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APM 08279+5255: AN ULTRALUMINOUS BROAD ABSORPTION LINE QUASAR AT A REDSHIFT $z = 3.87$

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ABSTRACT

We report on the discovery of a highly luminous, broad absorption line quasar at a redshift of $z = 3.87$, which is positionally coincident, within 1″, with the *IRAS* Faint Source Catalog source F08279+5255. A chance alignment of the quasar and the *IRAS* source is extremely unlikely, and we argue that the optical and far-infrared flux are different manifestations of the same object. With an *R*-band magnitude of 15.2 and an *IRAS* 60 μm flux of 0.51 Jy, APM 08279+5255 is (apparently) easily the most intrinsically luminous object known, with $L_{\rm Bol} \sim 5 \times 10^{15}\ L_{\odot}$. Optical CCD photometry of the system, taken in good seeing, shows evidence that the system is slightly elongated. Although these data are consistent with the superposition of the quasar on a vastly luminous galaxy, we argue that a more likely scenario is that the optical image implies the presence of two unresolved point sources. Such a configuration suggests that gravitational lensing may play a significant role in amplifying the intrinsic properties of the system. Point-spread function fitting of two discrete sources gives a separation of $\sim$0.″4 and an intensity ratio $\sim$1.1. The optical spectrum of the quasar clearly reveals the presence of three potential lensing galaxies, Mg II absorption systems at $z = 1.18$ and $z = 1.81$, and a damped Lyα absorption system at $z = 3.07$. Additional, as yet unseen, lensing galaxies may also be present. We estimate the total amplification of the optical component to be $\approx$40 but, owing to the larger scale of the emitting region, would expect the infrared amplification to be significantly less. Even making the conservative assumption that all wavelengths are amplified by a factor 40, APM 08279+5255 still possesses a phenomenal luminosity of $\gtrsim 10^{14}\ L_{\odot}$, indicating that it belongs to a small but significant population of high-redshift, hyperluminous objects with copious infrared emission.

Subject headings: gravitational lensing — infrared: galaxies — quasars: absorption lines — quasars: individual (APM 08279+5255)

1. INTRODUCTION

Apart from the detection of two strongly gravitationally lensed objects, the Seyfert II–like object IRAS F10214+4724 with $z = 2.286$ and the broad absorption line (BAL) quasar H1413+117, "the cloverleaf," at $z = 2.558$, and the recently identified ultraluminous galaxy SMM 02399−0136 at $z = 2.8$, which is mildly lensed by a galaxy cluster, there have been no detections of far-infrared (FIR) emission over the wavelength range 10–100 μm in objects with a redshift $z > 2$. F10214+4724 was discovered as part of a systematic redshift survey covering an area of 700 square degrees of 1400 *IRAS* Faint Source Catalog (FSC) galaxies brighter than 0.2 Jy at 60 μm by Rowan-Robinson et al. (1991). SMM 02399−0136 was similarly identified in a submillimeter survey of the fields of galaxy clusters exhibiting strong gravitational lensing features (Ivison et al. 1998), appearing as the brightest source at 450 μm in the field of Abell 370. H1413+117, which had previously been identified as a gravitationally lensed BAL quasar (Magain et al. 1988), was found to be an *IRAS* FSC entry by Barvainis et al. (1995), after it had been detected in the submillimeter continuum and had been shown to have CO line emission (Barvainis, Antonucci, & Coleman 1992; Barvainis et al. 1994) suggestive of thermal radiation from dust. Further recent detection of CO emission by Omont et al. (1996) and Guilloteau et al. (1997) in two even higher redshift quasars, $z > 4$, testify to the likely ubiquitous presence of dust at early stages of galaxy evolution. Neither of these $z > 4$ quasars has a counterpart in the *IRAS* FSC. Indeed it is clear that without the amplification due to gravitational lensing ($\approx \times 30$) both F10214+4724 and H1413+117 would also be absent from the *IRAS* FSC.

Because of the large number of sources in the combined *IRAS* Point Source Catalog (PSC) and FSC databases, spectroscopic follow-up campaigns have of necessity been rather limited in scope. Complementary to the FSC redshift survey of Rowan-Robinson et al. (1991) and the more recent extension of this by Oliver et al. (1996), were the "all sky" follow-up surveys of *IRAS* sources based on the PSC. The vast majority of these identifications belonged to low-redshift, $z < 0.1$, galaxies. Notable among these were the surveys of Rowan-Robinson et al. (1990) who carried out a sparsely sampled redshift survey of 2163 *IRAS* PSC 60 μm sources with $F_{60} \geq 0.6$ Jy at $|b| > 10°$ and the *IRAS* galaxy survey of Strauss et al. (1990) also flux limited at 60 μm with $F_{60} \geq 1.2$ Jy at $|b| > 5°$. Apart from the Rowan-Robinson et al. (1990) and Oliver et al. (1996) FSC surveys there appear to have been no systematic spectroscopic follow-up campaigns attempted for the FSC catalog, which helps to explain why the significance of the FSC source F08279+5255, introduced below, had not been evident before.

