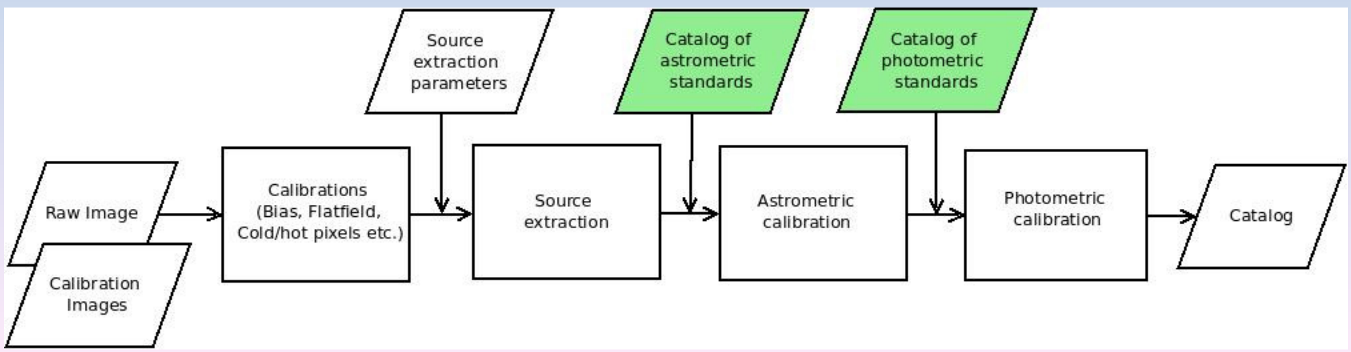
Photometry, Imaging Surveys & Virtual Observations

Gijs Verdoes Kleijn
Kapteyn Institute, room 147
verdoes@astro.rug.nl
050-3638326

"If you think of standardization as the best that you know today, but which is to be improved tomorrow; you get somewhere."

Henry Ford (1863 - 1947)

Modelling & Standardizing astronomical observations



Concepts discussed

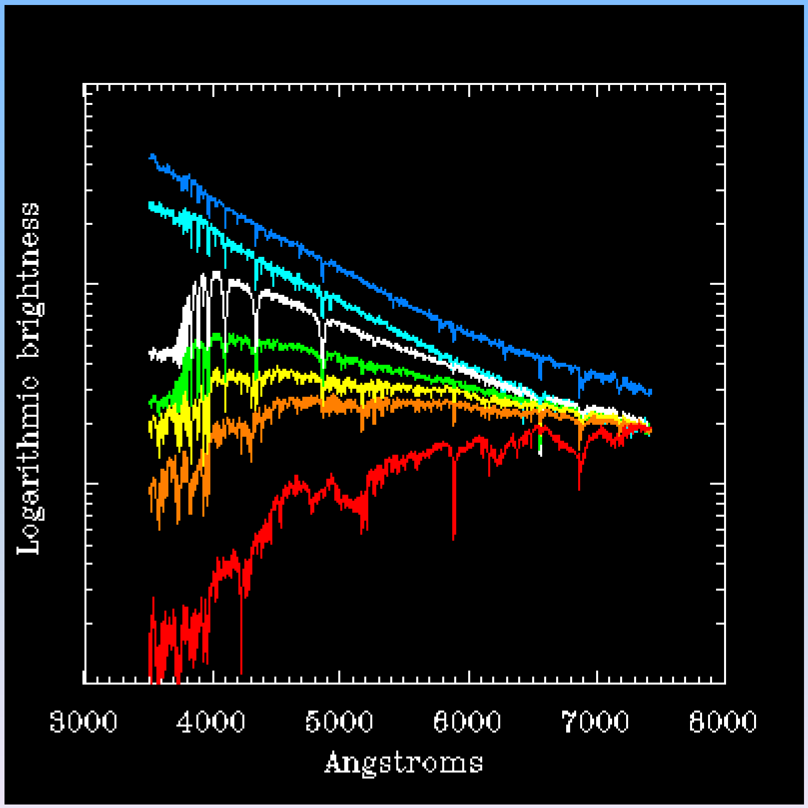
- The light path
- Photometric calibration
  - Standard systems
  - Calibration procedures
- Surveys & standardization

Jargon and conventions

- Flux (e.g., erg/s/cm^2, W/m^2)
- Flux density (e.g., erg/s/cm^2/Hz or /Ang)
- m(agnitude)=-2.5$\log_{10}$(flux/flux0)
- m: Apparent magnitude
- M: Absolute Magnitude= apparent magnitude at 10pc
- Color: e.g., blue-red (B-R)

Goal: physics via Spectral Energy Distribution (SED)

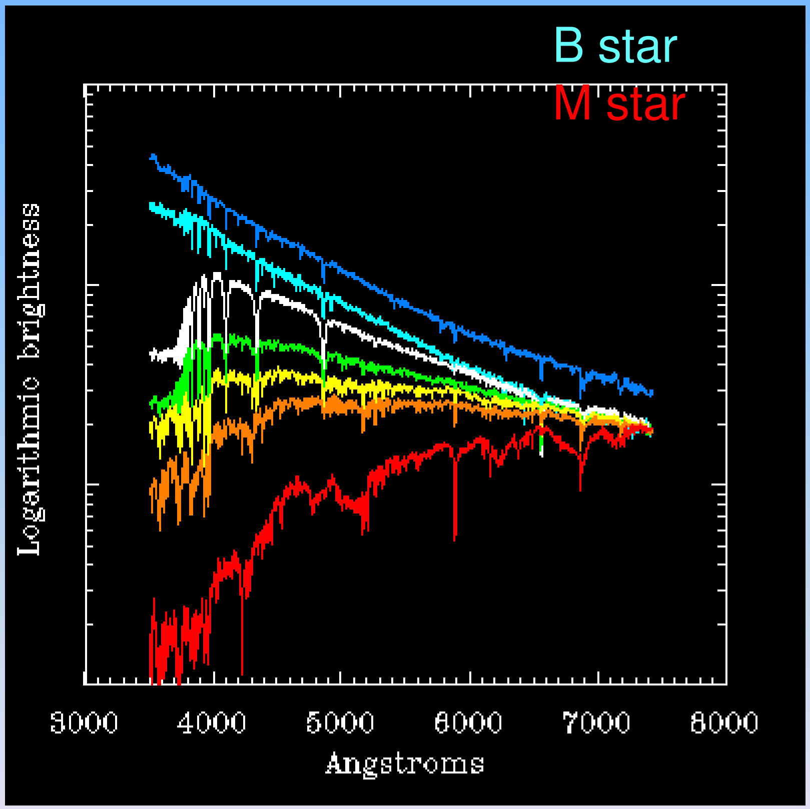
Stellar SEDs

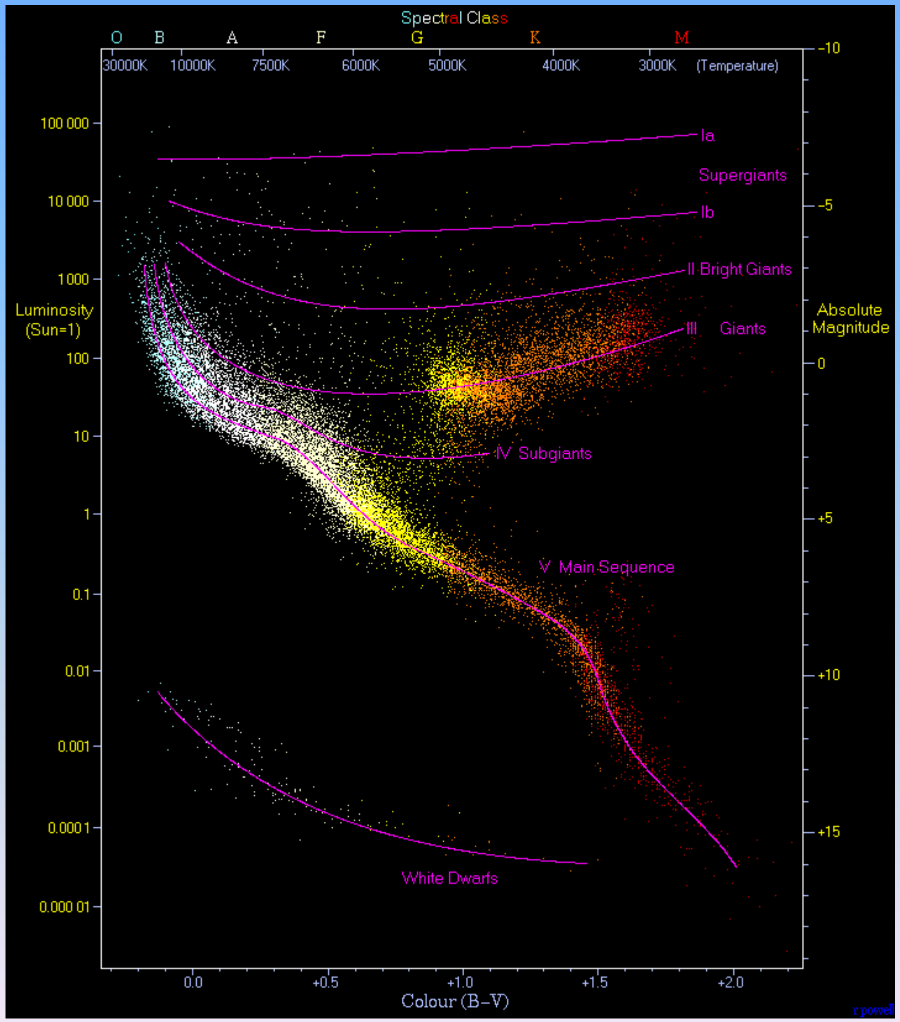


- What is required spectral resolution (λ/dλ) to get physics?
- Example: temperature of blackbody can be obtained from relative intensity at two wavelengths
- Spectral resolution ↓ →Efficiency↑
- broad-band spectroscopy =photometry

