Lecture 11

AGN and You

March 25 2003
8:00 PM
BPS 1420

Quiz 2

1. What system of time do astronomers use rather than the standard day-month-year system?

2. In that system, how long would it be between noon today (Tuesday) and midnight tomorrow (Wednesday night, going into Thursday)?

3. Name two types of pulsating variable stars.

4. What are pulsating variables useful for?

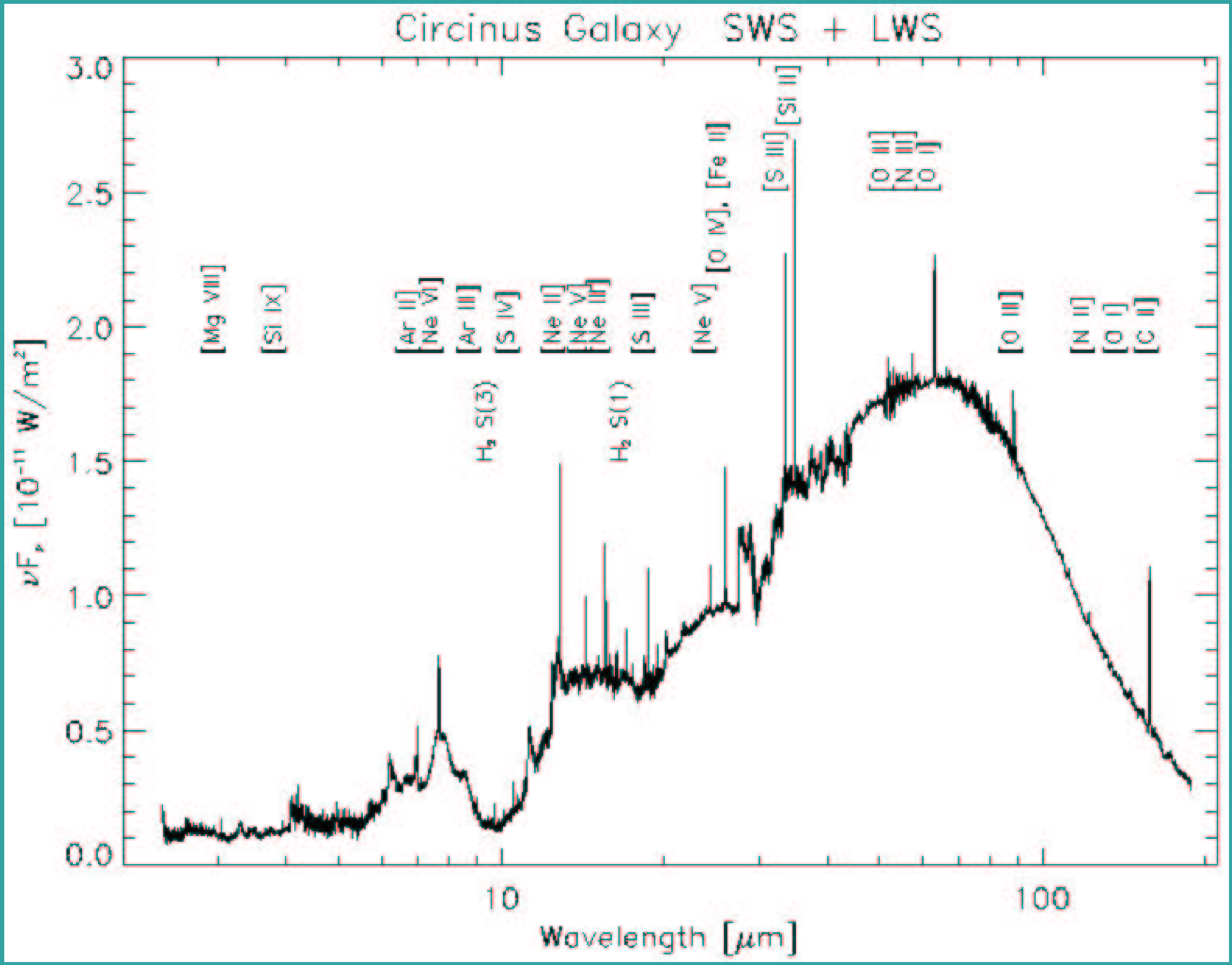
This week's topics

- History
- Types
  - Seyfert Galaxies
  - Radio Galaxies
  - Quasars
- Grand Unified AGN Theory

A Brief History of AGN

- 1908: Edward Faith observing spectra of "spiral nebula" (aka spiral galaxies)
  - Some had peculiar features

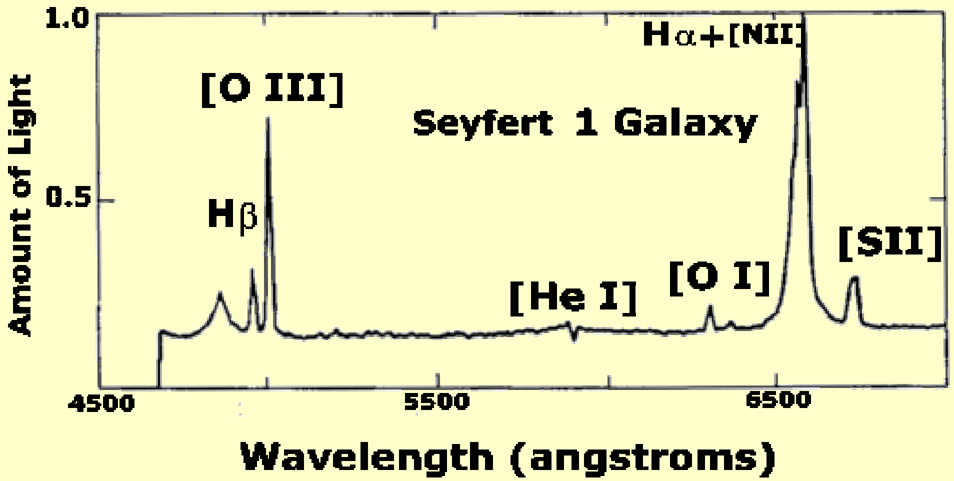
Peculiar Spectra

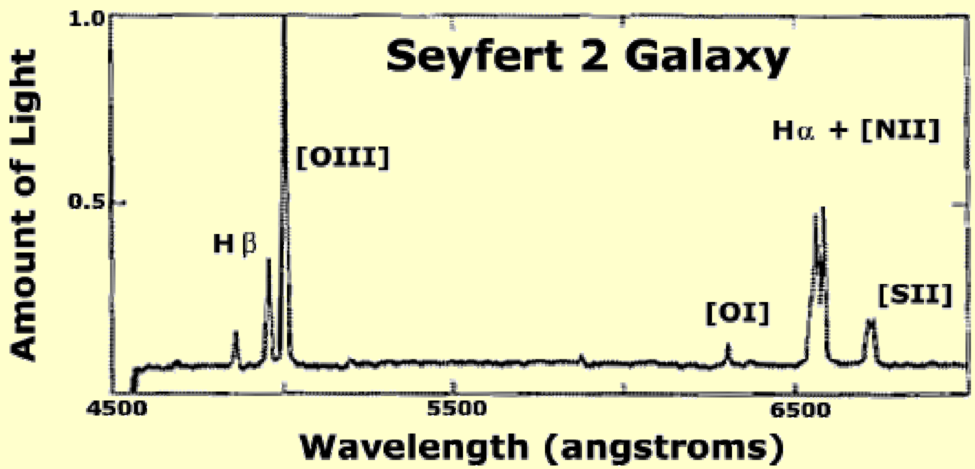


A Brief History of AGN

- 1908: Edward Faith observing spectra of "spiral nebula" (aka spiral galaxies)
  - Some had peculiar features
- 1926: Edwin Hubble recorded emission lines in three galaxies
- 1943: Carl Seyfert found that a small percentage of galaxies had bright nuclei that produce these emission lines

Seyfert Galaxies





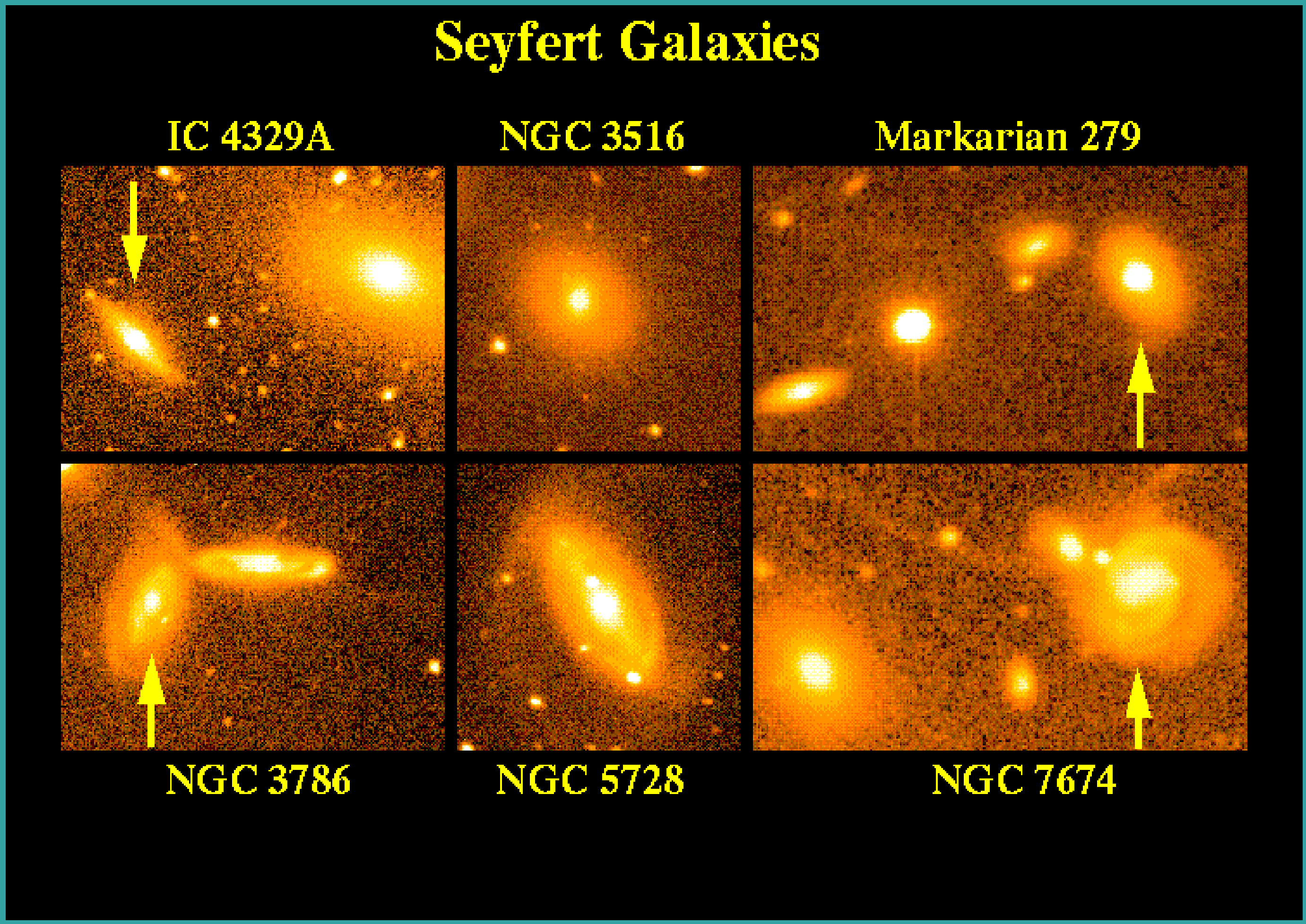
Seyfert galaxies have strong emission lines. In type 1, these lines are much more broad than in type2. This implies a much higher velocity (rotational) than in type 2.

