PHY405 Lecture 11:
AGN discovery and observed properties

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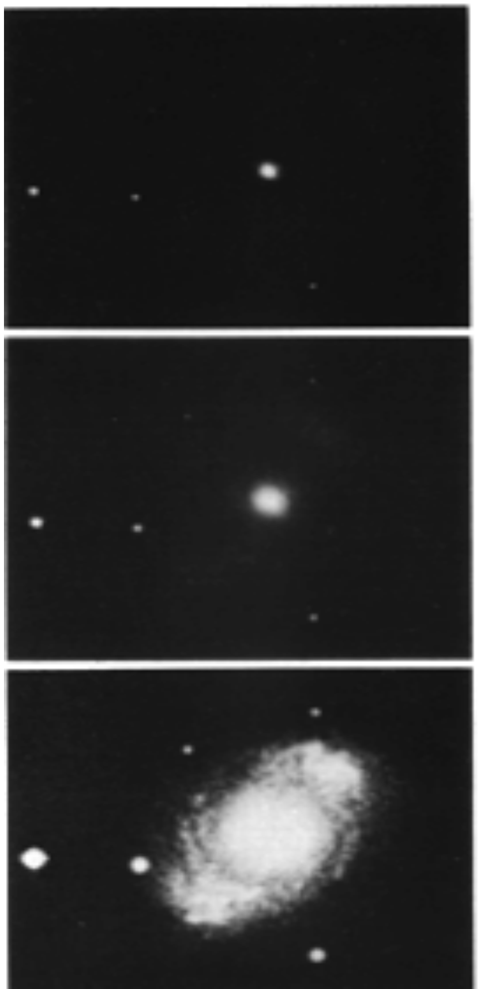
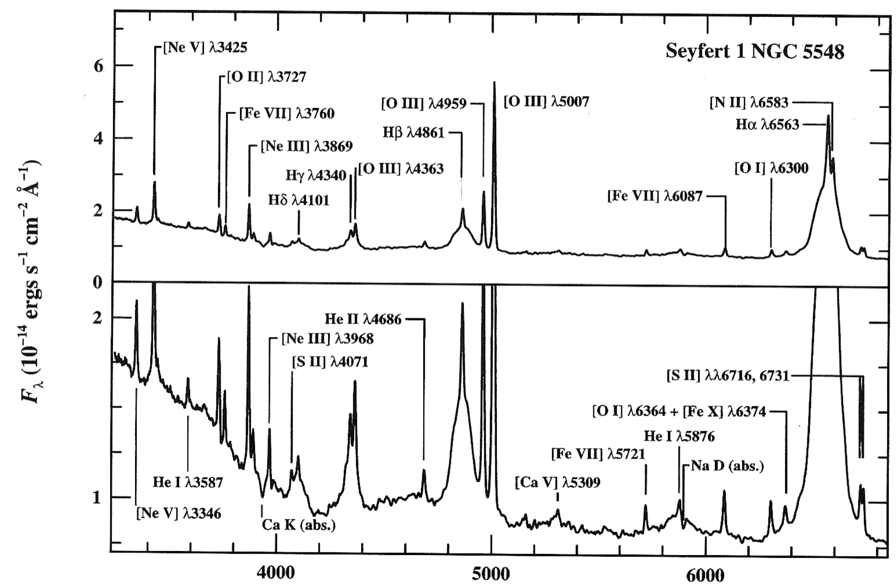
Seyfert Galaxies

Optical images



Optical spectra



Seyfert (1943)

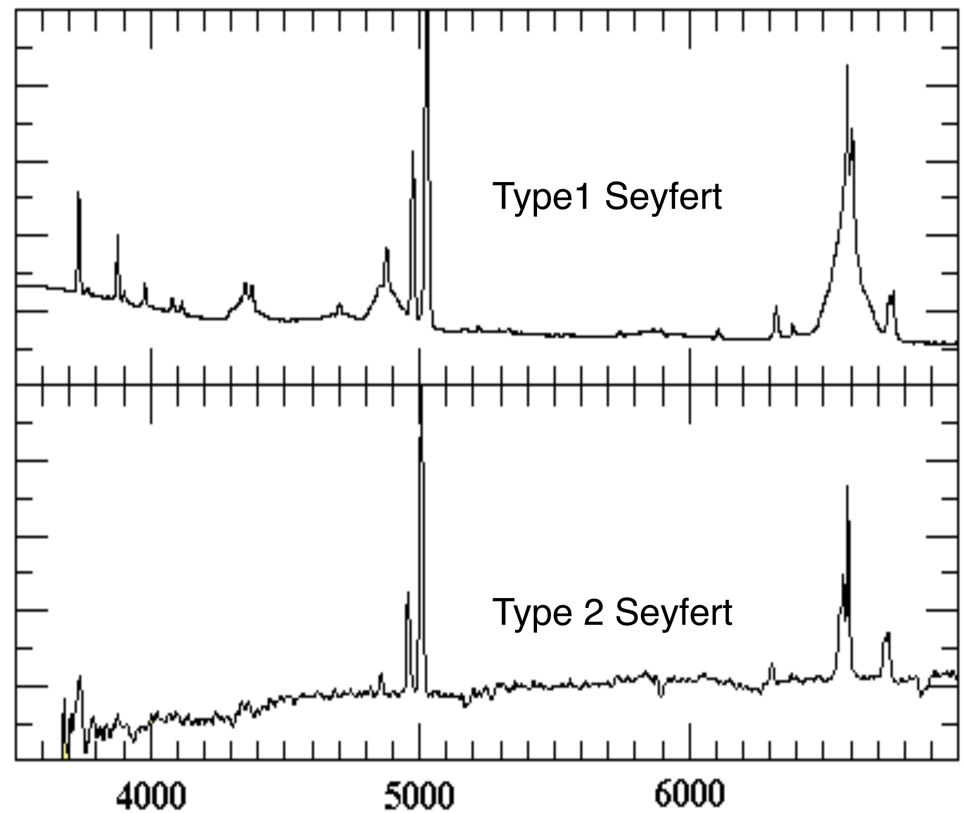
Type 1 and type 2 AGN

Type 1 AGN:

- Broad permitted lines (>1,000 km/s FWHM)
- Narrower forbidden lines (300 < FWHM < 1,000 km/s)
- Blue, non-stellar continuum

