THE COMPARISON OF OPTICAL MICROVARIABILITY FOR SELECTED RADIO-QUIET AND RADIO-LOUD QSOS

Minhwan Jang[1,2] and H. Richard Miller[1,3]

Electronic mail: jang(miller)@chara.gsu.edu

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[1] Department of Physics and Astronomy, Georgia State University, Atlanta, GA 30303

[2] Guest Observer, *Rosemary Hill Observatory*, University of Florida, Gainesville, FL 32611

[3] *Jet Propulsion Laboratory, 4800* Oak Grove Dr., Pasadena, CA 91109

ABSTRACT

A selected sample of radio-quiet and radio-loud quasi-stellar objects has been optically monitored in an effort to test some of the prominent theoretical mechanisms proposed for the origin of optical microvariability in active galactic nuclei. Two out of 10 radio-quiet QSOS and 6 out of 7 radio-loud QSOS observed show evidence for microvariations. This apparent contrast in microvariations between radio-quiet and radio-loud QSOS implies substantial support for models based on propagating shocks on relativistic jets as the process probably responsible for producing most of the microvariations observed in AGNs.

Subject headings: galaxies: active - galaxies: photometry -- quasars: general

1. Introduction

Microvariations, which are luminosity variations with durations extending from minutes to days and can be either discrete events or parts of longer term trends, set a limit to the size of the emitting region. Therefore the study of mi crovariations provides a powerful way to understand the physical processes involved in the production of the observed luminosities from the central region of AGNs.

Historically, there have been many reports of detection of rapid optical flux variations. The first report of microvariation was made by Matthews & Sandage (1963) for 3C 48 where they detected a *0.04* msg. change in 15 minutes. Oke (1967) found 3C 279 varying with an amplitude of 0.25 msg. in 24 hours. Racine (1970) reported fluctuations of 0.1 msg. over a few hours for BL Lacertae. Angione (1971) detected a rate of 0.3 msg. per hour change in 3C 454.3. Bertaud *et al.* (1973) reported a 1.3 msg. change for BL Lacertae in 24 hours and a 0.7 msg. change in 74 minutes. Miller (1980) detected variations in 3C 446 with a 0.13 msg. change in 2 hours.

While these and other early claims for the detection of microvariations were made, the poor signal to noise ratios, the limitations in photographic, single channel photoelectric instruments and the possible contaminations from the extinction changes implied that one could not give full support to the claims of detections of low amplitude rnicrovariations. It was not until the development of modern CCD cameras in 1980's, that one could claim the detection of rnicrovariations with confidence, Those claims were made by Miller *et al.* (1989) for BL Lacertae, by Carini *et al.* (1990) for OQ 530, by Carini & Miller (1992) for PKS 2155-304. However, most of AGNs which have been found to exhibit microvaritions, to date, are confined to radio-loud blazar type AGNs. The first systematic attempt to " investigate microvariations in radio-quiet AGNs was made by Gopal-Krishna *et al.* (1993, 1995), and they found two highly probable detections of microvariations.

The difference between radio-quiet and radio-loud AGNs has long been argued, particularly in the context of the unified theories (e.g. Antonucci 1.993). Radio-loud sources are expected to have relativistic jets which dominate their emission (Bregman 1992). In contrast, it is believed that most radio-quiet AGNs do not have relativistic jets (Antonucci *et al.* 1990) or show only a very weak jet (Miller *et* al. 1993, Kellermann *et al.* 1994). At low redshift, it seems that the host galaxies of radio-quiet AGNs are spirals and those of radio-loud AGNs are elliptical (Hutchings *et al.* 1989, Alloin *et* al. 1992). Recently Wilson & Colbert (1995) suggested that the cause of the difference between the classes could be associated with the spin of the black hole at the nucleus.

Even though the causes of the difference is still the subject of disputes, the difference in radio emissions makes the test of viable theoretical explanations of microvariability possible by comparing variability characteristics of radio-quiet and radio-loud AGNs. One of the widely contemplated models is based on disturbances in accretion disks. Wiita *et al.* (1991, 1992, also Chakrabarti & Wiita 1993, Mangalam & Wiita 1993) proposed that numerous flares or hot spots on the accretion disk surrounding the central engine produce the microvariations in AGNs. They argued that the rnicrovariations detected for blazars can be interpreted as the result of disturbances on the accretion disk. Thus, if these explanations are correct, one would expect that microvariabili ties shoud be present in both classes of AGNs. In the other hand, another major model for microvariations, the shocked jet based model which was proposed by Marscher & Gear (1985), Hughes *et al.* (1985), Valtaoja *et al.* (1988) and Qian *et al.* (1991), predicts the presence of microvariation only in radio-loud AGNs which have considerable jets.

For radio-quiet AGNs, since they do not have relativistic jets or only have very weak ones, onc can probably exclude the effect of a shocked jet based model and expect only the effect of accretion disk based model in microvariability characteristics. For radio-loud AGNs, one could expect the effect from both models or either one of them. Therefore

comparison of microvariation between radio-quiet and radio-loud A GNs could strictly constrain some of the prominent theoretical explanations proposed for the origin of optical microvariability in AGN.

In our preliminary results, Jang & Miller (1995, hereafter Paper I) showed that there is a distinctive difference in optical microvariability between radio-quiet QSOs(RQQSOs) and radio-loud QSOs(RLQSOs). These results did not provide substantial support for the dominance of the accretion disk based model which predicts the ubiquity of microvariations in both classes. Encouraged by the preliminary results, we continued to monitor a larger number of objects in both classes to compare microvariation characteristics; here we present the analysis of our subsequent observations.

2. Observations and Data Reductions

We chose the QSOS to be monitored from the Palomar Bright Quasar Survey and the list of non-OVV AGNs which were monitored for long-term variations in brightness at Rosemary Hill Observatory at the University of Florida (Pica *et al. 1988).* We also utilized the list of Schmidt & Green (1983) and VLA observations of Kellermann *et al.* (1989). In our selection of QSOS, we included a few luminous Seyfert 1 galaxies, because of their similarities to QSOS in most characteristics except the relatively low luminosities (Schmidt & Green 1983).

The objects in our sample were selected based on the following criteria: i) The objects with $m_B \lesssim 16$ were selected, in order to achieve a reasonable signal-to-noise ratio using a modest exposure time. ii) To define the RQQSOs, we confined the ratio R, of radio to optical flux density (ratio of total flux density in mJy at 6 cm to optical flux density in mJy at an effective observed wavelength of 4400 Å, computed from the relation described by Kellermann *et al.*(1989)), to be less than 1 in order to assure the objects are reasonably

radio-quiet. iii) We required that the CCD frame should contain the QSO and at least 2 or 3 standard stars with similar apparent magnitudes. We also tried to observe objects close to the local zenith to minimize possible airmass induced fluctuations.