Other Features of Seyfert Galaxies

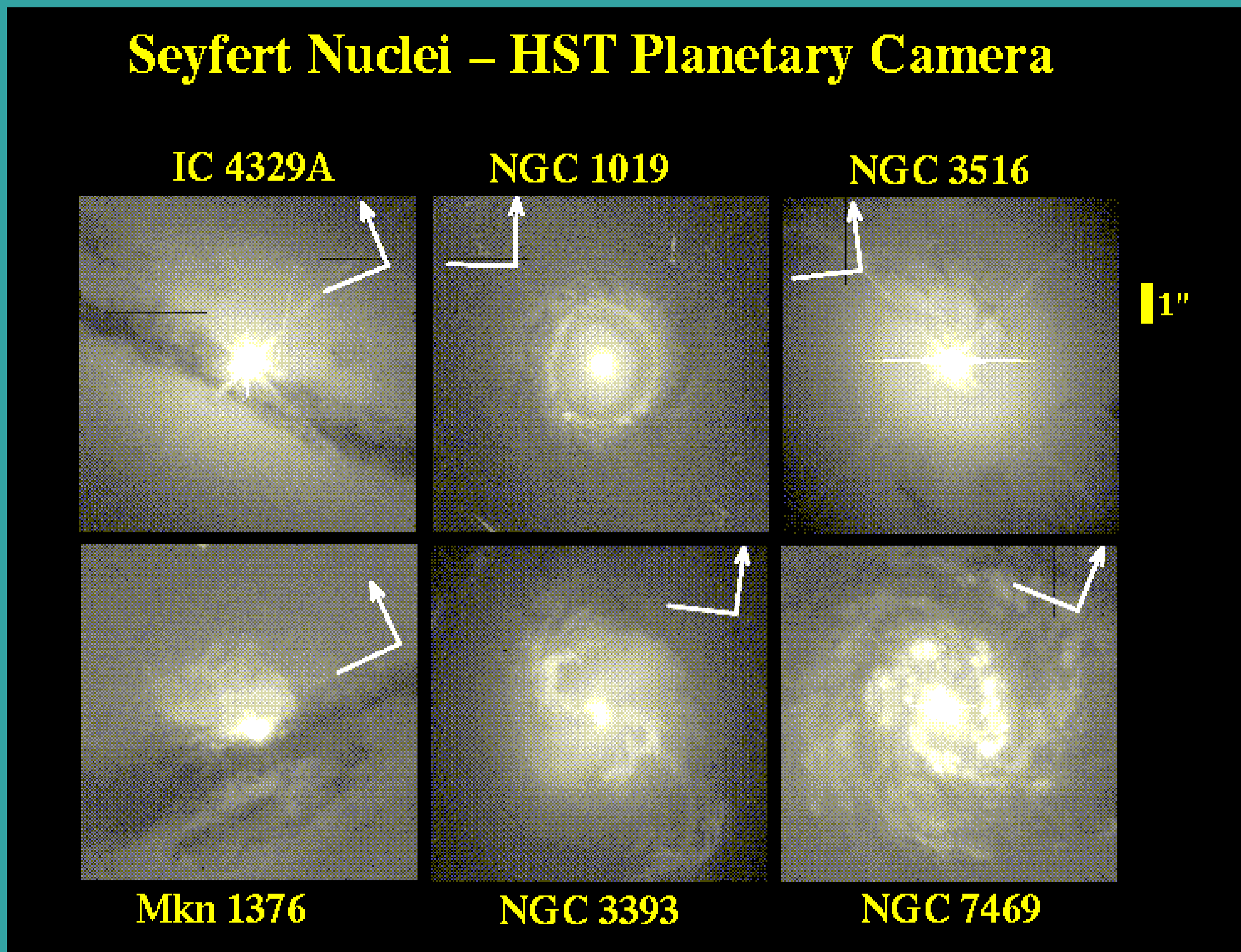
- Emission comes from central region.
- This central region has a star like appearance.

- Definition of what is and isn't a Seyfert galaxy has evolved somewhat. It now depends on particular details in the spectra.

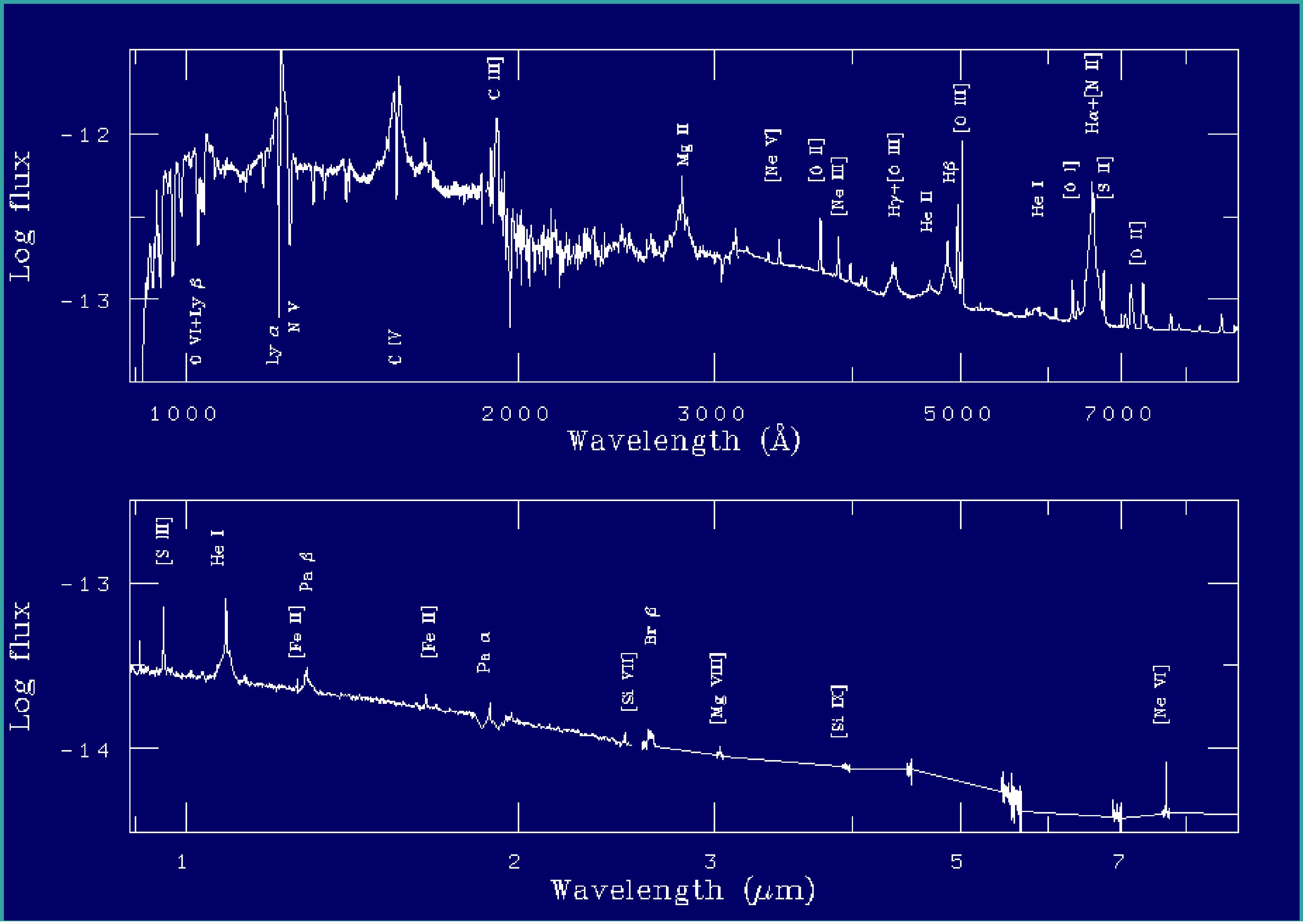
HST Gallery of Seyfert Galaxies



Central Regions of Seyfert Galaxies



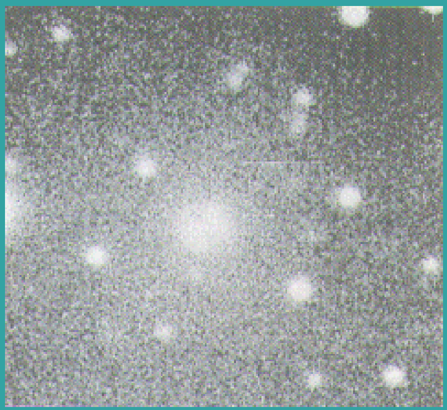
Detail Spectra (NGC4151)



Radio Galaxies

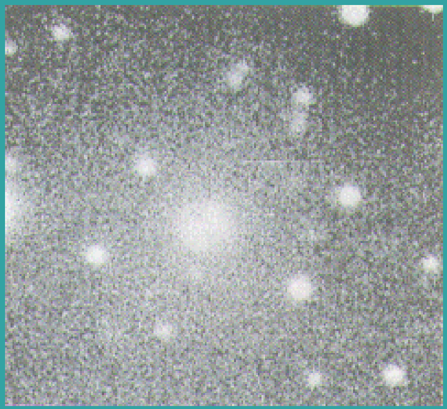
- Post WWII, radio astronomy became widespread.
- Walter Baade and Rudolph Minkowski were able to find an optical counter part to a strong radio source, Cygnus A (the radio position found by F. Graham Smith).

