Astronomical observations: an introduction for physicists

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See: https://arxiv.org/abs/1812.07963

What do astronomers measure?

Spectral irradiance, flux density, spectral radiance, specific intensity, monochromatic flux

$$f_\nu(\theta, \varphi, \nu, t)$$

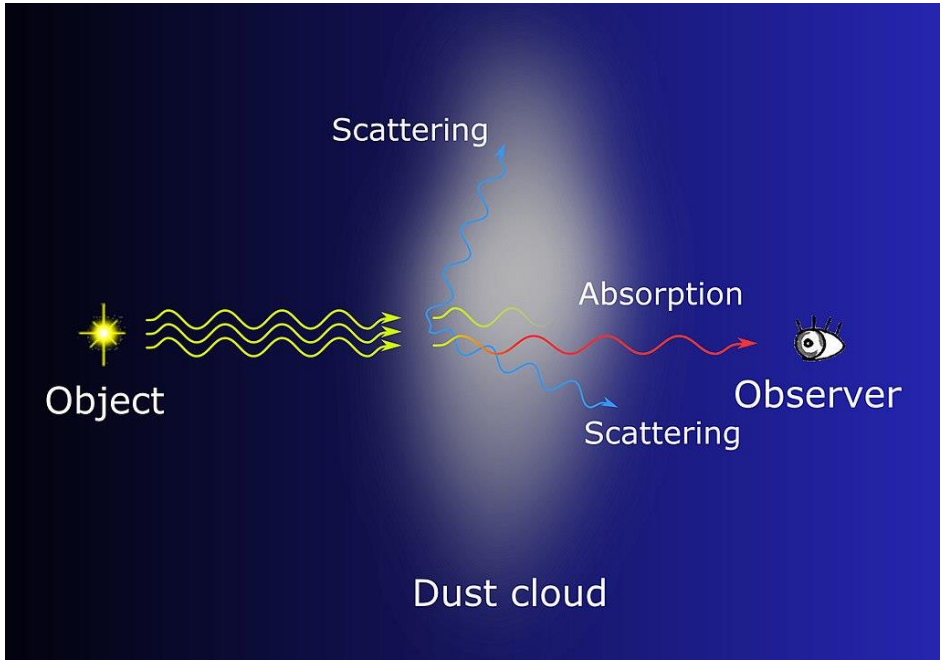
$\mathrm{W\ m^{-2}\ Hz^{-1}\ sr^{-1}}$

$$f_\lambda(\theta, \varphi, \lambda, t)$$

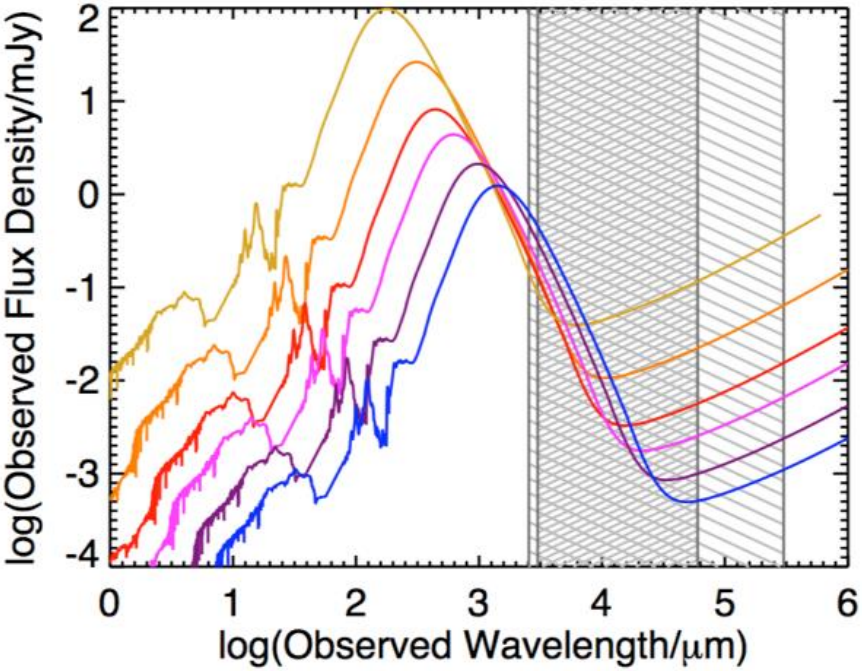
$\mathrm{W\ m^{-3}\ sr^{-1}}$
$\mathrm{W\ m^{-2}\ \mu m^{-1}\ sr^{-1}}$
$\mathrm{W\ m^{-2}\ \text{Å}^{-1}\ sr^{-1}}$

