Understanding Astronomical Filters

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Overview

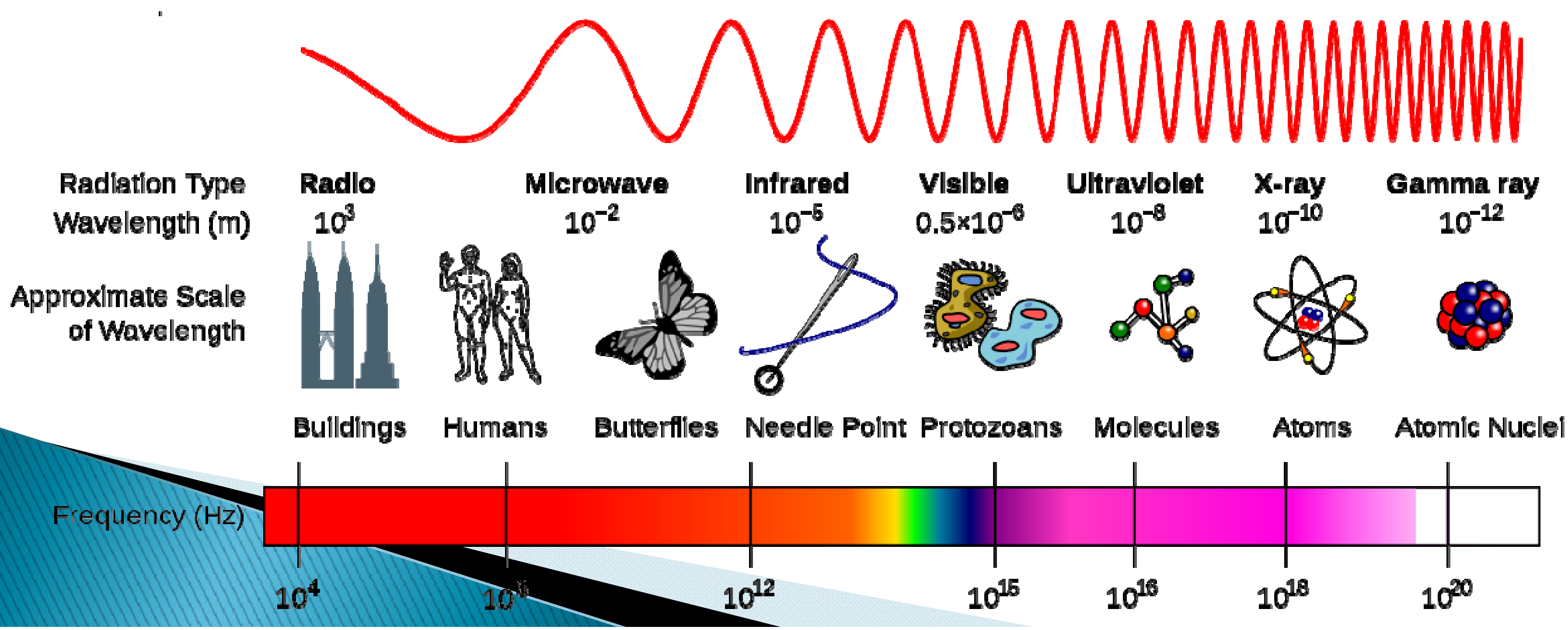
- What are we looking at & how

- Introduction to filters
  - Different types
  - How they work
  - Nomenclature

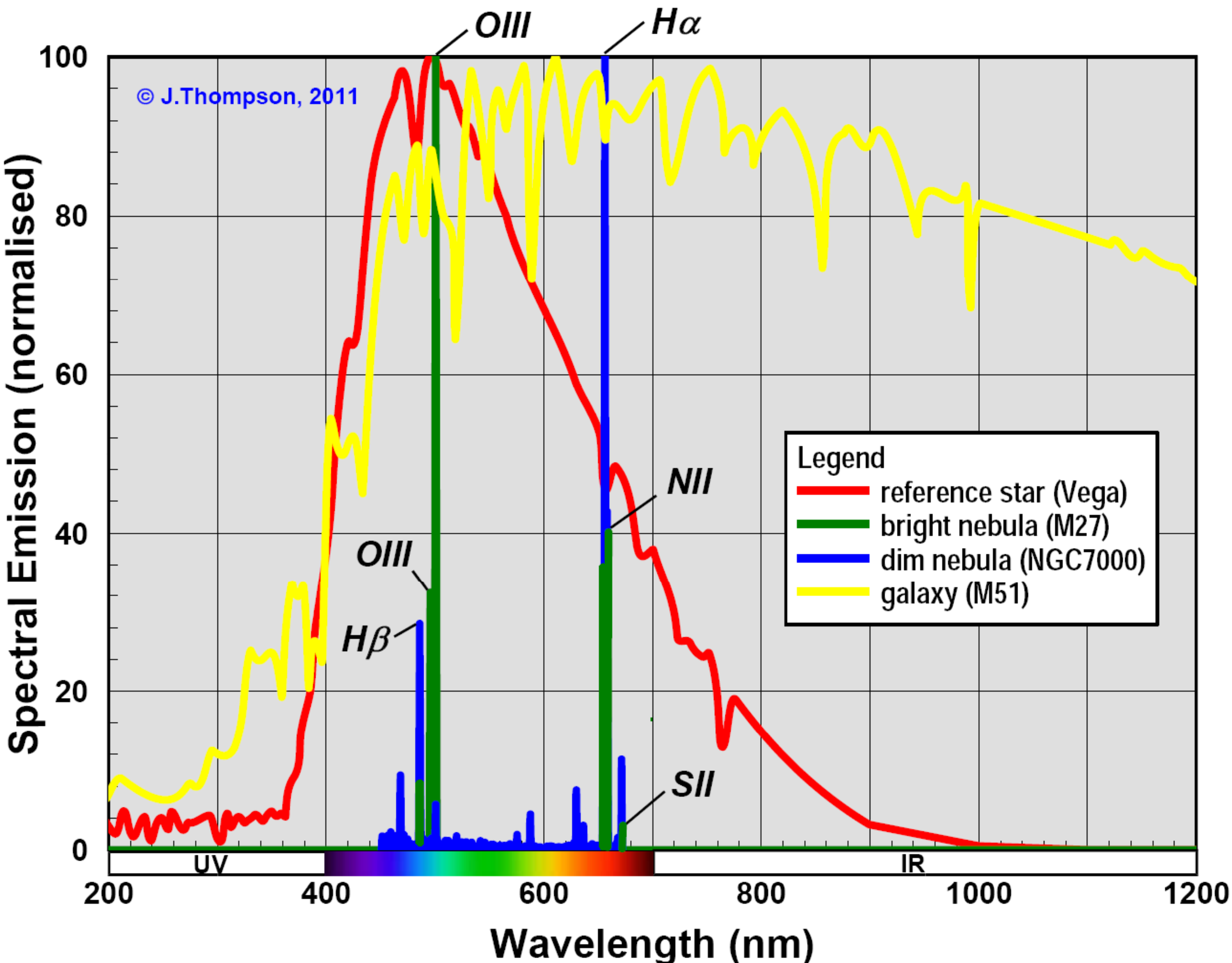
- Uses of filters in amateur astronomy
  - Enhancing solar system observing
  - Controlling light pollution
  - Suggestions & things to remember

What are we looking at?

