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DETECTION OF A SUPERNOVA IN THE HOST GALAXY OF THE QSO 1059+730

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ABSTRACT

A blue stellar object has been discovered within the fuzz surrounding the quasar 1059+730. This object was observed in multiple CCD frames taken on one night, but it is not visible in other images of the QSO. We propose that the object is probably a supernova event in the host galaxy of the quasar. The detection of this supernova provides a consistency argument that QSOs are at their cosmological distances and demonstrates that the envelopes surrounding QSOs contain stars and possibly star formation. *A priori* statistical arguments predict supernova rates in QSO host galaxies that are consistent with the observation of at least one supernova to date.

Subject headings: quasars — stars: supernovae

I. OBSERVATIONS AND DATA REDUCTION

The object 1059+730 is a nearby ($z = 0.089$) QSO that was discovered as a serendipitous X-ray source by the *Einstein Observatory* (Chanan, Margon, and Downes 1981). Underlying the bright nucleus of this object is a symmetric elongated structure, about $9'' \times 16''$ in extent, that resembles an edge-on disk, or perhaps barred galaxy (Hutchings *et al.* 1984). The nucleus has $M_B = -21.7$ (Hutchings, Crampton, and Campbell 1984; values of $H_0 = 100$ km s^{-1} Mpc^{-1}, $q_0 = 0$ are assumed throughout this *Letter*), a luminosity characteristic of a quasar, rather than a Seyfert galaxy. In blue light the brightness of the underlying galaxy is 0.9 mag fainter than the nucleus.

The QSO 1059+730 was observed on 1983 May 10 UT as part of an ongoing program to study the colors and luminosity profiles of the fuzz surrounding QSOs (Pritchet, Christian, and Campbell 1985). Observations were obtained with the Galileo Imaging Team/Institute for Astronomy 500 × 500 Texas Instruments three-phase CCD (Hlivak, Henry, and Pilcher 1983). This instrument was mounted at the Cassegrain focus of the University of Hawaii 2.2 m telescope. The observations consisted of four 900 s exposures (7:51–9:03 UT) through a "60" filter ($\lambda_c = 6048$ Å, $\Delta\lambda_{1/2} = 650$ Å), and two 1800 s exposures (6:41–7:44 UT) through an "80" filter ($\lambda_c = 8050$ Å, $\Delta\lambda_{1/2} = 680$ Å). Seeing for the observations was approximately 1″ FWHM.

The observations were reduced on a VAX 11/750 plus I^2S image processing system using the software package R2D2 (coded by C. P.). Preliminary data reduction consisted of (*i*) determination of the floating bias level, relative to the mean bias level, from overclocked pixels; (*ii*) subtraction of the floating bias level from each exposure; (*iii*) subtraction of a mean bias frame; (*iv*) subtraction of a dark frame; (*v*) division by a flat field; and (*vi*) alignment and co-addition of multiple exposures.

Upon inspection of the reduced frames, it was immediately apparent that a faint stellar object was present in all of them, approximately 2″.6 SE of the QSO. Inspection of the red and blue plates discussed by Hutchings *et al.* (1982, 1984) and Hutchings, Crampton, and Campbell (1984) shows no sign of the object (Hutchings 1984). These plates were obtained in 1981 January and December. This object is also not mentioned by Malkan, Margon, and Chanan (1984), who obtained multicolor SIT area photometer frames of 1059+730 in 1982 May.

Figure 1 (Plate L1) compares our composite "60" image of 1059+730 with a 5 minute *B* exposure acquired with an RCA CCD on the Canada-France-Hawaii 3.6 m telescope in 1984 July. This latter image was reduced as above, expanded to match the scale of the UH 2.2 m exposures, and photometrically normalized. The object is not visible in the 1984 July frame, and we estimate it was at least 2 mag fainter than in 1983 May.

To test whether this object is perhaps similar to the extended variable object near OX +029 = II Zw 123 (Craine

