Why Are Some Quasars Radio Loud?

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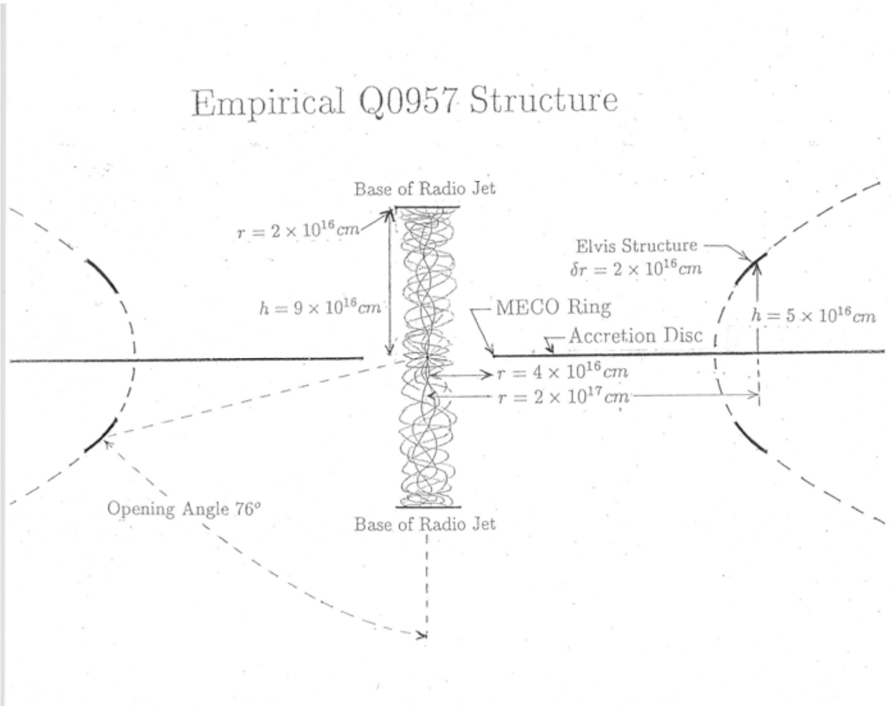
Abstract: New microlensing-reverberation analysis of optical and radio brightness data have produced a significantly revised view of quasar structure. For lensed radio quiet Q2237 (Einstein Cross) quasar we find inner structure contributing only 1/3 of the total UV-optical luminosity and originating just within 6 Rg. The outer luminosity originates in Elvis structures located just within the outer light cylinder. Surprisingly, radio loud Q0957 (The First Lens) has its inner region swept clean of luminous matter out to radius 74 Rg with continuum-luminous outer Elvis structures just within the outer light cylinder. The radio core containing 1% of the 6 cm luminosity is 40 Rg above the accretion disc plane.

Structure of Q0957 suggests action of a centrally anchored magnetic propeller. A sharp luminous ring at the inner edge of the accretion disc strongly supports the MECO model of Leiter and Robertson, rather than a black hole. In the MECO model, which is a magnetic variant of the Mitra ECO, the inner accretion disc edge is inside of co-rotation for Q2237, but outside co-rotation for radio loud Q0957. Analysis of forces produced by this structure suggests that charge separation and an outer light cylinder would be important unique MECO properties which now need careful investigation. Most probably, the quasar's highly blue-shifted high-ionization emission lines imply charge separation producing the ionized outer wind and inner electron jet, but a different flow pattern originating inside of co-rotation quenches the jet in the hi-soft radio quiet quasar state.