While conducting a survey for distant cool carbon stars in the Galactic halo we discovered an extremely bright 15th magnitude BAL quasar at a redshift $z = 3.87$. The quasar is

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positionally coincident, within an arcsecond, with the *IRAS* FSC object F08279+5255. Further ground-based imaging and spectroscopy of other potential optical counterparts within 1′ of the *IRAS* source revealed no other likely optical counterpart. The excellent positional coincidence, the extreme optical rarity of such bright high-redshift quasars, and the *IRAS* spectral signature provide a compelling case that the *IRAS* source is related to the extreme properties of the BAL quasar.

In the remainder of this paper we briefly discuss the survey leading to the discovery of the BAL quasar, the current suite of observations we have made to determine its nature, various hypotheses regarding the object, and the likelihood of further surprises in the *IRAS* object catalog databases.

2. OBSERVATIONS

2.1. *Spectroscopic Observations*

The spectroscopic observations were taken as part of the Automatic Plate Measuring Facility (APM) survey to identify distant cool carbon stars in the Galactic halo by use of the 2.5 m Isaac Newton Telescope (INT) at the Roque de los Muchachos Observatory, La Palma, between 1998 February 27 and March 6. Given the expected colors and magnitudes of cool carbon stars, candidate objects with $11 < R < 17$ and $B_J - R \gtrsim 2.5$ had been selected for observation from APM sky catalogs at Galactic latitudes $|b| > 30°$ (see Totten & Irwin 1998 for more details). Candidates were observed over the wavelength range 3850–7250 Å by means of the intermediate dispersion spectrograph (IDS) with the R300V grating and a 1k × 1k TEK CCD, giving a resolution of 3.3 Å pixel^{-1}. Pseudo–real time extraction was employed to ascertain the nature of the candidate objects.

One of the observed sources, at $\alpha = 8^h27^m57^s.89$, $\delta = 52°55'26''.4$ (B1950) with an R-band magnitude of $R = 15.2$, was clearly a highly luminous quasar at a redshift close to $z = 4$. The spectrum displayed in Figure 1 is a combination of two spectra with overlapping wavelength coverage and shows the typical mix of broad emission lines and strong blueshifted absorption lines found in high-redshift BAL quasars (Turnshek 1988; Weymann 1995; Storrie-Lombardi et al. 1996). Interpretation of the spectrum is complicated by strong self-absorption of the Lyα line and the complex pattern of absorbers blueward of C IV λ1549 and close to the Lyα + N V lines. However, the presence of a relatively clean S + O feature provides a straightforward estimate of the systemic redshift, which we confirmed by obtaining a spectrum up to 10,000 Å, where C III] λ1909 was plainly visible at ~9300 Å.

