J. Andersen (ed.), Reports on Astronomy, Vol. XXIVA , 85–92.
©2000 IAU. Printed in the United States of America.

DIVISION III: PLANETARY SYSTEMS SCIENCES

(SCIENCES DES SYSTEMES PLANETAIRES)

PRESIDENT: Michael F. A'Hearn
BOARD: W. J. Baggaley, Catherine de Bergh, Stuart Bowyer, Martha S. Hanner, Christoph Leinert, Mikhail Marov, Hans Rickman, Jill Tarter, Iwan P. Williams, Donald K. Yeomans & Vincenzo Zappalá

Commission 15: Physical Study of Comets, Minor Planets, and Meteorites
Commission 16: Physical Study of Planets and Satellites
Commission 20: Positions and Motions of Minor Planets, Comets, and Satellites
Commission 21: The Light of the Night Sky
Commission 22: Meteors and Interplanetary Dust
Commission 51: Bioastronomy

1. SCIENTIFIC OVERVIEW

Because the division consists of many very active commissions, most activities are included in the reports of the individual commissions. This report highlights a small subset of the major achievements that are covered in detail in the reports by the commissions. Some administrative activities of the division and reports of the divisional working groups and committees are also included as subsequent sections of this divisional report.

This triennium saw an explosion in the rate of discovery of trans-Neptunian objects, and the beginnings of physical studies of these objects, dramatically increasing our understanding of the outer portions of the solar system (Commissions 15 and 20). We similarly saw a doubling of the known planetary systems around stars other than the sun, particularly including a system with multiple identified planets around υ And (Commission 51). Major advances in understanding the planets have come from many sources. ISO, for example, was used to quite unexpectedly detect water in the stratospheres of all the giant planets, a result implying infall of material to the giant planets. A variety of observations from both Galileo and HST have provided information on the properties of the ocean predicted to lie under the surface of Europa. In the inner solar system, observations from Lunar Prospector showed significant abundances of H, inferred to be in ice, in craters near the poles of the moon (Commission 16). The advent of comets Hyakutake and Hale-Bopp have led to dramatic new results on the physics and particularly the chemistry of comets (Commission 15). New routes from the main belt to Earth by way of Mars-crossing orbits have been identified that appear capable of explaining the observed number of large NEAs and Mars crossers (Commission 15). The prediction of meteor "storms" of the Leonids in 1998 and 1999 has drawn considerable public and scientific attention (Commission 22). Some of the ISO results on interplanetary dust have also proven interesting (Commissions 21 and 22).

2. WORKING GROUP ON NEAR-EARTH OBJECTS

The members of the Working Group on Near-Earth Objects (WG NEO) for the 1996-1999 triennium were: Richard P. Binzel, Edward Bowell, Andrea Carusi (*Vice-Chairman*), Clark R. Chapman, Paolo Farinella, Alan W. Harris, Syuzo Isobe, Brian G. Marsden, Andrea Milani, David Morrison (*Chairman*), Karri Muinonen, Syuichi Nakano, Steven J. Ostro, Hans Rickman, P. Kenneth Seidelmann, Viktor Shor, Iwan P. Williams, and Donald K. Yeomans.

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press

2.1. Charge to the Working Group

This WG is sponsored jointly by Divisions I and III, with a charge to provide on behalf of the IAU (1) Liaison with SpaceGuard Foundation (2) Advice on coordination of NEO activities worldwide (3) Advice on reporting of NEO hazards, and (4) Advice on research relevant to NEOs. In addition, the WGNEO provides rapid peer review of reports or discoveries of NEOs that may pose a danger to the Earth, and it advises the IAU on technical issues relevant to public positions about the danger of NEO impact.

2.2. Background

A number of minor bodies in the solar system (asteroids and comets) exist whose orbits intersect or pass close to that of the Earth. The possibility therefore exists that some of these bodies may impact sometime in the future, as has happened throughout solar system history. Although estimated time scales for impacts with catastrophic consequences range from hundreds of thousands to millions of years, there are good reasons, scientific as well as social, for conducting vigorous research programmes to improve our knowledge of these bodies. In particular, it is the primary objective of current searches for NEOs to discover all NEOs larger than 1 km diameter and to project their orbits forward in time to determine if any poses a near-term threat to the Earth. As the knowledge of NEO orbits improves, we move from a position of estimating statistical probabilities toward a posture in which any future impact can be accurately predicted, providing a warning time of decades in which mitigation efforts may be initiated.

