THE LOW-REDSHIFT QUASAR-QUASAR CORRELATION FUNCTION FROM AN EXTRAGALACTIC Hz EMISSION-LINE SURVEY TO z = 0.4

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ABSTRACT

We study the large-scale spatial distribution of low-redshift quasars and Seyfert 1 galaxies using a sample of 106 luminous emission-line objects (\(M_B \approx -23\)) selected by their Hz emission lines in a far-red objective prism survey (0.2 < z < 0.37). Of the 106 objects, 25 were previously known active galactic nuclei (AGNs), and follow-up spectroscopy for an additional 53 objects (including all object pairs with separation \(r < 20 \ h^{-1} \ Mpc\)) confirmed 48 AGNs and 5 narrow emission line galaxies (NELGs). The calculated amplitude of the spatial two-point correlation function for the emission-line sample is \(A = 0.427 (r < 20 \ h^{-1} \ Mpc) \times 20.1^{\pm1.8} = 142 \pm 53\). Eliminating the confirmed NELGs from the sample, we obtain the AGN clustering amplitude \(A = 98 \pm 54\). Using Monte Carlo simulations, we reject the hypothesis that the observed pair counts were drawn from a random distribution at the 99.97% and 98.6% confidence levels for the entire sample and the AGN subset, respectively. We measure a decrease in the quasar clustering amplitude by a factor of 3.7 \(\pm 2.0\) between \(z = 0.26\) and \(z \approx 1.5\), and present the coordinates, redshifts, and follow-up spectroscopy for the 15 previously unknown AGNs and four luminous NELGs that contribute to the clustering signal.

Subject headings: galaxies: clusters: general — large-scale structure of universe — surveys

1. INTRODUCTION

With the emergence of systematic quasar surveys of relatively high surface density in the early 1980s, the study of the large-scale spatial distribution of quasars became an active area of research (cf. Osmer 1981). Currently, there are numerous measurements of the mean clustering properties of quasars at 1 < z < 2 (e.g., Croom & Shanks 1996; La Franca, Andreani, & Cristiani 1998), with improved constraints expected soon from the Two-Degree Field (2dF) quasar survey (Smith et al. 1998) and the Sloan Digital Sky Survey (Gunn & Weinberg 1995). However, much less work is available at low redshift (z < 0.3), for which the dominant UV-excess technique for selecting quasars is less effective (e.g., Marshall 1985), and relatively small cosmological volumes are sampled. Measurement of the clustering of low-redshift active galactic nuclei (AGNs), however, provides the zero point and leverage to discriminate among models for the evolution of large-scale structure.

The primary studies of AGN clustering at low redshift are those of Boyle & Mo (1993) and Georgantopoulos & Shanks (1994). Boyle & Mo measured the correlation function, \(\xi(r)\), for an X-ray sample of 183 AGNs (z < 0.2) selected in the all-sky Einstein Extended Medium Sensitivity Survey. At small scales, they found a marginal detection of clustering, \(\xi(r < 10 \ h^{-1} \ Mpc) = 0.7 \pm 0.6\). Georgantopoulos & Shanks investigated the spatial distribution of a far-infrared sample of 192 Seyfert galaxies (56 Seyfert 1 and 136 Seyfert 2) at z < 0.1 selected in the all-sky IRAS survey. They detected Seyfert clustering at the \(\approx 3 \sigma\) confidence level on small scales, with \(\xi(r < 10 \ h^{-1} \ Mpc) = 0.52 \pm 0.13\). By comparison to measurements of quasar clustering at \(z \approx 1.5\), both groups favored a comoving evolution model, in which \(\xi(r)\) is constant with redshift, and marginally excluded a stable evolution model, \(\xi(r) \sim (1 + z)^{-1.2}\).

We undertake a similar study using a sample of 106 luminous emission-line objects (\(\approx 95\) Seyfert 1/quasar) identified in a large-area objective-prism survey (Sabbey 1999; C. N. Sabbey et al. 2000, in preparation). With the unique far-red bandpass (6000 < \(\lambda\) < 9200 Å) of the observations, we are able to select AGNs by their Hz emission lines to \(z \approx 0.4\) for the first time. In contrast to the samples described above, the sample employed here is optically selected and emphasizes luminous (\(M_B \approx -23\)) Seyfert 1 galaxies and quasars at (0.2 < z < 0.37), as opposed to lower luminosity Seyfert 2/Seyfert 1 galaxies in the nearby universe. In contrast to searching for blue point sources (UV-excess selection; Sandage 1965), the Hz survey is relatively independent of object color and morphology, and has a high selection efficiency (\(\approx 90\%\)) at bright (and faint) apparent magnitudes, with a large dynamic range (12 < \(m_B\) < 20).