The universe gets in the way

Scattering, absorbing

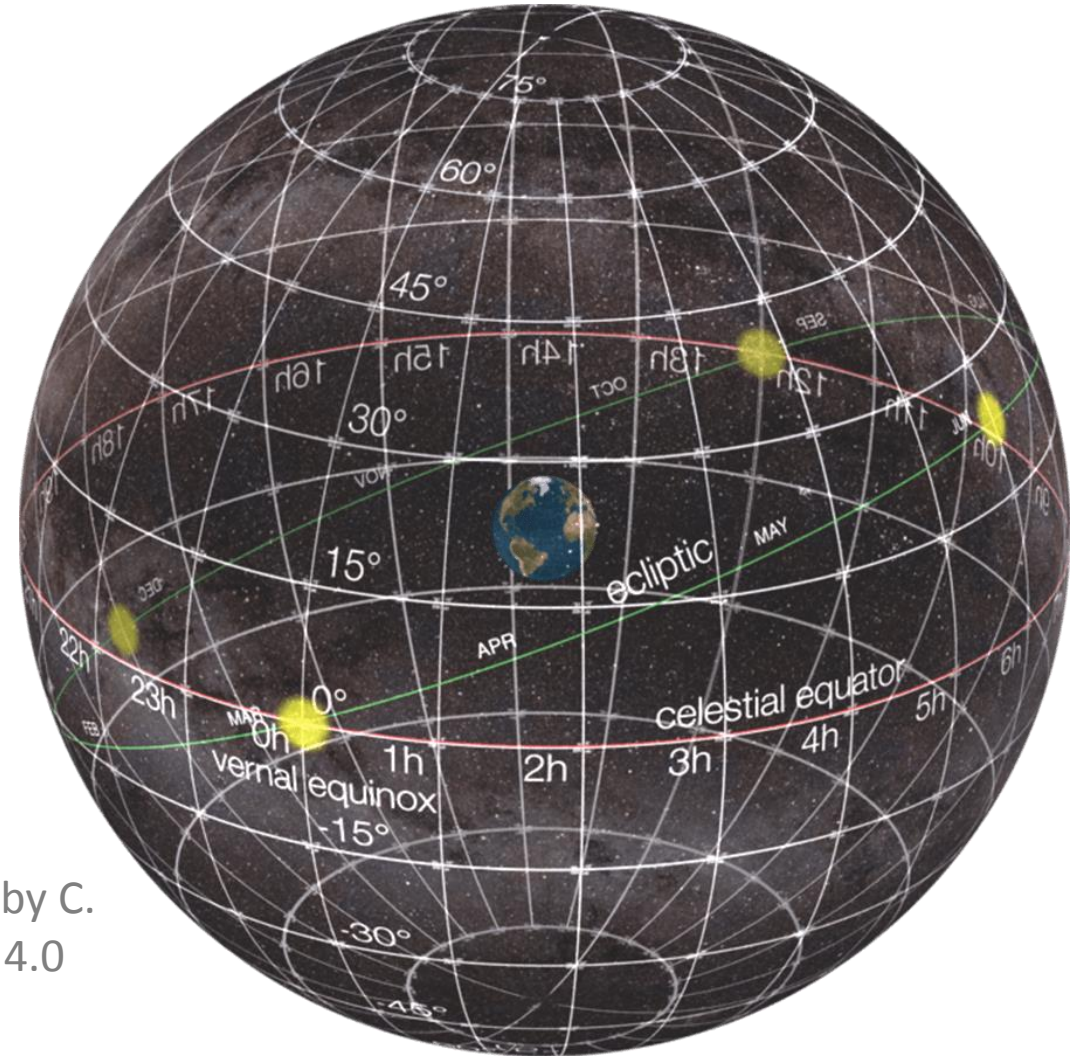


Redshifting



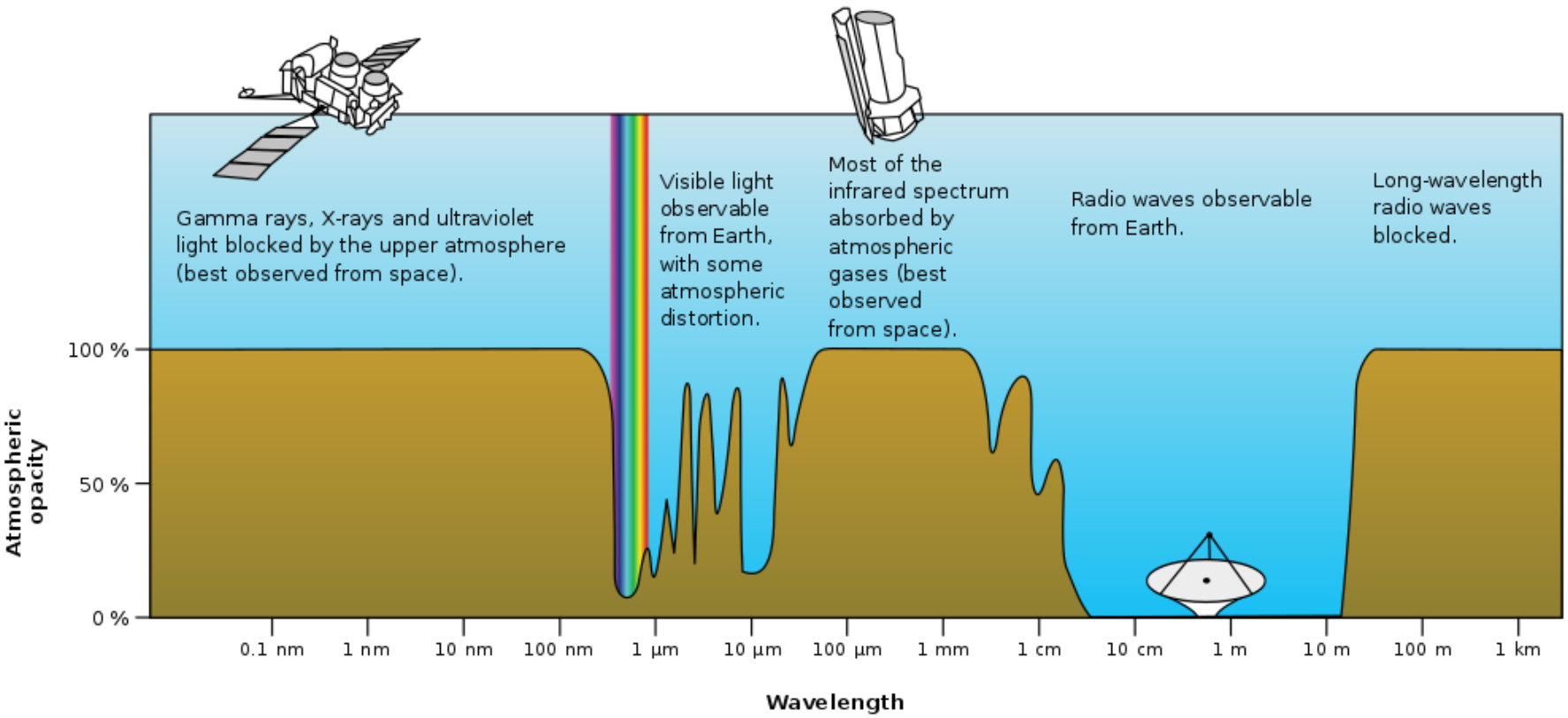
Casey et al 2015

Earth & Sun get in the way



Celestial Sphere – Full - Image by C. Ready under License CC BY-SA 4.0 via Wikimedia Commons