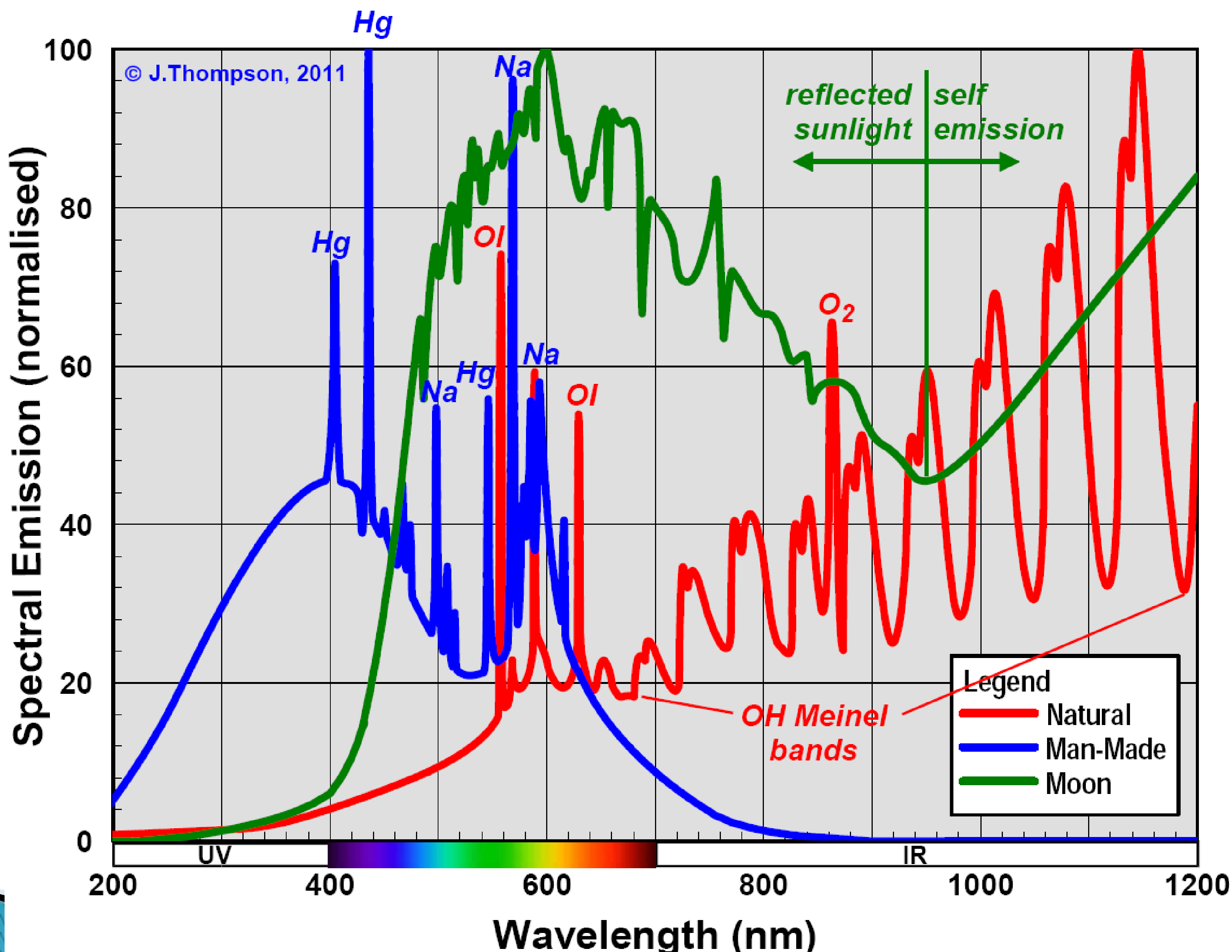
- Amateur astronomers use only small slice of Electro-Magnetic spectrum
- No inherent colour in nature, only photons of different energy levels (wavelengths)
- Our brain (eye) or electronics (CCD) interprets different wavelengths as colours



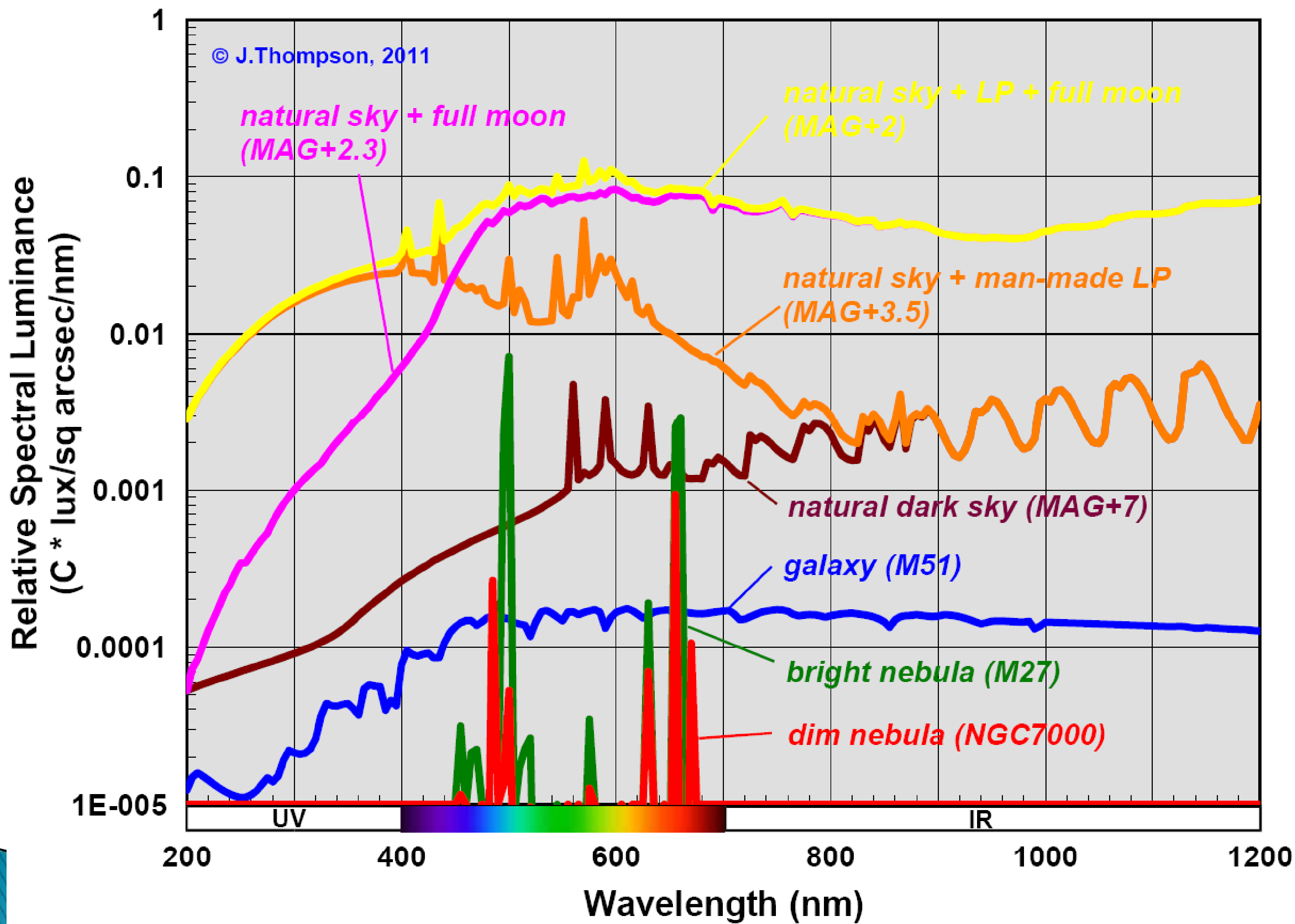
Night sky is full of "colours"