2. THE LOW-REDSHIFT QUASAR CATALOG

The objective-prism data were taken during seven nights in 1999 January through May with the QUEST 16 CCD drift-scan camera on the 1 m Venezuelan Schmidt telescope.
S/N spectra and fits a Gaussian profile to all peaks more than 1 \( \sigma \) above the apparent continuum to measure the emission-line signal-to-noise ratio (S/N), equivalent width (EW), and center. The minimum S/N required for selection is a function of EW, ranging from S/N > 5.5 for EW > 50 Å to S/N > 2.5 for EW > 100 Å (see Sabbey 1999). The survey covers approximately 700 deg\(^2\) in the equatorial region and contains 719 emission-line candidates, of which 11% are previously known emission-line objects and fewer than 10% are expected to be false detections. The magnitude range is 9.7 \( \leq M_B \leq 20.2 \) (see Fig. 1). Follow-up spectroscopy for a total of 258 emission-line objects (including 88 below the survey detection thresholds) confirmed 97 Seyfert 1 galaxies and low-z quasars \((z \leq 0.37)\), 25 Seyfert 2 galaxies \((z \leq 0.49)\), 4 quasars \((1.5 \leq z \leq 2.8)\), and 132 narrow emission-line galaxies (NELGs).

Of the 258 follow-up spectra, 135 were obtained using the Wisconsin-Indiana-Yale NOAO Hydra multifiber spectrograph (Barden & Armandroff 1995). During 1999 April, May, and June a total of 25 Hydra fields were observed \((20 \) deg\(^2\)) in order to characterize the emission-line sample and establish target selection criteria. Fibers were placed on all objects with a peak above the apparent continuum with S/N \( \geq 1.5 \). Of the 71 emission-line candidates in the Hydra sample with S/N \( \geq 2.5 \) and EW \( \geq 50 \) Å, 67 were confirmed as actual emission-line objects \((three of the four spurious detections were the result of spectrum overlaps in the objective prism data)\). The remaining 123 follow-up spectra were obtained with a slit spectrograph on the du Pont 2.5 m at Las Campanas (during 1999 April and 2000 April) and with FLAIR at the Anglo-Australian Observatory \((2000 \) May\). The Las Campanas targets \((92 \) spectra) were preferentially taken from the AGN candidate list \((specified below)\), while the FLAIR targets \((31 \) spectra not including duplicate objects or unclassifiable spectra) were drawn from the full candidate list described above.

The follow-up spectroscopy demonstrated a straightforward selection criterion for identifying AGNs in the sample: of the 78 objects in the follow-up sample with a candidate emission line at \( \lambda > 7850 \) Å \((i.e., z > 0.2)\), 60 were Seyfert 1 galaxies or quasars, 6 were Seyfert 2 galaxies, and 12 were luminous NELGs. (We identify Seyfert 1/quasars by their broad Balmer lines, FWHM \( > 1000 \) km s\(^{-1}\), and Seyfert 2 galaxies by the line ratio \( \lambda 5007/\lambda H\beta > 10 \), or \( \lambda 5007/\lambda H\beta > 2.5 \) and 0.5 \( \leq \lambda 6584/H\alpha < 1.5 \) [Veilleux & Osterbrock 1987]. The remaining objects are labeled as NELGs.) In addition, all 116 detections at \( \lambda > 7500 \) Å in the follow-up sample were H\alpha, resulting in extremely reliable H\alpha identification. The relative absence of star-forming galaxies at \( z > 0.2 \) in our survey is expected, because of their faint apparent magnitudes and inverse correlation between luminosity and emission-line EW \((e.g., Fig. 4 of Salzer, MacAlpine, & Boroson 1989)\). In addition, the strong C\( \alpha \) emission of a high-redshift quasar is unlikely to be mistaken for H\alpha due to the expected appearance of Ly\alpha in our bandpass.