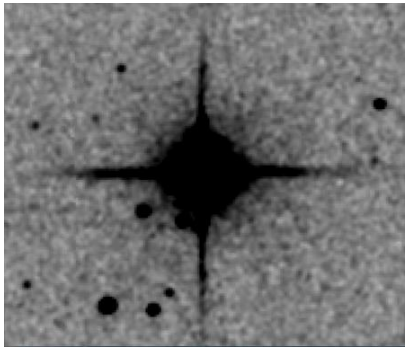
Earth's atmosphere gets in the way

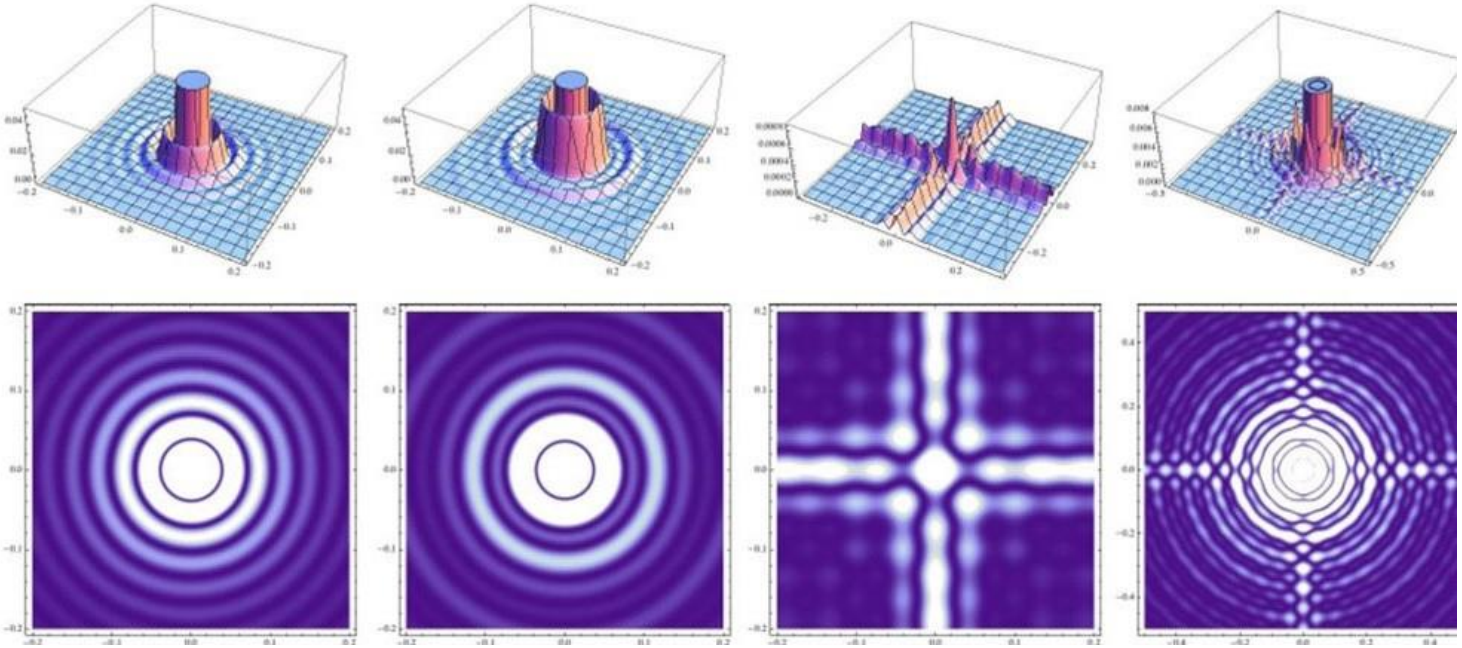


NASA, public domain via Wikimedia Commons

Telescopes improve spatial resolution

$$\theta \propto \lambda / D$$

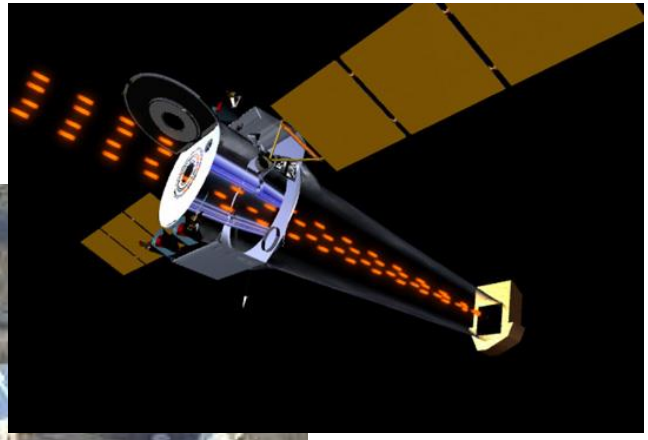




Moretto 2013

Telescopes improve sensitivity

$$A \propto D^2$$



Gemini Observatory/AURA
NASA/CXC/D. Berry
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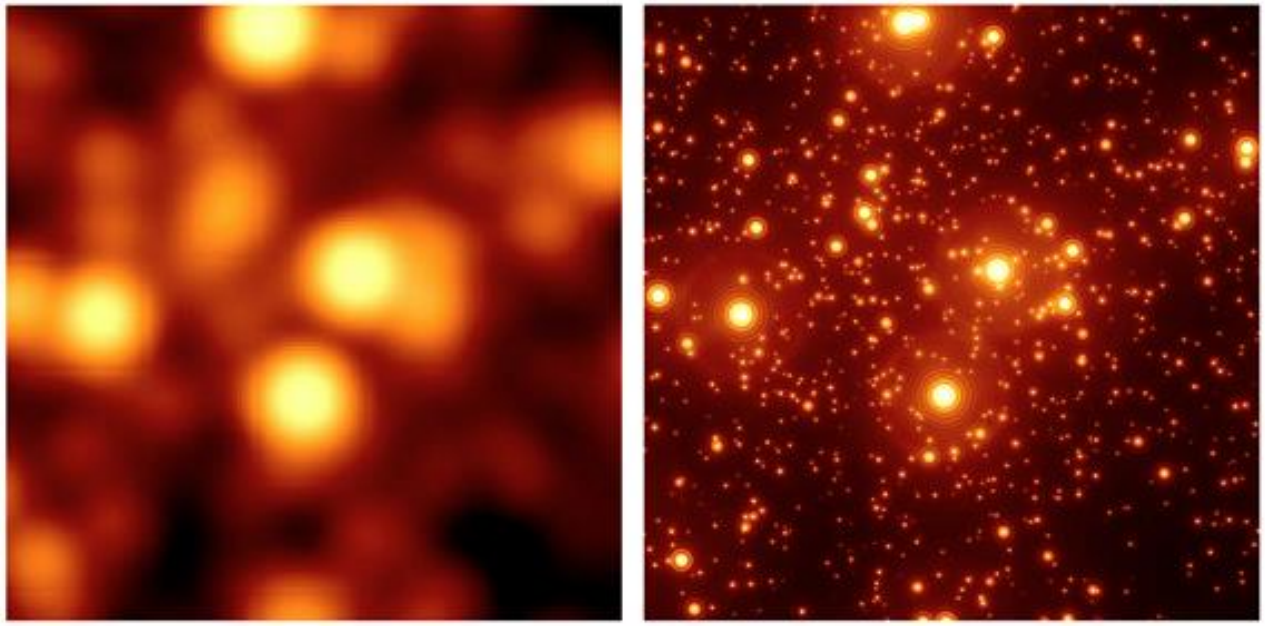
Adaptive optics improves resolution & sensitivity

