Understanding Astronomical Filters

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Who is Jim Thompson?

- Aerospace Engineer (M.Eng, P.Eng) – Propulsion & Aerodynamics
- 25yrs Davis Engineering – design & build IR suppression systems for ships & aircraft
- Live with wife & kids in Ottawa, Canada – Bortle 9+
- Re-activated interest in astronomy ~2009
- Bad LP + Lack of Data = Filter Expert

Research, analysis, testing

Overview

Three-Part Presentation…

- Part I: What Are They
  - What do they do
  - Different types
  - How they work
  - Nomenclature

- Part II: How To Use Them
  - Enhancing solar system observing
  - Controlling light pollution
  - Suggestions & things to remember

- Part III: Latest Filter Research

Part I: What Are They?


What Do Filters Do?
Block Light You Don't Want To See
Improve contrast & sharpness
Emphasize features
See faint details
5

Example Application – Planets

From Earth / From Orbit

Green Filter / Red Filter

simulated images

Example Application – Deepsky

Types of Filters

- Planetary
- Colour (Wratten)
- Absorption

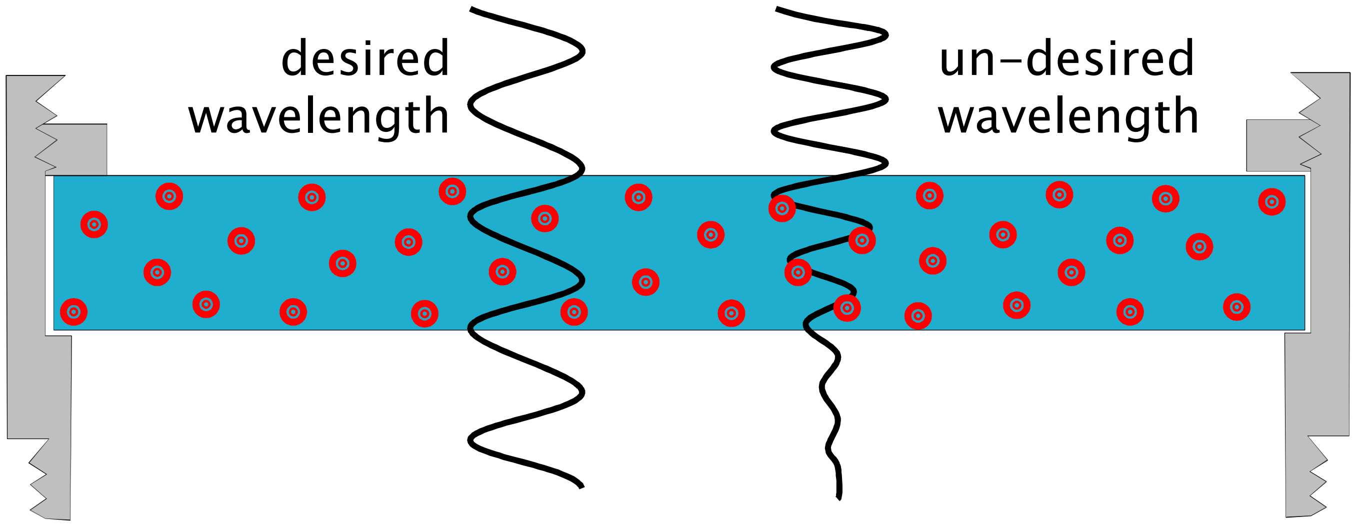
- Deepsky
- Nebula
- Light Pollution
- Interference (reflection)

Special Filters

- Some special combo-type filters also exist for:
  - Planetary observing
  - Chromatic aberration correction
  - Solar observing
  - UV/IR blocking

- Let's ignore for now

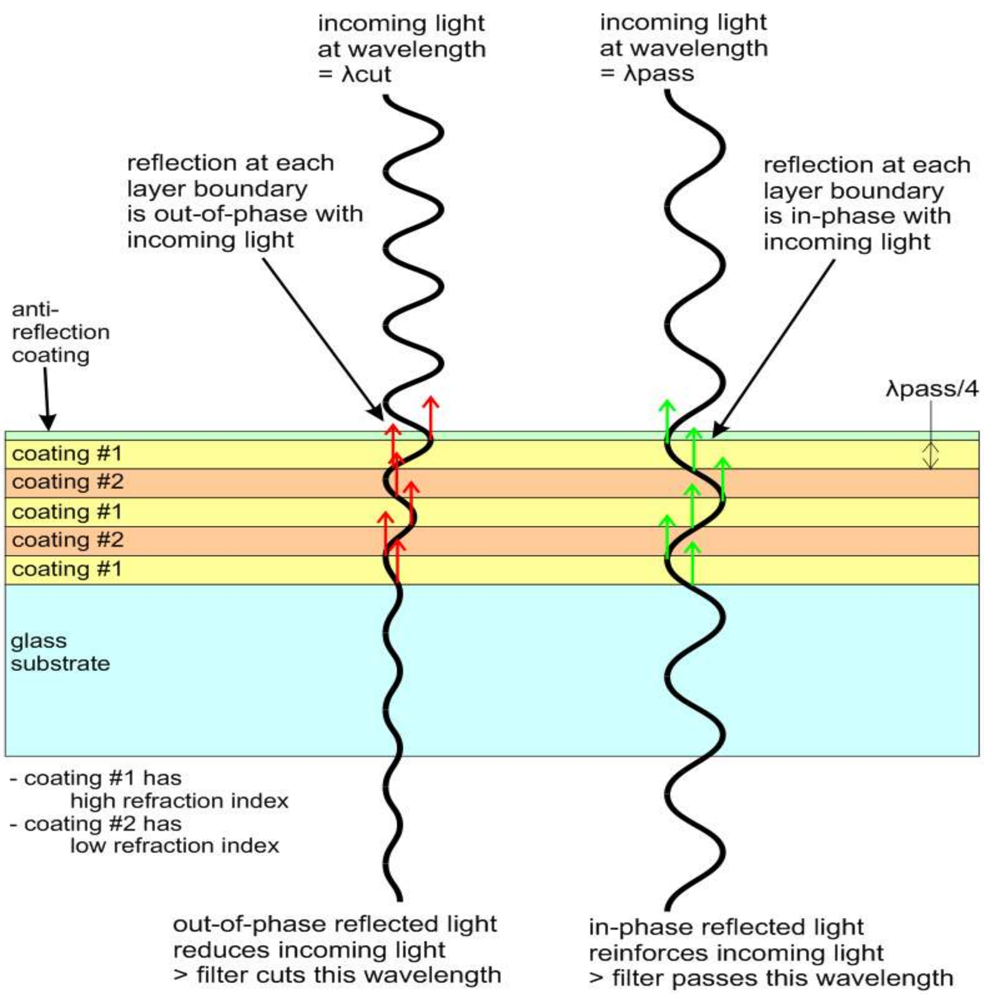
Absorption filters



- Dye infused glass, or gel sandwiched between glass
- Molecules in dye absorb some wavelengths but not others
- Broad pass bands, very gradual cut-offs

* Wratten (bought by Eastman Kodak in 1912)