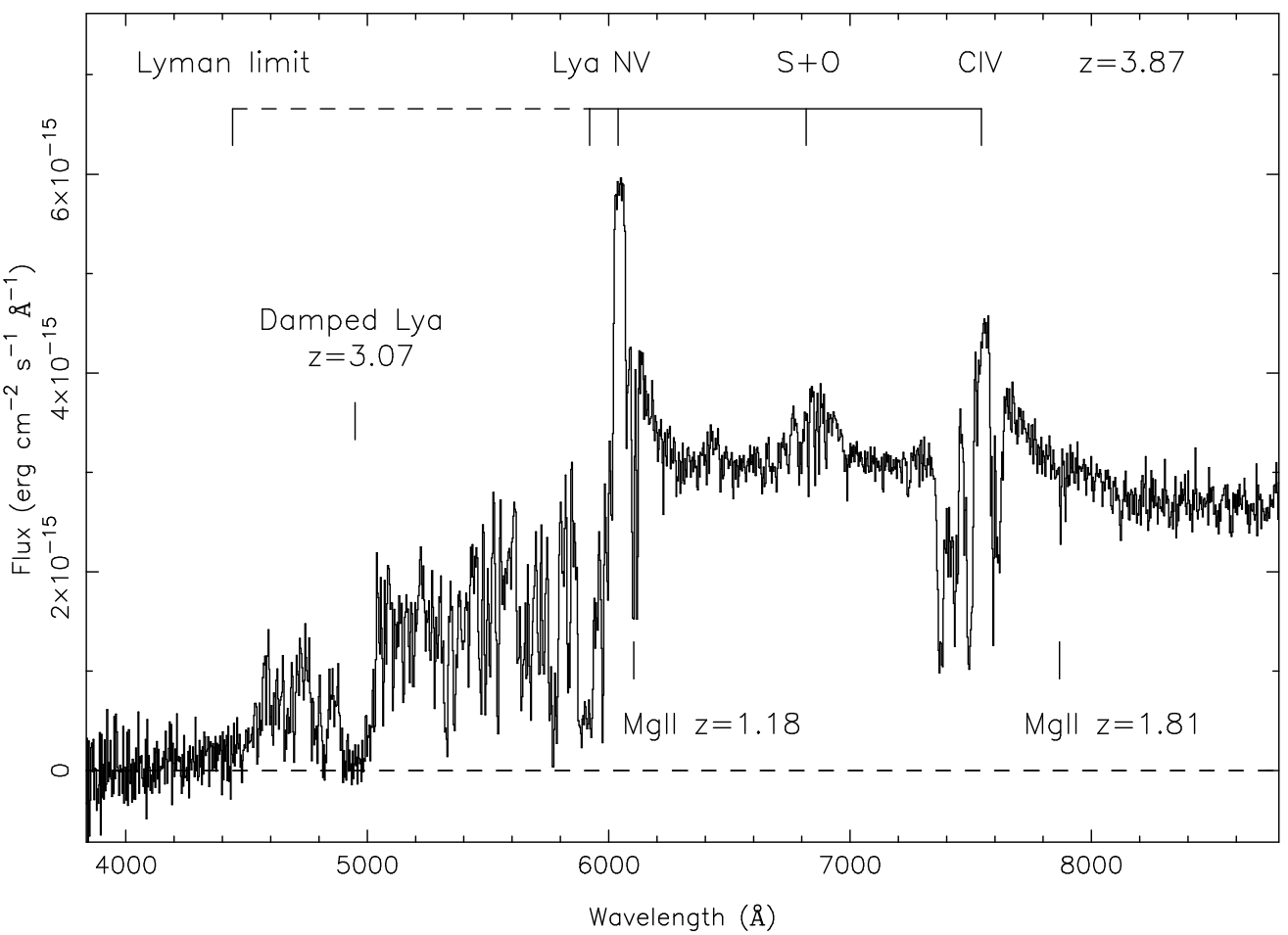

FIG. 1.—Optical spectra of APM 08279+5255 taken with the 2.5 m Isaac Newton Telescope. Features typical of high-redshift quasars, namely, strong N V and C IV emission lines, are clearly visible. The emission lines are seen to possess broad absorption troughs consistent with high-velocity bulk outflows associated with the quasar. It is interesting to note that Lyα emission is extremely weak, probably due to self-absorption by neutral gas along the line of sight but within the quasar. Also apparent is absorption beyond the Lyman limit and in the Lyα forest. Coupled with this, a damped Lyα system is visible at $z = 3.07$, as well as Mg II doublets of equivalent widths 10.3 Å and 2.8 Å, consistent with galactic systems at $z = 1.18$ and $z = 1.81$, respectively.

Blueward of Lyα there is a strong continuum drop caused by intervening Lyα forest absorbers with a complex series of absorption features dominating the spectrum. A candidate-damped Lyα system at $z = 3.07$ is clearly present, which we confirmed with further higher resolution spectra. The "gray" Lyman limit at ≈4400 Å is at the redshift of the quasar and is associated with the strong self-absorption of Lyα seen at 5920 Å. The broad emission features at 6040 Å and 7550 Å can be identified with N v λ1240 and C iv λ1549, as expected from a quasar at $z = 3.87$. Emission in Lyα is apparent, but is much weaker than emission from other species; this is a point we will return to in § 6.

Two Mg ii absorbers are clearly present in the quasar spectrum. The stronger of the two is slightly redward of N v, with an equivalent width of 10.3 Å and at a redshift of $z = 1.18$. Farther to the red beyond C iv is another Mg ii doublet with equivalent width 2.8 Å highlighting the presence of another intervening galaxy at $z = 1.81$. We have taken higher resolution spectra over the wavelength range 4000–10,000 Å to search for more examples of intervening absorption systems, but apart from the complex series of absorption lines around the main quasar emission features we have found no evidence for further intervening absorbers. Although we attempted to correct for atmospheric absorption using a featureless flux standard as a template, residual atmospheric *A*-band absorption features are still apparent redward of C iv.

2.2. *Photometry*

The APM measurements of the Palomar Sky Survey plates E/O-679 taken in 1953 February were calibrated by use of the guide star photoelectric sequence for this field (Lasker et al. 1988) and indicate that the source had an *R*-band magnitude in 1953 of $R = 15.6 \pm 0.1$ and a color equivalent to $B_J - R = 2.8 \pm 0.1$.

Following the spectroscopic detection, further photometric data were kindly taken on our behalf by Schlegel using the CCD camera on the 0.9 m Jacobus Kapteyn Telescope (JKT), also at the La Palma observatory. Two frames, exposed for 150 s and 450 s in a broadband *R* filter, were obtained. Covering 5′.6 on a side, these frames probe the field around the BAL quasar with a resolution of 0″.33 pixel^{-1}. Although the conditions were not photometric, the seeing was measured to be 0″.9. A reproduction of the central 4′ × 4′ of the long exposure frame is given in Figure 2, with the *IRAS* 3 σ error ellipse superposed. Contours of the quasar image, derived from this frame, are displayed in Figure 3*a*.