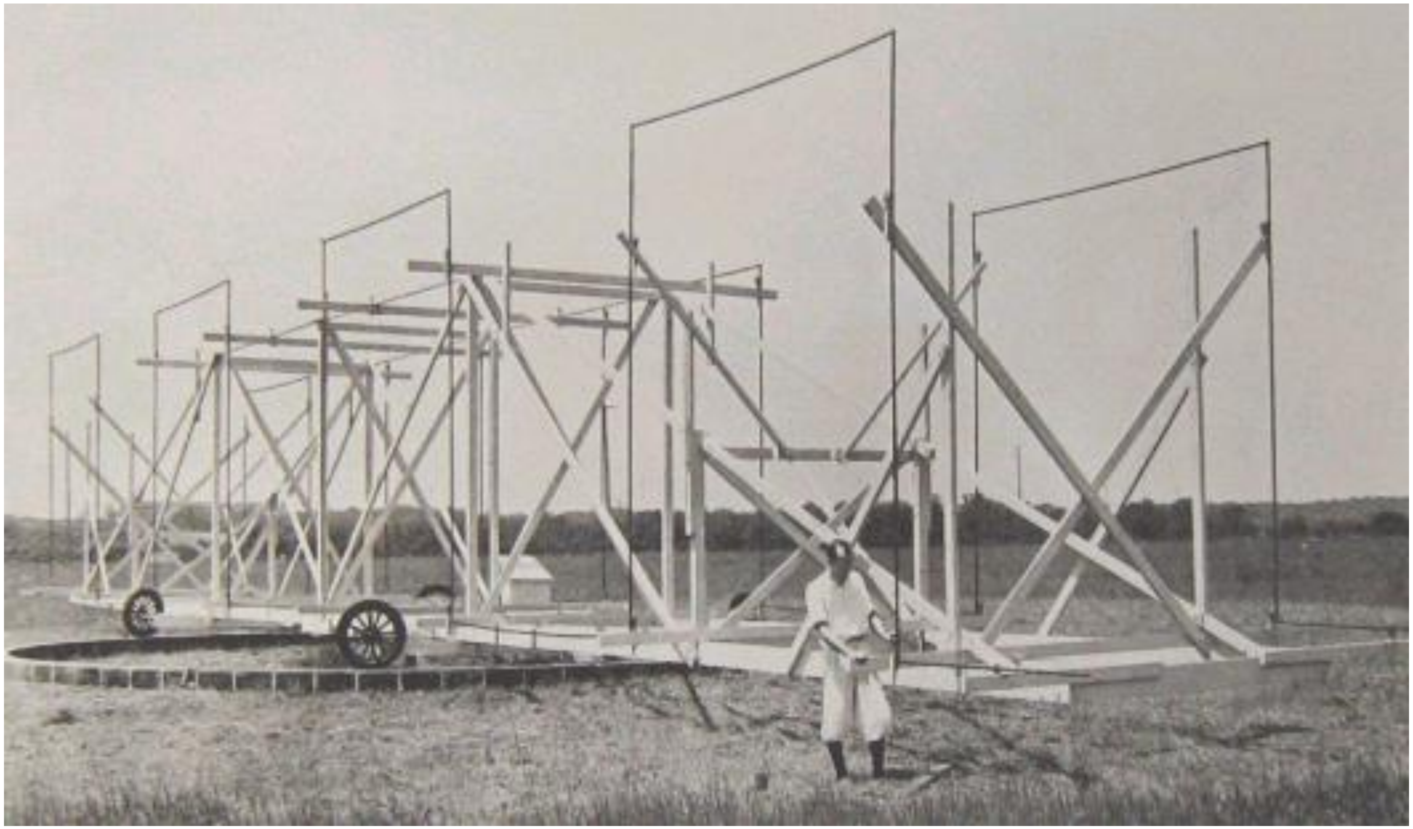
Type 2 AGN:

- Narrow forbidden and permitted lines (300 < FWHM < 1,000 km/s)
- Red, stellar continuum



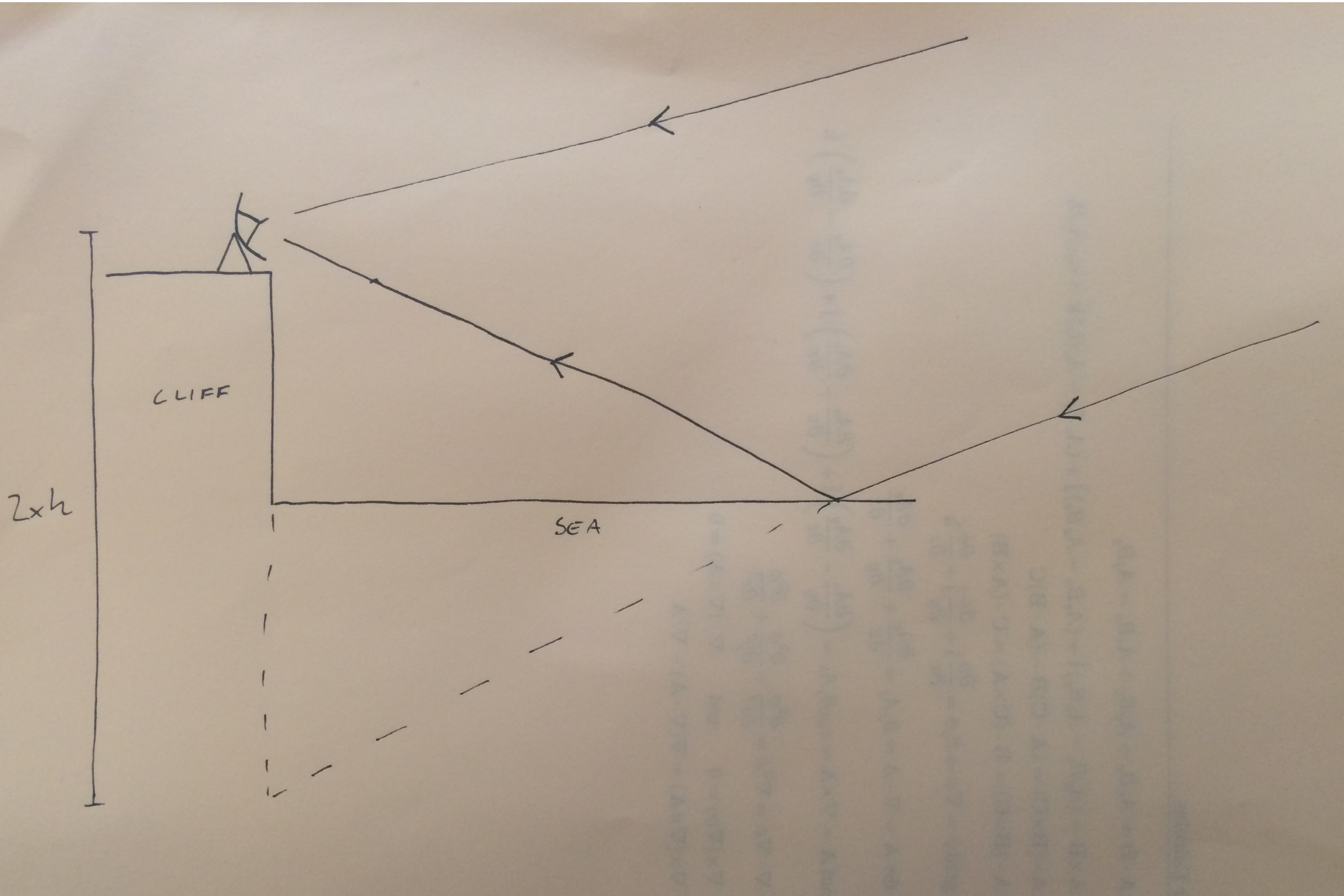
N.B. Although the “narrow lines” of AGN are considered narrow compared with the broad permitted lines observed Seyfert 1 galaxies, they are significantly broader than the emission lines emitted by normal star forming regions (HII regions).

Early days of radio astronomy

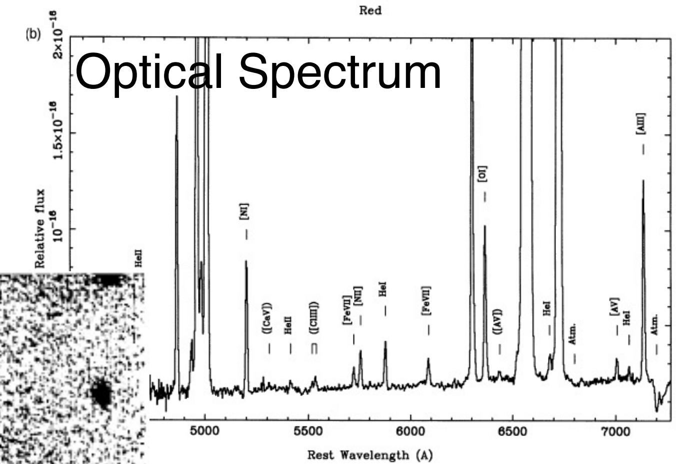


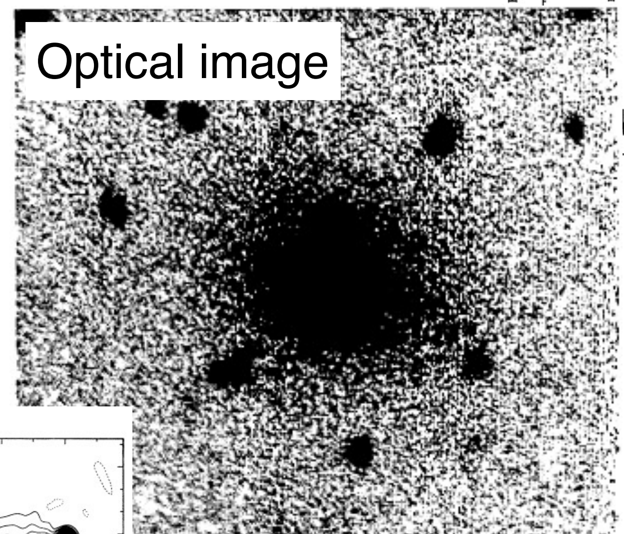
The first radio telescopes weren't parabolic dishes like we're used to seeing today, but instead arrays or wires in which radio waves induced electrical signals. As you may expect, the resolution of these telescopes were very poor - tens of degree, in fact.