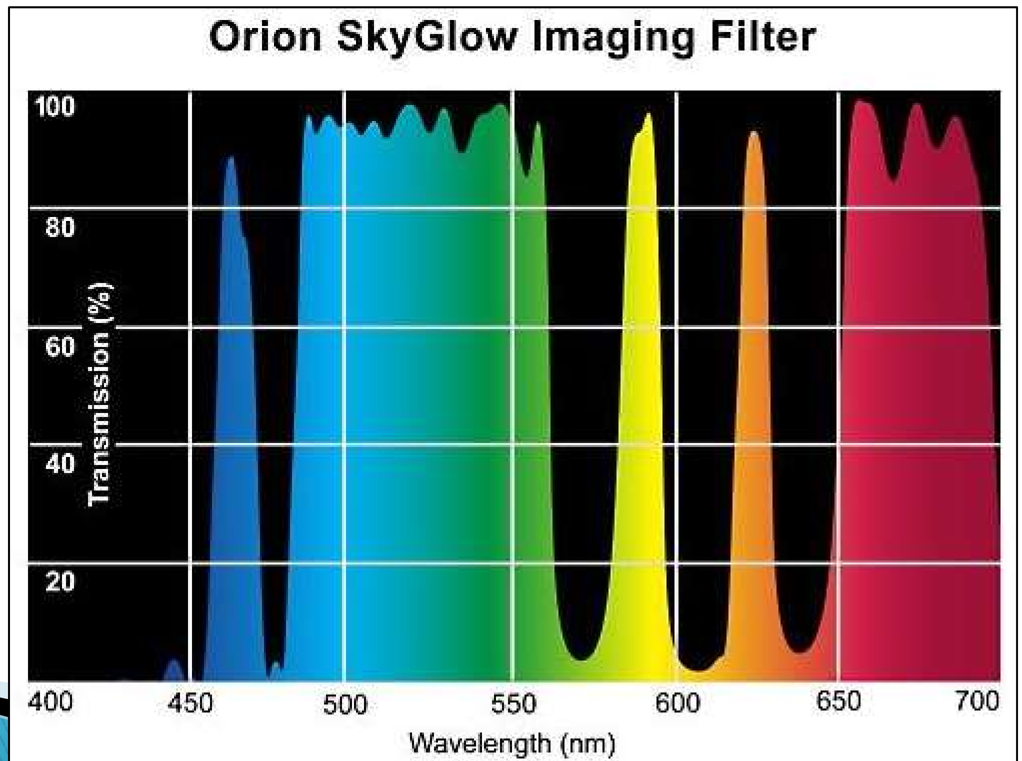
Interference filters



- 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
- older filters sandwich layers between glass

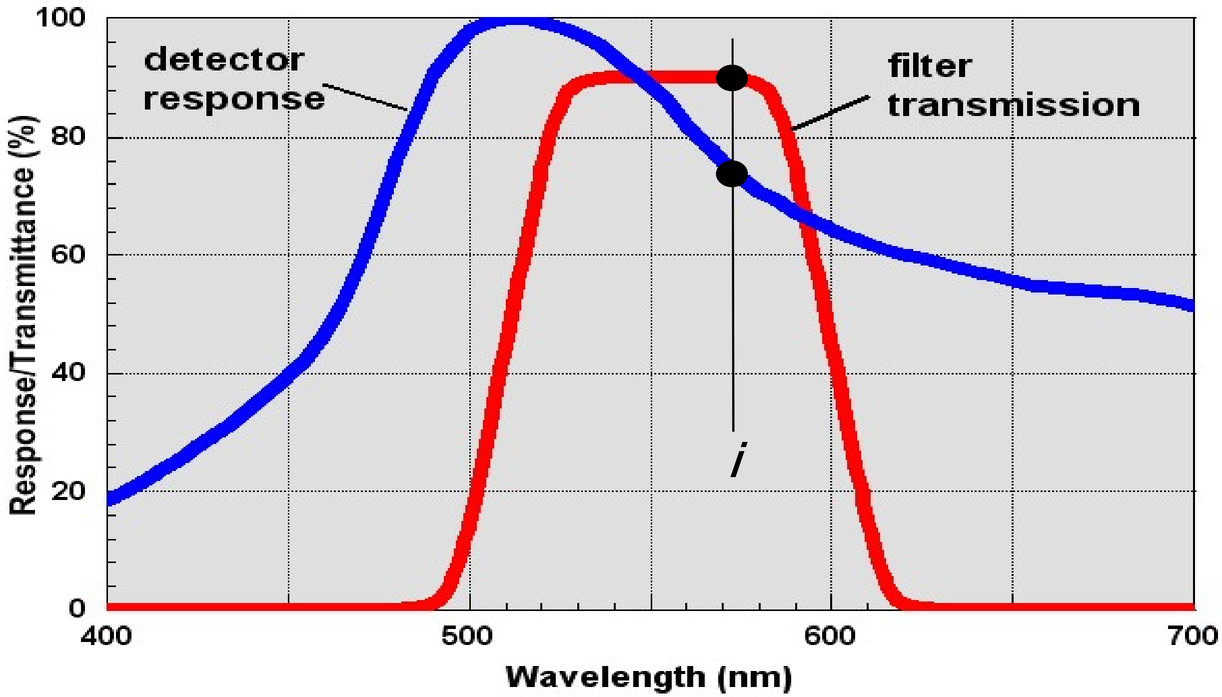
Filter Spectrum

- Visually represent filter transmission vs. wavelength
- Allows easy comparison between filters
- Provides information on how filter performs



Luminous Transmissivity (%LT)

- Measure how "dark" filter is (how much light it blocks), w/ 100% = clear
- Calculated based on response of detector (eye, CCD, …)
- Most often quoted assuming daytime visual use!

