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QUASARS

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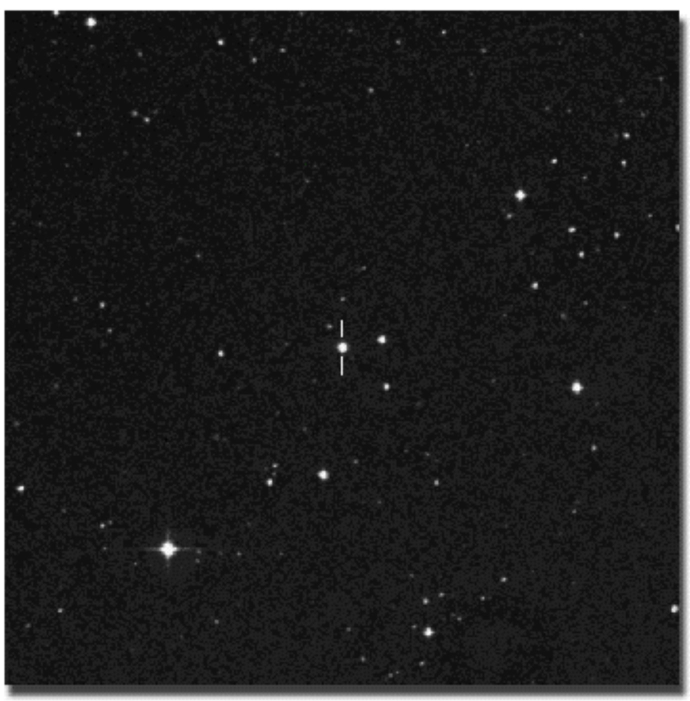
GALAXIES AT HIGH REDSHIFT: QUASARS

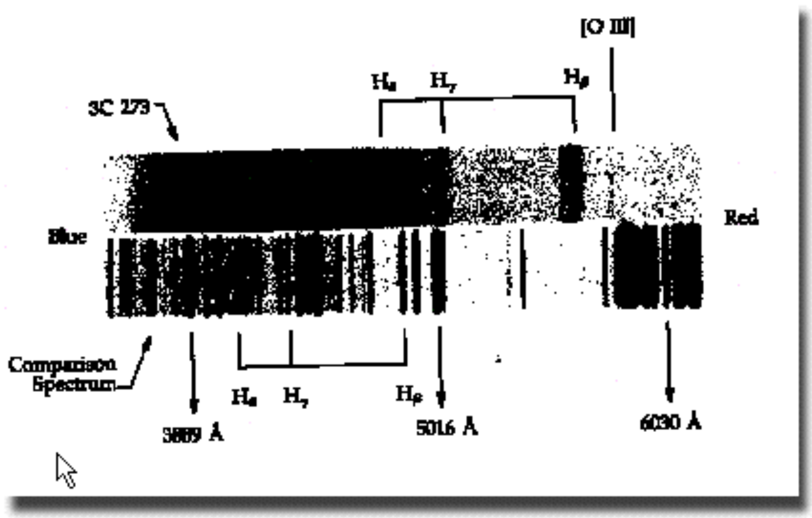
How quasars were discovered:

During the 1950's, a number of radio surveys were done on the sky. On some of these radio maps were what seemed point sources. It wasn't until 1960 when Thomas Mathews and Allan Sandage looked at one of the point sources in the constellation Triangulum. What they observed was a 16th magnitude star like object that looked blue in colour. This object was designated 3C 48 (object 48 in the 3rd Cambridge catalogue of radio sources). Three years later the object 3C 273 was observed as a 13th magnitude object in the constellation Virgo. Still at this time nobody had any idea as to what these objects were. This was mainly due to the fact that the emission lines did not match any normally observed in stars and galaxies.