…Including some we don't want



Altogether now…



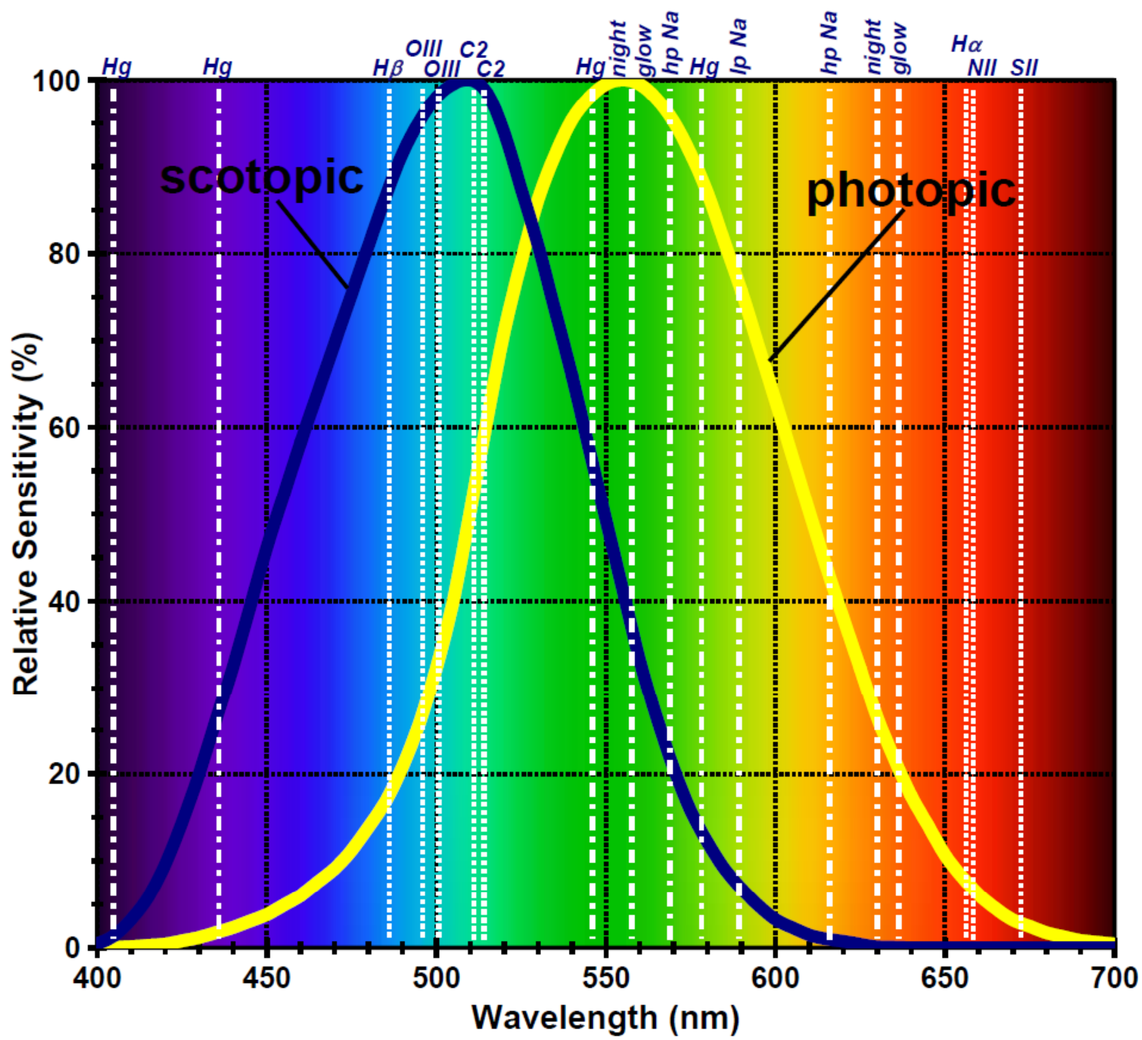
Your eye as a detector

- Billions yrs of evolution = eyes that see 400-700nm portion of EM spectrum
- Not by accident – Sun's energy that makes it to Earth's surface centered around visible & NIR band
- Eye + visual cortex = powerful optical data gathering & processing machine

…but how is it for astronomy?