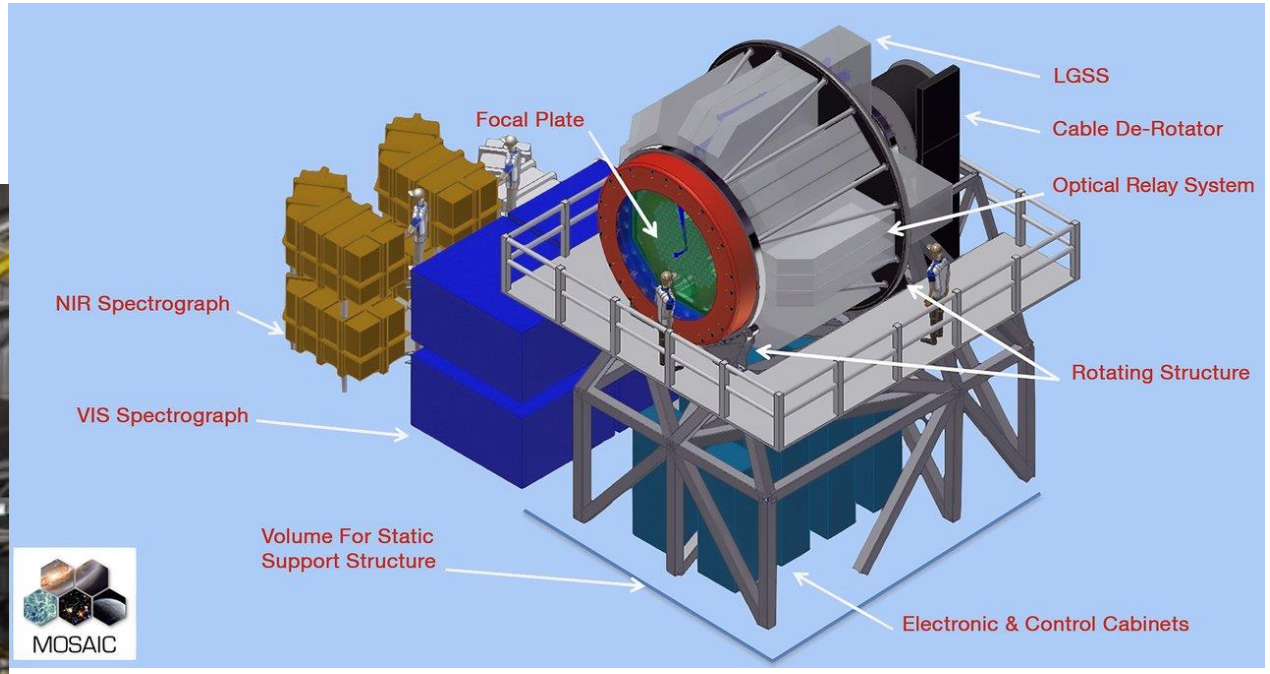
$$S/N \propto D^4$$



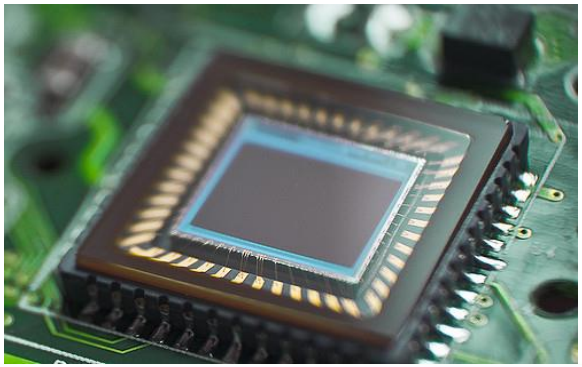
Giant Magellan Telescope | GMTO Corporation

How do we capture the light?

EAO



ESO



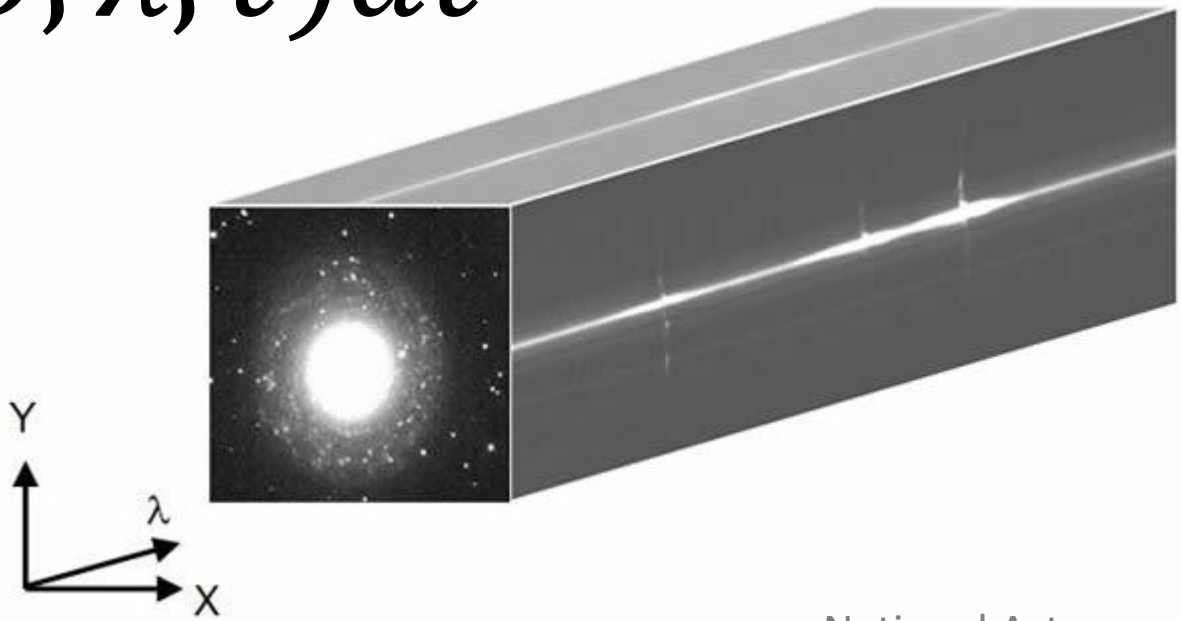
