AS1001
STARS and
ELEMENTARY
ASTROPHYSICS

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STARS AND ELEMENTARY ASTROPHYSICS

- Synopsis
  1. Telescopes and Instruments
  2. Distances to Stars
  3. Electromagnetic Radiation
  4. Stellar Astrophysics
  5. Motions of Stars in Space

  (Kutner's "Astronomy", parts of Chapters1,2,3,4,5)

- ASTRONOMY
  - studies of the stars, and by extension,
  - studies of the Universe

- STARS
  - points of light in night-time sky
  - grouped into CONSTELLATIONS

    (not usually physical groups - just chance projections of stars onto the sky as seen by us from Earth)
  - brighter and fainter stars

Hot stars blue, cool stars red

- STARS
  - how far away are they?
  - do they all have the same “intrinsic” brightness? (NO!)
  - how do we know what stars are?
  - is the Sun a star? (YES!)

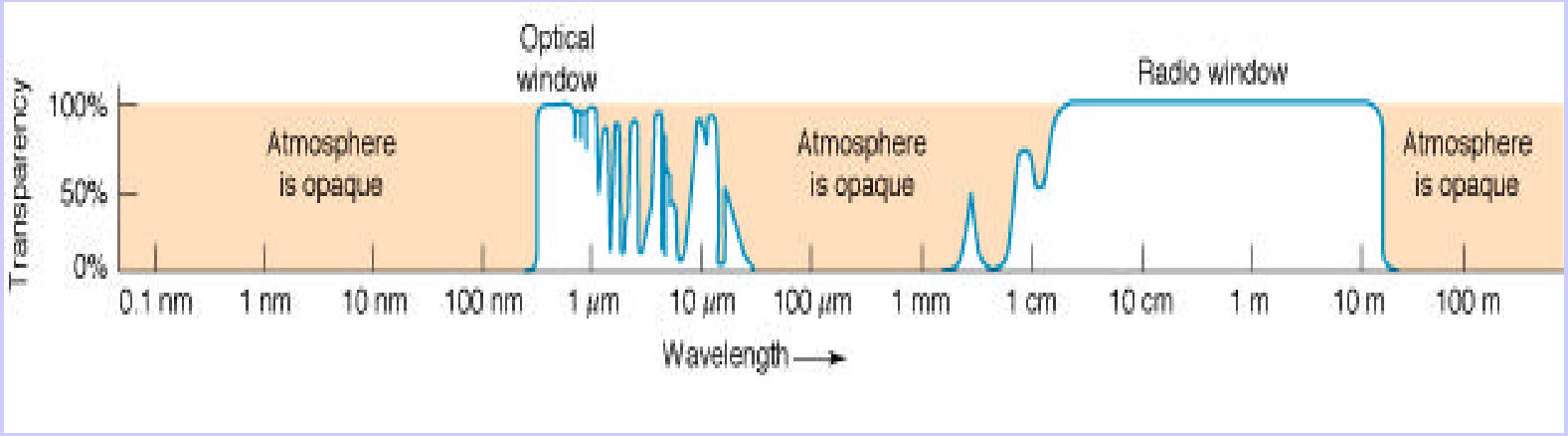
We use telescopes+associated instruments to measure starlight, and apply physics to build computer models of stars, to answer these questions.

[Concepts you will learn in Stars and Elementary Astrophysics are fundamental to the whole subject of astronomy. The ideas (e.g. distances, motions) apply to stars, extend to galaxies, and then the Universe, in other parts of AS1001.]

1. TELESCOPES AND INSTRUMENTS

To collect and record electromagnetic radiation (light) from astronomical sources (planets, stars, nebulae, galaxies)

Transparency of the Earth's atmosphere to radiation



High energy

short wavelength

Low energy

long wavelength

Observing through the Earth's atmosphere

- 2 main "transparent" regions

1. Optical Window - wavelengths λ 300-800 *nm*

(*nm* = nanometre = 10^{-9} *m*)

human eye λ 400-700 *nm*

violet - red

2. Radio Window - wavelengths 1 *mm* - 20 *m*

The infrared region - (heat) - wavelengths 1 - 10 ì m

(*mm* = micrometre = 10^{-6} *m* = micron)

– is only partially transparent due to water vapour

– best observed from dry high-altitude sites

Earth’s atmosphere is OPAQUE to :

gamma-rays (Ó-rays), X-rays, the ultraviolet (UV) region, and the far-infrared to millimetre regions of the electromagnetic spectrum.

