The Interplanetary Network Supplement to the BATSE Catalogs of Untriggered Cosmic Gamma-Ray Bursts

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ABSTRACT

We present Interplanetary Network (IPN) detection and localization information for 211 gamma-ray bursts (GRBs) observed as untriggered events by the Burst and Transient Source Experiment (BATSE), and published in catalogs by Kommers et al. (2001) and Stern et al. (2001). IPN confirmations have been obtained by analyzing the data from 11 experiments. For any given burst observed by BATSE and one other distant spacecraft, arrival time analysis (or “triangulation”) results in an annulus of possible arrival directions whose half-width varies between 14 arcseconds and 5.6 degrees, depending on the intensity, time history, and arrival direction of the burst, as well as the distance between the spacecraft. This annulus generally intersects the BATSE error circle, resulting in a reduction of the area of up to a factor of \( \sim 650 \). When three widely separated spacecraft observed a burst, the result is an error box whose area is as much as 30000 times...
smaller than that of the BATSE error circle.

Because the IPN instruments are considerably less sensitive than BATSE, they generally did not detect the weakest untriggered bursts, but did detect the more intense ones which failed to trigger BATSE when the trigger was disabled. In a few cases, we have been able to identify the probable origin of bursts as soft gamma repeaters. The vast majority of the IPN-detected events, however, are GRBs, and the confirmation of them validates many of the procedures utilized to detect BATSE untriggered bursts.

Subject headings: gamma-rays: bursts; catalogs

1. Introduction

This paper presents the 8th catalog of gamma-ray burst (GRB) localizations obtained by arrival time analysis, or “triangulation” between the missions in the 3rd interplanetary network (IPN), which began operations in 1990 and continues to operate today. Two of these catalogs (Hurley et al. 1999a,b) were supplements to the BATSE 3B and 4Br burst catalogs (Meegan et al. 1996; Paciesas et al. 1999). The others involved bursts observed by numerous other spacecraft (Laros et al. 1997, 1998; Hurley et al., 2000a,b,c). In this paper, we present IPN data on 211 untriggered bursts which occurred throughout the entire Compton Gamma-Ray Observatory (CGRO) mission (1991 April through 2000 May). The BATSE data on these events, such as durations, fluxes, fluences, and coarse location information, appear in two catalogs, Kommers et al. (2001) and Stern et al. (2001). A final IPN supplement catalog, to the BATSE 5B catalog, is in preparation (Hurley et al. 2004, Briggs et al., 2004).

The purpose of searching the BATSE data for untriggered events was mainly to extend the number-intensity (log N-log S) distribution to weaker bursts than those that could trigger the detector, and thus to gain more information on the burst distribution, particularly at the weak end. Other objectives included the detection of bursts from known and unknown soft gamma repeaters, and very soft transients which could constitute a previously unknown phenomenon. (One significant outcome of this effort was the detection of the bursting pulsar). The purpose of searching the IPN data for these events was to confirm as many of them as possible, reduce the sizes of their error circles, and validate the procedures used to identify these untriggered events.
2. Instrumentation, Search Procedure, Derivation of Annuli, and Burst Selection Criteria

We have used the same procedures as those employed in the other BATSE catalog supplements, and refer the reader to Hurley et al. (1999a,b) for the detailed descriptions. Generally speaking, using the arrival time and direction of a burst at BATSE, and its time history, we searched the data of the near-Earth spacecraft for a confirmation at the same time; for the spacecraft which were far from Earth, we searched for a confirmation (i.e., an event with a matching time history) in the appropriate crossing time window. Although more than 15 separate gamma-ray burst experiments were operating on over a dozen missions throughout the duration of the CGRO mission, confirmations were obtained from the data of just 11 experiments: the BeppoSAX Gamma-Ray Burst Monitor (Frontera et al. 1997; Feroci et al. 1997), the Defense Meteorological Satellite Program (DMSP, Terrell et al. 1992), Ginga (Murakami et al. 1989), Konus-A (Aptekar et al. 1997), Konus-Wind (Aptekar et al. 1992), the Near Earth Asteroid Rendezvous mission (NEAR, Goldsten et al. 1997), PHEBUS (Terekhov et al. 1994), Pioneer Venus Orbiter (Klebesadel et al. 1980), SROSS C-2 (Kasturirangan et al. 1997), Ulysses (Hurley et al. 1992), and WATCH - GRANAT (Brandt, Lund, & Rao 1990). We note here, however, two important differences in the procedures and results between the triggered and untriggered events.

First, the untriggered burst catalogs contain a much higher proportion of weak events than the BATSE triggered burst catalogs. Because the IPN instruments are generally much less sensitive than BATSE, they detected a smaller fraction of the untriggered than the triggered ones.

Second, the untriggered event time histories were recorded in the 1.024 s resolution BATSE data, while the triggered event time histories were recorded with much higher time resolution. Thus when an untriggered event was detected only by BATSE and another near-Earth spacecraft, the low time resolution and the proximity of the two spacecraft results in a very wide annulus which is consistent with, but does not constrain the BATSE error circle. Twenty-one events fell into this category, and it is only possible to confirm their detection, but not to obtain a meaningful annulus or error box for them.

