

Astronomical observations: an introduction for physicists

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

What do astronomers measure?

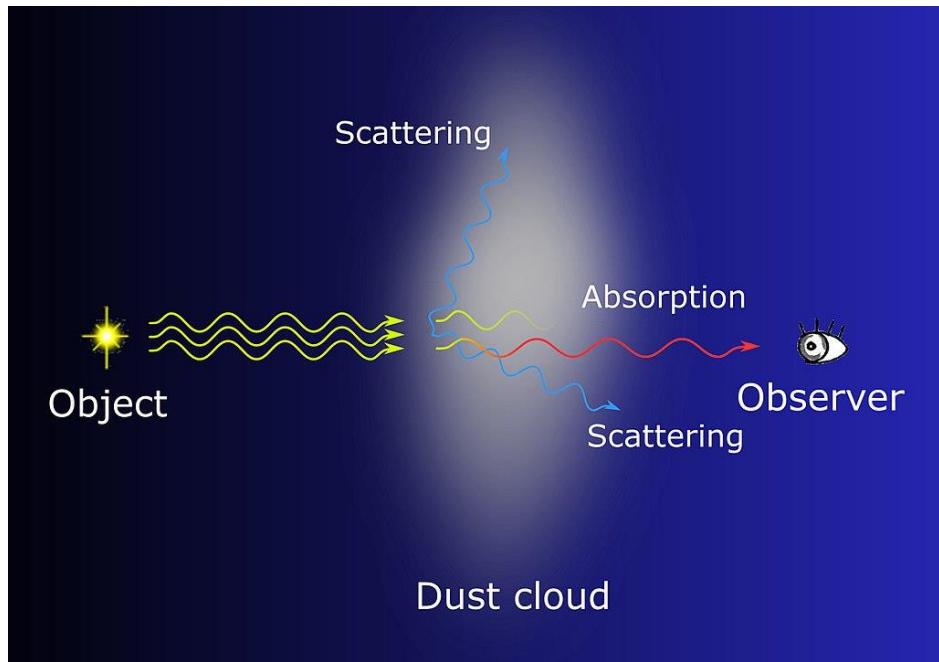
Spectral irradiance, flux density,
spectral radiance, specific intensity,
monochromatic flux

$$f_\nu(\theta, \varphi, \nu, t) \quad \text{W m}^{-2} \text{ Hz}^{-1} \text{ sr}^{-1}$$

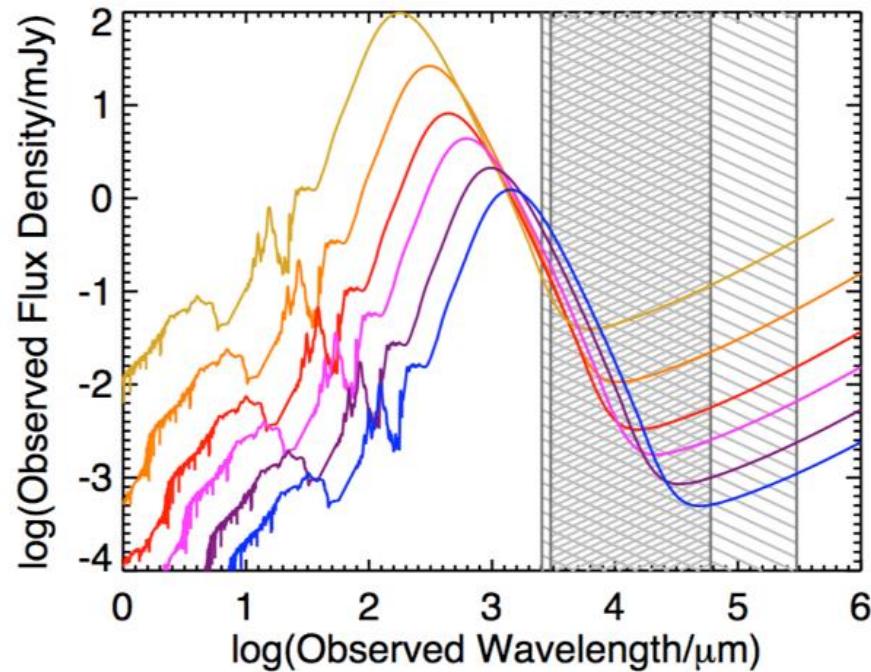
$$f_\lambda(\theta, \varphi, \lambda, t) \quad \begin{aligned} & \text{W m}^{-3} \text{ sr}^{-1} \\ & \text{W m}^{-2} \mu\text{m}^{-1} \text{ sr}^{-1} \\ & \text{W m}^{-2} \text{\AA}^{-1} \text{ sr}^{-1} \end{aligned}$$