Cygnus A



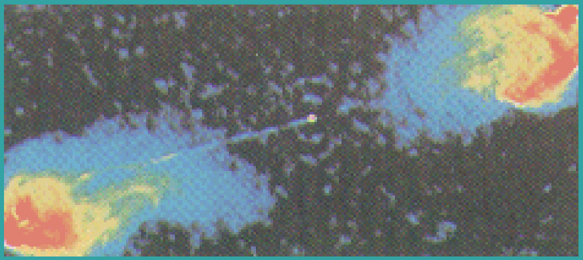
Optical image of Cyg A. Not very remarkable.

Cygnus A

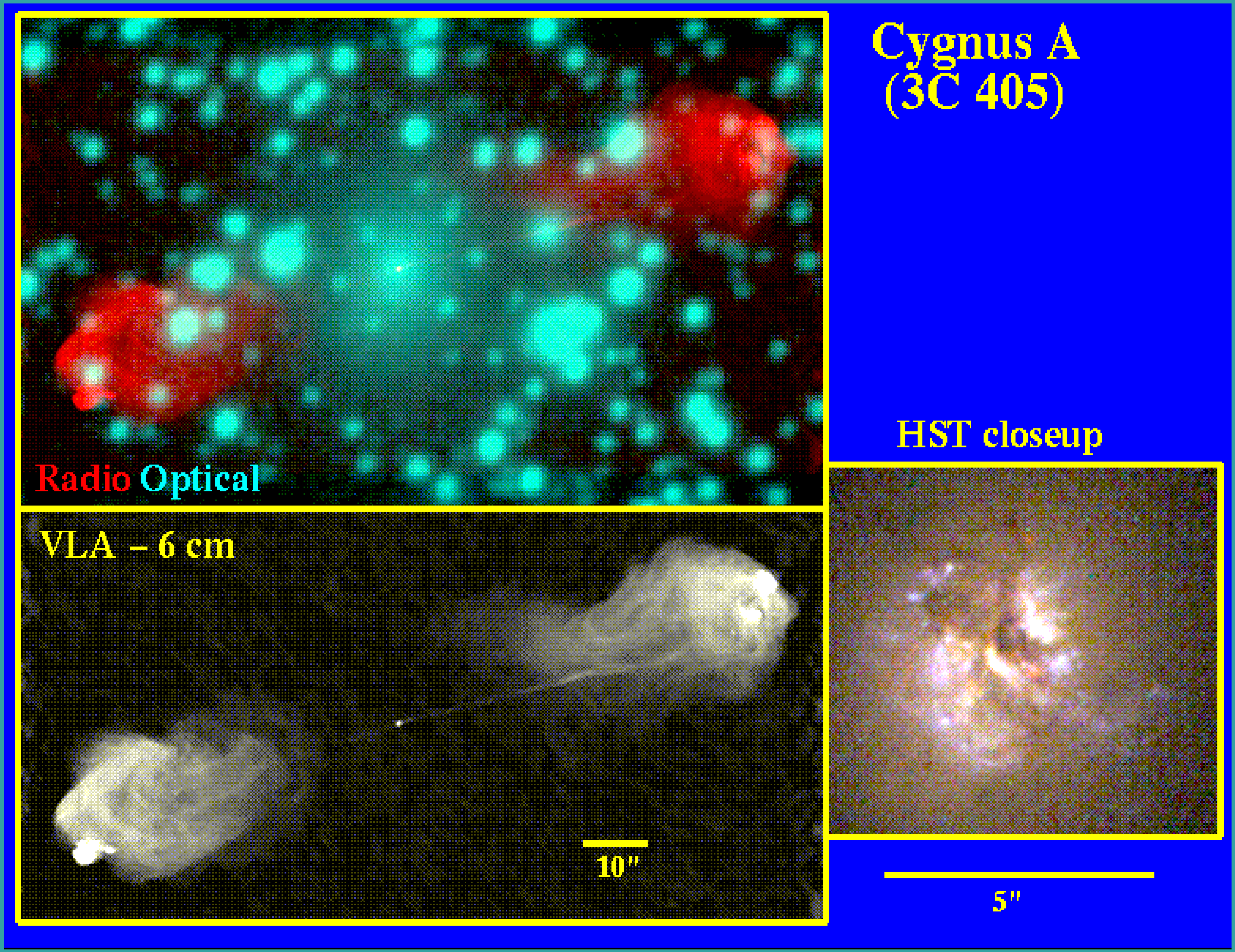


Optical image of Cyg A. Not very remarkable.

In radio, Cyg A looks quite different. There is a double lobed radio "jet" that can be clearly seen.



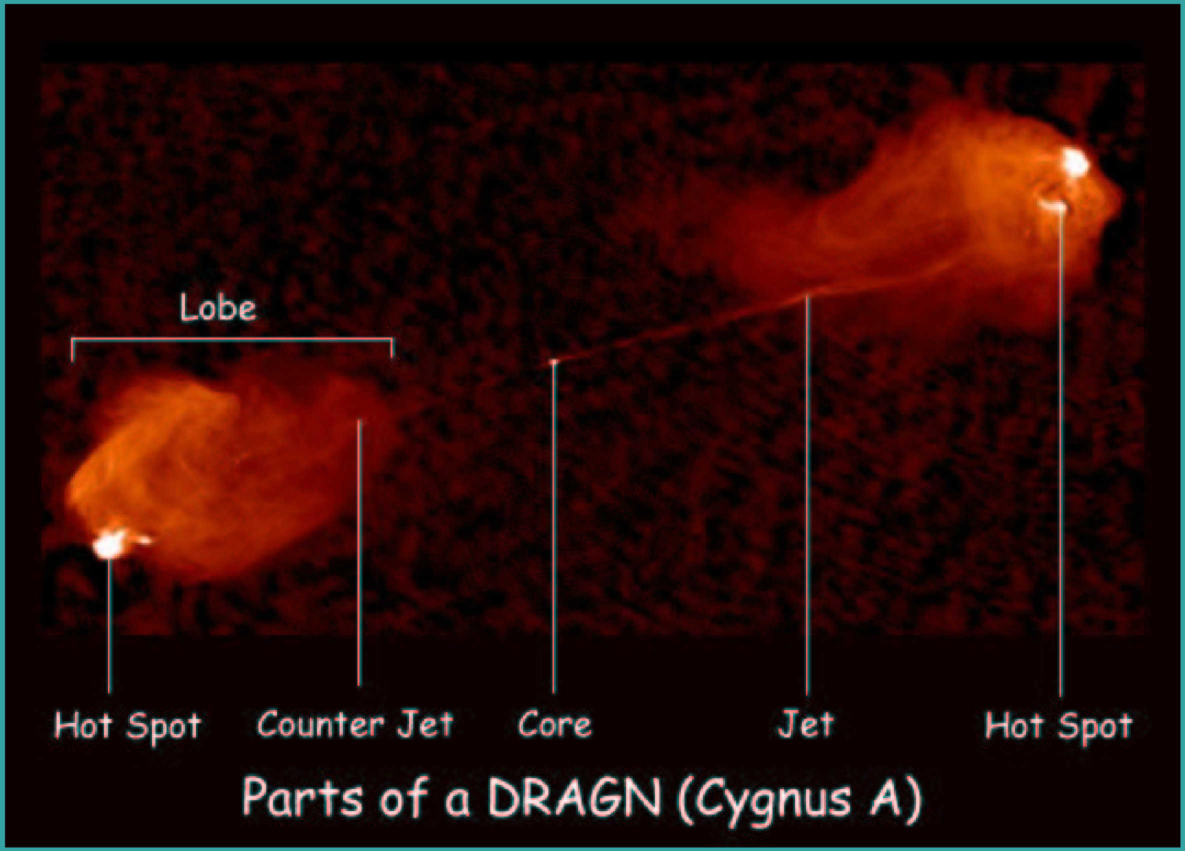
Cygnus A (detail)



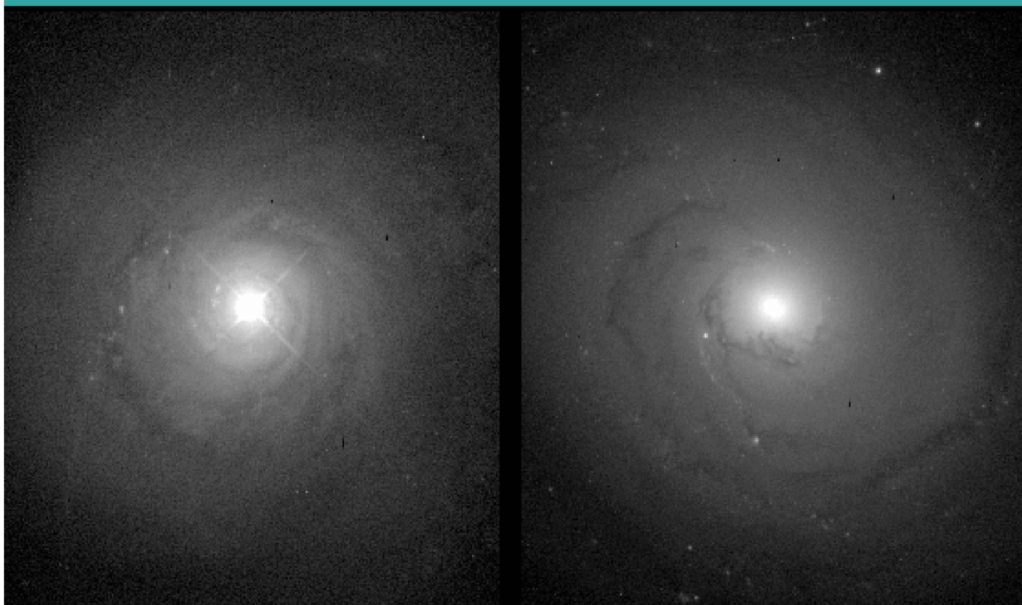
More on Radio Galaxies

- Two types, much like Seyferts;
  - BLRG (Broad Line Radio Galaxies)
  - NLRG (Narrow Line Radio Galaxies)
- Main difference is large radio emission
- The double lobed feature sometimes called DRAGN (Double Radio sources Associated with Galactic Nuclei)
  - Proving once again that it is the name that matters most...
  - Most often associated with elliptical galaxies