M. Laskowski via Flickr

Observations usually integrate specific intensity

$$f_\nu(\theta, \varphi, \nu, t)$$

Data cube

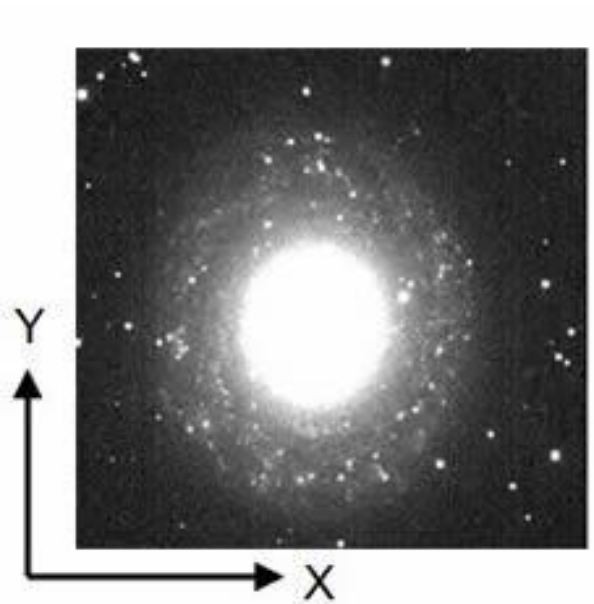
$$\int f_\lambda(\theta, \varphi, \lambda, t)\,dt$$