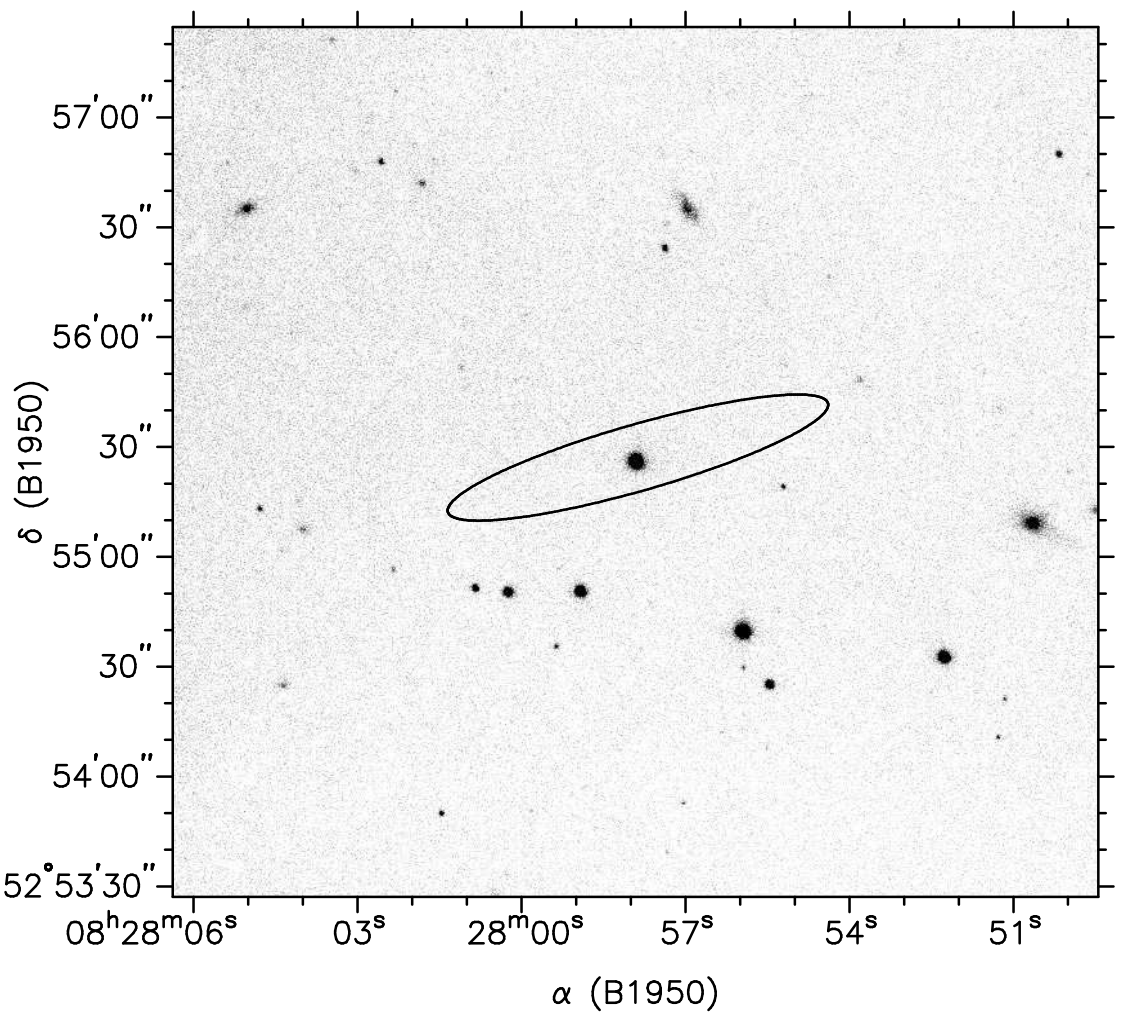

FIG. 2.—The 3 σ uncertainty ellipse in the position of the *IRAS* source F08279+5255 is shown superposed on a 4′ × 4′ subsection of the *R*-band image obtained from the JKT photometry. Above the detection limit of $R = 21.4$, the only object present within this ellipse is the $R = 15.2$ BAL quasar discovered in the APM survey.

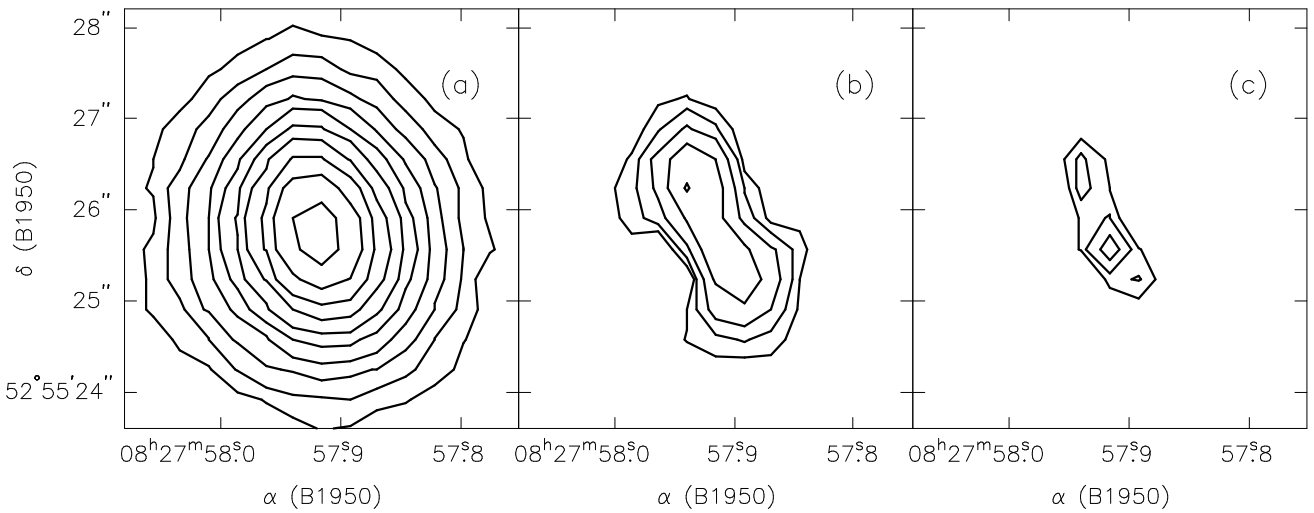

FIG. 3.—(*a*) Contours of the BAL quasar. (*b*) Residuals resulting from fitting a single PSF to the image of (*a*); the fitting process was constrained to give positive residuals. The residual is rather bright, being only 2.7 mag fainter than the original image. (*c*) Residuals from the best fit with two PSFs (image separation $d = 0\farcs33$, brightness ratio $I_1/I_2 = 1.06$). The contour levels in all these diagrams start at $1e^-$ pixel^{-1} s^{-1} and increase in equally spaced logarithmic intervals to $100e^-$ pixel^{-1} s^{-1}.

