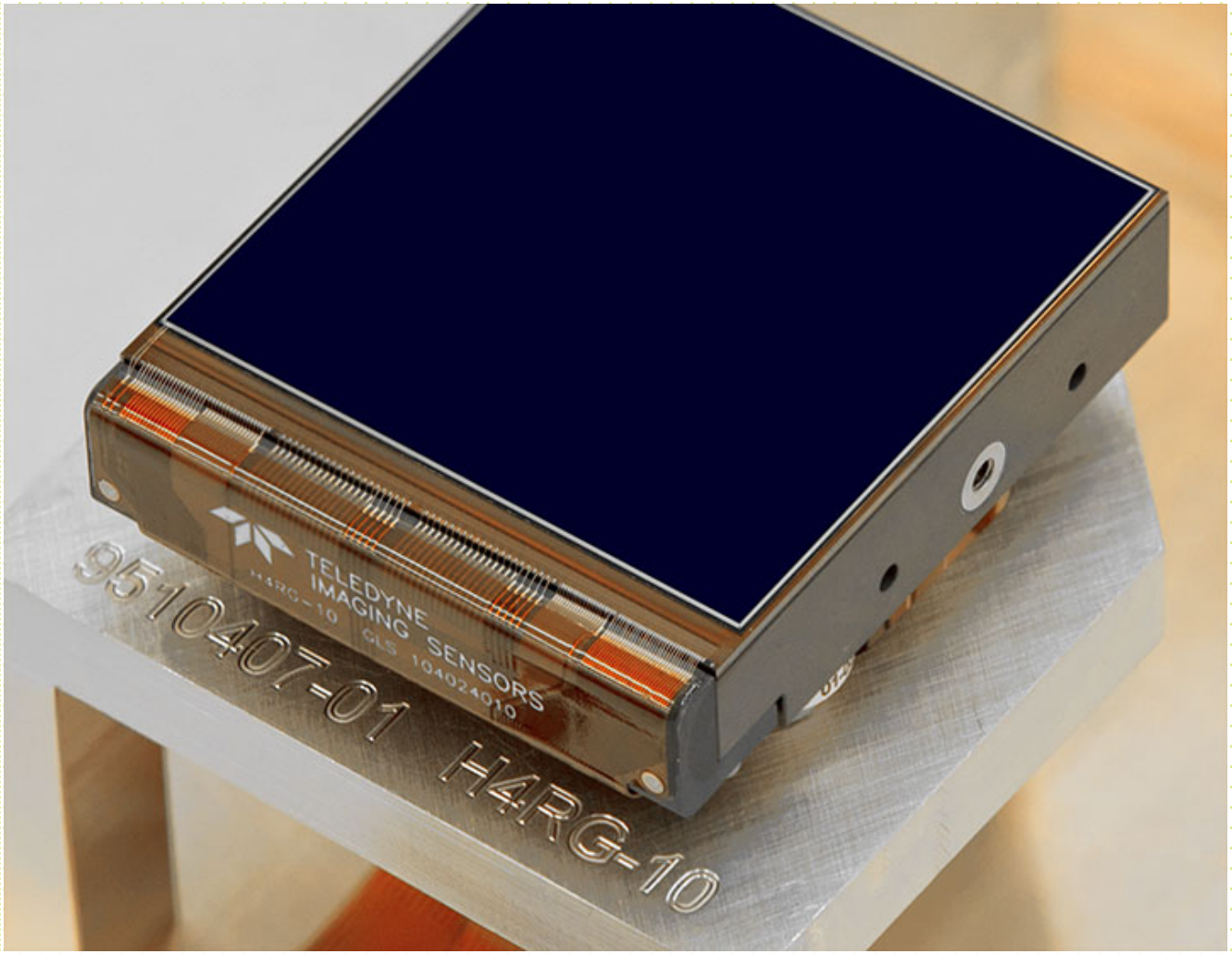
- Original IR detectors were lead-sulfide, then germanium *bolometers*.

