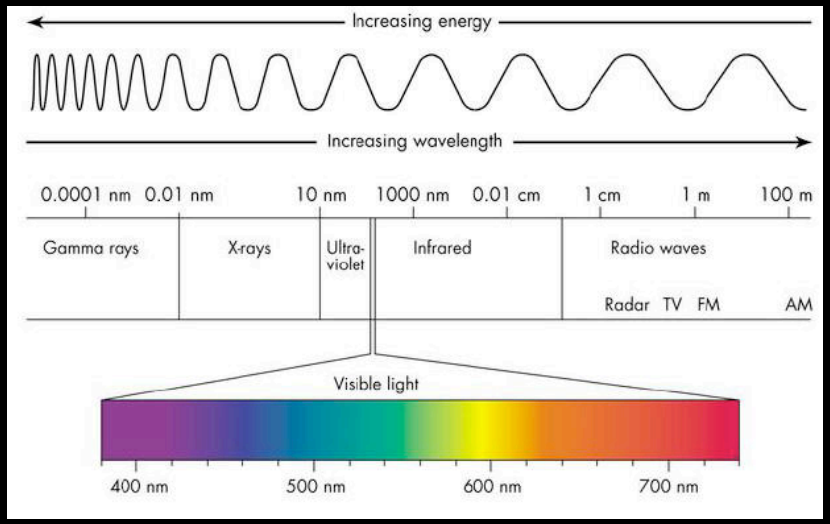
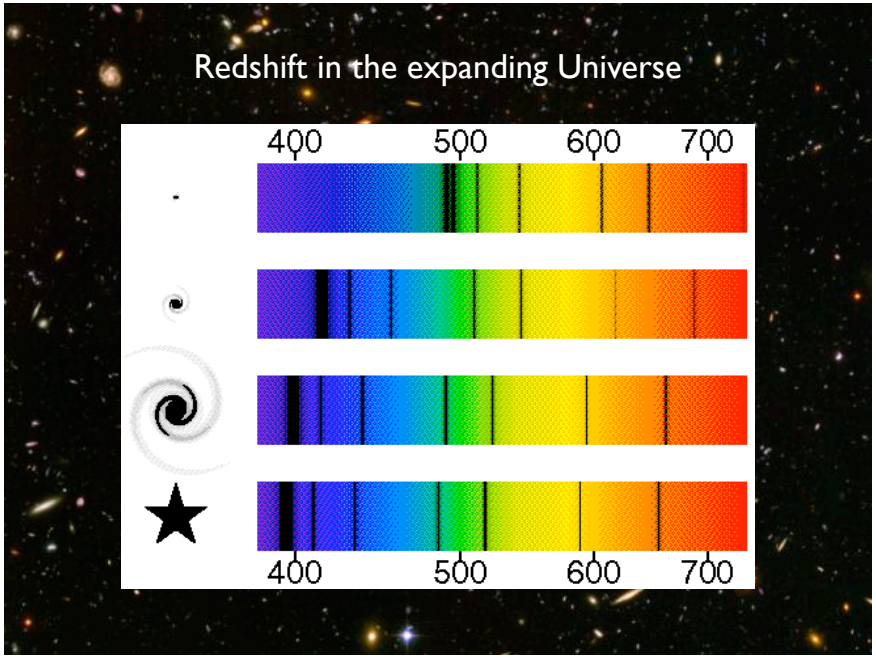
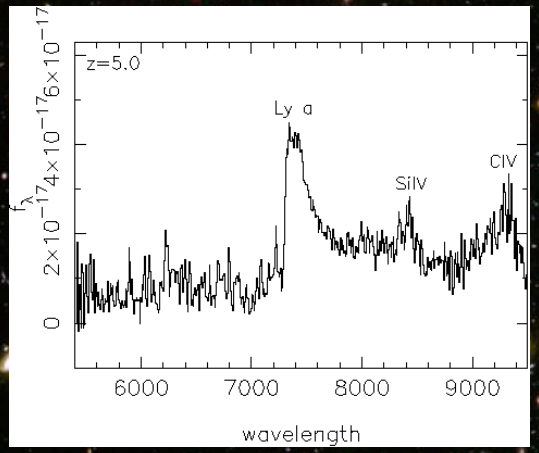
WAVES