The raw CCD frames were preprocessed by standard techniques. The DAOPHOT package (Stetson 1987) was employed to find and perform aperture photometry on objects in the frame. Relative to the field stars, the CCD image of the quasar was found to be 0.38 ± 0.05 mag brighter than the Palomar plate image, exposed in 1953. Variability of this amplitude is commonly observed in quasars (Hook et al. 1994). Thus, a better estimate of the present brightness of the object is $R = 15.2 \pm 0.1$.

A point-spread function (PSF) for the frame was also constructed with the DAOPHOT package. Modeled as a sum of a Gaussian and a Lorentz function plus a look-up table, this PSF was also constrained to vary linearly over the frame. The resulting PSF model gives an excellent fit to ~ 50 point sources over the frame, but the fit to the BAL quasar image is poor, as the DAOPHOT goodness-of-fit parameter is $\chi = 1.8$. Imposing the constraint of non-negative residuals to the image fitting, results in the elongated image of image residuals displayed in Figure 3*b*. The brightness of this residual is ≈ 2.7 mag fainter than that of the original image.

Since the image of the quasar is elongated, it is natural to also attempt to fit it as the sum of two slightly offset point sources. A good fit results if the separation between the images is in the range $0\farcs30 \lesssim d \lesssim 0\farcs45$, and if the ratio of the relative brightnesses is in the range $1.05 \lesssim I_1/I_2 \lesssim 1.15$. The residuals from the best-fit solution with $\chi = 1.2$ are displayed in Figure 3*c*.

Although no other obvious optical counterparts are close to the *IRAS* 3 σ error ellipse, we obtained spectra of the two galaxies visible to the north and to the west of the quasar, respectively. Neither had unusual features that could be attributed to the *IRAS* emission.

3. SPECTRAL ENERGY DISTRIBUTION

A search through various on-line sky catalogs showed that the BAL quasar had been detected in both the *IRAS* FSC and FIRST surveys; these are detailed in Table 1. The *IRAS* source F08279+5255 is at $\alpha = 8^h27^m57\fs87$, $\delta = 52°55'27\farcs1$, within an arcsecond of the BAL, as illustrated in Figure 2. There is also a positionally coincident source in the FIRST survey at $\alpha = 8^h27^m57\fs96$, $\delta = 52°55'27\farcs2$ with a flux of 0.92 mJy at 1.4 GHz. However, the *ROSAT* Bright Source Catalog (with a limiting count rate of 0.05 counts s^{-1} in the 0.1–2.4 keV energy band) contains no sources within 30′ of the quasar. Neither is any emission detected in the NRAO VLA Sky Survey (NVSS) catalog (at 1.4 GHz with a detection limit of 2.5 mJy) or in the Westerbork Northern Sky Survey (WENSS) catalog (at 4.85 GHz with a detection limit of 18 mJy). The lack of significant radio flux in this system is consistent with its BAL nature, as these systems are typically radio quiet. Indeed APM 08279+5255 lies along the extension of the radio-quiet locus found in the well-studied correlation between radio and FIR luminosities (e.g., Fig. 1 in Sopp & Alexander 1991).

In Figure 4 we present the spectral energy distribution (SED) of the BAL quasar, assuming that the *R*-band flux and the *IRAS* and FIRST emission arise from the same object. The SEDs of three other hyperluminous systems—IRAS F10214+4724 at $z = 2.286$ (Rowan-Robinson et al. 1991), SMM 02399−0136 at $z = 2.8$ (Ivison et al. 1998), and H1413+117 at $z = 2.558$ (Barvainis et al. 1995)—are also shown. Gravitational lensing is thought to influence the properties of all of these systems, enhancing the observed flux by factors of ≈ 30, 2.5, and 30, respectively. No correction for such effects is applied to Figure 4, which presents only the observed flux values. It is immediately apparent that, even though it is at a higher redshift, APM 08279+5255 appears brighter than any of these sources in

TABLE 1

IRAS AND FIRST FLUX MEASURES OF APM 08279+5255

Catalog	Flux (Jy)	Error (%)
IRAS:		
12 μm	<0.1010	...
25 μm	0.2261	16
60 μm	0.5111	10
100 μm.....	0.9511	24
FIRST:		
21 cm	0.92×10^{-3}	10