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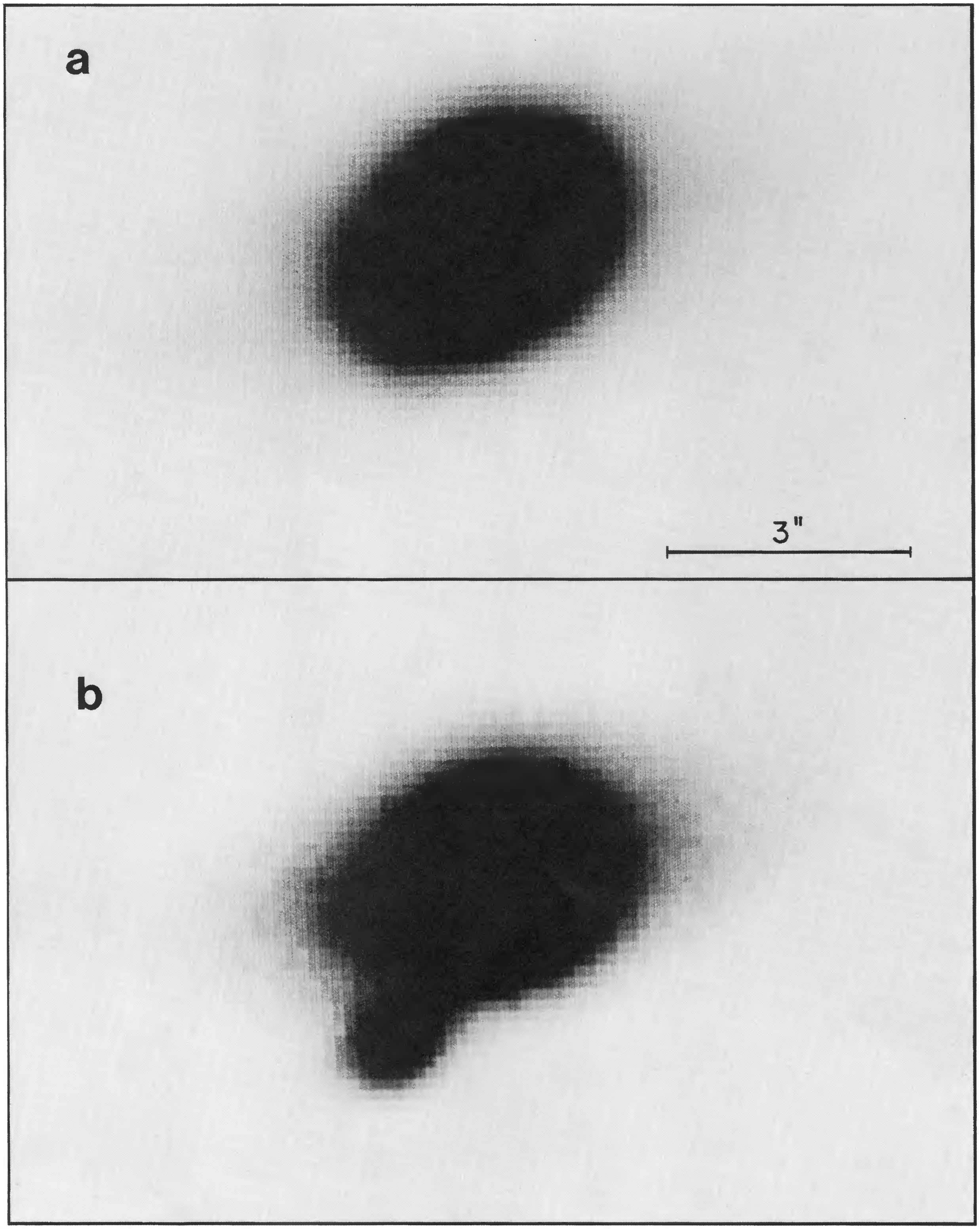

FIG. 1.—(*a*) The object 1059+730 in 1984 July. Observations were taken with a *B* filter on the CFH 3.6 m telescope with the RCA 320 × 512 CCD. (*b*) The object 1059+730 on 1983 May 10 UT, "60" filter, TI 500^2 CCD, UH 2.2 m telescope. Orientation and scale match that of (*a*). North is up, and east is to the left. The shape of the QSO fuzz appears slightly different in these two images because of guiding errors.

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and Warner 1976; Stocke and Epps 1979), we have made use of the fact the fuzz around 1059+730 is quite symmetric. The following procedure was used to produce an image of the object uncontaminated by light from the underlying galaxy. Two new images were created by alternatively reflecting 1059+730 across its major axis and rotating it by 180° about the nucleus. These images were combined with the original image using a 3 pixel median operation. The resultant image (= QSO + host galaxy − variable object) was subtracted from the original picture to produce an image of the companion object by itself (="fuzz subtracted"). Comparison of this image with stars elsewhere in the field show that the variable object has a stellar profile.

Aperture photometry was performed on the fuzz-subtracted "60" and "80" filter frames, with the background determined from the mode of pixels in surrounding annuli. The photometry was calibrated and converted to V and I magnitudes using observations of Landolt (1973, 1983) standard stars. The magnitude of the object is $V = +19.6$, with an estimated error of 0.2 mag. The color of the object is $V - I = 0.0$, with an estimated uncertainty of 0.1 mag.