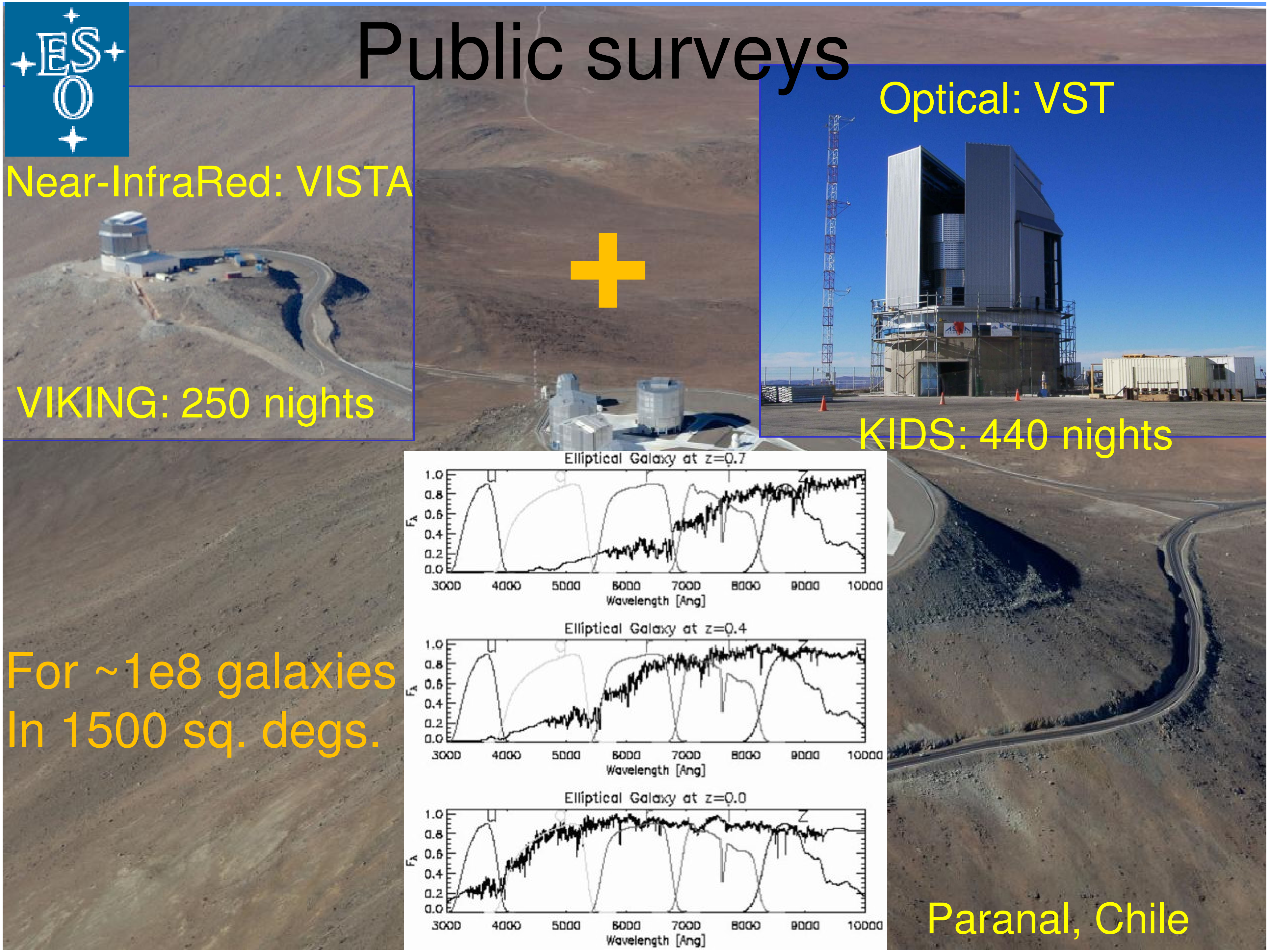
Stellar colors-> stellar physics

Hertzsprung **R**ussell Diagram



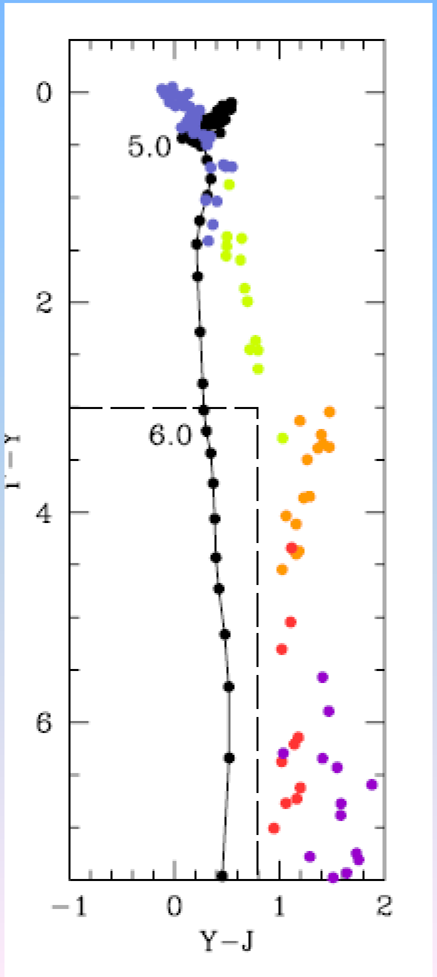


Public surveys

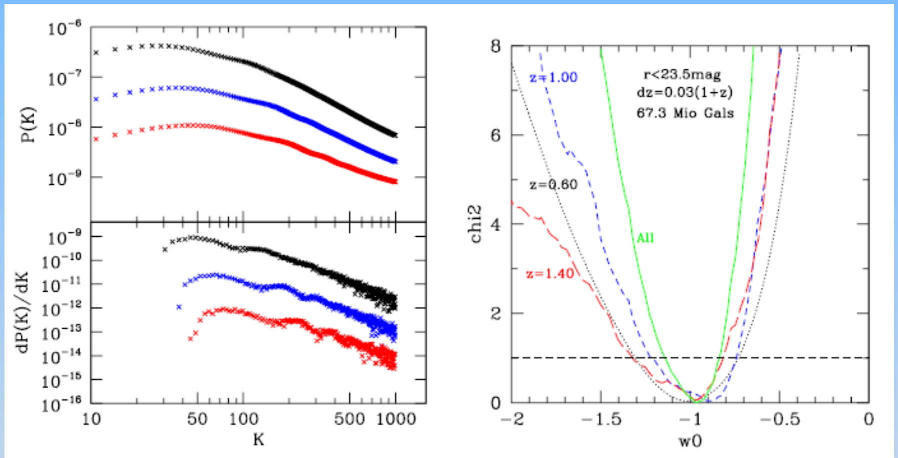


Science from opt+near-IR photometry includes…

Extremely high-z Quasi-Stellar Objects (QSOs) by color

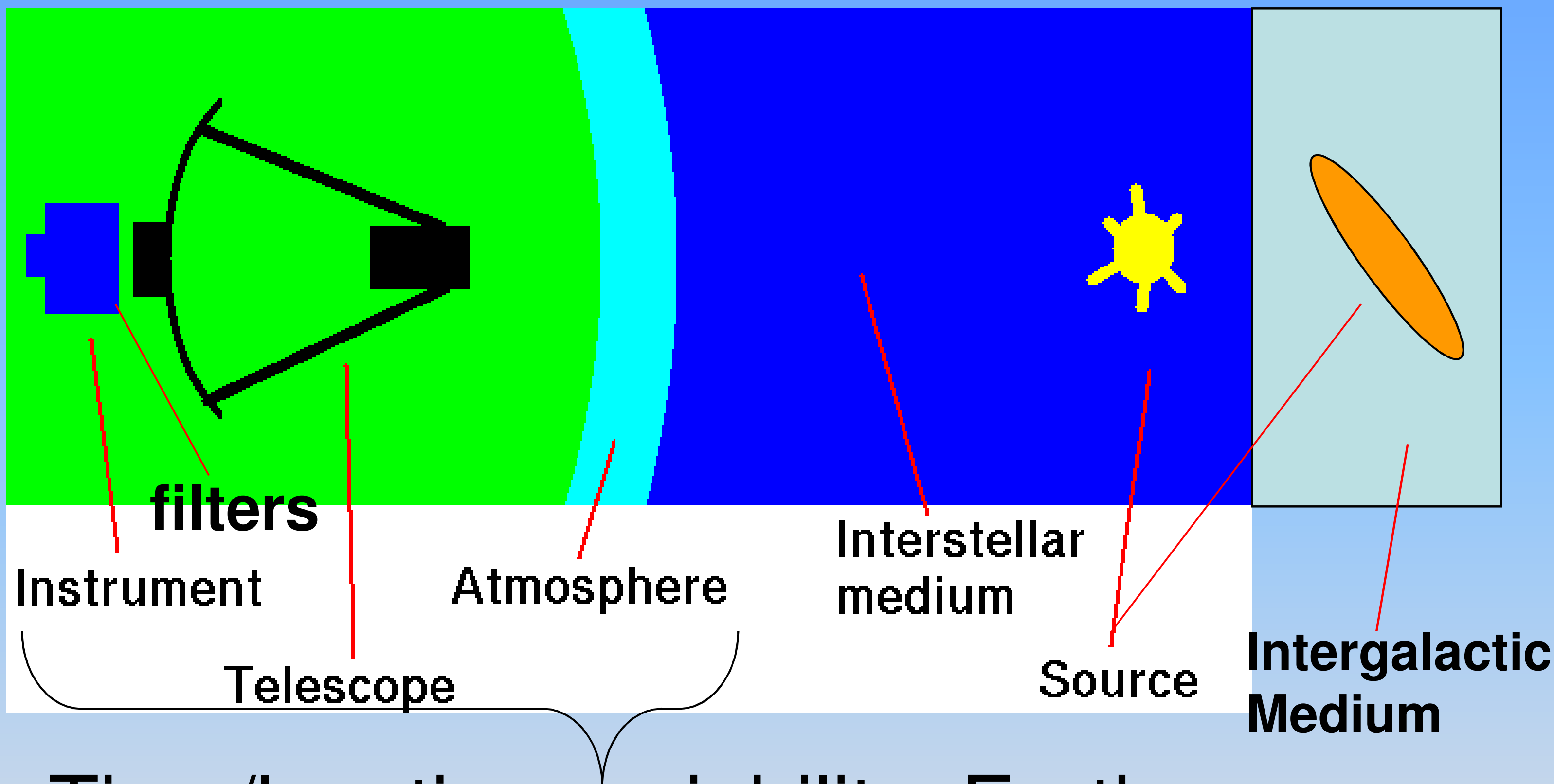


•Evolution of galaxy & clusters, AGNs
•White/Brown dwarfs
•Dark matter from weak-lensing
•Dark energy from BAOs



Redshifts of paramount importance: "phot-z's"
….extremely homogeneous photometry across
•1500 sq. Degrees
• 10 filters
•100's of nights in several years
•100's Tbytes