PHOTOGRAPHIC PLATE SHOWING 3C 273

Soon however the problem was solved. Maarten Schmidt from Caltech discovered that the normally familiar Balmer lines from Hydrogen was shifted so far towards the red, that they had gone unnoticed. The redshift of 3C 273 was calculated to be 0.158 and using the relativistic Doppler equation, its' recessional velocity was found to be 14% of the speed of light. Other quasars had redshifts that exceeded this and it was soon found that the emission lines that would usually be observed in the Ultra Violet was shifted into the visual. The Earth's' atmosphere is opaque above 2900 Angstroms, so to observe these objects it was important to get observatories above the atmosphere.

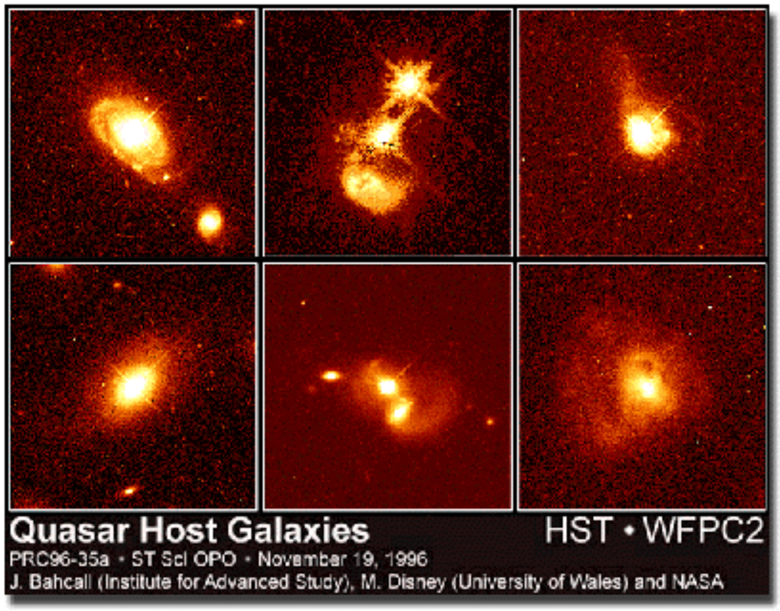


SPECTRA OF 3C 273 SHOWING THE REDSHIFT

The astronomers found that because quasars emit more ultraviolet light than stars of similar colours at larger wavelengths, the index U-B is less than -0.4 (for 3C 48, U-B=-0.61). This allowed them to achieve a quantitative search for quasars visible in telescopes. This formula works fine although quasars at a very high redshift appear redder. It was also found that although 3C 48 and 3C273 were radio emitters, the majority of quasars are either non emitters or weak emitters.

What is a quasar?

Quasars are thought to be the highly luminous, dense cores of galaxies. They somehow consume material from their host to produce an object that is so intrinsically bright that they appear starlike. It was once thought that not all quasars resided within galaxies. This posed a large problem when considering how the quasar obtained its material. Then in 1996 high resolution photographs were taken of many quasars which resulted in the discovery of their host galaxies. So it seems that all quasars are within a galaxy of some size or type.



HUBBLE TELESCOPE PICTURES OF QUASARS AND THEIR GALAXIES

The quasar 3C 273 shows just how luminous these objects are. It has an apparent magnitude of about 13, yet has a distance of over 800 MegaParsecs (depending on the value of the Hubble constant, here it has the value of 55). The average range of absolute magnitude of quasars is between -24 and -30, where as the most luminous galaxy is around -23 (again depending on the Hubble constant). So there must be an astonishingly large amount of matter being consumed by these objects.

One theory as to what they are is that of a supermassive black hole. These objects can have a mass of around 10^9 *solar masses, while their Schwarzchild radius is around 3´109 km or 20 astronomical units. The assumed model for a quasar is an object that has material falling from a nearby area into an accretion disk which then spirals into a black hole. From this black hole are two jets of material shooting off into space in opposite directions to one another. This jet has been observed in many quasars, most notably 3C 273. If the quasar is radio loud (as is 3C 273), then radio lobes may also protrude away from the object. When 3C 273 was first being studied, astronomers used a lunar occultation to accurately pin point two radio sources 20 arcseconds from one another. The visible component was observed at one of these sources. The other source is thought to be part of a radio lobe. The lifetime of these lobes can be easily calculated and range between* 10^7 *and* 10^8 *years.*