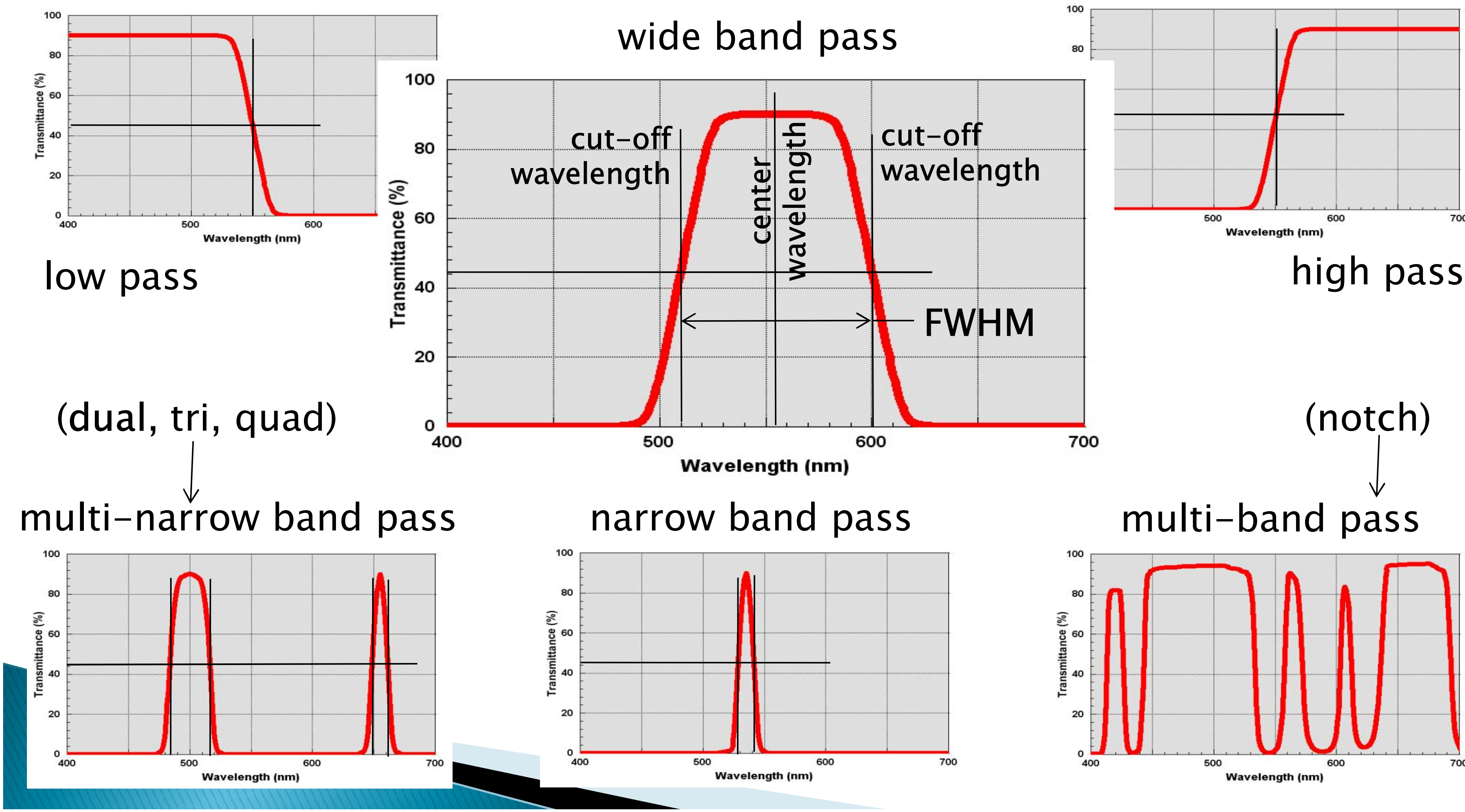


- Average brightness weighted by detector sensitivity

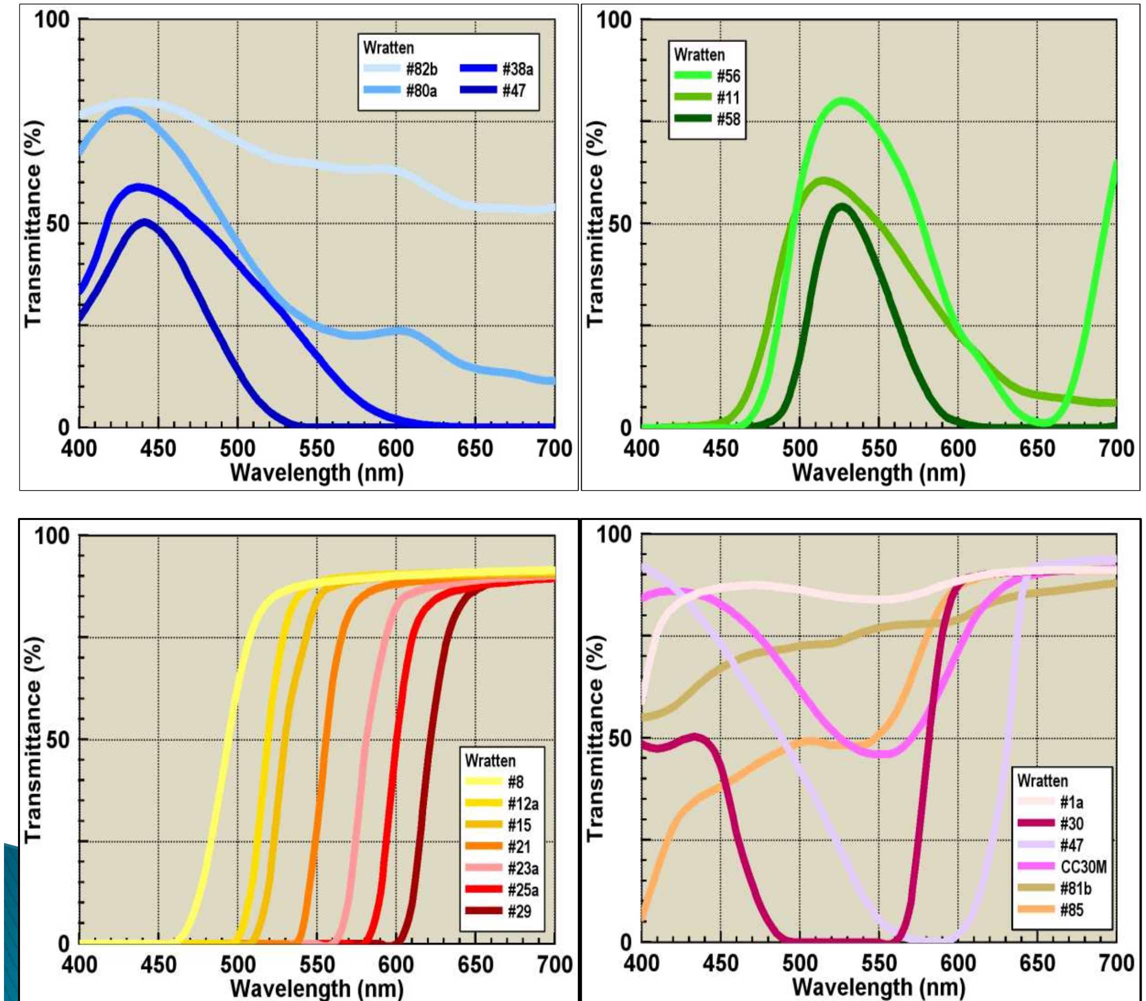
$$\%LT = \frac{avg(\%DR_i * \%FT_i)}{avg(\%DR_i)}$$

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

Filter response nomenclature



Colour Filter Spectra

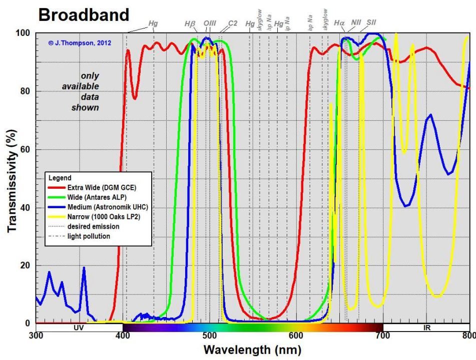


- Blue & green filters – wide band pass
- Yellow/Orange/Red/IR filters – high pass
- Purple/pink/brown – combination of pass types
- Gentle cut-offs, low tranmissivities
- Colour filters w/steep cut-offs available – combo-type

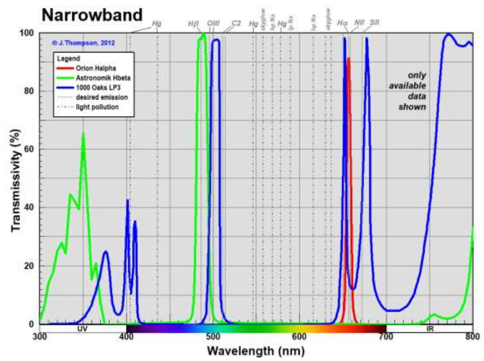
Deepsky Filter Spectra

- Pass desired object wavelengths: Hβ (486.1), O-III (495.9 & 500.7), Hα (656.3), NII (658.4), SII (672.4), NIR (>700)
- Block LP – extent varies by filter type

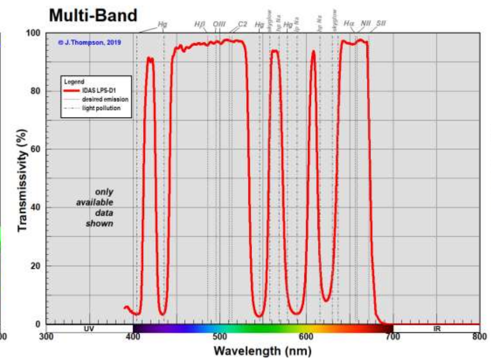
NEW!



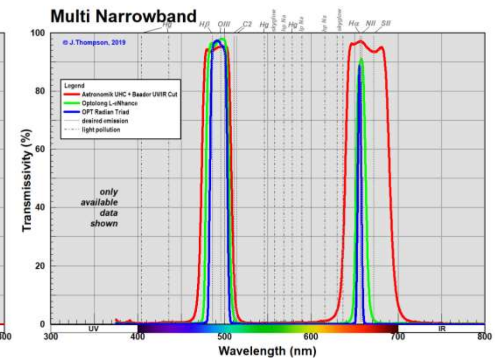
- Large pass band around Hβ & O-III
- Meant for visual so often no Hα
- Sub-divided by FWHM:
  - Extra Wide (>70nm)
  - Wide (50-70nm)
  - Medium (35-50nm)
  - Narrow (20-35nm)



- Narrow pass band around single wavelength
- Hα, NII & SII only for imaging
- Range of FWHM available:
  - Visual or Imaging – 10-20nm
  - Imaging Only – <10nm



- Multiple broad pass bands
- Blocks discrete LP wavelengths
- Provide best white balance
- Overall LP reduction is moderate-to-poor
- Broadband LP (eg. LED) reduces effectiveness



- Narrow pass bands around >1 emission wavelength
- Dual-, tri-, or quad-
- Maximize LP blocking when observing/ imaging emission nebulae
- Recently popular w/ OSC imagers

Part II: How To Use Them

Solar System Observing

- Use filters to darken some features but not others
- Primarily using colour (absorption) type
- Filter choice very subjective:
  - A lot of trial-and-error
  - Personal preference