“Maltreatment” of photons

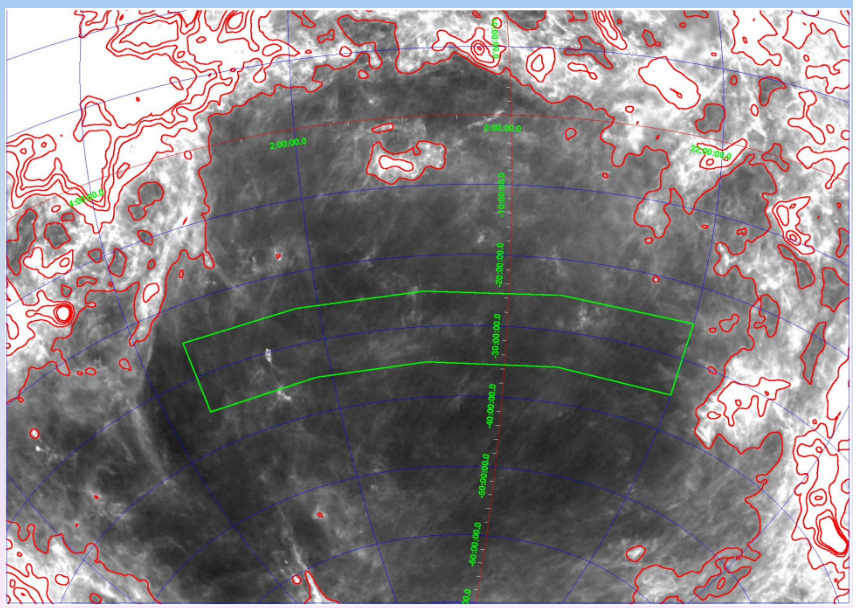


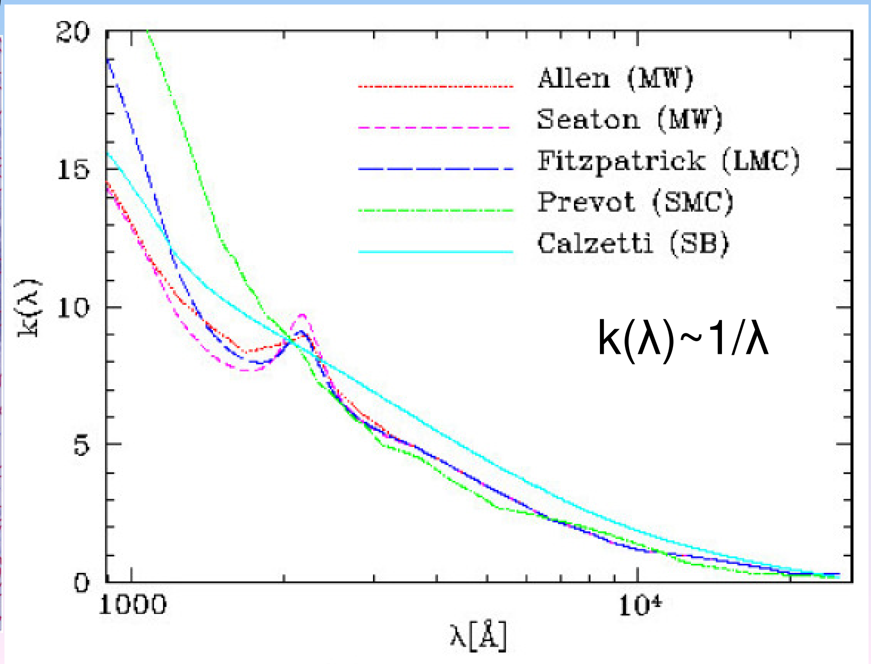
- Time/location-variability: Earth atmosphere, telescopes, filters, detectors.
- How to compare results with this variability?

http://www.sc.eso.org/~isaviane/photometry/Optical%20 Photometry_files/v3_document.htm

Galactic ISM: Interstellar extinction

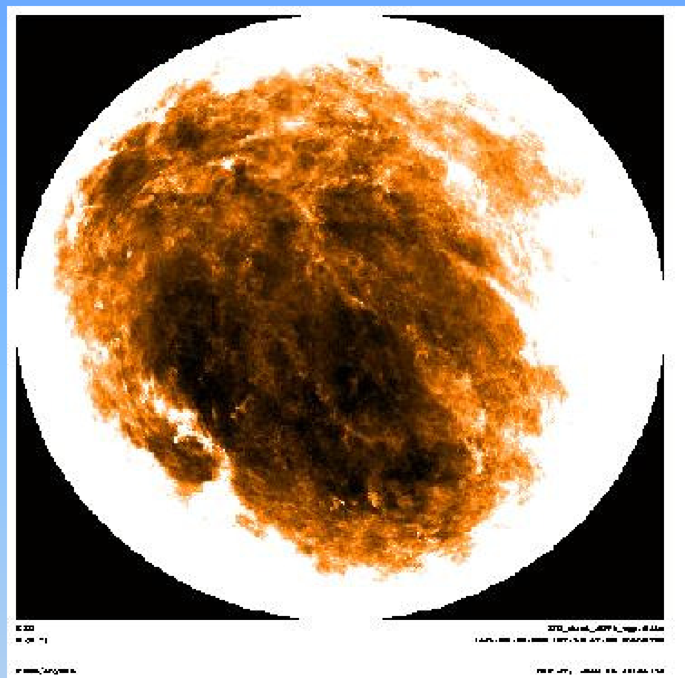
- Discovery: 1930s
- Extinction=(Mie) scattering+absorption by dust particles
- Net effect: reddening

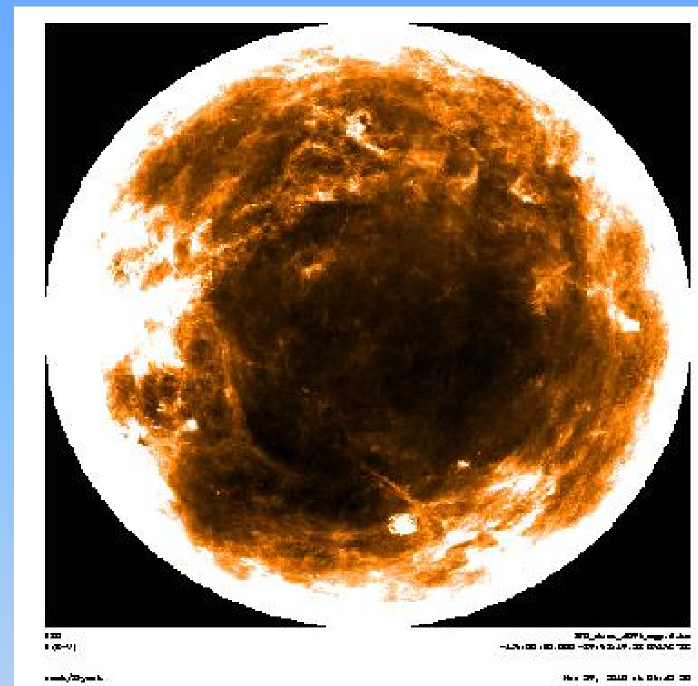


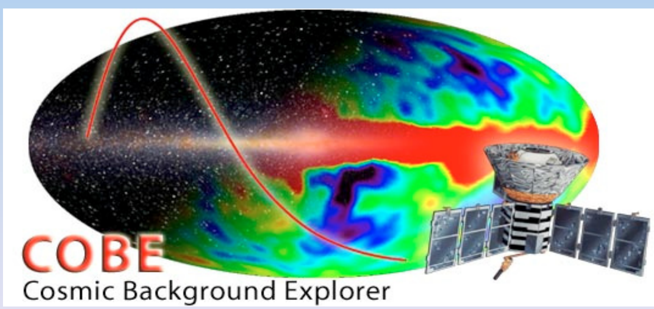


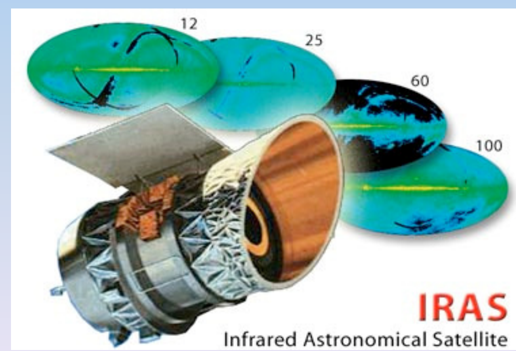
http://webast.ast.obs-mip.fr/hyperz/hyperz_manual1/node10.html

How we got extinction maps….





