Ton 202 as a Star

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Evidence is marshaled from proper motion, emission line spectrum and absorption line spectrum to show that the quasar Ton 202 (1425+267) is a star and that its properties are consistent with the expectations of the PLAST theory.

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1. Introduction

When the spectrum of the star-like object 3C 273 was first observed in 1963, it was found to have one strong line and one medium/weak strength line. The problem was, however, that these lines were at wavelengths where no strong lines were expected from laboratory spectra. It has been a traditional assumption in astronomy that the intensities of lines in astronomical sources will be similar to those in the laboratory under ordinary excitation conditions. Schmidt assumed that these two lines were redshifted H alpha and H beta lines, and obtained a redshift of 0.157. Subsequently, when other such objects with broad emission lines were discovered (3C 48, 3C 191 etc) they were also labelled quasars and the spectra were similarly interpreted on the redshift hypothesis. In conjunction with Hubble's law it meant that quasars were very distant objects. This in turn led to the well known difficulties concerning their energy generation mechanism, optical variability, lack of correlation in the redshift-magnitude diagram, superluminal motion etc. Theoretical and experimental investigations in physics in the next decade showed that when a high temperature plasma rapidly expands (for example, in vacuum) the resulting cooling leads to a population inversion in the lower levels of the atom, and this can lead to laser action. Also, it is well known that in certain types of stars (Wolf-Rayet, P Cygni); matter is ejected more or less continuously. This led Varshni [1-11] to propose the following realistic model of a quasar: A quasar is a star in which the surface plasma is undergoing rapid radial expansion giving rise to population inversion and laser action in some of the atomic species. The assumption of the ejection of matter from quasars at high speed is supported from the fact that the widths of emission spectral lines observed in quasars are typically of the order of 2000 - 4000 km/sec. The ejected matter can form a nebulosity around the quasar or dissipate into space, depending on the rate of mass loss, how long the ejection has been going, the surroundings of the quasar etc. Laser action is enhanced if the hot plasma ploughs into this colder gas. Thus no redshifts are required to explain the strong emission lines. This model is called the plasma-laser star (PLAST) model.

The spectrum of Ton 202 was first observed in the visible region by Greenstein and Oke [12] and by Barbieri [13]. It was found to show broad emission lines at unexpected wavelengths, like other quasars, and so it was assumed to be a quasar and it was given a redshift of 0.366 by Greenstein and Oke [12].

This theory that quasars are stars raises the question of their proper motions. In the present paper we discuss the proper motion and distance of the quasar Ton 202. The proper motions (absolute) of 951 faint blue stars have been determined by Luyten [14] based on plates taken at Palomar. A search of Luyten's measurements [14] has shown that the quasar Ton 202 has a substantial proper motion. From the data given by Luyten, the absolute proper motion for Ton 202 turns out to be 52.6 ms/year with a mean error of 16 ms/year. Ton 202 had not been recognized as a quasar at the time of Luyten's measurements, because its spectrum had not been observed and Luyten thought it to be a star.

The Hipparcos data goes only down to 7.3 mag and TYCHO2 data goes down to 11 mag only. There does not seem to be any more accurate measurements of the proper motion of Ton 202 ($m = 16$). We may also mention some problems with present day techniques. VLBI measurements are open to argument that they refer to the radio emitting region, which may or may not coincide with the quasar. Often such measurements are based on the International Celestial Reference System (ICRS). The O_x axis of ICRS was implicitly defined in the initial realization of the IERS celestial reference frame in 1988 by adopting the mean J2000.0 right ascensions of 23 radio sources (quasars) in a group of VLBI catalogues. It was implicitly assumed that quasars being so far away have no perceptible motion. On the other hand, stars do have motions. If quasars are stars, then any measurements which are based on ICRS clearly would not give correct results. This problem is known amongst workers in this field. Based on ICRS, they have found proper motions for certain quasars, where they should have been zero on the redshift hypothesis. However, such results have not been published in the open literature. One learns about them from certain websites and in discussions at conferences.

Large proper motions are indicative of the nearness of the astronomical object. Faint stars are often considered to be far away, but there is one important exception, planetary nuclei, which are intrinsically faint stars. Ton 202 is also a faint object, $m = 16$, and it shows broad emission lines like some planetary nuclei. Analogy is a powerful tool in science. In an earlier paper [4] we have pointed out the similarities between quasars and Wolf-Rayet type planetary nuclei. The faintness and the similarity of the spectrum of Ton 202 with some planetary nuclei suggests that perhaps we can get some idea of its distance by comparison, assuming that Ton 202 has the same sort of velocity as planetary nuclei.

