THE MINOR PLANET BULLETIN

BULLETIN OF THE MINOR PLANETS SECTION OF THE ASSOCIATION OF LUNAR AND PLANETARY OBSERVERS

VOLUME 25, NUMBER 4, A.D. 1998 OCTOBER-DECEMBER 37.

1000 AND MORE!

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(Received: 23 October Revised: 20 June)

Twenty one years after the search for my first asteroid, I saw the thousandth in 1996. Only four other observers, by their passion and their perseverance, are confirmed to have succeeded in visually spotting 1000 asteroids. Visual observation, by which the first minor planets were discovered, can yet improve our understanding of these tiny objects of our solar system.

Since the discovery of Ceres in 1801, there have been numerous observers who have visually detected asteroids among the stars, but few of them have reached 1000 different asteroids. To learn of these active observers, I have corresponded with Dr. Frederick Pilcher and sent nearly 40 letters to active observers in 12 countries. The *Minor Planet Bulletin* and the *Minor Planet Observer* have also published my call for information. As a result, I can reasonably assert that only five people have attained 1000 visual asteroid sightings prior to the end of 1997. These are: Paul G. Comba, G. Roger Harvey, Frederick Pilcher, Andrew Salthouse, and myself.

Frederick Pilcher, Illinois College, Jacksonville, USA, was the first who reached the 1000 plateau. Having obtained the *Ephemerides of Minor Planets* in 1968, he located his first asteroid (Pallas) on February 24 and 25, 1968 by its motion between stars and its absence on the *Atlas Eclipticalis*. He then ordered the *Falkauer Atlas* to identify minor planets more conveniently among fainter stars with a 25-cm Celestron telescope. In late 1973, he had observed 317 asteroids when he acquired a 35-cm Celestron telescope, also located at the Walter H. Balcke Observatory of Illinois College. This telescope enabled him, with the help of the Vehrenberg *Atlas Stellarum* (and despite city lights) to track asteroids as faint as magnitude V14.9. In the 1970's, Pilcher located several objects distant from their predicted positions by a few arcminutes to many tens of arcminutes by searching along the line of variation. He also drew lightcurves of several asteroids and noted a number of magnitude discrepancies. On January 2, 1981 he observed his 1000th different asteroid 750 Oskar, 13 years after first observing Pallas. In the 1980's, he used the *Lick Photographic Star Atlas* which, unlike the *Stellarum Atlas*, showed stars to and beyond the telescope limit for almost all fields in the sky. As of early April 1998, he has located 1780 minor planets, many of which he has seen many times. Frederick Pilcher, immortalized by the asteroid 1990, is well known for his activities as Recorder of the ALPO Minor Planet Section since 1983. He has written numerous papers in the *MPB* and each year publishes the report of asteroid observations by the ALPO members. He has also written the "Discovery Circumstances" section of the scholarly books, *Asteroids* and *Asteroids II*.

The second observer who reached 1000 visual asteroid sightings is G. Roger Harvey. Influenced by Dr. Jay U. Gunter and *Tonight's Asteroids*, Harvey observed his first asteroid 4 Vesta, in 1974, from his observatory, near Concord, in North Carolina, USA. Passion aroused quickly and he located 129 objects with his 25-cm telescope, then changed to a 51-cm telescope which allowed him to gain 1.5 magnitudes. On March 31, 1984 1847 Stobbe became his thousandth visual asteroid, less than 10 years after his start. Then, with a new 73-cm Newtonian, it took him only three years to see his second thousand, passing the 2000 mark on October 29, 1987 with 3250 Martebo. Five years later, he saw his 3000th visual object, (5189) 1990 UQ, on May 3, 1992. He accumulated asteroid observations including many Trojan and near-Earth objects. His farthest observed object is 2060 Chiron. He succeeded in recovering visually 2212 Hephaistos on December 16, 1987 at more than 1.1 minute of right ascension west of the predicted position. Harvey has also spotted hundreds of minor planets with true magnitudes fainter or brighter than those predicted. Now, light pollution at Concord is increasing, limiting his visual magnitude to 16.0 during clear nights. He moves from object to object by the coordinate circles and uses *Stellarum* charts with fainter stars from the *Lick Atlas*. He sometimes locates more than 20 asteroids per night, and many hundred objects during a typical year (374 in 1983). Once his targets are located, he returns to them twice in the night to confirm their motion. For his outstanding contribution, the IAU has honored him with the asteroid 4278 following the suggestion of J.U. Gunter and the agreement of B.J. Marsden. On May 15, 1998 his total was 3336 asteroids. Harvey holds by far the absolute record of different asteroids visually observed. When will he reach 4000?