The universe gets in the way

Scattering, absorbing



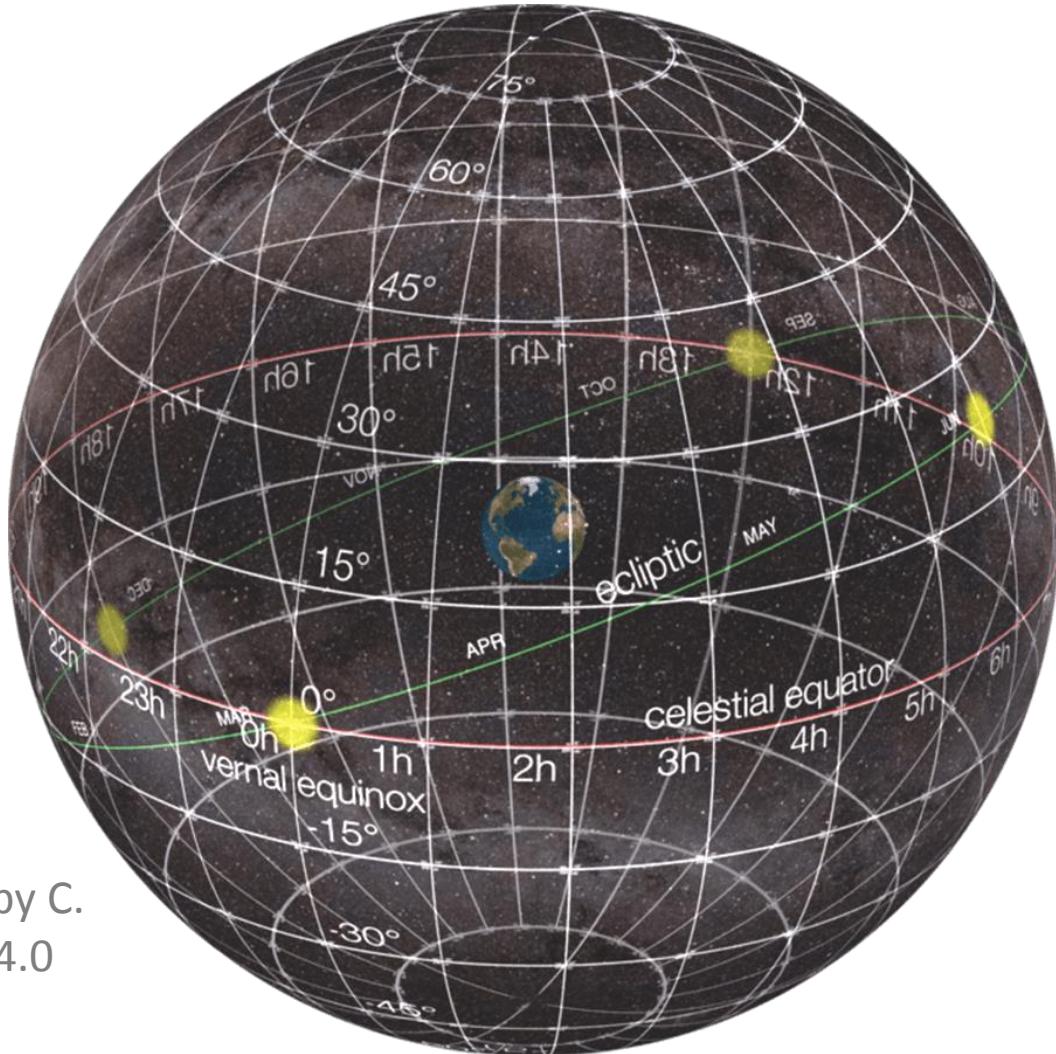
Redshifting



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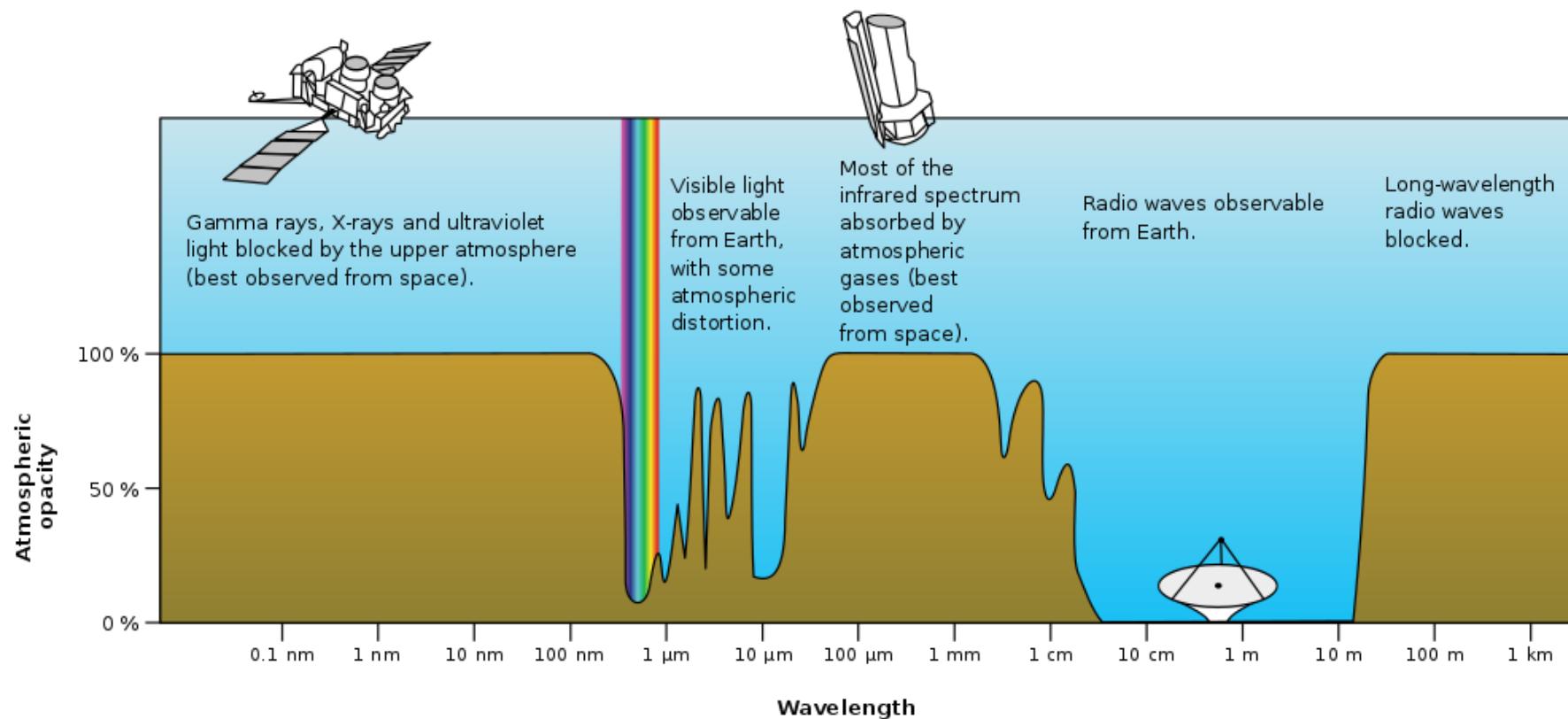
Casey et al 2015