The observations were carried out from October 1994 to February 1995 at Rosemary Hill Obervatory(RHO) at the University of Florida using the standard Johnson-Cousins r and v photometric filters. The images were obtained with a Photometrics Star I CCD camera located at the f/4 Newtonian focus of the 0.8 m reflector behind a 1.5 diopters Barlow lens. This camera has the format of 384 x 576 pixels with a pixel size of 23 microns. Each pixel on the image frame corresponds to 1.56 arcseconds in the sky. Since this camera has the highest Quantum Efficiency (QE) in I-band, we chose the r-band filter for continuous monitoring to achieve the maximum signal-to-noise ratio on each frame. Bias, dark current and flat field frames were taken each night to reduce the observational noise. For a small number of nights, at least one frame in the v-band was taken to complement the r-band frames in order to provide color information. In no instance were any color variations found to be present on these time scales. Each object was observed a minum of 3 hours or more. The selection of this time interval is based on the suggestion of Carini (1990) who reported that there was approximately a 50% chance of detecting variability when the blazar type object was monitored for at least 3 hours.

The observed QSOS are listed in Table I, along with their 1950 coordinates, redshift, z, apparent B magnitude, the ratio R as defined above, and absolute B magnitude. H_0=50 km/s/Mpc and q_0=0.5 were assumed for all numerical results in the table.

The data were reduced using a DECstation 5000 system employing the IRAF software package. Each exposure is processed through an aperture photometry routine which reduces the data as if it were produced by a multi-star photometer. Then differential magnitudes can be computed for any pair of stars on the frame. Howell (1989) examined the photometric precision as a function of increasing aperture radii. He showed that S/N

is a maximum when the aperture is approximately the full width at half maximum of the point spread funtion (FWHMPSF) of the object and decreases for both larger and smaller apertures. To select the best fit aperture size, a median value of FWHMPSF was calculated for each frame, then several trial aperture sizes were chosen around that value. Using *phot* routine in IRAF with these aperture sizes, the differential light curves for two of the comparison stars were produced and examined. This procedure was repeated until the scatter in the comparisons was minimized, thus determining the optimal aperture size. Average aperture 'sizes used in this work ranges approximately from 2 to 4 pixels in radius. Simultaneous observations of the QSO, comparison stars and the sky background allow one to remove the dominant possible sources of error: the effect of color differences and fluctuations in either atmospheric seeing or transparency, Carini *et al.* (1992) examined the plots of magnitude differences between comparison stars of different colors versus airmass, and found that over a large range of airmass, there is no evidence that large color differences in the sets of the comparison stars affect t] ıe overall accuracy of the photometry, or introduce systematic variations not intrinsic to the source. Also Carini *et al.* (1991) showed that even for sources with significant underlying galaxy components, any spurious variations introduced by fluctuations in atmospheric seeing or transparency are typically smaller than the observational uncertainties. They examined MCG 8-11-11, which has a very prominent galaxy component associated with it, reducing the data using the same aperture size and maintaining it over the length of tile observations. Examination of the object-comparison star and comparison-check star data sets exhibit no significant difference in standard deviations. Therefore, the variations detected are not the result of variation ei thcr in seeing or transparency. The observational errors quoted for the present paper have been calculated assuming that variations intrinsic to the object can be identified and " removed. When the object-comparison star data set showed linear trend, we have fit both the object-comparison star (O-C) observations and the comparison-check star (C-K) data

with a straight line via a linear least square analysis. In each case, the standard deviation of the data points about the fitted straight line has been calculated. The largest value of the standard deviation has been used as the measure of the observational error. The forma] errors for each data point are substantially smaller than the standard deviation (σ) of the comparison-check star data. This scatter (σ) is a much more generous estimate of the true observational error than the formal errors. Therefore, we have quoted this error (σ) rather than the formal errors.

3. Results

In Tables II and 111, we summarize the observations for the sample of RQQSOS and RLQSOS, respectively. Column 1 lists the object designation; Column 2 lists the date of the observations; column 3, the observational error; column 4, the confidence level, which is the difference as the multiples of standard deviations calculated by the method described in Carini (1990), for the reality of the variability, A 9970 confidence level for the reality of variability was set at 2.576σ of the normal function; column 5, the duration of each observation, in hours; and column 6 indicates whether the microvariabilit y was detected in our observations of each source. If no variability for an object is detected within *one* night's data set, we also compared the night-to-night brightness changes for each object to determine if variations were present on the time scales of days. The results are discussed below.

Among the 17 QSOS presented here, 10 objects are classified as radio-quiet and 7 objects are classified as radio-loud. Recall that our classification used R values less than 1 to define the radio-quiet objects. We now present very brief discussions of each of 8 sources for which the light curves were plotted and a few more sources of interest.

Radio-Quiet Objects: 8 objects show no significant variation within a night, or on a

night to night basis which exceeds the observational uncertainty. But 2 objects, TON 951 and TON 1057 exhibit microvariations.

MKN 335. Classified as a Type 1 Seyfert, it is the brighest object in our sample. We observed it for 3 nights with excellent S/N ratios, but found no detection of variation.

PG 0804+761. This bright classic QSO is the most densely observed in our sample, with observations on 5 nights. However, this source provided no evidence for rapid variations.

TON 951. This object produced our first clear detection of intranight variation in the radio-quiet AGN class. Except for the night of November 2, on January 25, 30 & February 1, it showed significant rapid variations. When those nights' observations are compared to search for night to night variations, considerable changes in mean brightness level were also found. On the night of January 25, the object brightened $\sim$ 0.08 msg. in 1.5 hours after small amplitude fluctuations. On the night of January 30, the object increased in brightness by $\sim$ 0.05 msg. in 2.6 hours after $\sim$ 0.04 n ıag. decrease in 1 hour, Furthermore, comparison of these two nights' light curves shows $\sim$ 0.12 msg. decrease in mean value of the O-C light curve while the C-K light curve remained unc.hanged. These 2 nights' data sets were overlapped and are shown in Figure 1.

TON 1057. This RQQSO was observed for 2 nights. On the night of Feburary 5, the object was increased in brightness by $\sim$ 0,07 msg. in 1.7 hours and then started to fluctuate about the higher level. The light curve of this data set is shown in Figure 2.

Radio-Loud Objects: 6 out of 7 objects monitored show evidence for intranight vari at ions.

III Zw 2. This Seyfert 1 galaxy had been monitored optically for 10 years at RHO, and has a documented range of 1.5 msg. variation during that period (Pica *et al.* 1988). It was " observed for 2 nights in our present study and showed significant intranight variations each night. On the night of November 26, the object brightened $\sim$ 0.09 msg. in 3.6 hours. The

light curve is shown in Figure 3.

MKN 1014. Observed on November 1, this object shows an amplitude of $\sim$ 0.08 mag. fluctuations in the form of a general trend of fading in the time span of 3.3 hours. The light curve is shown in Figure 4.

MKN 110. This object was observed for single night, December 26. The light curve shows $\sim$ 0.07 msg. increase in the first 1.5 hours. Then it exhibits $\sim$ 0.05 msg. span of decrease and increase in 1.7 hours. The plot of this data is shown in Figure 5.

