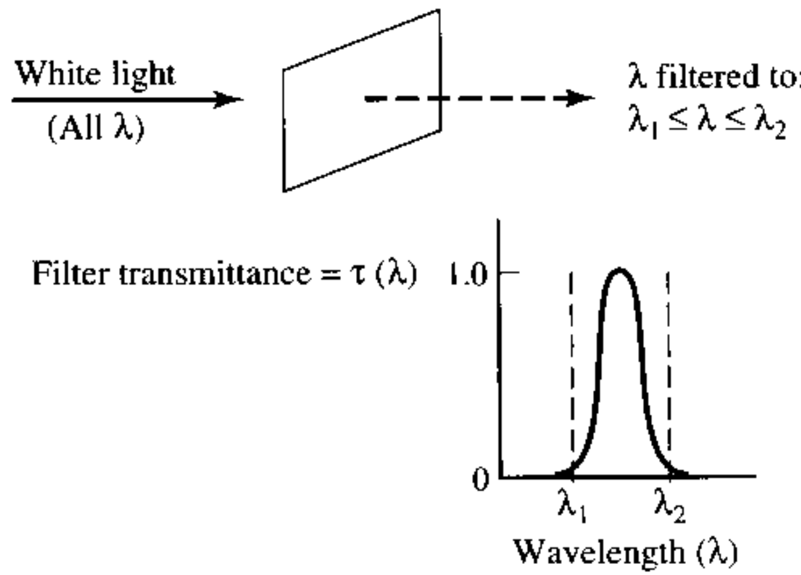
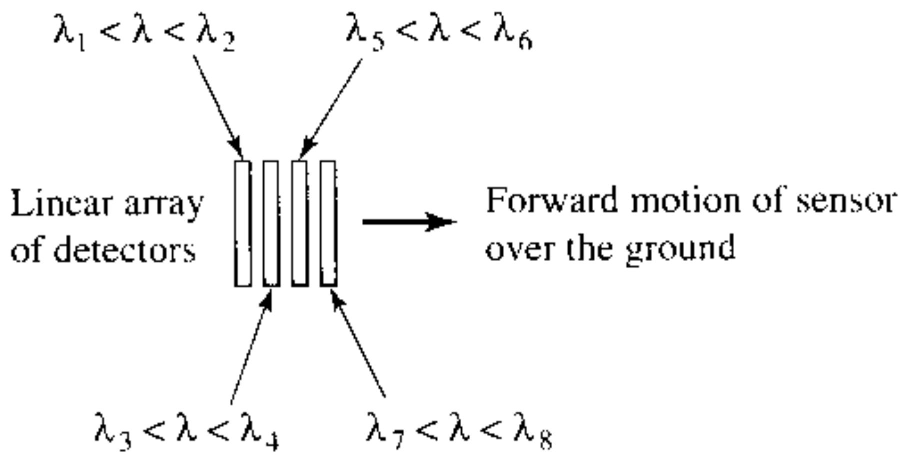
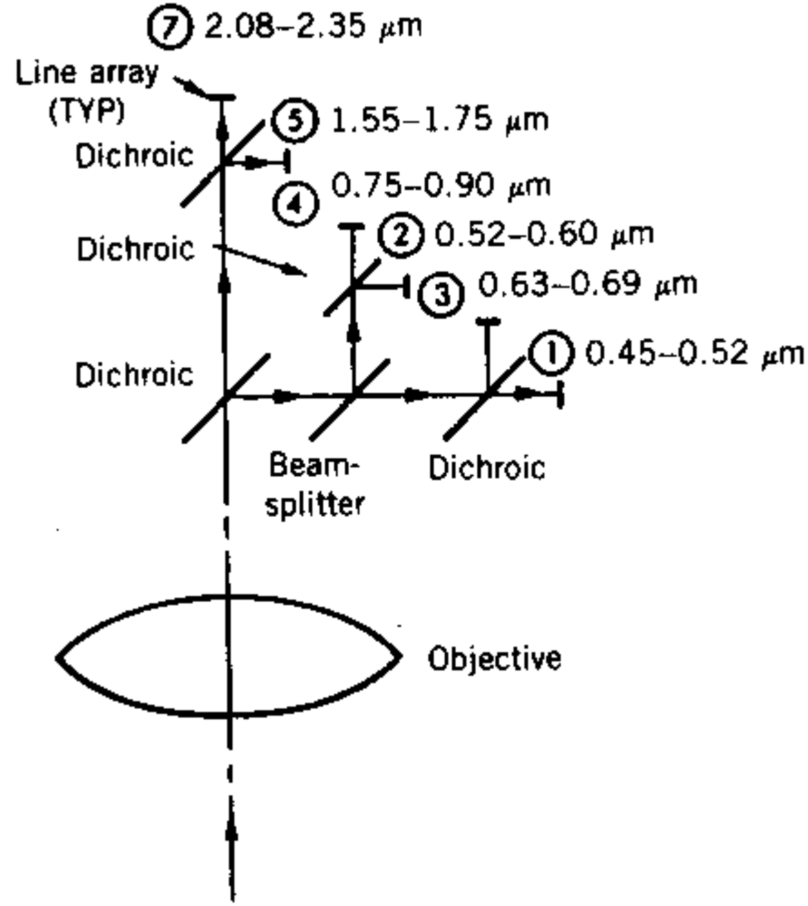
Dispersion Elements: Transmission Filters



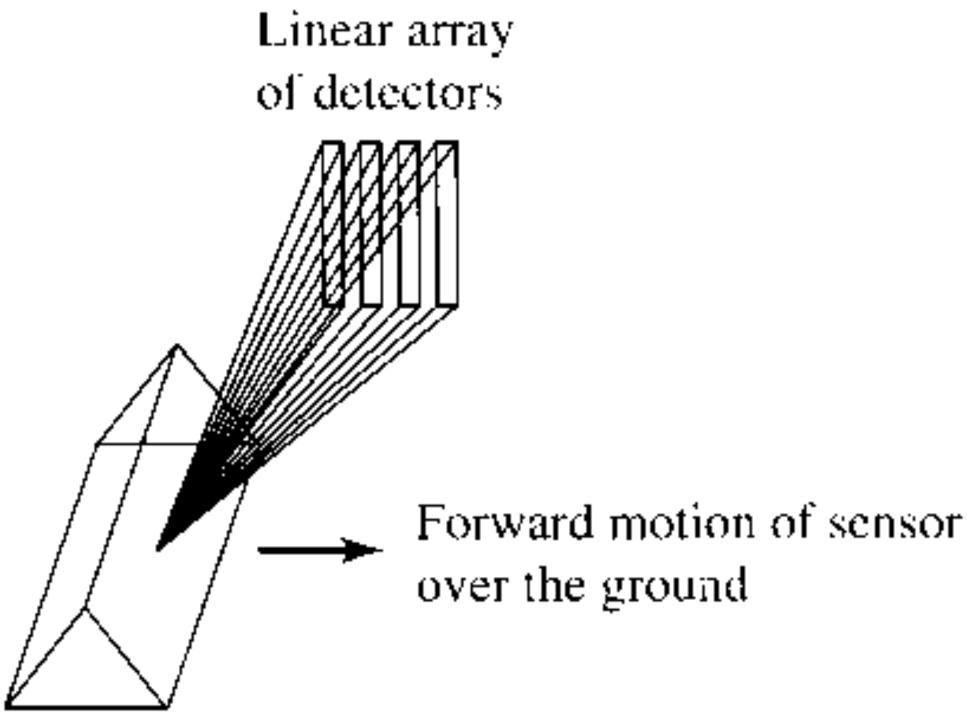


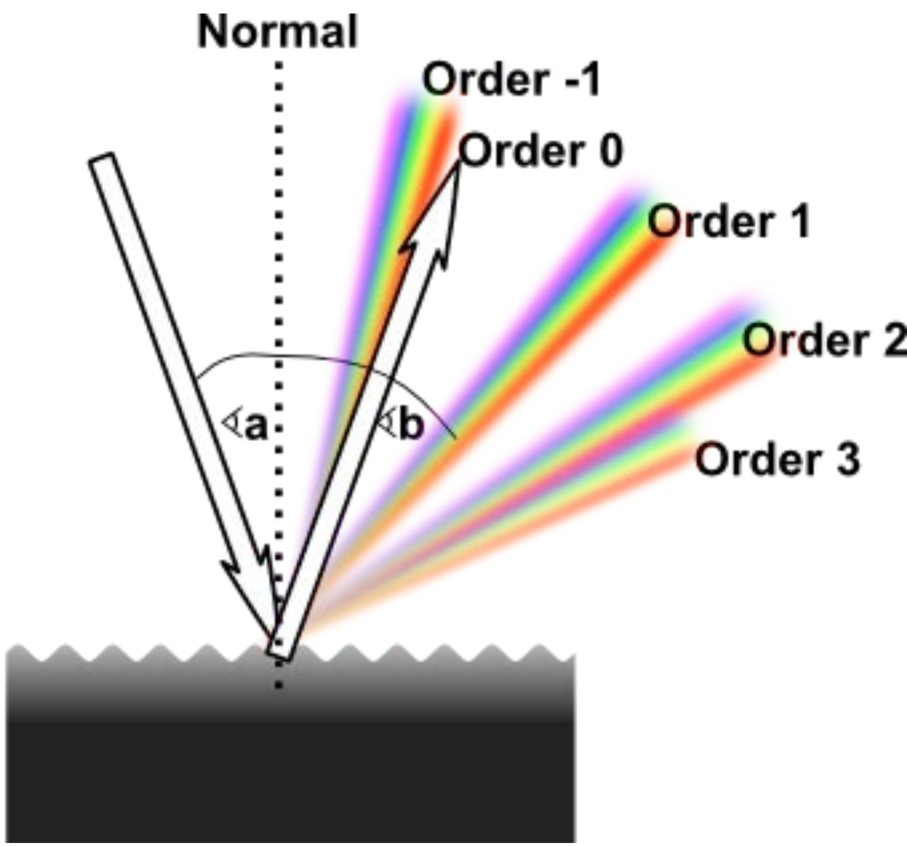
Dispersion Elements: Dichroic Mirrors



(a)

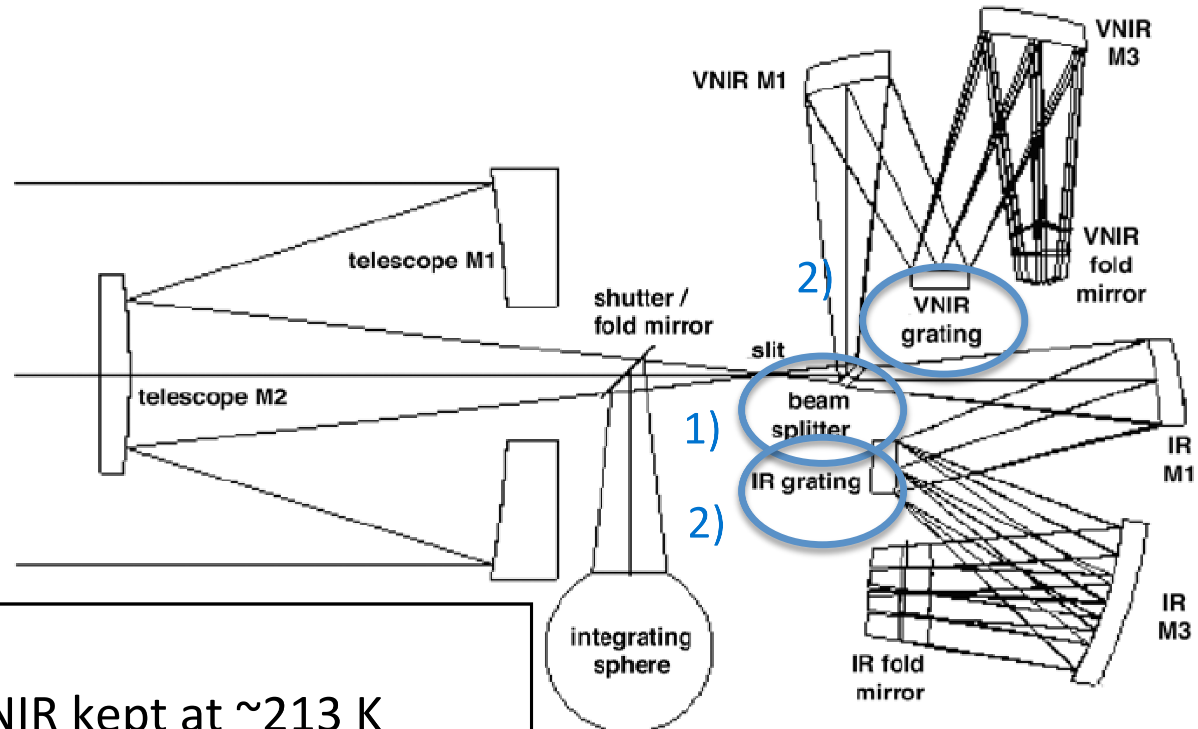
Dispersion Elements:
Prisms and Diffraction Gratings