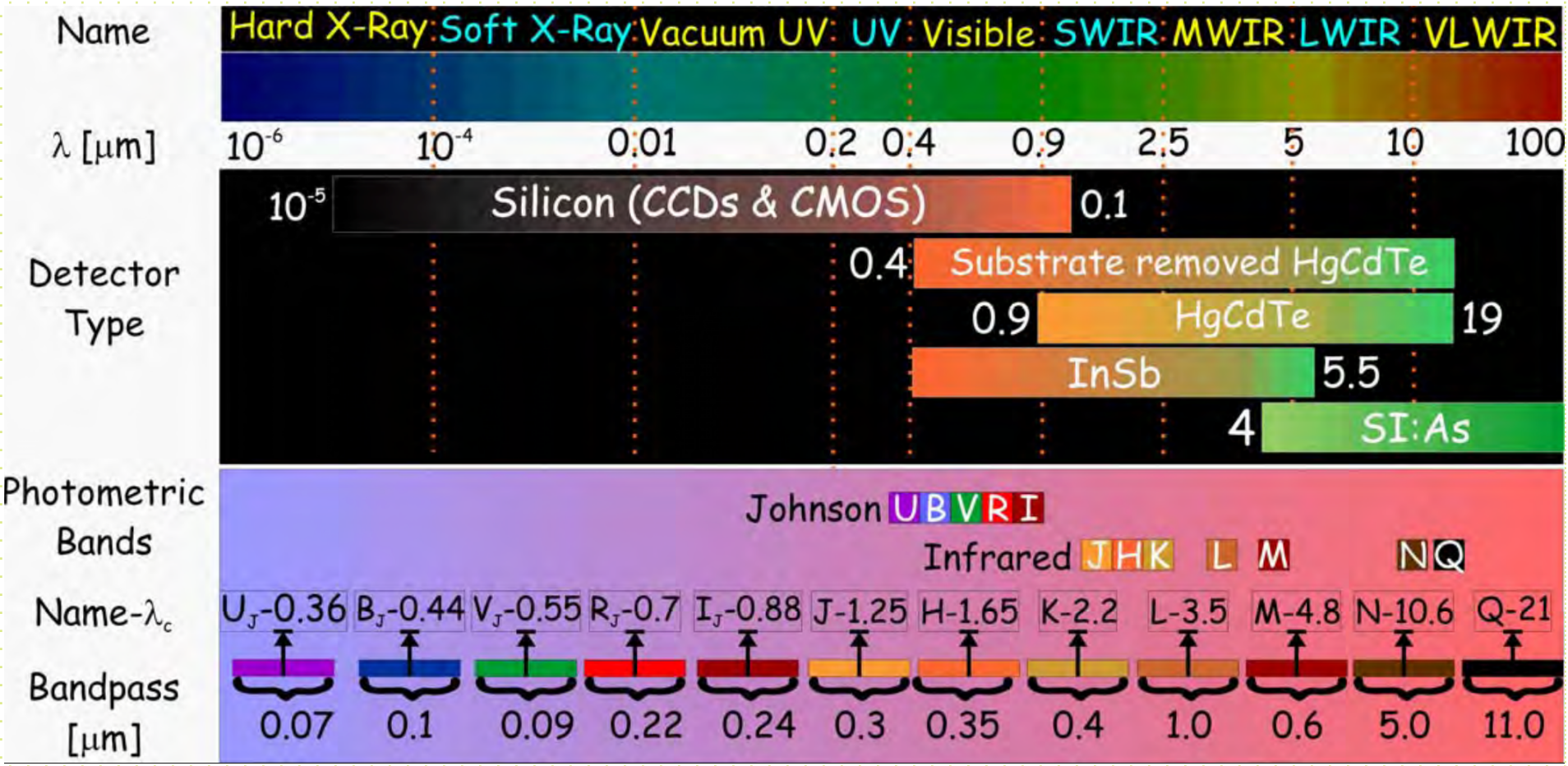


Photoconductive: resistance a very sensitive function of T. Ran at liquid helium temperatures (4K).

