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DISCOVERY OF A LUMINOUS QUASAR IN THE NEARBY UNIVERSE[1]

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ABSTRACT

In the course of the Pico dos Dias survey (PDS), we identified the stellar-like object PDS 456 at coordinates $\alpha = 17^h28^m19\overset{s}{.}796$, $\delta = -14°15'55\overset{''}{.}87$ (epoch 2000), with a relatively nearby ($z = 0.184$) and bright ($B = 14.69$) quasar. Its position at Galactic coordinates $l = 10\overset{\circ}{.}4$, $b = +11\overset{\circ}{.}2$, near the bulge of the Galaxy, may explain why it was not detected before. The optical spectrum of PDS 456 is typical of a luminous quasar, showing a broad (FWHM ~ 4000 km s^{-1}) Hβ line, very intense Fe II lines, and a weak [O III] λ5007 line. PDS 456 is associated to the infrared source IRAS 17254−1413 with a 60 μm infrared luminosity $L_{60} = 3.8 \times 10^{45}$ ergs s^{-1}. The relatively flat slopes in the infrared [$\alpha(25, 60) = -0.33$ and $\alpha(12, 25) = -0.78$] and a flat power index in the optical ($F_\nu \propto \nu^{-0.72}$) may indicate a low dust content. A good match between the position of PDS 456 and the position of the X-ray source RXS J172819.3−141600 implies an X-ray luminosity $L_X = 2.8 \times 10^{44}$ ergs s^{-1}. The good correlation between the strength of the emission lines in the optical and the X-ray luminosity, as well as the steep optical to X-ray index estimated ($\alpha_{OX} = -1.64$), suggests that PDS 456 is radio quiet. A radio survey previously performed in this region yields an upper limit for radio power at about 5 GHz of approximately 2.6×10^{30} ergs^{-1} Hz^{-1}. We estimate the Galactic reddening in this line of sight to be $A_B \simeq 2.0$, implying an absolute magnitude $M_B = -26.7$ (using $H_0 = 75$ km s^{-1} Mpc^{-1} and $q_0 = 0$). In the optical, PDS 456 is therefore 1.3 times more luminous than 3C 273 and the most luminous quasar in the nearby ($z \leq 0.3$) universe.

Subject headings: infrared: general — quasars: individual (PDS 456, IRAS 17254−1413) — X-rays: galaxies

1. INTRODUCTION

The Pico dos Dias survey (PDS) is a systematic search performed at the Pico dos Dias Observatory (OPD; operated by LNA/CNPq) to discover young stellar objects. Using the Digitized Sky Survey (DSS), we have selected candidates brighter than magnitude 14 and declination $\delta < +30°$, associated to *IRAS* sources that were chosen following specific color criteria (Gregorio-Hetem et al. 1992; Torres et al. 1995). High-resolution (0.7 Å) spectra of all the candidates were then taken using the coudé spectrograph at the 1.6 m telescope, centering the spectra near Hα. $UBV(RI)_C$ photometry was also performed using FOTRAP (Jablonski et al. 1984), a fast photometer installed at the 60 cm Zeiss telescope of the OPD. The survey is now complete, and final results will soon be published, providing information on about 440 new sources.

In this Letter, we report the discovery of a new quasar. This object, which looks like a 14th magnitude star on the DSS, is located at coordinates $\alpha = 17^h28^m19\overset{s}{.}796$ and $\delta = -14°15'55\overset{''}{.}87$ (astrometric positions, epoch 2000) and was given the number PDS 456 in our catalog. Its peculiar position, at Galactic coordinates $l = 10\overset{\circ}{.}4$, $b = +11\overset{\circ}{.}2$, near the bulge of our Galaxy, may explain why this relatively bright quasar has escaped detection until now.

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2. DISCOVERY AND OBSERVATIONS

A coudé spectrum of PDS 456 was taken on 1996 May 12. On this spectrum we distinguished at least three broad emission lines, suggesting that this object could be an active galactic nucleus (either a Seyfert or a quasar). The narrow wavelength coverage of this high-dispersion spectrum did not allow us, however, to identify immediately the nature of these lines. On 1996 July 6, three spectra were obtained with the Cassegrain spectrograph of the OPD. For this observation, we used a 900 line mm^{-1} grating blazed at 5000 Å, giving a resolution of about 3 Å. One spectrum was taken with 5 minutes exposure time and the two others with 20 minutes each. The extraction of the spectra was done with the tasks in the APEXTRAC and ONED packages in IRAF.[6] The combination of the three spectra is shown in Figure 1.