2.3. Recent Progress in NEO Research

During the triennium 1996-1999, the rate of discovery of NEOs has greatly accelerated, due in part to the increasing capability of automated wide-field cameras and search software, and in part to the dedicated efforts of a small number of observers. In the United States, the National Aeronautics and Space Administration (NASA), in collaboration with the US Air Force, is implementing a search program to meet the objectives of the Spaceguard Survey, as set down in the NASA Spaceguard reports of 1992 and 1995. Follow-up of the discovery observations is provided by a largely volunteer team of international observers, both professional astronomers and amateurs. The objective of this effort is to discover 90% of Near Earth Asteroids (NEAs) larger than 1 km by the end of 2009.

The table provides a summary of recent discovery performance prepared by Alan Harris. The values in the table are the numbers of NEOs brighter than absolute magnitude 18.0 (*i.e.*, D > 1 km) discovered in successive 6-month periods by various teams.

Table 1. NEA DISCOVERIES JULY 97 THROUGH JUNE 99 (D > 1 km)

Discoverer	97(2)	98(1)	98(2)	99(1)
LINEAR	2	10	26	21
NEAT	3	5	2	0
Spacewatch	1	2	1	5
LONEOS	0	0	4	3
Catalina	0	0	0	3
Other	2	2	2	2
Total	8	19	35	34

By the middle of 1999, we had discovered almost 20% of the NEAs larger than 1 km. However, the recent performance of the survey as shown in the table is roughly a factor of 5 below that required to meet the Spaceguard goal of 90% completeness by 2009.

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press

Two newly discovered NEAs attracted special attention by the media and public as well as the astronomical community. In March 1998 asteroid 1997 XF11 was incorrectly reported as posing a danger of impact in 2028, creating world-wide attention and concern. An accurate orbit was calculated and a correction issued within 24 hours, but the event led to some criticism of the science community for issuing the false-alarm. In 1999, there was a similar interest in future close approaches of asteroid 1999 AN10, but this time the science community carried out a more careful internal review that showed that the danger of impact was negligible. These cases led to the proposal of an IAU procedure for providing rapid peer review of cases of possible threats, and also to the adoption by most of the NEO community of the "Torino Scale" for impacts. Both of these are discussed further below.

In addition to ground-based surveys and a much deeper understanding of orbital dynamics of NEOs, the current triennium has seen excellent progress in the radar imaging of NEOs and in their direct investigation by spacecraft. In particular, the NASA Near Earth Asteroid Rendezvous (NEAR) spacecraft made a close flyby of NEA 433 Eros in 1998 and is scheduled to begin orbiting this asteroid in February 2000.

2.4. The 1999 IMPACT Workshop in Torino, Italy

Following is a brief summary of results of a well-attended workshop held in June 1999 on the subject of International Monitoring Programs for Asteroid and Comet Threats:

- Search and Discovery: The rate of discovery of NEAs has greatly accelerated, as reported above. However, to meet the Spaceguard objective of discovering 90% of NEAs > 1 km in diameter by 2009, it will be necessary to extend the search down to visual magnitude 20.5, which has not been demonstrated for 1-m telescopes.

- Follow-up Observations: NEA discoveries must be rapidly followed up to determine orbits. Many groups, including amateur astronomers, now contribute to follow-up observing programs. This work is quite effective, but as the discovery rate of faint NEAs increases, there may be a problem with follow-up.

- Availability of data: As the number of NEA observers increases, and as more people have the capability to calculate orbits and impact probabilities, we should move toward more rapid dissemination of data on NEA positions.

- Cooperation and Coordination: A successful Spaceguard program requires detailed coordination of observations to avoid redundancy and make full use of the available resources. Some observers are already posting their observing plans on the Internet. Better coordination will be required, however, as the rate of discovery continues to increase.

- Physical Characterization: There is a continuing need for physical characterization of NEOs, primarily using ground-based telescopes and radar. In addition, a number of spacecraft missions to comets and asteroids are planned or underway, which should greatly increase our knowledge of the nature of these objects.

2.5. Proposed IAU procedural guidelines in the event that a potentially Earth-threatening object is discovered

The IAU WGNEO, believing that NEO scientists have a professional obligation to seek peer review of their results before any public announcement of impact risk or threat, recommends the following procedures to be available to the members of the astronomical community in any future case of discovery and/or theoretical analysis leading to the prediction of impacts that fall at level 1 or higher on the Torino Impact Hazard Scale.