Earth & Sun get in the way



Celestial Sphere – Full - Image by C.
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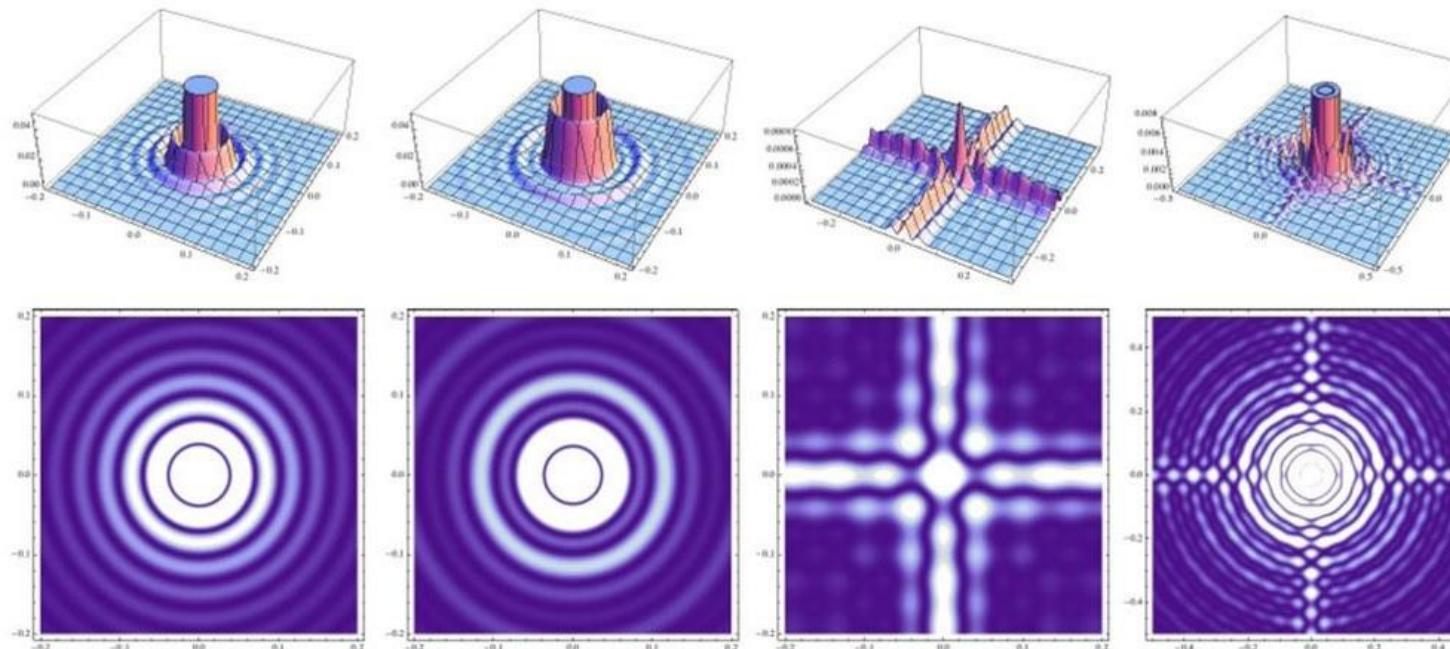
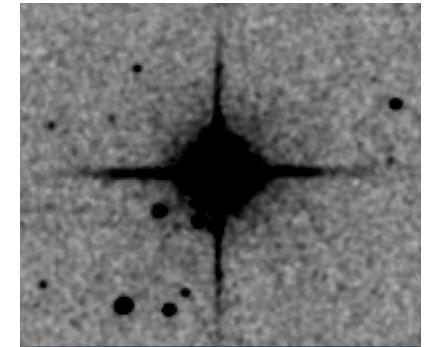
Earth's atmosphere gets in the way



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Telescopes improve spatial resolution