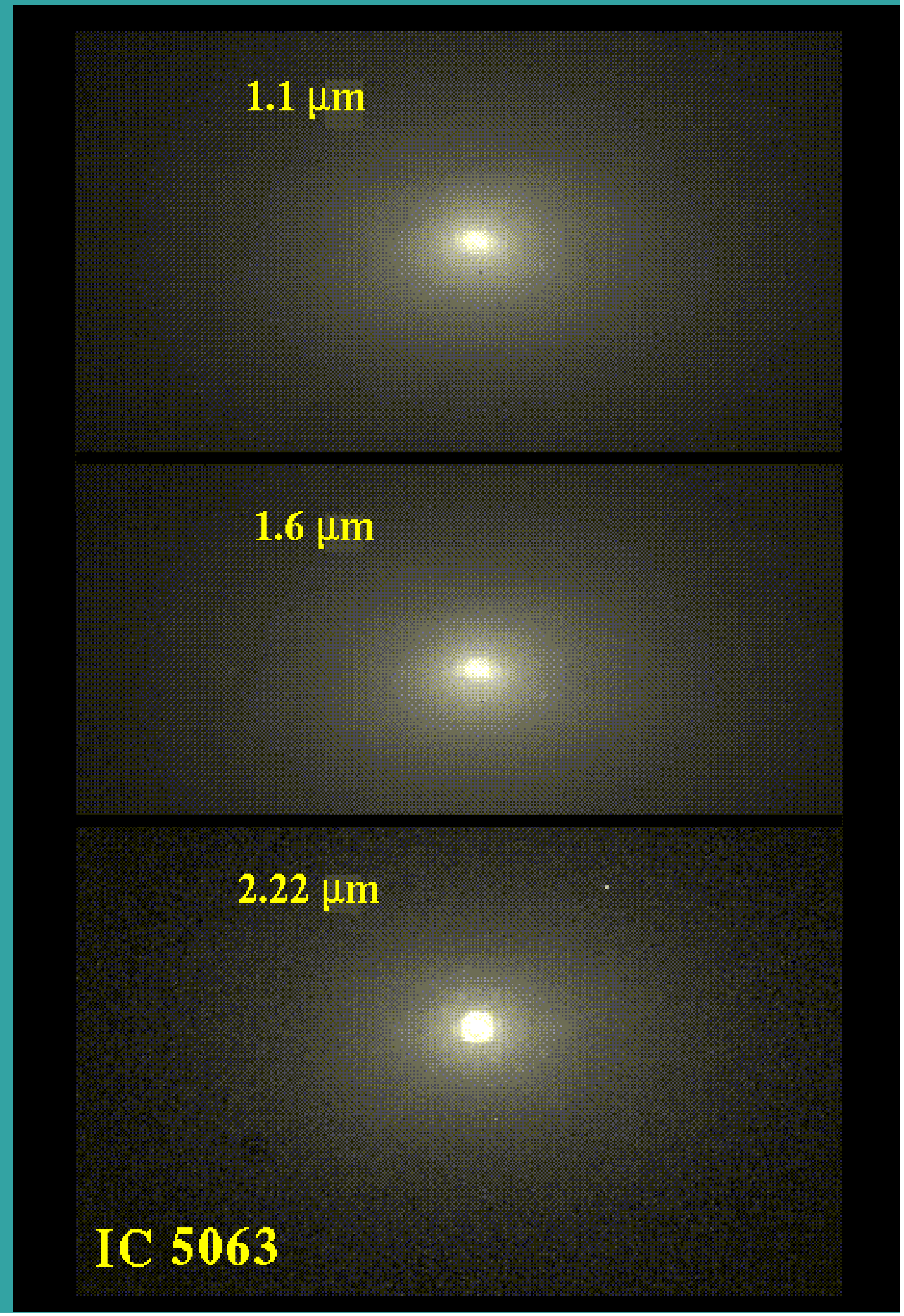
DRAGN detail



Optical Properties



AGN Normal Galaxy



Quasars

- 1960: after 3C (3^{rd} Cambridge) Radio survey was released, Thomas Matthews and Allan Sandage were searching for optical counterparts to the radio sources.
  - Radio sources were typically associated with radio galaxies
- 3C 48 was different

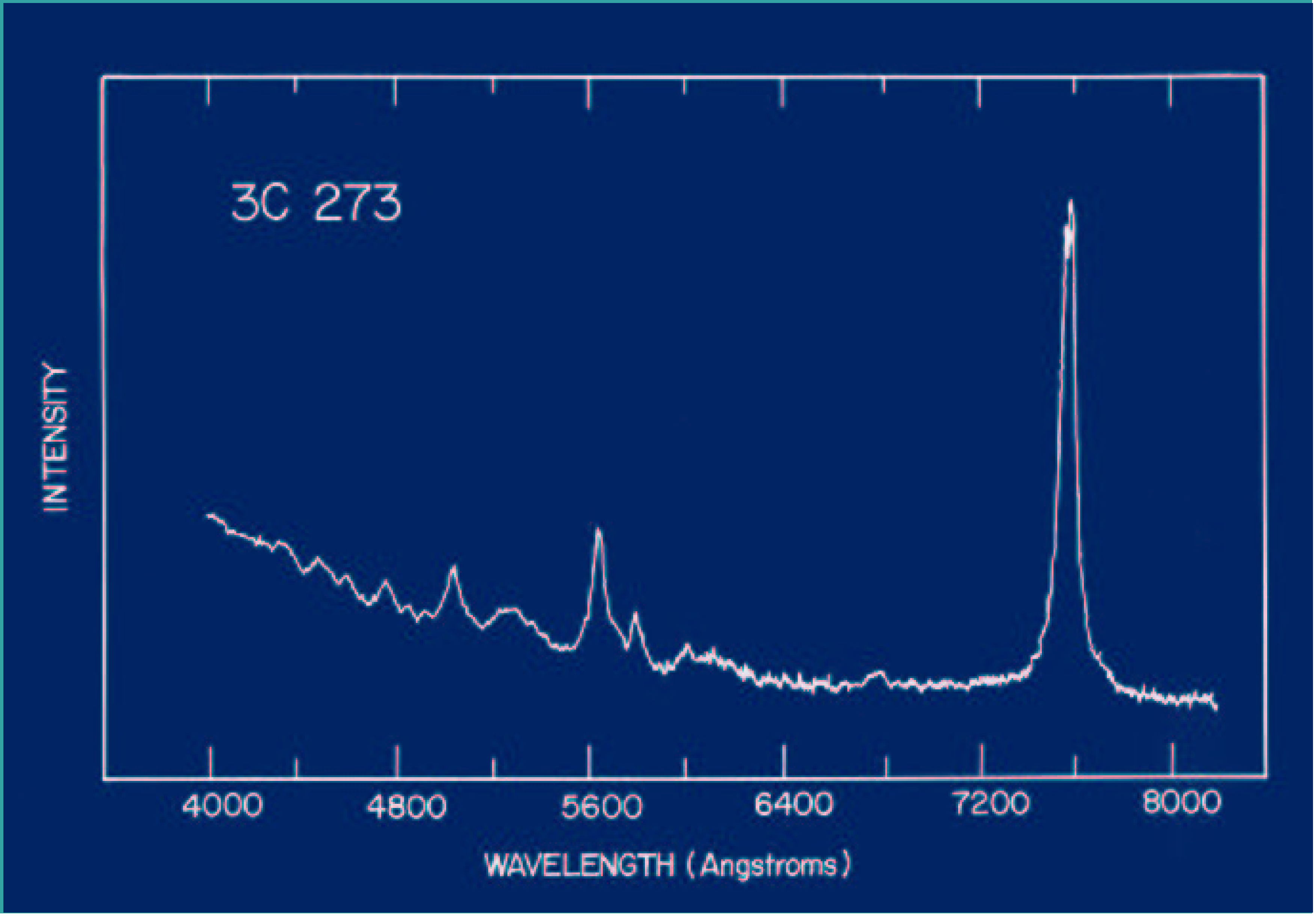
3C 48 and 3C 273

3C 48 was a 16th magnitude star like object. 3C 273 (pictured at right) imaged in 1963 was similar, although it did have a small jet structure.

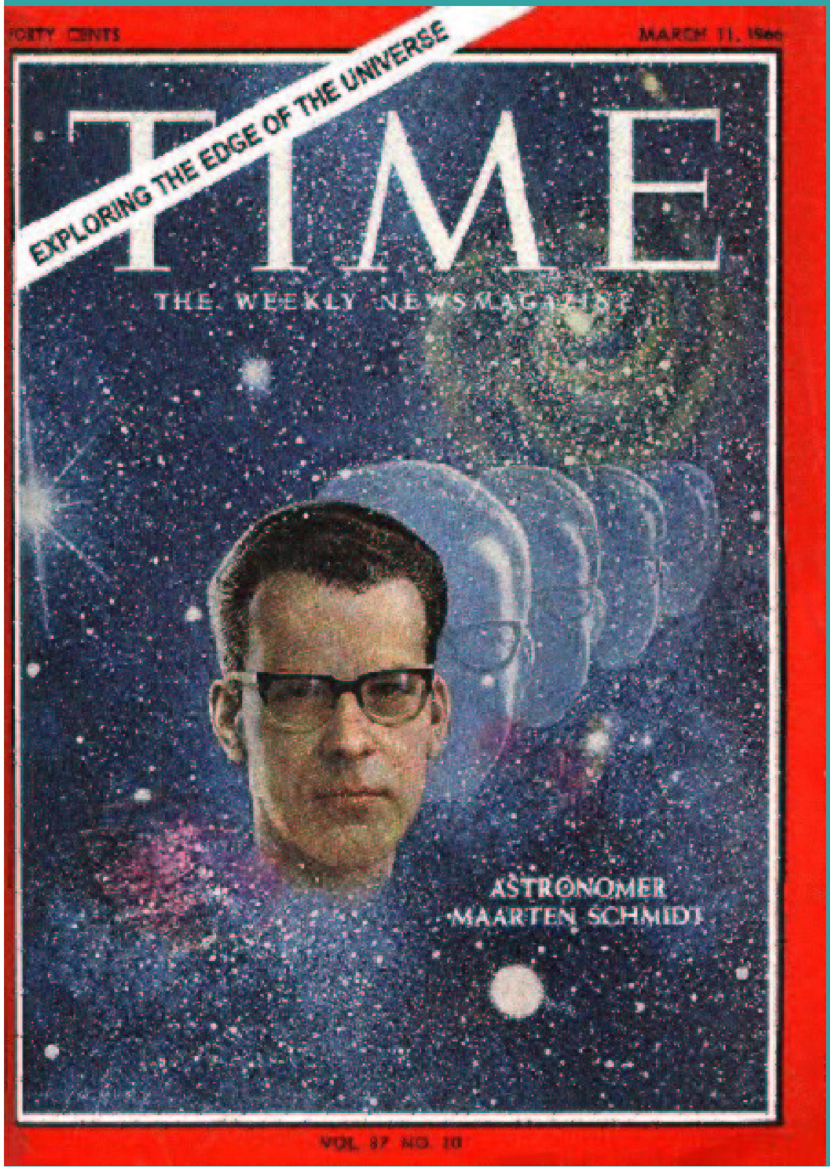
These and similar objects were dubbed Quasi-Stellar Radio Sources or quasars.