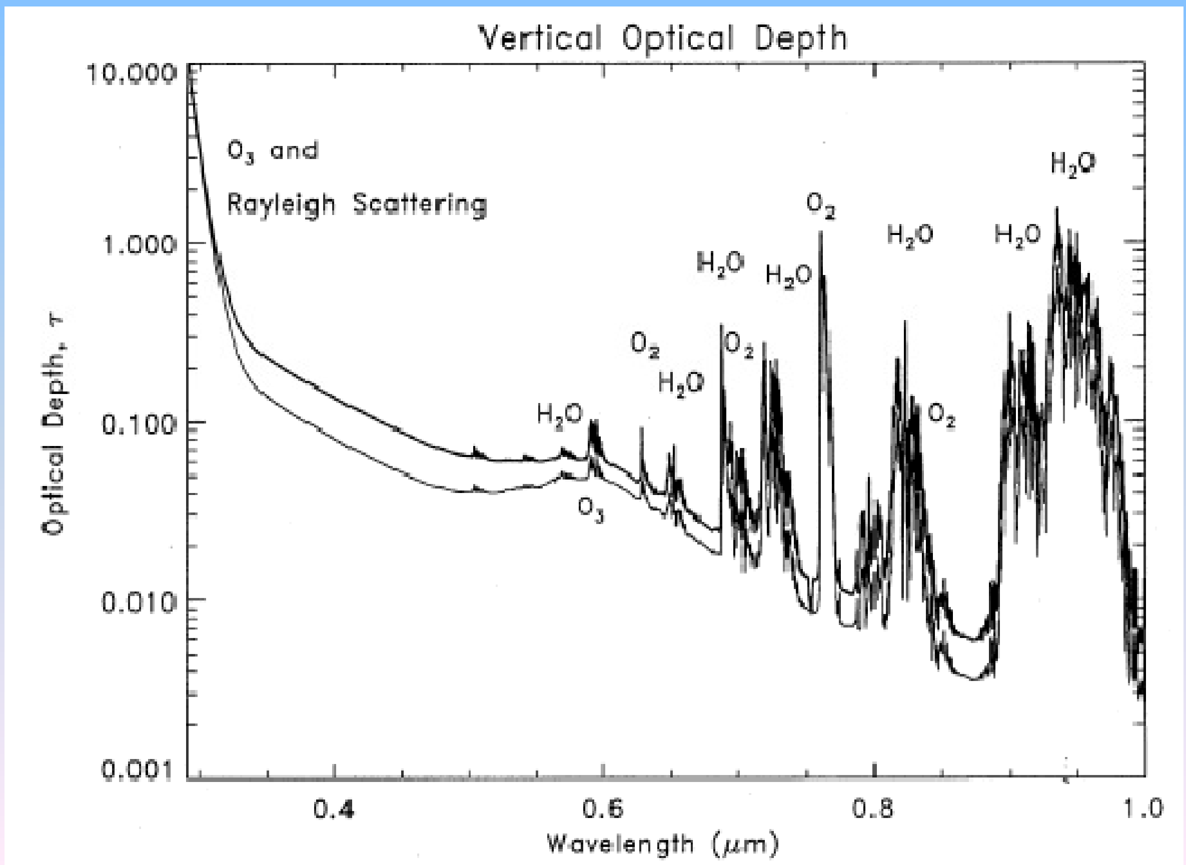




Schlegel, Finkbeiner, Davis, ApJ 500, 525, 1998

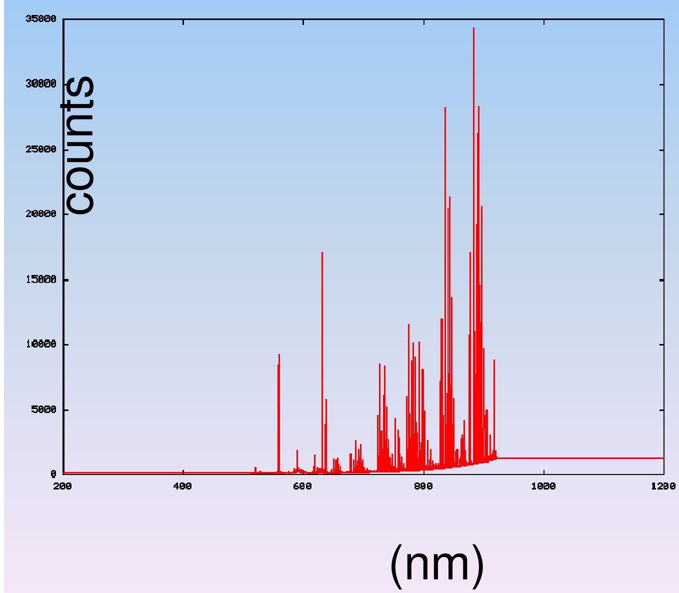
Atmosphere: obscures+shines

- **- Extinction** by dust, aerosols, molecules



Atmosphere: obscures+shines

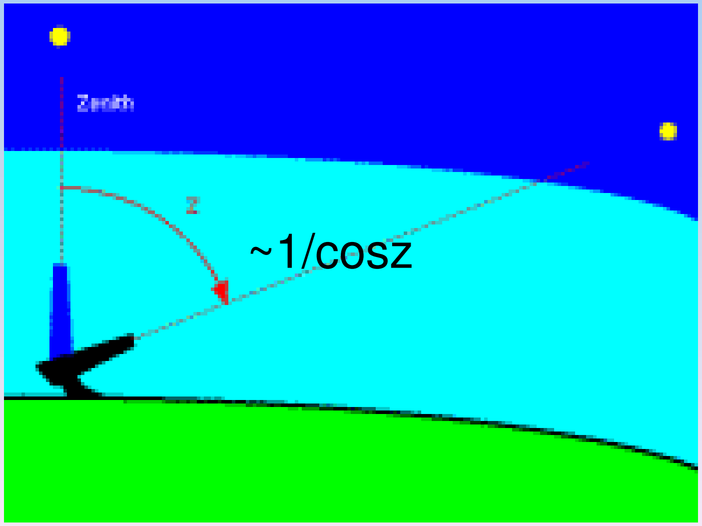
- **Continuum**
- **Line-Emission**



Days from new moon	**Sky Brightness**					
	U	B	V	R	I	z
0	22.0	22.7	21.8	20.9	19.9	18.8
3	21.5	22.4	21.7	20.8	19.9	18.8
7	19.9	21.6	21.4	20.6	19.7	18.6
10	18.5	20.7	20.7	20.3	19.5	18.3
14	17.0	19.5	20.0	19.9	19.2	18.1

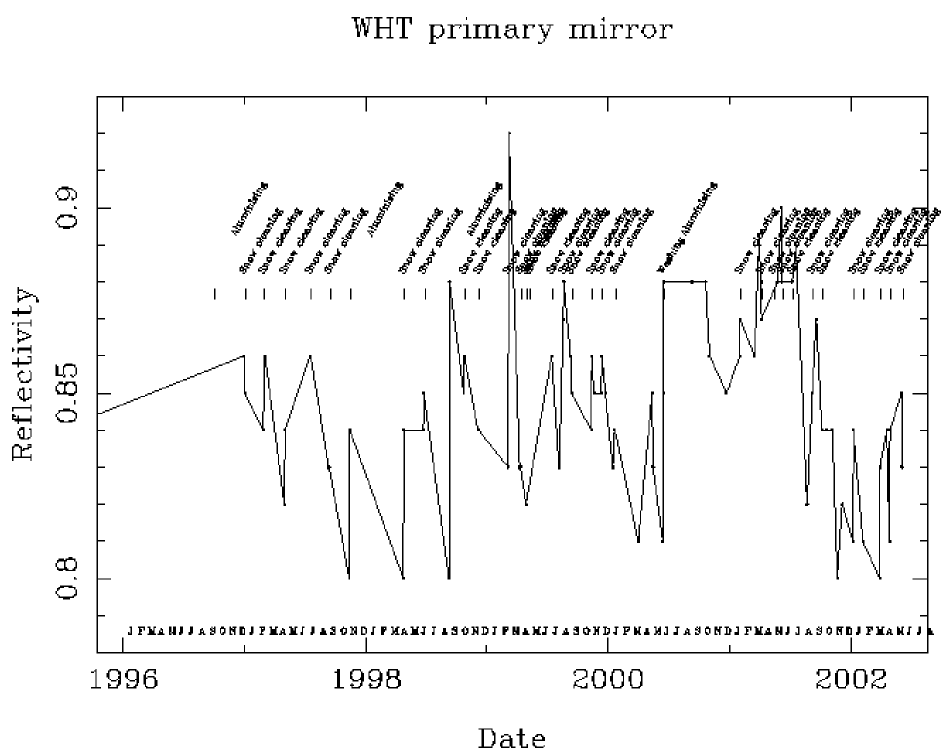
Atmospheric extinction

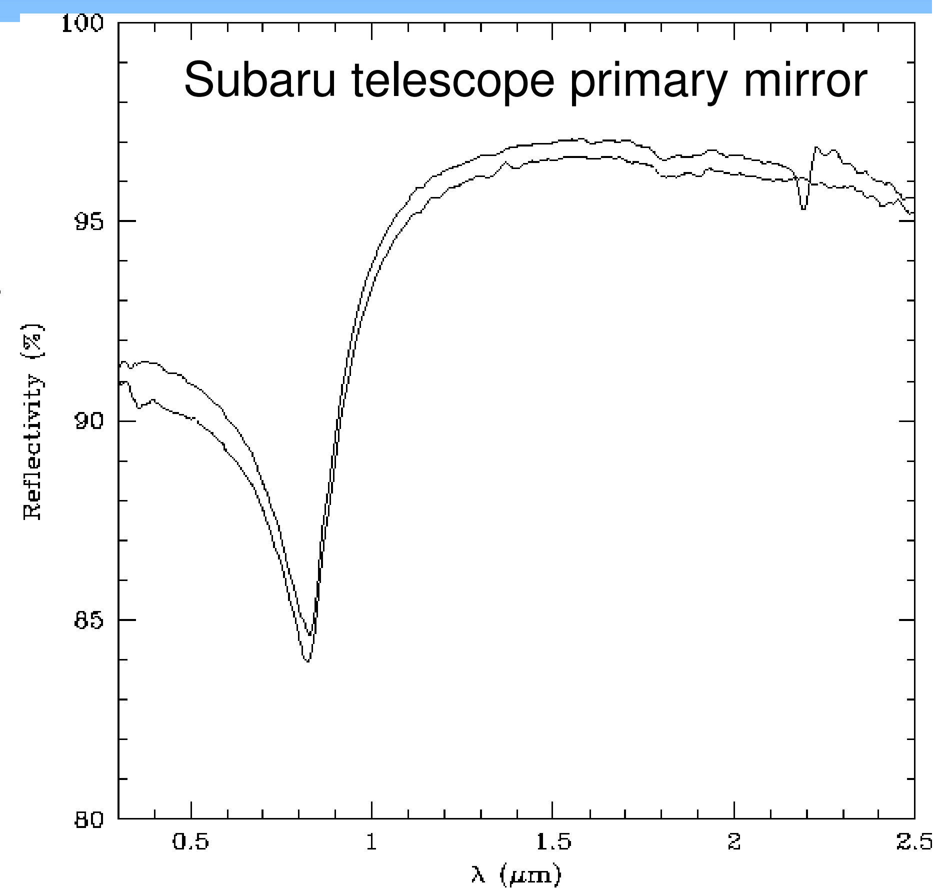
- Extinction per unit atmosphere is time/location dependent (haze, clouds, dust (El Nino)
- Proportional to airmass~1/cosz