Paul G. Comba is the third confirmed observer who has attained 1000 visual minor planet sightings. His first asteroid was 6 Hebe which he detected in September 1976. Most of his observations were made from Brookline, Massachusetts, USA, near Boston. He used a 8-cm spotting scope, a 15-cm refractor, a 20-cm Celestron, a 28-cm Schmidt-Cassegrain and telescopes of clubs, at Star Parties. In July 1992, Comba settled in Prescott, Arizona, USA, under clear skies. He bought a 46-cm NGT telescope with which he observed in June 1994 his thousandth visual asteroid 1018 Arnolda. He also

visually observed 2060 Chiron in 1995 and currently reaches magnitude V15, his faintest being V15.8. His score, in late 1996, was 1288 visual objects. Comba had also undertaken, since July 1994, to do astrometric measures of his own photographic objects. Hundreds of these measures have been published in the *Minor Planet Circulars*, in addition to the discovery of an asteroid of mag. V16.5. In April 1996, Comba stopped his visual observations and launched into the realm of CCDs with an ST8 camera and the software *Astrometrica*. Since this year, he accumulated results of more than 5300 astrometric positions and 393 provisional designations for new discoveries, most of magnitude 18 or 19. Seven of them have now been numbered.

Two years after Paul Comba, I was the fourth observer and the first European to become a member of the "Millennium Club". I observed my first asteroid, 4 Vesta, with my 7x50 binoculars, in Casablanca, Morocco, on July 19, 1975 and two others with my 90-mm telescope, before my return to France in March 1976. In 1978, I purchased a 20-cm Celestron and in 1979, only with the *Becvar Atlas Eclipticalis* and some ephemerides of bright asteroids, I saw 16 objects. In 1980, I began to use the Vehrenberg *Falkauer Atlas* and the *EMP* in 1981, to increase the number of observable objects. With the C8 my limiting magnitude was V13.5 during clear nights in Grenoble, where from my balcony, asteroids were visible three hours, after their passage across the meridian. Nevertheless, I reached a total of 250 objects during 1983. In 1984 and 1985, I made numerous expeditions in mountains to altitudes of 600m to 2500m. Under the best circumstances, Trojan asteroids up to V15.7 were seen with my C8. During the years 1985 and 1986, I wrote the chronicle "Le monde des petites planetes" in the french review *Pulsar* and in 1986, I moved to Varces, 12km south of Grenoble. There, the C8 limiting magnitude of V14.6 permitted me to detect some hundred known asteroids in 6 years. In late 1992, I bought a computer, the GSC catalog and the *Superstar* software to draw charts to a limit of V16. Unfortunately, *Superstar* calculations were always imprecise. The ephemerides had to be calculated with the Russian *Ceres* software and the asteroid positions plotted manually on *Superstar* charts. Since 1995, I pushed the magnitude limit near V16.0 with my C8 from a new observation site, at an altitude of 1170m. I observed notably 7 Iris with the naked eye, 2060 Chiron and about 40 asteroids with magnitude discrepancies. I also saw my 1000th asteroid by confirming the motion of 309 Fraternitas on June 14, 1996. On May 17, 1998, my total was 1141 asteroids visually seen. Now, I map charts with the excellent *Guide* software, eventually completed by the fainter stars of the *Microsky Atlas*. I hope to make asteroid discoveries and lightcurve measurements with my new CCD camera ST6, in the future.