The largest proper motion reported up to now for a planetary nucleus is 40 ± 3 mas/year for NGC 7293 (believed to be the nearest planetary nebula)[15,16] and it is an isolated case. Proper motions for all other planetary nebulae for which measurements exist [16,17] are smaller than 24 mas/year, with considerable uncertainty in many cases. The distance of NGC 7293 is estimated to be 212 pc; from this it would be reasonable to estimate that the quasar Ton 202 lies within a few hundred parsecs from the sun. In other words, Ton 202 lies in our galaxy.

Purely as an academic exercise, if we calculate the transverse velocity corresponding to the smallest value of the proper motion within the uncertainty range, assuming $H = 50$ km/sec per Mpc and $q_0 = 0$, it turns out to be 1100c. The evidence clearly indicates that Ton 202 is a star. More accurate astrometric investigations on quasars are clearly most desirable. We would give further evidence to support the view that Ton 202 is a star and that its properties are consistent with the PLAST theory.

Ton 202 is known to be surrounded by extended ionized nebulosity [18-20]; it is a consequence of the PLAST theory that many quasars will be surrounded by ionized nebulosity. According to PLAST theory, the emission lines will be broad as is the case for Ton 202.

2. Emission-Line Spectrum

Next we consider the spectrum of Ton 202. In the ultraviolet its emission line spectrum has been investigated by Gondhalekar *et al.* [21,22], and in the visible region by Greenstein and Oke [12] and by Barbieri [13], as noted earlier.

We identify the observed emission lines (wavelengths in Å):

- 1640 - He II λ1640 ,
- 2110 - Ca II λλ2103,2113 ,
- 2600 - O III λλ2598, 2605 and C III λλ2610,2614,2617 ,
- 3810 - It is a well known line in more than ten O VI sequence planetary nuclei and in several Sanduleak stars [4]. It is due to O VI λλ3811,3834 .
- 6850 - Lines at λλ6857, 6863 and 6872 due to C III, multiplet 19, have been observed in the W-R spectra [23].
- 9010 - A line at λ9015.00 is known to occur in novaelike stars [23]. The emitter has not been identified.

Thus we see that the emission lines which have been observed in Ton 202 also occur in certain type of stars.

In Table 1 we list the wavelengths and the corresponding equivalent widths found by them and the identifications of the lines at no redshift. All wavelengths are in Angstroms (Å)

3. Absorption-Line Spectrum

Next we come to the absorption-line spectrum of Ton 202. Its spectrum in the ultraviolet has been observed by Bechtold *et al.* [24] with the high-resolution gratings of the Faint Object Spectrograph on board the Hubble Space Telescope. Besides the interstellar lines, their list has 8 lines.

Observed Wavelength	EW	Lab Wavelength	Ion	Mult.	Difference
1653.55	38.4	1654.10	Fe II	68	–0.56
		1654.48	Fe II	42	–0.93
1658.05	7.4	1658.67	Mn III	25	–0.62
		1658.78	Fe II	41	–0.74
1684.58	16.3	1684.58	Mn II	75	0.00
		1685.95	Fe II	41	–1.37
1689.48	13.1	1689.49	Mn II	39	–0.01
		1689.61	Mn II	75	–0.13
		1689.82	Fe II	85	–0.34
2101.78	5.0	2100.96	Fe III	129	0.82
2105.69	21.1	2104.85	Cr III	41	0.84
		2105.02	Fe III	146	0.67
		2105.98	Mn III	10	–0.29
2110.55	17.7	2110.24	Fe II	290	0.31
		2110.37	Cr II	16	0.18
		2110.68	Cr II	26	–0.13
		2110.72	Fe II	108	–0.17
		2110.92	Cr II	26	–0.37
		2110.98	Cr II	26	–0.43
		2111.26	Cr II	26	–0.71
2115.38	10.2	2114.87	Cr III	41	0.51
		2115.17	Fe I	33	0.21

The average of the absolute value of the difference between the observation and identification wavelength for all the identifications is 0.47 Å which is quite satisfactory. The lines are of the same type as those which occur in the ultraviolet region of shell stars.

It would be of much interest to observe the absorption line spectrum of Ton 202 in the visible region (available spectra don't have enough resolution to resolve absorption lines). We expect that Fe II would be well represented in the absorption-line spectrum in the visible region.

We would also like to draw attention to certain similarities between Ton 202 and the star upsilon Sgr.

1. In the two-color (U-B) versus (B-V) plot, the positions of Ton 202 and upsilon Sgr are pretty close as can be seen from the following values. For Ton 202: (U-B) = -0.75, (B-V) = 0.10 and for upsilon Sgr: (U-B) = -0.51, (B-V) = 0.10.
2. Both objects show large infrared excesses. Infrared photometry of upsilon Sgr has been carried out by Lee and Nariai [25], Woolf [26], and by Treffers *et al.* [27], and that of Ton 202 is taken from the 2MASS survey.