Telescope

- Mirrors
- Lenses

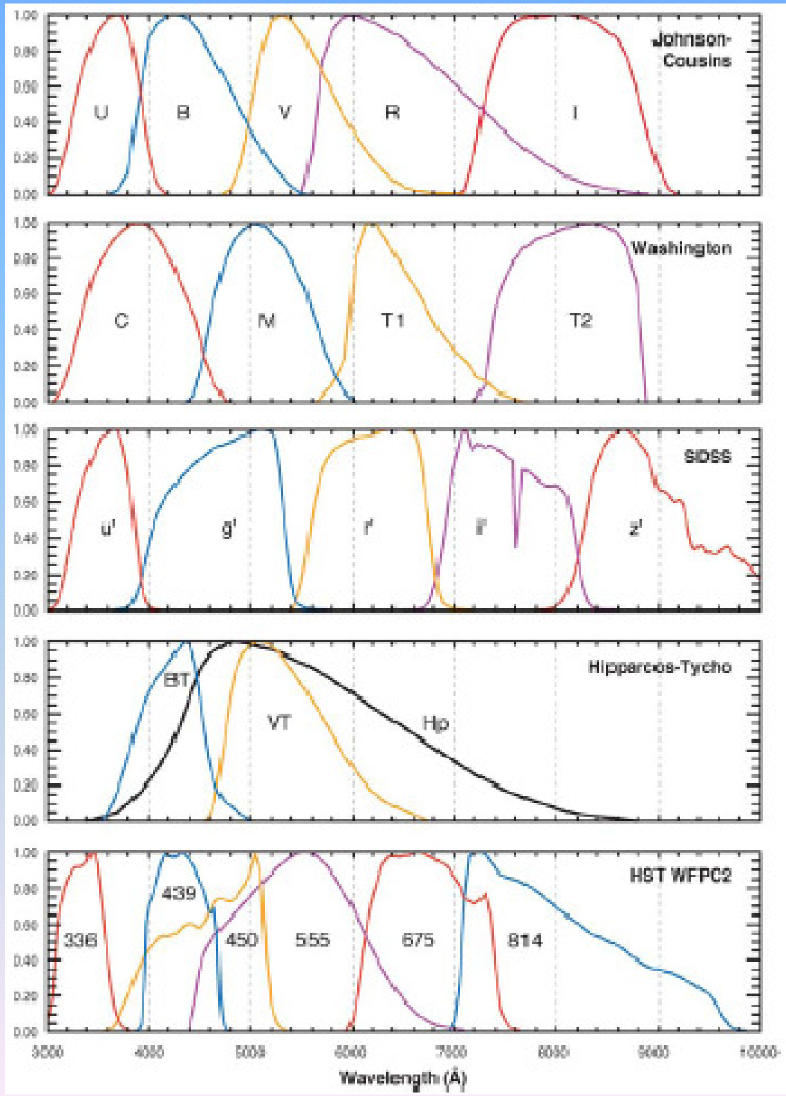




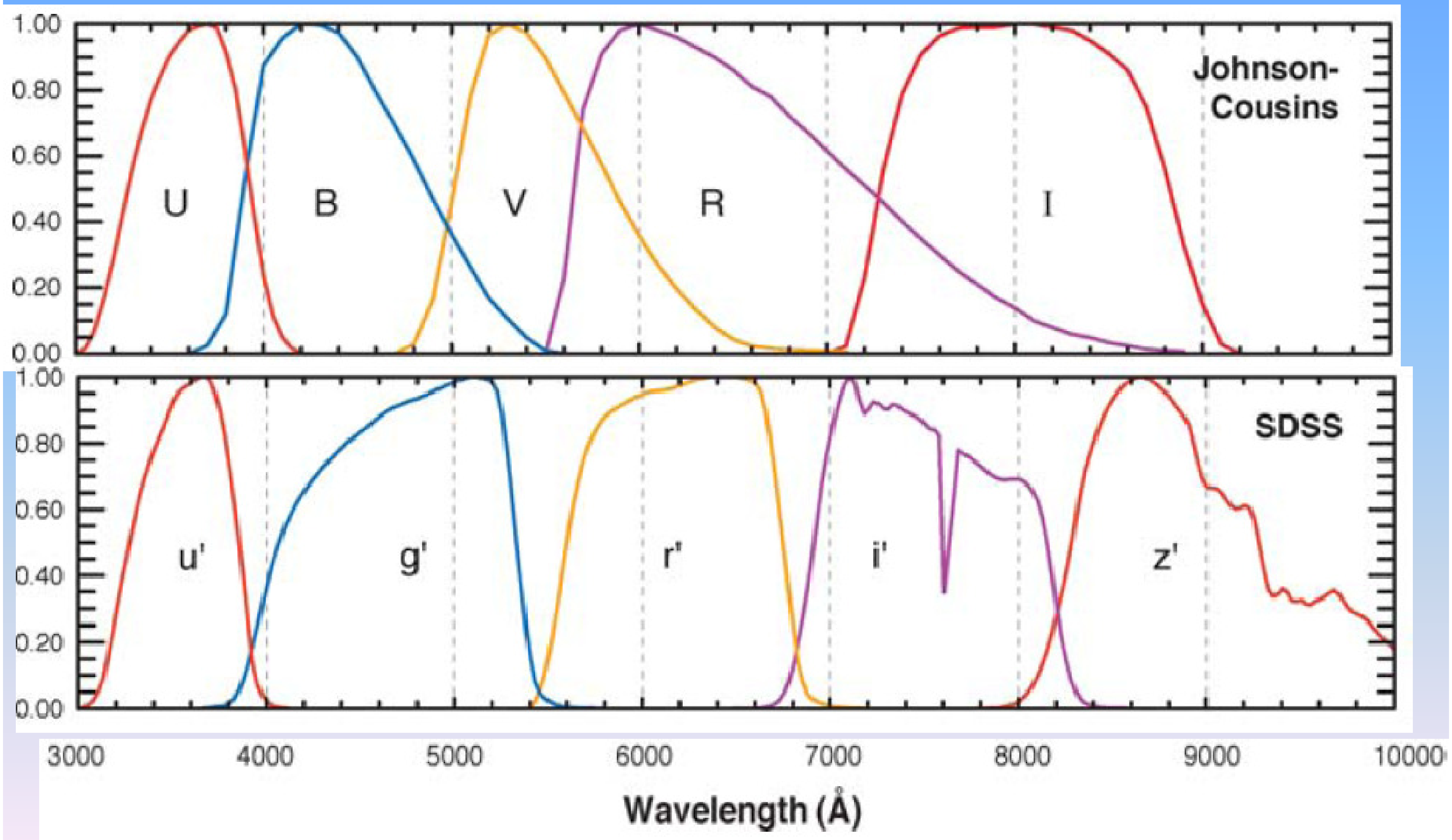
Filters

- Filter widths $\Delta\lambda/\lambda$
  - Narrow <0.02
  - Intermediate 0.02-0.1
  - Wide >0.1
- Filter materials:
  - Glass: red (IR) leaks
  - gelatin films
  - Interference