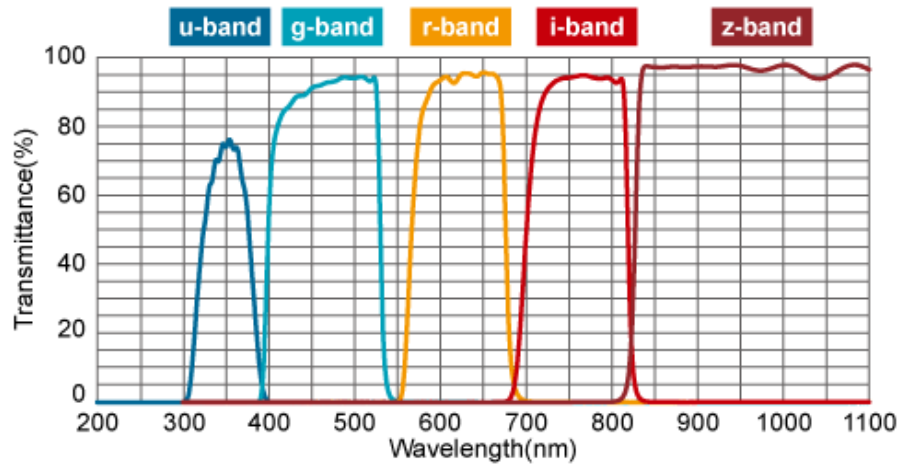
National Astronomical Observatory of Japan

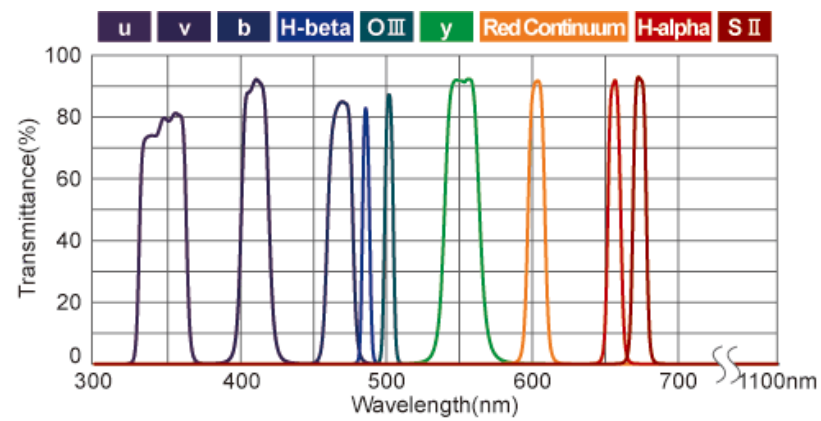
Image

$$\int f_\lambda(\theta, \varphi, \lambda, t)\, dt\, d\lambda$$



National Astronomical Observatory of Japan

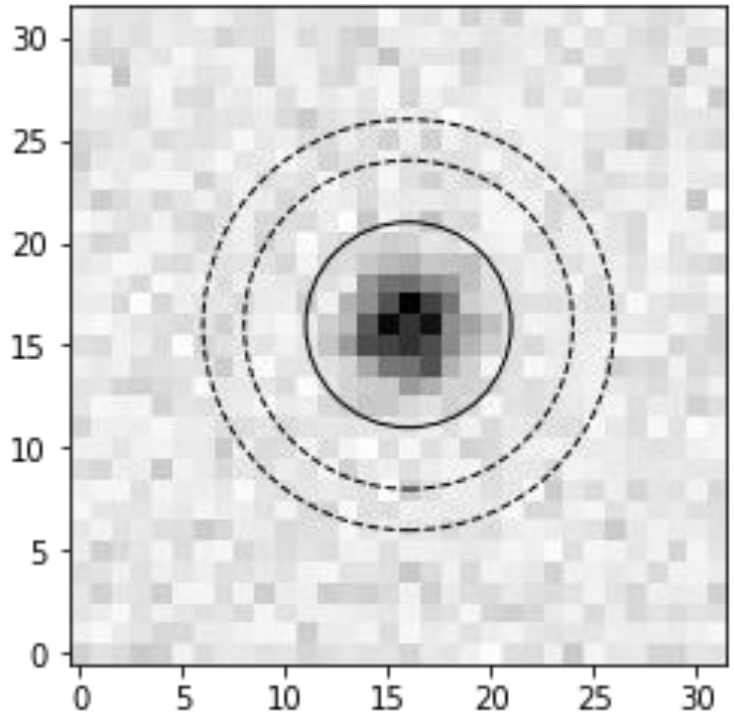


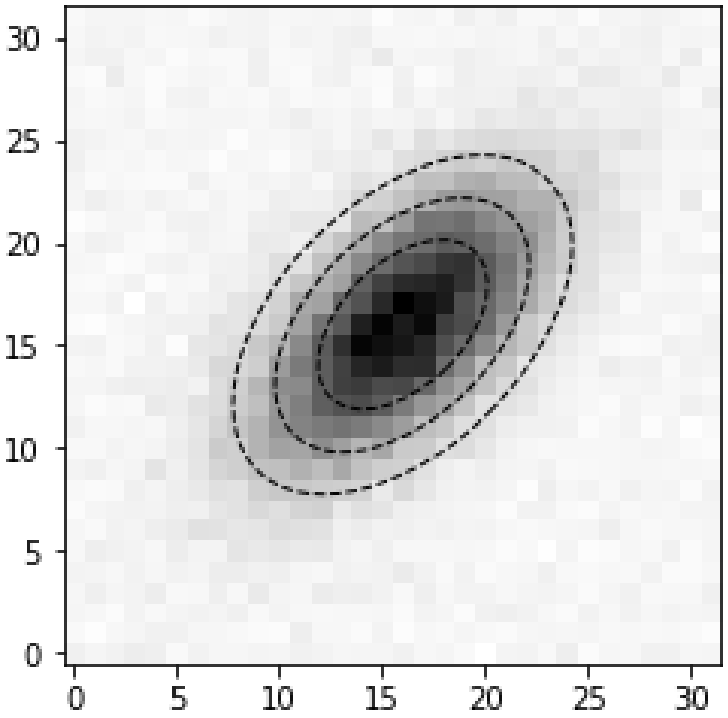


KOS, Inc.