WAVES

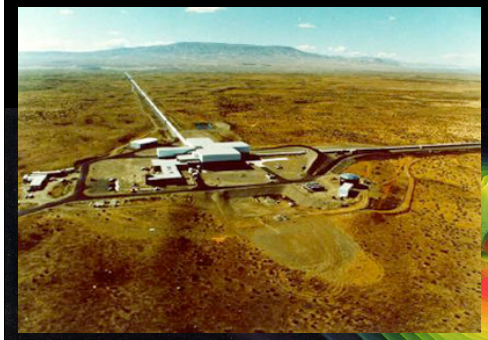

Increasing energy
Increasing wavelength
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 cm
1 cm
1 m
100 m
Gamma rays
X-rays
Ultra-violet
Infrared
Radio waves
Radar
TV
FM
AM
Visible light
400 nm
500 nm
600 nm
700 nm

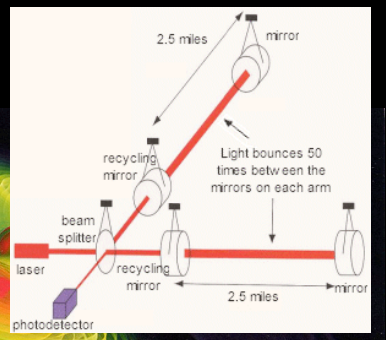

Redshift in the expanding Universe
400
500
600
700
400
500
600
700

Spectrum of a "redshift 5" quasar



Gravitational Waves detected using optical interferometry





L I G O

Laser Interferometer Gravitational-Wave Observatory

Radio Interferometry

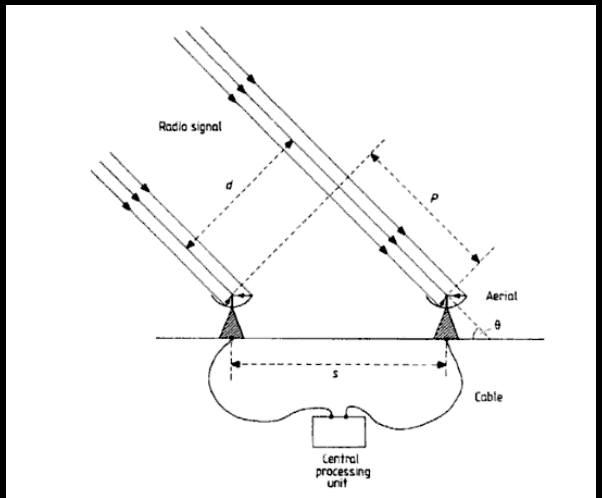
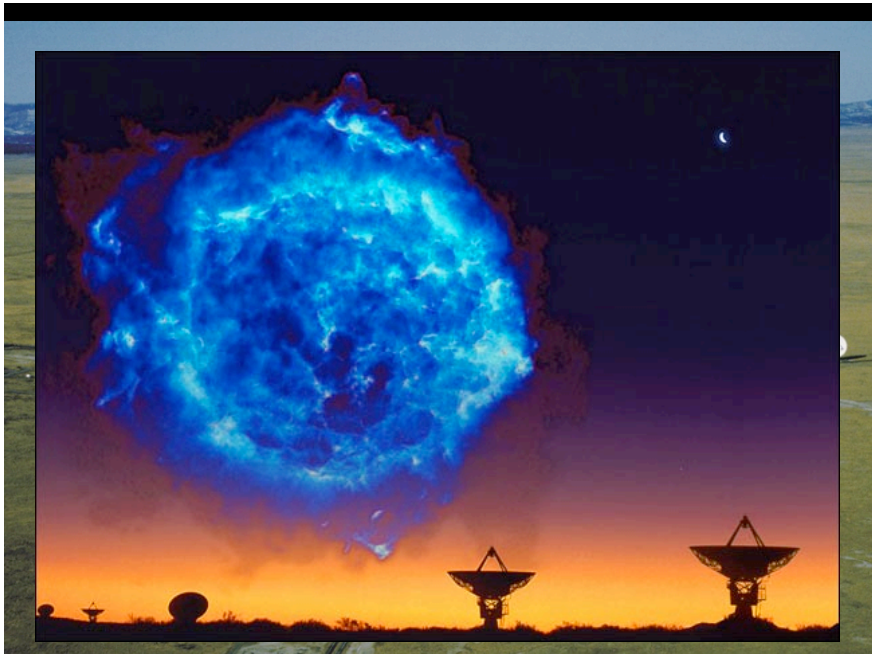


Figure 2.5.12. Schematic arrangement of a radio interferometer with fixed antennae.