Recently, Andrew Salthouse, Millington, New Jersey, USA, became the fifth person to reach the 1000 asteroid mark visually. On November 3, 1997 he confirmed his thousandth minor planet by seeing the motion of (5847) 1989 YB. Ceres was his first asteroid observed in November 1965 with his 11-cm reflector. Later, he saw a handful of other tiny planets over the years, principally with a 25-cm reflector. He was up to 54 by the end of 1990. Richard Binzel of MIT suggested to him to obtain information on the *Minor Planet Observer* newsletter. Then, with the use of the *MPO* charts and with his new home-made 44.5-cm Dobsonian, Salthouse started to observe asteroids more seriously and attained the score of 1000 in less than seven years. His observation site is very light polluted and the best he can do with his instrument is V14.4. Despite this bad sky, he has seen a small number of Trojans and made more than 6000 asteroid observations. On May 4, 1998 his total number of minor planets was 1045.

Two other amateurs may join the "Millennium Club" before the year 2000: Ben F. Hudgens, Memphis, Tennessee, USA, using 25-cm and 33-cm telescopes, under a polluted sky; Lawrence Garrett, Burlington, Vermont, USA, using a 32-cm Newtonian and some smaller telescopes. At the end of 1997, they respectively have observed 879 and 691 minor planets.

Lastly, in the past, two other observers came close to 1000 different asteroids. The first is Ray E. Fabre from Aiae in Hawaii, USA, who used a 20-cm then 33-cm and finally 44-cm Newton telescopes. After 15 years of observations, he had made in 1986 more than 1100 successful observations concerning 892 objects when he apparently stopped his program.

The second observer was the famous Austrian professional astronomer Johann Palisa (1848-1925) who visually discovered 121 asteroids, some fainter than magnitude V15, between 1874 and 1923 with the use of stellar charts patiently elaborated. No other astronomer has visually discovered more asteroidal objects. He used a 15-cm instrument at Pola Observatory, on the Adriatic coast and thereafter a 68-cm telescope at Vienna Observatory. He made thousands of excellent micrometric measures of asteroid positions, notably for the follow-up of Heidelberg Observatory objects photographically discovered since 1891. Palisa probably observed most of the 1039 minor planets already numbered before his death, considering his long career, but it is doubtful that he had seen 1000 different asteroids. Some objects were lost or non-existent and at that time astronomical news did not quickly go round between world observatories. Orbital elements were also more imprecise than now. In order to know his score, one should analyze Palisa observation reports and *the Astronomische Nachrichten* until 1924. The answer is surely in Germany or in Austria. Perhaps a local *MPB* reader will release it one day?

With the advent of CCD cameras, another era has begun... taking over from that of photographic and visual observers for whom it took long years to reach 1000 asteroids, a number accessible by an amateur in one or two months with CCD cameras. Nevertheless, visual observers can continue useful work by effecting the watch of stellar occultations by asteroids and by the observation of minor planets to detect those which magnitudes V and H would be inaccurate, through the participation to the Magnitude Alert Project of Lawrence Garrett. The most significant discrepancies visually found between 1980 and 1997 are in the table below. This table shows the interest of this type of visual work on asteroids.

I thank all the people who have helped me in the preparation of this paper, particularly Dr. Pilcher for his valuable assistance. Finally, I hope that this article will arouse new amateur vocations for asteroid observations and searches, whether by visual or other techniques, and that discoveries will be numerous.