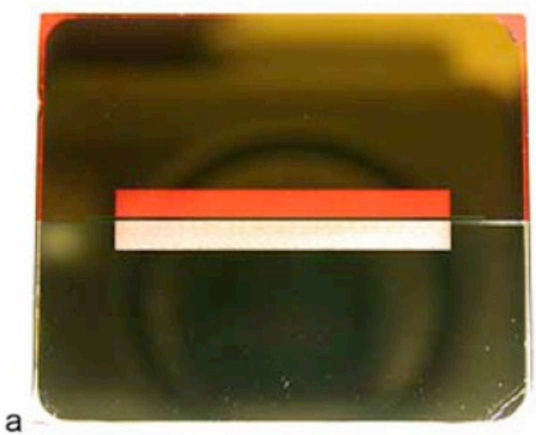
Real Spectrometers Might Use All 3!

CRISM
Compact Reconnaissance Imaging Spectrometer for Mars

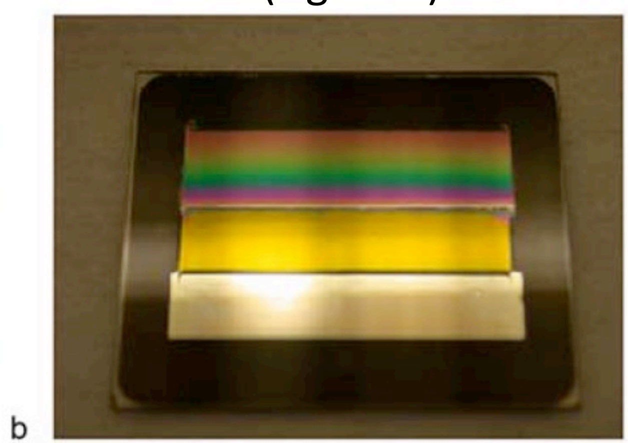


- Each detector 640x480 pixels
- IR actively cooled (~120 K), VNIR kept at ~213 K

VNIR (Si)



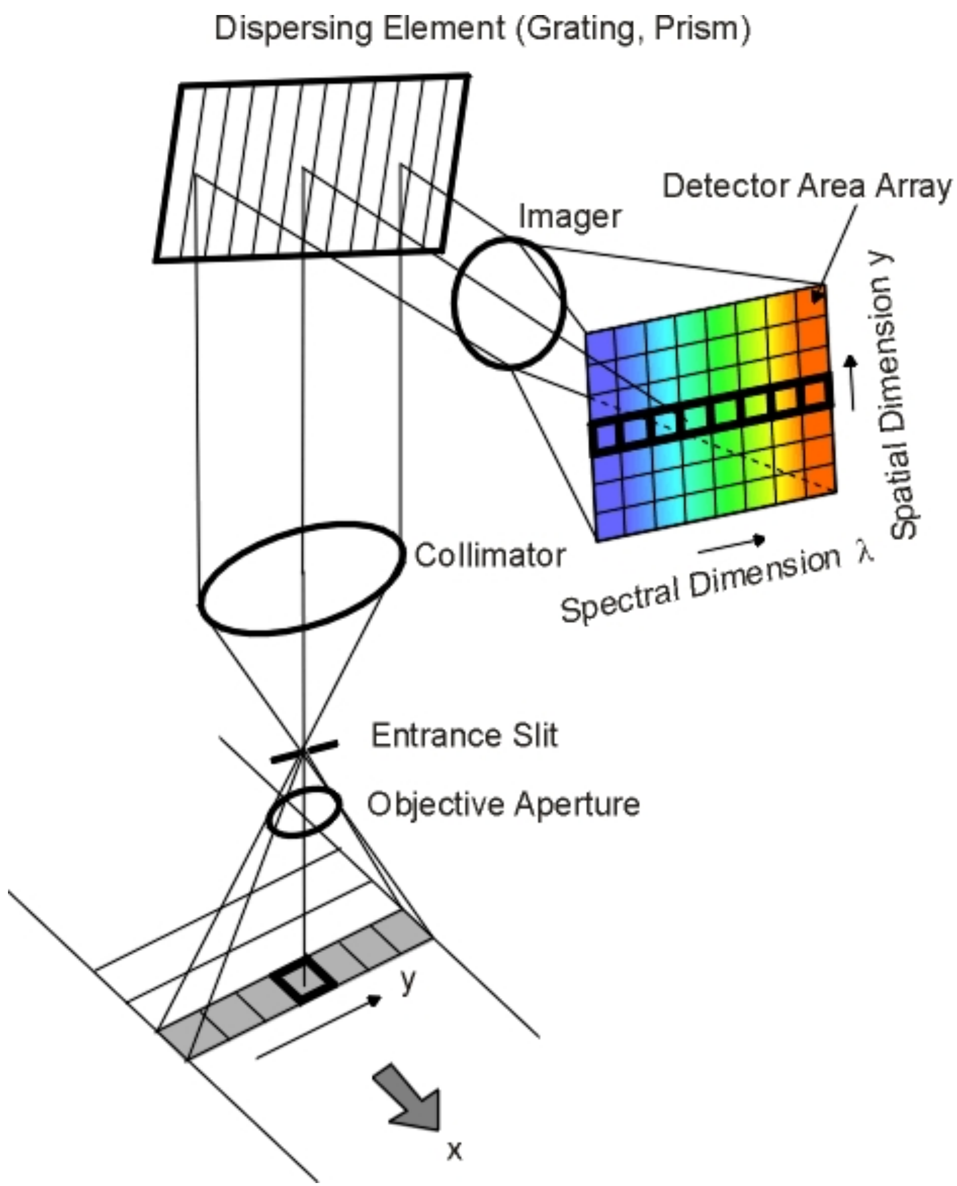
IR (HgCdTe)



3) "Order sorting" filters

Murchie et al. (2007)

Imaging Spectrometers



What if you can only sense/display a few bands?

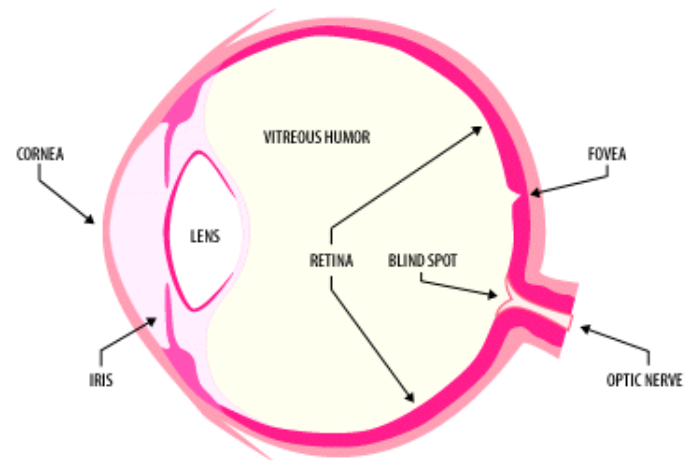
Let's start with how humans sense color:

Cone-shaped cells within the eye absorb light in 3 wavelength ranges – **RGB**

They send signals to the brain proportional to how much light is absorbed

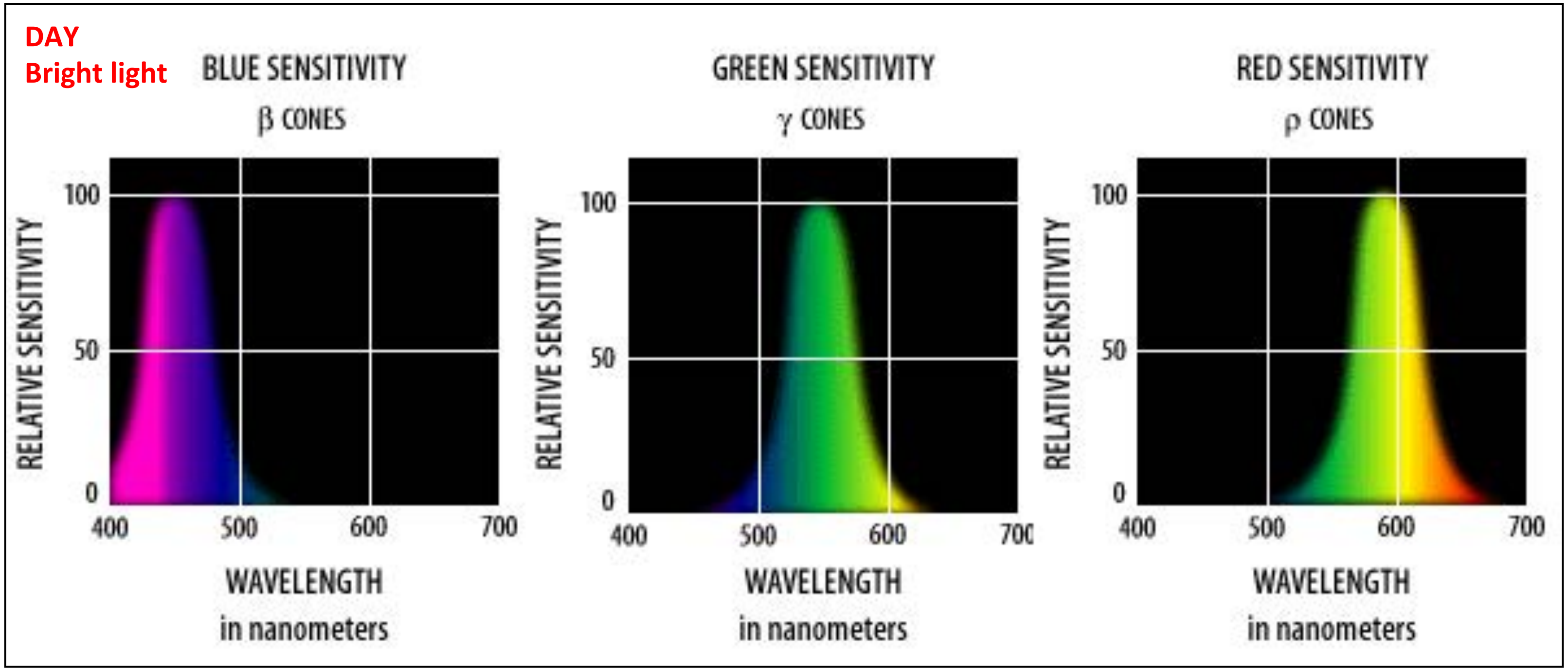
The brain turns these signals into the sensation of color