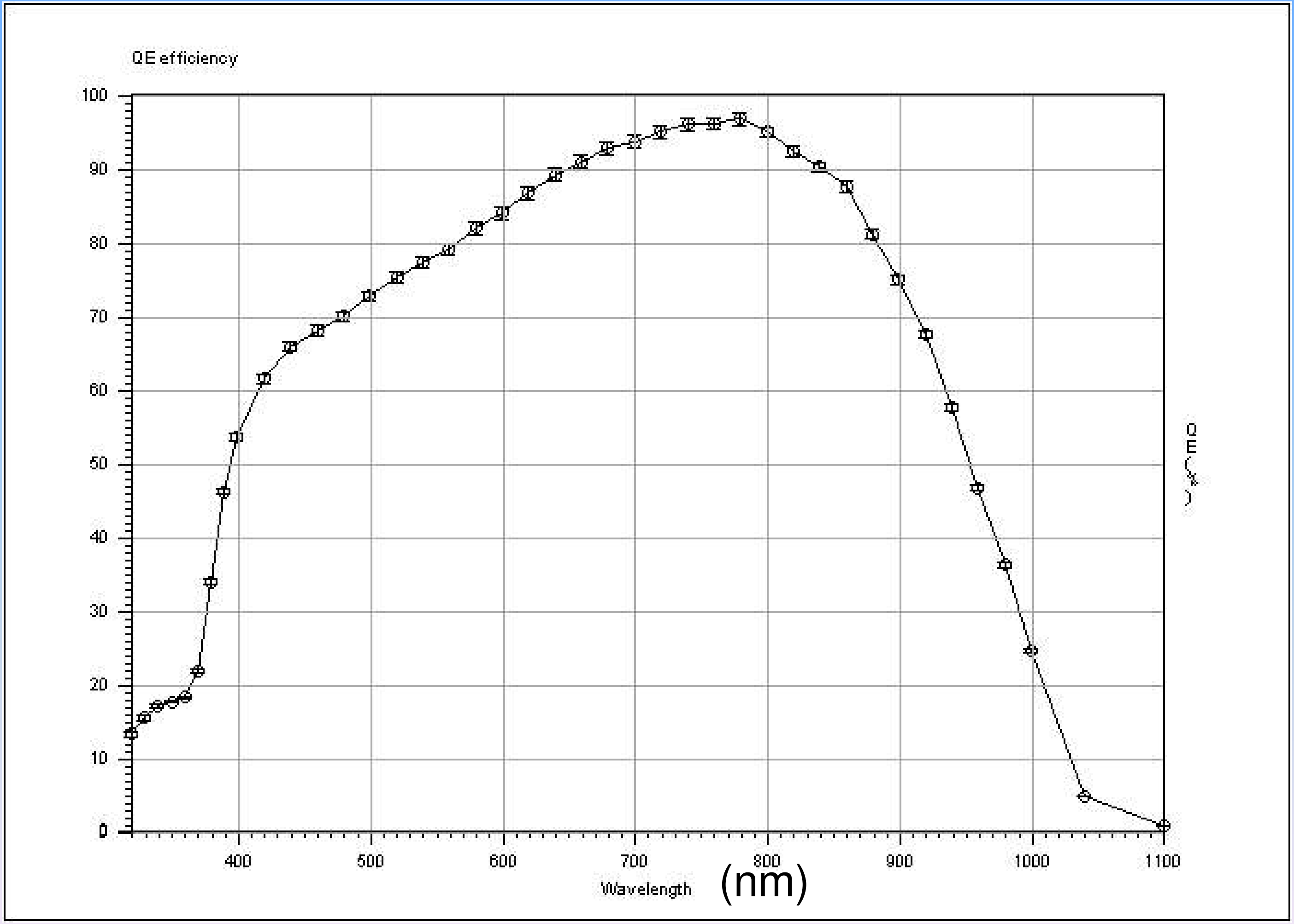
Passbands,transmission curves



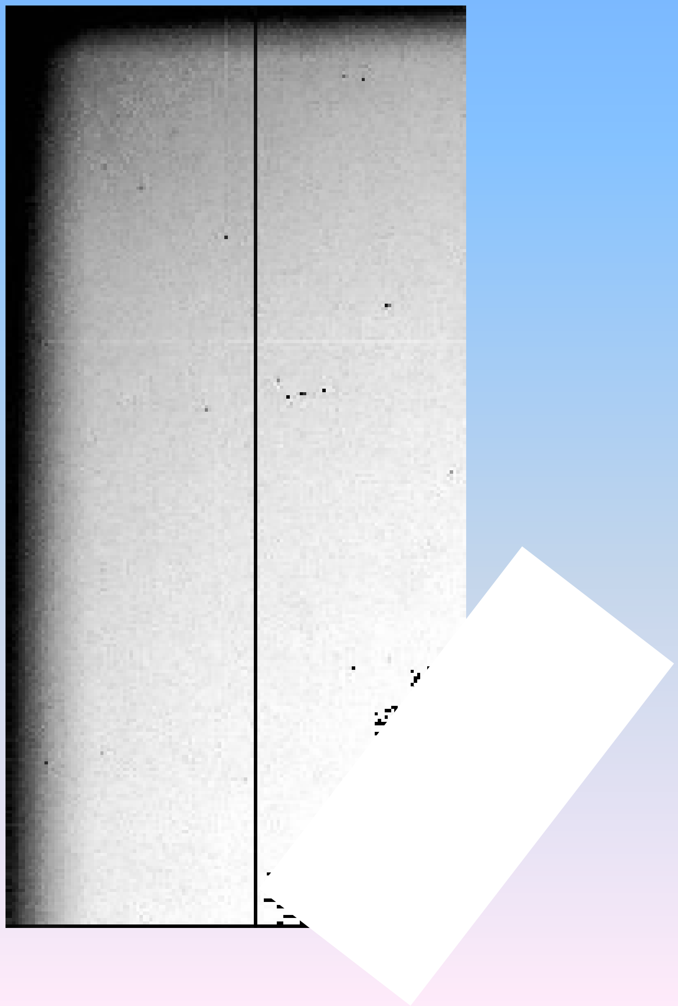
Commonly used filter sets



Detector effects: Quantum efficiency



Detector effects: pixel to pixel variation quantum efficiency: flatfield

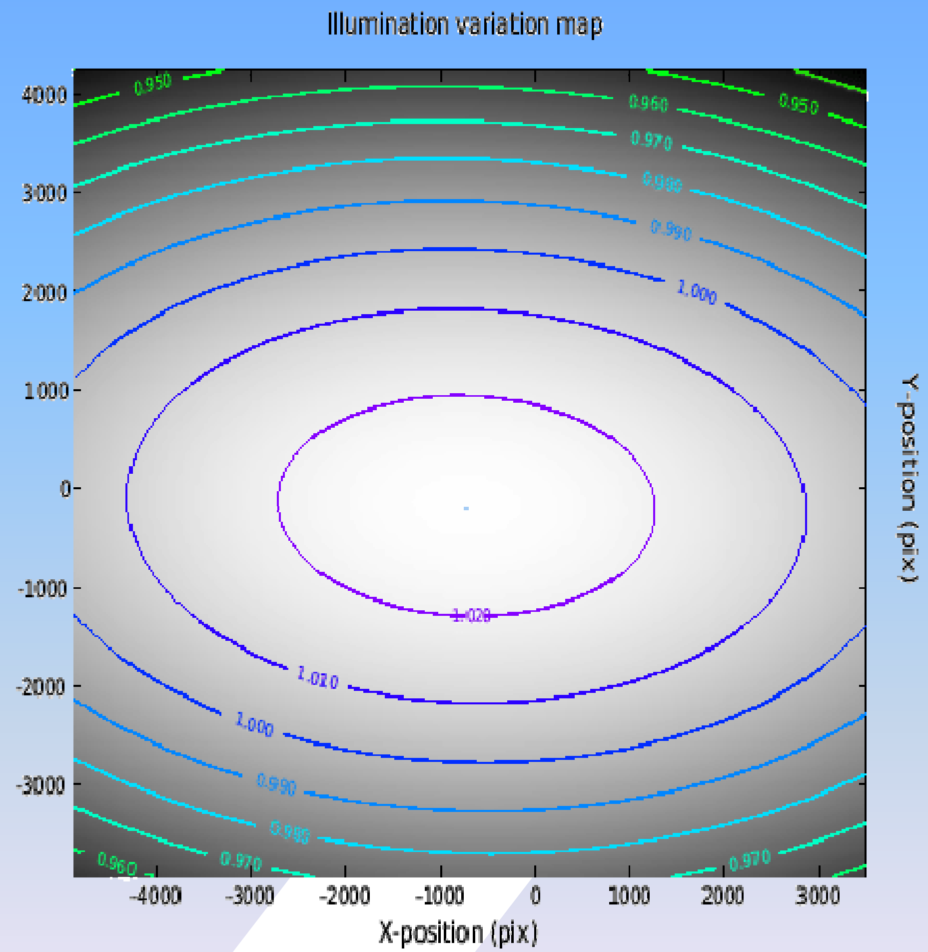


Detector effects: fringing

Fringing= variation in background light

- Origin: Interference of nightsky lines within CCD
- More pronounced in red part spectrum
- *Only affects "background" light*

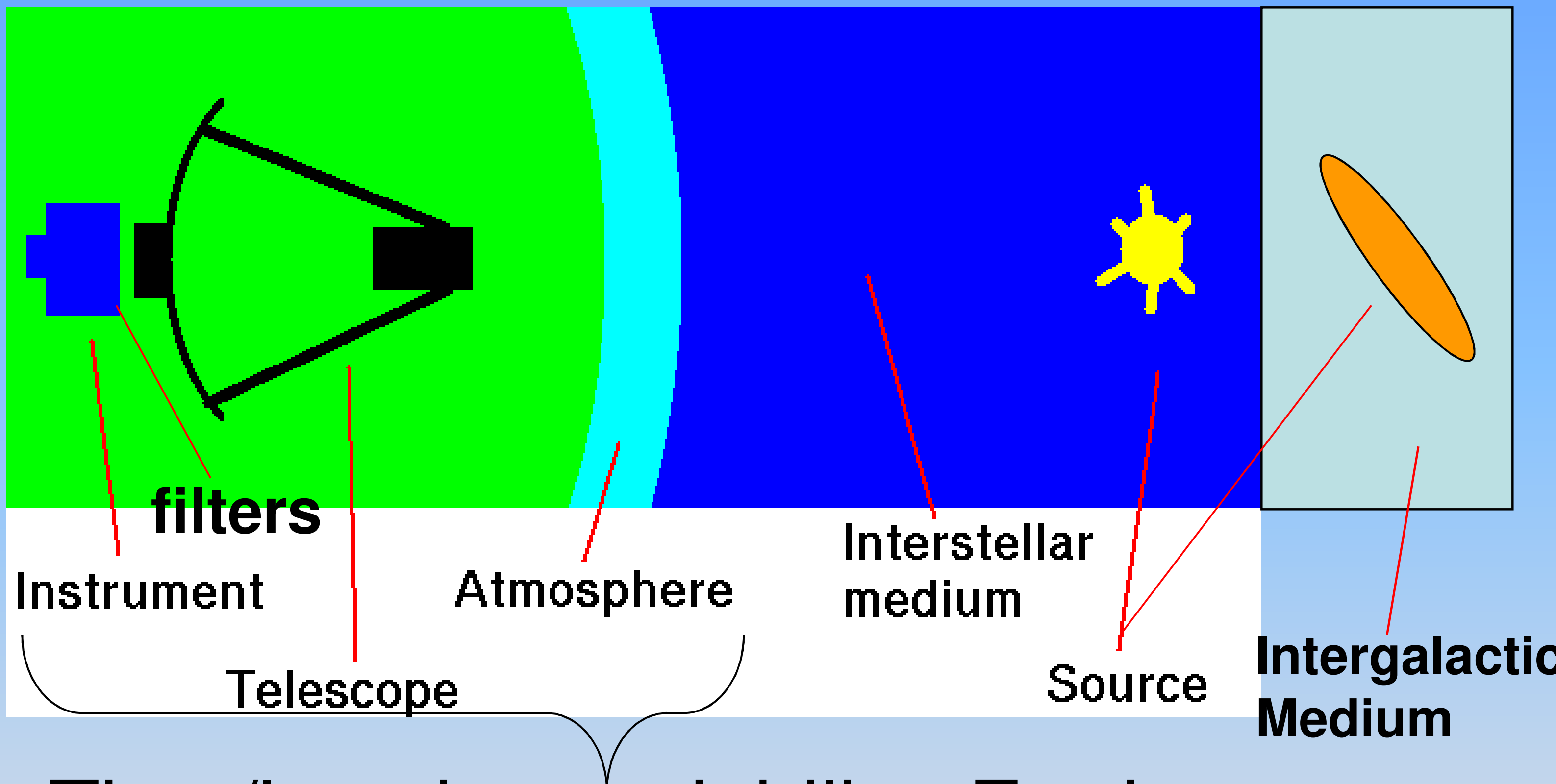
Detector effects: illumination variation



•due to internal scattering of light in instrument

•*Affects both source and background light*

"Maltreatment" of photons



- Time/location-variability: Earth atmosphere, telescopes, filters, detectors.
- How to compare results with this variability?

http://www.sc.eso.org/~isaviane/photometry/Optical%20
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Solution: relative measurements

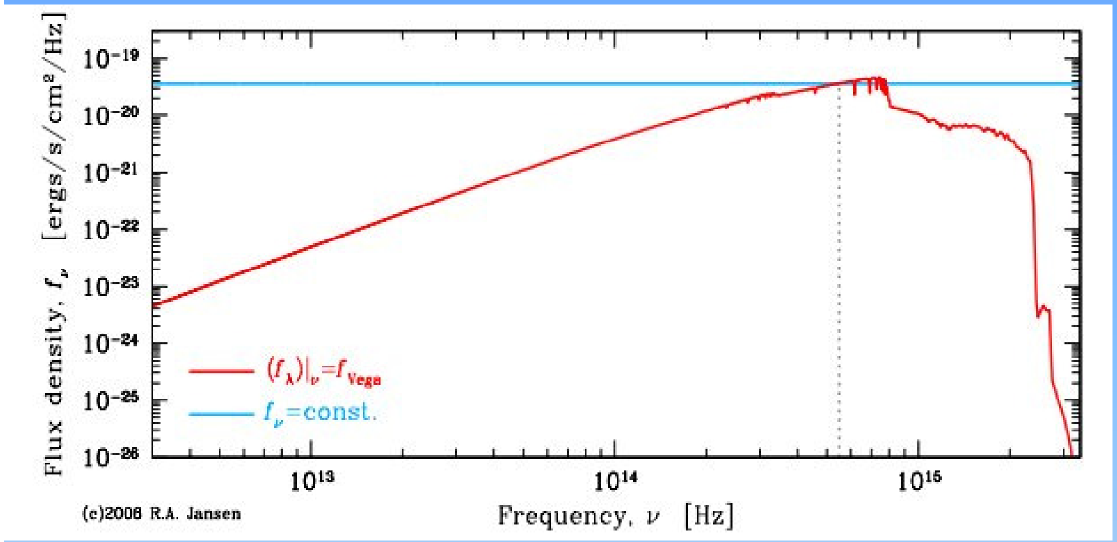
- Measure relative to flux I_0 of reference object:

$$m - m_0 = -2.5 \log_{10} (I/I_0)$$

  - i.e., measure (I/I_0) instead of I: constants cancel

- Unitless system
- $m_0 = -2.5 \log_{10} (I_0/I_0) = 0$ by definition
- I_0 proportional to flux, but can have arbitrary units:
  - $m = -2.5 \log_{10}$ (countrate) +zeropoint