In Figure 1 we compare the colors of Ton 202 with those of upsilon Sgr. It will be noted that both objects are very red at long wavelengths and the spectral energy distributions of the two are very similar. Two hypotheses have been advanced to explain the infra-red excess in upsilon Sgr. A late-type secondary or the circumstellar envelope. Parthasarathy et al. [28] have found that the companion is a hot star (late O or early B-type). Thus the second possibility seems most likely (see also Treffers *et al.*, [27]). In the case of Ton 202, it is a natural consequence of our theory that the ejected material from the star will form a circumstellar envelope and in due course some of it will condense to form dust, which will lead to infrared excess. We may note here that ISO (Infrared Space Observatory) data shows an infrared nebulosity around TON 202.

Upsilon Sgr shows a 10 micron emission feature (Treffers *et al.* [27]), which is similar to the 10 micron emission feature found around oxygen-rich stars and interpreted as being due to silicates. Irrespective of its interpretation it would be of interest to investigate if Ton 202 also shows the 10 micron emission feature.

Summarizing, in this paper we have shown from evidence concerning proper motion, emission line spectrum and absorption line spectrum that the quasar Ton 202 (1425+267) is a star with high probability and that its properties are consistent with the expectations of the PLAST theory. It is also readily seen that this model resolves the well known difficulties concerning quasars, e.g., their energy generation mechanism, optical variability, lack of correlation in the redshift magnitude diagram, apparent brightnesses not diminishing with increasing redshift [29], superluminal motion etc. Accurate astrometric data on many quasars are badly needed. At present at least three projects are underway for precision optical astrometry of quasars.

SIM - JPL Space Interferometry Mission [30,31], scheduled for launch in 2009. Two telescopes 10 m apart and 95 million km from earth will have 4 microarcsecond parallax accuracy, limiting mag 20. In its wide-angle mode, SIM will yield 4 microarcsecond absolute positions, and proper motions to about 2 microarcsecond/yr.

FAME - Full-Sky Astrometric Mapping Explorer (FAME) [32] is expected to observe many quasars.

GAIA - Global Astrometric Interferometer for Astrophysics. GAIA is a mission that will conduct a census of one billion stars to magnitude V = 20 in our Galaxy. It will monitor each of its target stars about 100 times during a five-year period, precisely charting their distances, movements and changes in brightness. To be launched in Mid-2011 by European Space Agency. GAIA will be placed in an orbit around the Sun, at a distance of 1.5 million kilometres further out than Earth. This special location, known as L_2, will keep pace with the orbit of the Earth. Gaia will map the stars from there.

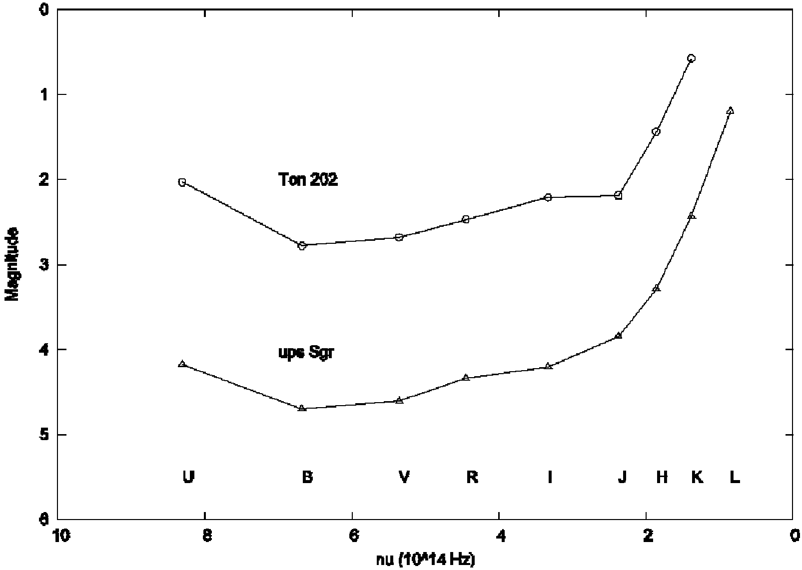

Figure 1. The colors of Upsilon Sgr and Ton 202. The data points for Upsilon Sgr are from Lee and Nariai [25] and for Ton 202 the data are from USNO NOMAD, which is an aggregation from several surveys, U band from the SIMBAD U-B value, B and V bands from a YB6, R band from a USNO re-scan of POSS II red plates, I band from a USNO re-scan of POSS-II IV-N plates and J, H and K bands are from 2MASS. To accommodate the two objects on the same plot, the magnitudes for Ton 202 have been increased by 13.

With these new high accuracy astrometric missions, it may be possible to determine the trigonometric parallax of some quasars.

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