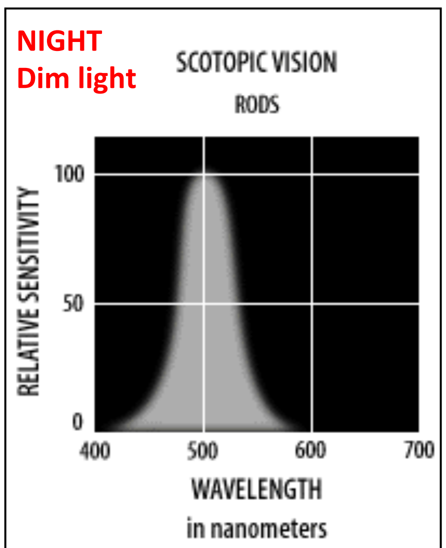
Color has three attributes –
hue, saturation, and intensity or lightness



Section of the eye

color (perception) is related to radiance (physical flux)



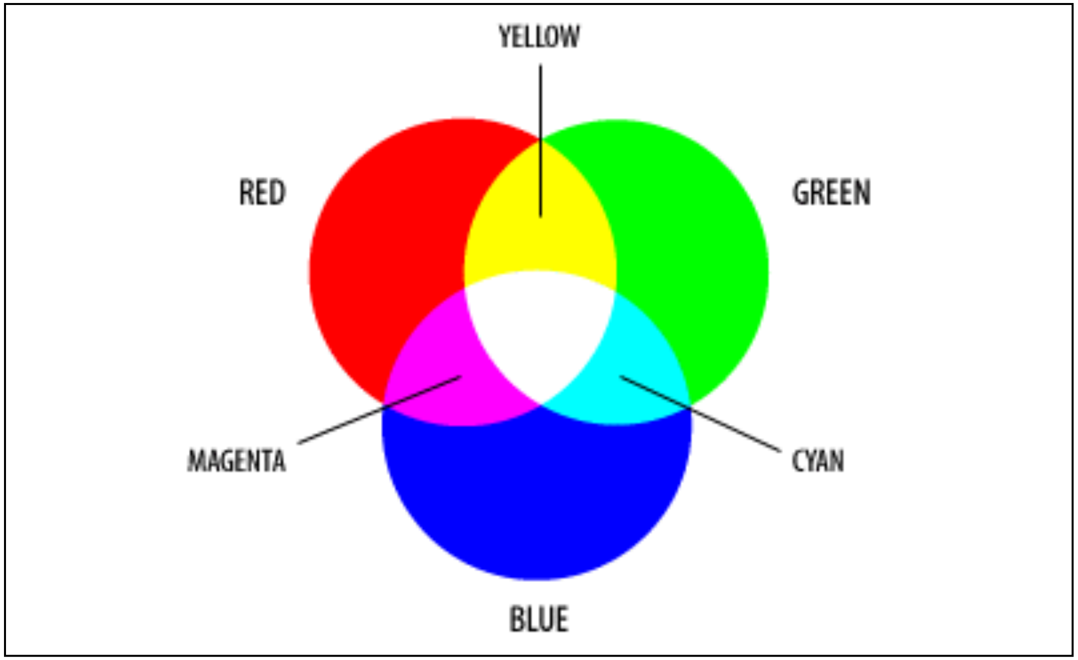


Rods are more sensitive than cones

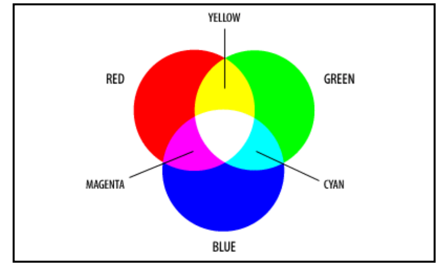
In **bright light**, the three sets of cones send strong signals to the brain that drown out the signal from the rods. The signals are interpreted as the sensation of **color**

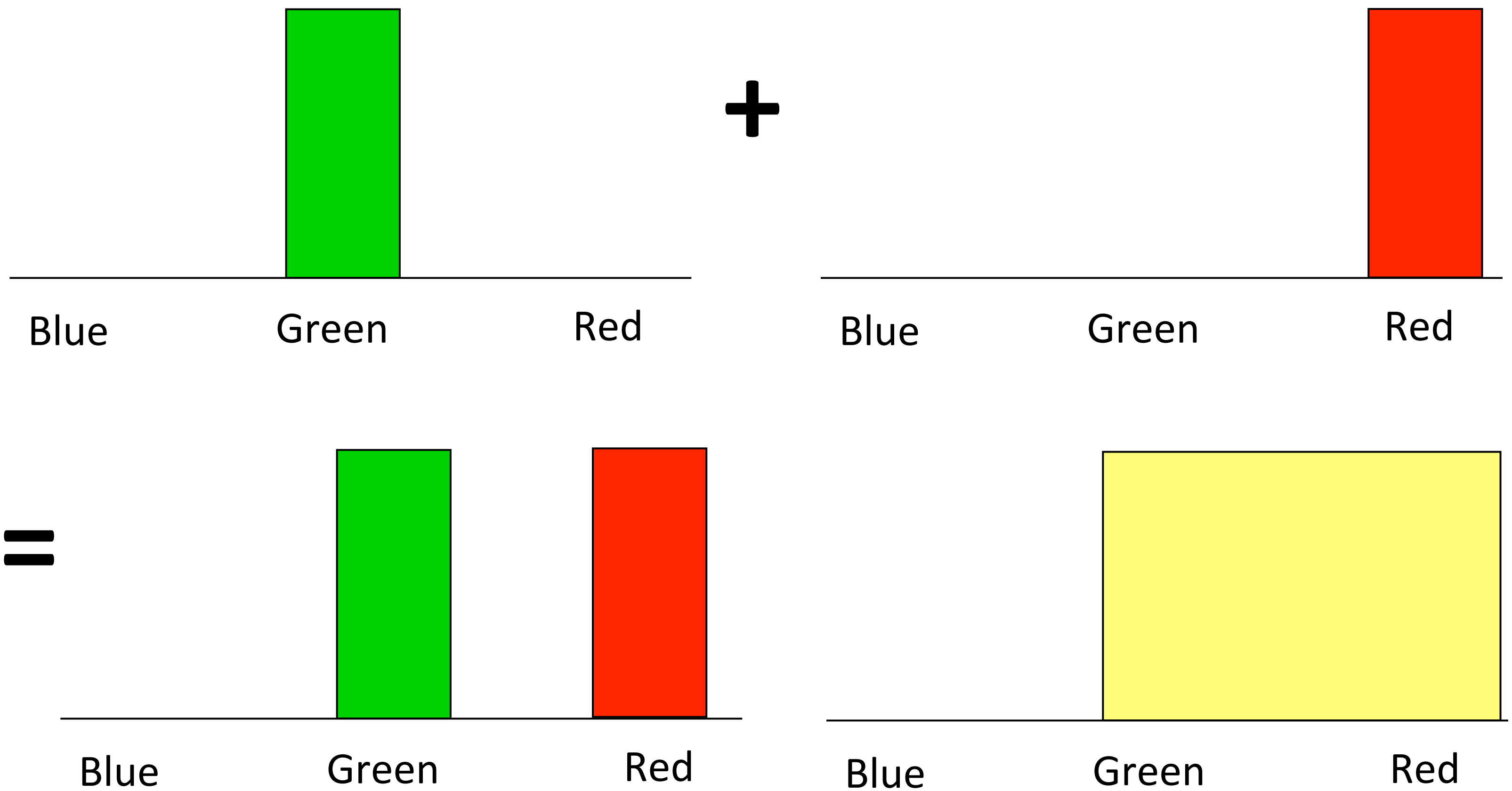
In **dim light**, the signal from the single set of rods is dominant. It is interpreted as the sensation of black/white (**gray**)

Additive Color



Additive Color





We can describe color in different **data "spaces", e.g.:**

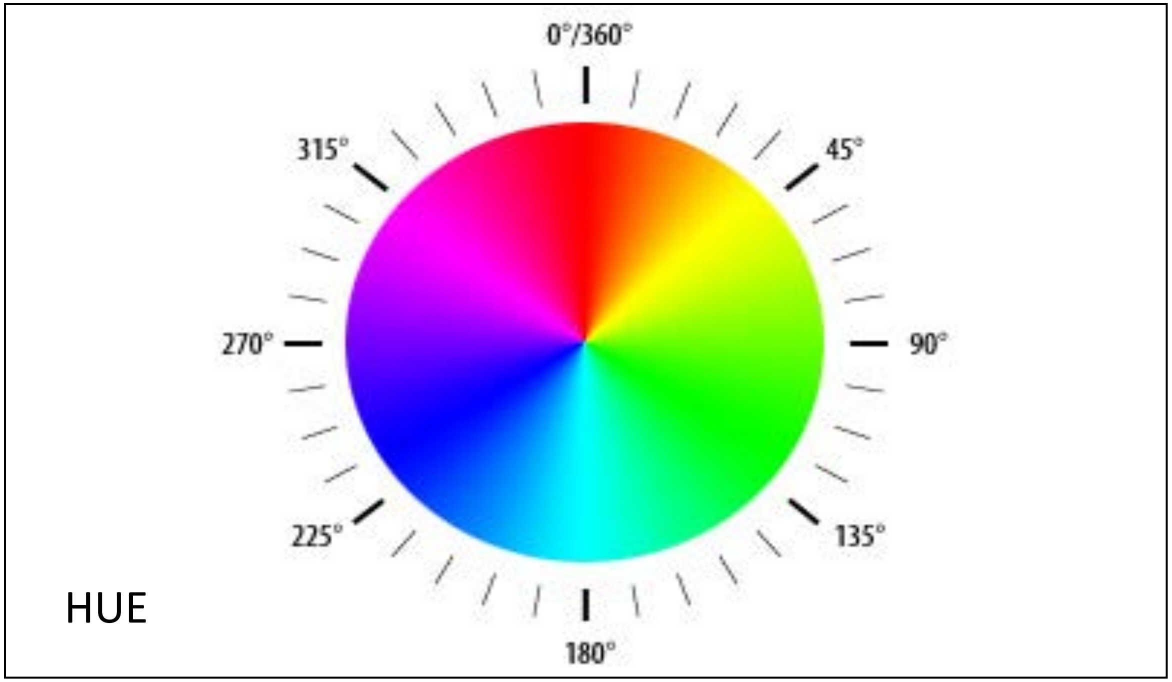
*<u>Perceptual</u> data space

– how we sense color intuitively (Hue, saturation, intensity)

*<u>Radiance</u> data space

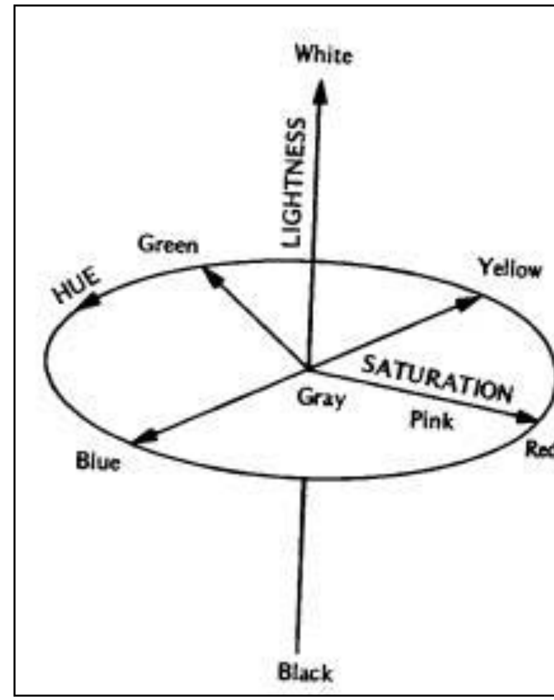
– how the color stimulus is described by the measured image data