Planetary Filters – The Long…

Object	Features	Recommended Filter
Mercury	Planet/Sky Contrast	#23A Light Red
	Features	#25 Red #29 Deep Red
Venus	Clouds	#38A Deep Blue #47 Violet #58 Green
	Planet/Sky Contrast	#25 Red #29 Deep Red
	Terminator	#25 Red #29 Deep Red
Moon	Detail	#56 Light Green
	Feature Contrast	#8 Light Yellow #12 Yellow #15 Deep Yellow #80A Blue
	Low Contrast Features	#82A Light Blue
	Glare Reduction	ND13 Neutral Density Variable Polarizer
Mars	Clouds	#15 Deep Yellow
	Maria	#8 Light Yellow #15 Deep Yellow #11 Yellow-Green #21 Orange
		#23A Light Red #25 Red #29 Deep Red
	Blue-Green Areas	#12 Yellow #23A Light Red
	Dust Storms	#38A Deep Blue #56 Light Green
	Polar Caps	#15 Deep Yellow #25 Red #29 Deep Red #47 Violet #56 Light Green #58 Green Deep Sky Filter
	Low Contrast Features	#82A Light Blue
Jupiter	Clouds	#11 Yellow-Green
	Belts	#8 Light Yellow #15 Deep Yellow #21 Orange #23A Light Red #25 Red #29 Deep Red #38A Deep Blue #56 Light Green #80A Blue
	Rilles	#80A Blue
	Festoons	#80A Blue
	Atmosphere	#56 Light Green
	Red-Orange Features	#12 Yellow
	Orange-Red Zonal	#8 Light Yellow
	Red/Blue Contrast	#11 Yellow-Green
	Blue/Light Contrast	#25 Red
	Great Red Spot	#38A Deep Blue #80A Blue
	Galilean Moon Transits	#25 Red #29 Deep Red
	Red/Blue/Light Contrast	#56 Light Green #58 Green
	Polar Regions	#21 Orange #23A Light Red
	Disc	#38A Deep Blue
	Low Contrast Features	#82A Light Blue
Saturn	Clouds	#11 Yellow-Green #12 Yellow #25 Red #29 Deep Red
	Belts	#15 Deep Yellow #21 Orange #23A Light Red #38A Deep Blue #58 Green
		#80A Blue
	Polar regions	#21 Orange #23A Light Red #58 Green #80A Blue
	Rings	#47 Violet
	Cassini Division	#11 Yellow-Green
	Red/Blue Contrast	#11 Yellow-Green
	Red/Orange Features	#12 Yellow
	Low Contrast Features	#82A Light Blue
Uranus	Dusky detail	#8 Light Yellow #15 Deep Yellow
Neptune	Dusky detail	#8 Light Yellow #15 Deep Yellow

- Many recommendations available!

Planetary Filters – The Short…

- My personal recommendations:
  - Magenta (CC20M, #47, #30) – Mars, Jupiter
  - Red (#23, #25, #29) – Moon, Mars
  - Light Tan/Orange (#81B, #85) – Jupiter, Saturn
  - Variable Polarizer or ND – Moon, Venus

- Just want single all-purpose filter?
  - Special type – "Moon & Skyglow" (Baader)

- Remember: filters block light … view is darker
  - Dark filters (low %LT) require large scope

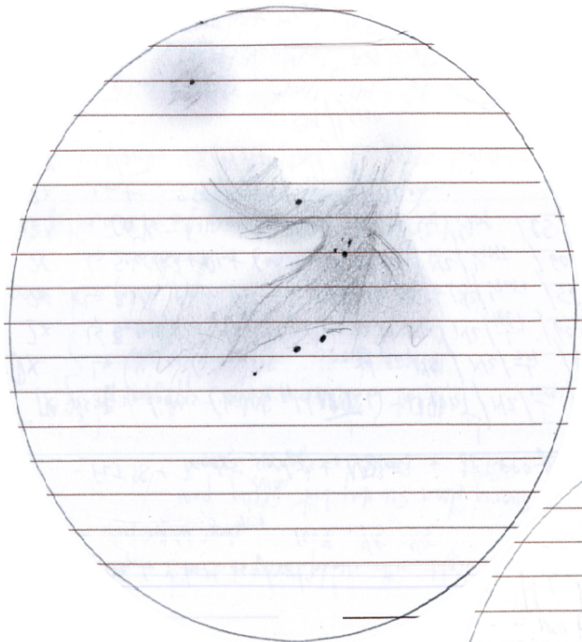
Solar System Imaging

- Contrast, colour, etc. all controlled in post processing
  - Colour filter not needed

- Main concern is “seeing”
  - At a minimum – UV/IR cut
  - Or try longer wavelengths – red or IR high pass (monochrome)

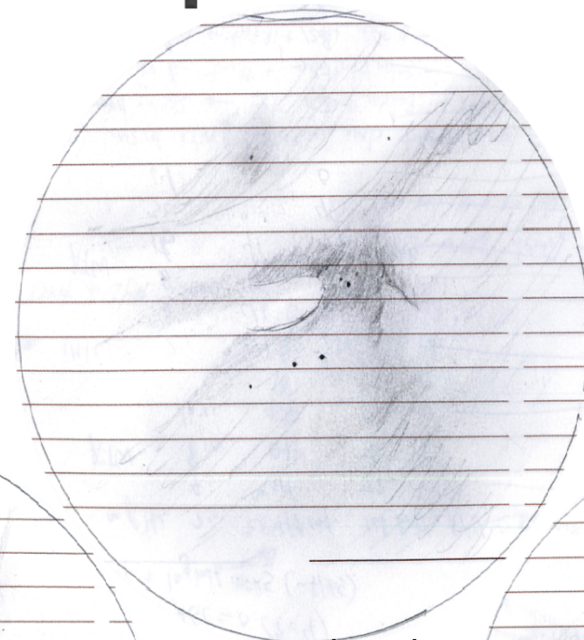
- Good all-purpose planet/Moon imaging filter
  - “Moon & Skyglow” (Baader, UV/IR cut incl.)