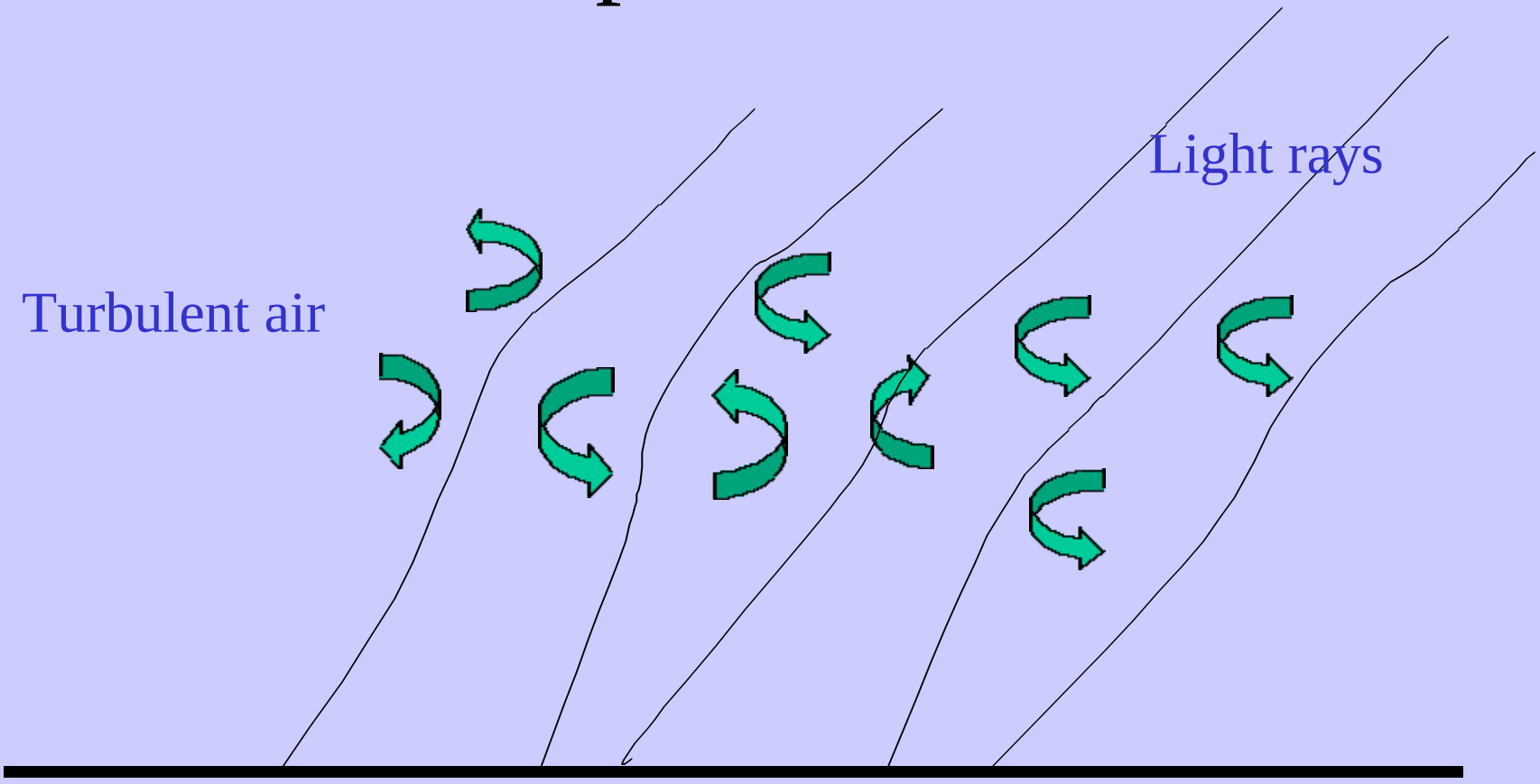
Such radiation from astronomical sources is observable only above Earth’s atmosphere - hence the need for spacecraft in orbit about the Earth.

