Active Galactic Nuclei Influence the Genesis of Galaxies

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Abstract: *Most or all spiral and elliptical galaxies were formed by quasars with supermassive black holes. The genesis of such galaxies occurred when the universe was young, approximately 5 billion years ago. Quasars are extremely bright masses of energy and light. They are high redshift sources of electromagnetic radiation. The quasar and the supermassive black hole form active galactic nuclei (AGN). The combination of quasars and its black hole engine formed large accretion disks as matter from the quasar. A considerable amount of matter from the accretion disk escaped the gravitational pull from the event horizon of the black hole. This matter led to the formation of stars, planets, asteroids, etc., after the quasar burned out. These eventually become spiral and elliptical galaxies.*

I. Introduction

Quasars are extremely distant objects in our known universe. They are the furthest objects away from our galaxy that can be seen. Quasars are extremely bright masses of energy and light. The name quasar is actually short for quasi-stellar radio source or quasi-stellar object. They are the brightest objects in the universe. They emit radio waves, x-rays and light waves. Quasars appear as faint red stars to us.[1]

Quasars are the most energetic and distant members of a group of objects called active galactic nuclei (AGN). Quasars are extremely luminous and were first identified as being high redshift sources of electromagnetic energy, including radio waves and visible light that appeared more similar to stars rather than galaxies. There are very broad emission linear intersections, unlike stars, hence "quasi-stellar". Quasars' luminosity can be 100 times greater than the Milky Way.[2] Most quasars were formed 5-12 billion years ago.

A quasar is a compact region in the center of a massive galaxy surrounding a central supermassive black hole. The energy emitted by a quasar derives from mass falling onto the accretion disk around the black hole. An accretion disk is a flat, disk-like structure of gas that rapidly spirals around a larger object, like a black hole, a new star, a white dwarf, etc. A quasar gradually attracts this gas and sometimes other stars with their super strong gravity. These objects get sucked into the black hole. When a star, gas, or other objects are absorbed into a quasar in such a way, the result is a massive collision of the matter that causes a gigantic explosive output of radiation energy and light. This great burst of energy results in a flare which is a distant characteristic of quasars. The quasar's jet (flare) comes from the edge of the accretion disk, rather than the center.[3]

Quasars are the most luminous, powerful and energetic objects in the universe. They inhabit the center of active young galaxies and emit up to a thousand times the energy output of the Milky Way.[4] Quasars have a very high redshift, which is a result of the expansion of the universe. The implication of the large redshift is that quasars are very distant, meaning they are objects from much earlier in the universe's history. Very high redshift is an effect of the metric expansion of space between the quasar and the earth.[5]The redshift of quasars interpreted in terms of Hubble's law infer quasars are very distant objects. At very high redshifts, the inefficiency of atomic and molecular cooling via H and H_2 excitations is compensated by Compton cooling; Compton drag provides an additional mechanism for transferring angular momentum and allowing collapse.

Quasars are believed to be powered by accretion of material into supermassive black holes in the nuclei of distant galaxies, making these luminous versions of the general class of objects known as active galaxies. The emission of large amounts of power from a small region requires a power source far more efficient than the nuclear fusion that powers stars. The release of gravitational energy by matter falling toward a massive black hole is the only process to produce such a high power continuously. Quasars can be detected over the entire observable electromagnetic spectrum including radio, infrared, visible light, ultraviolet, x-ray and even gamma rays. The luminosity created is 10^{40} (the typical brightness of a quasar), a supermassive black hole would have to consume the material equivalent of 10 stars per year. The huge luminosity of quasars results from the accretion disks of central supermassive black holes, which can convert on the order 10% of the mass of an object into energy as compared to 0.7% for the P-P chain nuclear fusion process. This mechanism explains why quasars were more common in the early universe.[6] Once supermassive black holes are formed, the final black hole mass is enhanced during the hierarchical merging process, when dynamical friction and dissipative drag on gas can drive supermassive black holes into the center of the developing protogalaxy. Mergers provide a continuing supply of gas, and gas dissipation and accretion feed the central black hole.