Deepsky Filter Impact – Visual



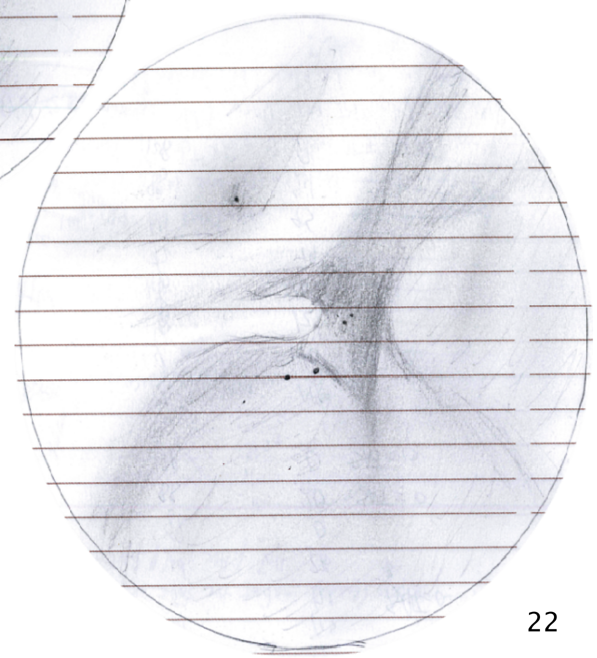
No Filters

Medium Broadband



Narrowband O-III

Multi-Narrowband



- Downtown Ottawa (Mv ~ +3.0)
- 4” APO refractor
- 6.7mm UWA eyepiece

Deepsky Filter Impact – Imaging

No Filters

Wide Broadband

Medium Broadband

Medium Broadband + IR Cut

Multi-Narrowband

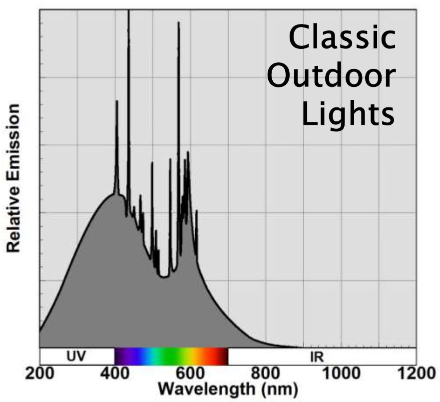
Narrowband Halpha

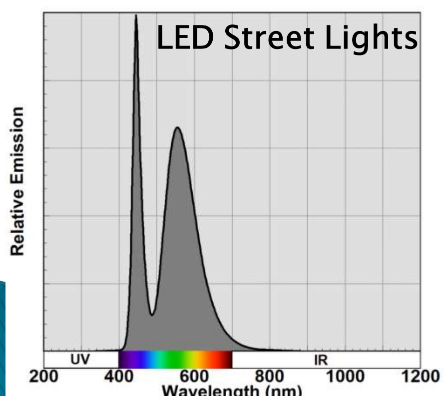
Choosing a Deepsky Filter

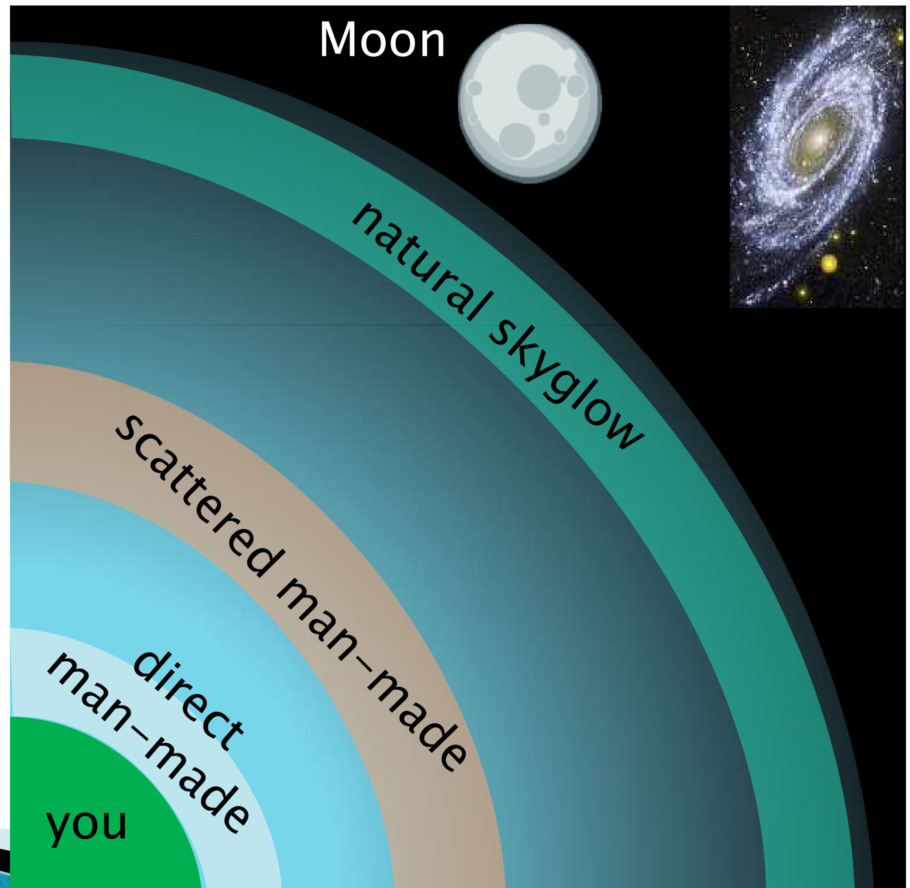
- Like Planetary, want to increase contrast
- Interference-type filters more capable
  - precise bandwidths & steep cut-offs
- Best filter to use depends on:
  - amount and type of light pollution
  - object type (galaxies, clusters, nebulae)
  - size & type of optics
  - tracking capability (EAA or imaging)

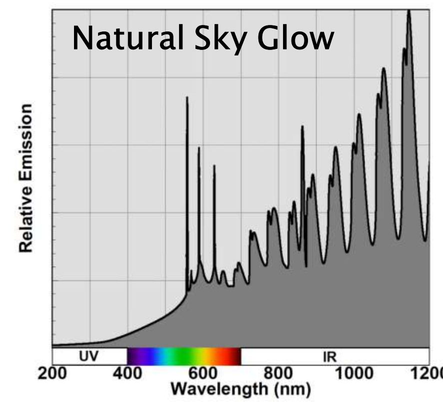
Light Pollution Spectra

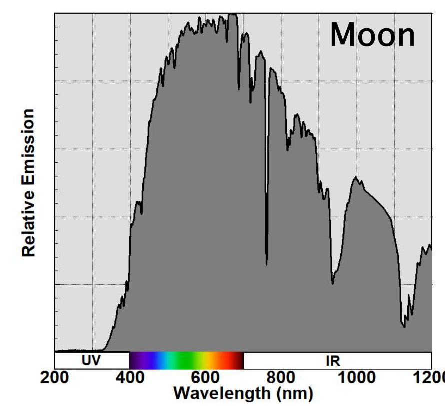
- LP is everything between us & deepsky object