1) A simple perceptual color space (HSI)

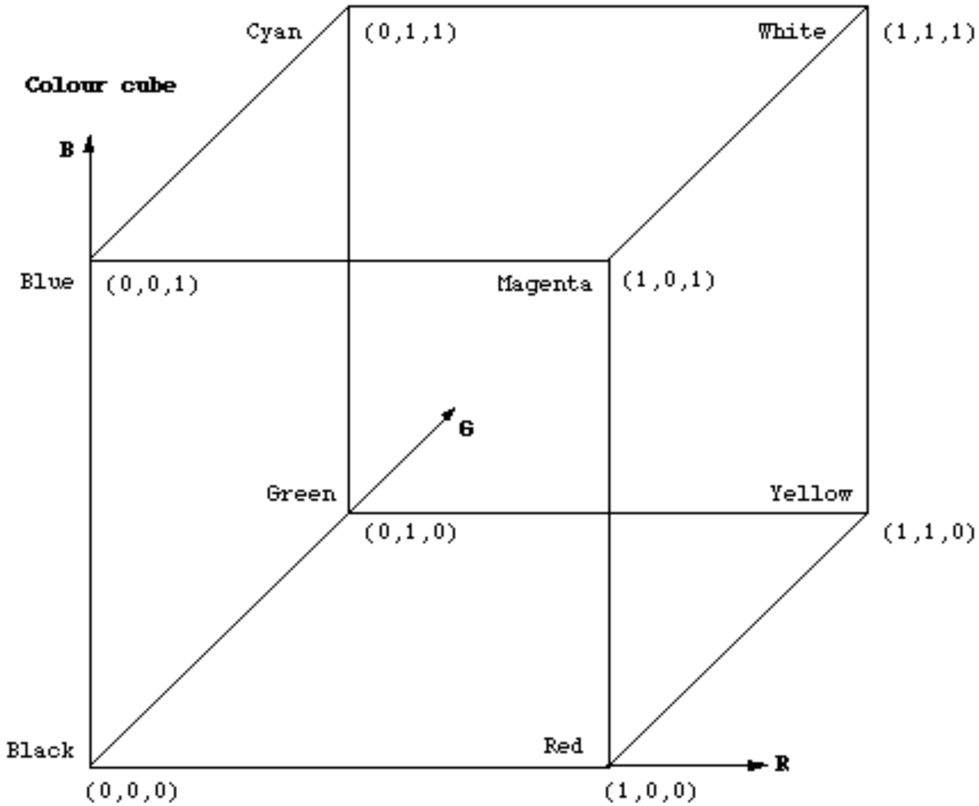


SATURATION

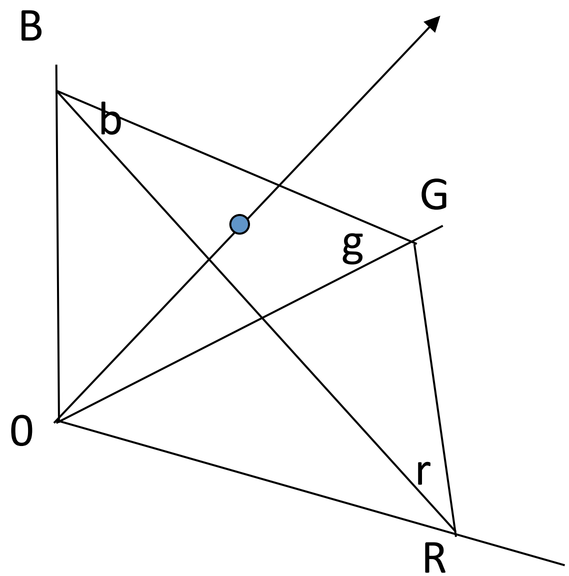
INTENSITY (LIGHTNESS)



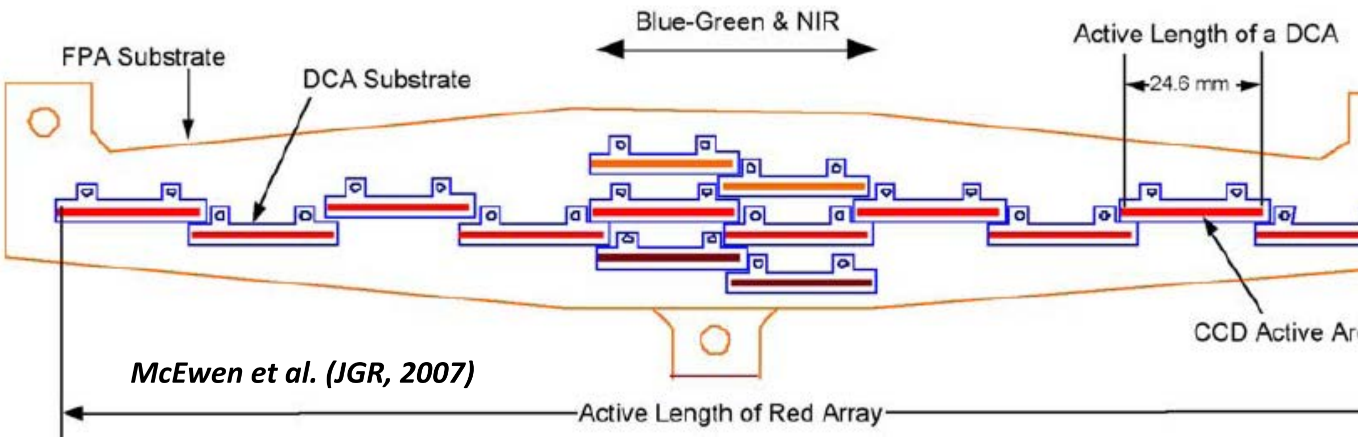
2) RGB radiance space



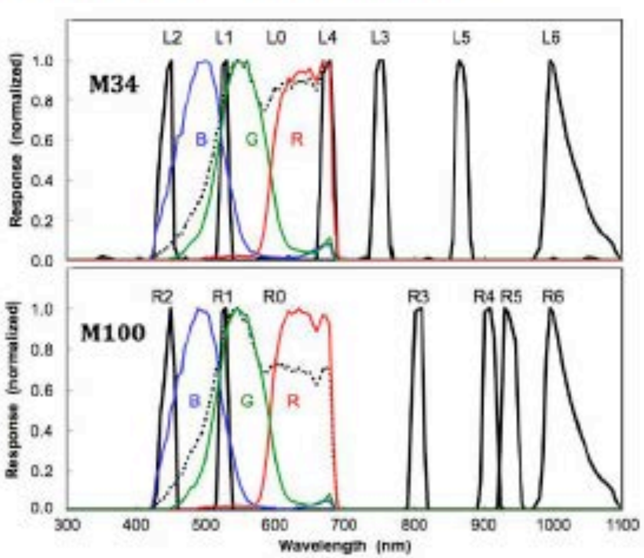
$r=R/(R+G+B)$
$g=G/(R+G+B)$
$b=B/(R+G+B)$