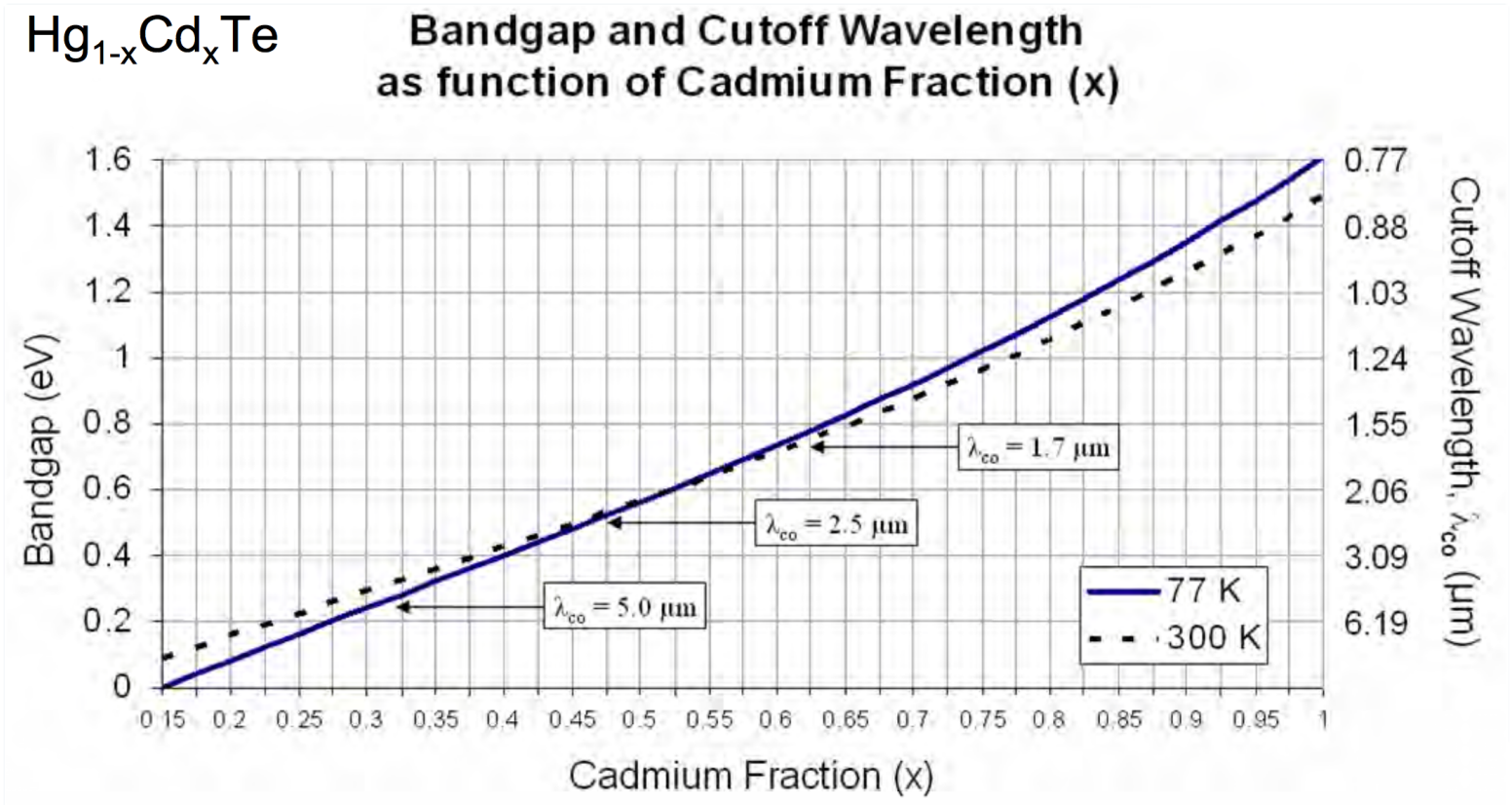
- 1980's the first photo-diode (CCD-like) detectors became available with semicondutors that had smaller bandgaps than silicon

larger dark currents!


TELEDYNE
IMAGING SENSORS
H4RG-10 GLS 104024010
9510407-01 H4RG-10


Name
Hard X-Ray
Soft X-Ray
Vacuum UV
UV
Visible
SWIR
MWIR
LWIR
VLWIR
λ [μm]
10-6
10-4
0.01
0.2
0.4
0.9
2.5
5
10
100
Detector Type
10-5
Silicon (CCDs & CMOS)
0.1
0.4
Substrate removed HgCdTe
0.9
HgCdTe
19
InSb
5.5
4
SI:As
Photometric Bands
Johnson UBVRI
Infrared JHK L M NQ
Name-λc
UJ-0.36
BJ-0.44
VJ-0.55
RJ-0.7
IJ-0.88
J-1.25
H-1.65
K-2.2
L-3.5
M-4.8
N-10.6
Q-21
Bandpass [μm]
0.07
0.1
0.09
0.22
0.24
0.3
0.35
0.4
1.0
0.6
5.0
11.0

$Hg_{1-x}Cd_xTe$


Bandgap and Cutoff Wavelength
as function of Cadmium Fraction (x)
Bandgap (eV)
Cutoff Wavelength, λco (μm)
Cadmium Fraction (x)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.77
0.88
1.03
1.24
1.55
2.06
3.09
6.19
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
λco = 1.7 μm
λco = 2.5 μm
λco = 5.0 μm
77 K
300 K

Property	CCD	Hybrid CMOS
Resolution	> 4K x 4K	up to 4K x 4K
Pixel pitch	10 – 20 µm	10 – 40 µm (up to 100 µm if required)
Typical wavelength coverage	400 – 1050 nm	400 – 1050 nm with Si PIN 400 – 18,000 nm with HgCdTe 400 – 5,000 nm with InSb
Noise	Few electrons	Few electrons with multiple sampling
Shutter	Mechanical	Electronic, rolling shutter, snapshot
Power Consumption	High	Typ. 10x lower than CCD
Radiation	Sensitive	Much less susceptible to radiation
Control Electronics	High voltage clocks, at least 2 chips needed	Low voltage only Can be integrated into single chip
Special Modes	Orthogonal Transfer Binning	Windowing, Guide Mode, Random Access, Reference Pixels, Large dynamic range (up the ramp)

Material	wavelength(μ)	$T_{operate}$
Si	<1.1μ	160K
HgCdTe	0.8 - 5μ	65K
InSb	1 - 5.6μ	35K
SiAs	6 - 27μ	10K

Special considerations for IR observing

- Hardly any!
- Chopping (highly variable background)
- Backgrounds are enormous
- Don't ignore detector dark/readout noise
- Telescope designers be careful
  - Baffling
  - Cold pupils
  - Underfilled secondaries