The spectra for these objects were "exceedingly weird" (A. Sandage).

Spectrum of 3C 273



Schmidt and Redshift



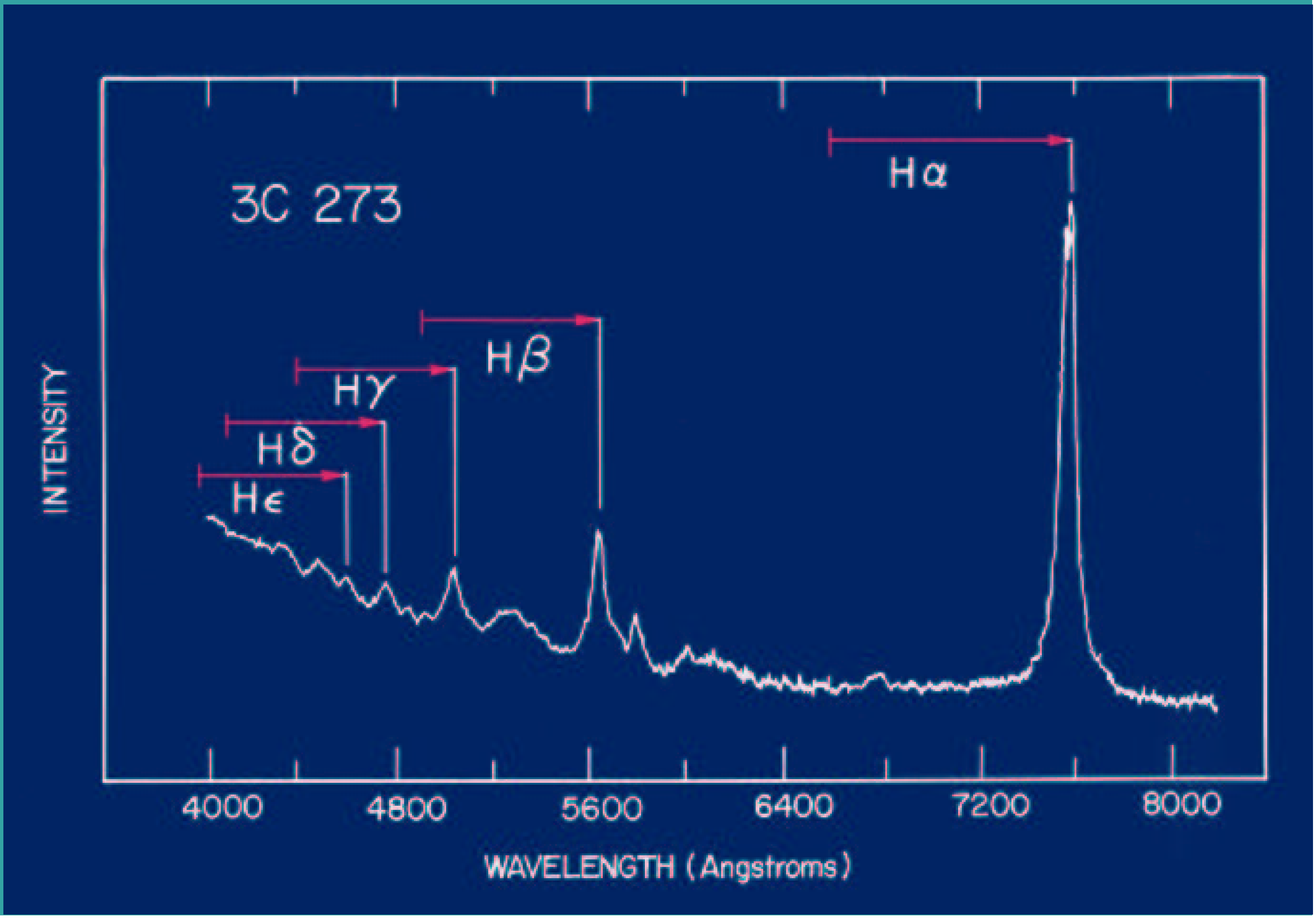
Maarten Schmidt (a Dutch astronomer) realized that the spectrum was just red-shifted by a huge amount.

Recall that redshift is measured by comparing the observed and expected wavelengths:

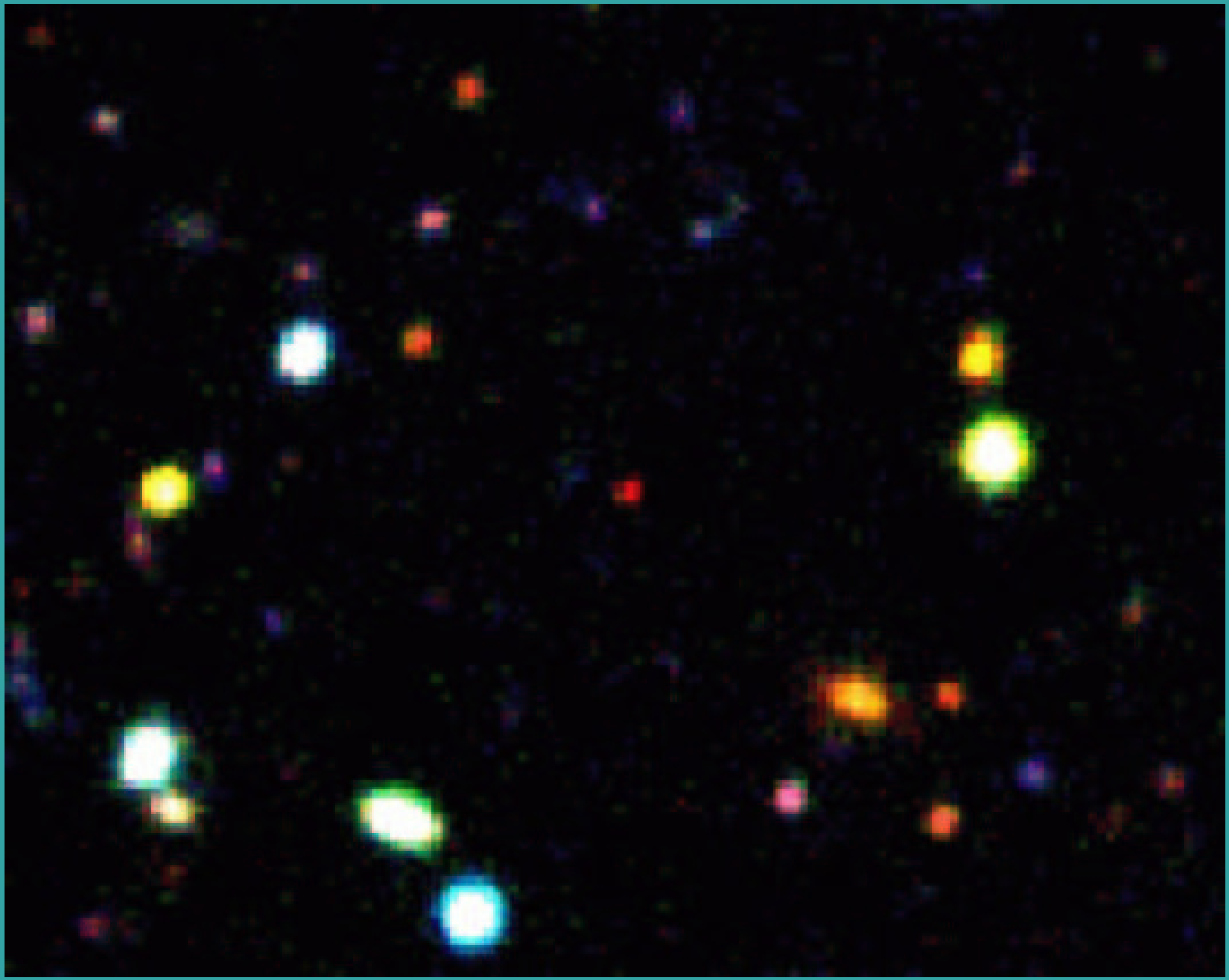
$$z = \frac{\lambda_{obs} - \lambda_{rest}}{\lambda_{rest}}$$

z for 3C 273 was 0.158, meaning that 3C 273 was receding from Earth at 14.6% of the speed of light.

Spectrum of 3C 273



Spot the Quasar!