II. Discussion

The mechanism of gravitational energy production explains why quasars were more common in the early universe as this energy production ends when the supermassive black hole consumes all of the gas and dust near it. It is possible that all spiral and elliptical galaxies have gone through an active stage. The majority of these galaxies are now quiescent because they lack a supply of matter to feed into their central black holes to generate radiation. The oldest quasar is one with a redshift of 6.4 which was about 800,000 years after Big Bang.[7] At a redshift of about 4.0 there was a rapid increase of quasars. About this time early galaxies formed, collected enough material to make a fairly massive black hole, and had enough massive stars in its immediate neighborhood to devour and produce the heavy elements as seen in quasar spectra.

Looking at the very distant objects ii the universe is equivalent to looking back in time because of the constant spread of light in a vacuum. The number of quasars peaks at a redshift of 2.25 which is about 3 billion light years ago. The number of quasars reduce sharply at a redshift of 1.5.

When we look at quasars with a redshift of 3 or higher, we are looking back in time, before the formation of Earth and possibly our solar system. Since quasars are far more common when the universe was young, then the feeding mechanism must be fostered by conditions which were present then compared to now. Interactions between gas-rich galaxies were far more common in the early universe than now. This explains why most quasars were born a long time ago and have died out by now.[8]

The quasar distribution tells us directly that at least some massive black holes form early. Indeed, the quasar commoving density peaks at $z > 2$, and only declines at $z > 3$ (Shaver *et al.*1996); on the other hand, the peak of galaxy formation occurs at $z \approx 1.5$ (Madau*et al.* 1996; Connolly *et al.* 1996), although there is uncertainty about the effects of extinction in leading to an underestimate of the galaxy luminosity at high redshift.[7]

In fact, the known quasars, or their dead counterparts, are likely to be within the cores of at least 30 percent of these galaxies. To see this, note that combining the integrated density in quasar light, with the assumption that quasars radiate at or near the Eddington limit yields an estimate of typical dead quasar (or black hole) mass (Soltan 1982; Chokshi& Turner 1992) as $10^7 – 10^8 M_\odot$. Whether one actually could observe an AGN component in high redshift galaxies depends sensitively on the adopted lifetime of the active phase: higher redshift helps. The observed correlation between massive black holes and dynamically hot galaxies then suggests that most hot galaxies, amounting to of order a third of all galaxies in terms of stellar content, could contain such a massive black hole[10] (Faber *et al.* 1996) The dynamically hot galaxies would essentially cool down when the AGN burns out.

The first stars forming from pure hydrogen and helium were quite different from the ones we see today. The first stars were very massive and hot, exploding with more violence than today's supernovae. The great abundance of quasars in the early universe is consistent with the notion that a quasar shuts off when its black hole engine has consumed the fuel surrounding the host galaxy. In the early universe there most likely was more mass available to black holes than today because much of it has already been consumed. These black holes ran out of fuel and eventually shut down. Today there are vast voids between galaxies and little food for the massive black holes, which has caused most of the quasars to have been shut down. One must take a considerable look way back in time to see many quasars.[9] a sufficiently intense wind from the central quasar can sweep up the gas into a shell, push it outwards at constant velocity.

$$V_s = \left(\frac{F_w L_{Edd}\ 8\pi 2G}{f_{gas}\ 6 2}\right)^{1/3}$$

In this expression, the mechanical (*i.e.* wind) luminosity is taken to be a fraction f_w of the Eddington luminosity $L = 4\prod Gc M_{bh} k^{-1} = 1.3 \times 10^{46} M_8 ergs\ s^{-1}$, Note that $f_w \equiv M_{out}v^{2/w}/L_{E} = \epsilon^{-1}(v_w/c)^2 \approx 0.01$, where $\epsilon = L_E/M_{inf}c^2$ is the radiation efficiency.