OPTICAL & INFRARED RADIATION

Effects of Earth's atmosphere

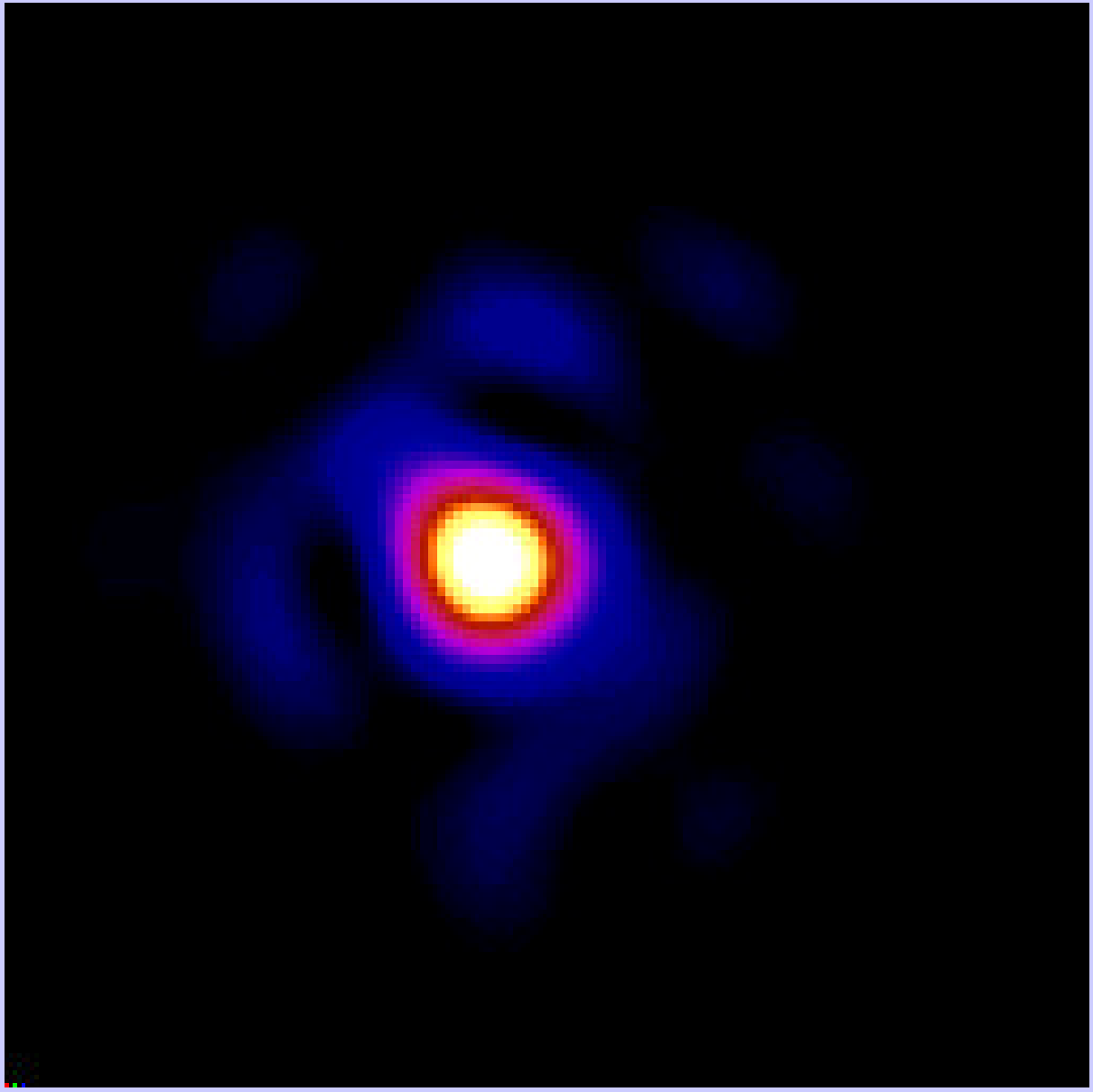
- SCINTILLATION
  - stars twinkle - turbulent layers of atmosphere, at different temperatures and densities, deflect the incoming light rays
  - extended objects - planets - twinkle less

Atmospheric effects



Scintillation = brightness changes

Seeing = angle changes



- a telescope collects light over a much larger area than the eye - hence reduces scintillation
- BUT the image of a point source seen through a telescope appears to be smeared, made up of vibrating speckles - a phenomenon called “SEEING”
- good seeing
  - image diameter ~ 1 arc second