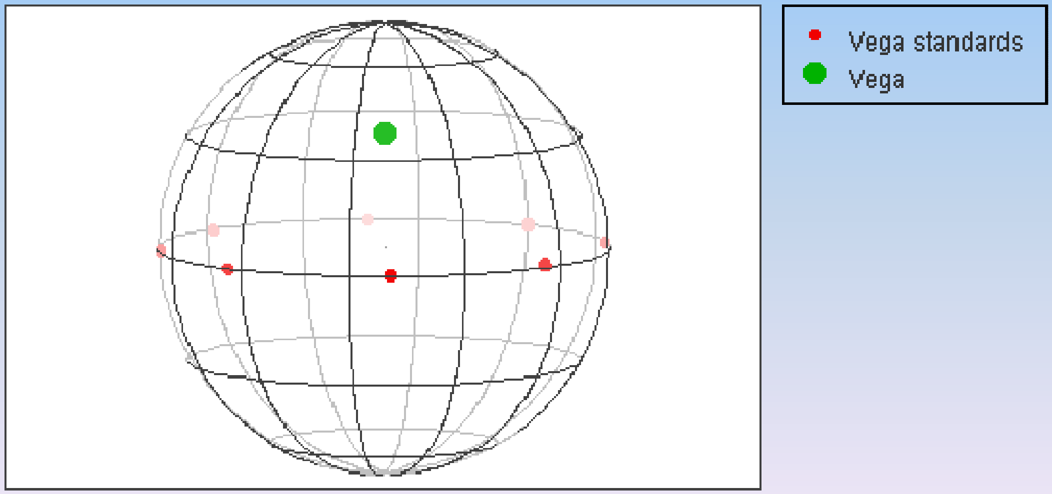
I_0: Vega vs AB



$$m = -2.5 \log_{10}\left(\frac{S}{S_0}\right)$$

$$m = 8.9 - 2.5 \log_{10}\left(\frac{S}{Jy}\right)$$

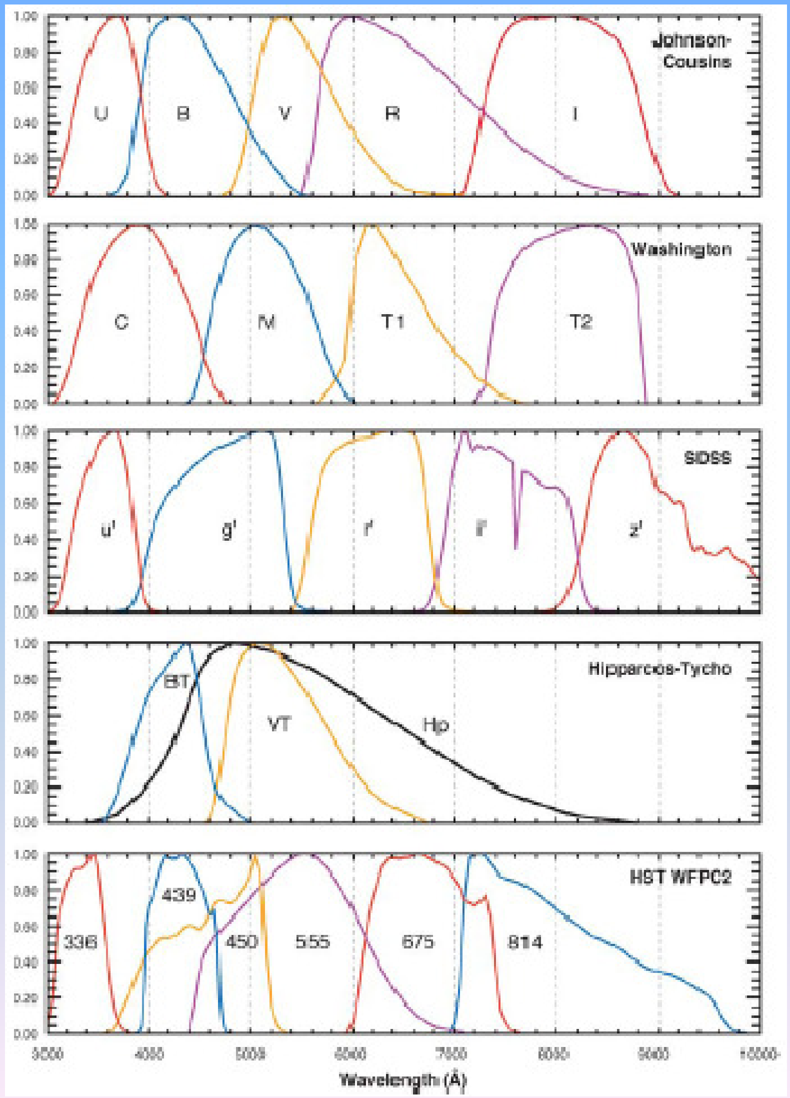
NB: $S = \int I(\lambda) \text{SystemResponse}(\lambda) d\lambda$



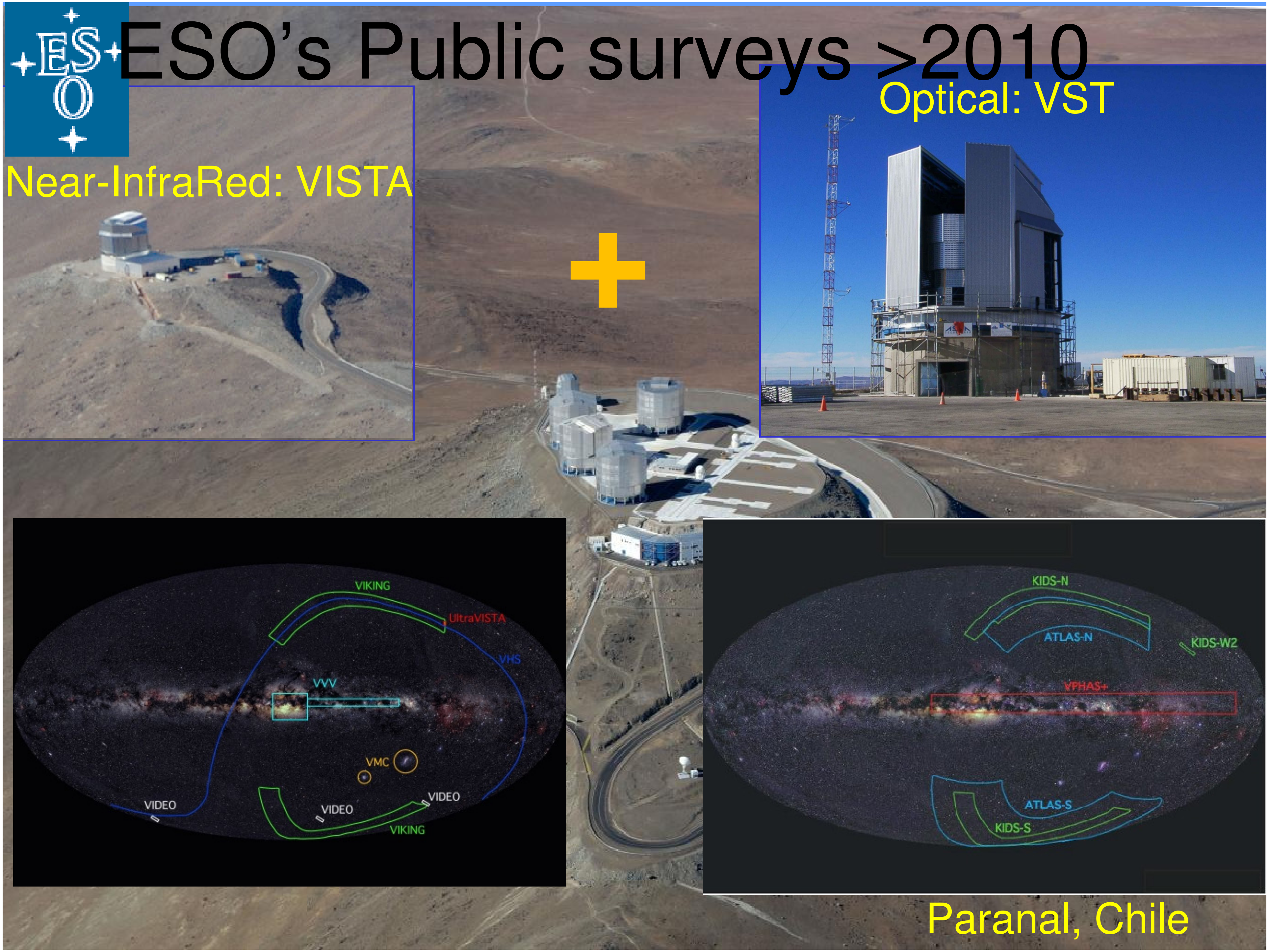
Large-scale surveys offer tertiary standards

Photometric standard systems

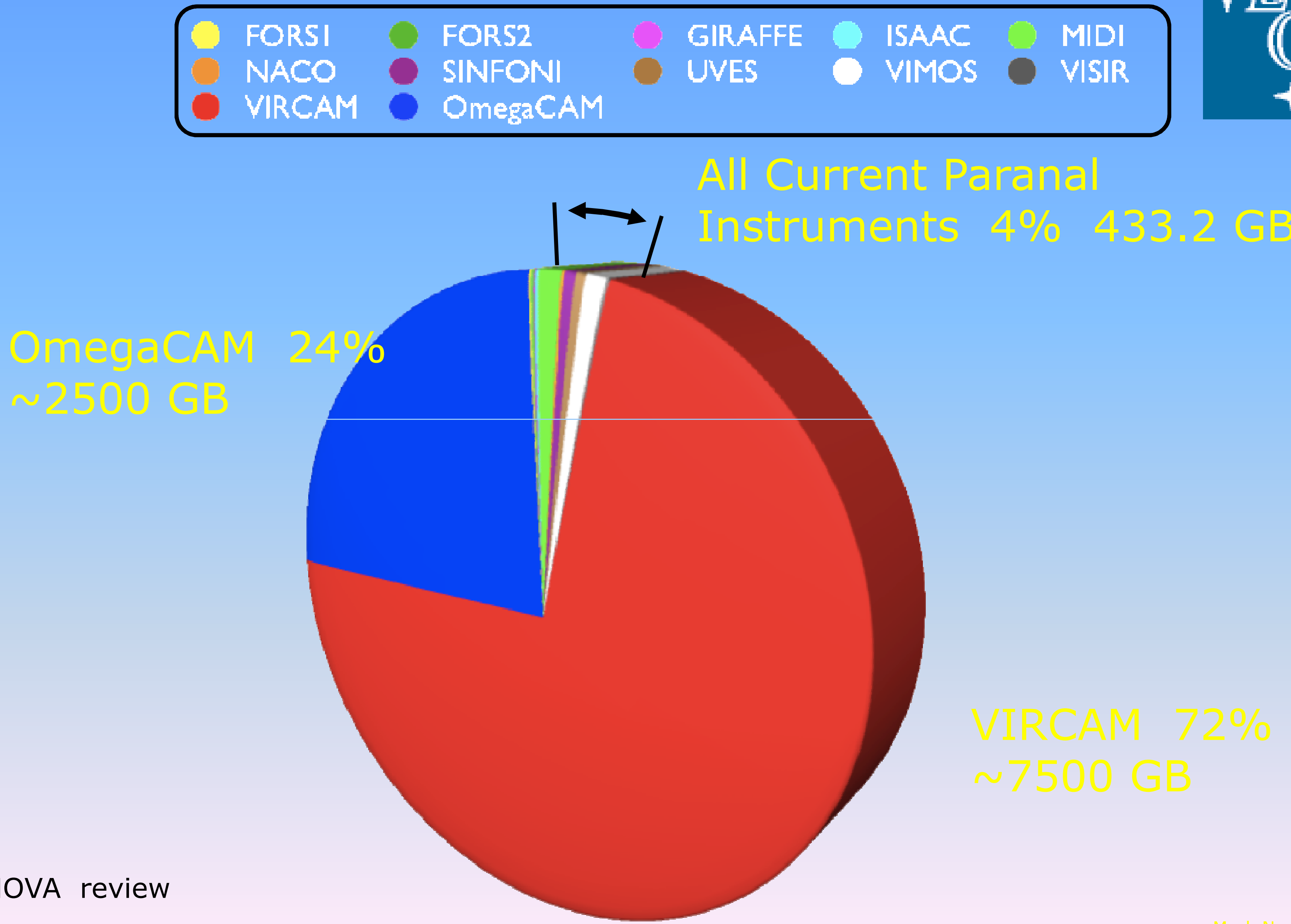
- Goal: putting mags on common scale
- Standard system=
  - telescope+filter+detector
- Natural system=
  - Your telescope+filter+detector
- Convert your measurements as if observed with standard system
- Example standard systems:
  - Johnson-Cousins
  - Sloan
  - Stroemgren
  - Walraven