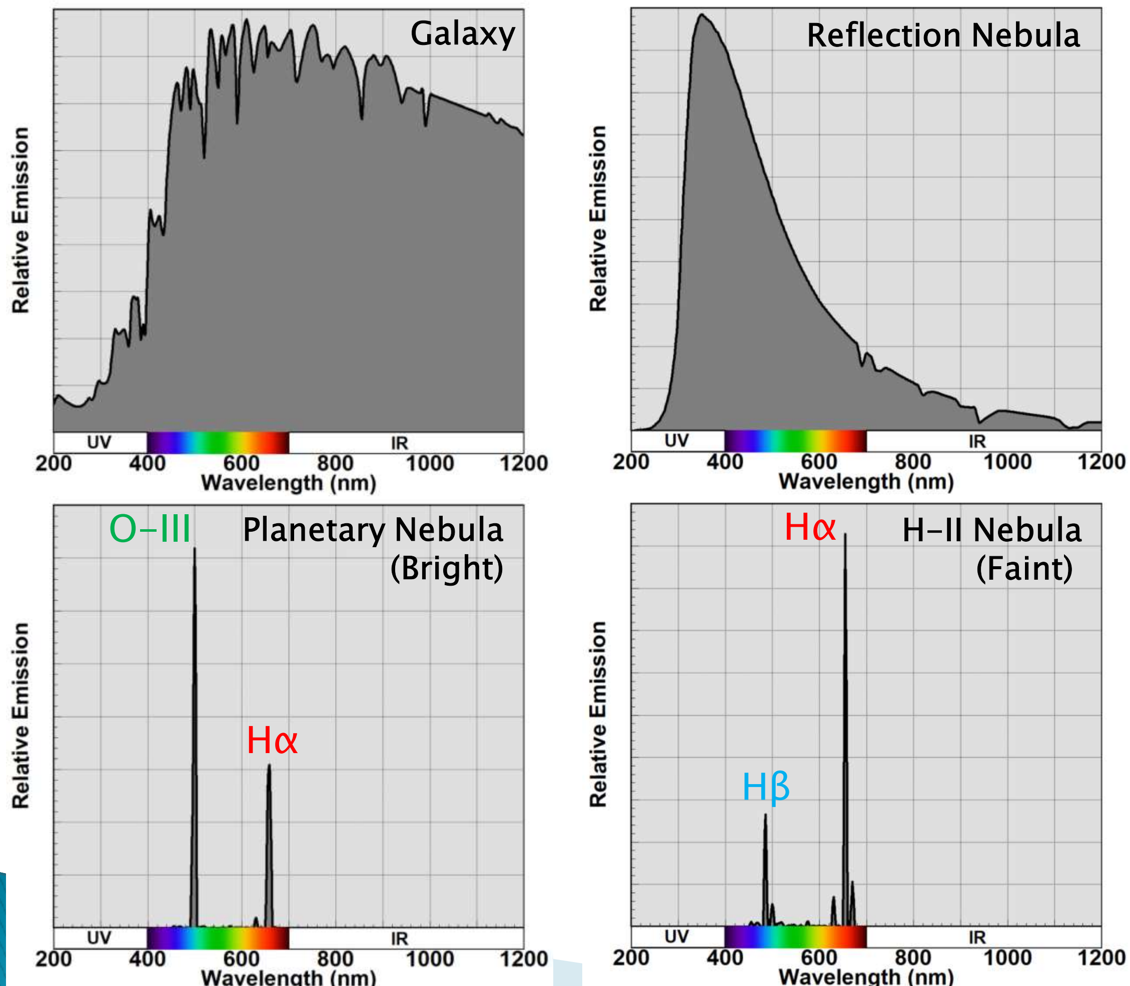




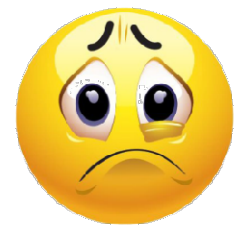




Deepsky Object Spectra



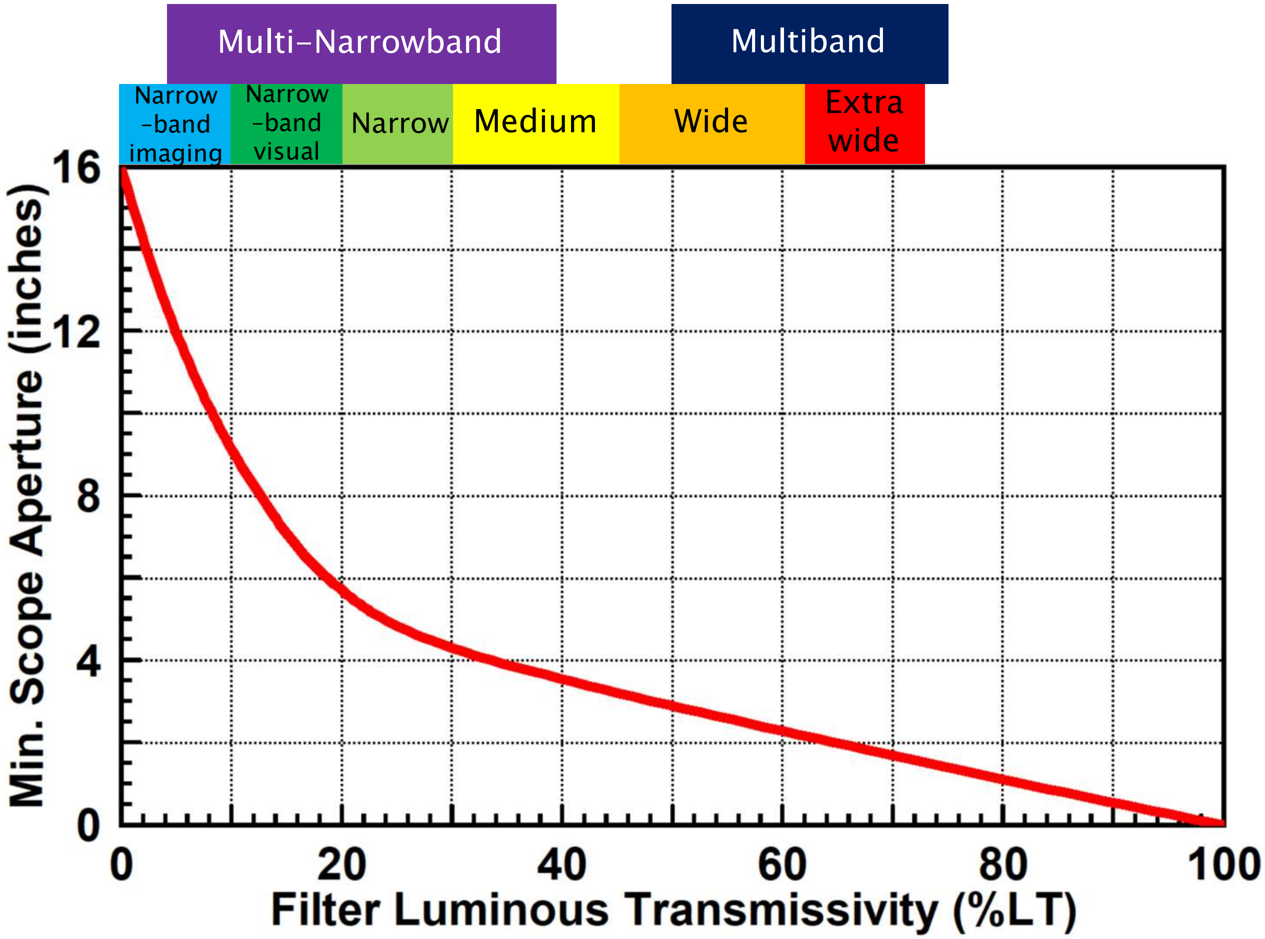
- Galaxies, reflection neb., stars, globular & open clusters = broad spectrum



- Emission nebulae (HII, planetary, super nova remnant) = narrow band

Deepsky Filters vs. Aperture

- Recall that filters make scene darker



- %LT of filter limits practical scope aperture for visual use
- no limit on aperture for EAA/ imaging – compensate w/exposure time (tracking)
- Impact on broad spectrum objects MUCH WORSE

Choosing a Deepsky Filter, cont'd

Object Type	Dark Sky	Light Polluted Sky
Narrow Band: Emission Nebulae (incl. planetary & supernova remnants)	– Narrowest filter aperture (visual) or mount tracking (EAA/imaging) will support. Adding IR cut can also help improve contrast with camera.	
Broad Spectrum: Galaxies, globular clusters, open clusters, reflection nebulae	– Don't use filters visually. – IR cut *can* help contrast with camera.	– No significant benefit visually. – EAA/imaging, filters that pass IR req'd, wide to medium band pass working best. Best contrast on galaxies w/IR high pass filters, but long exposure time req'd.

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

Some Other Effects of Filters

- Filter changes white balance (WB)
  - Broadband, O-III, Hbeta, Halpha, IR pass
  - Some filters better than others (eg. Multi-band)
  - Post processing may not completely correct (EAA/imaging)

- Filter changes focus slightly

- Filter adds more surfaces
  - Reflections (halos); quality filters have anti-reflective coatings
  - Dirt, dust, or dew – most evident with bright objects

You Get What You Pay For

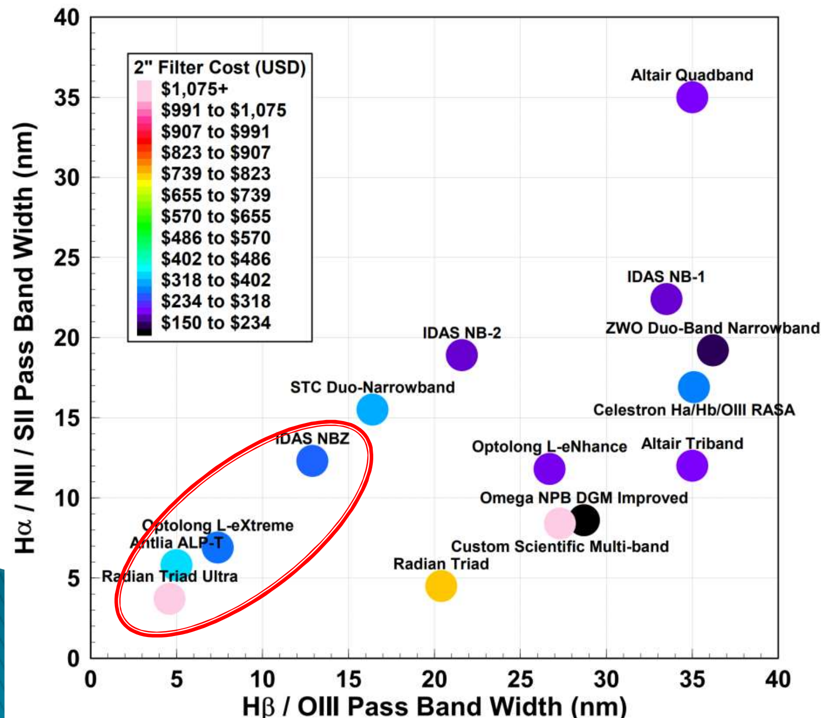
- Tempting to buy cheapest, but quality suffers
  - reflections, de-lamination, poor machining, optical distortion, poor transmission

