A SINGLE EXHAUST MODEL FOR BACKWARD EMISSION IN FAST MOVING QUASARS

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The main difficulty with the Doppler interpretation of quasar redshift has been that if quasars emit radiation isotropically a typical observer would see a predominance of blueshifted quasars in a flux limited sample. It is suggested that this difficulty is overcome if quasars emit most of their radiation in a narrow backward cone.

We show that the twin exhaust model of Blandford and Rees can be adapted to describe quasars moving rapidly through intergalactic medium. The ram pressure of the IGM acts in such a way as to stop the forward jet and allow only the single jet in backward direction. The model appears to satisfy all the gasdynamical and observational constraints imposed on it and offers an explanation for (i) the paucity of radio loud quasars; (ii) the existence of a single jet in quasars and (iii) why nebulosity is expected around low redshift quasars.

Although the majority of astronomers believe that the redshifts of quasars are of cosmological origin, the issue is still subject to controversy. The Doppler origin of the quasar redshift has been suggested in the past to be one of the alternatives. This interpretation, however, has a major drawback in that, it predicts a preponderance of blueshifted quasars in flux limited samples. In fact a quantitative calculation by Strittmatter (1967) gave the ratio of blueshifted quasars to redshifted ones to be as high as 81. One of the assumptions made in this calculation was that quasars emit isotropically in their rest frame. However, if quasars emit most of their radiation in a narrow backward cone, then this difficulty can be overcome. (Strittmatter (1967), Hoyle (1980)). We give here an astrophysical scenario for backward emission.

Our model for a fast moving quasar is an adaptation of the twin exhaust model of Blandford and Rees (1974, BR). It consists of three components : (i) a central source of hot plasma (ii) a cloud of gas and dust surrounding the central source and (iii) a matter distribution whose gravity holds the cloud together. For a "Doppler" quasar moving at relativistic velocities through the intergalactic medium (IGM) there is an appreciable ram pressure from the IGM in the forward direction. This ram pressure does not allow the forward jet to form. A single jet in the backward direction results and relativistic plasma is accelerated to large velocities through a de Laval nozzle. The bulk of the quasar's continuum is emitted by this plasma in the backward direction due to relativistic beaming. Further, the line radiation from cooler clouds in the squirted plasma is blocked in the forward directions by the dust in the object itself, while it escapes relatively undisturbed in the backward direction. Figure 1 illustrates the general scenario.

There are several gasdynamic constraints to be taken into account. Firstly the gas cloud which is needed for collimation of the plasma,

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should not be itself swept away under the onslaught of the IGM. This requires a sufficiently strong gravitational binding. We find that this constraint can be satisfied for the parameters of our model. Further one can show that the IGM does not introduce significant distortion into the internal structure of the cloud. This is due to the fact that for our model parameters, the ratio of the pressure scale height of cloud to the characteristic distance over which the effect of the IGM is felt is very small.

Although the IGM does not blow away or distort the gas cloud it plays an important role in controlling the structure of the jet issuing from the central region. Plasma ejected by the central engine, initially expanding isotropically, soon encounters uneven pressure from the surroundings because of the incoming IGM. If the IGM ram pressure is comparable to central pressure of the gas cloud the plasma is forced to escape in the direction of least resistance, in this case the backward direction. Situations like this have been discussed in the context of single jet models by Wiita and Siah (1982). Once the plasma breaches the confining cloud in the backward direction, a rarefaction wave results. This further helps in stopping the expansion in other directions which the IGM ram pressure is already doing and a single backward jet results.

