Astronomical Techniques I

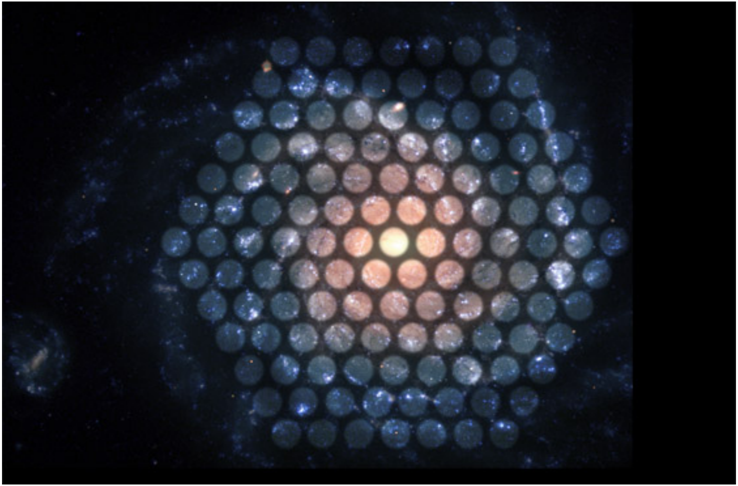
Lecture 13

Yogesh Wadadekar

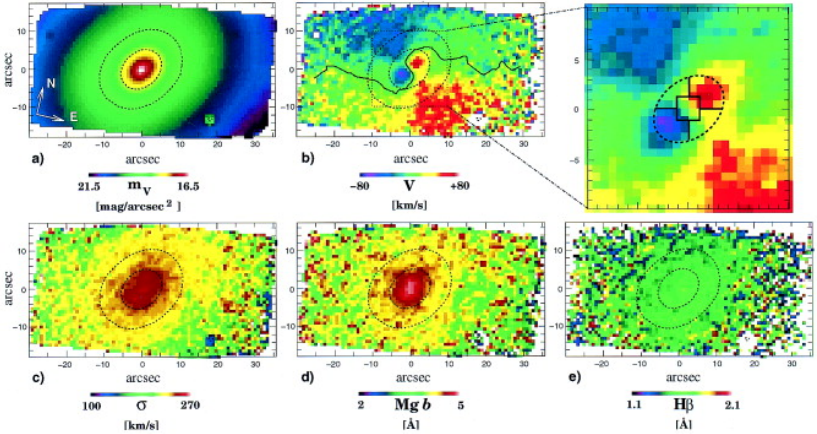
Jan-Feb 2015

Assignment 2, Date for seminar

Tiling a galaxy with lenslets



Integral field spectrograph



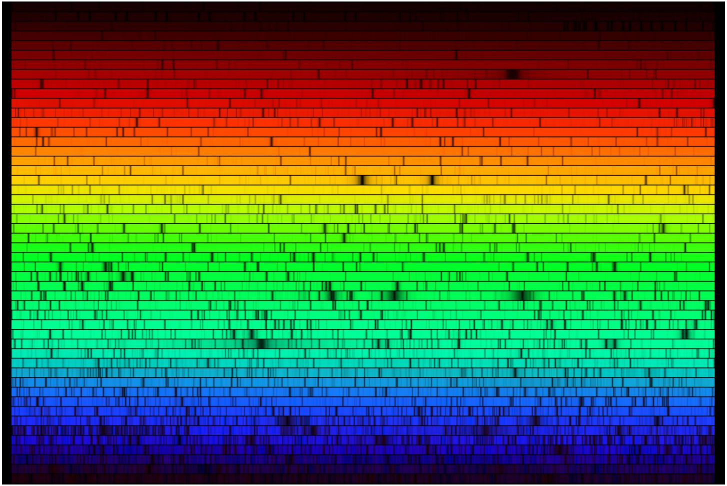
Wavelength calibration

- usually done with a hollow cathode lamp (copper) + vapour (argon) calibration setup. The setup produces emission lines at known wavelengths.
- If the moon is up, could you somehow use moonlight for wavelength calibration?

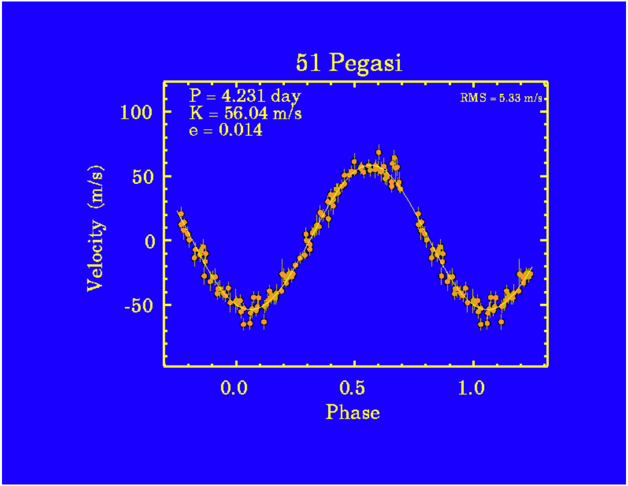
Finding extrasolar planets

- obtain a spectrum of an I_2 absorption cell with flat lamp illumination.
- obtain the spectrum with and without the absorption cell in place
- Fit the cell +star spectrum using the cell and star only spectra as templates. Offsets between star and cell spectra are used to compute changes in the doppler shift. offset changes with time.
- offset very small - Jupiter causes an amplitude of 12 km/sec. This implies a shift of 0.00024 Åat 6000 Å. This is 0.15 % of a typical line width.
- need to correct for all motions of the earth and sun.