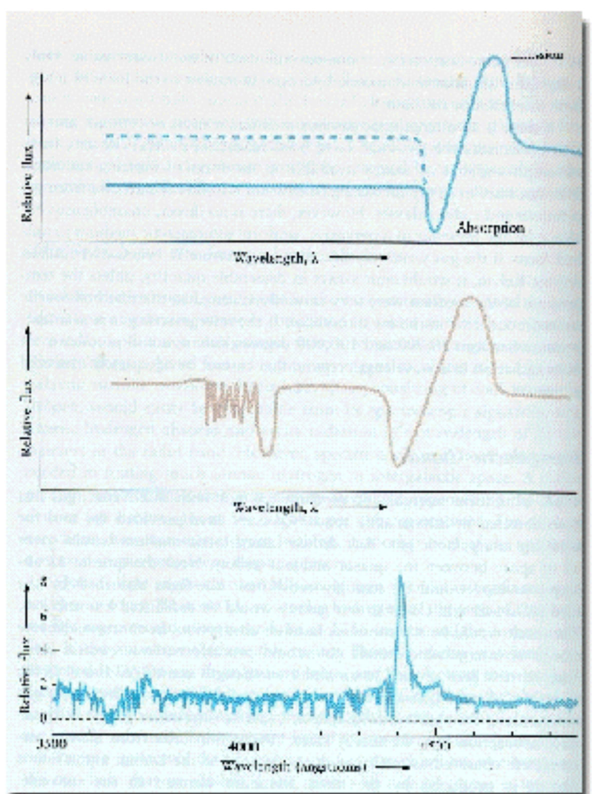
RADIO LOBES PROTRUDING FROM THE QUASAR 3C 345

What quasars can teach us:

A quasars spectra can be split up into two component parts. One is the large emission line from the quasar itself, the other the short thicket of lines going towards the blue end of the spectrum. Both of these are Hydrogen Lyman Alpha lines and are created when an electron jumps or drops between the two lowest energy levels.

The absorption lines on the blueward side of a quasars spectra are due to the interaction of light with Hydrogen clouds. These clouds lie in-between the quasar and the Earth.

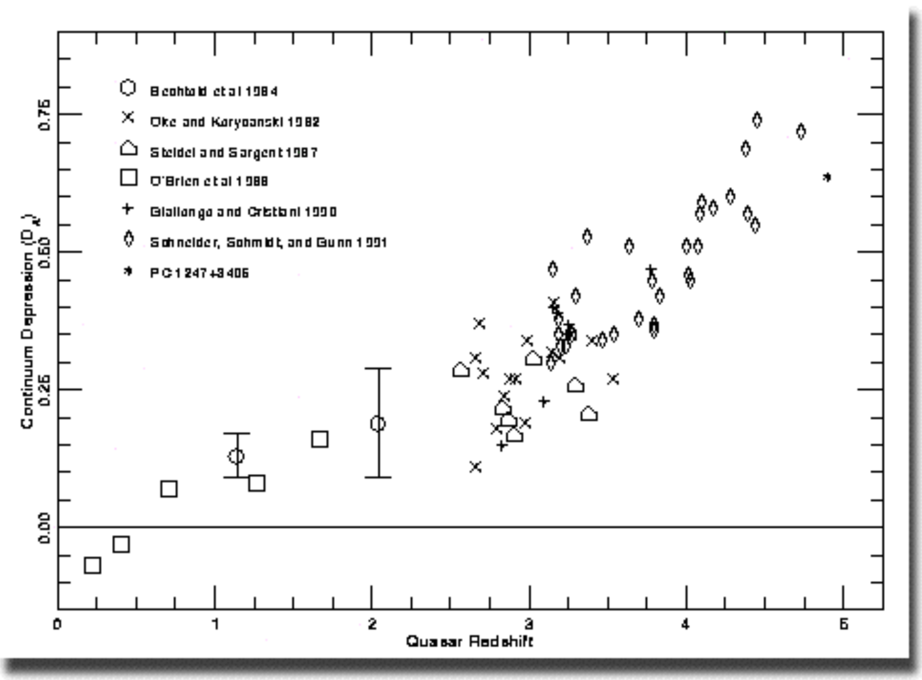
This series of graphs explain what we see.