Photometric measurements

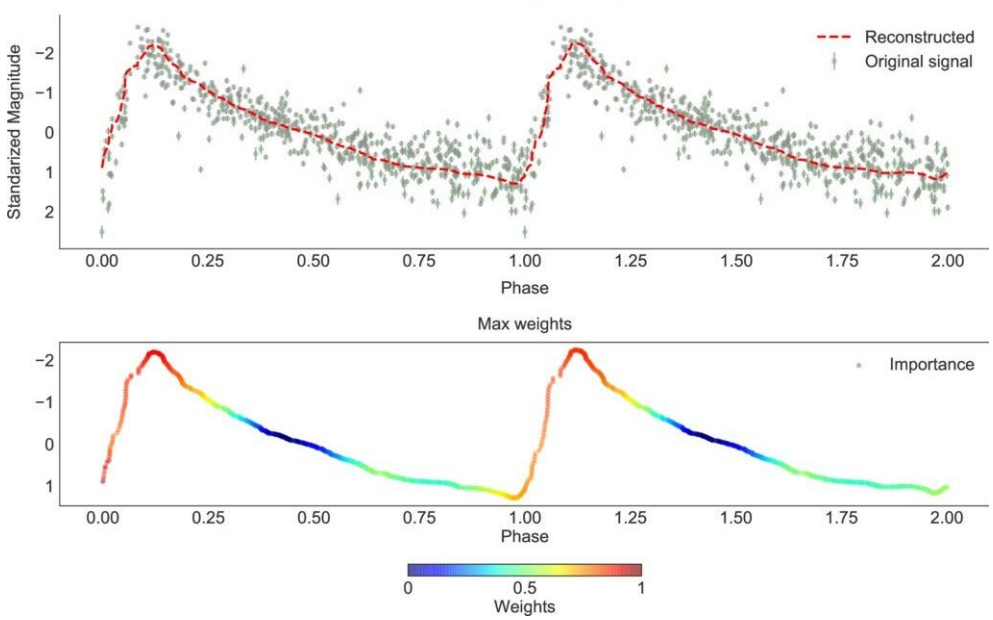
Brightness, structure, temperature



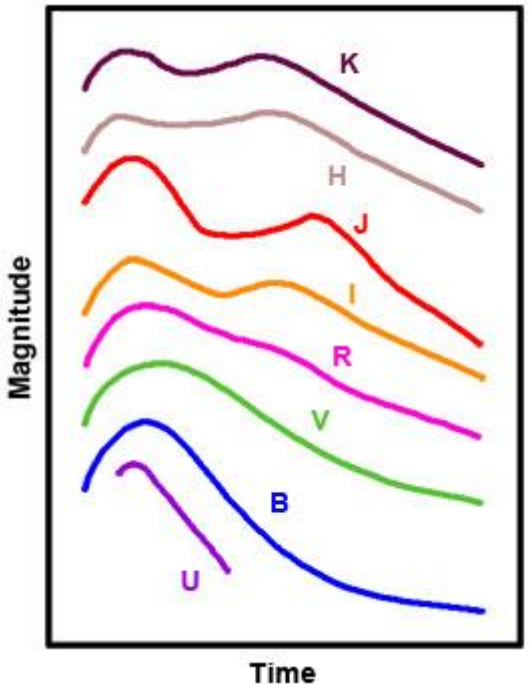


Time series photometry

$$\int f_\lambda(\theta, \varphi, \lambda, t)\, d\lambda\, d\Omega$$



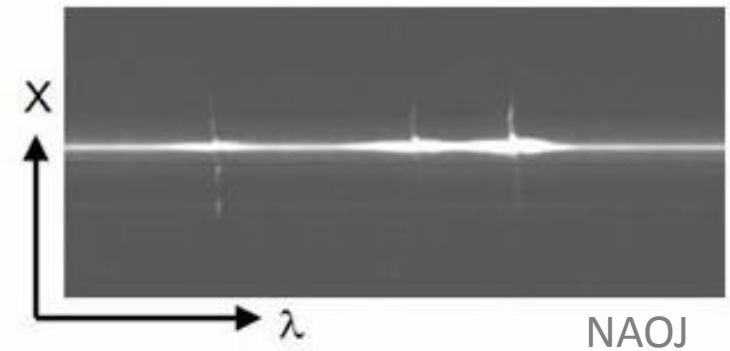
Pieringer et al 2019



Swinburne Astronomy Online