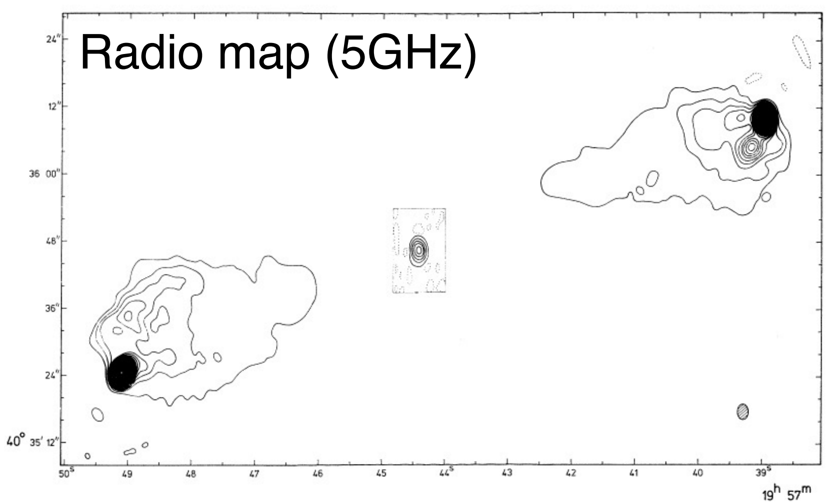
Cliff-top radio interferometry



The discovery of radio galaxies

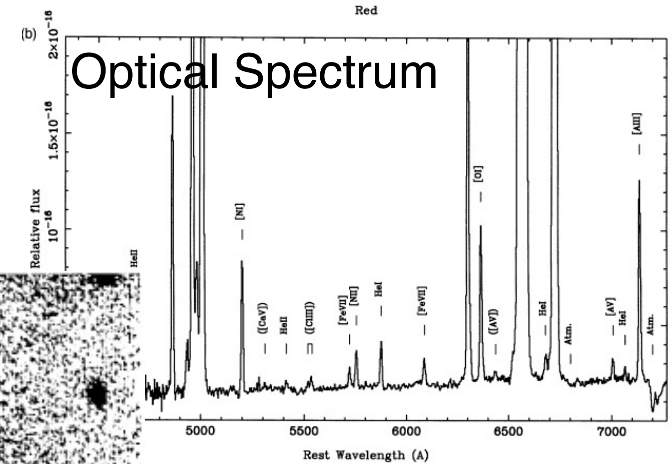


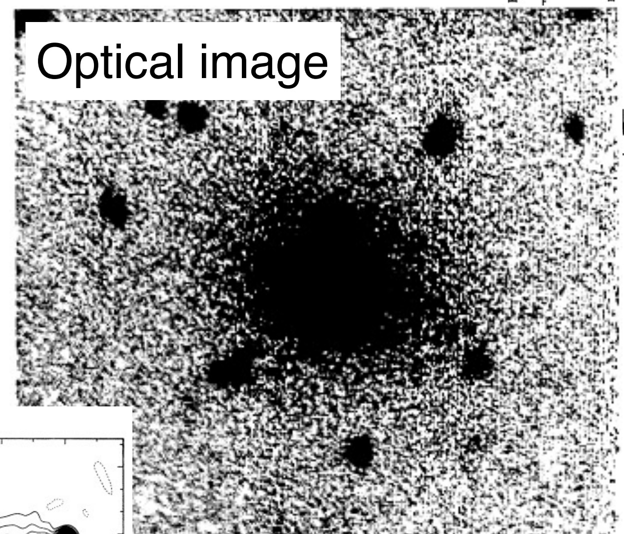




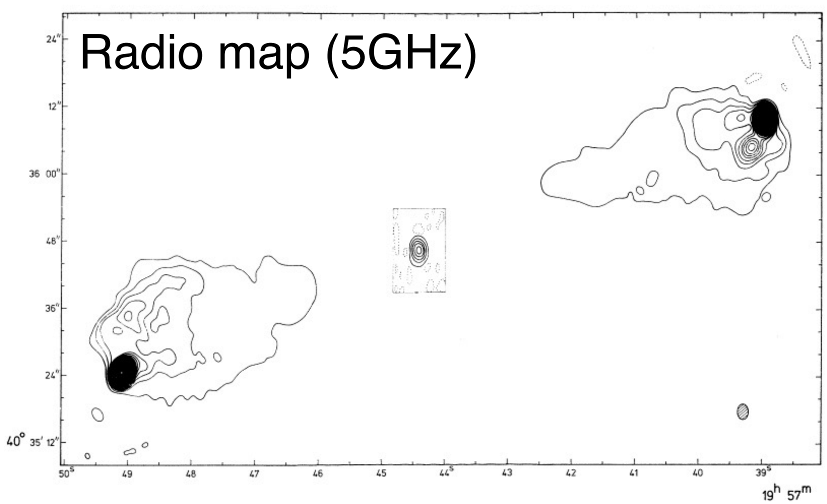
The radio galaxy Cygnus A was optically identified by Baade & Minkowski in 1954, based on an accurate radio position from radio interferometry.

The discovery of radio galaxies





At a redshift z=0.056 Cygnus A is ~10^6x more luminous than the Milky Way at radio wavelengths



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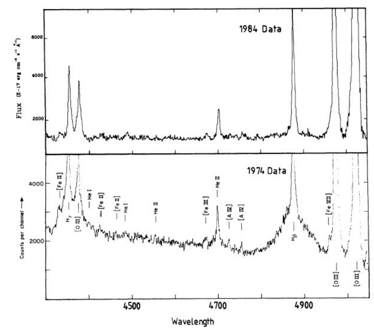
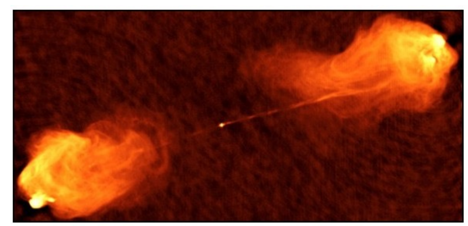
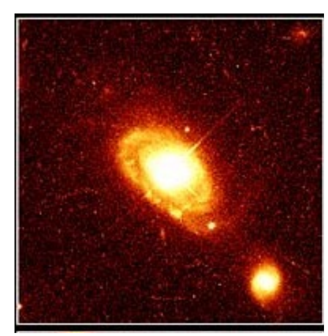
AGN classification I: Main divisions in AGN types

- <u>Broad line/narrow line:</u>
  - Seyfert 1/Seyfert 2
  - BLRG/NLRG
- <u>Radio quiet/radio loud:</u>
  - RQQ/RLQ
  - Seyfert 1/BLRG
  - Seyfert 2/NLRG
  - LINER/WLRG
- <u>Luminosity:</u>
  - RQQ/Seyfert 1
  - RLQ/BLRG