- The top graph is that plotted as if the universe was completely homogenous. Each area of matter will be infinitesimally redshifted from its neighbour and so leads to a smooth absorption line.
- The middle graph shows what the absorption line would look like if the inter galactic medium were made up of separate gaseous areas at different redshifts.

- The bottom graph shows what is actually seen. It shows that the inter galactic medium is made up of low density homogenous matter interspersed with higher density clouds.

As each Lyman alpha line is located at a different wavelength, it is clear that they are produced by a number of clouds, each line represents a single cloud. Knowing how much the line has been redshifted can give astronomers an estimate of the clouds distance. The Lyman lines seem more abundant at higher redshifts, this has lead to theories that these clouds are pre-galactic in nature and may be the fragments that collapsed to produce galaxies.



GRAPH OF REDSHIFT VERSUS ABSORPTION

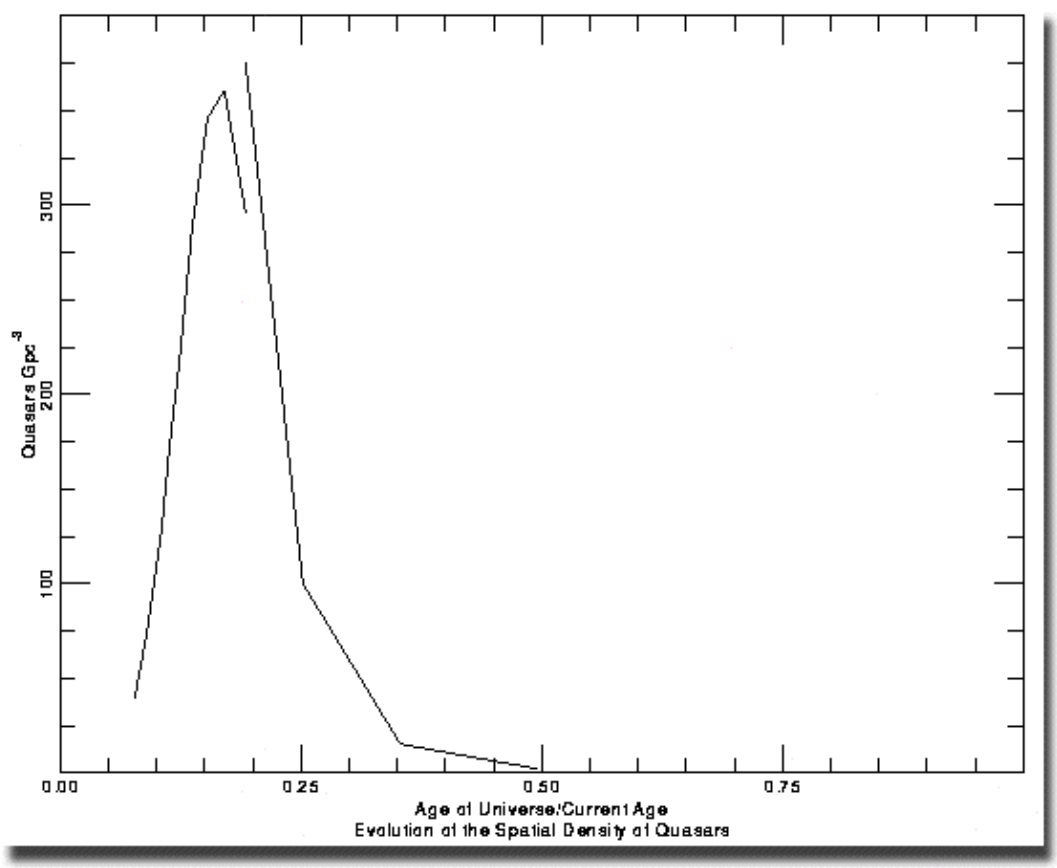
The above graph shows the absorption of the quasars light when plotted against redshift. It can be seen that the lower the redshift, the more absorption by Hydrogen clouds. For a redshift of 4 for example, only half of the light reached Earth. This tells us that the gas clouds were more abundant in the past than they are now. One piece of evidence for this is the fact that the clouds seem 'metal free' (astronomers terming any element heavier than Helium a metal). However recent results have shown metal lines in some of the Lyman forests.