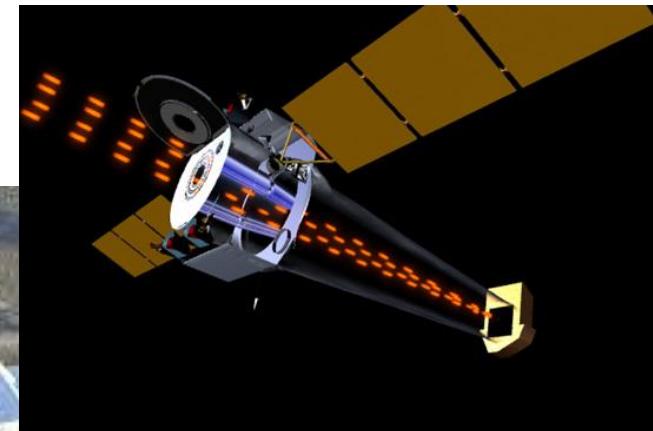
$$\theta \propto \lambda/D$$



Moretto 2013

Telescopes improve sensitivity

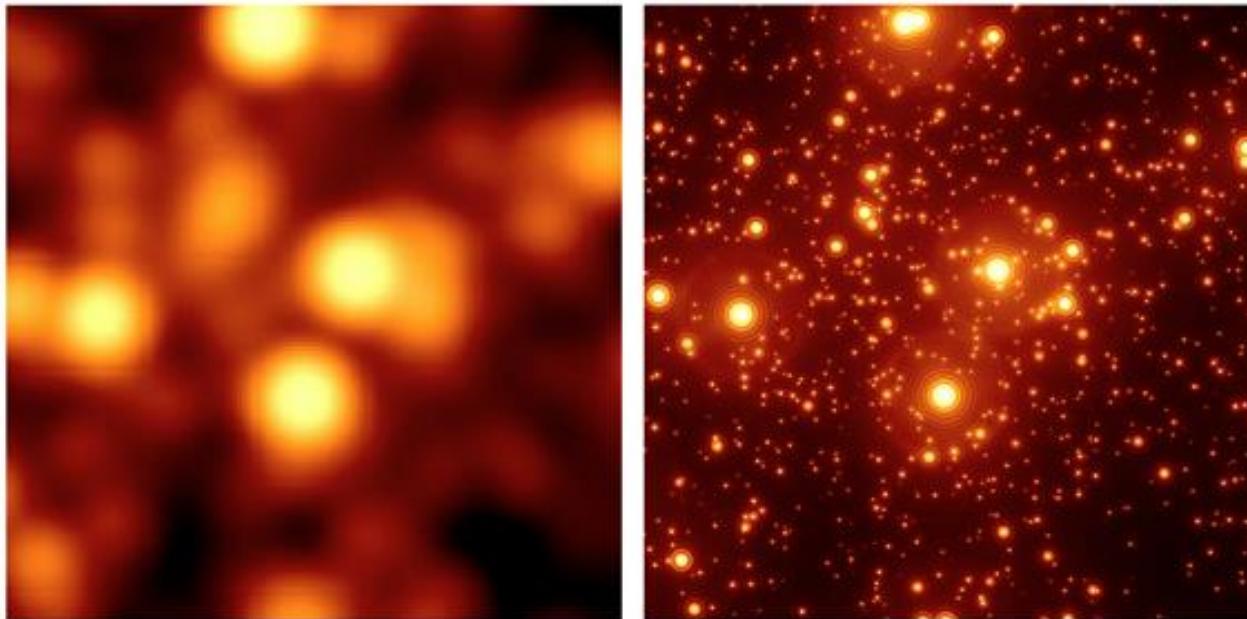
$$A \propto D^2$$



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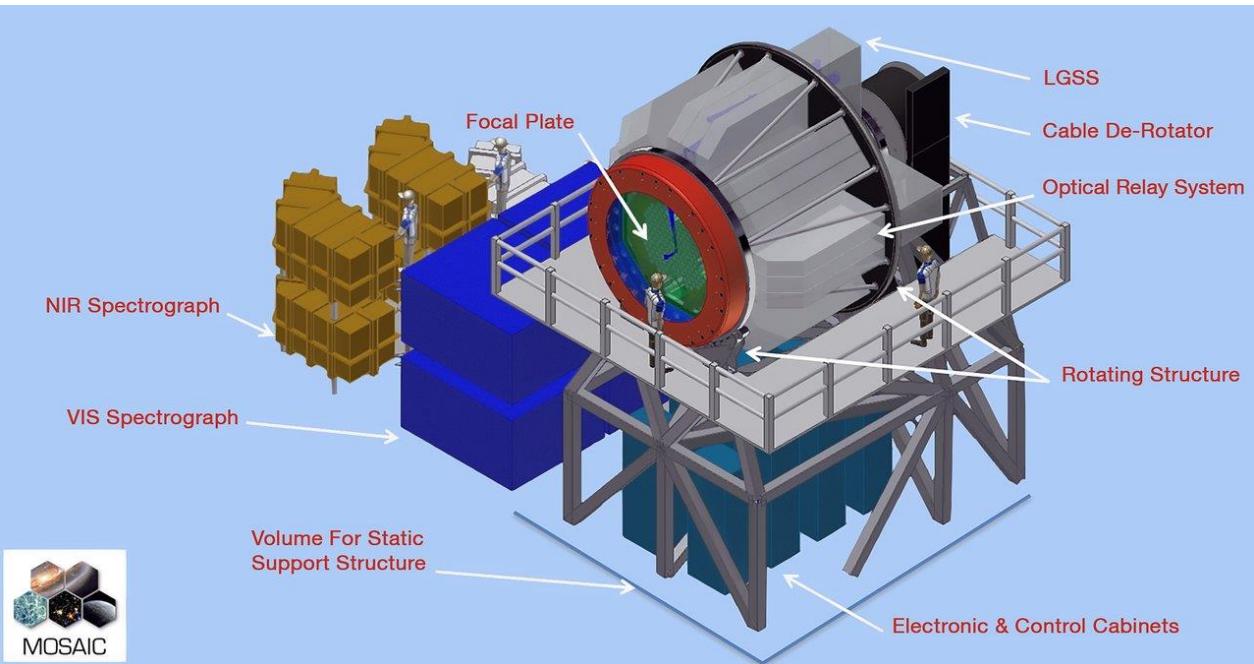
Adaptive optics improves resolution & sensitivity