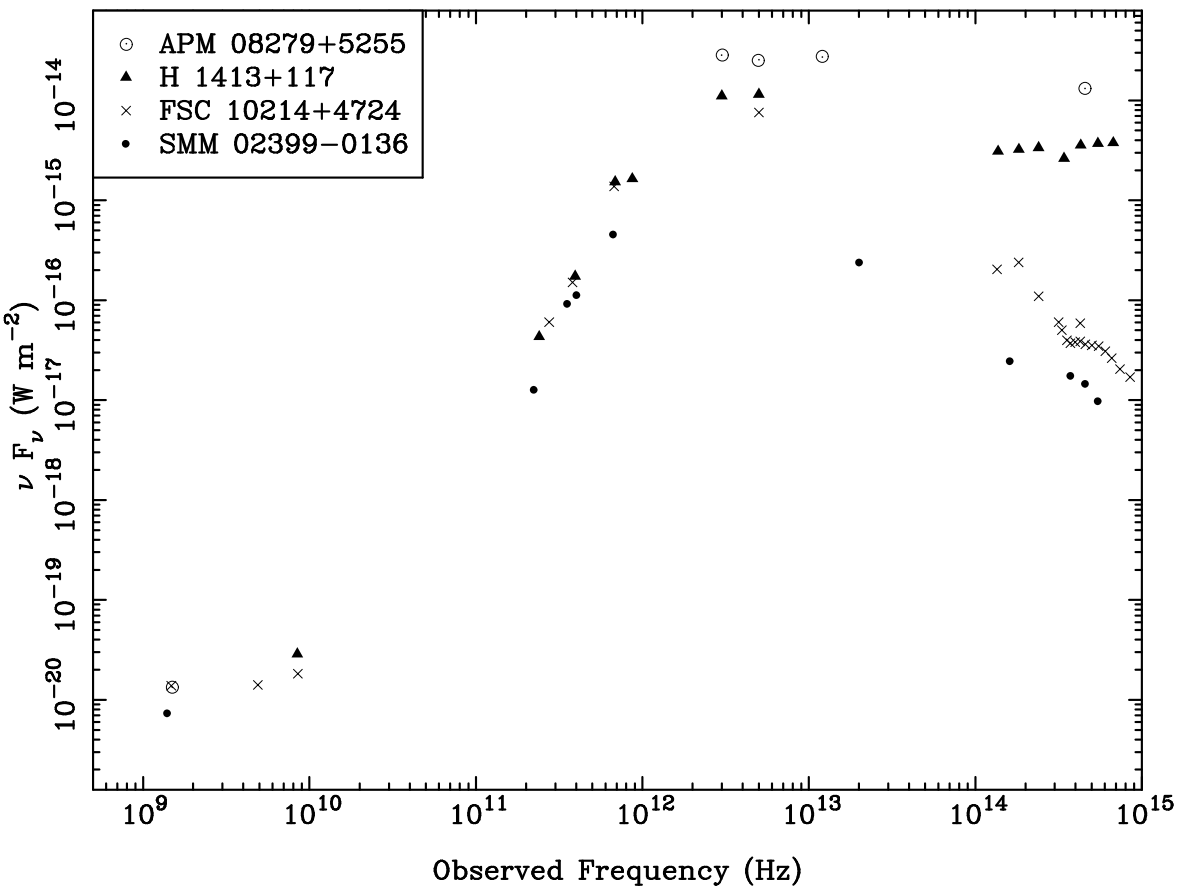

FIG. 4.—Spectral energy distribution of APM 08279+5255 ($z = 3.87$) compared to the ultraluminous galaxies IRAS F10214+4724 ($z = 2.286$), SMM 02399−0136 ($z = 2.8$), and H1413+117 ($z = 2.558$). Each data set represents the *observed* flux in the form of νF_ν; only detections have been included, and upper limits are not plotted. Note that H1413+117 possesses complex radio structure, and the value in this plot represents the sum of the components labeled A, B, and C′ by Kayser et al. (1990).

both the optical and FIR and has a very similar SED to H1413+117. It is also apparent that, whereas the flux in IRAS F10214+4724 and SMM 02399−0136 is dominated by an emission peak in the FIR, presumably due to reprocessing by a dusty component, both APM 08279+5255 and H1413+117, although having similar FIR fluxes, also emit copiously in the optical wavebands. In the *B* band, the SED of APM 08279+5255 effectively turns over due to absorption in the Lyα forest, although beyond the Lyman limit there is little or no observed flux.

4. INTERPRETATION

How does APM 08279+5255 compare to other quasars at $z \sim 4$? Considering a standard Friedmann-Walker universe, the distance modulus to $z = 3.87$ is 46.02(47.12) − 5 log h for $\Omega_0 = 1(0.2)$. Typically, studies of the quasar luminosity function at high redshift assume a $\Omega_0 = 1$ cosmology with $h = 0.5$; we adopt such a cosmology to ease comparison with other studies leading to a distance modulus of 47.52. In a weak-lined BAL quasar such as this, an approximation for the *K*-correction in the *R* band can be obtained by assuming a power-law continuum with slope $\alpha \approx -0.5$ leading to $K_R = -0.86$ at a redshift of 3.87. Using these values implies that APM 08279+5255 has an absolute magnitude of $M_R \approx -33.2$. Taken at face value, therefore, APM 08279+5255 is by far the most intrinsically luminous object known, and, likewise, integrating over the SED presented in Figure 4 implies that the bolometric luminosity of this system exceeds $\sim 5 \times 10^{15} L_\odot$.