4C 13.41. Smith *et al.* (1992) monitored this QSO for 18 years and found an amplitude of *0.8* msg. for its variations. In our present study, we observed it for 2 nights. On the night of December 5, the object showed fluctuations with an amplitude of $\sim$ 0.05 msg. in 3.1 hours similar to the configuration of intranight variation found in Seyfert 1 galaxy AKN 120 by Miller & Noble (1995). The light curve is shown in Figure 6.

3C 249.1. This RLQSO was observed on the night of January 23 and its light curve is shown in Figure 7. 'l'he object increased in brightness by $\sim$ 0.08 msg. in 2 hours and then stayed about the same level. Penston & Cannon (1970) monitored this RLQSO and reported a flare of 0.3 msg. over several days.

PKS 2344+092. The strongest radio source in our sample had been also monitored for variability at 2.7 GHz by Kesteven *et al.* (1976). They claimed this source as a variable based on 8 observations in 2 year period. In our observations, we monitored it for 2 nights and detected rapid variations each night. The data set of November *24 is* shown in Figure 8. On this night, the object showed steep decrease in brightness, $\sim$ 0.16 msg. in 3.7 hours.

4. Discussion

When variability in AGNs is examined, one should be particularly careful to account for possible spurious variations induced by the underlying galaxy component in these objects.

This is especially true for Seyfert galaxies. Although no evidence of a significant underlying galaxy component was present from a simple visual inspection of all CCD image frames used for this dissertation, it is worthwhile investigating the possibility of this contamination in order to evaluate the significance of the variations presented here. As mentioned in section 2, Carini (1990) tested for the possible effect of a galaxy component contributing to the variability in the aperture photometry. His observations of MCG 8-11-11 showed that, in spite of conditions of unstable seeing and variable transparency on the night of the observations, the object remained non-variable, implying seeing did not introduce spurious variability in an object which has a very prominent galaxy component. However, there is another method to check for such possible contamination. If the variation measured is artificial, there should be an inverse correlation between amplitude and redshift. This relationship could be produced when the galactic contribution is diminished at higher redshift. To examine this possibility, redshift versus the confidence level was plotted using all objects which show more than 10 fluctuations including the objects presented in Paper I. To simplify the plot, when variations are detected on a few nights, only the night which has the highest amplitude of variation was used. The plot is shown in Figure 9. No evidence of correlation which could be related to the error associated with the underlying galaxy component was found in this plot, However, the objects observed for this work are confined to the relatively low redshift objects. A reasonable indicator of seeing is the full width at half maximum of the point spread function (FWHMI 'SF). In the upper panel of Figure 10, we plot the FWHM (in pixels) of MKN 110 observed on December 261995 (△), the FWHM of comparison star (□), and the difference between these two (*). While it is clear that there is some variation of the FWHM throughout the night, there is no significant correlation (correlation coeficient;0.40) between this difference and the differential magnitudes between " the object and the comparison star displayed in the lower panel. Therefore, variations in seeing, which are present during these observations, are not responsible for the variability

detected for the object.

When we designed our observations, we allocated more observation time for RQQSOS than for RLQSOS assuming the possibility of detecting microvariations would be very low in RQQSOS based on our preliminary results described in Paper I. This distribution of effort resulted in more nights with no detection of microvariation in RQQSOS and fewer nights devoted to RLQSOS, although most showed microvariations, strenghtening the contrast between these two classes, Among 10 RQQSOs monitored, only 2 objects exhibit evidence for microvariation. In contrast, 6 out of 7 RLQSOs observed exhibit evidence of microvariation. When we include the results from Paper I, 3 out of 19 RQQSOS (16%) show detectable microvariations while 9 out of 11 RLQSOs (82%) show evidence of microvariations. This very low detection rate for RQQSOs is consistent with the work of Gopal-Krishna *et al.* (1993, 1995) who reported two highly probable detections of microvariation in their sample of 12 RQQSOS. The result for the RLQSOS are similar to the results of Heidt & Wagner (1995) who found intraday variability in 82% of their sample of 34 BL Lacs and Noble (1995) who found intraday variability in 76% of his sample of 25 blazars. Carini (1990) also showed that more than 8 hours of observation for his sample of 20 blazar type objects led to over 80% chance of detecting microvariation. If we assume RLQSOs and RQQSOS are drawn from a single parent population for which one has an 80% chance of detecting microvariability (i.e. the same as that found for RLQSOs), then the probability of 3 or fewer of 19 RQQSOs exhibiting microvariability is 3.4×10^{-9}, using the binomial distribution. Therefore, the low detection rate for microvariability in RQQSOs demonstrates the distinctive nature of this class of AGNs.

Our results strongly indicate that microvariability is very likely associated with radio-loud AGNs. This association supports the models based on jets being primarily " responsible for observed variations. The premise of the shocked jet model is a relativistic shock which moves down the jet and interacts with inhomogeneous structures. In this

scheme, due to the very high Reynolds number in a relativistic jet, the jet plasma becomes turbulent, so that the shock will propagate through regions of different densities, and different magnetic field strengths, producing variable observed flux on its way (e.g. Qian *et al.* 1991, Marscher *et al.* 1992). Also the trajectories of the relativistic shocks could be deviate slightly from the line of sight and produce rapid changes (e.g. Gopal-Krishna & Wiita 1992). Another related model involves the non- axisymmetric knots carried outward in relativistic magnetized jets (Camenzind & Krockenberger 1992).

Since it is believed that most of AGNs have the accretion disk around their nuclear region, another family of widely contemplated models which are based on discrete events on the accretion disk were also developed to explain microvariation (e.g. Zhang & Bao 1991, Wiita *et al.* 1991, Mangalam & Wiita 1993). These models, which are analysed for both α- and β-disks, invoke the phenomena of hot spots including geometrical effects such as the eclipsing of the hot spots by another part of the disk and rotation induced Doppler shifts. Such hot spots are expected to arise from instabilities induced by gravitational perturbations, spiral shocks, magnetic instabilities, etc. Thus if the AGNs are viewed close to face-on as unified schemes indicate for both in the case of RQQSOs and RLQSOS, the intrinsic variabilities are expected to be visible to the observer. But our results show a clear contrast between these two classes. It could imply that the strengths of disturbances, if they are present on the accretion disks, are so low as not to be detected in most cases. otherwise, as Wiita (private communication 1995) suggested, the weak disk disturbances could be swamped by jet based disturbances for radio-loud AGNs.