Hires Spectrum



Doppler shifts of 51 Pegasi planet



Flux calibration

- not always required: you may be interested only in Doppler broadening of a line to calculate velocity dispersions

Flux calibration

- not always required: you may be interested only in Doppler broadening of a line to calculate velocity dispersions
- similar to photometric calibration, but one needs to observe spectrophotometric standards eg Oke & Gunn (1983).
- sky needs to be subtracted by subtracting a sky spectrum.
- The flux calibration process is straightforward: the object and standard star spectra are summed in the same pass bands as the reference tables. The correction factors can then be calculated by comparing the standard star spectrum with the reference tables.

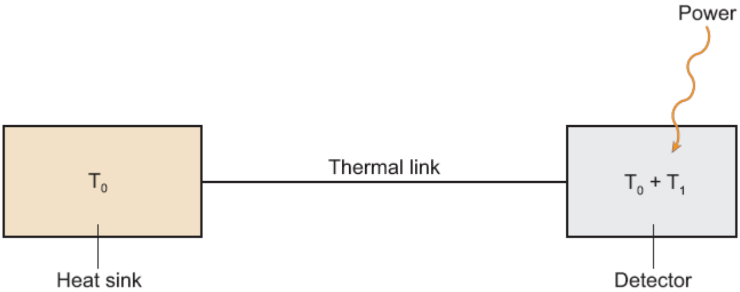
Infrared instrumentation

- Use of infrared detector arrays in astronomy began roughly 20 years ago, and our detection capabilities in parts of this spectral range have doubled about every seven months since then if measured by (# of pixels) $\times$ (sensitivity per pixel $)^2$.
- four distinct technologies are used:
  1. direct hybrid arrays of InSb and HgCdTe (mercadtel) photodiodes that operate from 0.6 μm - we covered this already.
  2. Si:As impurity band conduction detectors from 5 μm to 28 μm - not covered
  3. photoconductive diodes - far infrared - not to be covered - technology immature
  4. bolometer arrays read out by transistors or superconducting devices in the far-infrared through millimeter-wave spectral range (where heterodyne receivers begin to become more efficient) - to be covered now.

Why far-infrared technology lags behind?

near (1-5 μm) and mid (5-30 μm) technology has developed dramatically due to military applications in night vision, guided missiles etc. Far IR has few military or commercial applications, so the technology has stagnated. Far IR astronomy can only be done from space, further restricting the market size and therefore the R & D investment. Spitzer and now Herschel therefore open out the unexplored warm, dusty universe for the first time.

Far Infrared bolometric detectors

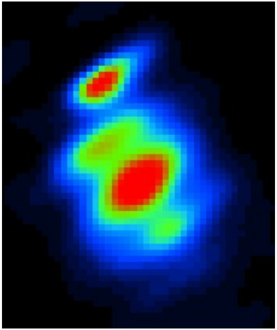


Beyond 350 μm heterodyne receivers become more efficient and we enter the regime of sub-millimeter astronomy and coherent astronomy is the norm.

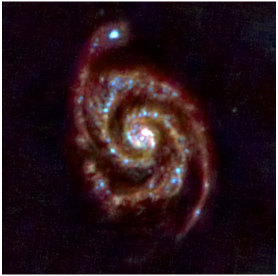
Noise Equivalent Power (NEP) used to characterise detectors

- NEP is the signal power that yields an rms signal to noise of 1, in a frequency bandwidth of 1 Hz (smaller NEP is desirable).
- this is a property of the detector only, unlike SNR which depends on source properties also.
- $NEP_T = \frac{(4kT^2G)^{1/2}}{\eta}$ where k is the Boltzmann const. T is the temperature, η is the quantum efficiency, G is the strength of the thermal link (thermal conductance).
- Thermal time constant $\tau_T \propto \frac{1}{G}$

Far-IR Astronomy in the last three decades

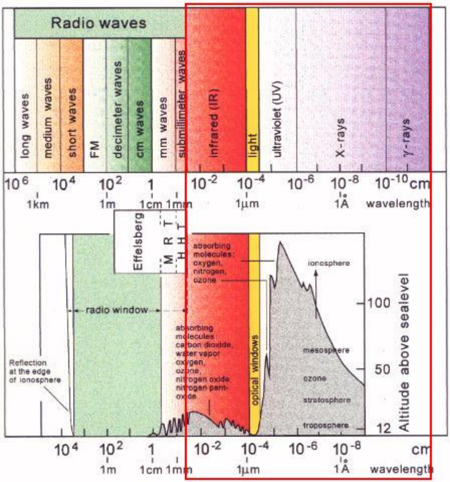


(a) IRAS



(b) Herschel

Why X-ray astronomy is hard?