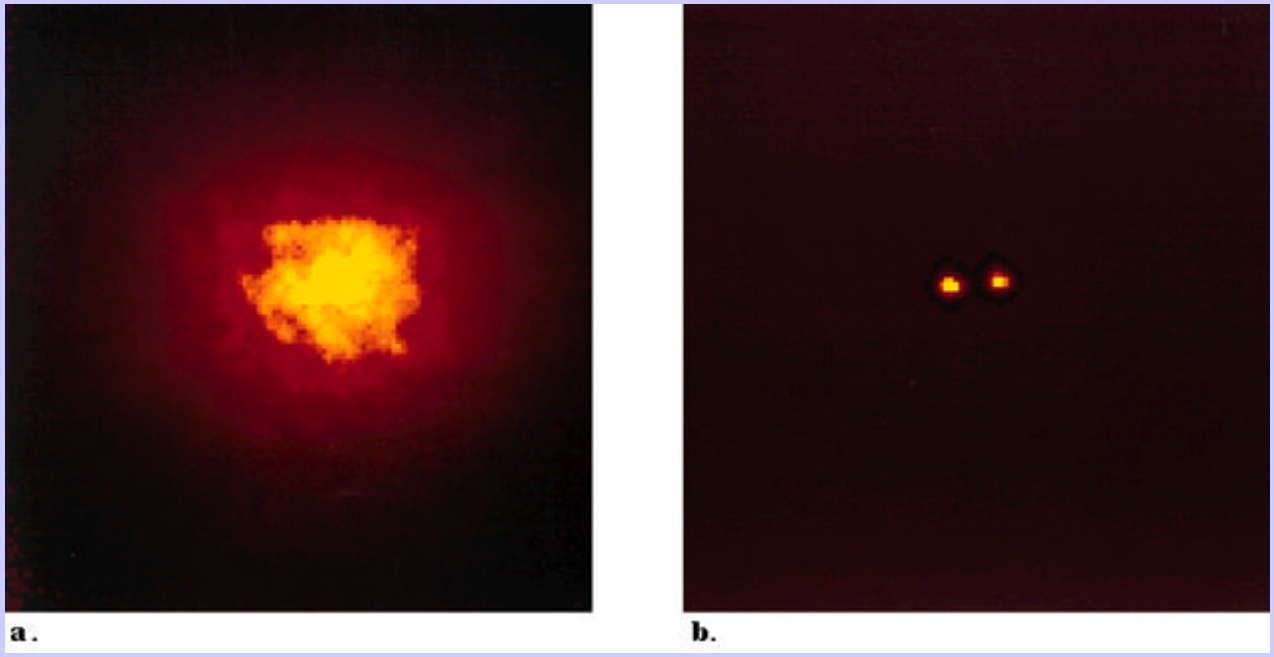
    (best conditions at sea level St Andrews ~ 2 arcsec

    best astronomical sites ~ 0.5 arcsec

  1 arcsec = 1/3600 degree = 1 penny / 4 km

spacecraft missions not affected (e.g. Hubble Space Telescope) - image diameter ~ 0.05 arcsecond

The seeing disc and the use of adaptive optics to unblur images



- Atmospheric EXTINCTION
- reduction in flux of radiation by scattering and absorption by atoms, molecules in the atmosphere
- scattering - randomize direction
- absorption - remove energy
- stronger effect at short wavelengths
- Hence blue sky, red Sun at sunrise/sunset.

- Best astronomical sites in world are above the main cumulus cloud layer (2000 *m*) and with very low rainfall (< 250 *mm yr* $^{-1}$) and excellent seeing
  - perfect clear sky (no clouds) ~70% of year
  - useable conditions ~95% of year

- Mauna Kea, Hawaii (4000 *m* above sea level)
- La Palma, Canary Islands (2500 *m*)
- Northern Chile (2500 *m*)

  all remote from cities, light pollution, etc.

- For RADIO ASTRONOMY

  much less critical, except for interference from microwave ovens, electrical power lines, radio, television, mobile phones, …..

- UK: Jodrell Bank, Cambridge
- Netherlands
- Germany — many large steerable dishes
- U.S.A. — + large arrays
- Australia

Optical and Infrared Telescopes

- collect light over a large area, to study very faint sources
- magnify the apparent angular size of sources, for better resolution
- accurate positions of sources in the sky