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

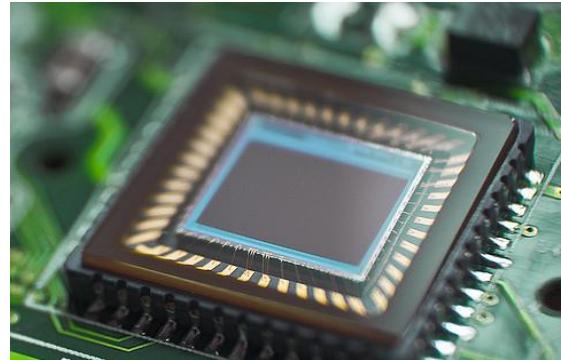


Giant Magellan Telescope | GMTO Corporation

How do we capture the light?



ESO



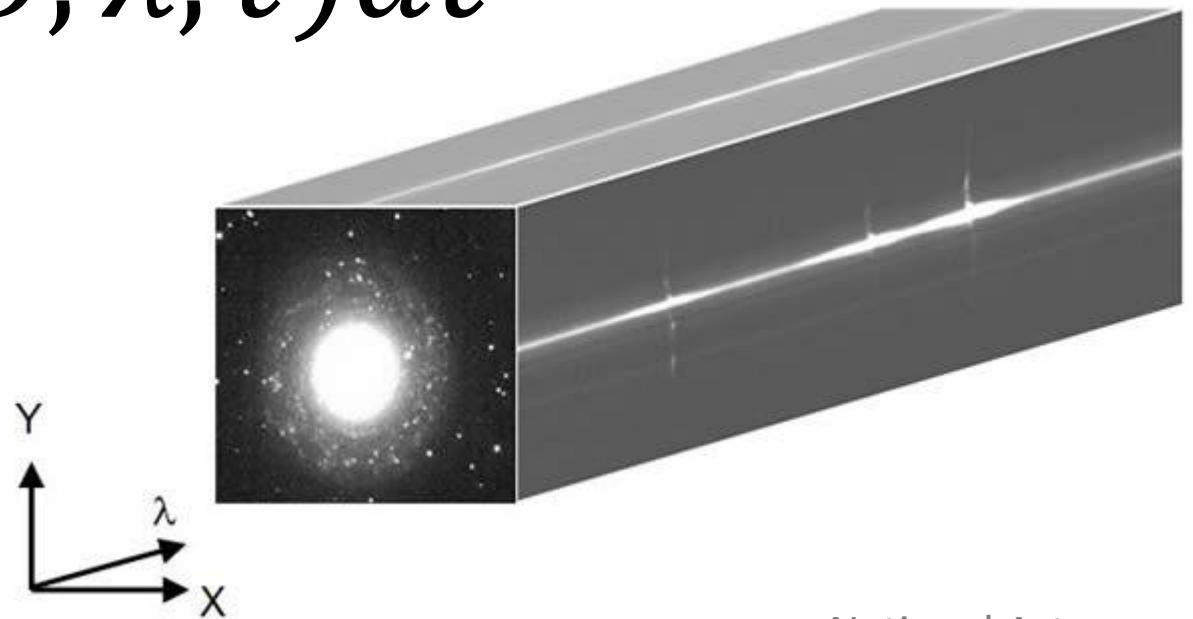
M. Laskowski via Flickr

Observations usually integrate specific intensity

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

Data cube

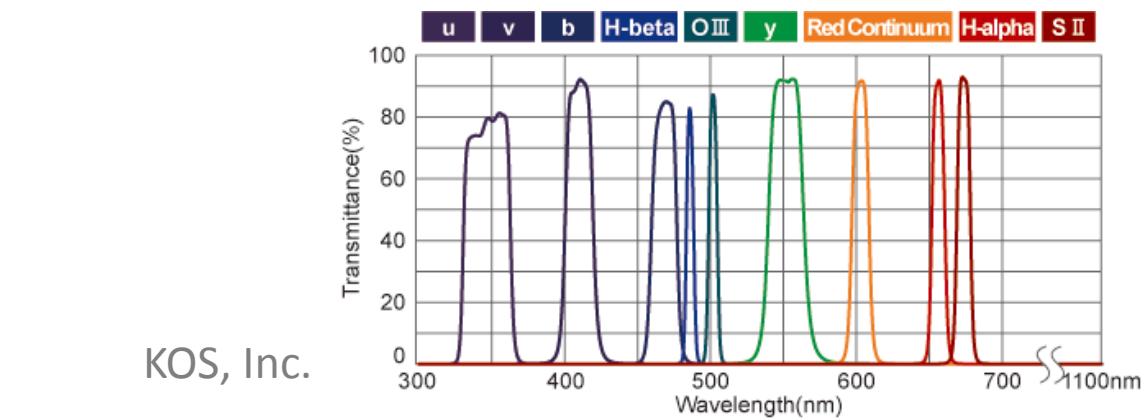
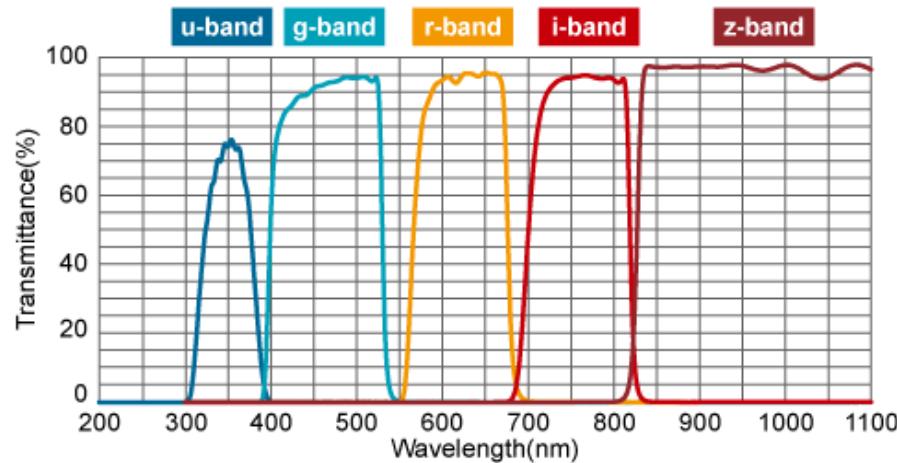
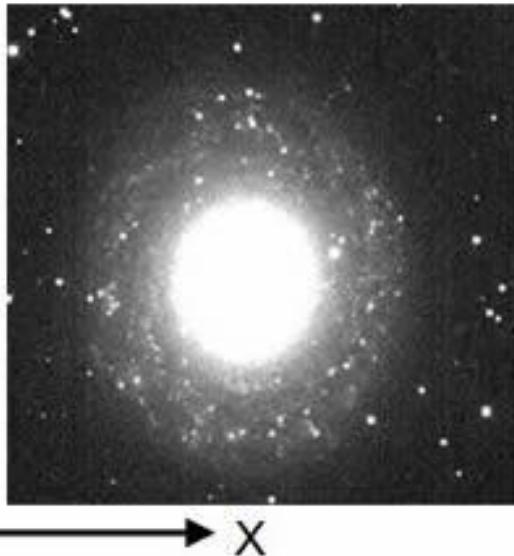
$$\int f_{\lambda}(\theta, \varphi, \lambda, t) dt$$