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TABLE I. SELECTION OF GREAT DISCREPANCIES OF MAGNITUDE SEEN VISUALLY FROM 1980 TO 1997

ASTEROIDS	DISCREPANCY OBSERVED ON MAG.V	DATES	NAME OF OBSERVERS	MAG. B(1,0) EMP 87	MAG. H EMP 88-91	MAG.H EMP 92-97	REMARKS
	(F=fainter/B=brighter than predicted in the annual EMP)						
316 GOBERTA	1.2 +B	88/11/11	PILCHER	11.5	11.52	9.8	CORRECTION ON EMP92
473 NOLLI	1.0 +F	88/02/10	HARVEY		10.0	12.3	CORRECTION ON EMP92
1206 NUMEROWIA	1.6 +F	89/10/22	HARVEY	12.4	9.48	11.2	CORRECTION ON EMP92
1212 FRANCETTE	2.0 +F	80/02/12	PILCHER	8.0	9.38	9.54	CORRECTION ON EMP87
	0.8 +F	83/08/09	FABRE				(VAR.>= 0,04 MAG)
	2.2 +F	85/10/10	HARVEY				
1293 SONJA	1.8 +F	92/11/08	HARVEY	15.4	14.0	12.0	ERROR ON EMP92
	1.3-1.6 +F	96/08/09	FAURE				
1656 SUOMI	1.0 +F	87/11/21	HARVEY	15.4	13.1	12.4	ERROR ON EMP87/92
	1.1 +F	96/02/24	FAURE				
1663 VAN DEN BOS	1.5 +B	90/11/12	HARVEY	14.9	13.7	12.2	CORRECTION ON EMP92
1890 KONOSHENKOVA	1.0 +F	95/12/21	HARVEY	12.6	11.2	10.8	ERROR ON EMP92 ?
2143 JIMARNOLD	2.5 +F	97/08/31	FAURE	15.3	14.1	11.2	ERROR ON EMP92
2183 NEUFANG	1.0 +F	90/06/20	HARVEY	12.6	11.4	11.5	VAR. > 0,1 MAG
2491 TVASHTRI	1.5 +F	87/01/03	HARVEY	14.6	13.74	13.68	
2791 PARADISE	1.3 +F	88/01/24	HARVEY	13.0	11.5	12.24	VAR. 0,25 MAG
3578 CARESTIA	1.8 +F	91/10/04	FAURE		10.5	8.1	ERROR ON EMP89
	1.9 +F	91/10/13	HARVEY				
	3.0 +F	96/07/22	GARRETT				ERROR ON EMP92
	3.1 +F	96/09/04	GARRETT				
3873 RODDY	1.4 +F	92/12/03	HARVEY		13.1	11.8	ERROR ON EMP92
	1.3-1.6 +F	96/06/11	FAURE				
4116 ELACHI	1.2 +F	94/03/16	HARVEY		13.30	13.0	
4729 1980 RO2	1.3 +B	90/10/17	HARVEY			13.1	
4744 1988 RF5	1.2 +F	91/01/26	HARVEY		11.6	10.9	ERROR ON EMP92 ?
5641 MC CLEESE	1.7 +F	95/03/25	HARVEY			12.7	
5905 1981 CJ1	1.1-1.4 +F	95/08/02	HARVEY			13.0	

RECOVERIES, FOLLOW-UP OBSERVATIONS AND NUMBERING OF MINOR PLANETS

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(Received: 9 July Revised: 11 August)

This paper discusses follow-up observations of previously discovered asteroids, and the development of strategies to enhance the effectiveness of observations from discovery to numbering.

A previous paper (Comba 1997) described the author's minor planet observing activities at Prescott Observatory during the first fully-instrumented year of operation. Starting in March, 1996, observations were made with a 46-cm f/4.5 reflector and an ST-8 CCD camera, and analyzed with the Astrometrica program. The net results were the discovery of 207 minor planets, plus several hundred astrometric observations of other asteroids. (The referenced paper gave 210 as the number of discoveries, but it was later found that 3 of them were duplicates.)

This paper discusses the recoveries and re-observations of a subset of the first year's discoveries, and presents some strategies intended to improve the effectiveness of observations, from discovery to the numbering of the asteroids.