There are several possible explanations for our current observations including the following:

Chance alignment.—The redshift $z = 3.87$ BAL quasar and the source of the *IRAS* emission are unconnected and lie along the same line of sight. Regardless of the spectral properties of the object, the likelihood ratio for this being the correct identification given the distance from the *IRAS* position and the density of optical images to this magnitude is LR ≈ 55 (e.g., Prestage & Peacock 1983). All other putative optical counterparts to the limit of the JKT *R*-band data at $R = 21.4$ have likelihood ratios LR $\ll 1$. Furthermore, the selection of this unusual system, derived from an APM plate color and brightness criterion, is unbiased with respect to the FIR flux, so the chance alignment with any *IRAS* FSC object is highly improbable. We conclude that the excellent positional coincidence, the extreme optical rarity of such bright high-redshift quasars, and the characteristic "dust" spectral signature of the *IRAS* measurements provide a compelling case for the BAL quasar and the *IRAS* source to be either the same object, or, somewhat more unlikely, for the *IRAS* source to be related to an intervening gravitational lens that is amplifying the flux from the QSO.

Single object.—In the simplest model the system consists of a single source with an extremely luminous FIR and

optical flux. Absorption features in the spectrum imply the presence of other material along the line of sight, although in this model we assume this matter does not significantly influence the observed properties of the APM 08279+5255 system that are intrinsic to the source. However, this hypothesis is hard to reconcile with the brightness of the image residuals of Figure 3*b*, as the underlying extended emission would have an absolute magnitude of $M_R > -30$. Although not impossible, the coincidence that such an unusually bright QSO should reside in such an unusually bright galaxy seems somewhat contrived.

Gravitational lensing.—Gravitational lensing by intervening material has proved to be important in explaining the properties of a number of high-redshift sources. The indication of the existence of significant mass concentrations lying along the line of sight to this system, specifically the damped Lyα system and the two Mg II absorbers, plus the small residuals resulting from the two PSF fit to the image (Fig. 3*c*), lend support to this hypothesis. In this scenario, the *IRAS* flux is most likely to be associated with the quasar, rather than the lensing galaxy.

On balance, we feel that gravitational lensing is the most likely explanation and discuss it in more detail in the next section.

5. THE INFLUENCE OF GRAVITATIONAL LENSING

Several sources that have appeared to exhibit quite phenomenal properties have later been shown to be significantly influenced by the action of gravitational lensing by a foreground mass distribution (e.g., the protogalaxy candidate cB58; Yee et al. 1996; Williams & Lewis 1996; Seitz et al. 1998, and the ultraluminous *IRAS* source, F10214+472; Broadhurst & Lehar 1995). Considering the potential ranking of APM 08279+5255 as the brightest object known, such a scenario must be investigated.

The limited ground-based data, however, allow us to only apply the simplest of models to the lensing potential in this system. To this end, we consider the lens mass to be described by a singular isothermal sphere (Schneider, Ehlers, & Falco 1992), a model that has been applied as a convenient description of galaxy and cluster lenses for a number of years (e.g., Kochanek 1993). If the source and the lens are then highly aligned, the source may split into two images, with the amplification being larger the closer both images are to equal brightness.

In the case of perfect alignment the amplification can be (formally) infinite. For the isothermal sphere model, given the estimates of the relative image brightnesses (§ 2.2), the total amplification for a point source is estimated to be ≈ 40. In the infrared the spatial extent of the emission region is likely to be larger than in the optical, and we would expect the infrared flux to be correspondingly less amplified. Furthermore, because of the simplicity of the lensing model, this should be considered only a first approximation to the influence of gravitational lensing.

Whereas the degree of magnification depends on the detailed distribution of mass in the vicinity of the lens, the image separation is a probe of the total mass contained within the images. Given the ground-based data, it is this property that is considered further. We consider three individual redshifts for the potential lensing object; first, $z = 3.07$, coinciding with the redshift of the damped Lyα system; $z = 1.81$, corresponding to the galaxy that gives rise to the weaker of the Mg II doublets; and $z = 1.18$, the site of the strong Mg II absorber that is close to the statistically most probable location of a lens in an $\Omega = 1$ universe (Kochanek 1993). Assuming a component separation of 0.″4, the resulting one-dimensional velocity dispersions for the isothermal model are 299 km s^{-1}, 162 km s^{-1}, and 130 km s^{-1}, respectively.

It is interesting to note that the small change, $\approx 40\%$, in the image brightness, over a 4 decade period suggests that gravitational microlensing by compact objects within the lensing body (Perna & Loeb 1997) or along the line of sight (Hawkins 1996) is unlikely to play a significant role in contributing to the overall amplification, although this can only be strictly ruled out with long-term monitoring of the image components.

A consequence of gravitational lensing in this system is that it provides two lines of sight through the damped Lyα system. If this system is the source of the lensing, then these paths are separated by 1.31(2.17) h^{-1} kpc in a $\Omega_0 = 1(0.2)$ universe. If, however, the system corresponding to the Mg II doublet at $z = 1.18$ is the dominant lensing body, as seems most likely, these paths are separated by 0.18(0.22) h^{-1} kpc. Spatially resolved spectra would then probe the structure through the damped Lyα system on subgalactic scales (e.g., Zuo et al. 1997).

6. CONCLUSIONS

In this paper we have presented the discovery of a high-redshift, ultraluminous BAL quasar, APM 08279+5255. Taken at face value, this system possesses a phenomenal bolometric luminosity $\gtrsim 5 \times 10^{15}\ L_\odot$, making it, intrinsically, the brightest object known in the universe. After examining several possibilities, we suggest that the prodigious nature of this object is most likely a consequence of gravitational lensing by some foreground mass. Even after correcting the degree of amplification with a simple lensing model, the intrinsic luminosity of APM 08279+5255 still ranks among the most luminous objects known.