Restricting the emission-line candidates to the detections at \( \lambda > 7850 \) Å \((z > 0.2)\), with a conservative minimum line S/N \( \leq 2.7 \) \((EW > 100 \) Å\), yields a sample of 108 AGN candidates. Based on Veron-Cetty & Veron (2000) and the NASA Extragalactic Database \((NED)\), 25 of the 108 candidates are previously known objects \((21 \) quasars, three Seyfert 1, and one Seyfert 2). The follow-up spectroscopy described above provided spectra for an additional 55 objects in the AGN candidate list, identifying 45 Seyfert 1 galaxies or quasars, three Seyfert 2 galaxies, five NELGs, and two false detections. The two false detections were due to spectrum overlaps \((reducing the AGN candidate list to 106 objects)\), but these had been flagged as possible overlaps based on the proximity of objects of comparable brightness, and no further false detections due to overlaps are expected.

The primary selection effect in the objective prism data is the dependence of the magnitude limit on the emission-line equivalent width \((e.g., Gratton & Osmer 1987)\). Of the 10 AGNs listed in NED in our \( \approx 700 \) deg\(^2\) survey region with \( 0.2 < z < 0.37 \) and US Naval Observatory \((USNO)\) \( m_B < 17.0\), we independently rediscovered nine in our AGN candidate list. For \( m_B < 18.0\), the fraction rediscovered decreases to 15 out of 25. All but one of those not rediscovered in our AGN candidate list have \( z \geq 0.3\), corresponding to the decline in detector quantum efficiency at \( \lambda > 8500 \) Å. If we consider the redshift interval \( 0.0 < z < 0.37\), then the rediscovery rates in our survey increase to 15 out of 16 for USNO \( m_B < 17.0\), and 24 out of 36 for USNO \( m_B < 18.0\). Calculations of the expected emission-line S/N for reasonable H\alpha equivalent width distributions gave results comparable to the rediscovery rates \((Sabbey 1999)\).

A cone diagram of the resulting emission-line catalog of 106 objects \((78 \) confirmed\) is shown in Figure 2, and the sky coordinates are shown in Figure 3. The objective prism redshift uncertainty is \( \sigma_z \approx 0.0042 \) \((the standard deviation between the prism redshifts and the 53 follow-up redshifts measured using the \([O\; II]\) \( \lambda 5007 \) line) corresponding to a comoving scale of \( \approx 9 \) h\(^{-1}\) Mpc at the average redshift of the sample, \( \bar{z} = 0.26\). The survey volume is roughly a section of a torus with a radial extent of \( \approx 350 \) h\(^{-1}\) Mpc \((\Omega = 1)\), a right ascension extent of \( > 1000 \) h\(^{-1}\) Mpc, and a declination extent \((thickness)\) of \( \approx 70 \) h\(^{-1}\) Mpc. There are 19 pairs of objects with separation \( r < 20 \) h\(^{-1}\) Mpc, including one quintuplet and one triplet of objects. Follow-up spectroscopy confirming all objects in pairs except one is shown in Figure 4, and object coordinates and redshifts are listed in Table 1. A paper in preparation \((C. N. Sabbey et al.)\).
2001, in preparation) describes the survey technique further, providing all follow-up spectroscopy, coordinates, redshifts, and spectral line measurements.

3. THE CORRELATION FUNCTION

To quantify the large-scale spatial clustering of the quasar sample, we measure the two-point quasar-quasar

![Figure 2](image1)

![Figure 3](image2)