2.1. *Characteristics of the Optical Spectra*

The Cassegrain spectrum of PDS 456 is typical of a luminous quasar. We identify the most prominent line with Hβ, corresponding to a redshift of 0.184 ± 0.001. Comparison with the spectrum of PG 1700+518 (Wampler 1985) shows very similar characteristics. The Fe II lines are particularly strong and well resolved. If [O III] λ5007 is present, it is much weaker than the Fe II multiplets. This is consistent with the anticorrelation found by Boroson & Green (1992) between measures of Fe II and the [O III].

The analysis of such a complex spectrum is obviously not the goal of this Letter. We did a preliminary analysis, however, using in IRAF the routine DEBLEND in SPLOT to verify some

[6] IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

TABLE 1

SPECTROSCOPIC ANALYSIS OF PDS 456

Feature	λ_{obs}	FWHM (km s^{-1})	EW (Å)	F_λ (10^{-14} ergs cm^{-2} s^{-1})
$H\beta_{broad}$	4849 ± 4	3974 ± 764	21 ± 8	28 ± 1
$H\beta_{narrow}$	4862 ± 1	1239 ± 56	7 ± 1	10.2 ± 1
[O III] λ5006.84	5009.8 ± 0.3	702 ± 27	2.1 ± 0.3	2.7 ± 0.4
Fe II λ5018.434	5023.7 ± 0.2	736 ± 39	2.1 ± 0.3	2.7 ± 0.3

hypotheses. We decomposed the Hβ line by assuming two Gaussian components: a broad and a narrow one. We did the same analysis for the broad emission feature at about 5000 Å, assuming that it was composed of the Fe II line at λ5018 Å and of the [O III] λ5007 line. The results are presented in Table 1. The errors were determined by repeating the measures 3 times, varying the level of the continuum and the starting position of the lines. The results of this analysis are consistent with the hypothesis that the Fe II lines have the same profile and same widths as Hβ and suggest also that we do see a weak [O III] λ5007. The ratio log ([O III]/Hβ) = −0.6 and the Hβ luminosity $L(H\beta) = 6.7 \times 10^{42}$ ergs^{-1} are in good agreement with the values predicted by the anticorrelation found by Steiner (1981).

2.2. *Photometry and Absolute Magnitude of PDS 456*

The $UBV(RI)_C$ magnitudes of PDS 456 were obtained on six nights in 1997 April and May. During two nights we observed the quasar twice. The results are summarized in Table 2. In *V*, *R*, and *I* the quasar seems constant, within the measurement errors. In *U* and *B* the variance is somewhat greater, but observations separated by 3 weeks show that the fluxes in these bands do not vary by more than about 10%.