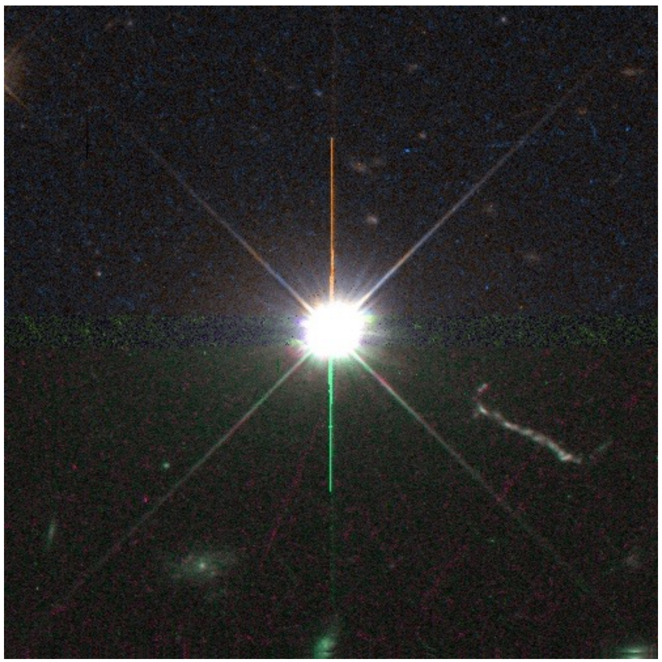




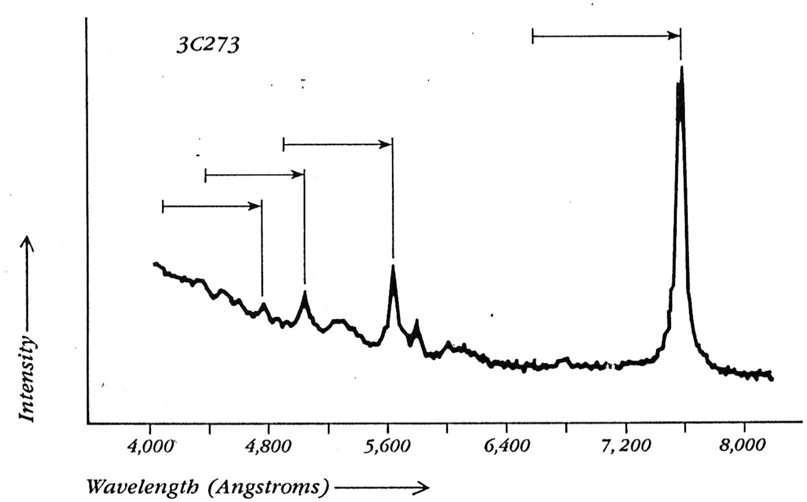
The discovery of the quasar 3C273

(Schmidt 1963)

Optical image



Optical spectrum   z=0.158



At the distances estimated from the redshifts of the emission lines, quasars have a luminosity 10 - 10,000x the integrated light of all the stars in the Milky Way.

AGN classification II: radio-loud vs radio-quiet

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Type 1

Type 2

AGN classification II: radio-loud vs radio-quiet

Radio quiet

Radio quiet quasar (RQQ)

Seyfert 1

Type 1

Type 2

Narrow Line Radio Quiet Quasar

Seyfert 2

AGN classification II: radio-loud vs radio-quiet

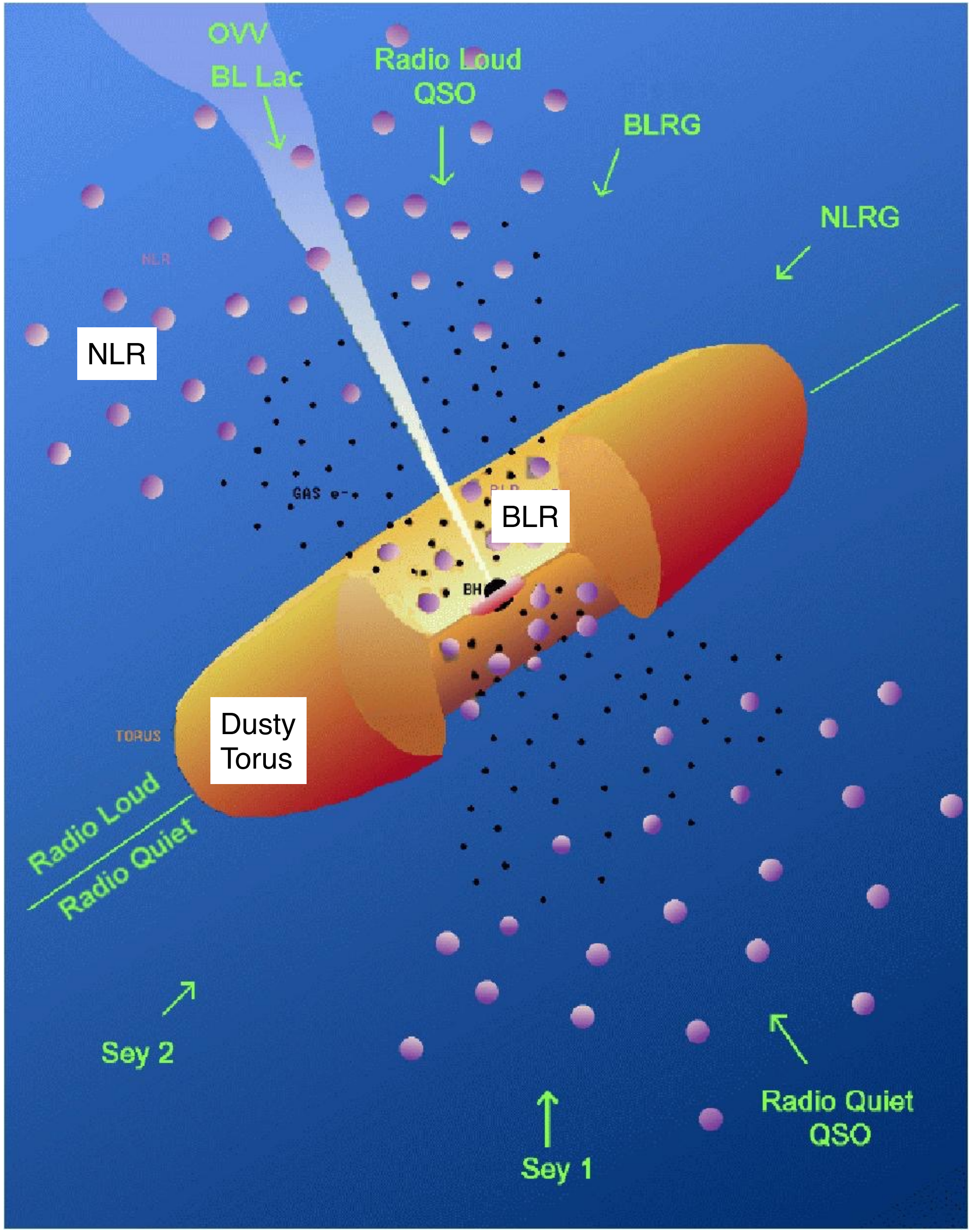
	Radio quiet	**Radio loud**
Type 1	Radio quiet quasar (RQQ) Seyfert 1	Radio loud quasar (RLQ) Broad line radio galaxy (BLRG)
Type 2	Narrow Line Radio Quiet Quasar Seyfert 2	Narrow line radio galaxy (NLRG)

AGN Unification

When Type 2 AGN spectra are taken in polarised (i.e., reflected) light, we see evidence of broad emission lines similar to those of Type 1 AGN.

This implied that Type 2 AGN contained a broad line region (BLR) that is obscured from our line of sight. However, it can’t be completely obscured along all lines of sight, since we see the BLR in polarised light.