1. Microlensing-Reverberation Analysis of Quasar Structure

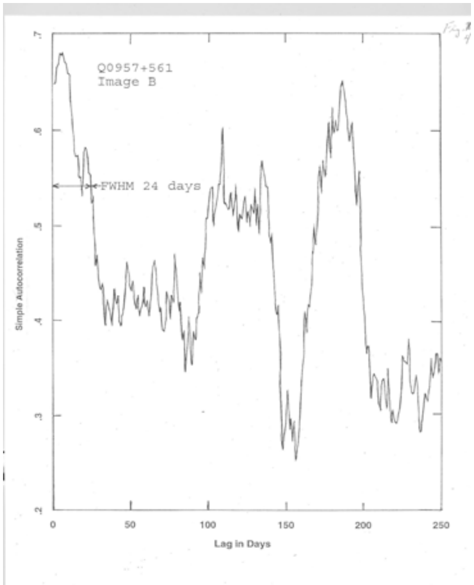
The long brightness records at optical and radio wavelengths for quasar Q0957+561 A,B (The First Lens) have been analyzed to find the principal luminous structures. We have found reverberations of the UV-optical radiation at locations where the Elvis outflow structures produce the broad blue-shifted emission lines, and we interpret this to be the determination of the outflow structures at distances approximately 350 R_g from the central source[1,2]. Adopting the conical outflow picture, we find that the continuum emission originates from ring-like structures at 90 R_g above the accretion disc plane. Because the radio emission arrives 35 days later than the UV-optical, its jet core is estimated to be 170 R_g above the plane, and the amplitude and duration of its weak microlensing events shows that 1% of the luminosity originates within a core of radius 37 R_g. These results are developed in [1,2] from which we repeat the cross-sectional view of the inferred radiating structures.



Cross sectional view of the Q0957 quasar, drawn to scale with dimensions in cm, as inferred from reverberation-microlensing analysis. Full details are available at astro-ph/0505518.

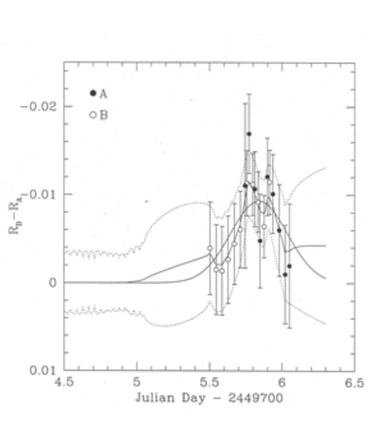
How do we determine size scales?

We do it from reverberation analysis. It has been observed that if the quasar suddenly becomes bright, it will actually produce a sequence, or train, of 5 pulses (some of which might overlap). The pulses are characterized by their lag, measured in days, and by their duration (days) and amplitude (in magnitudes or fractional luminosity units). These lags evidently represent reflections, or fluoresces, off of the outer luminous quasar structures, and can be found in a long quasar brightness record by calculating the autocorrelation function of the brightness history. Following is the Q0957A auto-correlation plotted as a function of lag, in days. In this plot I see an initial peak of 25-days width, which probably shows what the size of the luminous central structure is. Then after lags of 129 and 195 days secondary peaks of 50 day width are found, representing the reverberations off of the outer quasar structures right where the Elvis structures, recognized in the blue-shifted broad emission lines, are found. Therefore I have interpreted these as continuum luminous sources associated with the Elvis wind outflow surfaces [3]. The distances of these structures from the central source are determined from the lags converted to cm and corrected for (1+z) cosmological time dilation.



2. **Microlensing**

Since microlensing is also observed, the sizes and fraction of the quasar luminosity of the microlensed structure can be inferred from microlensing theory. Following I show a plot of the extremely rapid microlensing of the inner Q0957 structure. An event of duration 1 day and brightness amplitude of 1% was observed [4]. With correction for cosmological (1+z) the event took only 10 hours. Recalling that the quasar is typically x100 brighter than its host galaxy, a 1% quasar brightness change represents the entire luminosity of an ordinary galaxy. Thus the observed event represents an entire galaxy amount of luminosity disappearing in 5 hours, and reappearing in 5 hours. Of course this amount of energy has not been absorbed; it has just been redirected to some other place in space by the microlensing.



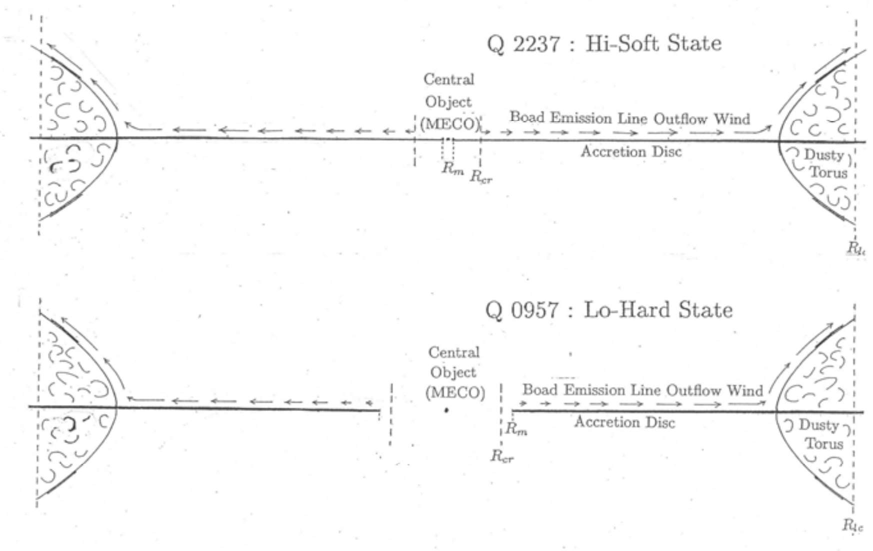
For such rapid microlensing to occur, 2 conditions must be met. The quasar must have very sharp structure, with size scale of order 1 R_g, and the lens galaxy must have fine granular structure with the mass of planets, meaning that technically we are observing nano-lensing. The only structure imagined to have 1 R_g size scale is the luminous inner edge of the accretion disc, and we explain in our published report that this would be the thickness of the ring-shaped structure at the inner accretion disc edge. In [5] a similarly rapid microlensing for the FeK_alpha line from the same quasar structure has been observed .