1) Use filters sequentially via spacecraft motion or filter wheel

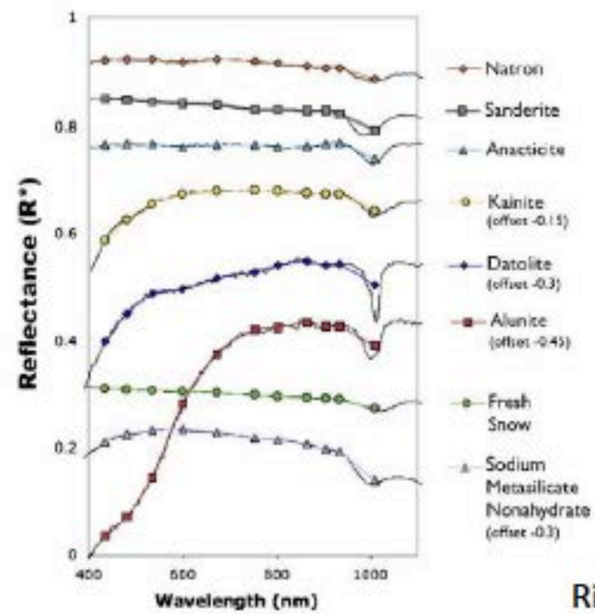


e.g. Mastcam Camera Filters



Bell et al., 2012

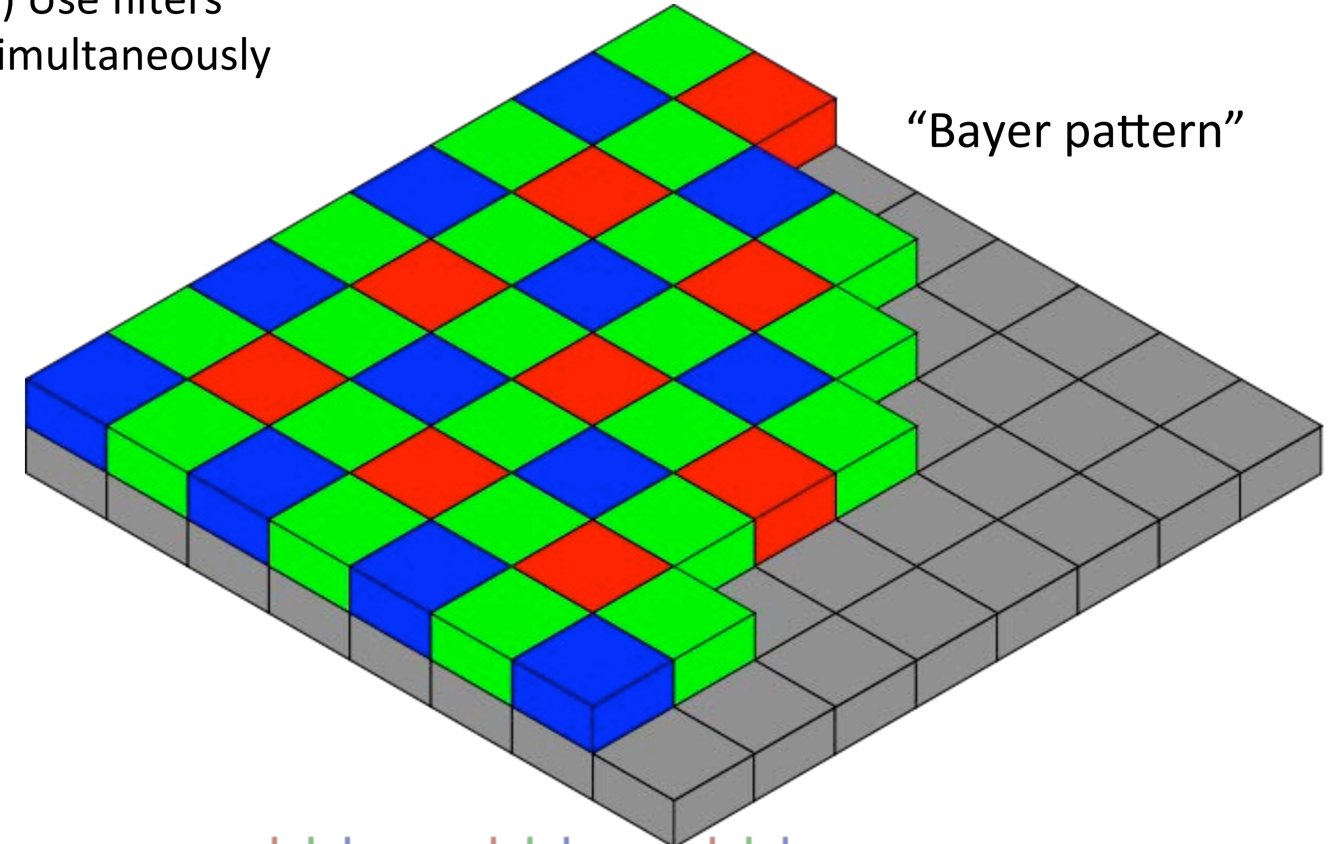
Hyperspectral vs. Multispectral

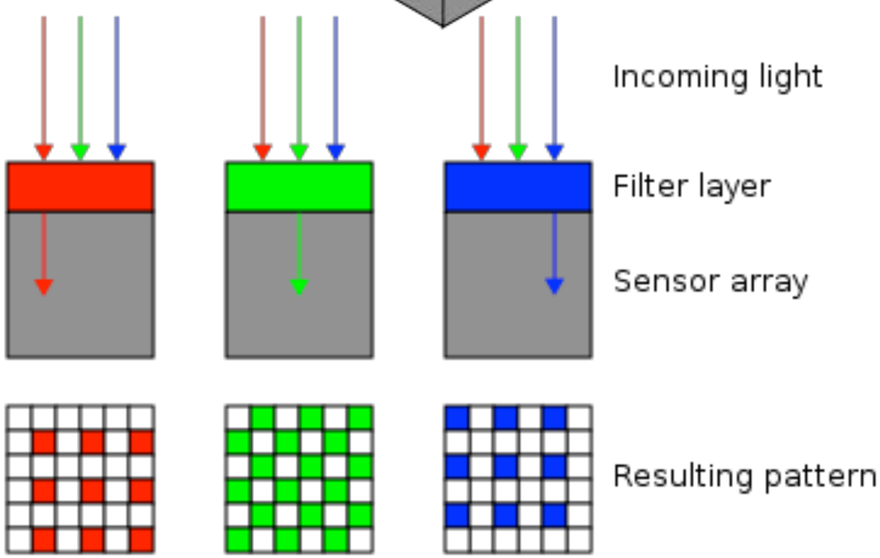


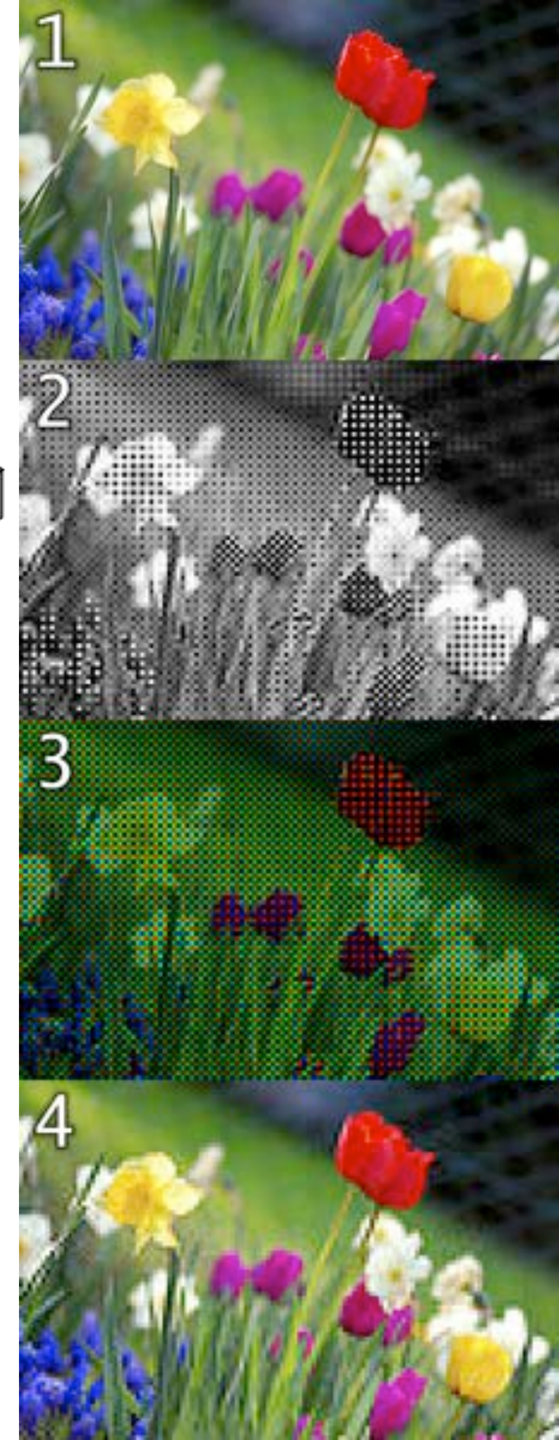
Rice et al., 2010

2) Use filters simultaneously

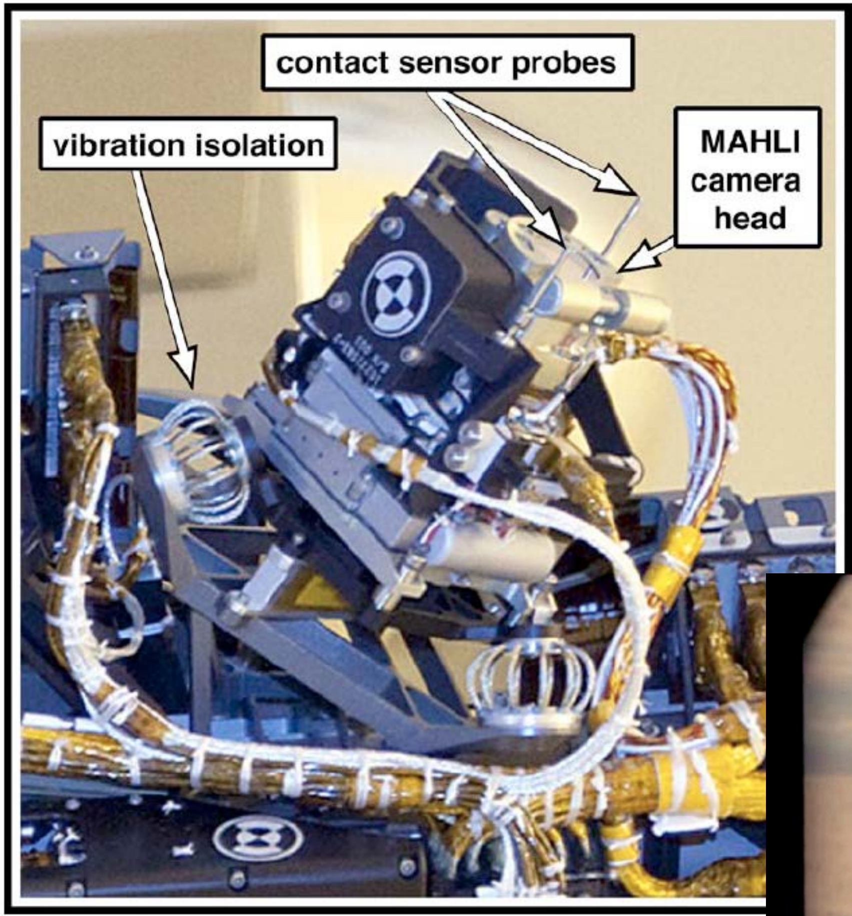
"Bayer pattern"