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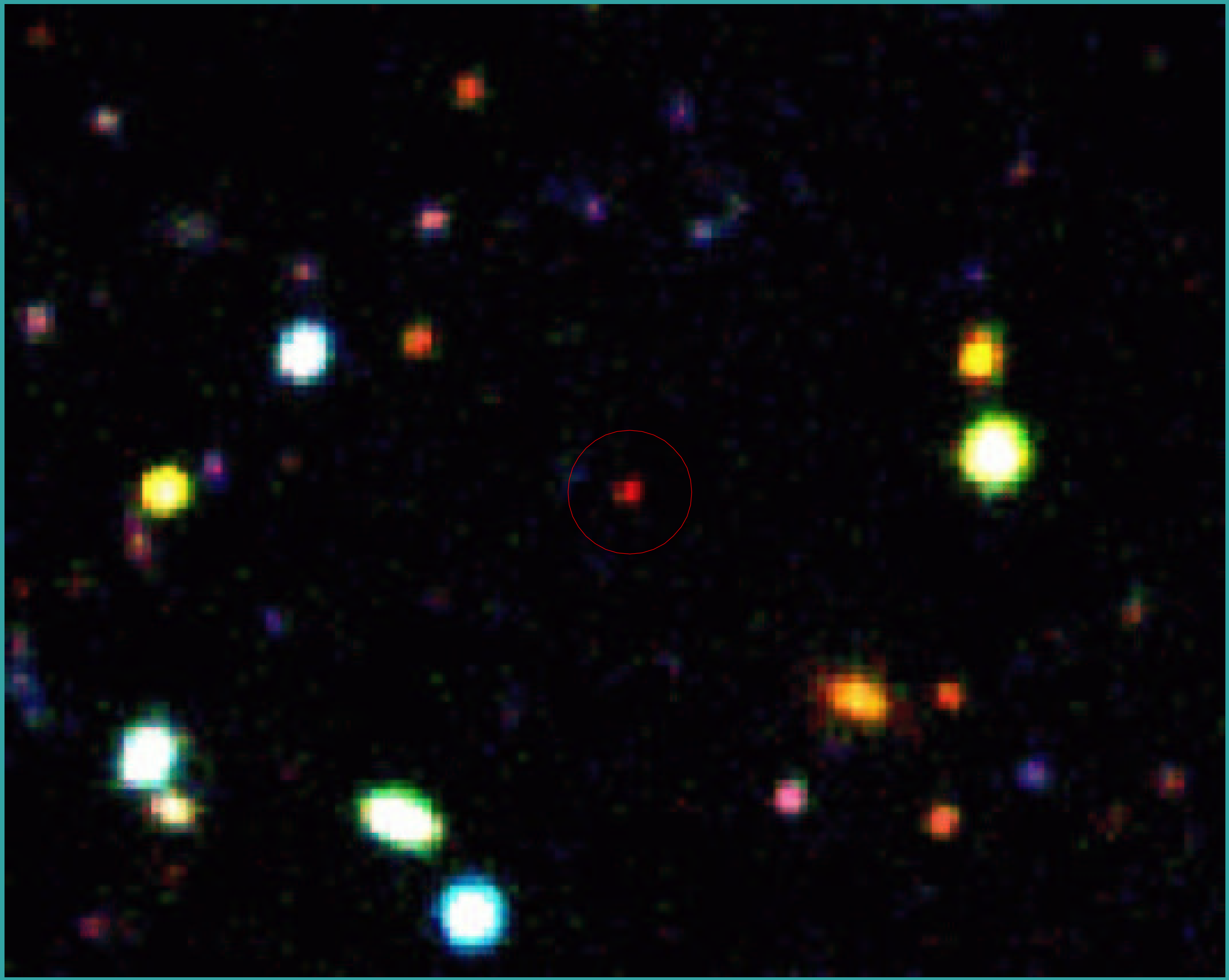

$z = 5.5$ quasar from Sloan Digital Sky Survey

$v = 0.95\ c$

distance of almost 14 billion light years

Quasars

- Energy output of a quasar can be as high as 10^5 times the energy of the entire Milky Way
- Energy from a quasar is over a huge range of wavelengths. (Stars tend to act like blackbody radiators with a peak wavelength somewhere near the visual range)
- Not all objects that are quasi-stellar in appearance and highly energetic have a large radio output. A more generic label is Quasi-Stellar Object (QSO) with quasars being a type of QSO with high radio output.

How to find a QSO

- Radio?

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- Radio?
  - No, not all QSO's have radio.
- Appearance?

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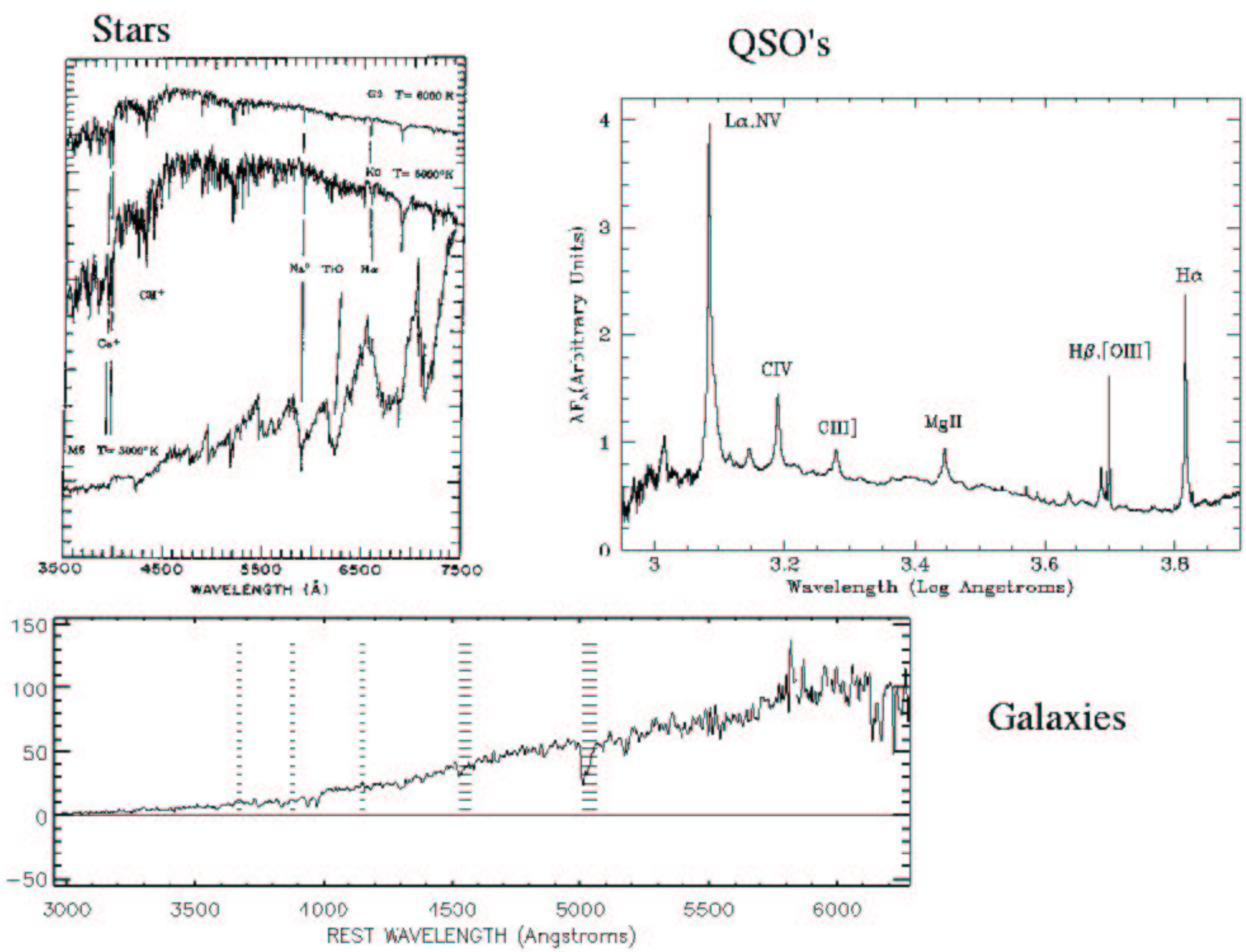
- Radio?
  - No, not all QSO's have radio.
- Appearance?
  - Not entirely. Stars also look star like....
- UV Excess?
  - Again not entirely. QSO's have more UV than your average star, but some stars do have high UV output.
- Spectra?

Quasar Hunting (continued)

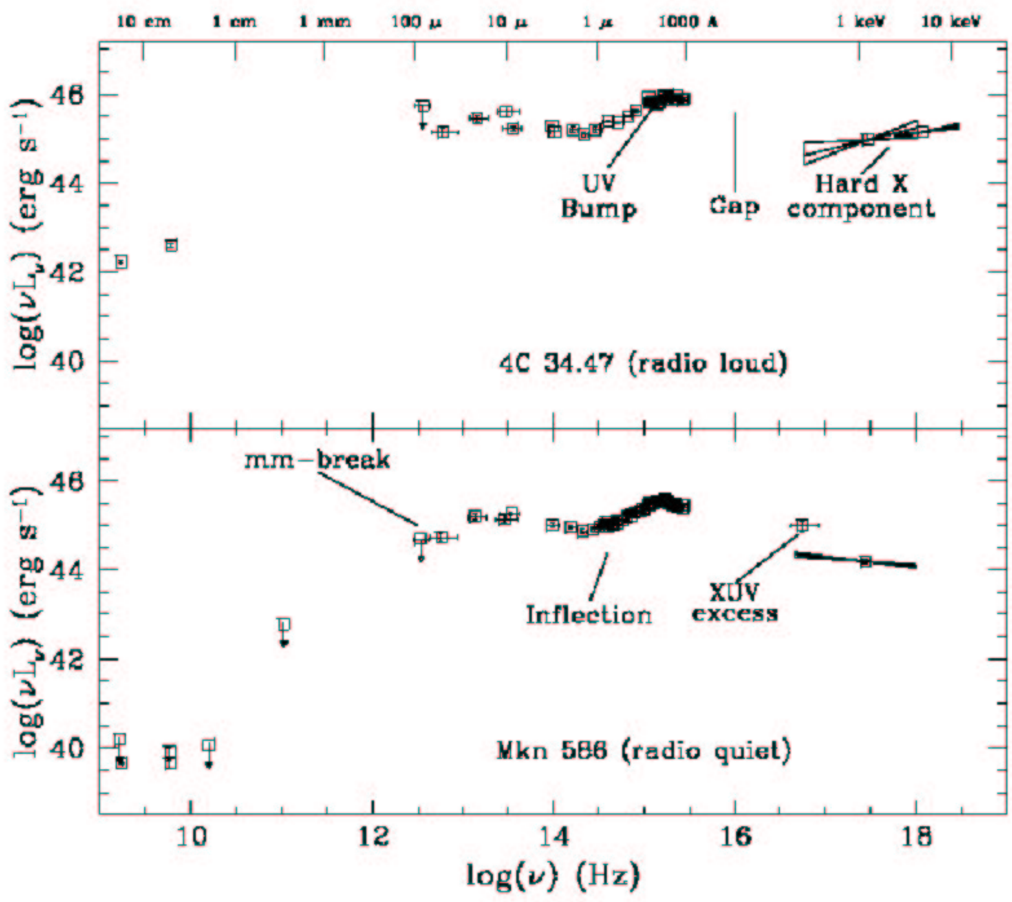
- Spectra are perfect, but these are distant objects. It would be intractable to take spectra of all objects that are star like.
  - Often we use the UV excess and star like appearance to get candidates and take spectra of all of them.