Human eye spectral response

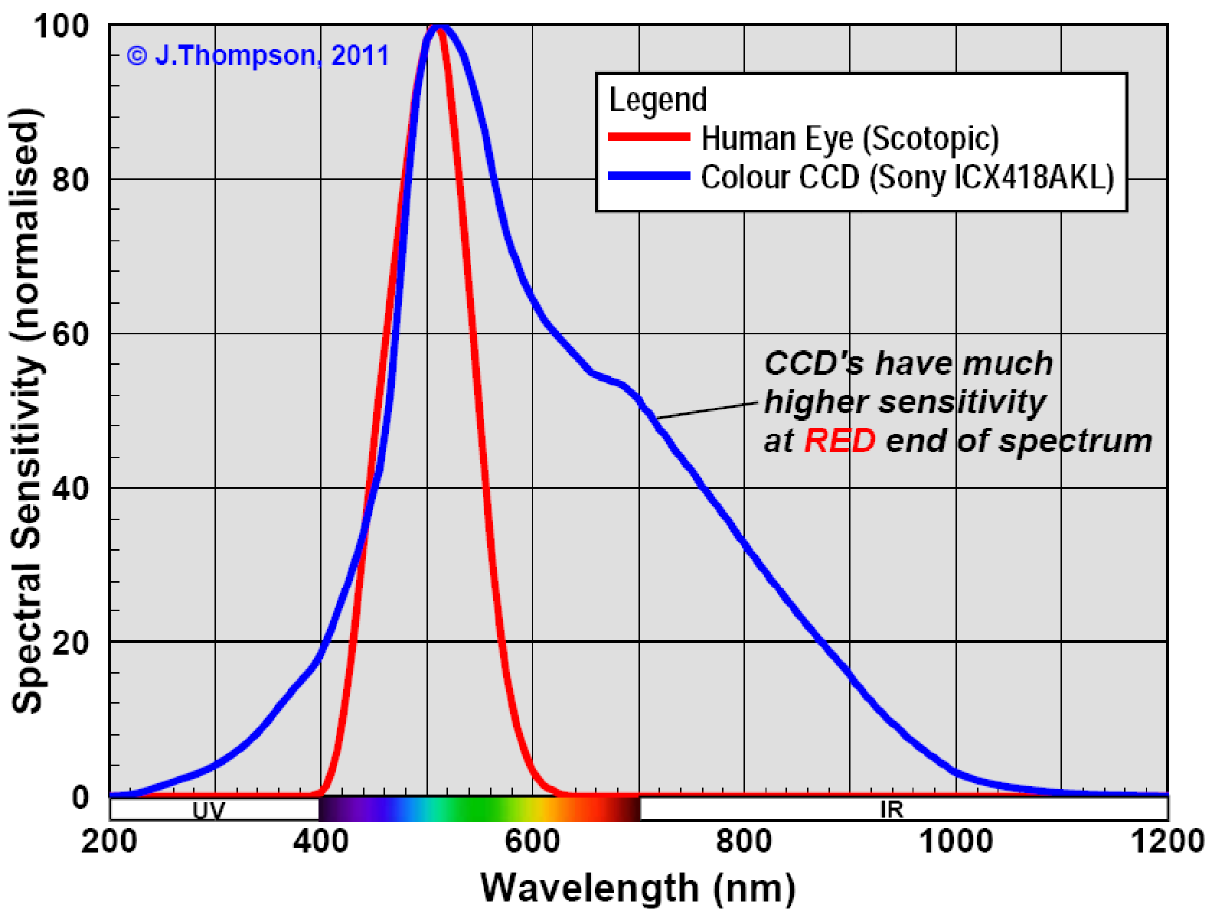
- Eye optimized for "eat or be eaten" world that is illuminated by the Sun



+ large dynamic range
- no "colour" if dark
- limit to sensitivity
- narrow overall spectral range

Colour CCD spectral response

- commercial CCD's have wider response, but still designed as surrogate for human eye – produce "pleasing" image
  - smaller dynamic range
  + >> response to red and NIR
  + >> sensitive than human eye
  + net result: more red + more sensitivity = awesome!



Astronomical Filters

- Piece of glass designed to make what we don't want to see darker

- Makes what we want to see easier to see (<u>but not brighter</u>)

Planetary (Colour)

Deepsky (Interference)*

* also known as: nebula filters or light pollution filters

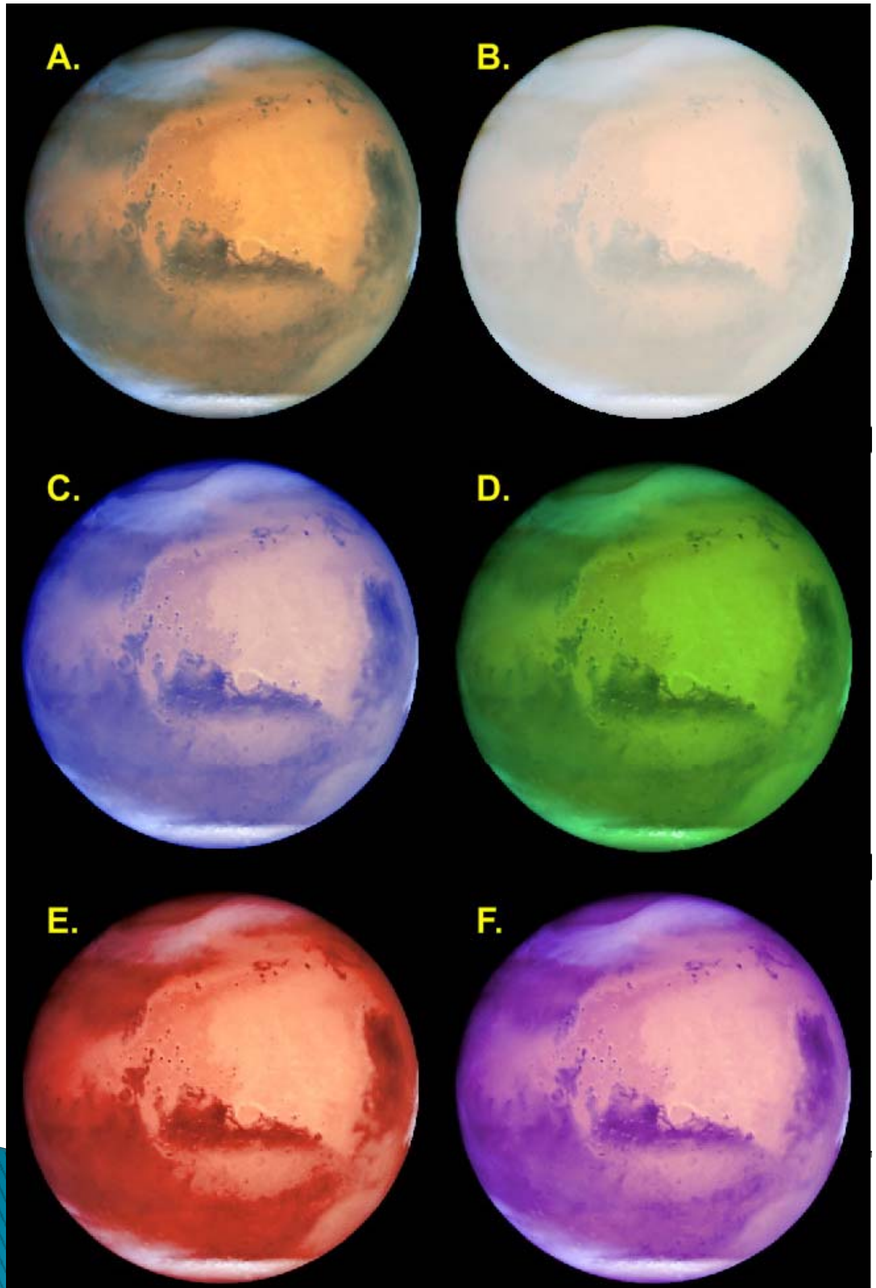
Special Filters

- Some special interference type filters also exist for:
  - Planetary observing
  - Chromatic aberration correction
  - Solar observing