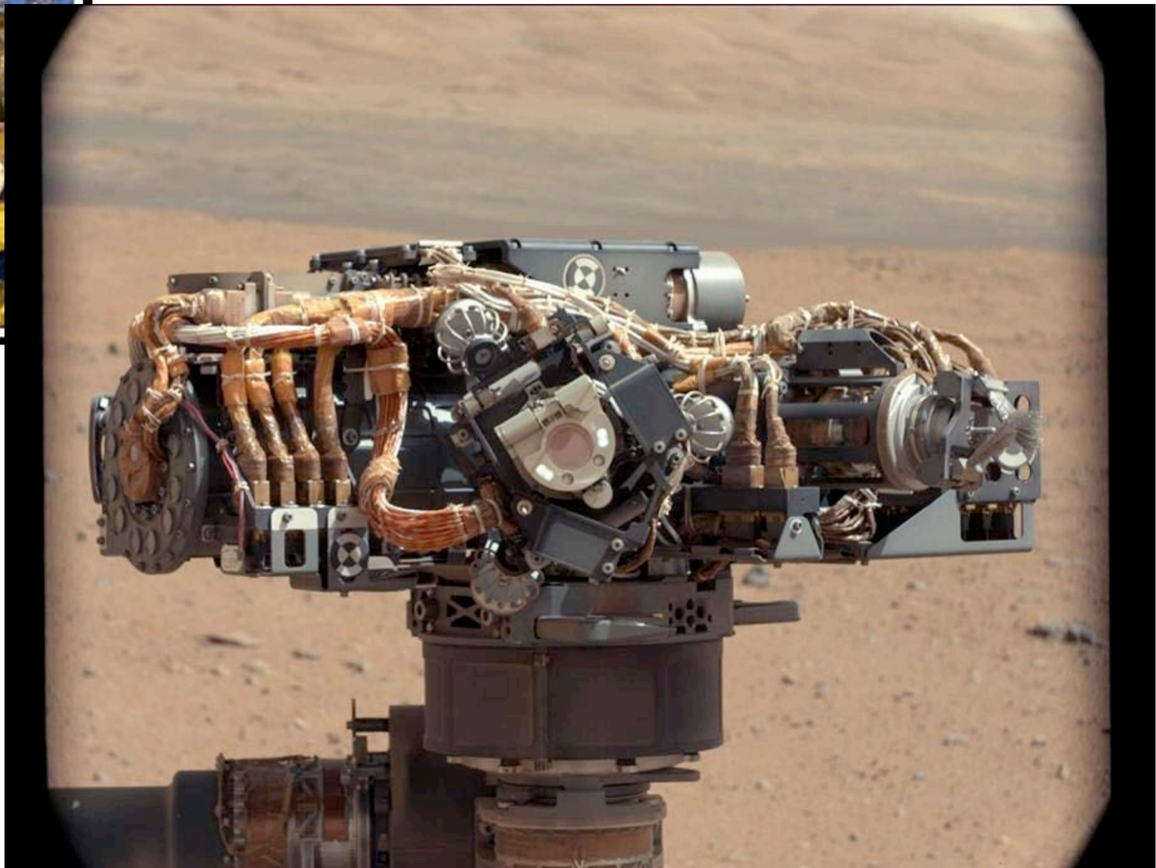




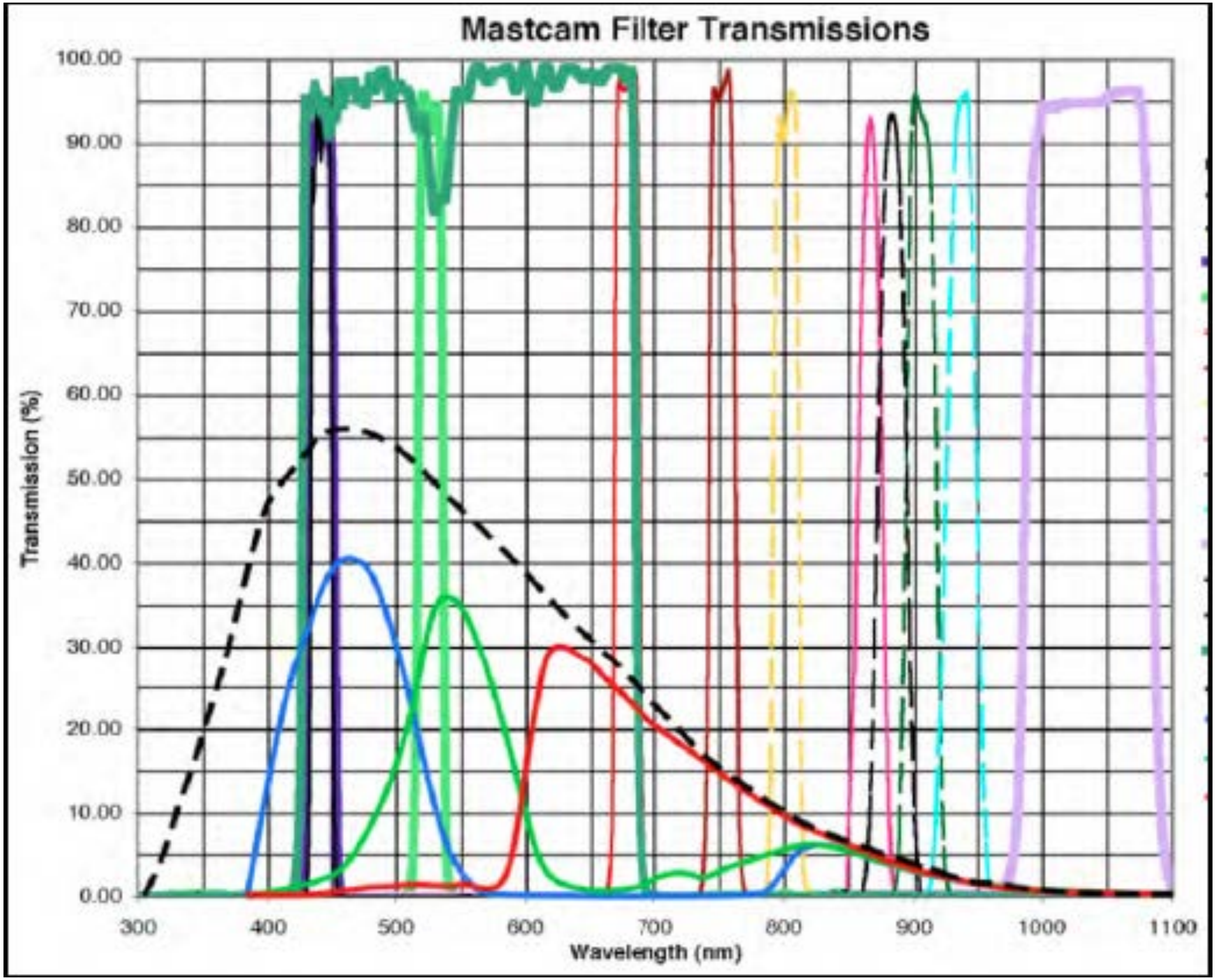


Bayer pattern user: Curiosity's Mars Hand Lens Imager (MAHLI)

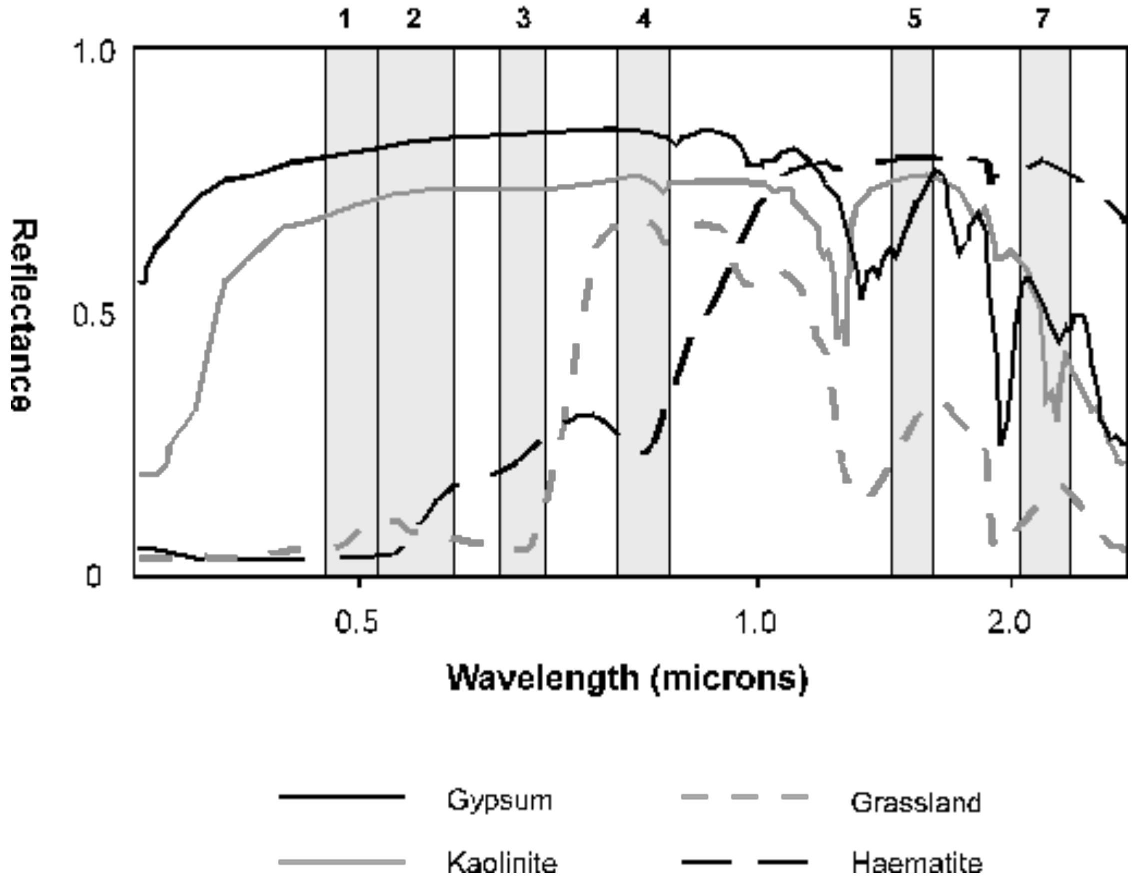




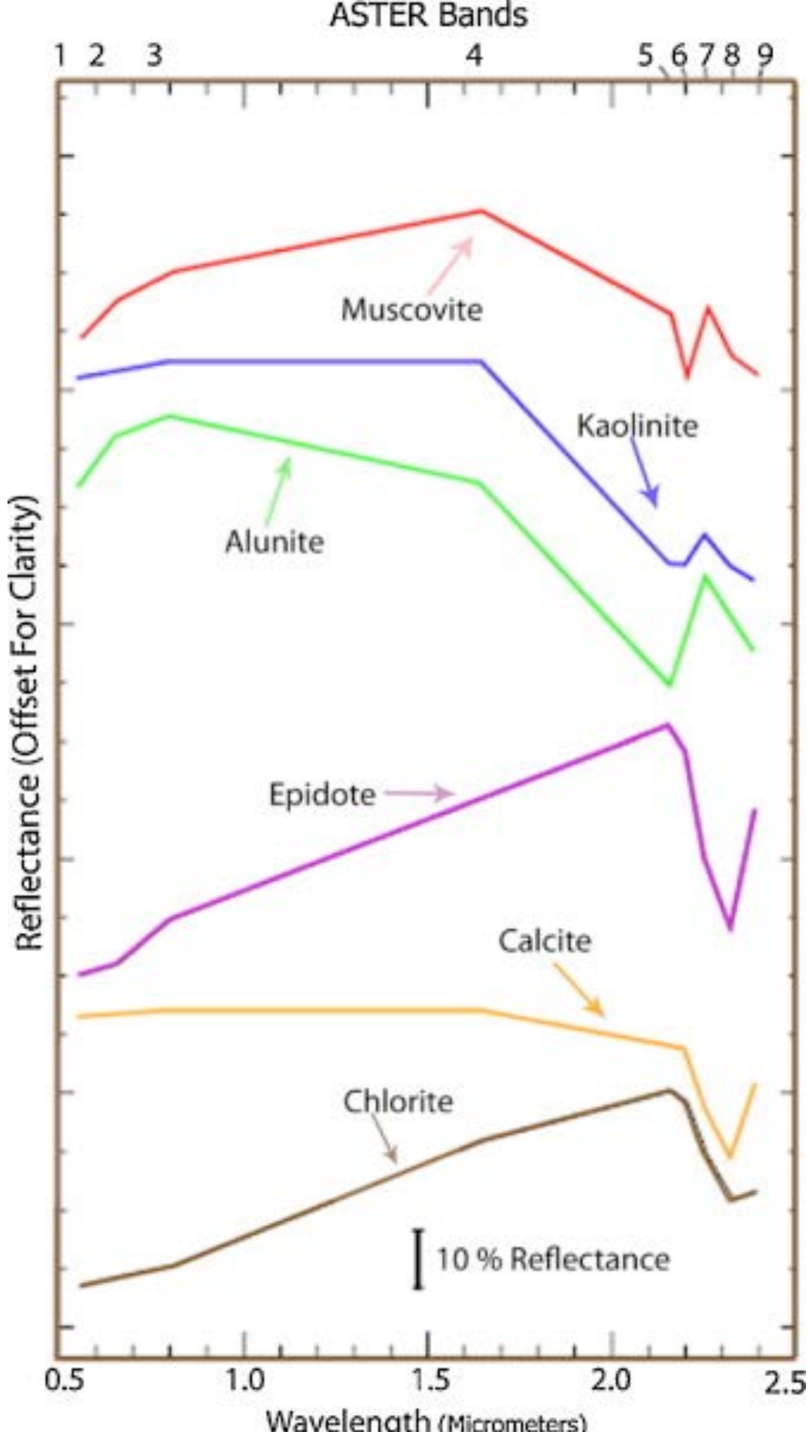
Curiosity's Mastcam: Bayer pattern *and* filter wheel



Landsat Thematic Mapper Bands



Band	Wavelength (μ)	Resolution (m)
1	0.450-0.515 (blue)	30
2	0.525-0.605 (green)	30
3	0.630-0.690 (red)	30
4	0.750-0.900 (near-IR)	30
5	1.55-1.75 (mid-IR)	30
6	10.4-12.5 (thermal-IR)	60
7	2.08-2.35 (long-IR)	30
Panchromatic	0.52-0.90 (green-near IR)	15



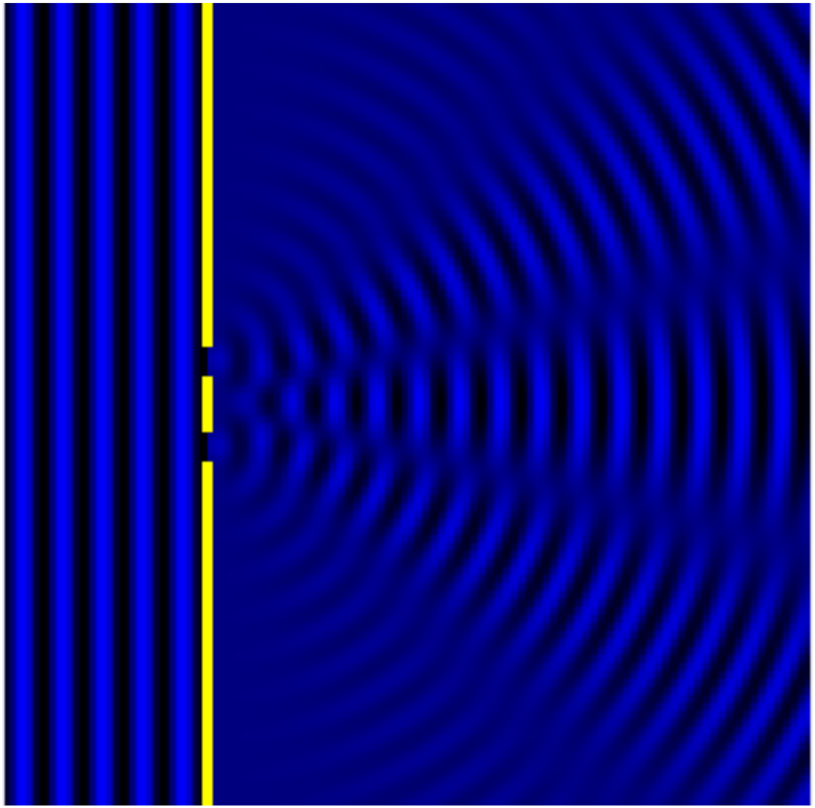
ASTER on board Terra: closely spaced SWIR filters to discriminate OH-bearing minerals