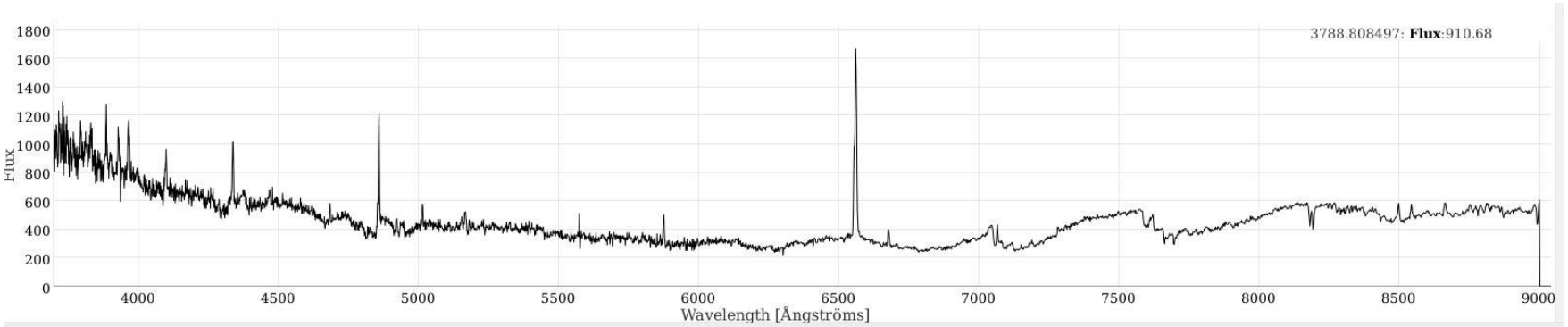
Spectrum (1D or 2D)

$$\int f_\lambda(\theta, \varphi, \lambda, t)\, dt\, d\Omega$$



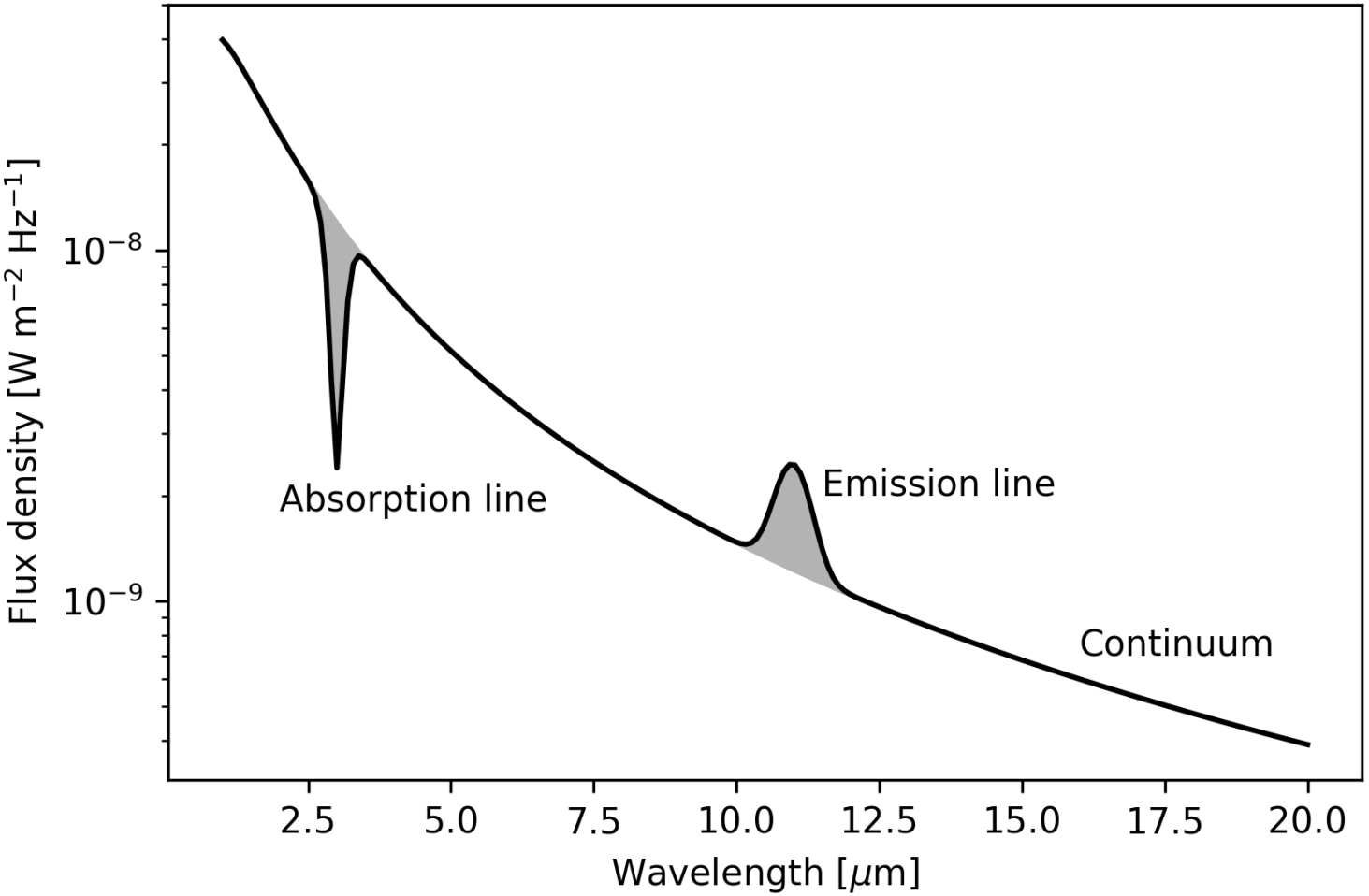
NAOJ

Skoda et al 2016



Spectroscopic measurements

Composition, physical conditions, kinematics, cosmology



Astronomical catalogs & data-mining