- Let's ignore for now

Special Filters

Example Application – Planets



simulated images

A. from orbit
B. from Earth
C. add Blue filter
D. add Green filter
E. add Red filter
F. add Magenta filter

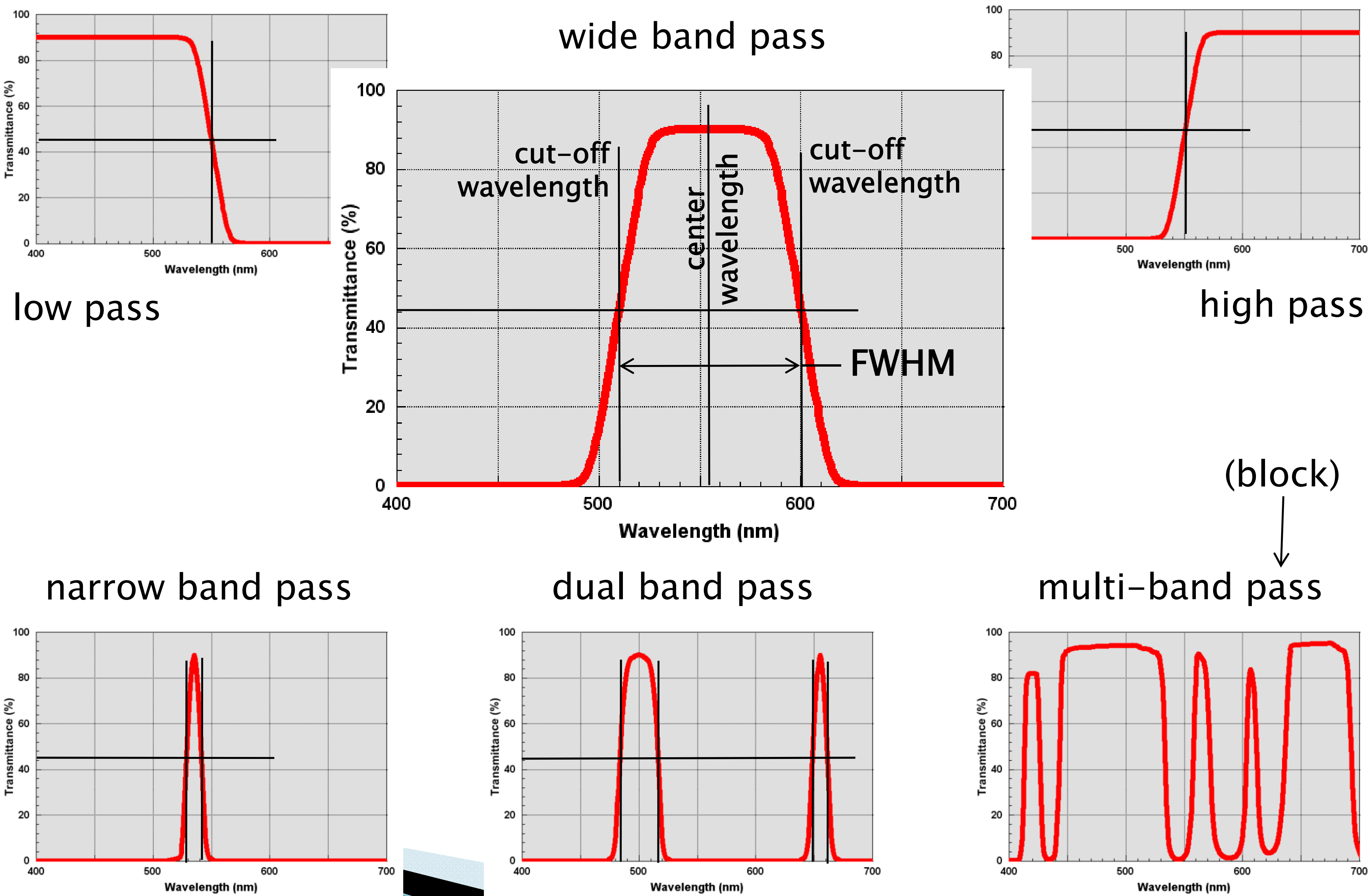
Planetary (Colour)

Example Application – Nebulae

Deepsky (Interference)