These lines can be split into two parts, those with Z<1.5 and those with 1.2<Z>3.5.

- The metal lines with Z<1.5 are mainly Magnesium (Mg II) and are due to halos around normal galaxies or regions of star formation. The redshift distribution of these lines corresponds to the expected distribution of galaxies at the epoch when the universe was a factor of 1+Z smaller. Some of these lines have been visually identified as galaxies with redshifts of less than one.

- The metal lines that lie between 1.2 and 3.5 are mainly Carbon (C IV) lines due to clouds in young galaxies that are ionised by hot OB stars.

Studies into quasars and the intervening matter show that a typical Lyman gas cloud has the mass of a few hundred Suns, and that they number into the thousands, yet occupy only a small area of the universe. They also tell us that the gas halo that surrounds a galaxy extends further than previously thought. The fact that these metal lines exist in the Lyman clouds and galactic halos, means there must have been at least one generation of star at this epoch to undergo supernova explosion. These elements could only be produced by nucleosynthesis and not from the big bang. As these quasars can have very high redshifts, it shows that star and galaxy formation occurred when the universe was only a few percent of its' current age.



GRAPH SHOWING THE AGE OF QUASARS

This is also shown by the distribution of redshifts of quasars. It can be seen that the 'age of quasars' lie between the redshifts 2 to 2.5. Also that a quasar existed when the universe was about 7% of its' current age shows that galaxies must have evolved at this period. However at this epoch, it has been calculated that only a few percent of galaxies actually had quasars residing in them. This does not mean that only a few galaxies will ever develop quasars. It means that we cannot detect exceptionally high redshift quasars as of yet. However the most likely reason is that quasars are short lived. They have all died out by half the age of the universe. The fact that our galaxy and our near neighbours do not seem to have visible quasars also backs *this hypothesis.*

Now if the majority of galaxies did have quasars within them, then the galaxies that are close to us should have quasar remnants. Studies of the 1.3 cm H_2O line from the galaxy NGC 4258 revealed that stars were revolving around a massive black hole.

Conclusion:

Quasars are probably one of the most important, yet far from understood phenomenon in the known universe. They have proved useful, not only in their study, but of the universe as a whole. They can tell us a lot about early formation of galaxies, the matter that lies between the galaxies, dust and gas clouds, high density matter and cosmology. Finding quasars and using quasars as beacons to show the furthest and faintest of objects can help astronomers understand the universe at very early epochs.

Bibliography:

Beschtold, G. (1997) Shadows Of Creation ***Sky And Telescope*** *Sept pp 29-34*

Bruning, D. (1995) A Galaxy Of News ***Astronomy*** *June pp 40-43*

Carroll, B and Ostlie, D (1996) Active Galaxies ***An Introduction To Modern Astrophysics*** *pp 1167-1214*

Carroll, B and Ostlie, D (1996) Black Holes ***An Introduction To Modern Astrophysics*** *pp 661-674*

Hirshfeld, A and Sinnott, R.W (1985) ***Sky Catalogue 2000.0*** *Cambridge University Press Vol.2 pp 35-36*

Narlikar, J (1977) ***The Structure Of The Universe*** *Oxford University Press pp 82-87*

Nicolson, I (1996) Black Hole Basics ***Astronomy Now*** *Feb pp26-27*

Roth, J (1996) Quasars: Not Naked After All ***Sky And Telescope*** *March p 12*

Roy, A and Clarke, D (1989) Quasars Astronomy: ***Structure Of The Universe*** *ch 14.4 pp 226-228*

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