Expulsion of this shell requires that its velocity should exceed the escape velocity from the protogalaxy: *i.e.* $V_s > \acute{o}$. The condition for this to be the case is that

$$M_{bh} > \alpha\frac{\acute{o}^5 K}{G^2 c} = 8\ X 10^8 \gamma(\acute{o}/500 km s^{-1})^5 M_\odot, \quad \textbf{(1)}$$

where $\acute{o}_{500} = \acute{o}/500 kms^{-1} \equiv 32\prod^3 f_w / f_{gas} \sim 1/$

The implications of (1) are that a massive hole, if it continues to emit at close to the Eddington rate, could expel gas completely from its host galaxy. (The amount of gas that has to be accreted is in itself negligible in this context: each unit mass of gas accreted into the whole can release enough energy to expel of order $(c/v)^2$ times its own mass from the far shallower potential well of the halo.) However, the fueling demands osteoarthritis continuing accumulation of gas in the centre (probably supplied by hierarchical merging). We

can, therefore, interpret (1) as setting an upper limit to the mass of a hole that can exist in a galaxy where star formation can proceed efficiently.

Expression (1) gives a relation between a black hole and its surrounding halo. If a significant fraction of the Eddington luminosity emerged in "mechanical" form, this gives the criterion that the energy liberated on the dynamical timescale of the halo is equal to the gravitational binding energy. The same expression can be derived by a different argument. The maximum rate at which gas can be fed towards the centre of the galaxy (as the outcome of mergers, etc.) is $\sim \acute{o}^3/G$, where $\acute{o}$ is the velocity dispersion in the merged protogalactic system. A quasar could expel all this gas from the galactic potential well on a dynamical timescale if its mass exceeded a critical value obtained by requiring that $\acute{o}^5/G = 4 \prod GcM_{bh}^{cr}/k$.[10]

AGN activity generates outflows that can interact dynamically with the surrounding protogalactic gas as well as provide a possible early flux of hard ionizing photons. Star formation in the accretion disk surrounding the broad emission line region of the AGN is likely to proceed.

III. Conclusion

There are interesting consequences for the intergalactic medium (IGM), since quasar-driven winds could readily eject enriched material from the shallow potential wells that characterize the earlier stages of hierarchical clustering. This could account for the apparent presence of up to 1 percent of the solar abundance of heavy elements even at high z. If this is the case, a time delay is likely between the epoch of most quasar activity and the epoch of the bulk of star formation in the universe. One observes a time delay corresponding to $\acute{o}z \approx 1$: studies of quasars have confirmed a peak in the quasar number density between $z = 2$ and 3, and the star formation history of the universe is found to peak between $z = 1$ and 2.[10]

Quasars are responsible for amajority of the elliptical and spiral galaxies in the universe, even if the active galactic nuclei (AGN) which contains the quasar and black hole burned out long ago. Quasars were plentiful when the universe was $1/6^{th}$ its current size. A quasar and its supermassive black hole produce an accretion disk of matter. As the matter form, the quasar increases, the accretion disk also increases in size. Eventually, large amounts of matter escape the gravitational pull from the event horizon. The large amounts of matter continue to follow the circular type pattern of the accretion disk. As the large amount of matter become more depressed, they produce stars, planets, asteroids, etc. Eventually, the quasar is used up and the supermassive black hole becomes dormant, but by that time a new spiral or elliptical galaxy is formed. The galaxy genesis was produced by the quasar and its engine. All spiral and elliptical galaxies in the universe today originate from quasars. One can look at the objects with a redshift to observe how galaxies formed. All types of heavy elements, including heavy metals, were produced and seeded throughout the galaxy, including our Milky Way. The ability of producing various electromagnetic radiation from radio waves to gamma rays are distributed throughout these galaxies as well.

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