It was therefore suggested the BLR (and nucleus) is surrounded by a dusty torus in both Type 1 and Type 2 AGN. In the case of Type 1 AGN, we are observing into the “hole” of the torus



General properties of active galaxies

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- Bright, point-like nuclei at optical wavelengths

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- Nuclei comparable in luminosity to the integrated stellar emission from the host galaxies or greater (i.e. $L_{AGN} \geq L_{star}$)
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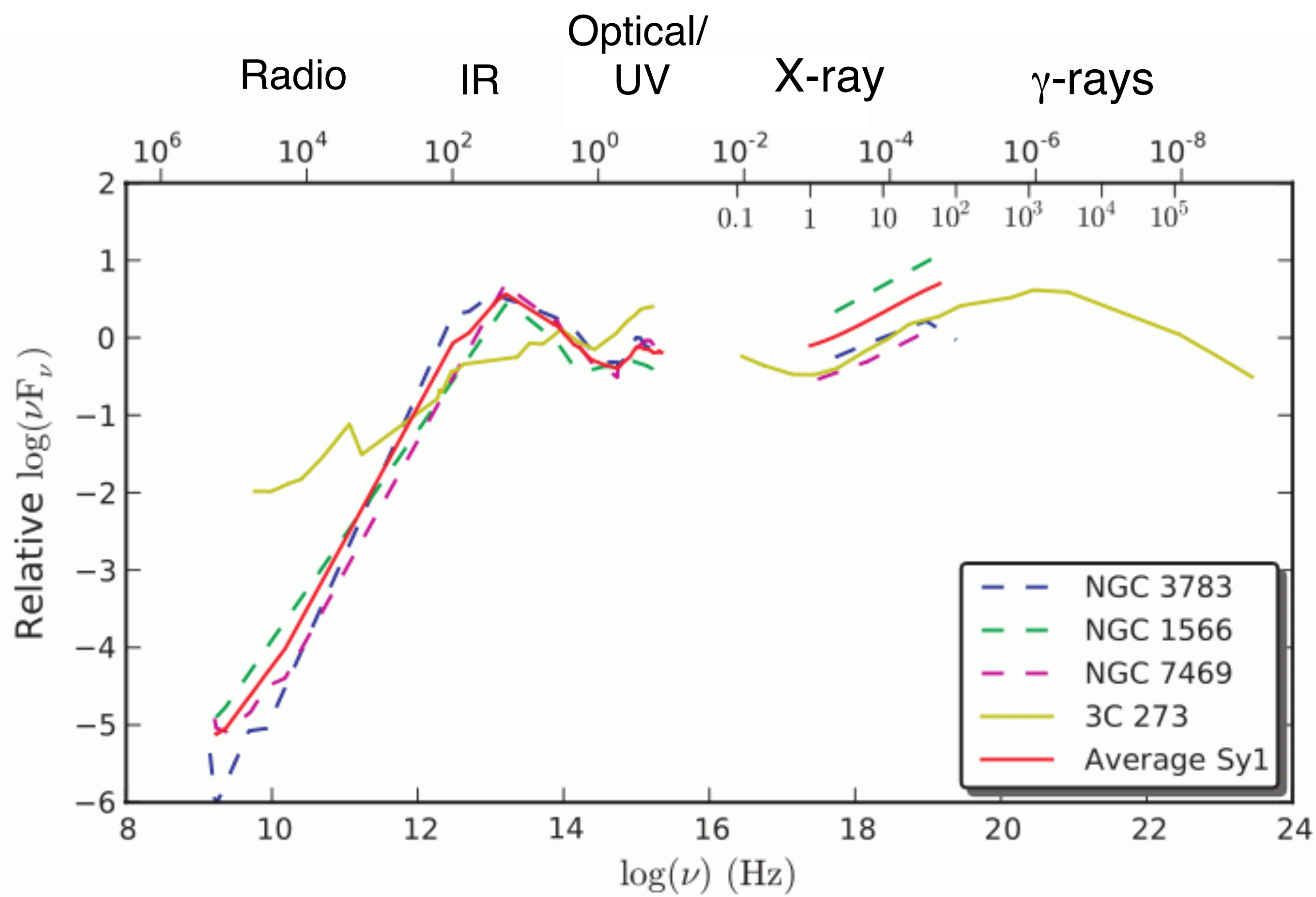
- Compared with normal galaxies, AGN emit strongly across the entire electromagnetic spectrum from X-ray to radio

Finding AGN in wide-field surveys – I Quasars: colours, morphologies and spectra

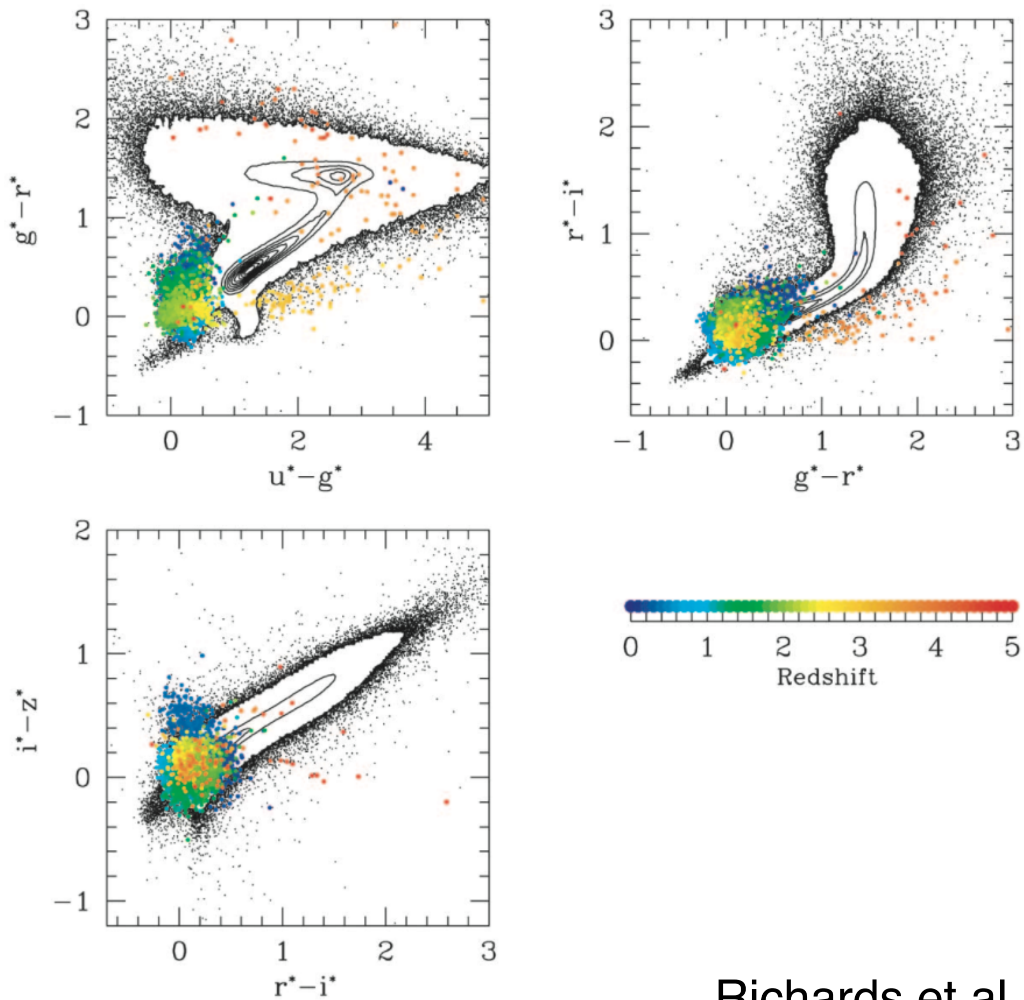
- Identify point sources in optical/UV images
- Select quasar candidates based on colour-colour diagrams
- Use spectra to confirm quasar classification, based on the characteristic quasar broad permitted lines
- >100,000 quasars identified in this way in SDSS survey to z~6.5 over ~35% of sky

AGN spectral energy distributions



AGN are extremely broad-band emitters, emitting over 12 decades
In wavelength frequency, from radio to gamma rays!