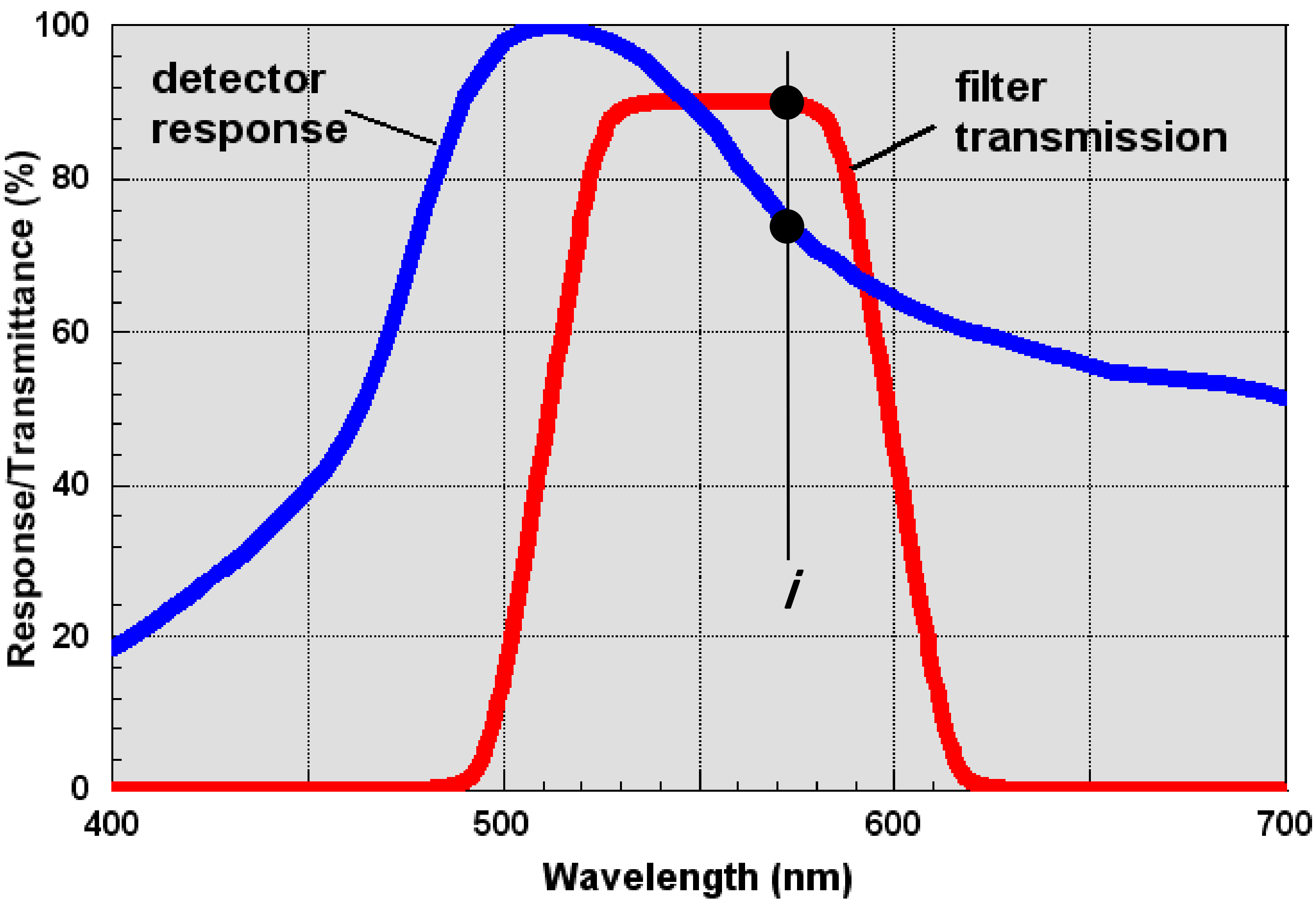
actual images

Filter response nomenclature



Luminous Transmissivity (%LT)

- A measure of how "dark" a filter is (how much light it blocks), with 100% = clear
- Calculated based on response of detector
- Most often quoted assuming daytime use!



- Average brightness weighted by detector sensitivity

$$\%LT = \frac{avg(\%DR_i * \%FT_i)}{avg(\%DR_i)}$$

, where $i = \lambda 1$ to $\lambda 2$

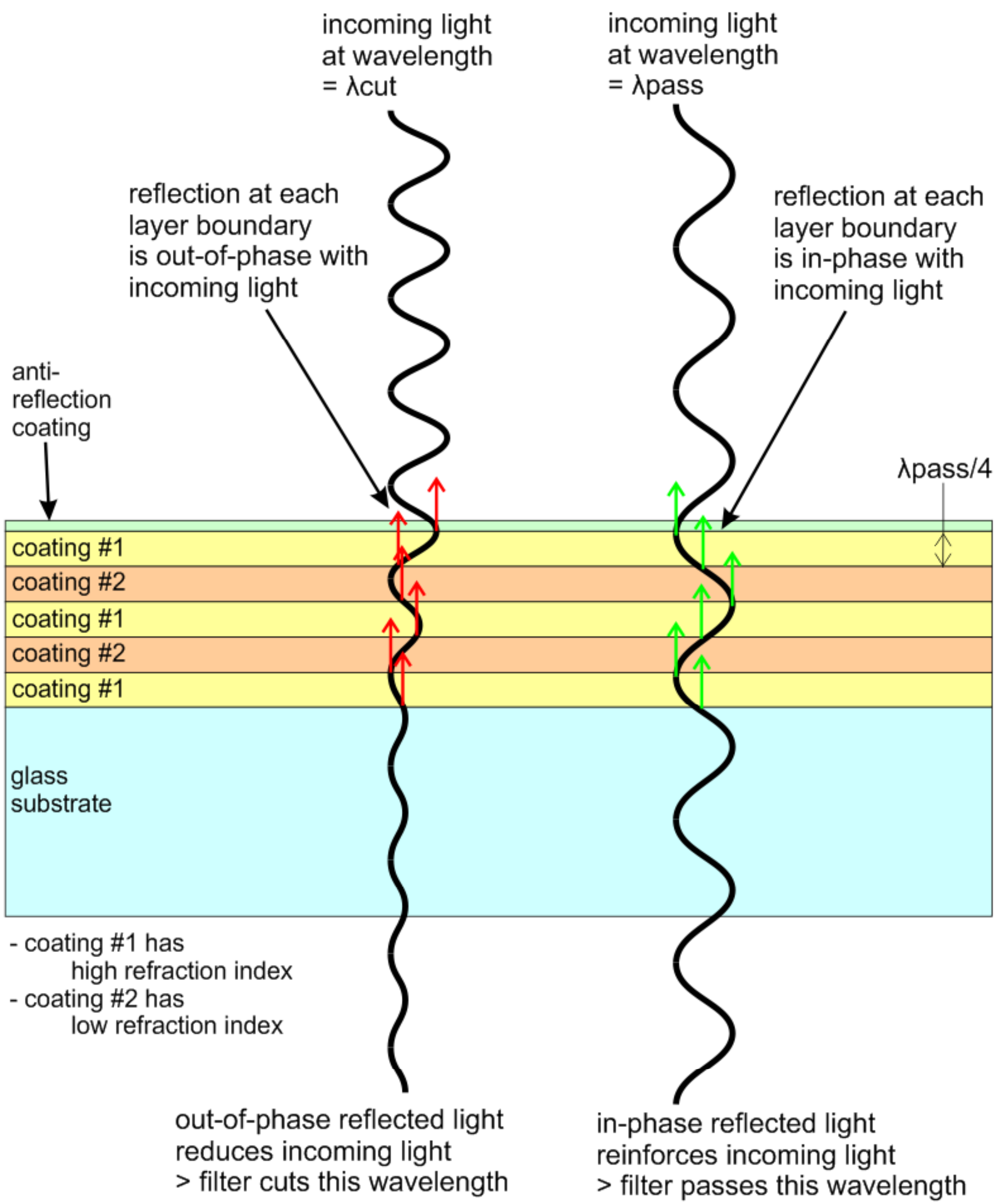
How do they work?

- Piece of glass held in an aluminum cell that screws to your eyepiece/camera

- Planetary filters:
  - glass is either infused with a dye or dyed gelatin is sandwiched between layers of glass
  - dye molecules absorb some wavelengths of light and not others
  - dye technology around since Stone Age!

- Deepsky filters:
  - more complex – use wave property of light

Interference filters



- 10's to 100's of alternating coatings on a glass substrate
- each coating has different refractive index
- light partly reflects at each boundary
- by design all undesired wavelength reflections are out-of-phase – null each other out

Overwhelming choices

- Planetary filters:
  - originate with Wratten series of colour filters for film photography (circa 1910)
  - are still produced today by a myriad of manufacturers
  - my research alone considered 56 different filters
  - generally low cost

- Deepsky filters:
  - technology to manufacture is relatively new so cost to purchase is still high
  - due to complexity in design, filters vary widely in performance from manuf. to manuf.
  - my research alone considered 101 different filters (does not include narrow band filters for astrophotography)

- How does one choose?