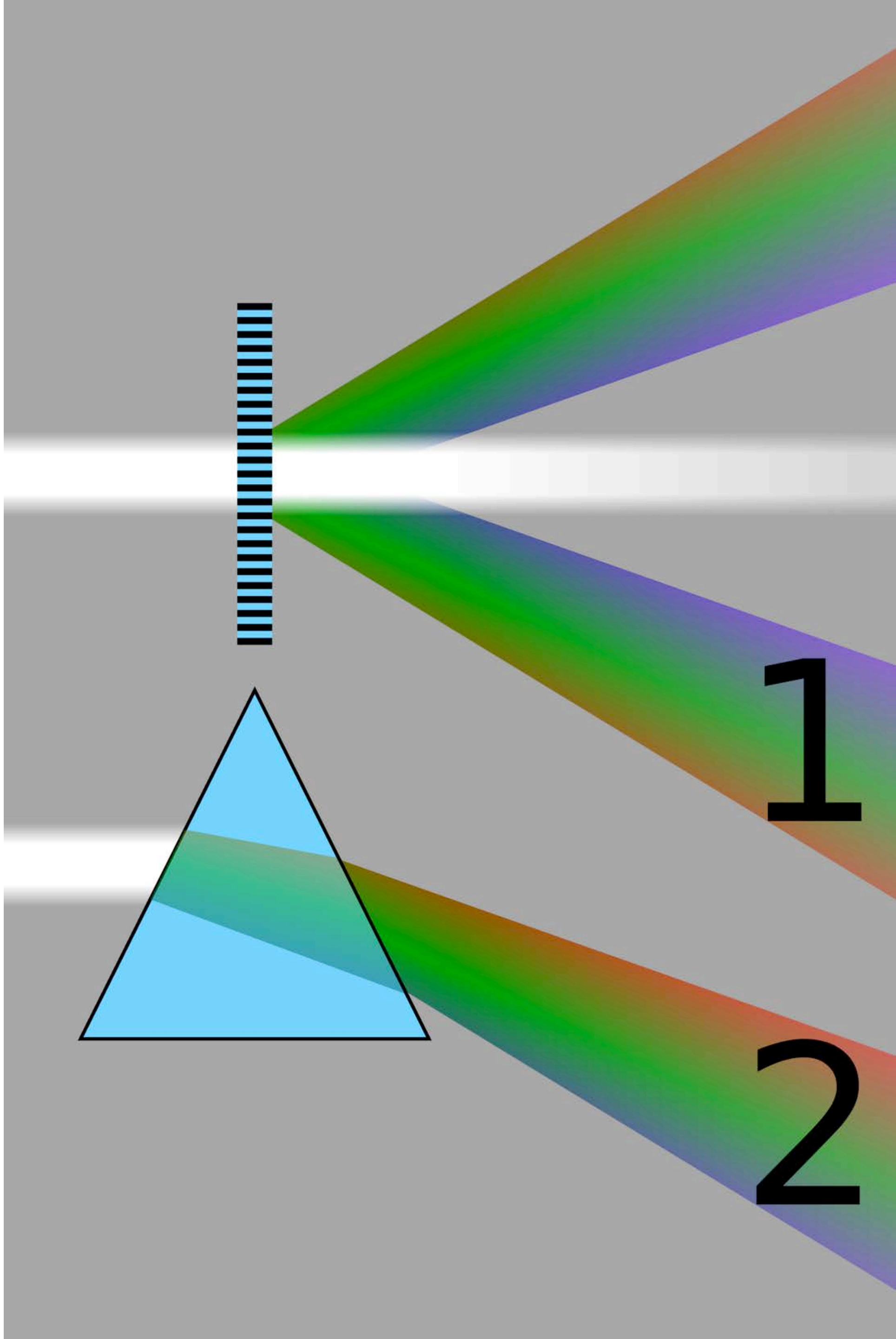
Band	Label	Wavelength (µm)	Resolution (m)	Nadir or Backward	Description
B1	VNIR_Band1	0.520–0.600	15	Nadir	Visible green/yellow
B2	VNIR_Band2	0.630–0.690	15	Nadir	Visible red
B3	VNIR_Band3N	0.760–0.860	15	Nadir	Near infrared
B4	VNIR_Band3B	0.760–0.860	15	Backward	
B5	SWIR_Band4	1.600–1.700	30	Nadir	Short-wave infrared
B6	SWIR_Band5	2.145–2.185	30	Nadir	
B7	SWIR_Band6	2.185–2.225	30	Nadir	
B8	SWIR_Band7	2.235–2.285	30	Nadir	
B9	SWIR_Band8	2.295–2.365	30	Nadir	
B10	SWIR_Band9	2.360–2.430	30	Nadir	
B11	TIR_Band10	8.125–8.475	90	Nadir	Long-wave infrared or thermal IR
B12	TIR_Band11	8.475–8.825	90	Nadir	
B13	TIR_Band12	8.925–9.275	90	Nadir	
B14	TIR_Band13	10.250–10.950	90	Nadir	
B15	TIR_Band14	10.950–11.650	90	Nadir	

Diffraction gratings

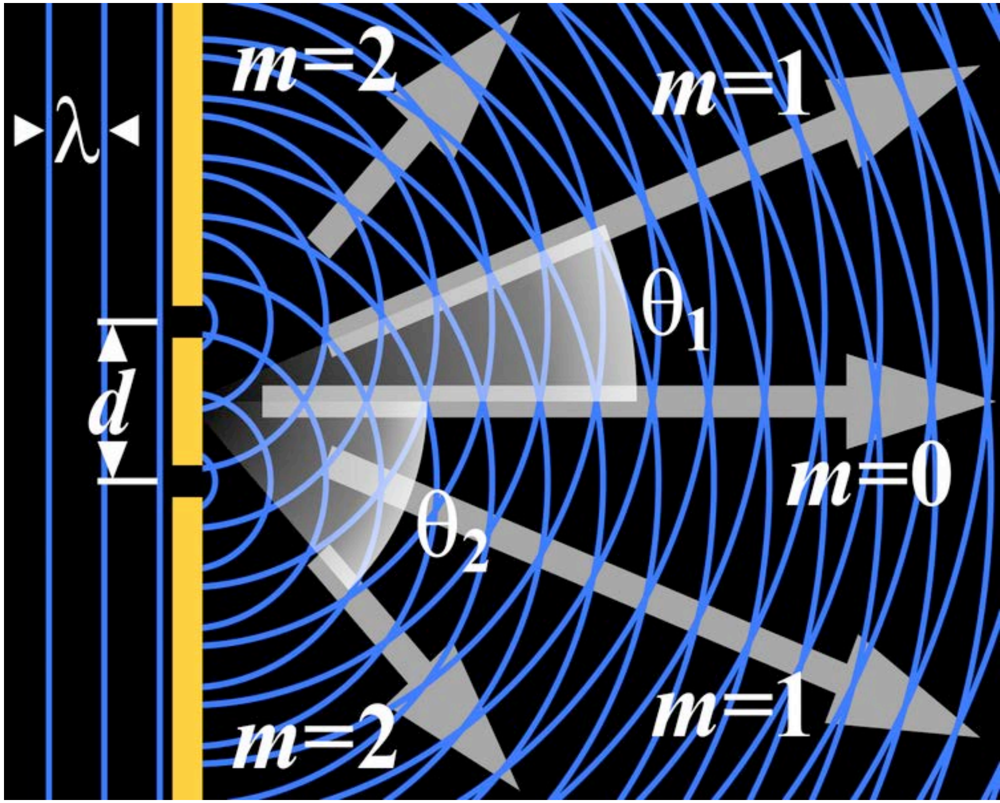
e.g., CDs and DVDs

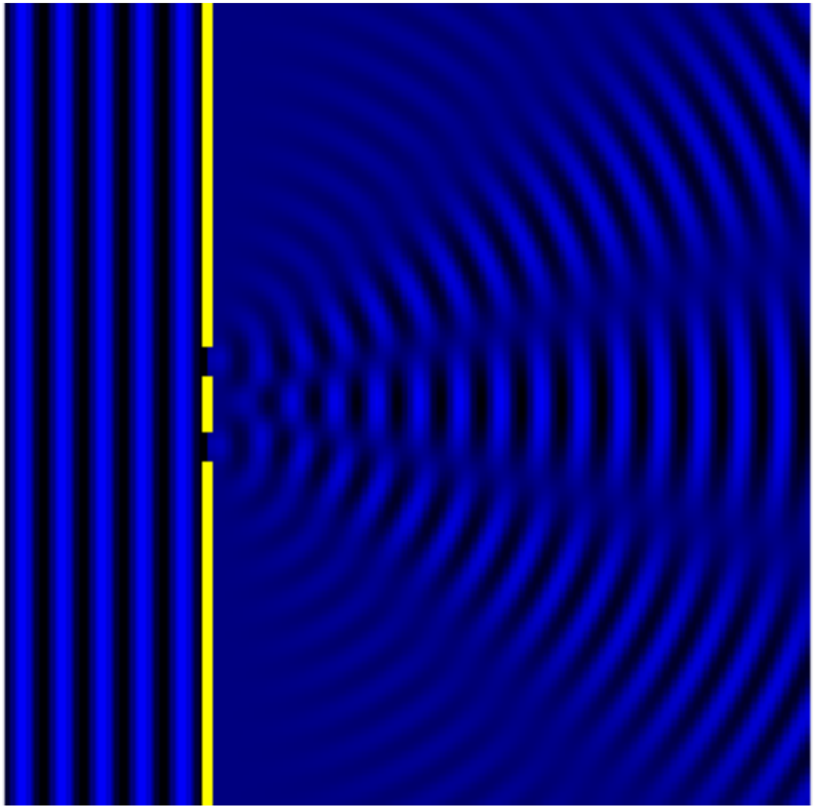
(Also AVIRIS, PSR-3500,
most planetary reflectance spectrometers)