The IAU establishes the following review procedure available on a voluntary basis to all scientists involved in prediction of possible NEO impacts. The information leading to

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press

such a prediction, consisting of an evaluation of the case and all data and computational details necessary to understand and reproduce the studies carried out by the authors, shall be transmitted for confidential review to the chair of the WGNEO, the General Secretary of the IAU, and the members of the WGNEO Review Team, before any announcement and/or written document on the subject be made public on any information media, including the World Wide Web. The membership of the standing Review Team will be selected by the Chair of the WGNEO with the concurrence of the Division III President and the General Secretary, with names and e-mail addresses posted on the IAU NEO webpage. The individual members of the NEO Review Committee shall review the work for technical accuracy and shall communicate within 72 hours the results of their reviews to the Chairman of the WGNEO and directly to the authors of the report or manuscript.

If the consensus of the above review supports the conclusion that there is a significant impact risk, the results of this analysis will be posted on the IAU webpage for public access. If the review disagrees with the original analysis or if there is not a consensus among the reviewers, the confidential results of the review will be given to the authors so they can revise or improve their work, as they see fit. The news posted on the WGNEO webpage shall represent the official position of the IAU; no further information will be provided by the WGNEO, unless important updates become necessary.

The authors of the work are encouraged to refer the media to this IAU position if they choose to make a public release of their conclusions. If so requested by various agencies (e.g., NASA or ESA), the IAU will also inform the responsible officials of these agencies of the results of the WGNEO review.

2.6. The Torino Scale for Impact Hazards

The Torino Scale is a "Richter Scale" for categorizing the Earth impact hazard associated with newly discovered asteroids and comets. It was developed by Richard Binzel to serve as a communication tool for astronomers and the public to assess the seriousness of predictions of close encounters by asteroids and comets during the 21st century.

The Torino Scale utilizes numbers that range from 0 to 10, where 0 indicates that an object has a zero or negligibly small chance of collision with the Earth. (Zero is also used to categorize any object that is too small to penetrate Earth's atmosphere intact, even if a collision will occur.) A 10 indicates that a collision is certain, and the impacting object is so large that it is capable of precipitating a global climatic disaster.

The description of the Torino Scale as well as additional information on NEOs is posted on the internet at (impact.arc.nasa.gov), which also provides access to many other websites dealing with NEOs, such as the Spaceguard Foundation (spaceguard.ias.rm.cnr.it/SGF) and the NASA NEO Program Office (neo.jpl.nasa.gov). The IAU Minor Planet Center is found at (cfa-www.harvard.edu/cfa/ps/mpc.html), while the general IAU website for NEOs is (www.iau.org/neo.html)

David Morrison
Chairman of the Working Group

3. SMALL BODIES NAMES COMMITTEE

The members of the Small Bodies Names Committee (SBNC) for the 1996–1999 triennium were: Michael F. A'Hearn (*Chairman*), Kaare Aksnes, Julio Fernández, Pam M. Kilmartin, Yoshihide Kozai, Brian G. Marsden (*Secretary*), Hans Rickman, Lutz D. Schmadel, Viktor A. Shor, Richard M. West and Donald K. Yeomans.

During the 23rd General Assembly, it was decided that this committee would move from Commission 20 to Division III. This better reflected the wider interests in naming comets and minor planets than did its previous position with Commission 20 since there are two different commissions within the division that deal primarily with these bodies.

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press

During the triennium the SBNC adopted names for 1478 new minor planets, a 53-percent increase over the number of names adopted during the previous triennium. New names, together with their citations, are published in the *Minor Planet Circulars* (*MPC*s), generally at intervals of two months. Names and citations are also collected in the *Dictionary of Minor Planet Names* (*DMPN*), the third edition of which contained explanations for all but 124 of the names assigned to 5252 of the first 7041 numbered minor planets. Edited by Schmadel, this edition was published in 1997, and a fourth edition should be available in 2000.

It is important to note, however, that as many as 3945 minor planets were given new numbers during the triennium and therefore became eligible for naming. The naming/numbering ratio of 37 percent was dramatically down from the 67 percent of the previous triennium. In terms of the totality of objects numbered and named, the ratio of 74.6 percent in mid-1996 was only slightly down from the 76.4 percent in mid-1993; yet the ratio had dropped to only 61.3 percent in mid-1999.