However, clear detection of microvariations in only a few RQQSOs is not fully understood by utilizing the present models unless one assumes selective presence of strong hot spots on accretion disks in some RQQSOs. Therefore it would be very useful to investigate another class of AGN, edge-on radio-loud Seyfert 2 galaxies, in order to arrive at firmer conclusions on the underlying physical mechanisms for microvariability. Since direct

view of the nuclei of Seyfert 2 galaxies are thought to be blocked by dusty tori, the effect of disturbances on the accretion disk should be hardly detectable. Then only the jet related effect which is produced outside the hidden region (at distances $\gtrsim$ 1 pc), if there is any, could be seen by the observer. If the rates of detection of microvariations in these objects are consistent with those of other classes of radio-loud AGNs, one might find conclusive support for the models based on the shocked jet mechanism. We have begun such a program which includes observations of a selected sample of radio-loud Seyfert 2 galaxies.

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Table I. List of the AGNs observed. The coordinates are 1950.0

SOURCENAME	α	δ	z	m_B	R	MB
MKN 335	000345,0	+19 5530	0.03	13.75	0.?7	-22.14
III Zw 2	000756.7	+10 4148	0.09	16.11	197	-22.56
PG 0052+251	005211.1	+25 0924	0.16	15.42	0.?4	-24.48
PG 0117+213	011734.7	+21 1804	1.49	16.05	0.15	-29.22
MKN 357	01 1957.0	+22 5435	0.05	15.41	0.99	-22.12
MKN 1014	01 5716.3	+00 0910	0.16	15.20	2.12	-24.83
PG 0804+761	080435.3	+76 1132	0.10	15.15	0.60	-23.78
10N 951.	084433.9	+34 5609	0.06	14.00	0.03	-23.95
MKN 110	092144.4	+52 3014	0.04	15.62	1.49	-21.00
TON 1057	092305.8	+200707	0.19	16.04	0.14	-24.32
4C 13.41	100445.1	+13 0338	0.24	15.93	228	-24.96
3C 249.1	110027.4	+77 1508	0.31	15.86	322	-25.64
PG 1322+659	132210.0	+65 5722	0.17	15.86	0.12	-24.23
TON 182	140258.8	+26 0959	0.16	15.57	0.23	-24.46
PG 1411+442	1411 50.0	+44 1412	0.09	14.99	0.13	-23.68
4C 37.43	151246.9	+37 0156	0.37	15.97	190	-25.92
PKS 2344+092	234403.7	+09 1405	0.68	16.00	1010	-27.23

Table II. Summary of the observations of the radio-quiet AGNs

OBJECT	DATE	ERROR	CONFIDENCE	DURATION	VARIABLE?
MKN 335	10/23/94	0.010		5.4	No
	10/24/94	0.011	–	7.5	
	12/07/94	0.010		4.3	
PG 0052+251	12/24/94	0.008		4.2	No
	12/25/94	0.012		4.8	
PG 0117+213	12/27/94	0.012	–	4.5	No
	12/31/94	0.007		3.7	
MKN 357	12/28/94	0.008		4.5	No
	01/08/95	0.008		3.7	
	01/09/95	0.012	–	3.7	
PG 0804+761	11/03/94	0.008	–	4.3	No
	11/05/94	0.008	–	5.2	
	11/24/94	0.012	–	3.2	
	11/25/94	0.008	–	3.1	
	11/26/94	0.008	–	3.7	
TON 951	11/02/94	0.008	–	3.7	Yes
	01/25/95	0.006	6.8	3.4	
	01/30/95	0.007	3.9	4.0	
	02/01/95	0.006	2.9	4.3	
TON 1057	02/05/95	0.009	5.8	4.4	Yes
	02/06/95	0.008	–	4.6	

Table II.(continued)

OBJECT	DATE	ERROR	CONFIDENCE	DURATION	VARIABLE?
PG 1322+659	01/26/95	0.005	·	3.4	No
	01/30/95	0.014	--	4.0	
TON 182	02/05/95	0.011	–	3.9	No
	02/06/95	0.009		4.2	
PG 1411+442	02/01/95	0,012	–	4.9	No
	02/04/95	0.012		4.2	

Table 111. Summary of the observations of the radio-loud AGNs

OBJECT	DATE	ERROR	CONFIDENCE	DURATION	VARIABLE?
111 Zw 2	11/26/94	0.012	3.8	3.8	Yes
	12/06/94	0.013	3.9	4.1	
MKN 1014	11/01/94	0.006	3.5	3.5	Yes
MKN 110	12/26/94	0.007	3.2	3.6	Yes
4C 13.41	12/05/94	0.006	2.6	3.3	Yes
	02/04/95	0.010	–	3.5	
3C 249.1	01/23/95	0.010	3.5	4.5	Yes
4C 37.43	02/08/95	0.010		3.8	No
PKS 2344+092	11 /23/94	0.011	3.3	3.8	Yes
	n/24/94	0.010	7.2	3.9	

FIGURE CAPTIONS

Fig. 1- Overlayed r band observations of TON 951 obtained 25 January 1995 and30 January 1995. observations on 25 January 1995 are denoted by (*), observations on30 January 1995 are denoted by (A).

Fig. 2-- r band observations of TON 1057 obtained 05 Febuary 1995.

Fig. 3- r band observations of 111 Zw 2 obtained 26 November 1994.

Fig. 4- rbandobservations ofMKN 1014 obtained 01 November 1994.

Fig. 5- r band observations of MKN 110 obtained 26 December 1994.

Fig. 6- rbandobservations of4C 13.41 obtained 05 December 1994.

Fig. 7- rbandobservations of3C 249.1 obtained 23 January 1995.

Fig. 8- rbandobservations of PKS 2344+092 obtained 24 November 1995.

Fig. 9- The plot of redshift vs. confidence of variability.

Fig. 10 -The plot of the FWHMPSF of MKN 110. The FWHM of the object is denoted by (A), the FWHM of comparison star is denoted by (□), and the difference between these twois denotedby (∗).