Colour selection of quasars in SDSS



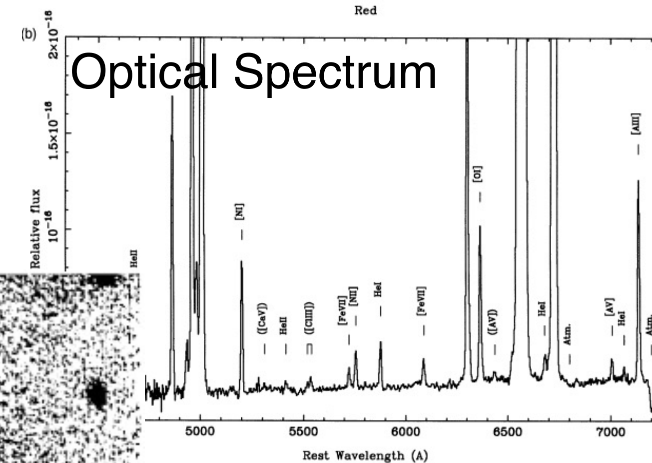
Richards et al. (2002)

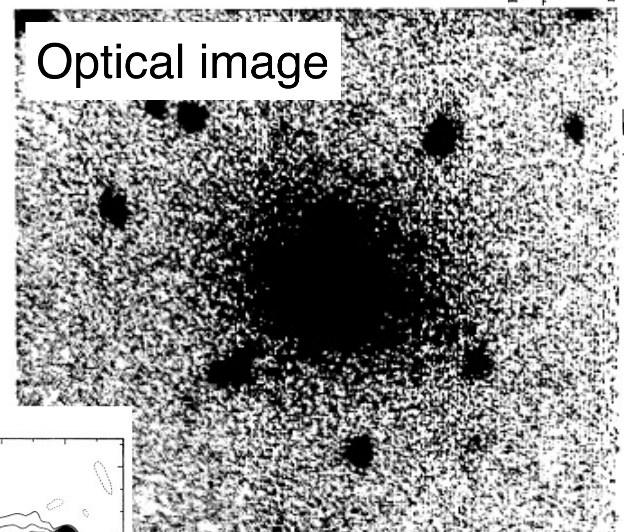
The Sloan Digital Sky Survey (SDSS)

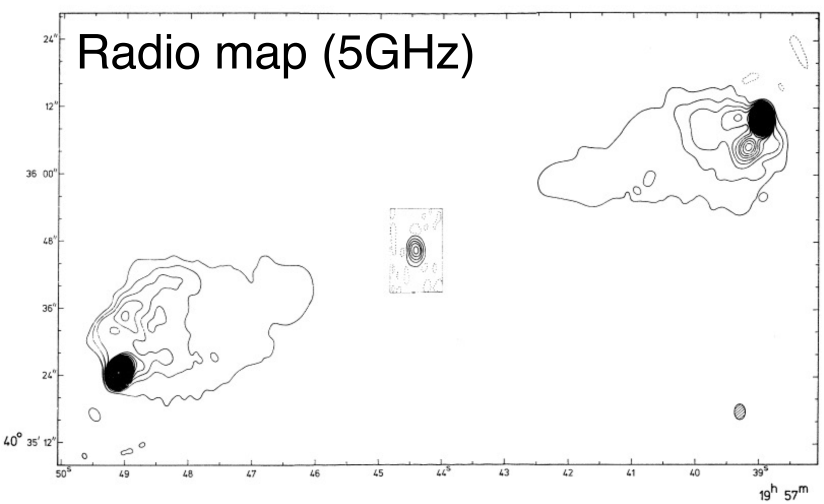
- 2.5m telescope with 1.5 square degree field of view.
- Has covered 14,555 square degrees (~33% of the sky) with deep, multi-colour imaging and spectroscopy observations.
- Fibre-fed multi-object spectrographs capable of observing 600 galaxies in a single observation.
- So far, high quality spectra have been taken for more than 800,000 galaxies, 100,000 quasars and 185,000 stars.

Sloan Telescope, Apache Point, New Mexico

Finding AGN via their radio emission







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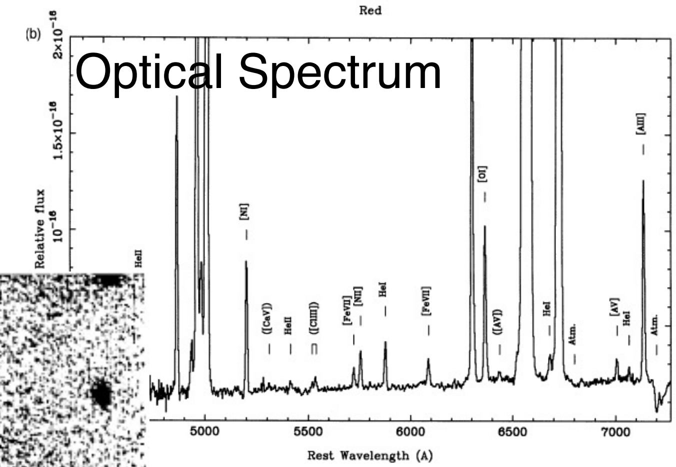