The observation of daily microlensing shows that planet mass compact objects in the lens galaxy must dominate the dark matter, as will be discussed further in the report by Minakov et al today [6], now that these rapid microlensing events have also been observed in other lens systems.

3. An important Difference between Radio Loud and Radio Quiet Quasars.

A second quasar, Q2237 (Einstein Cross) has also been studied with similar techniques, and structures again determined in location and size. But Q2237 is a radio quiet object, and it is useful to look for structural differences that may be related to the important difference in radio brightness [1].

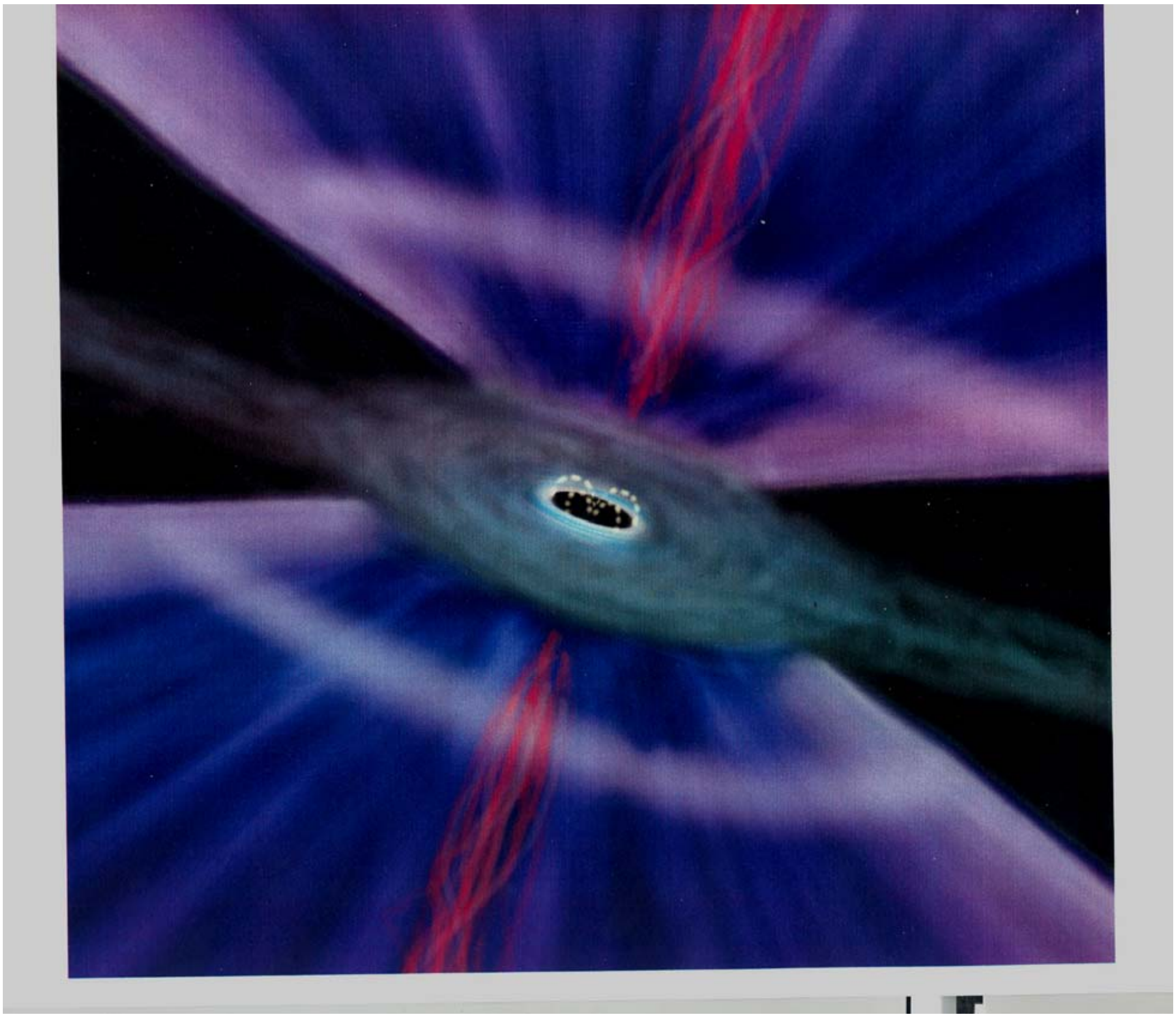
An important difference that we find is the location of the inner edge of the accretion disc relative to the co-rotation radius. Recall that any rotating object dragging a dipole magnetic field must have a co-rotation radius, where the Keplerian orbital speed matches the sweeping field anchored to the rotating central object. Inside of the co-rotation radius, neutral matter responds most strongly to the gravitational field and rotates around the massive central object faster than the sweeping speed of the magnetic field. Outside of co-rotation, where the sweeping magnetic field leads the Keplerian orbital motion, the magnetic forces on charged particles are reversed. Since effectively all quasars have strong blue-shifted emission lines, it has long been inferred that because the in-spiraling material must be ionized, these magnetic fields cause charge separation, with the positive ions swept outwards in a wind, and electrons inward where they form a jet.