**TABLE 1**

| Name          | R.A. (J2000) | Decl. (J2000) | $m_B$ | $z$   | Nonoptical* | Spectral Class | Reference |
|---------------|--------------|---------------|-------|-------|-------------|----------------|-----------|
| QUEST 0847–0209 | 08 47 51.1   | –02 09 48.8   | 17.8  | 0.2534| FIRST/RASS  | QSO            |           |
| QUEST 0852–0211 | 08 52 53.4   | –02 11 17.9   | 16.9  | 0.2545| QSO         | QSO            |           |
| QUEST 1011–0212 | 10 11 21.2   | –02 12 39.5   | 18.4  | 0.2045| QSO         | QSO            |           |
| Q1010–0056     | 10 13 17.2   | –01 10 56.1   | 18.4  | 0.202 | RASS        | QSO            | 1         |
| QUEST 1027–0216 | 10 27 35.3   | –02 16 12.8   | 18.1  | 0.2180| FIRST       | AGN            |           |
| QUEST 1028–0043 | 10 28 36.9   | –00 43 14.4   | 17.6  | 0.2189| QSO         | QSO            |           |
| Q1026–0144     | 10 28 57.2   | –01 59 22.8   | 16.8  | 0.217 | QSO         | QSO            | 1         |
| QUEST 1115–0001| 11 15 23.5   | –00 01 12.9   | 19.7  | 0.2165| NELG        | NELG           |           |
| QUEST 1116–0039 | 11 16 19.9^b| 11 17 14.6    | 19.3  | 0.2101| NELG        | NELG           |           |
| QUEST 1120–0024 | 11 20 17.7   | +00 24 21.6   | 18.6  | 0.2077| FIRST       | NELG           |           |
| QUEST 1122–0030 | 11 22 50.0   | +00 30 31.2   | 17.9  | 0.2088| RASS        | QSO            |           |
| QUEST 1157–0017 | 11 57 55.5   | +00 17 04.0   | 18.6  | 0.2603| RASS        | QSO            |           |
| QUEST 1157–0022 | 11 57 58.7   | +00 22 20.6   | 17.0  | 0.2603| RASS        | QSO            |           |
| QUEST 1307–0259 | 13 07 45.5   | –02 59 01.7   | 17.6  | 0.3056| QSO         | QSO            |           |
| QUEST 1310–0352 | 13 10 41.1   | –03 52 53.1   | 17.2  | 0.3109| QSO         | QSO            |           |
| Q1317–0142      | 13 19 50.4   | –01 58 03.5   | 16.8  | 0.225 | FIRST       | QSO            | 1         |
| Q1321–0145      | 13 23 52.8   | –02 01 01.7   | 17.5  | 0.224 | FIRST/RASS  | QSO            | 1         |
| UM 602          | 13 41 13.9   | –00 53 14.8   | 17.4  | 0.237 | FIRST/RASS  | QSO            | 2         |
| Q1342–000       | 13 44 39.5   | –00 15 59.6   | 17.1  | 0.245 | RASS        | QSO            | 2         |
| QUEST 1502–0212 | 15 02 49.1   | –02 12 57.6   | 17.4  | 0.2139| FIRST       | NELG           |           |
| QUEST 1504–0248 | 15 04 07.5   | –02 48 16.5   | 16.6  | 0.2194| FIRST/RASS  | QSO            |           |
| QUEST 1513–0019 | 15 13 18.2   | +01 09 52.8   | 17.6  | 0.2174| QSO         | QSO            |           |
| QUEST 1513–0017 | 15 13 39.8   | +01 17 27.6   | 18.4  | 0.2123| QSO         | QSO            |           |
| QUEST 1522–0011 | 15 22 03.8   | +00 11 28.6   | 17.6  | 0.2389| QSO         | QSO            |           |
| QUEST 1523–0043 | 15 23 30.1   | +00 43 34.5   | 17.8  | 0.2391| RASS        | QSO            |           |

**Note.**—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

* See Voges et al. 1999, White et al. 1997.

* For this object, only a redshift estimate from objective prism data is available.

**References.**—(1) Hewett, Foltz, & Chaffee 1995; (2) Surdej et al. 1982.
correlation function (Peebles 1980),

\[ \xi(r) = \frac{N_{\text{obs}}(r)}{N_{\text{rand}}(r)} - 1, \]

where \( N_{\text{obs}}(r) \) is the observed number of quasar pairs with comoving separation \( r \), and \( N_{\text{rand}}(r) \) is the average number of quasar pairs at that separation scale in random comparison catalogs of the same size. The comparison catalogs are generated using both coordinate shuffling and random sampling of the smoothed redshift distribution (Osmer 1981; Iovino & Shaver 1988), yielding similar results (within 0.2\( \Delta \xi \)). We calculate the comoving separations between the quasars within the standard Friedmann model assuming \( H_0 = 100 \, h \, \text{km s}^{-1} \text{Mpc}^{-1} \) and \( \Omega = 1 \) (see Kundic 1997). Qualitatively similar results are obtained in a nearly empty universe, as expected due to the independence of relative object separations on \( \Omega_0 \) (Alcock & Paczyński 1979).
The resulting correlation function is shown in Figure 5 for the full sample and with the confirmed NELGs removed from the sample. On small scales, we detect a marginally significant positive signal (at the 2.7 and 1.8 $\sigma$ levels). At a scale of $r \sim 30$ h$^{-1}$ Mpc, $\xi(r)$ drops below the power law ($\approx 2$ $\sigma$ below), possibly corresponding to a known feature of galaxy autocorrelation functions (see Peebles 1993, p. 362, and references therein). At larger scales, $\xi(r)$ is consistent with zero within the uncertainties. To quantify the significance of the observed clustering, we use Monte Carlo simulations to test the null hypothesis that the 19 pairs (12 pairs with the NELGs removed) were drawn from an unclustered population. In $10^6$ random catalog simulations produced by shuffling the object redshifts, only 254 simulations for the full sample and 13,526 simulations for the AGN subset produced as many or more pairs at $r < 20$ h$^{-1}$ Mpc. Thus, we reject the hypothesis that the samples do not exhibit clustering on the $r < 20$ h$^{-1}$ Mpc scale at the 99.97% and 98.6% confidence levels.