Spectra



Stars
G5 T= 6000 K
K0 T= 5000°K
Ca+
CH+
Na°
TiO
Hα
M5 T= 3000°K
3500
4500
5500
6500
7500
WAVELENGTH (Å)
QSO's
Lα,NV
CIV
CIII]
MgII
Hβ,[OIII]
Hα
λF_λ(Arbitrary Units)
Wavelength (Log Angstroms)
Galaxies
150
100
50
0
−50
3000
3500
4000
4500
5000
5500
6000
REST WAVELENGTH (Angstroms)

Detail of QSO spectra

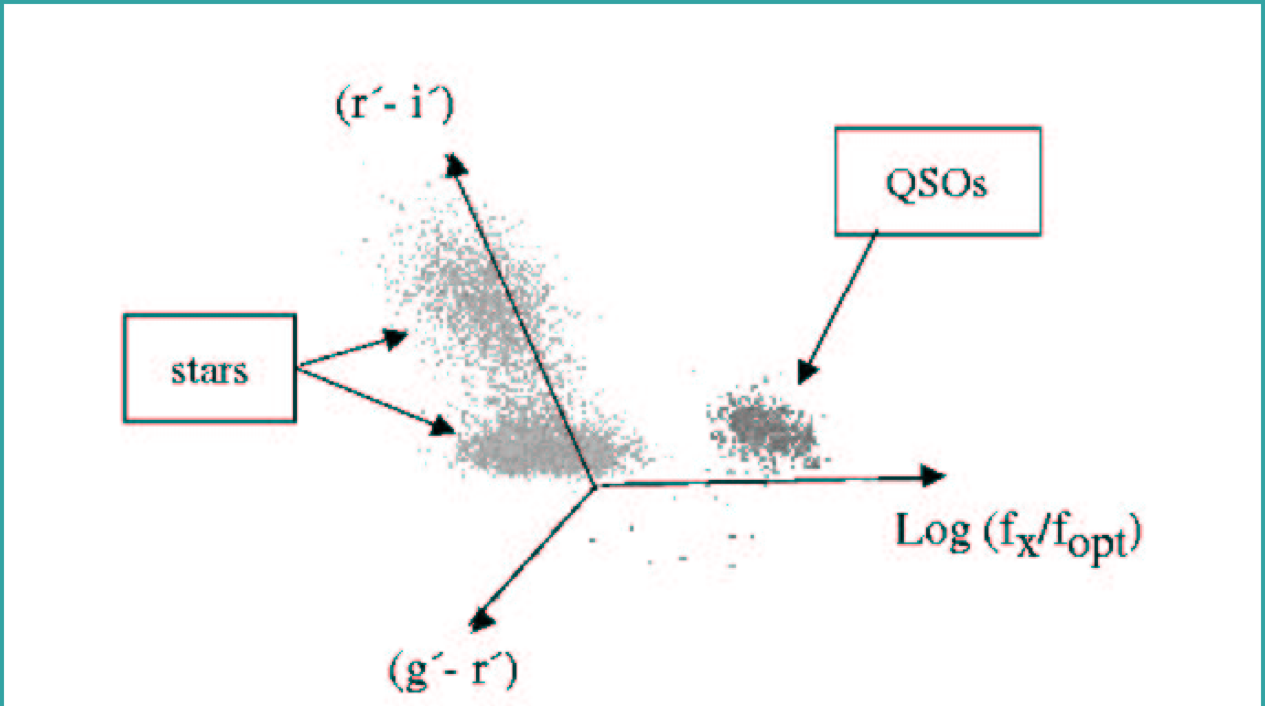


ChaMP

- The Chandra Multi-wavelength Project
  - Quasars have emission over a huge range of wavelengths
  - Can make new "colors" to try and separate QSOs from stars
    - In this case use the x-ray emission as well as some optical filters.

Color-Color-Color Space

Make an x-ray color by comparing the flux in the x-ray with the flux in the optical, make two other colors using optical filters (as per a standard color-color plot)



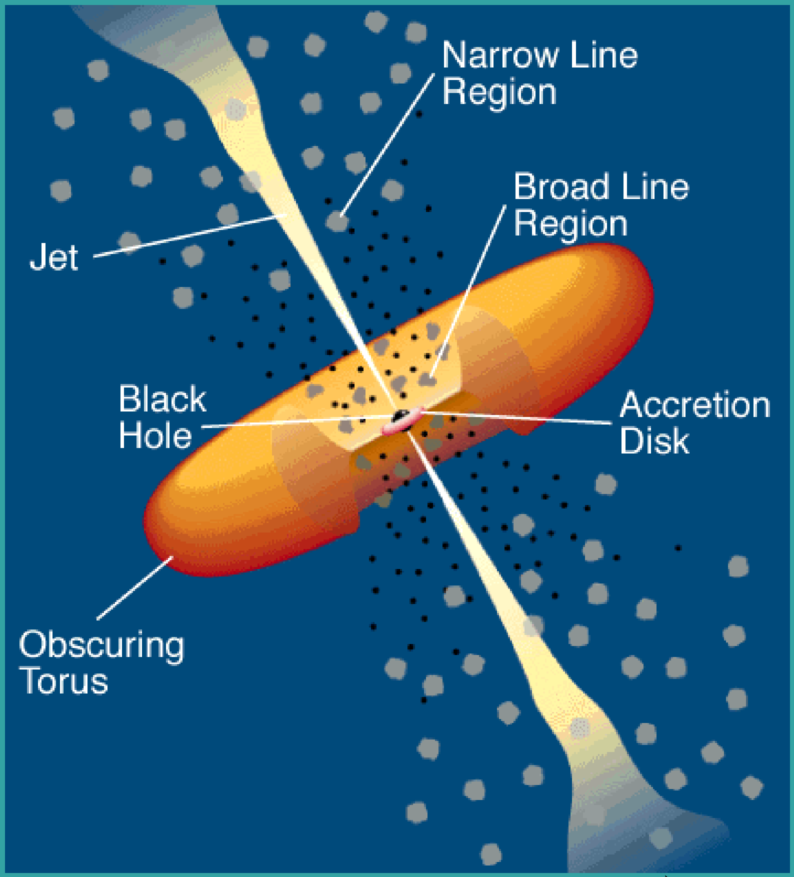
This should be sufficient to separate 100% of QSO's from the stellar population.

Grand Unified AGN Theory

- There is speculation that all AGN are the same type of object, just seen at different angles and locations.

AGN Standard Model

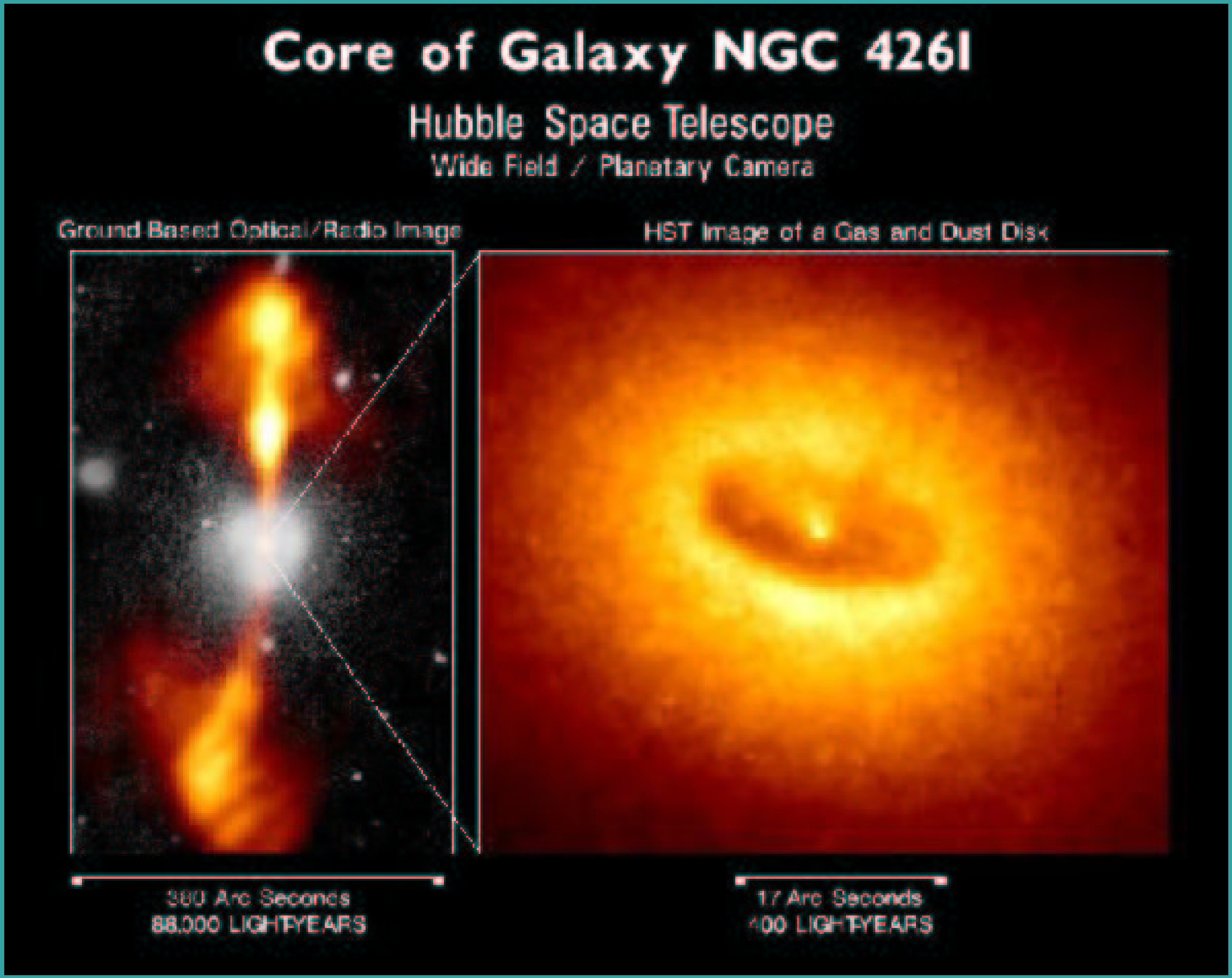
We can see into the BLR, this gives us Seyfert 1 and BLRG