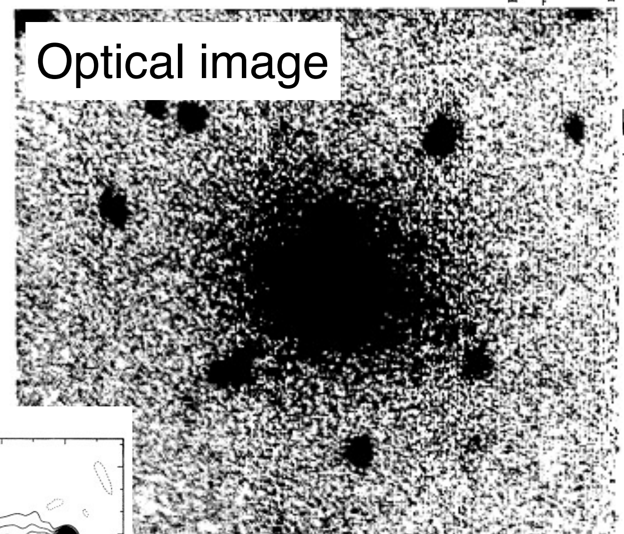

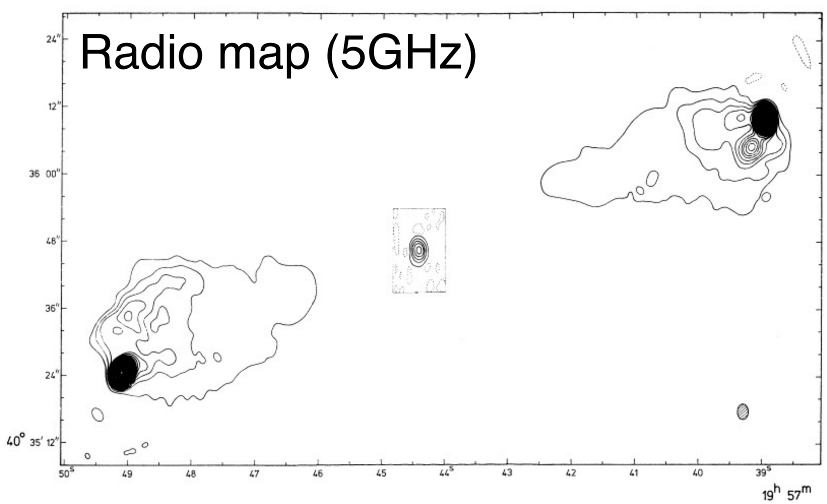

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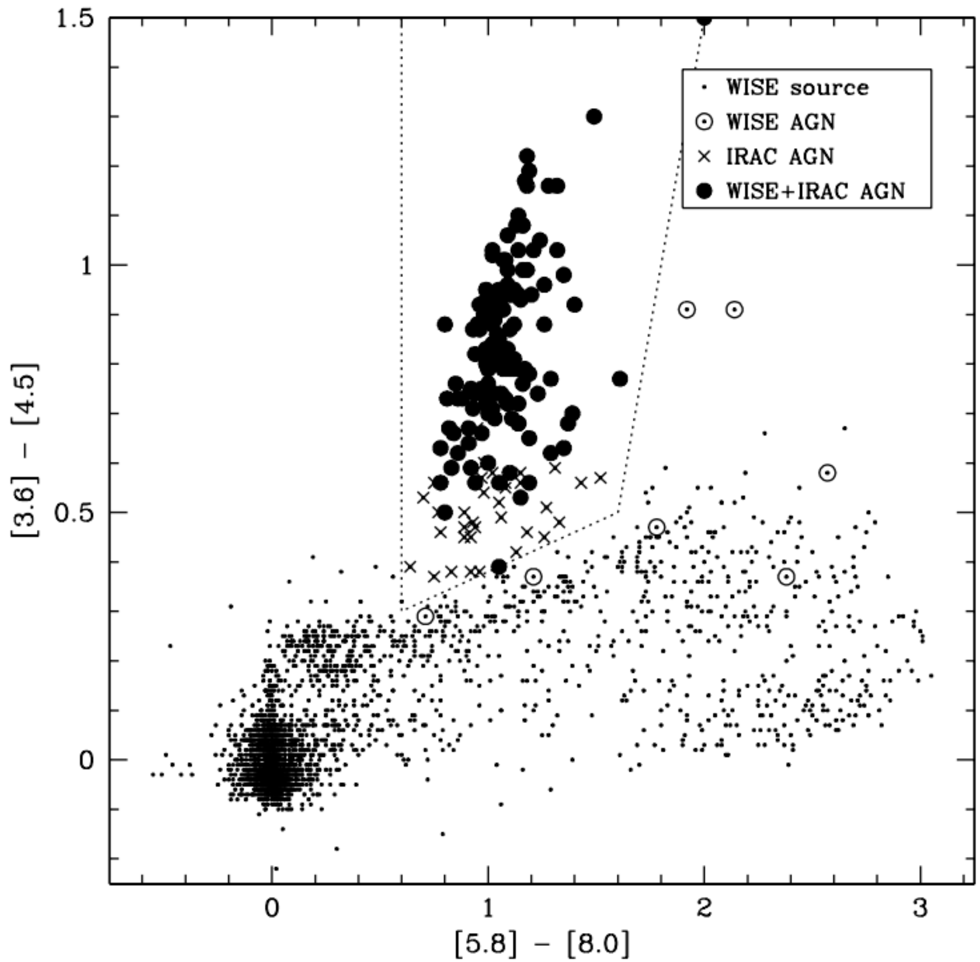
Finding AGN in wide-field surveys – II Radio surveys

- A sub-set of AGN (~10%) have strong radio synchrotron emission with luminosity $>10^{24}$ W Hz^{-1} at 1.4GHz (greater than radio emission of the most extreme surveys)
- Radio surveys include 3CR (> 10 Jy at 0.178 GHz, northern hemisphere, 328 sources), and FIRST (> 1 mJy at 1.4 GHz, northern hemisphere, ~900,000 sources)
- Require follow-up spectroscopy to measure the redshifts of the sources, and thereby confirm that the sources are genuinely radio-luminous and not merely nearby starbursts
- But not all AGN are powerful at radio wavelengths…

Finding AGN in wide-field surveys – III mid-IR colours

- AGN tend to have relatively red colours at mid-IR wavelengths ($\geq 3.5\ \mu$m), relative to stars and galaxies
- Therefore colour-colour plots can be used to select AGN in both deep-field and wide-field mid-IR surveys (e.g. Spitzer, WISE satellite)
- This technique has the advantage that it can be used to detect both obscured and unobscured AGN

mid-IR colour selection



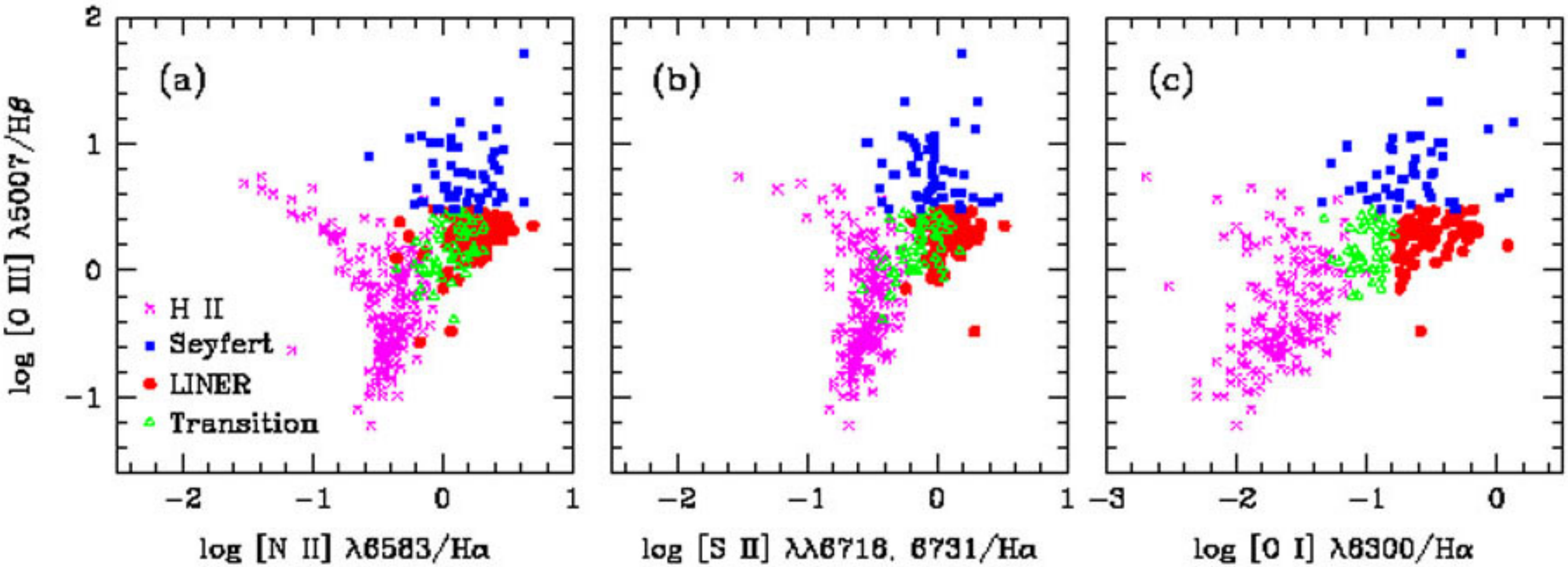
Stern et al. (2012)