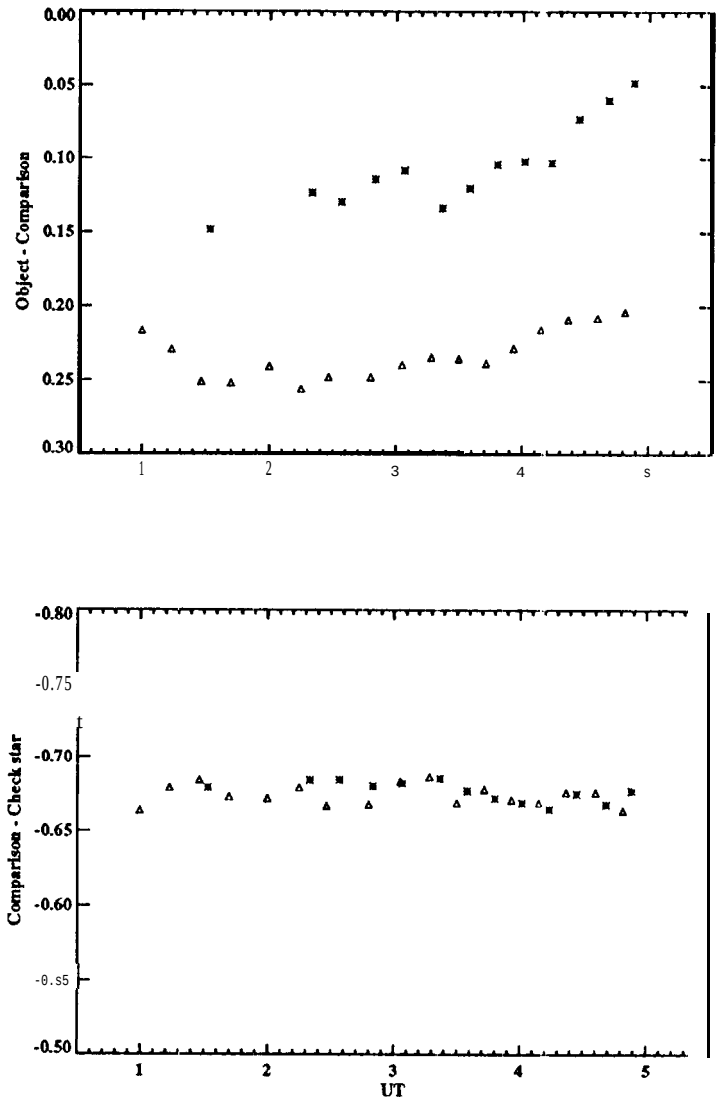

0.00
0.05
0.10
0.15
0.20
0.25
0.30
Object - Comparison
1
2
3
4
s
-0.80
-0.75
-0.70
-0.65
-0.60
-0.50
Comparison - Check star
1
2
3
4
5
UT

Figure 1.

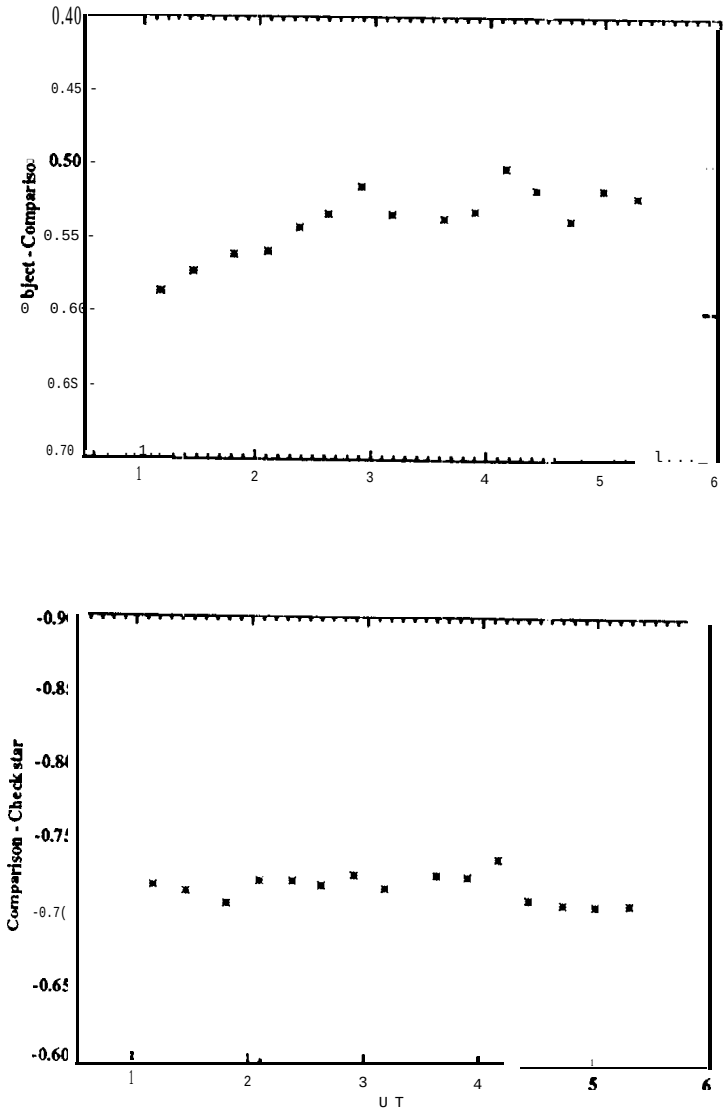


Figure 2.

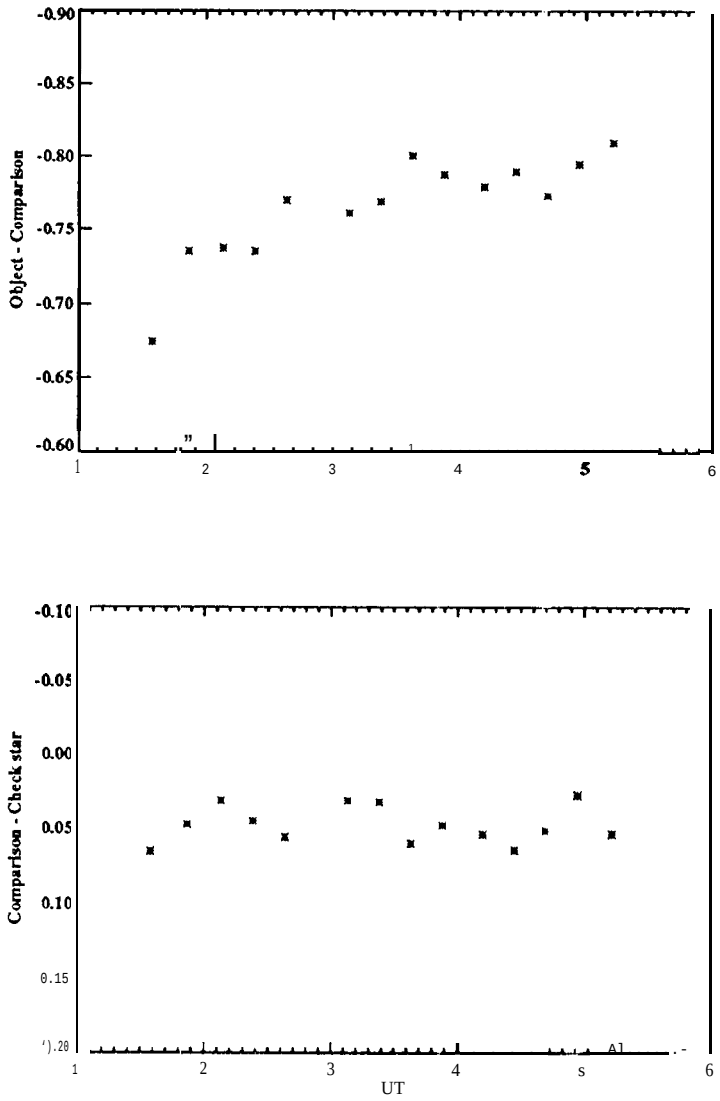

-0.90
-0.85
-0.80
-0.75
-0.70
-0.65
-0.60
Object - Comparison
1
2
3
4
5
6
-0.10
-0.05
0.00
0.05
0.10
0.15
Comparison - Check star
1
2
3
4
s
6
UT

Figure 3.