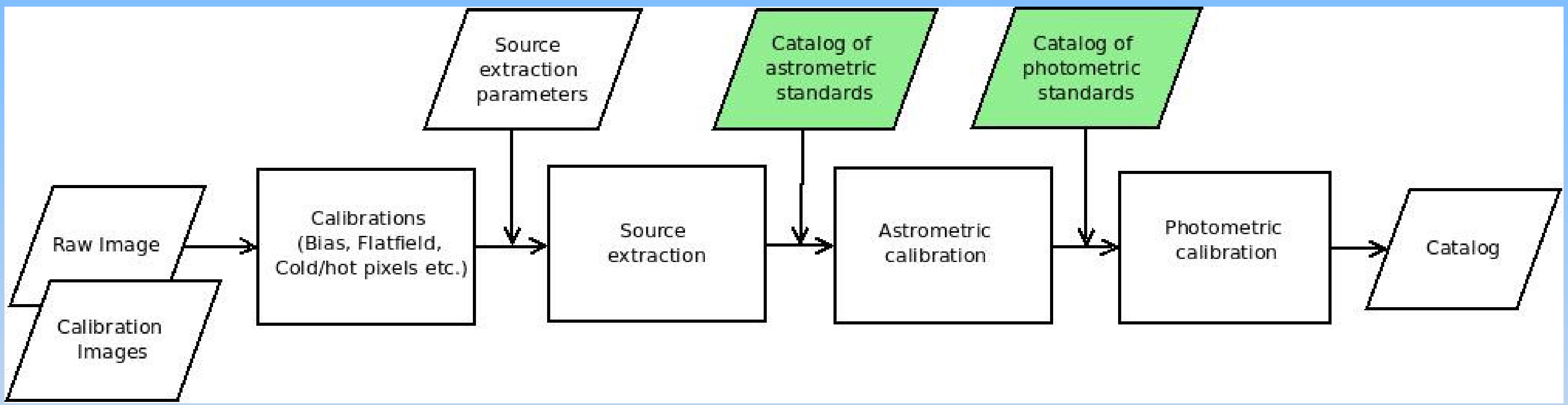
ESO's Public surveys >2010



Paranal Monthly Data Rates 2007 statistics



Modelling & Standardizing astronomical observations



Surveys

"What one observes"

- Effects of ism, atmosphere, telescope, filter and detector QE and flatfielding are multiplicative gains:
  - $I_{obs} = I*g_{ISM}(\alpha,\delta) * g_{atm}(k,z_0) * g_{tel}*g_{filt1}* g_{det1}(x,y)$
  - $I_{0,obs} = I_0*g_{ISM}(\alpha_0,\delta_0) * g_{atm}(k,z) * g_{tel1}*g_{filt1}* g_{det1}(x_0,y_0)$

(neglecting fringing and illumination correction)

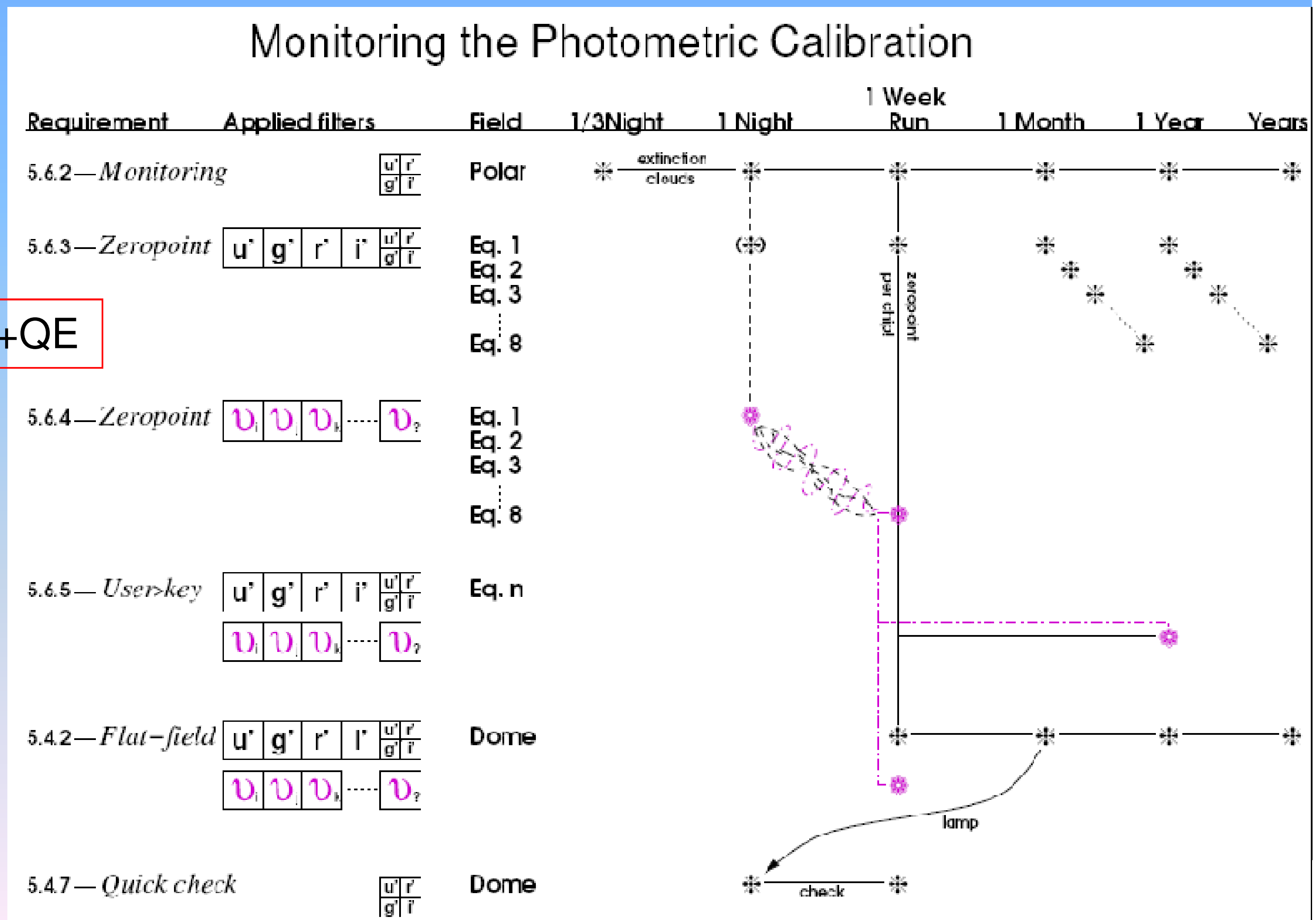
- For telescope2,filter2,detector2 (remember VISTA & VST):
  - $I_{obs} = I*g_{ISM}(\alpha,\delta)*g_{atm}(k,z)*g_{tel2}*g_{filt2}*g_{det2}(x,y)$
  - $I_{0,obs} = I_0*g_{ISM}(\alpha_0,\delta_0)*g_{atm}(k,z_0)*g_{tel2}*g_{filt2}*g_{det2}(x_0,y_0)$

Integrating up-link and down-link: Determining gains translate into procedurized observations

Atmosphere

Telescope+filter+QE

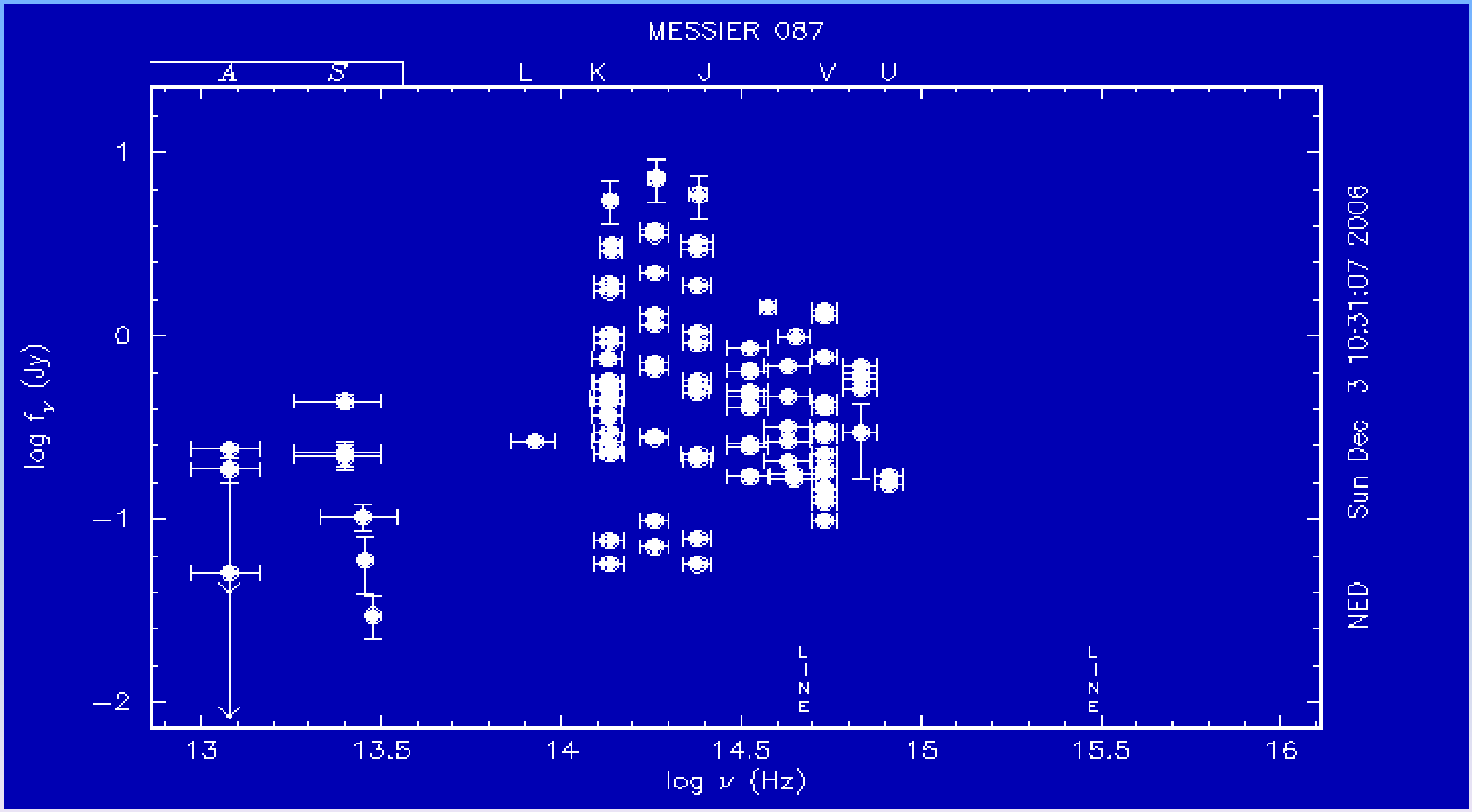
Flatfielding



Unified Content Descriptors for photometry (Virtual Observatory)

- E | phot | Photometry
- E | phot.antennaTemp | Antenna temperature
- Q | phot.calib | Photometric calibration
- C | phot.color | Color index or magnitude difference
- Q | phot.color.excess | Color excess
- Q | phot.color.reddFree | Dereddened, reddening-free color
- E | phot.count | Flux expressed in counts
- E | phot.fluence | Fluence
- E | phot.flux | Photon flux
- Q | phot.flux.bol | Bolometric flux
- E | phot.flux.density | Flux density (per wl/freq/energy interval)
- E | phot.flux.density.sb | Flux density surface brightness
- E | phot.flux.sb | Flux surface brightness
- E | phot.limbDark | Limb-darkening coefficients
- E | phot.mag | Photometric magnitude
- Q | phot.mag.bc | Bolometric correction
- Q | phot.mag.bol | Bolometric magnitude
- Q | phot.mag.distMod | Distance modulus
- E | phot.mag.reddFree | Dereddened magnitude
- E | phot.mag.sb | Surface brightness in magnitude units

How to compare magnitudes of extended sources…



NED: http://nedwww.ipac.caltech.edu

END
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&
Virtual Observations