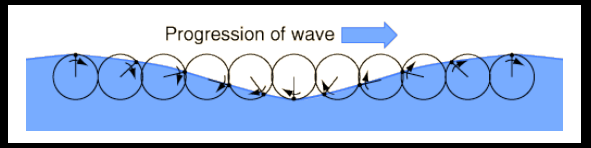


Water waves

"[water waves] that are easily seen by everyone and which are usually used as an example of waves in elementary courses [...] are the worst possible example [...]; they have all the complications that waves can have"

— Richard Feynman (1918-88)

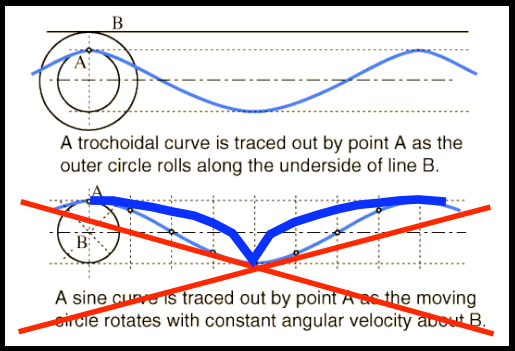
Water waves



- Water waves are more complicated!
- Particles execute roughly circular motion (with small net advance)
- Speed depends on wavelength and depth
- Shape isn't quite a sine wave

http://hyperphysics.phy-astr.gsu.edu/hbase/watwav.html

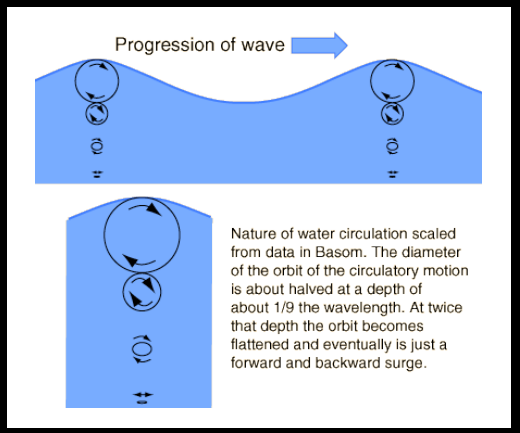
Wave shape



CYCLOID!

- Shape is approximately a "trochoid"
- As amplitude increases, waves become more "peaky", and unstable for height:λ>1:7

Water motion



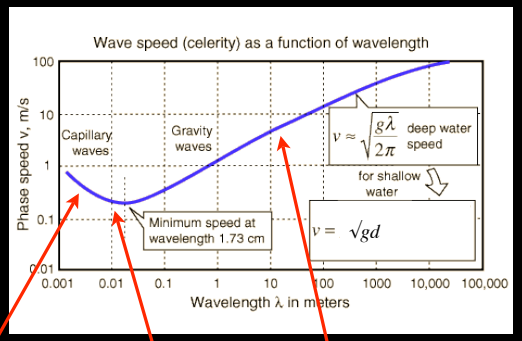
- Kind of both transverse *and* longitudinal!

Wave speed

- 2 regimes: deep water and shallow water
- Q: How do I make v from g, k and d?

- v ≈ √(gd) for shallow water
- v ≈ √(g/k) for deep water

$$v \simeq \sqrt{(g/k)\tanh(dk)}$$



Deep vs Shallow

"Capillary waves", a.k.a. "ripples"
- dynamics dominated by surface tension

Minimum speed at λ≈2cm

"Gravity waves", a.k.a. "waves"
- restoring force is gravity

Wave generation

- Waves created by steady wind:
  transfer of energy from atmosphere to ocean
  complicated in detail (turbulence vs laminar)
- As amplitude grows, wave easy to speed up
- Growth ceases when:
  waves approach wind speed
  wind stops or changes direction
  wave runs out of ocean!

Waves on the shore

- As waves approach shallower water:
  speed of the waves decrease (as d decreases)
  so wavelength becomes shorter
  peak height increases (because of water motion)
- When height > λ/7, peaks are unstable
- Because peaks are faster than water below:
  waves "break" on the shore

West Coast of Vancouver Island

More complications!

- Waves is real media can involve:

  "non-linearities" (i.e. not small amplitudes)

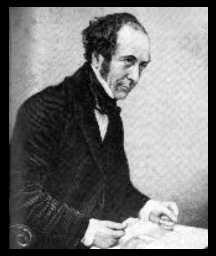
  "self-interaction"

  feedback effects

  turbulent/chaotic behaviour

- And a vast range of other effects we've ignored!

"Solitary Wave"
or "Soliton"



John Scott Russell
(1808-82)

Modern recreation

Great Red Spot,
non-linear optics,
particle physics,
....

Wave power?