To compare the measured AGN clustering strength to that of galaxy systems in the local universe and high-redshift quasars (see the following section), we calculate the AGN clustering amplitude, $A_i$. The volume-averaged two-point correlation function on scales $r < R_0$ is

$$\xi(R_0) = \frac{1}{V} \int_{V} \xi(r) dV = \frac{3}{R_0^3} \int_{0}^{R_0} \xi(r) r^2 dr .$$

Substituting in $\xi(r) = A r^{-1.8}$, we obtain $A = 0.4\xi(R_0)R_0^{-1.8}$. When edge effects are negligible, $\xi(R_0)$ can be measured by

$$\xi(R_0) = \frac{N_{\text{obs}}(r < R_0)}{N_{\text{rand}}(r < R_0)} - 1 ,$$

where $N_{\text{obs}}(r < R_0)$ and $N_{\text{rand}}(r < R_0)$ are the number of observed and randomly simulated pairs, respectively, with comoving separations $r < R_0$. We set $R_0 = 20$ h$^{-1}$ Mpc, corresponding to our 2 $\sigma$ redshift errors, and obtain $A = 98 \pm 54$ ($N_{\text{obs}} = 12, N_{\text{rand}} = 5.67$). Using only objective prism redshifts (i.e., not using any of the available follow-up redshifts), we obtain $A = 113 \pm 56$ ($N_{\text{obs}} = 13, N_{\text{rand}} = 5.70$). Removing the one object in Table 1 that has not been confirmed with follow-up spectroscopy (and could be a NELG), we obtain $A = 85 \pm 52$ ($N_{\text{obs}} = 11, N_{\text{rand}} = 5.60$).

4. EVOLUTION

We consider three commonly used, although quite simple, “models” for parameterizing clustering evolution with redshift: (1) comoving evolution, $\xi(r) = \text{const}$; (2) stable evolution, $\xi(r) \sim (1 + z)^{-1.2}$; and (3) collapsing evolution, $\xi(r) \sim (1 + z)^{-3}$. Thus, we assume evolution of the form

$$\xi_i(r, z) = A_i(z) r^{-1.8}$$

for a galaxy system $i$. The dependence of the correlation amplitude on redshift is given by $A_i(z) = A_i^0 (1 + z)^{-(1 + \epsilon_i)}$, where $A_i^0$ is the clustering amplitude for galaxy system $i$ at $z = 0$, and $\epsilon_i = -1.2, 0, 1.8$ in the comoving, stable, and collapsing models, respectively. We use measured values of the correlation amplitudes for galaxies, groups, and rich clusters: $A_{\text{galaxy}}^0 = 21$ (Bahcall & Choksi 1991), and $A_{\text{group}}^0 = 100$ (Bahcall & Soneira 1983). Although significantly weaker correlation amplitudes for rich clusters have been presented in the literature (e.g., Dalton et al. 1992), it has been suggested that the discrepancy is due to systematic differences in cluster richness (Bahcall & West 1992). We therefore use the larger Bahcall & Soneira (1983) measurement to represent the full range of clustering strengths observed locally.

The measured AGN amplitude is comparable to the amplitude expected for clustering of groups of galaxies, but is less consistent with the clustering properties of normal galaxies and rich clusters. We quantify this in terms of the observed number of quasar-quasar pairs with $r < 20$ h$^{-1}$ Mpc, and the expected number of pairs for each clustering strength $A_i$ in combination with each evolution model. We first evaluate the $\xi(z, r)$ at the average redshift of the observed quasar sample ($z = 0.26$) for the three evolution models, obtaining $\xi_r(0.26)$. Then we integrate $\xi(r, 0.26)$ from $r = 0$ to $20$ h$^{-1}$ Mpc, obtaining $\xi(20, 0.26)$. Finally, we multiply $\xi(20, 0.26)$ by $N_{\text{rand}}(r < 20)$ to obtain the predicted number of quasar-quasar pairs in our sample for each galaxy system clustering strength. That is, $N_{\text{predicted}}(r < 20) = \int \left[ 1 + \xi(20, 0.26) N_{\text{rand}}(r < 20) \right] .$