Review of discovery process

1. An observer obtains astrometric observations of a moving object on two nearby nights and sends them to the Minor Planet Center (MPC). The MPC tries to determine whether the observations pertain to a known object. If no such identification can be made, the object is given a provisional designation, such as 1996 FP3. In either case, the observer is informed of the result. The receipt of a provisional designation may be considered a discovery in the extended sense.

2. If further observation of the object are submitted to the MPC in the following weeks, the MPC computes a more precise orbit. It may then happen that, upon further checking, the new object is found to be identical to a previously discovered one that was given a different designation. The MPC then declares one of the designations to be the principal one, and the corresponding observer gets credit for the discovery. The principal designation is awarded not necessarily to the first discoverer, but to the one who first supplies the observations from which a "reasonable" orbit is determined.

3. When a minor planet has been observed repeatedly at several oppositions, so that a very precise orbit can be computed, it gets numbered. In the strict sense, a discovery is recognized only when the planet's number and the discoverer's name are published in the Minor Planet Circulars. The requirements for numbering are discussed further below.

Follow-up on first year discoveries

Table I classifies the discoveries made in the first year and their subsequent history. The class labels are briefly described in the body of the table. L+ and L- refer to objects that were identified (linked) with earlier discoveries, and were credited to the author or to another discoverer respectively. The numeric class labels refer to the number of days from the first to the last observation during the discovery opposition. In general, the objects in the classes L+, L- and 50+ were brighter than visual magnitude 18.5 at discovery, while the others were fainter. Among the class L+ objects, 11 had been observed at one previous opposition, 8 at two, and 2 at three.

One column shows the number of objects that were recovered (the term applies to objects that have been observed at a single opposition) or re-observed at a later opposition; this number does not include those that were subsequently numbered. The "missed" objects were searched for repeatedly over a fairly wide area, hence their residuals (observed minus calculated) were probably 15 arc minutes or more. The "too faint" could not be reobserved because of their being too faint, too low in the sky, or in the Milky Way.

The single "too faint" object in the 50+ class was 1996 UJ, a Mars crosser that was at opposition in May 1998 at magnitude 21, declination -43, and in the Milky Way--a triple whammy. The 3 rediscoveries of class 30- were unplanned and made accidentally by other observers.

Figure 1 is a plot of the recovery R. A. residuals as a function of the observation arc length. The R. A. residuals were in all cases much greater than the Dec. residuals. It should be noted that many recoveries occurred well before opposition, when the objects had a smaller apparent motion and less time had elapsed since the previous opposition observations. The median residual for class 50+ objects is 1.3 arc minutes, and it is clear from Figure 1 that almost all these objects could have been recovered even with a camera/telescope having a rather small field, say 10 arc minutes.

In light of the first year's experience, an effort was made in the second year to increase the number of discoveries of brighter objects (magnitude less than or equal to 18.5). This was achieved in part by doing some searches with a smaller telescope, 25-cm f/4, which yields a field of 47x31 arc minutes. Brighter objects are more likely to have been observed before, or of being observable for 50 days or more. As a result, while the total number of discoveries declined to 175, the number of class L+ or 50+ objects increased to 51.

Optimal patterns of observations

Beginning observers and discoverers tend to make unnecessarily many observations. To define a sufficient but non-redundant pattern of observations, one must consider several issues. First, how many observations of the same field should be made on a given night? If the purpose is to discover new objects, the answer is two, and the images should preferably be

Table I. Disposition of first year discoveries

Class	Description	Total	Reobs/ recov	Reobs & numbered	Missed	Too faint
L+	Linked, credited to author	21	10	8		3
50+	Arc of 50 days or more	21	20			1
30-49	Arc of 30 to 49 days	9	3		3	3
30-	Less than 30 days, 3+ nights	76	3			
2N	2 nights	73				
L-	Linked, credited to others	7				