II. DISCUSSION

The object that we have discovered is clearly variable, but the discovery frames show that it had constant brightness for ~ 1 hr, and so it is almost certainly not a flare star (e.g., Kahler *et al.* 1982). It is equally improbable that it is an asteroid, since it shows $< 0\farcs1$ motion in ~ 2 hr, it is far from the ecliptic, and it is quite blue. Furthermore, it is unlikely to be a dwarf nova, since the local number density of such objects (Patterson 1984) translates into a surface density $\lesssim 10^{-2}$ deg^{-2}.

In the absence of any other reasonable explanation, we propose that this object is a supernova in the host galaxy of 1059+730. The absolute magnitude ($M_v = -17.6$ if $z = 0.089$) and blue color are consistent with it being a Type II supernova near maximum light (cf. Tammann 1977, 1982; Schurmann, Arnett, and Falk 1979; Branch *et al.* 1981; Trimble 1982), or a Type I supernova 20–40 days after maximum light (cf. Kowal 1968; Lee *et al.* 1972; Tammann 1977, 1982; Sandage and Tammann 1982; Branch *et al.* 1983; Trimble 1982).

If this object is indeed a supernova, we may then deduce the following:

1. Detection of this supernova provides a consistency argument that the QSO 1059+730 is at its cosmological distance, and, by inference, that other QSOs are at their cosmological distances.

2. This supernova provides direct and compelling evidence for the existence of stars in the fuzz surrounding QSOs.

3. This object is apparently the most distant supernova reported to date.

4. We can compare the observation of this one supernova with the expected frequency of such events. There is now substantial evidence from fuzz spectra, morphology, and colors (Boroson, Oke, and Green 1982; Hutchings and Campbell 1983; Hutchings, Crampton, and Campbell 1984; Malkan, Margon, and Chanan 1984) that many, if not all, low-redshift QSOs do reside in spiral galaxies, rather than ellipticals. The mean frequency derived by Tammann (1982) for supernovae (Type I + Type II) in all types of spiral galaxies (types for QSO host galaxies are not known), adjusted to $H_0 = 100$ km s^{-1} Mpc^{-1}, is

$$\nu_{\rm SN} \approx 3.4\left(10^{10} L_{B\odot}\right)^{-1} (100\ {\rm yr})^{-1}.$$

This frequency is, of course, not at all well determined, due to uncertainty in inclination corrections, selection effects, and the Hubble constant. Hence the following calculation is meant to be illustrative only.

The mean luminosity-weighted absolute magnitude of QSO host galaxies is $M_B \approx -21$ for the sample of Hutchings, Crampton, and Campbell (1984), and so the expected supernova rate in such a galaxy is ~ 0.13 yr^{-1}. Taking typical redshifts, fuzz absolute magnitudes, and fuzz scale heights from the Hutchings *et al.* sample, we find that about one-quarter of the supernovae would be missed in the glare of the central object. We would then expect to observe ~ 0.10 SN yr^{-1} in a typical QSO host galaxy. We estimate that a supernova would be visible for ~ 50 days (~ 2 mag fading).[3] Therefore the probability of observing a supernova in any single observation of a QSO (chosen as in the Hutchings *et al.* sample) is ~ 0.014, if the host galaxies are predominantly spirals.

How many nearby QSOs have been observed more than once, with sufficient precision for a supernova to be detected? This is a difficult question to answer, because of the decidedly mixed quality of data that have been accumulated to date. As an example, we again refer to the 78 quasars in the sample of Hutchings, Crampton, and Campbell (1984). Of these, ~ 30 have been observed in each of B and R, which should have provided a time and/or color baseline sufficient to detect a supernova. No such "variable" object was detected, but from the frequency calculated above, we would have expected only ~ 0.8 events. If altogether some 200 low-redshift QSOs have been imaged, then about three supernovae may have been recorded but are not detectable for lack of multiple images. We conclude that detection of a supernova in 1059+730 is not inconsistent with expectations for such events.

We note that measurement of the supernova rate in the environs of QSOs could provide a powerful probe of local environmental effects of quasar activity and could improve our limited understanding of the phenomena that trigger QSO activity in galaxies. At the very least, the rate of supernovae in QSO galaxies (and especially the number ratio of Type I to Type II events) could reveal much about the properties of galaxies that host nuclear activity. A survey to determine the QSO supernova rate could be carried out with a CCD mounted on a midsized telescope, although good seeing ($\lesssim 1''$ FWHM) would be necessary to detect supernovae at $z > 0.2$. Plans for systematic, semiautomated surveys of supernovae in nearby ($z \lesssim 0.1$) normal galaxies are well advanced (e.g., Trimble 1983); such surveys would provide a much needed reference sample with which to compare surveys of supernova activity in active galaxies.

[3] This result is independent of supernova type. While Type II events are fainter than Type I events at maximum light, Type II events decline more slowly.

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