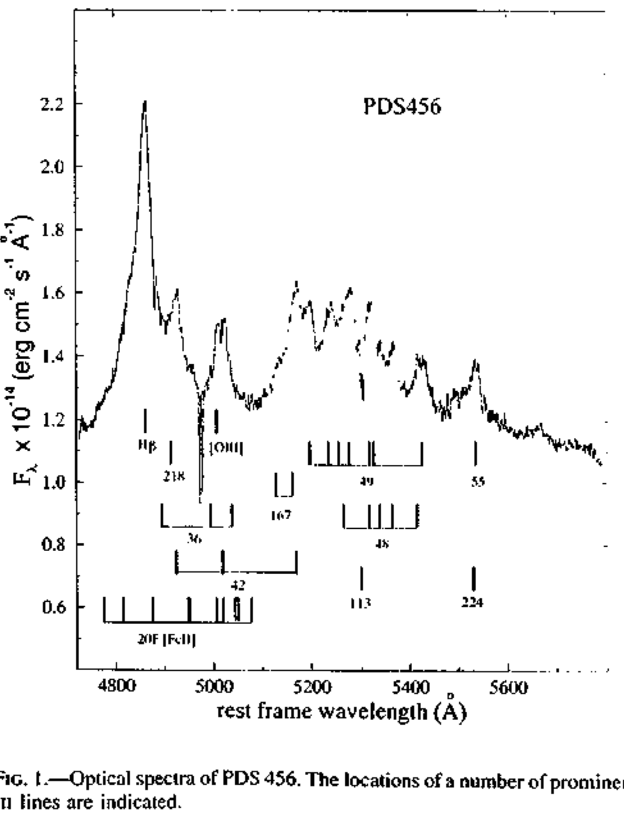

FIG. 1.—Optical spectra of PDS 456. The locations of a number of prominent Fe II lines are indicated.

To estimate the reddening in this region of the Galaxy, we used the main diffuse interstellar bands present in our spectra (Herbig 1975, 1993), which yields $A_V \sim 1.5$ mag. This is consistent with the value obtained using the equivalent widths of the interstellar line Na D1, assuming that it has multiple components (Munari & Zwitter 1997). Our value for the reddening is also consistent with the value $A_B = 1.9$ mag based on the extinction maps of Burstein & Heiles (1982). The extinction-corrected magnitudes and colors are given in the third column of Table 2. We use $A_V = 1.5$ and Seaton's (1979) expression for the reddening in our Galaxy. The extinction-corrected colors are in relatively good agreement with the evolutionary path of colors of quasars at various redshifts as derived by Cristiani & Vio (1990).

The absolute *B* magnitude of PDS 456 was determined using the following relation (Schmidt & Green 1983): $M_B = B + 5 - 5\log[cz(1 + z/2)/H_0] + K - A_B$ (using $H_0 = 75$ km s^{-1} Mpc^{-1} and $q_0 = 0$). In this expression, the *K*-correction is given by $2.5(1 - \alpha)\log(1 + z)$, and A_B is the correction for Galactic reddening. We used $\alpha = -0.3$ in order to compare with the absolute magnitudes of the quasars in the Véron-Cetty & Véron (1996) compendium. The absolute magnitude of PDS 456 is −26.7. In Figure 2, we compare PDS 456 with all the quasars in the list of Véron-Cetty & Véron (1996). The absolute magnitudes were reduced to the same cosmology and corrected for Galactic reddening out of the disk using the following expression (Lang 1980, p. 586): $A_B = 0.18\,[\csc b - 1] + 0.25$. A mean value of $A_B = 1.6$ was assumed in the disk ($|b| \le 5°$). In the optical, PDS 456 is therefore about 1.3 times more luminous than 3C 273 (at $z = 0.158$) and the most luminous quasar up to a redshift of about 0.3.

2.3. *Infrared, X-Ray, Radio Characteristics and Spectral Energy Distribution*

PDS 456 is located in the center of the positional error ellipse of IRAS 17254−1413. According to the *IRAS* Faint Source Catalog, it was not detected at 100 μm. The relatively flat spectral slopes α(25, 60) = −0.33 and α(12, 25) = −0.78 may suggest a low dust content. Expressing the 60 μm lumi-

TABLE 2

$UBV(RI)_C$ PHOTOMETRY OF PDS 456

Magnitude/Color Index	Observed	Dereddened[a]
U	14.12 ± 0.06	11.71
B	14.69 ± 0.06	12.66
V	14.03 ± 0.03	12.44
R	13.58 ± 0.03	12.32
I	12.86 ± 0.03	11.90
U − *B*	−0.57 ± 0.04	−0.95
B − *V*	+0.66 ± 0.07	+0.22
V − *R*	+0.45 ± 0.05	+0.12
R − *I*	+0.72 ± 0.04	+0.42

[a] Using the Seaton 1979 law, with $A_V = 1.5$.