National Astronomical
Observatory of Japan

Image

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



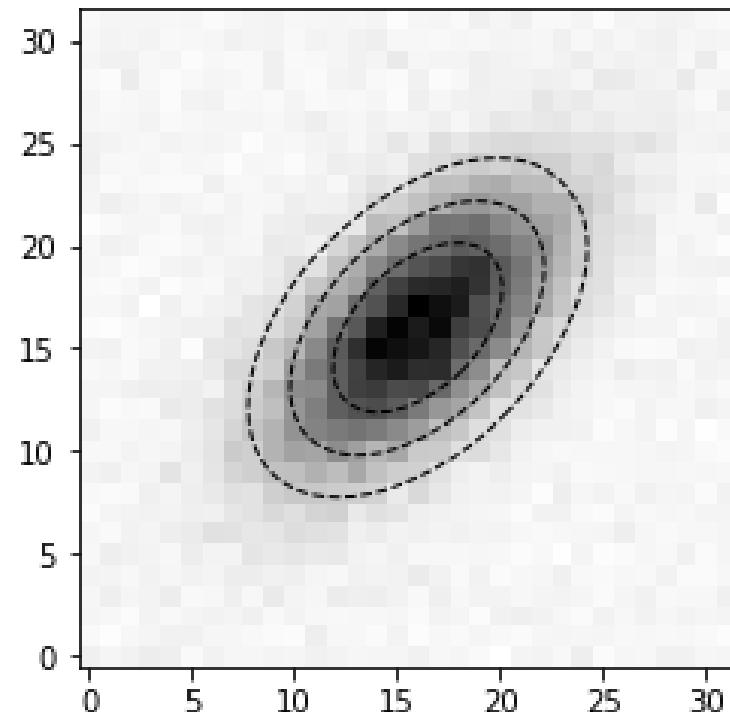
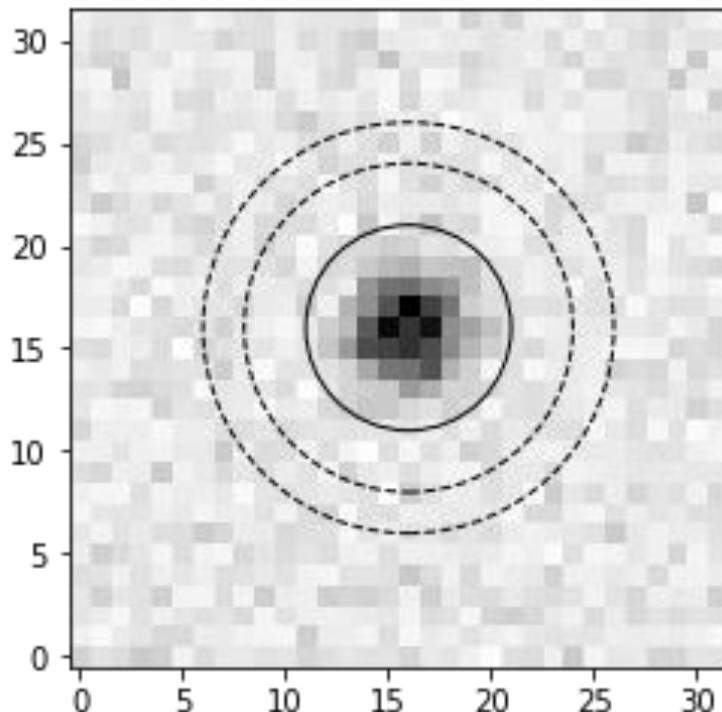
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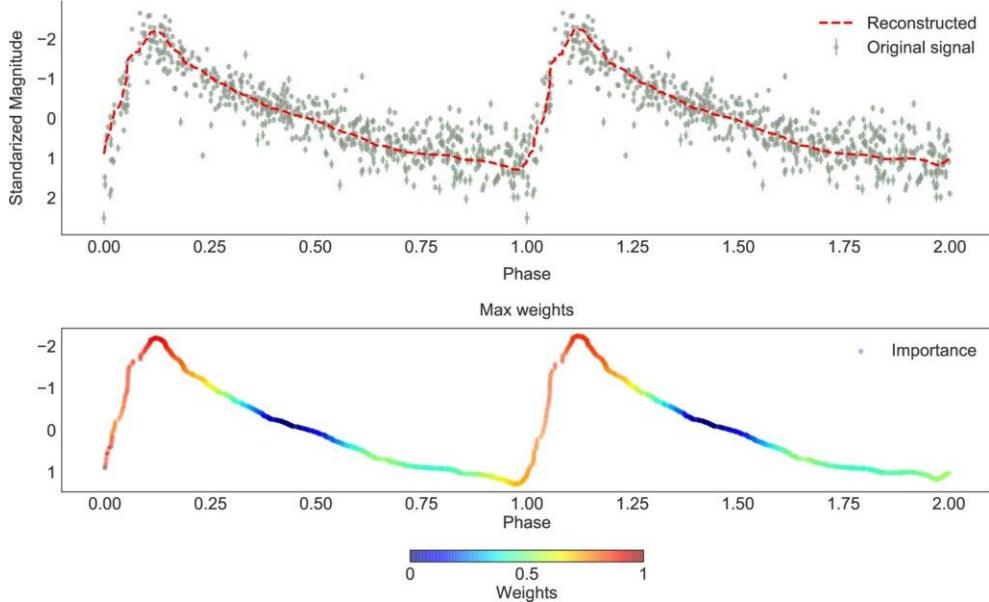
Photometric measurements