We have worked out the parameters of the model for different kinds of gravitational binding and for different ways by which the IGM can interact with the gas cloud (passing through it, or being stopped by the gas cloud in a bow shock). One such typical parameter set which assumes the number density of IGM , n_I , to be 10^{-5} cm^{-3} , has the gas cloud central pressure $p_o \simeq 1.5 \times 10^{-8}$ dynes/cm^2 , temperature $T \simeq 3 \times 10^5$ °K and number density 2×10^2 cm^{-3}. The jets nozzle has a radius of 2.26 pc , and stands at a distance of 9 pc from the centre. The whole system has a mass of $\sim 1.6 \times 10^7 M_\odot$ and the gas cloud can extend upto $\sim$ 230 pc ; before the IGM sweeping force dominates gravitational binding. For $n_I \sim 10^{-3}$ cm^{-3} the jet dimensions are scaled down by a factor of 10 and the mass of the quasar becomes $M \sim 1.6 \times 10^6 M_\odot$.

We now discuss the continuum and line radiation. We first note that in the rest frame of the quasar there is an inherent anisotropy. We have a backward jet through which the plasma moves out relativistically. The velocity of the plasma at the nozzle is $c/\sqrt{3}$ corresponding to a bulk γ-factor of 1.22. After going out from the nozzle γ increases further. If the jet is responsible for continuum radiation, it will be predominantly backwards in the quasars rest frame. In fact backward emission is enhanced by a factor of $\sim$ 27 even at the nozzle. Because of this, in a flux limited sample, those quasars will predominate for which the observer is located in the backward direction and such quasars tend to be redshifted.

We find the synchrotron process to be a viable mechanism for the optical continuum emission. We place a limit on the magnetic field in the jet by saying that, its pressure should not influence' the gas dynamics. For a jet of length d_{pc} , and $n^I \sim 10^{-5}$ cm^{-3}. Some typical numbers are $B \sim 10^{-4}$ gauss, $n_e \sim 1.6 \times 10^{-6}$ d^{-1} pc , the average γ value of the relativistic electrons is $\sim 10^5$ with lifetimes of $\sim$ 130 years. Detailed calculations indicate that the power emitted in optical frequencies by a jet of length $\sim$ 150 pc is $\sim 10^{40}$ ergs s^{-1}. Also the power emitted by the same region at radio frequencies is much smaller. Hence a correspondingly larger emitting volume is required, unless the beaming effect mentioned earlier operates. This may explain why < 10% of all quasars are radio sources and why the radio emission comes from an extended volume.

In the context of local quasars, the total mass of the line emitting region comes out to be $\sim 10^{-2} M_\odot$. Thus the line emitting regions do not affect overall dynamics of the system and as such they can be placed anywhere in the composite systems with affecting our previous results. We could imagine $\sim 10^4$ such clouds, each of $10^{-6} M_\odot$, coexisting with the relativistic plasma in the jet. These clouds have small enough mass to be thought of as ejecta from the central source. From considerations of the forces influencing the cloud motion, one can show that over the quasar's life time, only clouds less than a certain escape speed V_D and within a characteristic distance D , will remain part of the composite system. This implies that the clouds exist only upto a distance D of the jet. Further, it can be shown that the presence of a small dust component ($n_{dust} \sim 10^{-2}$ n_{gas}) in the gas cloud, and the fact that the emission line clouds exist in the backward jet only upto a distance D , brings about an anisotropy in the line emission from the object. Thus even if we pick out a quasar coming towards us, it will appear lineless.

In the model outlined above the extent of the gas cloud is determined by the IGM ram pressure and hence the speed of the quasar. Hence quasars with larger Doppler shifts will have smaller clouds. If the cloud is seen as a fuzz around the object then it is likely to be associated with low redshift quasars.

Finally the model seems to offer an explanation as to why in all observed case of quasars only one radio jet is seen. A direct verification of the Doppler hypothesis will result if future VLBI observations are able to detect the proper motion of the quasar, especially if the motion is away from the observed jet.