AGN are found in a “wedge” region of the mid-IR colour-colour diagram

Finding AGN in wide-field surveys – IV emission line ratios

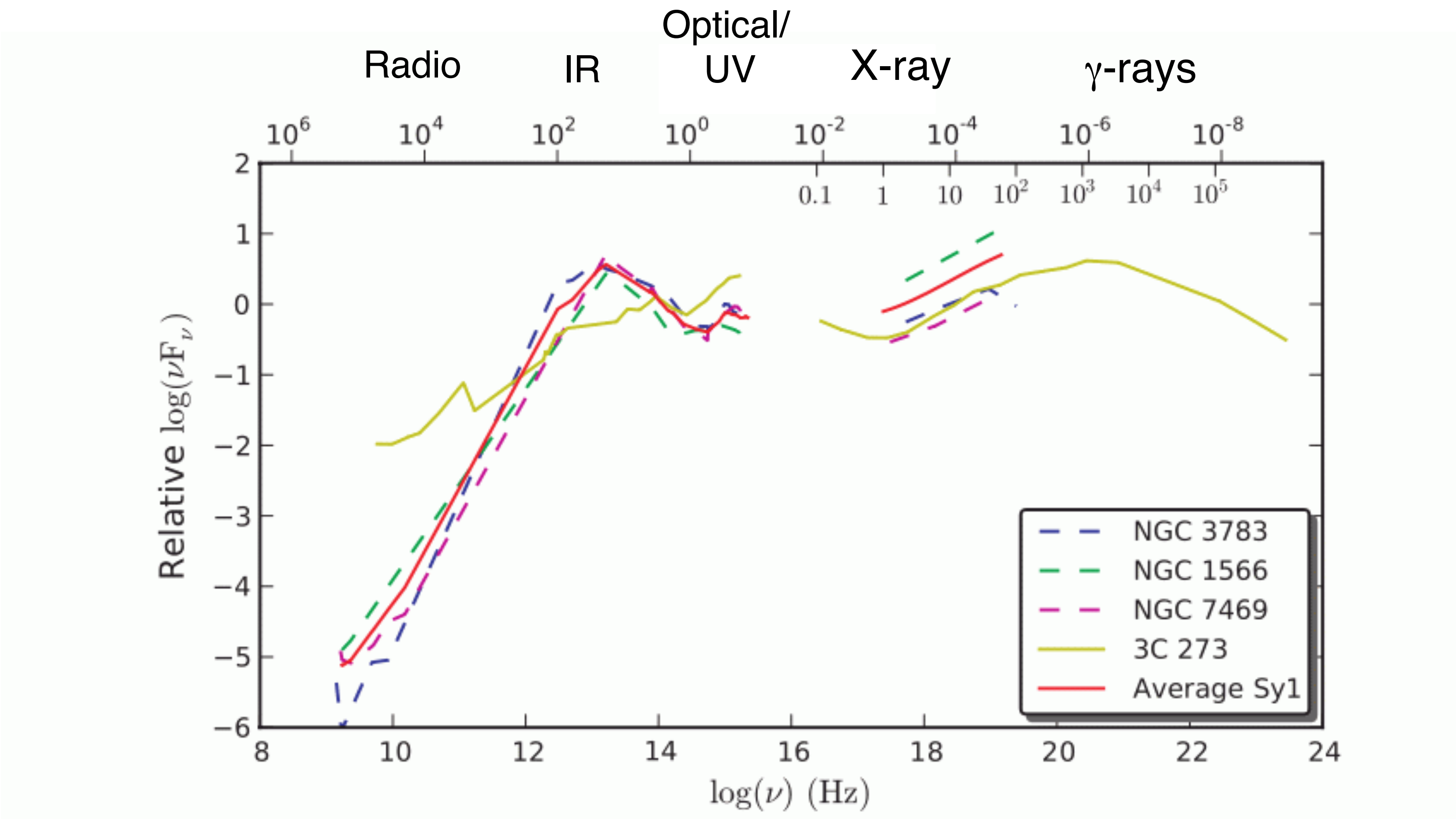
- Based on the fact that the emission line spectra of AGN show a much broader range of ionization than HII regions photoionized by stars, line ratio diagnostic diagrams can be used to find AGN
- >88,000 AGN have been identified in this way in the SDSS survey in the northern hemisphere
- Particularly useful for finding type 2 AGN in which the broad line and accretion disk emission are obscured by the central obscuring torus.

The ionization of AGN emission line regions: diagnostic diagrams



Seyfert, HII region and LINER spectra can be distinguished on the basis of diagnostic diagrams, which plot one line ratio against another. Different classes of objects occupy different zones in the diagnostic diagrams.

Finding AGN via X-rays



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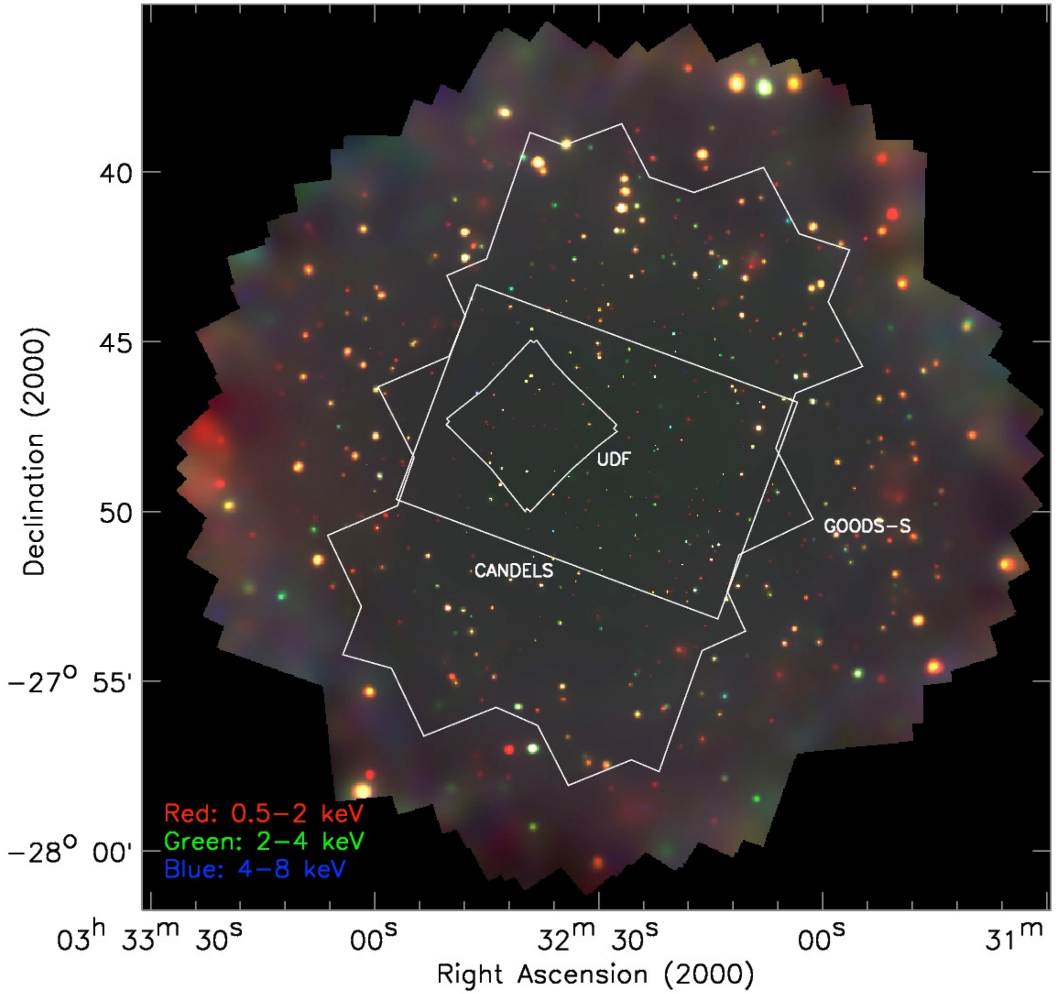
Finding AGN in deep field surveys: X-rays

- Deep X-ray imaging (>0.1 keV) is particularly effective at finding AGN in narrow-field surveys (e.g. Hubble Deep Fields)
- For example, the Chandra Deep Field South (CDFS), which encompasses the Hubble UDF, detected >300 AGN in a 44 day exposure of the 0.11 square degree area
- Objects detected in this way are unambiguously AGN, since most other types of astronomical sources tend to be much weaker X-ray emitters
- But some objects in which the AGN are particularly heavily obscured by gas in the torus may not be detected in this way…

The Chandra Deep Field South (CDFS)



Lecture 11 Learning Objectives

- Know how AGNs were first discovered
- Know the different types of AGN
- Understand the importance of radio astronomy in the identification and study of AGN
- Be able to describe the AGN unified model, and how it results in Type 1 and Type 2 AGN.
- Know the different ways of identifying AGN.