If the above is true for the Q0957 radio loud quasar, whose accretion disc is found to lie entirely outside of co-rotation, then a more complicated pattern must arise in radio quiet Q2237, whose accretion disc inner edge Rm is found to lie within co-rotation [1,7]. Since this quasar has the same outer wind with broad blue-shifted emission lines, the outer structure must be approximately the same in the two quasars. But in Q2237, the positive ions inside co-rotation are forced inwards, where they quench the electron jet. We believe that this profound difference in the relationship of the inner accretion disc edge to the co-rotation radius is the reason why some quasars are radio loud, and is also the heart of the mechanism producing lo-hard to hi-soft spectral state switching in the analogous ~10 Mo GBHC objects. Because in quasars the time for the spectral state switching would be many years, we find the quasars frozen in either the lo-hard (Q0957) or hi-soft (Q2237) state.

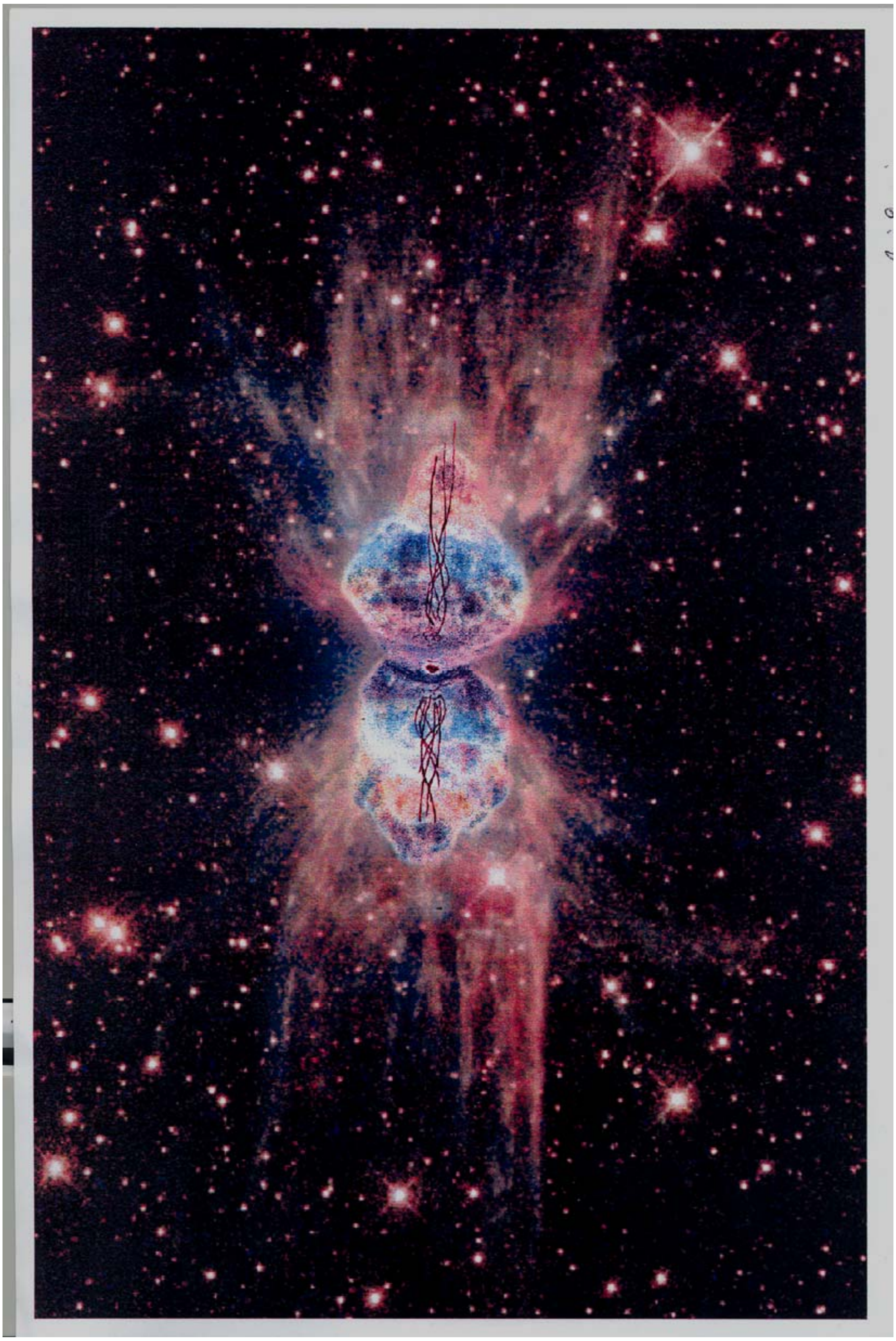
4. A New Picture of Luminous Quasar Structure

An artist's concept of the principal structures found in the central region shows the dipole magnetic field as dotted yellow curves anchored to the central MECO object. The luminous sharp ring at the inner edge of the accretion disc is the structure that becomes microlensed. The ultraviolet outer outflow winds above and below the accretion disc plane are where the blue-shifted broad emission lines and most of the continuum form. As these winds of multiply ionized light elements C, N, O flow outward, electrons flow inward and become tangled in extremely strong magnetic fields, to become jets (red structures) in the lo-hard Q0957 quasar. Notice that such a centrally anchored dipole field of a MECO object creates charge separation and strong Coulomb forces between the central and outer structures. The collapsed central object is faint (highly red-shifted and hardly visible to the distant observer), according to the ECO theory of Abhas Mitra (this conference).