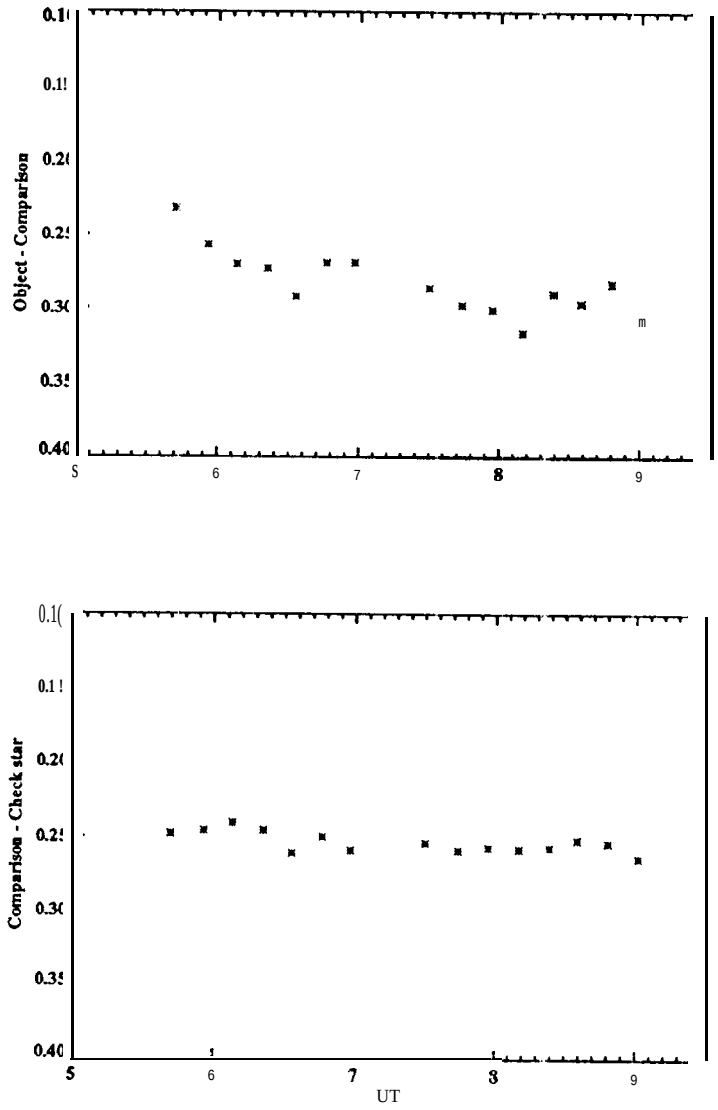


Figure 4.

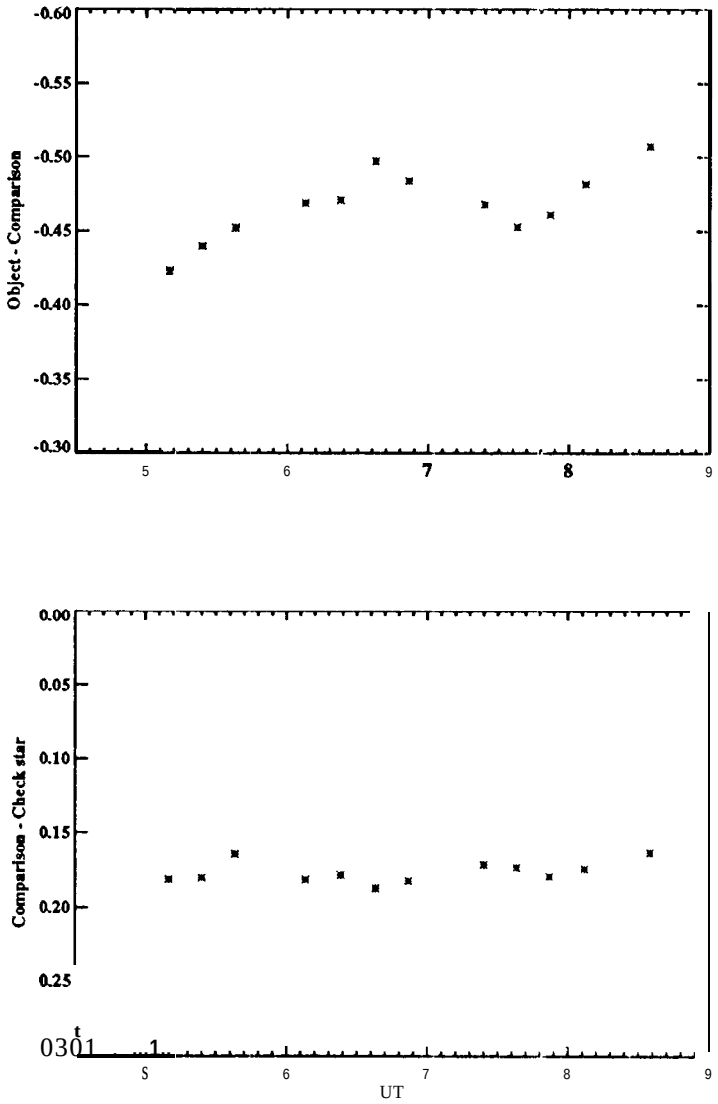

-0.60
-0.55
-0.50
-0.45
-0.40
-0.35
-0.30
Object - Comparison
5
6
7
8
9
0.00
0.05
0.10
0.15
0.20
0.25
Comparison - Check star
6
7
8
9
UT

Figure 5.

