

IS THE LYMAN ABSORPTION EDGE A GOOD OBSERVATIONAL TEST FOR AGN ACCRETION DISKS?

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1. MODEL PREDICTIONS

Geometrically thin and optically thick accretion disk models which use non-LTE stellar atmospheres predict a Lyman absorption edge near 912\AA in the quasar rest frame (Sun and Malkan 1987; Sun 1987). The detailed spectral shapes around the Lyman limit have been calculated for both Kerr and Schwarzschild metrics. The Lyman absorption edge, especially in the (more realistic) Kerr case, is markedly distorted and displaced by the relativistic effects of the strong gravitational field of the black hole and the large Doppler motions of the disk surface. Figure 1 shows a Kerr disk model accreting at 10% of its Eddington luminosity (L_{Edd}), typical for quasars, viewed from five different angles.

In the face-on case ($\cos i = 1$) where no first order Doppler motion is present, the dominant effect on the emergent radiation is the gravitational redshift. This effect shifts the edge redward by at least a few percent (up to 10%) in the quasar rest frame. At higher inclinations, however, the Doppler boosting effect takes over and the Lyman edge becomes blueshifted and broadened. In the edge-on case ($\cos i = 0$), the edge is almost undetectable.

As expected, the Schwarzschild disk models show much smaller relativistic effects around the Lyman edge. This is due to the much larger radius of the innermost edge of the disk (5 times that of the Kerr disk).

2. OBSERVATIONS

Nine high-redshift quasars were observed with a CCD spectrograph on the Lick 3-m Shane Telescope in June, 1988. We used a 3" slit and a 600 line/mm grating to obtain adequate resolution ($\sim 4\text{\AA}$). The UV Schmidt camera sensitivity provides reasonable S/N ratios in the quasar continua all the way down to the atmospheric cutoff (3200\AA). This gives us the advantage of observing lower-redshift quasars ($z \sim 2.6$) while still measuring the continuum blueward of 912\AA (in the rest frame) fairly well. Since the number of intervening intergalactic HI clouds along the line of sight rises very sharply with redshift, it is much better to measure these nearer quasars, since there is less ambiguity in separating intrinsic Lyman edges from breaks which are externally produced.

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Of the nine quasars we observed, four show gradual drops in their continua of 20 – 70% (in F_λ) across a range of 200 to 300 Å, as predicted by the disk models. Preliminary analysis shows that, for the quasar 1225-017, a Kerr disk with 0.9% L_{Edd} ($1.8 \times 10^9 M_\odot$, $0.11 M_\odot/\text{yr}$) at an inclination angle of $\cos i = 0.75$ provides very good fit (Fig. 2). We caution that the inferred black hole mass and the accretion rate may have large uncertainties since we still lack the important continuum data at longer wavelengths needed to rigorously constrain the disk model, as we previously did for bright quasars (Sun 1987).

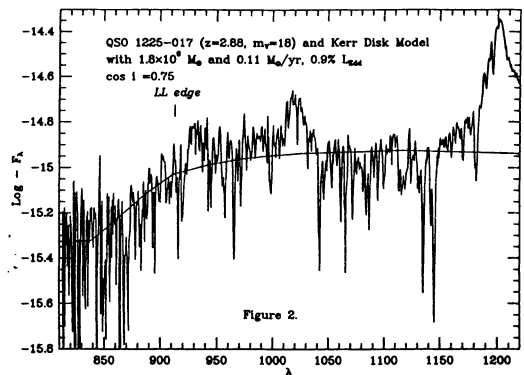
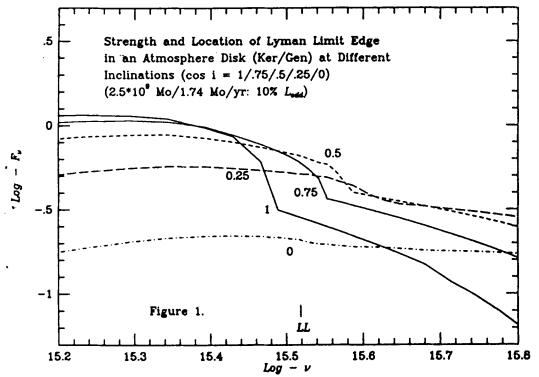
Also found in two other quasars, 1215+333 and 1334-005, are sharp partial discontinuities near the rest frame Lyman limit, of 40 and 20%, respectively. Since these are identified with strong L_α absorption lines we detected at the same redshift, they are evidently caused by intervening hydrogen clouds with redshifts slightly less than that of the quasar. 1607+183 has an optically thick Lyman system at a redshift of 2.77 which completely cuts off radiation below 3440 Å.

3. CONCLUSIONS

Disk spectra with non-LTE stellar atmospheres predict a Lyman limit absorption edge which would provide the most direct observational evidence for the optically thick accretion disk hypothesis. We observed several high-redshift quasars and found that the Lyman limit region of at least one quasar (1225-017) can be well described by a slightly inclined Kerr disk with moderate black hole mass and low accretion rate.

4. REFERENCES

1. Sun, W.-H., 1987, Ph.D. thesis, UCLA.
2. Sun, W.-H. and Malkan, M.A., 1987, in "The Third George Mason Astrophysics Workshop: Supermassive Black Hole", ed Kafatos M.



DISCUSSION

SMITH 1. What aperture size did you use? 2. How did you correct for refraction in the UV with such a small aperture?

SUN 1. We used a 3" slit on Lick 3-meter, with UV Schmidt camera. 2. We rotated the tub for every QSO so that the atmospheric dispersion is always parallel to the slit orientation. As confirmed by observations of nearby standard stars before and after each quasar with the same procedure, the error in the continuum caused by the UV refraction effect is very small.

KINNEY You have emphasized the case when a partial Lyman discontinuity was detected – a case that is well fitted by the accretion disk model. I would like to comment that the majority of quasars do not show such discontinuities.

SUN I agree that the Lyman discontinuity is not a universal feature in many quasars, especially the low-redshift ones. The accretion disk models predict a very small (or undetectable) continuum drop at higher inclinations. Also, we may have over estimated the strength of the edge by using unrealistically high surface gravity atmosphere models.

WHITTLE Are you confident that the depression shortward of the Lyman limit is not caused by the superposition of many narrow absorption lines?

SUN Our data were taken using a 600 line/mm grating and reached a resolution (FWHM) of $\sim 4 \text{ \AA}$. At this resolution, those moderately strong high- n lines which might depress the continuum would be revealed. Thus, we believe the continuum depression we observed is an intrinsic feature. Kinney and Antonucci (this conference) obtained similar data with even better resolution ($\sim 1 \text{ \AA}$). There is no indication in their data that the continuum depression (in a few objects) was caused by narrow absorption lines.

MARSHALL Have you extended your models to the He II 228 \AA edge? Is there any flux to shorter wavelengths? Is the edge as strong or does it have the same shape as the H I 912 \AA edge?

SUN The disk continuum models for most quasars extend to the far UV and there is flux shortward of 228 \AA in some cases. Since these photons are emitted at very high temperatures, the stellar atmosphere models we used sometimes predict an emission feature rather than absorption, at low surface gravity. The exact appearance around 228 \AA varies depending on the size of the emitting regions at high temperatures.