The lowest-numbered minor planet unnamed as of mid-1999 was (3337), while the highest-numbered minor planet named was (10233). In giving to (10000) the name *Myriostos* (Greek for ten-thousandth), the intent was to honor "all the astronomers, past and present, from all around the world, professional and amateur, observer and orbit computer, who participated, over an interval of 198 years, in the achievement of accumulating 10 000 minor planets with orbit determinations of the highest quality". There was some consideration that the number (10000) should be given to Pluto, thereby conveniently paving the way for numbering and naming other members of the Transneptunian Belt. This proposal had widespread international support but there was also a vocal opposition and the matter was resolved at the divisional level (see below).

The rapidly increasing lag between numbering and naming a minor planet can at least partly be interpreted as an indication that some of the leading discoverers have already "scraped the bottom of the barrel" of good ideas. Certainly, a spate of recent names honoring genera of trees and endangered species of birds does little to dispel this impression. Furthermore, some members of the SBNC have questioned the tradition whereby minor planets are named for family members of their discoverers. Understandably, the question came up as to whether it would be appropriate simply to stop naming minor planets completely. After all, one can argue that the principal purpose of a name is to provide redundancy if the number is given incorrectly. But the minor planet's principal provisional designation already provides that redundancy. In any case, if the IAU stops naming minor planets, it could be guaranteed that there would somewhere be an "International Asteroid Registry" eager to take up the task—for a fee. A better alternative would be to encourage discoverers to be imaginative in the names they choose. It has also been suggested that, as in the case of the Working Group on Planetary System Nomenclature, the members of the SBNC play an active role in actually proposing names for minor planets.

Nevertheless, the actual rate of naming can be expected to increase, and with this comes an increase in the problem of the preparation and publication of citations. Beginning in mid-1997, Susan Russell, president of The Russell Mark Group of "name specialists", has provided invaluable assistance editing citations on a *pro bono* basis. Even so, the amount of space needed for publishing the citations has become a problem for both the *MPC*s and the *DMPN*, and the decision has been made to restrict the text of future citations to a maximum of four printed *MPC* lines.

The SBNC has rejected the names proposed for some minor planets, usually on the grounds that the proposals are "too nearly similar" to existing names of other minor planets. In many such cases an appropriate modification of the name has been adopted instead, perhaps after some delay. In a few cases a name has been considered quite unsuitable, although even then, the SBNC has attempted to work with the proposer in the hope of finding a satisfactory alternative. Although it may not be widely known, there does exist a procedure for appealing an SBNC rejection or for a waiving of the rules. Involving action

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press

at an IAU General Assembly, the procedure has been applied precisely twice during the past decade and a half, in one case successfully.

Of the 161 comets that received designations during the triennium, all but one were named, the single case of comet X/1998 G3 being excluded because it was not possible to determine an orbit. For comets the name provides at least partial redundancy, and given that most discoveries nowadays come from a few organized search programs, it provides a useful indication of whether a particular comet is a sungrazer found by the Solar and Heliospheric Observatory (the name SOHO being applied to 69 comets during the triennium, an all-time record for a single "discoverer") or, perhaps, a cometary object found by the Lincoln Laboratory Near Earth Asteroid Research project (with the name LINEAR going to 28 comets during the triennium, as well as to one in combination with the name of an independent discoverer).

A particular problem that has come up with increasing frequency is that CCD detection may not indicate observationally that an object is other than a minor planet. Cometary nature may then be established "accidentally" by another observer who either makes an independent discovery or follows up what appears to be a main-belt minor planet. Alternatively, cometary nature may be established "deliberately" in the course of follow-up observations of an object already recognized as unusual (e.g., by placement in The NEO Confirmation Page) from its apparent motion, or even an unequivocal computation of the orbit. In an accidental case, it is thought that some credit should go to an individual who recognizes the object to be a comet. For that reason the SBNC took an unusual step and resolved to change the name of comet C/1997 L1 to "Zhu-Balam", honoring both the person who discovered the object itself and the person whose routine observations showed the presence of a tail (see *IAU Circular* 6811). On the other hand, if an object discovered in one of the established CCD search programs is found to be a comet, that comet will usually not be named for an individual observer, except in a case where that observer is actually at the telescope and it is immediately recognized as a comet.