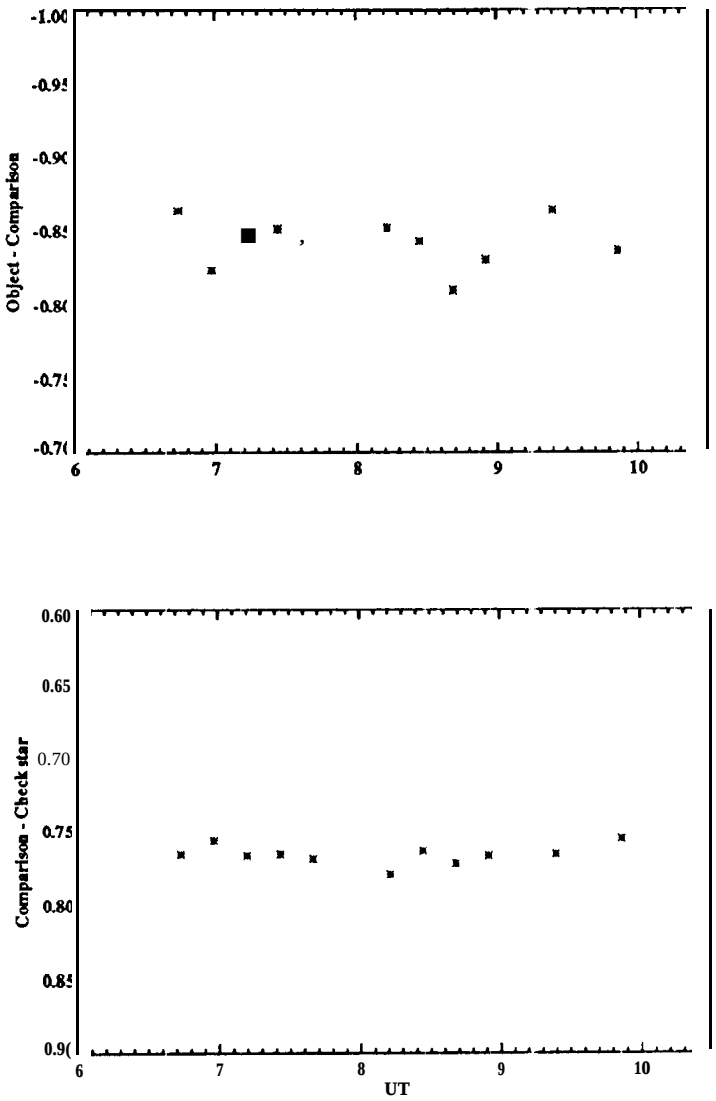
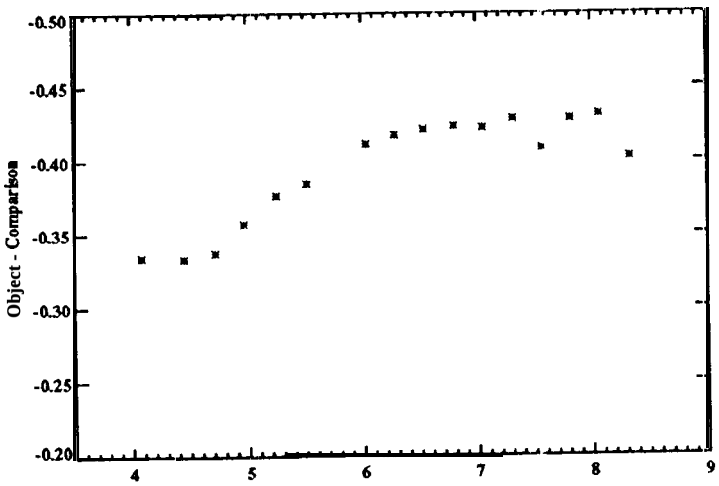
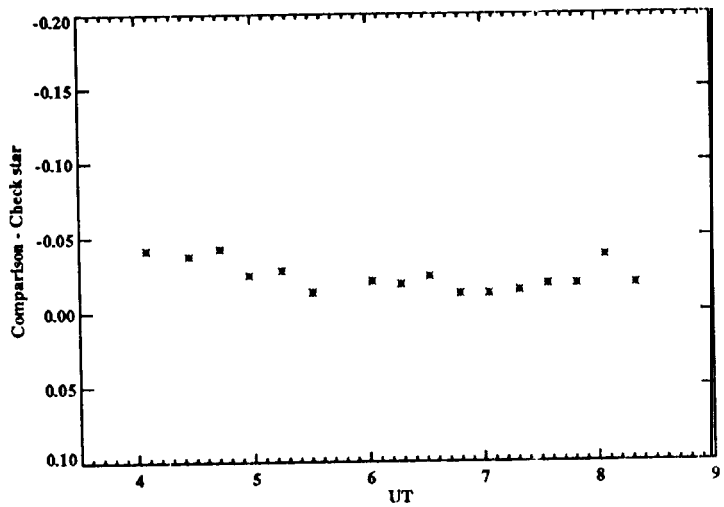

-1.00
-0.95
-0.90
-0.85
-0.80
-0.75
-0.70
Object - Comparison
6
7
8
9
10
0.60
0.65
0.70
0.75
0.80
0.85
0.90
Comparison - Check star
6
7
8
9
10
UT

Figure 6.


-0.50
-0.45
-0.40
-0.35
-0.30
-0.25
-0.20
Object - Comparison
4
5
6
7
8
9


-0.20
-0.15
-0.10
-0.05
0.00
0.05
0.10
Comparison - Check star
4
5
6
7
8
9
UT

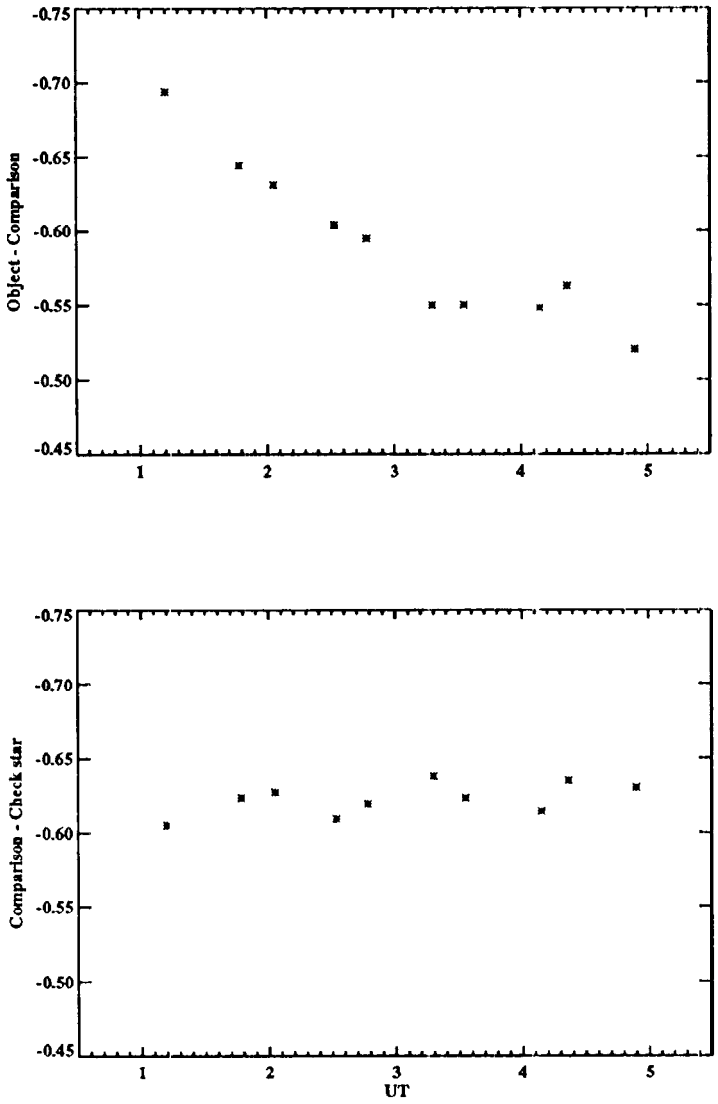

-0.75
-0.70
-0.65
-0.60
-0.55
-0.50
-0.45
Object - Comparison
1
2
3
4
5
-0.75
-0.70
-0.65
-0.60
-0.55
-0.50
-0.45
Comparison - Check star
1
2
3
4
5
UT