Diffraction gratings

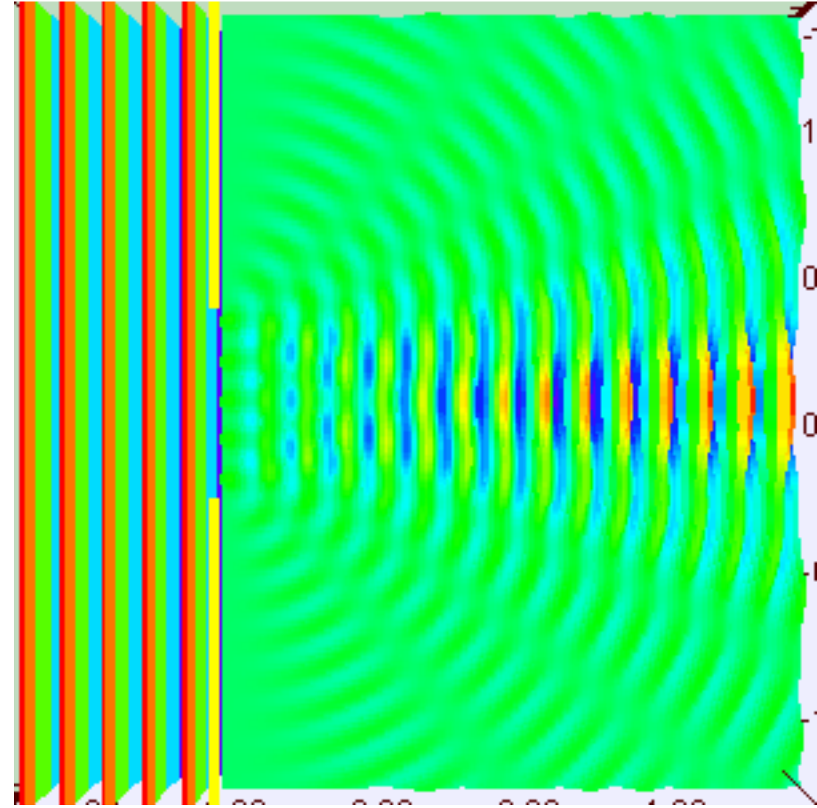


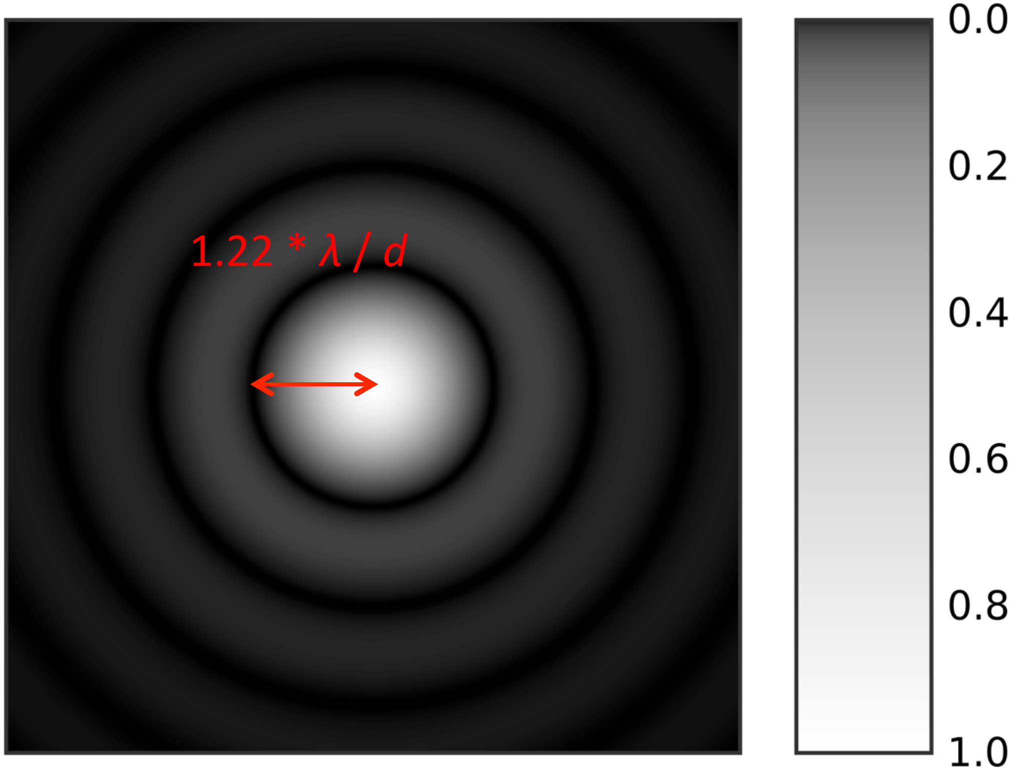


Constructive interference where:
$\sin\theta = m^*\lambda\ /\ d$

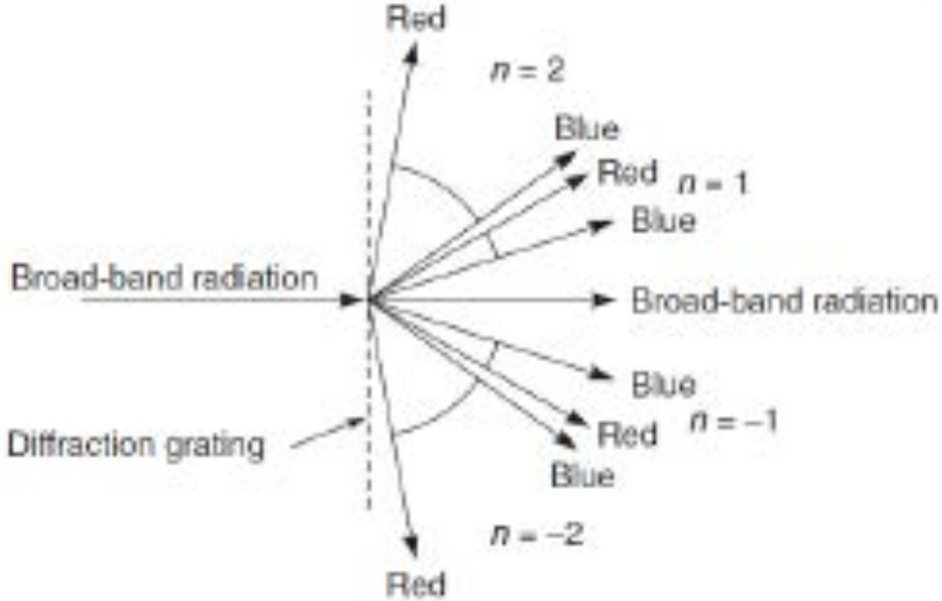
(If $d > \lambda$)

Single-slit diffraction





$$\sin\theta = \frac{n\lambda}{d}$$



Gratings allow hyperspectral wavelength spacing. But beware of "parasitic" light contributions from higher orders to a given channel

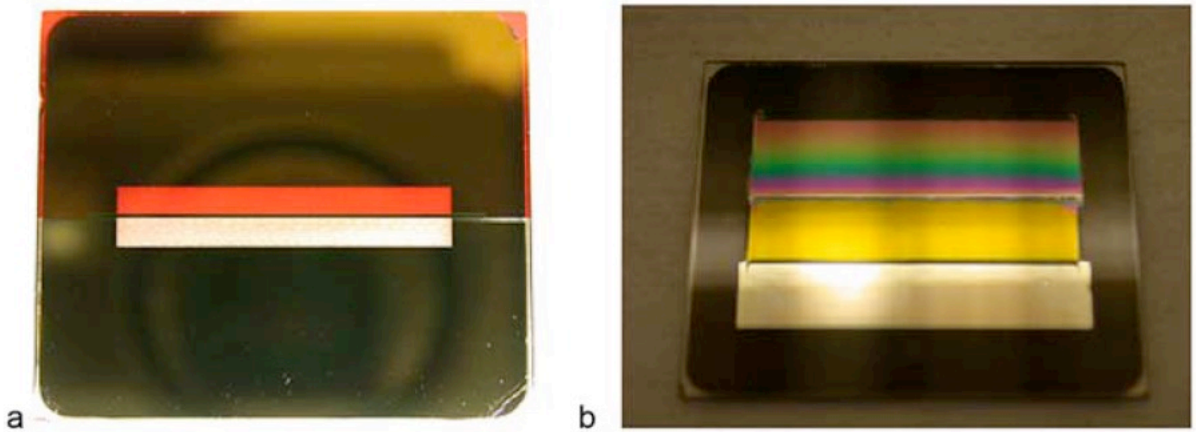
Figure 6.8. Dispersion of broad-band radiation by a diffraction grating. The values of n are the orders of the spectra.

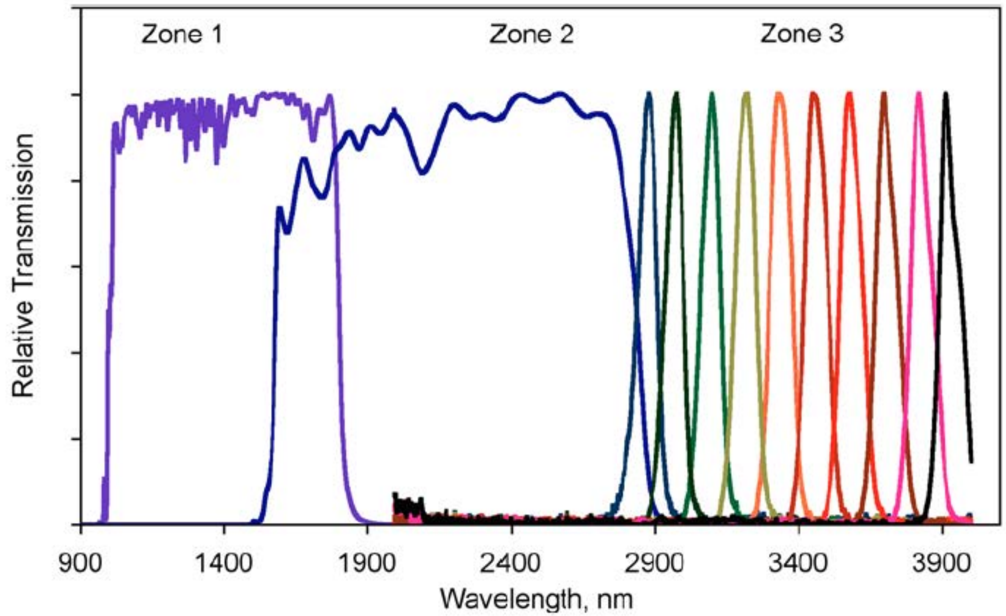
CRISM
Compact Reconnaissance Imaging Spectrometer for Mars

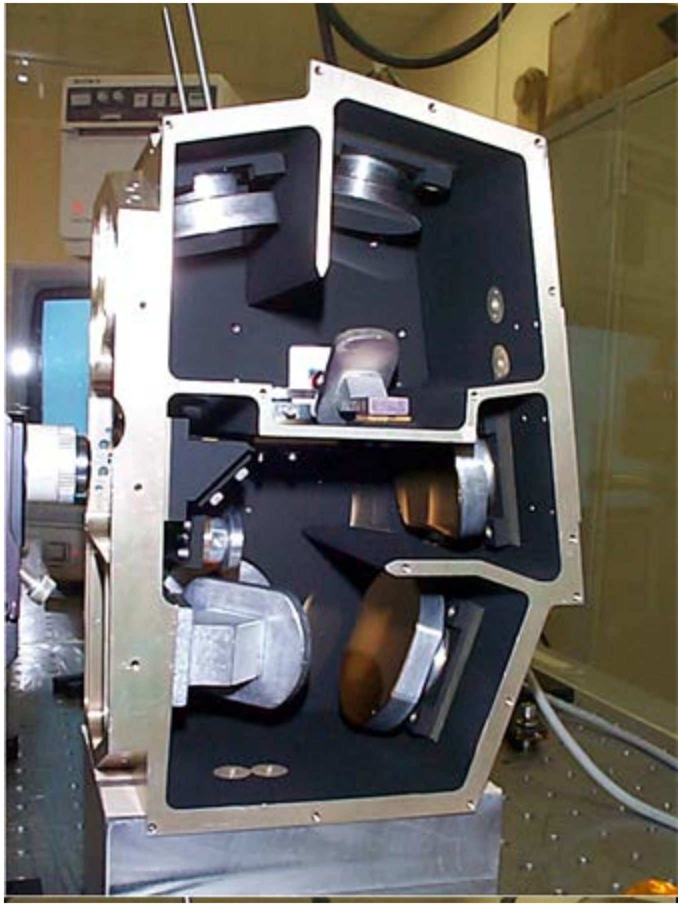
Grating, plus "order-sorting filters" on detector

VNIR (Si)

IR (HgCdTe)







Murchie et al. (JGR, 2007)