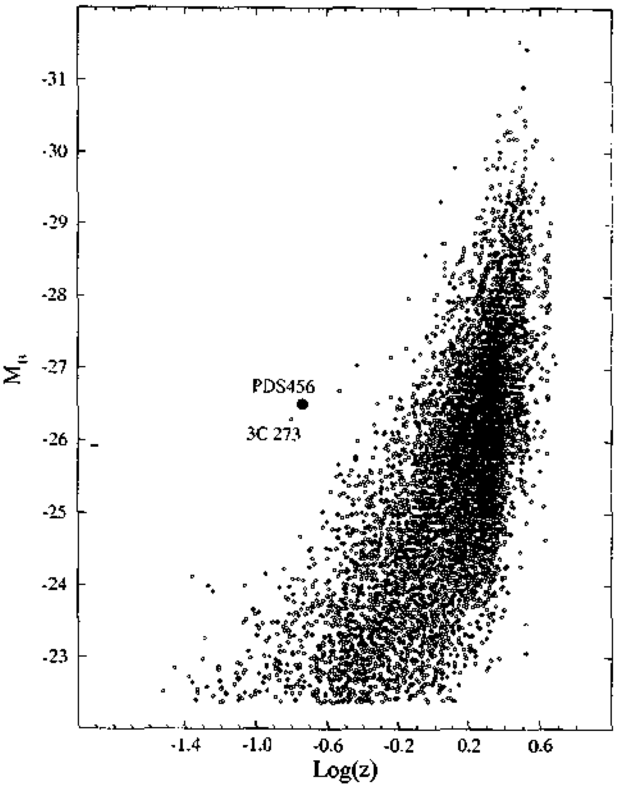

FIG. 2.—Comparison of the absolute magnitude of PDS 456 with the complete list of quasars in the Véron-Cetty & Véron (1996) compendium. The absolute magnitudes were corrected for $H_0 = 75$ and for Galactic reddening. PDS 456 is 1.3 times more luminous than 3C 273 and the most luminous quasar up to $z = 0.3$.

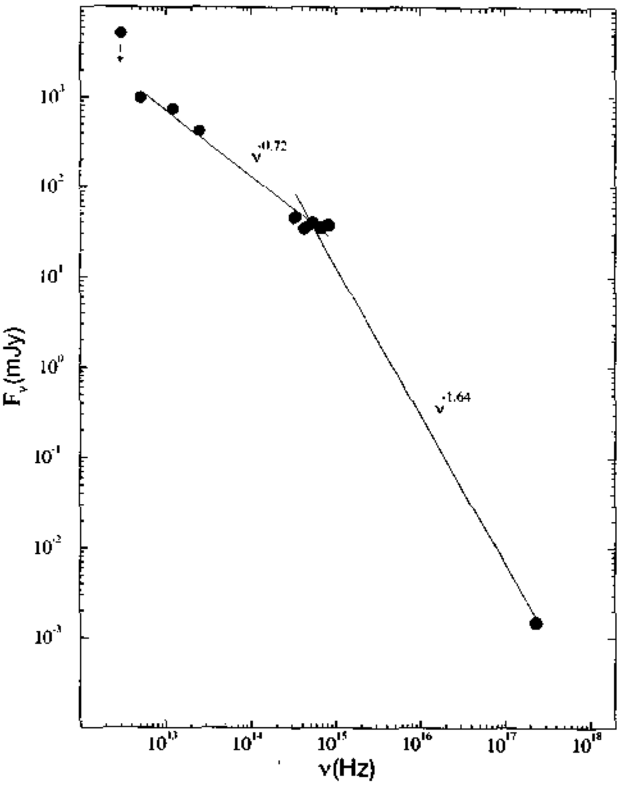

FIG. 3.—Spectral energy distribution of PDS 456. The solid lines represent two power laws of the form $F_\nu \propto \nu^\alpha$, with $\alpha = -0.72$ from the far-infrared to the optical and $\alpha_{OX} = -1.64$ from the optical to the soft X-rays.

nosity as $L_{60} = 4\pi d^2(1+z)^{-0.1}\nu_{60}f_{60}$ (Green, Anderson, & Ward 1992), where d is the distance and f_{60} is the flux in ergs cm^{-2} s^{-1}, yields $L_{60} = 3.8 \times 10^{45}$ ergs s^{-1}. This is slightly higher than the mean value found by Green et al. (1992) for their sample of quasars.