In addition to being optically luminous, this system appears to emit significant flux in the FIR, suggesting the presence of a copious quantity of dust. Comparison of the FIR flux with that of F10214+4724 suggests an uncorrected dust mass of $\approx 6 \times 10^{10}\ M_\odot$, or ≈ 1–$2 \times 10^9\ M_\odot$ after allowance for potential gravitational lensing. Although Lyα emission is extremely weak, probably due to self-absorption by neutral gas along the line of sight within the quasar, there is no significant reddening of the continuum compared to other high-redshift quasars. This suggests that the FIR emission originates in a physically distinct region from the optical source, consistent with the model proposed by Barvainis et al. (1995). In this context it is significant that the closest comparable object from the handful of other known ultraluminous systems is the cloverleaf quasar H1413+117, which has a similar SED and is also a BAL quasar.

Detection of APM 08279+5255 in the FIRST catalog suggests that further follow-up high-resolution observations covering the entire optical to radio spectrum are warranted to provide vital clues to the nature of this important system. In particular the role of gravitational lensing amplification over a wide range of wavelengths has still to be unambiguously confirmed.

A far-reaching consequence of this discovery is the possibility of similar systems still lurking in the *IRAS* FSC database. So far three ultraluminous high-redshift galaxies with

$z > 2$ have been detected in the *IRAS* FSC. Systematic spectroscopic campaigns have only probed a mere 10% of the galaxies in the FSC and uncovered F10214+4724. Both H1413+117 and APM 08279+5255 were discovered during other observing campaigns and subsequently found to have *IRAS* FSC fluxes. All three objects appear to be present in the *IRAS* FSC because of significant amplification by foreground lensing systems, which raises the question of how many more lensed high-redshift galaxies remain to be discovered in the *IRAS* database.

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REFERENCES

Barvainis, R., Antonucci, R., & Coleman, P. 1992, ApJ, 399, L19
Barvainis, R., Antonucci, R., Hurt, T., Coleman, P., & Reuter, H.-P. 1995, ApJ, 451, 9
Barvainis, R., Tacconi, L., Antonucci, R., & Alloin, D. 1994, Nature, 371, 586
Broadhurst, T., & Lehar, J. 1995, ApJ, 450, 41
Guilloteau, S., Omont, A., McMahon, R. G., Cox, P., & Petitjean, P. 1997, A&A, 328, 1
Hawkins, M. R. S. 1996, MNRAS, 278, 787
Hook, I. M., McMahon, R. G., Boyle, B. J., & Irwin, M. J. 1994, MNRAS, 269, 305
Ivison, R. J., Smail, I., Le Borgne, J.-F., Blain, A. W., Kneib, J.-P., Bézzcourt, J., Kerr, T. H., & Davies, J. K. 1998, MNRAS, in press
Kayser, R., Surdej, J., Condon, J. J., Kellermann, K. I., Magain, P., Remy, M., & Smette, A. 1990, A&A, 364, 15
Kochanek, C. S. 1993, ApJ, 419, 12
Lasker, B. M., et al. 1988, ApJS, 68, 1
Magain, P., Surdej, J., Swings, J.-P., Borgeest, U., & Kayser, R. 1988, Nature, 334, 325
Oliver, S. J., et al. 1996, MNRAS, 280, 673
Omont, A., Petitjean, P., Guilloteau, S., McMahon, R. G., Solomon, P. M., & Pecontal, E. 1996, Nature, 382, 428
Perna, R., & Loeb, A. 1997, ApJ, 489, 489
Prestage, R., & Peacock, J. 1983, MNRAS, 204, 355
Rowan-Robinson, M., et al. 1990, MNRAS, 247, 1
———. 1991, Nature, 351, 719
Schneider, P., Ehlers, J., & Falco, E. E. 1992, Gravitational Lenses (Berlin: Springer)
Seitz, S., Saglia, R. P., Bender, R., Hopp, U., Belloni, P., & Ziegler, B. 1998, MNRAS, submitted
Sopp, H. M., & Alexander, P. 1991, MNRAS, 251, 14
Stetson, P. 1987, PASP, 99, 191
Storrie-Lombardi, L. J., McMahon, R. G., Irwin, M. J., & Hazard, C. 1996, ApJ, 468, 121
Strauss, M. A., Davis, M., Yahil, A., & Huchra, J. P. 1990, ApJ, 361, 49
Totten, E. J., & Irwin, M. J. 1998, MNRAS, 294, 1
Turnshek, D. A. 1988, in QSO Absorption Lines: Probing the Universe, ed. J. C. Blades, D. A. Turnshek, & C. A. Norman (Cambridge: Cambridge Univ. Press)
Weymann, R. 1995, in QSO Absorption Lines, ed. G. Meylan (Berlin: Springer)
Williams, L. L. R., & Lewis, G. F. 1996, MNRAS, 281, L35
Yee, H. K. C., Ellingson, E., Bechtold, J., Carlberg, R. G., & Cuillandre, J.-C. 1996, AJ, 111, 1883
Zuo, L., Beaver, E. A., Burbidge, E. M., Cohen, R. D., Junkkarinen, V. T., & Lyons, R. W. 1997, ApJ, 477, 568