Soft and hard X-rays

- 10 to 0.1 nanometers (nm) (about 0.12 to 12 keV) soft X-rays
- 0.1 nm to 0.01 nm (about 12 to 120 keV) hard X-rays
- even hard X-Rays are totally absorbed after traveling through a few meters of air.

How to observe X-rays?

- payload in a rocket
- balloons - also affected by X-ray absorption
- satelites - best - XMM-NEWTON, INTEGRAL, Chandra. Also XRT on SWIFT. Also hopefully, later this year, Astrosat.

Why conventional mirrors and lenses don't work in X-ray telescopes?

Why not mirrors?

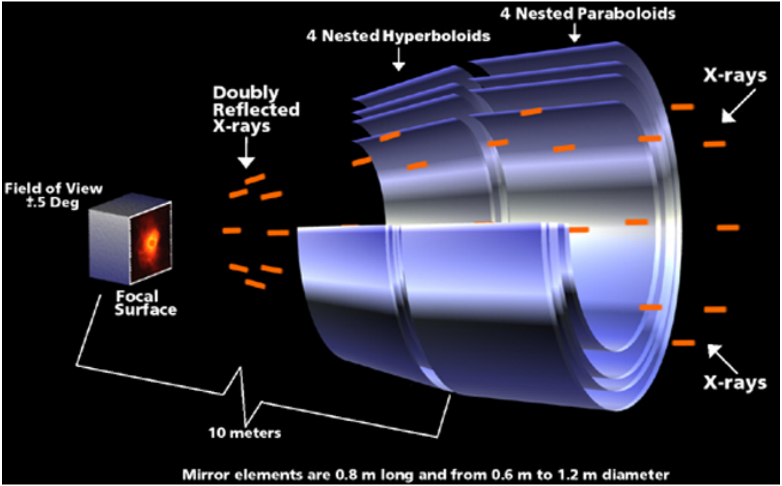
Why conventional mirrors and lenses don't work in X-ray telescopes?

Why not mirrors? because X-ray photons are transmitted or absorbed.
Why not lenses?

Why conventional mirrors and lenses don't work in X-ray telescopes?

Why not mirrors? because X-ray photons are transmitted or absorbed.
Why not lenses? refractive index too close to one (actually < 1) for all materials.

Basic principle of X-ray telescopes - total external reflection



Wolter telescope - two reflections to avoid coma.

Which X-rays will graze?

- where (grazing) angle is less than θ_c
- $\theta_c \propto \sqrt{Z}/E$,
- critical grazing angle defines maximum angular size of the FOV

Why such a focussing arrangement does not work for very hard X-rays or gamma rays?

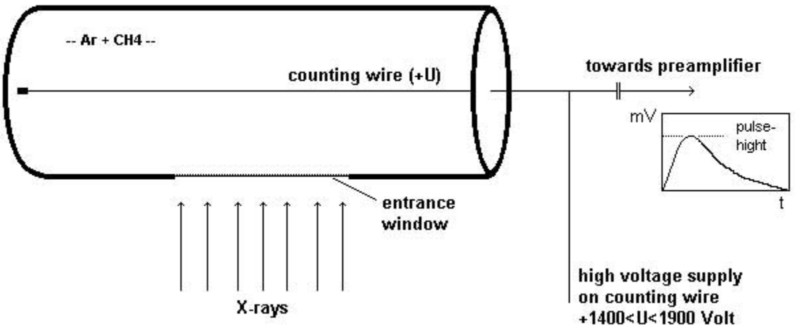
Materials used in X-ray telescopes

- Higher Z materials are more desirable since they have larger critical angle at any energy.
- current telescopes have energy ranges 0.1 to 10 keV and grazing angles 0.5 to 1 degree.

Materials used in X-ray telescopes

- Higher Z materials are more desirable since they have larger critical angle at any energy.
- current telescopes have energy ranges 0.1 to 10 keV and grazing angles 0.5 to 1 degree.
- for these energy ranges gold, platimum, iridium with Zerodur substrate are good reflectors for these energy ranges.
- for lower energies you can get away with berrylium, aluminium, nickel.
- surface accuracy needs to be near perfect, else photon scatters somewhere else.

Simplest X-ray detector - proportional counters, e.g. LAXPC and SSM are two such



CCDs more common these days

- multiple (primary and secondary) electrons generated by a single photon.
- number of electrons generated $= E/w$

CCDs more common these days

- multiple (primary and secondary) electrons generated by a single photon.
- number of electrons generated $= E/w$
- frame transfer CCDs common Why?
- to reduce telemetry rate only frames with “events” relayed to earth.

Since standard silicon CCDs are used in X-ray telescopes, how will you prevent optical light from generating photo electrons?