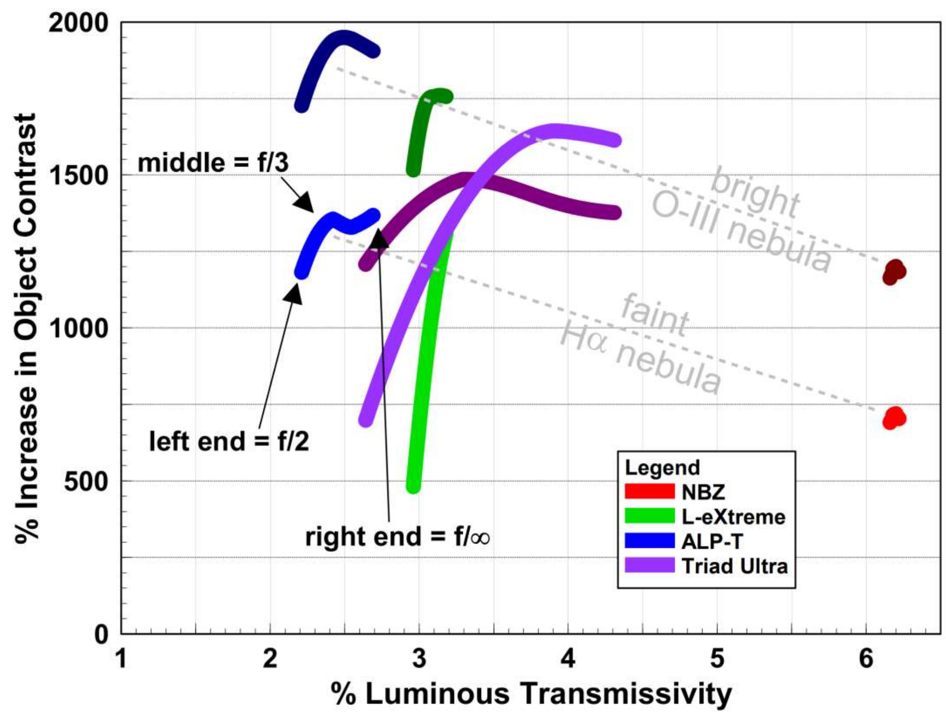
- (Too) Many filter manufacturers available
  - Premium ($$$$): Andover, Astrodon, Chroma, Custom Scientific, FLI, OPT Radian
  - High Quality ($$$): IDAS, Astronomik, Baader, Lumicon, Televue
  - Good Value ($$): 1000 Oaks, Meade, Optolong, Orion, Antlia
  - Discount ($): Antares, Arcturus, DGM, Omega, ZWO
  - Avoid: Canadian Telescope, Celestron, Kson, Olivon, Omegon, Optical Vision, Sirius, Svbony, Zhumell

Part III: Latest Filter Research

Multi-Narrowband Arms Race

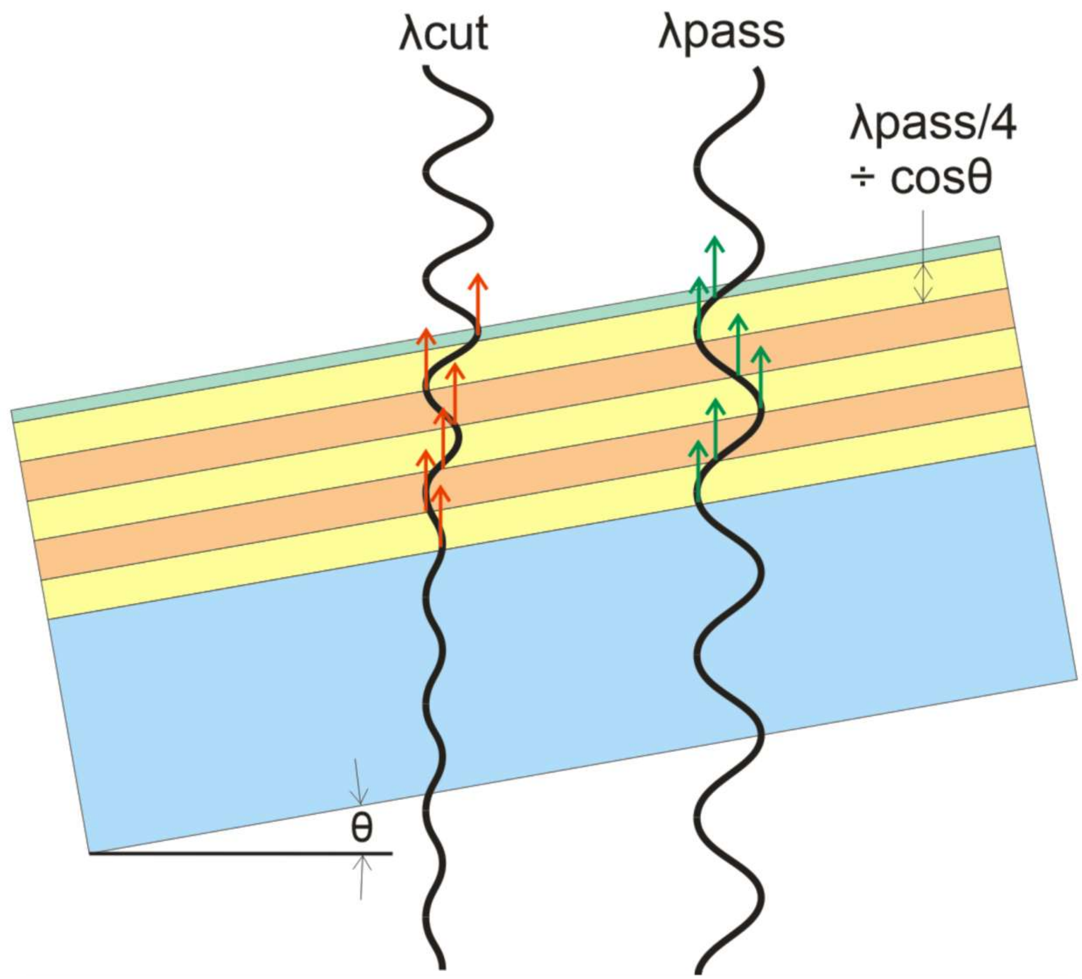
- Very popular with OSC imagers
- OEMs working to produce “ultimate” filter
- Narrower bands = higher contrast