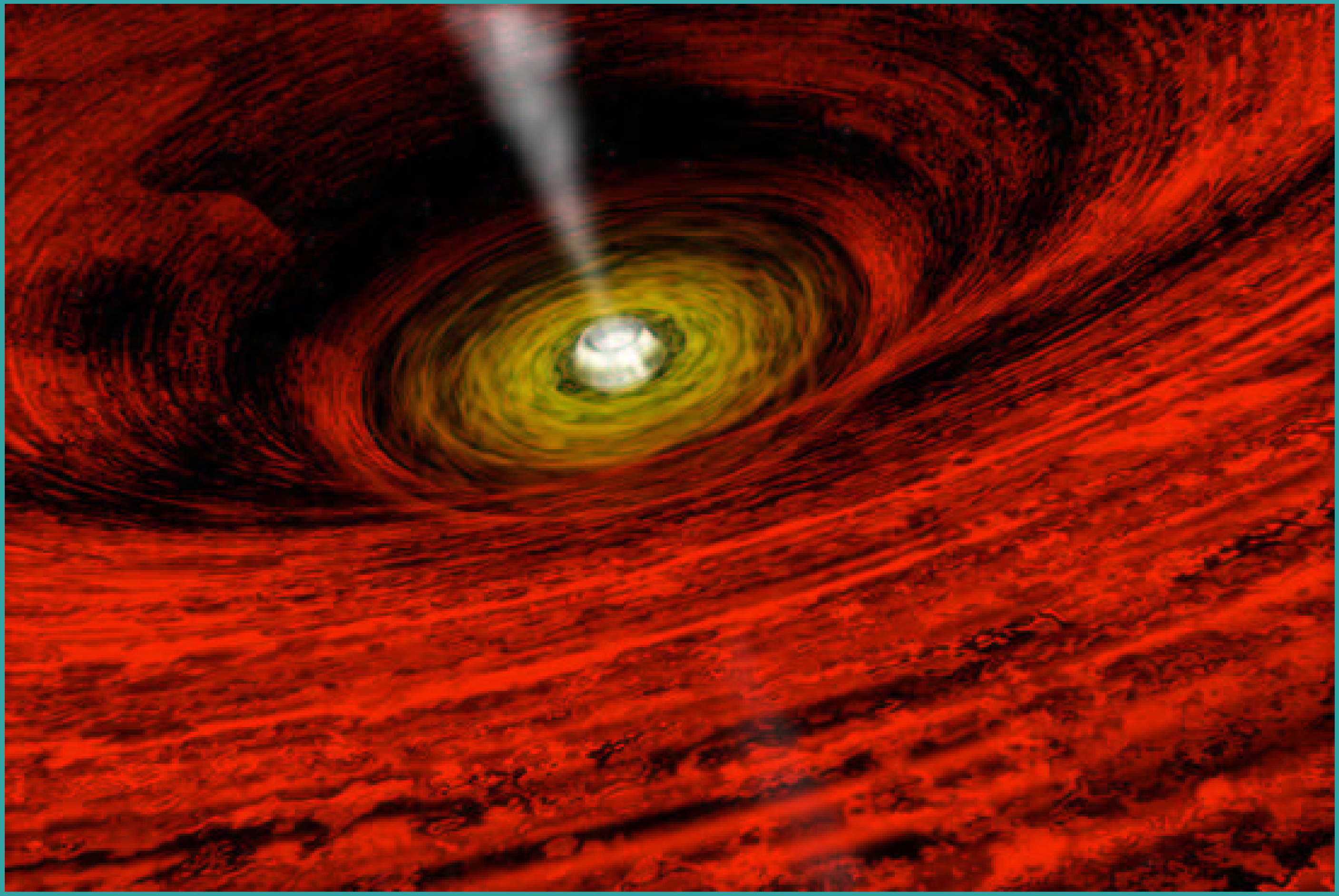
Torus blocks the BLR from view, this gives us Seyfert 2 and NLRG

Blazars

Evidence to Support Unified Model



The Core

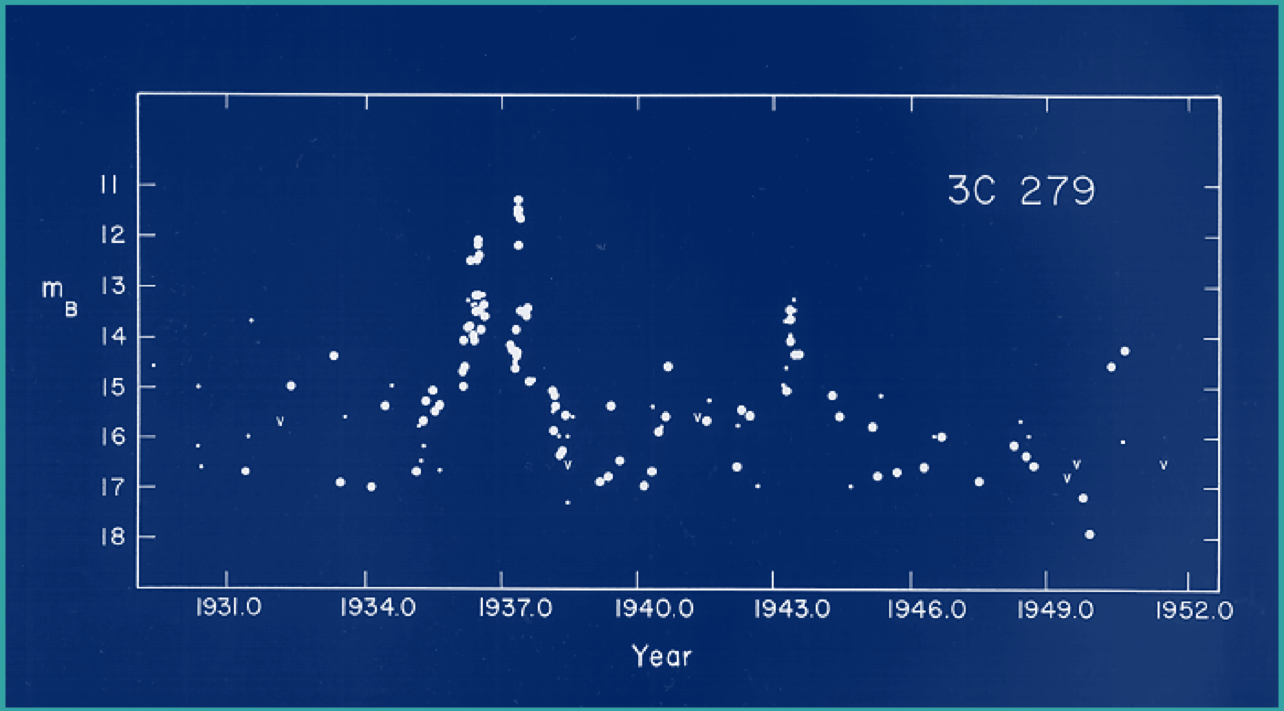


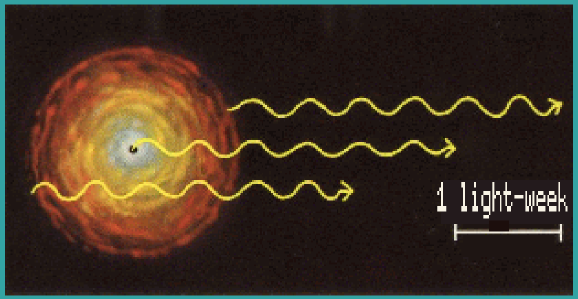
Magnetic fields

The rapidly rotating ionized material falling into the central black hole can create enormous magnetic fields. Coupled with that magnetic field are the outflowing "jets". The magnetic torques can help to remove angular momentum from the system and allow material to flow inwards.

Quasar Variability

The brightness of a quasar can vary a great deal over time. By looking at the amount of time over which a quasar changes in brightness, its size can be constrained.



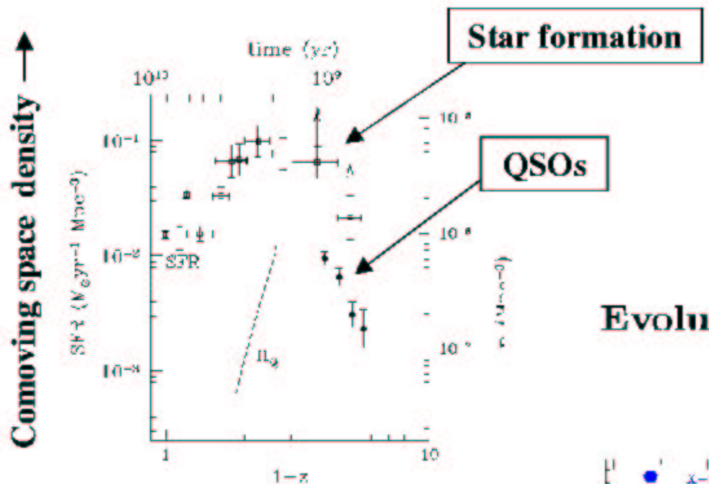


Imaging that the central accretion disk suddenly changed in brightness. Light from the edges as well as the center would be emitted at the same time, but arrive at our location at slightly different times. This limits the size of the light emitting region.

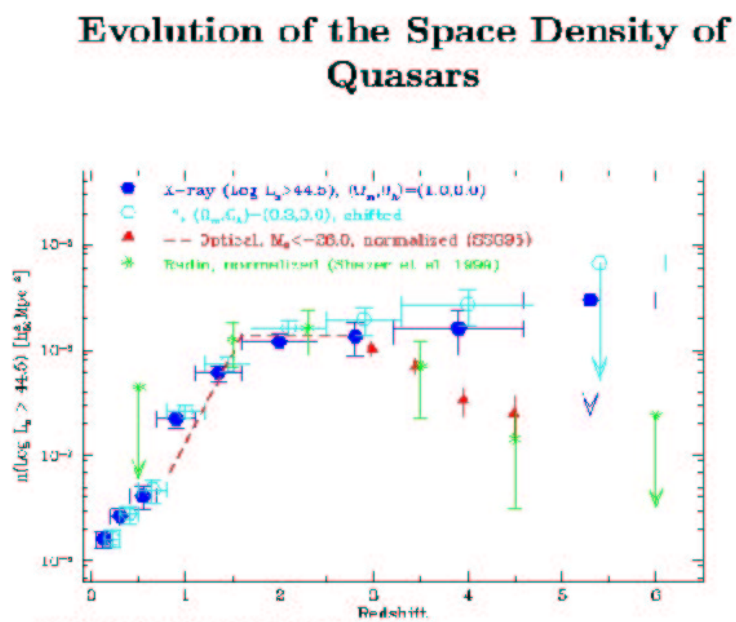
So what is left?

- The BLR is not well understood.
  - Spatial distribution of the clouds
  - Density of the individual clouds
  - Origin of the clouds
    - Composition is fairly well known from spectra
- Life cycle of QSOs

QSO Population Evolution



from Richstone et al. 1998



Miyaji et al. 2000, A&A, 353, 25