Brightness, structure, temperature

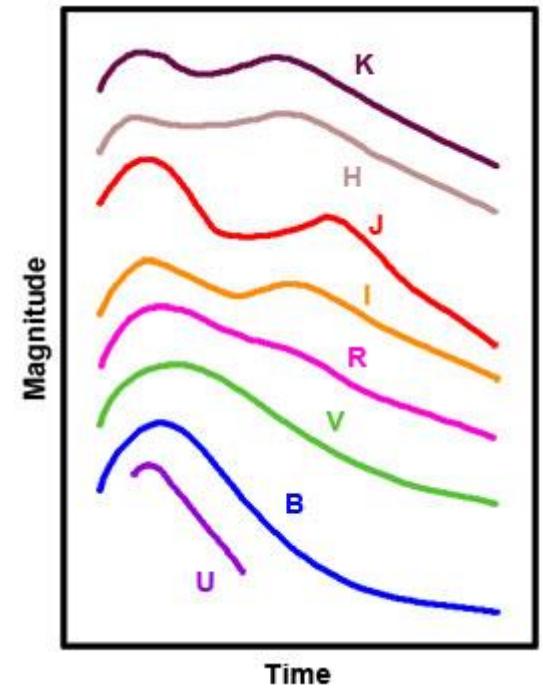


Time series photometry

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



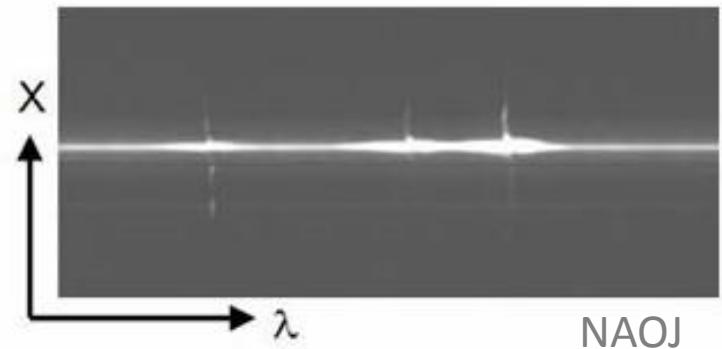
Pieringer et al 2019



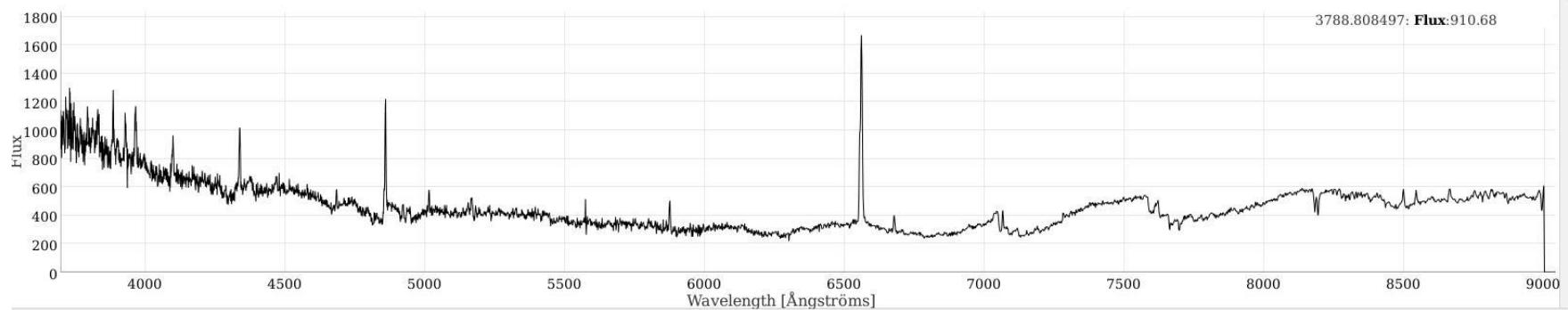
Swinburne Astronomy Online