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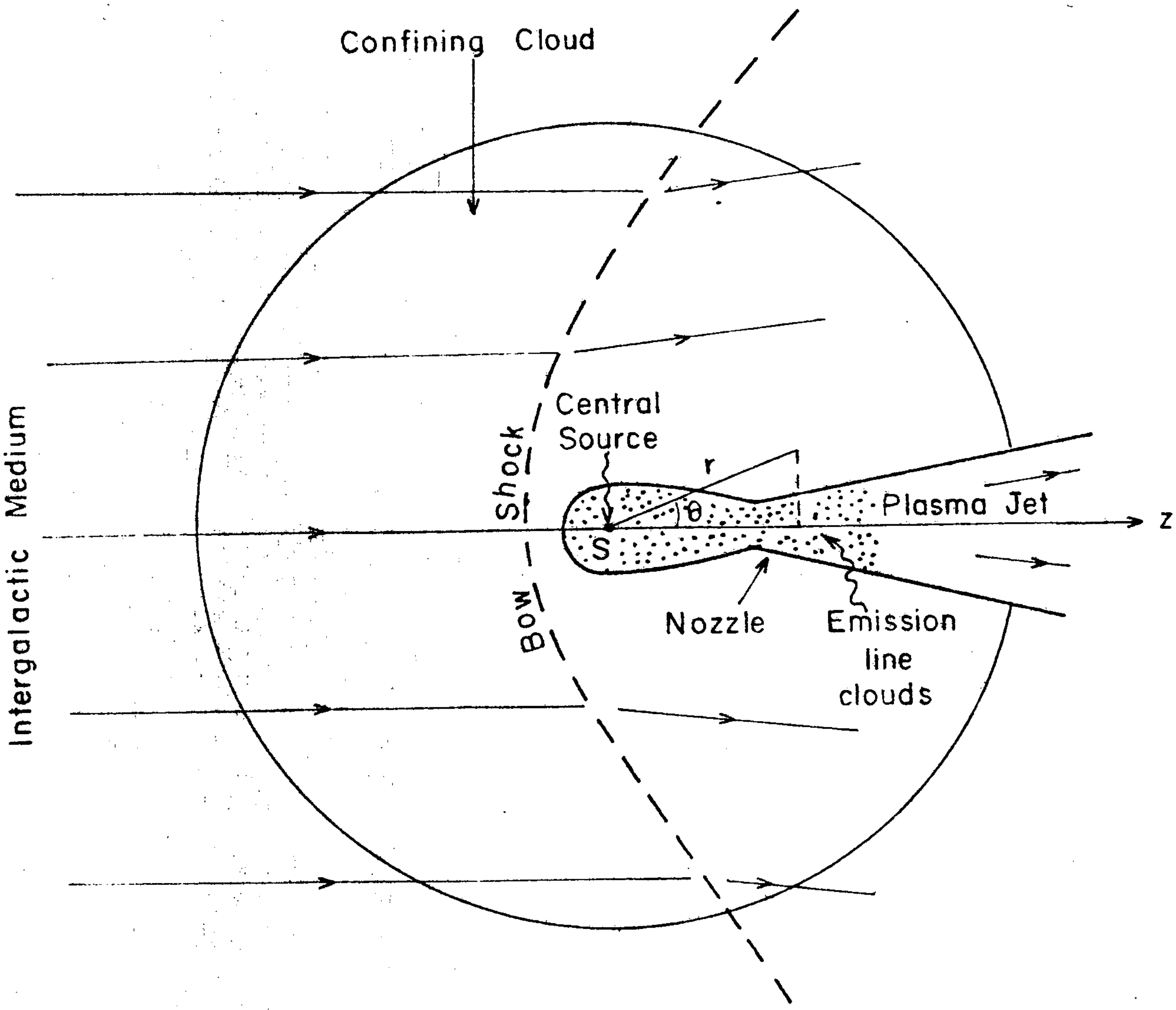
Confining Cloud
Intergalactic Medium
Bow Shock
Central Source
r
θ
S
Plasma Jet
z
Nozzle
Emission line clouds

Fig.1