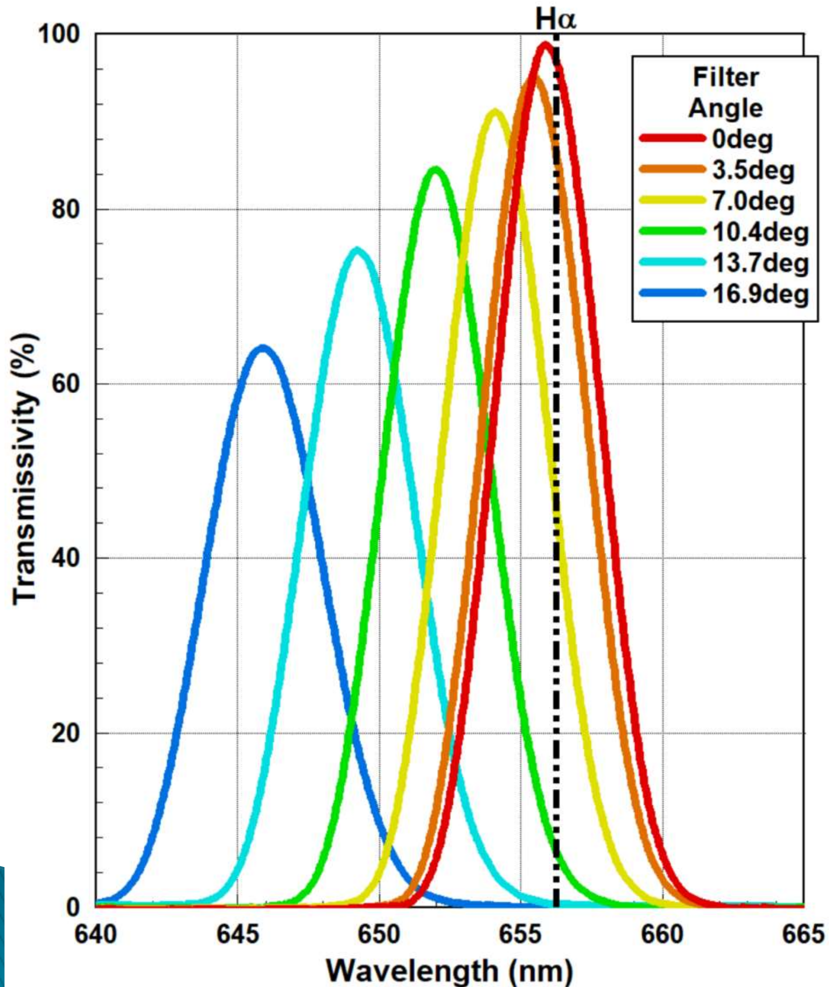


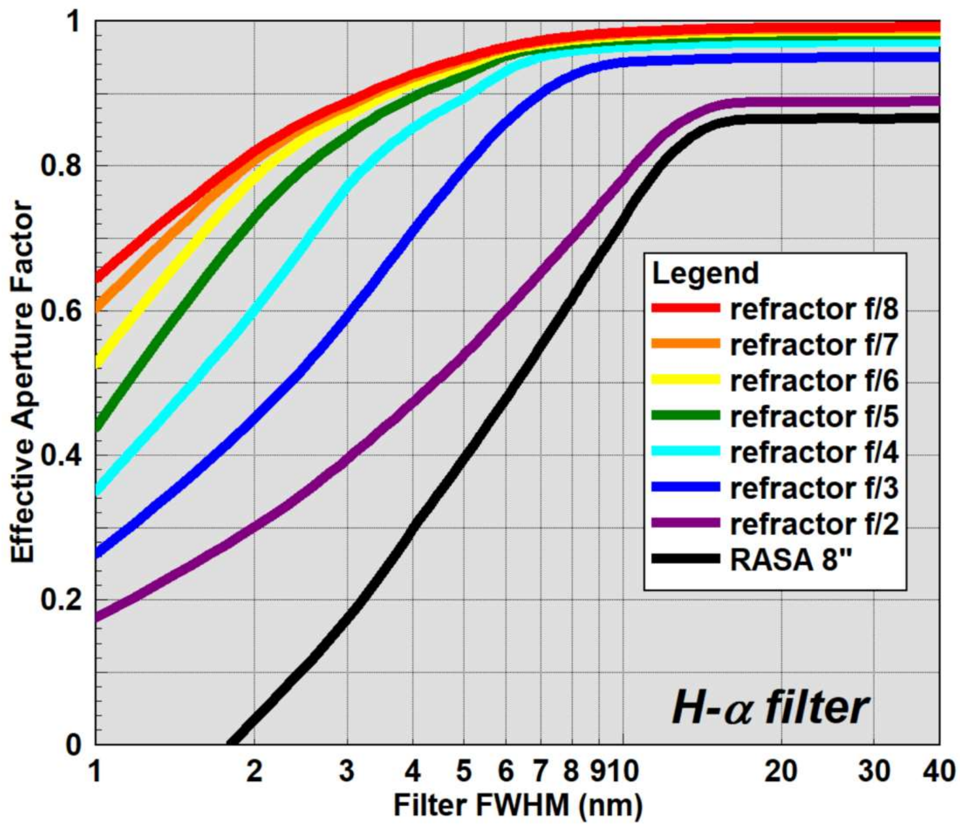
Narrowband Filters + Fast Optics

- Interference-type – layer thickness defines pass band
- Change thickness, change pass band
- Faster optics = steeper light cone
  - Shifts CWL down
  - Reduces %LT
  - Increases FWHM



Narrowband Filters + Fast Optics

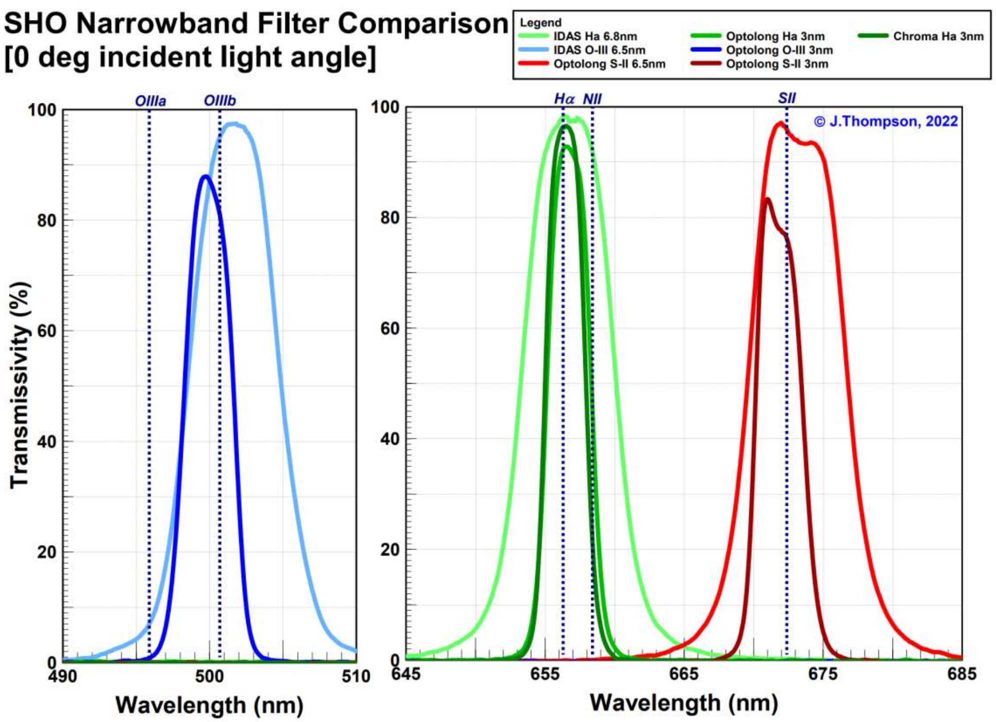


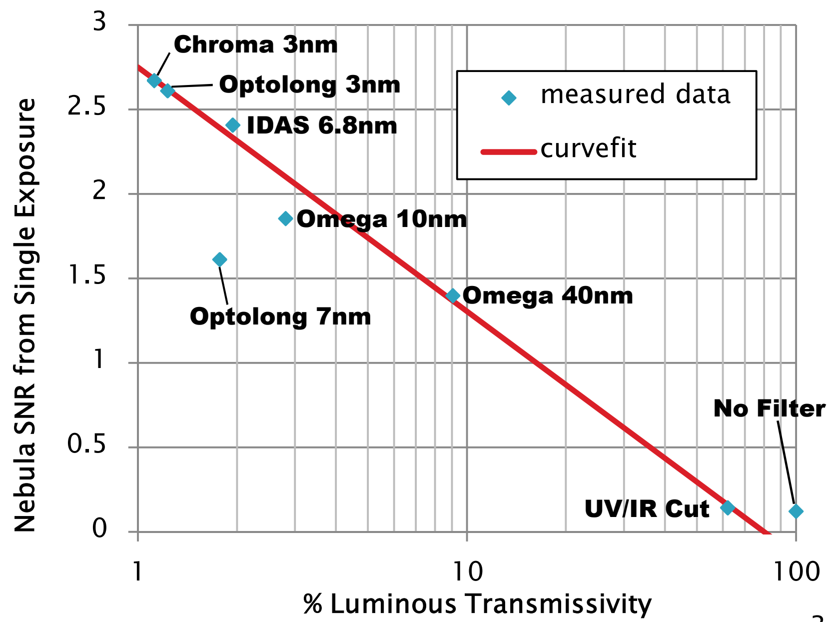


- Filter behaves like aperture mask
- Pre-shift band for fast optics

SHO Narrowband Testing

- Filters down to 3nm wide
- Had to upgrade spectrometer for better resolution (change slit & grating)
- Currently comparison image testing Halpha filters





The End: Questions?

Abbey Road Observatory:
http://karmalimbo.com/aro/