The number of observed quasar-quasar pairs is consistent with that predicted for the group clustering strength in each evolution model, but marginally inconsistent (at the 2 $\sigma$ level) with galaxy clustering and our assumed cluster-cluster amplitude. If confirmed with a larger sample, this
would suggest that \( z \sim 0.3 \) quasars tend to be located in small groups of galaxies (groups of 11 \( \pm 8 \) galaxies based on the current measurement and eq. [2a] of Bahcall & Choksi 1991). Indeed, several imaging studies have indicated that \( z \lesssim 0.4 \) quasars tend to reside in small to moderate groups of galaxies (see Hartwick & Schade 1990 and references therein). Other studies, however, have suggested that low-redshift quasars inhabit environments similar to normal galaxies (Smith, Boyle, & Maddox 1995).

In Figure 6 we compare the measured quasar clustering amplitude to measurements at other redshifts. Currently, it is not even clear whether the quasar clustering amplitude decreases with redshift (negative evolution), increases with redshift, or remains constant. Although a number of previous studies reported negative evolution (e.g., Iovino & Shaver 1988; Kruszewski 1988; Iovino, Shaver, & Cristiani 1991), there have also been reports of constant clustering (e.g., Andreani & Cristiani 1992) and positive evolution (e.g., La Franca et al. 1998). Given the large uncertainties, the current measurement at \( z = 0.26 \) is consistent with the assumed quasar clustering amplitude of \( A = 27 \) at \( z \sim 1.4 \) (La Franca et al. 1998).

Georgantonopoulos & Shanks (1994) measured somewhat weaker clustering in their low-\( z \) Seyfert 1 galaxy sample \( (A = -9 \pm 24) \), although this possible discrepancy is only at the 2.0 \( \sigma \) level. Such a discrepancy could possibly result from the significantly different samples employed (their nonoptical sample contains lower luminosity, relatively nearby AGNs). For example, IRAS galaxies are known to be relatively biased against high-density regions, and related effects could be manifest in the IRAS Seyfert sample used by Georgantonopoulos & Shanks. In addition, possible biases in the environments of low-redshift AGNs as a function of AGN luminosity have been suggested (Fisher et al. 1996), and different host galaxies as a function of AGN luminosity or redshift would be relevant because early-type galaxies are known to cluster more strongly by a factor of several than late-types (Davis & Geller 1976; Loveday et al. 1995).

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### TABLE 2

| \( N_{\text{rand}} \) | \( N_{\text{obs}} \) | \( N_{\text{galaxy predict}} \) | \( \sigma \) | \( N_{\text{group predict}} \) | \( \sigma \) | \( N_{\text{cluster predict}} \) | \( \sigma \) | \( N_{\text{QSO predict}} \) | \( \sigma \) | \( \text{Evolution Model} \) |
|-----------------|-----------------|-----------------|------|-----------------|------|-----------------|------|-----------------|------|-----------------|
| 5.56 \ldots \ldots | 12               | 7.02            | -1.9 | 12.12           | 0.0  | 28.90           | +3.1 | 7.42            | -1.7 | Comoving         |
| 5.56 \ldots \ldots | 12               | 6.70            | -2.1 | 10.56           | -0.4 | 23.27           | +2.3 | 9.44            | -0.8 | Stable           |
| 5.56 \ldots \ldots | 12               | 6.35            | -2.2 | 8.90            | -1.0 | 17.28           | +1.3 | 17.71           | +1.4 | Collapsing       |

### FIG. 6

Measured quasar-quasar correlation amplitude as a function of redshift, based on a representative set of publications. The full width of the horizontal ‘‘error bars’’ indicate half of the survey redshift extent. The \( z = 0.05 \) measurement is from the combined Georgantonopoulos & Shanks (1994) and Boyle & Mo (1993) samples (see La Franca et al. 1998). For the Seyfert 1 sample of Georgantonopoulos & Shanks (1994), the amplitude is \( A = -9 \pm 24 \) (not shown). The Osmer & Hewett (1991) measurement at \( z = 2.0 \) is \( A = -18 \pm 27 \). The \( z = 0.26 \) measurement, combined with the previous low-redshift AGN clustering measurements, is consistent with clustering measurements at \( z \approx 1.5 \) (suggesting weak or no evolution of quasar clustering out to intermediate redshift).
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