Spectrum (1D or 2D)

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

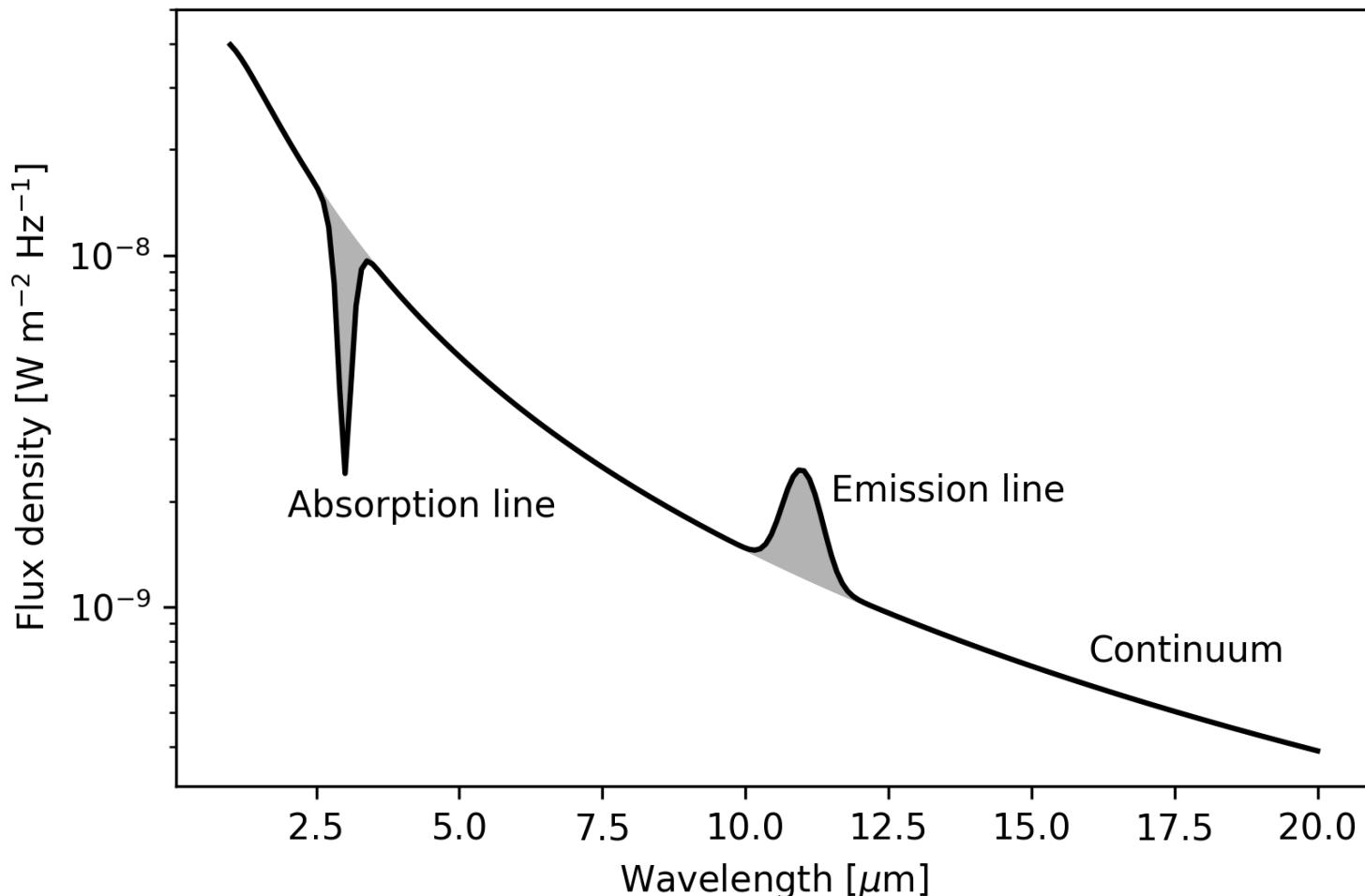


NAOJ



Spectroscopic measurements

Composition, physical conditions, kinematics, cosmology



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