We also find a good match between the position of PDS 456 and the position of the X-ray source RXS J172819.3−141600 (Voges et al. 1996), which has a count rate of 0.3 counts s^{-1} in the 0.1–2.5 keV energy band. Using the conversion factor 1 count $s^{-1} = 1.2 \times 10^{-11}$ $ergs^{-1}$ cm^{-2} as suggested by Alcala (1994) for 1 keV ($\nu = 2.4 \times 10^{17}$ Hz), we estimate a median flux of 0.0015 mJy. This corresponds to an X-ray luminosity $L_X = 2.8 \times 10^{44}$ ergs s^{-1}, which is a typical value for quasars. This result is also consistent with the anticorrelation between L_X and [O III]/Hβ as found by Grindlay et al. (1980) for radio-quiet quasars. The ratio log $(L_X/L_{60}) = -1.1$ is much lower than the mean for radio-quiet quasars and much lower, in particular, than the ratio found for 3C 273 [log $(L_X/L_{60}) = -0.06$; Green et al. 1992].

The spectral energy distribution of quasars displays a wide variety of shapes (Barvainis 1990). In a limited frequency range, it can be described as a power law in frequencies $F_\nu \propto \nu^\alpha$. In Figure 3, we combine the extinction-corrected magnitudes of PDS 456 with the *IRAS* fluxes and *ROSAT* X-ray flux to estimate the spectral indices α in the optical and α_{OX} from the optical to the soft X-rays. In the optical, we find $\alpha = -0.72$. This value is significantly flatter than usually found for quasars and Seyfert 1 galaxies (Edelson & Malkan 1986), which confirms the suggestion given by the slopes in the infrared that this quasar is relatively dust free. From the optical to the soft X-rays, we find $\alpha_{OX} = -1.64$. This value is consistent with the mean value ($\alpha_{OX} = -1.48$; Laor et al. 1997) observed for radio-quiet quasars.

The characteristics in the optical, the infrared, and X-ray as reported above all suggest that this is a radio-quiet quasar. A recent radio survey in the region of PDS 456 did not detect any source to an upper limit of 42 mJy (Griffith et al. 1994). At the distance of PDS 456 this upper limit corresponds to a power level at 4.85 GHz of 2.6×10^{30} $ergs^{-1}$ Hz^{-1}. This is 2 orders of magnitude lower than the power threshold that separates radio-quiet from radio-loud quasars (Woltjer 1990).

3. DISCUSSION

All the studies on the distribution of quasars in space concluded that there is a strong evolution of their number density, their luminosity, or both between an epoch corresponding approximately to $z = 2$ and the present (for a review see Hartwick & Schade 1990). The pure luminosity evolution (PLE) model assumes that all the quasars were born at the same time and are becoming less luminous at the same rate. Alternatively, the pure density evolution (PDE) model assumes that the birthrate of the most luminous quasars may have been highest in the early universe and is steadily decreasing, while the birthrate of the least luminous ones has roughly been constant. In this context, it is intriguing to find a nearby quasar even more luminous than 3C 273. Indeed, using the HH 1 model of Schmidt & Green (1983), based on the Bright Quasar Survey (BQS), we find that the density ϕ of quasars as luminous as 3C 273 in the nearby universe ($z \leq 0.2$) is only about 6 ×

10^{-11} Mpc^{-3}. The expected number of such quasars in the nearby universe is about 0.3. In other words, 3C 273 is an exception. Therefore, the fact that we just discovered another one suggests that our understanding of the local luminosity function, as deduced from the BQS, is not satisfactory.

A recent comparison of the Hamburg/ESO survey (HES) with the BQS by Köhler et al. (1997) implies that the surface density of bright quasars in the nearby universe is much higher than previously estimated. This result confirms previous claims by Wampler & Ponz (1985) and Goldschmidt et al. (1992). Using the luminosity function of Köhler et al. (1997) and extrapolating up to the absolute magnitude of PDS 456, we find a density $\log \phi = -8.8$ Mpc^{-3}. This means that in a volume of space including PDS 456 we could find as many as nine quasars as luminous as this one. Our discovery supports the claim of Köhler et al. (1997), which is that the evolution of the most luminous quasars in the universe probably proceeded at a lower rate than usually predicted by the PLE model.

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