How use…Planetary*

* including Lunar

- Want to increase contrast of details
  - many good suggestions in books, etc.
- Colour filters can help – IN THEORY
  - eyepiece observing = yes
  - video/imaging = more effective to adjust camera settings or in post processing
- I do recommend:
  - UV/IR cut to sharpen focus (all scope types)
  - "Moon & Skyglow" w/ IR cut (eg. Baader)
  - Red / IR (high) pass in bad seeing or daytime Lunar

Also good for white light Solar

How use...Deepsky

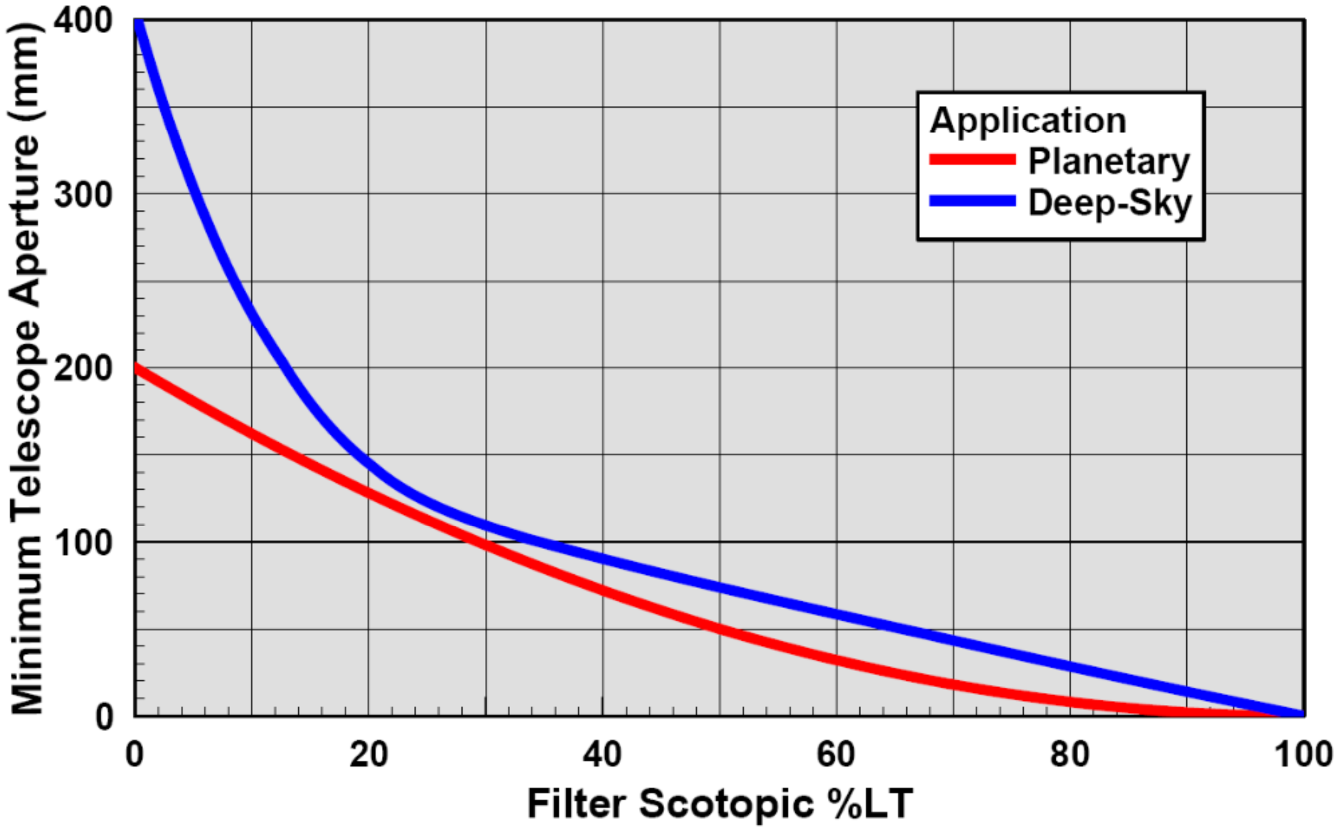
- Like Planetary, want to increase contrast

- Best filter to use depends on:
  - object type (galaxies/clusters, emission nebulae, or both)
  - amount and type of light pollution
  - type of optics
  - <u>tracking capability</u>

In general best contrast comes from using narrowest filter – but at the cost of bigger aperture / longer exposure

Aperture and filter choice

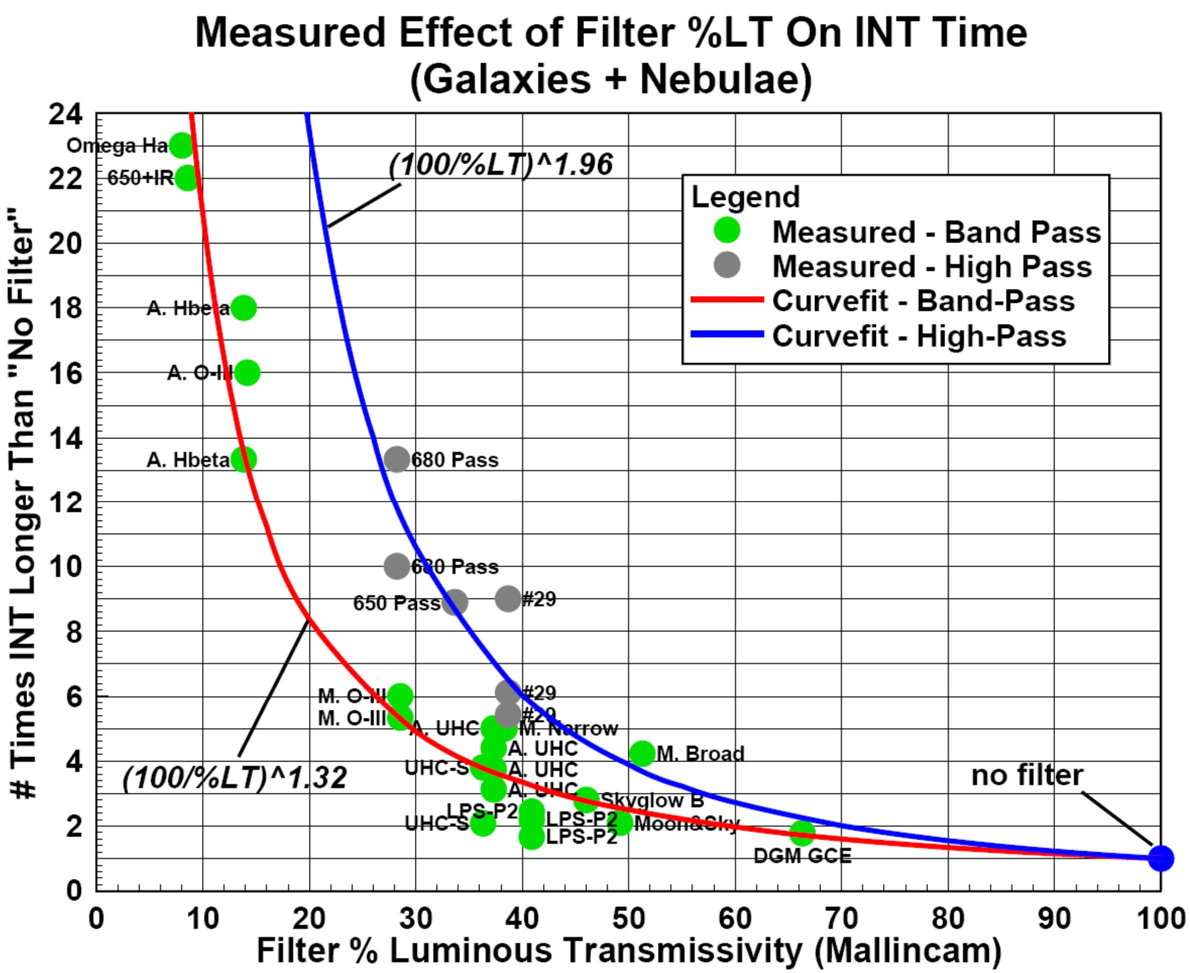
- Deepsky filters remove contribution to scene from light pollution
  - Whole scene gets darker, but…
  - Contrast between sky and object is better.