Figure 8

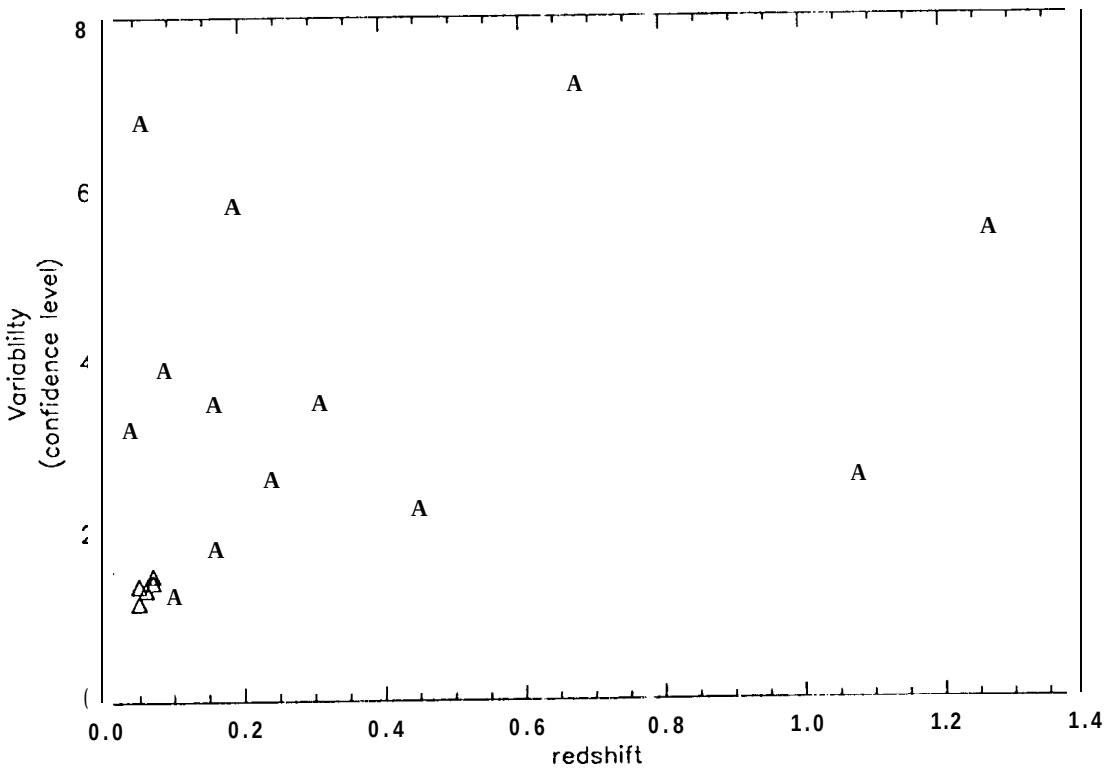
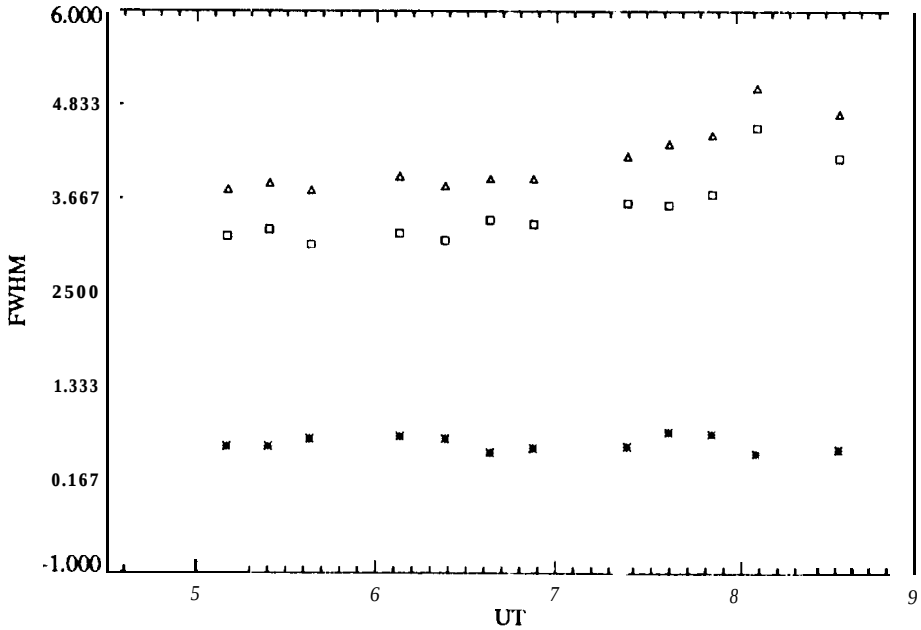

Variability
(confidence level)
redshift
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

Figure 9.


6.000
4.833
3.667
2500
1.333
0.167
-1.000
FWHM
5
6
7
8
9
UT

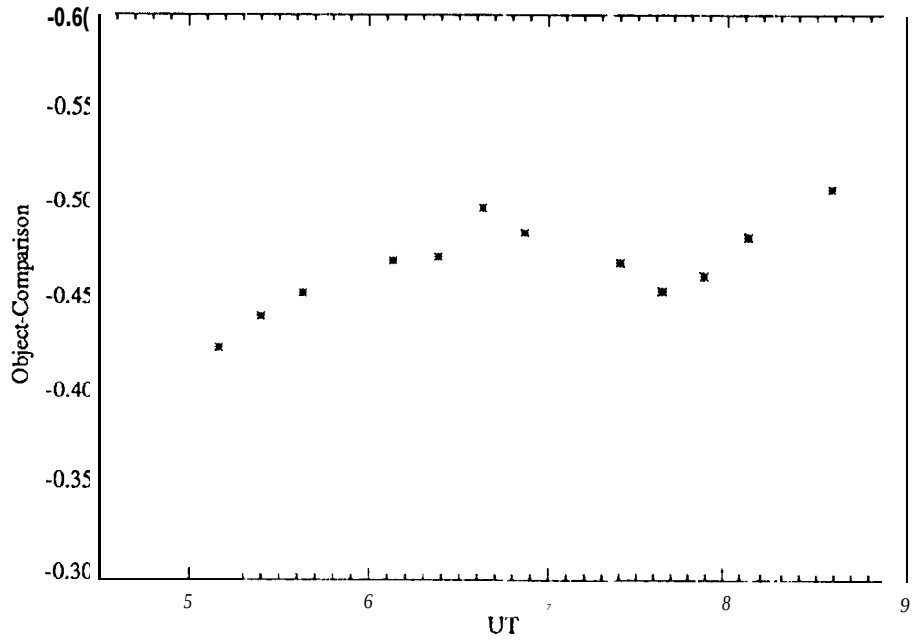

-0.6(
-0.55
-0.50
-0.45
-0.40
-0.35
-0.30
Object-Comparison
5
6
8
9
UT

Figure 10.