The guidelines for naming both comets and minor planets, which had been developed gradually through various resolutions of Commission 20, were updated and annotated to deal with the situations discussed above and to illustrate how the SBNC implements some of the guidelines. The guidelines are now maintained online at the committee's web pages at www.ss.astro.umd.edu/IAU/sbnc/. If the web address moves with changes in SBNC membership, it will still be reachable through the IAU's pages with links to Division III.

Since the guidelines for both comets and minor planets have not previously been collected in a single place, they are printed here, without the extra commentary, to provide a convenient summary.

3.1. Guidelines for Names of Minor Planets

- Discoverers have the privilege to propose names for ten years after numbering. Beyond that point, others may propose names.

- Names must be pronounceable, preferably expressible as a single word, and no more than 16 characters in length.

- Individuals or events principally known for political or military activities are unsuitable until 100 years after the death of the individual or the occurrence of the event.

- Names of pet animals are discouraged.

- Minor planets in certain dynamical groups should be named within more restrictive guidelines. For example,

  - Trojan asteroids (those that librate in 1:1 resonance with Jupiter) are named for heroes of the Trojan War (Greeks at L4 and Trojans at L5).

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press

- Trans-Jovian planets crossing or approaching the orbit of a giant planet but not in a stabilizing resonance are named for centaurs.
- Objects crossing or approaching the orbit of Neptune and in stabilizing resonances other than 1:1 are given mythological names associated with the underworld. (Planned guideline to follow the example of Pluto.)
- Objects sufficiently outside Neptune's orbit that orbital stability is reasonably assured for a substantial fraction of the lifetime of the solar system are given mythological names associated with creation. (Planned guideline - none yet named)
- Objects that approach or cross Earth's orbit are given mythological names.

- Any decision of the SBNC with which a proposer disagrees may be appealed by the proposer. Appeals should be addressed to the president of Division III, for action by the membership at the General Assembly.

3.2. Guidelines for Names of Comets

- Comets are generally named for their discoverers, although this need not always be the case.
- When a discovery is made by a team working together, whether on a single telescope or multiple telescopes, a single name will usually be given to the comet. The discovering team is free to suggest what that single name should be - whether it is a single name or acronym for the entire team or the name of an individual on the team who played a major role in the discovery.
- In the case of multiple, independent discoveries, the names of up to three independent discoverers may be assigned, although the actual number of names assigned in a particular case is at the discretion of the SBNC. When multiple names are assigned for independent discoveries, the names will usually be assigned in chronological order of the observations if that is easily and unambiguously determinable. In other cases, the CBAT and SBNC will make a determination of the order that seems most fair.
- Comets for which there are insufficient observations to determine an orbit will generally not be named (these comets receive X/ designations).

Michael F. A'Hearn
Chairman, SBNC
Brian G. Marsden
Secretary, SBNC

4. DIVISIONAL MATTERS

The most public activity of the division as a whole involved discussion of the status of Pluto and whether it should be included either in the catalog of Minor Planets as the first of many trans-Neptunian objects or in a separate catalog of trans-Neptunian objects. Proponents of doing either argued that the recent discovery of trans-Neptunian objects, commonly called plutinos, in the same commensurability with Neptune as is occupied by Pluto indicated a genetic relationship that improved our understanding of how Pluto came to be in its present orbit. Opponents argued that inclusion of Pluto in such a catalog would imply demotion from its status as a planet, which would be inconsistent with historical practice and argued that rather we should call Ceres a planet, with shape controlled by gravity rather than structural strength. After considerable discussion in the community and in the press, it became clear that a significant fraction of the relevant scientific community was

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press

strongly opposed to including Pluto with both classes of bodies with which it clearly shares properties, even with a reaffirmation of Pluto's status as a planet and regardless of the genetic relationship between Pluto and the plutinos. Division III therefore recommended that no action be taken to include Pluto in any catalogs of trans-Neptunian objects, whether the Minor Planet Catalog or a separate catalog.

Another significant activity of the division was to begin consideration of how best to include the study of non-solar planetary systems within the IAU. The IAU Executive Committee authorized formation of a working group to study the issue and report at the General Assembly. The working group is being urged to adopt the previous work of Commission 51 (see their report) in setting up the criteria for cataloging non-solar planetary systems. The membership of this working group was being established at the time of writing this report. There is, therefore, no report from this working group in this volume.

Michael F. A'Hearn
President of the Division

https://doi.org/10.1017/S0251107X00002649 Published online by Cambridge University Press