Recall also that a powerful rotating magnetic field has an outer light cylinder at the radius where the field lines and their entrained charged particles would be at light speed. Before this can happen, the magnetic field will bend down to become a toroidal field near the accretion disc plane. This is the field that causes the uplift for out-flowing particles, creating the Elvis structures.

What happens next? Here I must speculate, based upon an HST image of a recently collapsed rotating object with a dipole field anchored to its compact central mass (below). We see that before the outflow winds reach the light cylinder, toroidal magnetic fields further direct the outflow wind upward and away from the region of greatest magnetic field strength. Evidently they can there sense a strong Coulomb force, and curve back toward the electron jet. If they encounter electrons, recombination produces the strong X-ray fluxes observed. This produces the luminous structures that I have colorized ultra-blue. Notice that this entire structure seems to be confined within the outer light cylinder envelope.



I believe that because of the asymmetry of this structure, due to the alignment of the MECO rotation and the accretion disc rotation, the observed jets of MECO quasars will be North-South asymmetrical, even apart from relativistic beaming effects. A north-south asymmetry is evident in the observed structure; notice that the bulbous large structures representing the extension of the Elvis surfaces are not quite the same size on the top and bottom sides of this imaged structure.

I have come to Russia with this picture to challenge her scientists to describe the complex physics implied. I consider it a fair contest to see if Russian scientists with their strong tradition for analytical study, can beat out American simulation experts, who will try to analyze the complex interplay between the Coulomb forces, magnetic fields, and currents of charged particles, to explain this image.

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