- %LT of filter limits practical scope aperture for visual use
- no limit on aperture for video/ imaging

How deepsky filters affect exposure

- Darkening of scene using deepsky filter compensated with longer exposure time



- Darker background allows even longer exposures to further increase image contrast
- Amount more exposure is greater for galaxies & reflection nebulae

How deepsky filters affect contrast

- Predicted increase in contrast confirms deepsky filters work! – the narrower the better

Visual	Category	Model	%LT	O-III Rich Bright Nebula	H-alpha Rich Dim Nebula	Galaxy
	Multiband	IDAS LPS-P2	72.7	+33.2%	+28.5%	+3.5%
	Extra Wide	Orion Skyglow Broadband	64.8	+57.1%	+51.9%	+7.0%
	Wide	Lumicon Deepsky	60.5	+73.8%	+63.9%	+6.0%
	Medium	Astronomik UHC	33.6	+193.3%	+149.4%	+3.9%
	Narrow	Orion Ultrablock	26.5	+233.6%	+121.2%	+3.0%
	O-III	Televue O-III	27.3	+249.1%	+62.7%	+1.1%
	H-alpha	Baader Scientific 7nm	0.0	0.0%	0.0%	0.0%
	H-beta	1000 Oaks LP4	10.8	+36.6%	>500%	+20.2%
	IR Pass	Baader Scientific IR Pass	0.0	0.0%	0.0%	0.0%

Prediction based on:
- Mv = +3.5 (typical large city suburbs)
- 8” SCT w/ 8mm eyepiece (250x)

M57 = O-III rich bright nebula

NGC7000 = H-alpha rich dim nebula

M51 = galaxy

CCD (ICX418AKL)	Category	Model	%LT	O-III Rich Bright Nebula	H-alpha Rich Dim Nebula	Galaxy
	Multiband	IDAS LPS-P2	40.9	+92.2%	+81.6%	-11.8%
	Extra Wide	Orion Skyglow Broadband	46.0	+145.7%	+126.4%	+28.1%
	Wide	Lumicon Deepsky	49.2	+151.1%	+138.2%	+36.6%
	Medium	Astronomik UHC	37.3	+259.8%	+238.6%	+52.9%
	Narrow	Orion Ultrablock	9.4	+397.9%	+64.7%	-25.0%
	O-III	Televue O-III	25.9	+303.3%	-4.0%	+56.7%
	H-alpha	Baader Scientific 7nm	1.5	>500%	>500%	+60.9%
	H-beta	1000 Oaks LP4	24.1	+128.1%	>500%	+123.4%
	IR Pass	Baader Scientific IR Pass	31.1	-80.7%	-54.0%	+246.9%

Selecting a filter for deepsky

Object Type	Dark Sky	Light Polluted Sky
Emission Nebulae (incl. planetary neb. & supernova remnants)	Best contrast from narrowest deepsky filter your aperture (visual) or mount tracking (video/imaging) will support. Adding IR cut will also help improve contrast with CCD.	
Galaxies, globular clusters, open clusters, reflection nebulae	Don't use filters visually. Adding IR cut can help contrast with CCD.	No significant benefit visually. For video/imagine filters that pass IR are required, with wide to medium-wide band pass filters working best. Even more contrast on galaxies from IR high pass filters, if scope tracking will support.

- Unfocused IR in refractors (video/imaging):
  - Most ED doublets and APO triplets not a problem
  - Commercial camera lenses (esp. security) usually need IR cut

Some other effects of filters

- Adding filter will change white balance (WB)
  - Deepsky filters = magenta cast, OIII = green, Halpha = red, IR pass = orangish cast
  - Some filters provide better WB than others (eg. IDAS LPS-P2)
  - May not be able to completely correct for the filter (video/imaging)
- Filter glass another surface in optical train
  - can result in new reflections in your FOV, better quality filters have anti-reflective coatings
  - another surface upon which dirt, dust, or dew can settle – most evident when Solar observing

Pretty pictures #1

Light polluted sky (Ottawa)

No Filters (8sec INT, 0 BRT)

Orion Deepsky Wideband (8sec INT, >0 BRT)

IDAS LPS-P2 (8sec INT, >0 BRT)

Astronomik UHC(8sec INT, >0 BRT)

Pretty pictures #2

Semi-dark sky (Petawawa)

IDAS LPS-P2 (60sec INT, 0 BRT)

Meade O-III + BDRB (60sec INT, ~40 BRT)

IDAS LPS-P2 (60sec INT, 0 BRT)

Meade O-III + BDRB (60sec INT, ~70 BRT)

Pretty pictures #3

Dark sky (Foymount)

No Filters (60sec INT, 54 BRT)

Astronomik UHC + IR cut (60sec INT, 82 BRT)

Meade O-III + BDRB (60sec INT, 93 BRT)

Meade O-III + BDRB (120sec INT, 82 BRT)

Pretty pictures #4

Dark sky (Foymount)

No Filters (20sec INT, 0 BRT)

Baader UV/IR Cut (45sec INT, 0 BRT)

- Images captured with achromatic Canon TV camera lens (17–102mm zoom)
- Affect of unfocused IR very evident – not simply bloated stars, fuzzy stars

Last words

- Feel free to experiment. Recommendations here are based on MY experience; yours may be different.
- Do not feel obligated to buy one of everything. Start with an affordable general purpose filter and build from there.
- For goodness sake HAVE FUN!