3. A Few Statistics

There are 873 untriggered bursts in the Kommers et al. (2001) catalog and 1838 untriggered bursts in the Stern et al. (2001) catalog. The two sets are not mutually exclusive (Stern et al. 2001), and the total number of untriggered bursts is approximately 2000, de-
pending on the exact acceptance criteria. Their peak fluxes range from 0.06 to 25 photons cm\(^{-2}\) s\(^{-1}\). Figure 1 gives the IPN efficiency for detecting untriggered bursts as a function of their peak fluxes. This is defined as the number of bursts detected by the IPN divided by the total number of untriggered bursts in a particular flux range. There are many factors which determine whether a burst is detected by an IPN spacecraft. In addition to the burst intensity and time history, solar activity, Earth-blocking for spacecraft in low Earth orbit, the number of spacecraft active in the IPN, and data return all play important, time-variable roles. Figure 1 therefore gives time-averaged efficiencies. Approximately one out of nine untriggered BATSE bursts was observed by at least one spacecraft in the IPN. Their fluxes range from 0.15 to 25 photons cm\(^{-2}\) s\(^{-1}\). For comparison, approximately one out of every three triggered BATSE bursts was observed by IPN spacecraft (Hurley et al. 1999b). Of the 211 IPN events, only 90 could be localized (85 to annuli only, and 5 to error boxes).

4. Tables of Confirmed Bursts, Annuli, and Error Boxes

For each confirmed untriggered burst, table 1 lists the spacecraft which observed the event. (A list of all GRBs and the IPN spacecraft which detected them may be found at http://ssl.berkeley.edu/ipn3/masterli.html or http://heasarc.gsfc.nasa.gov/W3Browse/.)

For those bursts which can be localized, either to a single annulus whose width is comparable to or less than the diameter of the BATSE error circle (an example is shown in figure 2), or to an error box (an example is shown in figure 3), the 6 columns in table 2 give:

1) the date of the burst, in yymmdd format, 2) the Universal Time of the burst at Earth in seconds, 3) the right ascension of the center of the IPN annulus, epoch J2000, in the heliocentric frame, in degrees, 4) the declination of the center of the IPN annulus, epoch J2000, in the heliocentric frame, in degrees, 5) the angular radius \(R_{IPN1}\) of the first IPN annulus, in the heliocentric frame, in degrees, and 6) the half-width \(\delta R_{IPN1}\) of the first IPN annulus, in degrees; the 3 \(\sigma\) confidence annulus is given by \(R_{IPN1} \pm \delta R_{IPN1}\).

If the burst was detected by a third, distant spacecraft, and a non-degenerate second annulus could be derived for it, the information in columns 4, 5, and 6 is repeated for this annulus.

For the bursts in table 2, table 3 gives the BATSE error circles, from Kommers et al. (2001) and Stern et al. (2001), and either a) the intersection points of the IPN annulus with the error circle, or b) for the three-spacecraft localizations, the four corners of the IPN error box.
For each entry, the first line contains:

1) the date of the burst, in yymmdd format, 2) the Universal Time of the burst at Earth, in seconds, 3) the right ascension of the center of the BATSE error circle, in degrees, 4) the declination of the center of the BATSE error circle, in degrees, and 5) the radius of the BATSE error circle, in degrees; this is the combination of the one sigma statistical error and a 1.6 degree systematic error, summed in quadrature.

The four following lines contain the right ascension and declination, in degrees, of the error box. For those bursts which were observed by BATSE and a single IPN spacecraft (e.g. figure 2), the coordinates are those of the intersection of the $3\sigma$ IPN annulus with the $1\sigma$ (statistical plus systematic) BATSE error circle. Although all of the annuli are statistically consistent with the positions of their respective $1\sigma$ BATSE error circles, in some cases part or all of the annulus does not actually intersect the error circle. In those cases, the coordinates are set to zero. For those bursts which were observed by two distant IPN spacecraft (e.g. figure 2), and for which an IPN-only error box can be derived, the coordinates given are those of the IPN error box.

All coordinates are J2000, and all event times are the ones used to identify the bursts in the Stern et al. (2001) and Kommers et al. (2001) catalogs.

5. Notes on specific events

We note here a number of unusual circumstances surrounding some of the bursts in the Stern et al. (2001) and Kommers et al. (2001) catalogs.

- Some of the bursts in the two catalogs in fact correspond to BATSE triggers. In some cases, the triggers were not caused by the bursts, but the bursts were nevertheless recorded in triggered mode.

- The Kommers et al. (2001) catalog was divided into two parts: high energy (HE) events, and low energy (LE) events. Initially, there were 125 LE events, but 75 of them were intentionally eliminated from the final catalog because their origin was suspected to be either magnetospheric, X-ray binaries in outburst, or activity from soft gamma repeaters (SGRs). We have identified four of the 75 eliminated events as bursts from SGR1806-20. These four can be found in the complete list of SGR bursts identified in the Kommers et al. (2001) search, available at http://space.mit.edu/BATSE/data.html.

- A total of 9 of the untriggered events probably originated from soft gamma repeaters. In some cases, they had in fact triggered BATSE and were recorded in triggered mode.
The IPN localizations of these SGR bursts serve as a good calibration of the techniques and data used here, however. They verify, for example, that the 1 s resolution BATSE data files in the Stern et al. (2001) and Kommers et al. (2001) catalogs have the correct timing, and that the localization procedures used in these catalogs, and by the IPN, are accurate.

The following list gives the details.

GRB920903, 05728 s. This burst was observed by WATCH-GRANAT (Sazonov et al. 1995). Both the Ulysses/WATCH and Ulysses/BATSE annuli are consistent with the WATCH error circle, but do not intersect the BATSE error circle. The BATSE error circle lies $\sim 7$ degrees away from the WATCH error circle, but is consistent with it, given the statistical and systematic uncertainties. The intersection of the narrower Ulysses/BATSE annulus with the WATCH error circle is given here.

GRB920920, 04415 s. This event was recorded in triggered mode following BATSE trigger 1948. The trigger occurred due to a different GRB.

GRB930209, 15737 s. This event was recorded in triggered mode following BATSE trigger 2177. The trigger occurred due to a solar flare.

GRB930702, 68333 s. This burst corresponds to BATSE trigger 2426, which is believed to be a Cygnus X-1 fluctuation.

GRB931005, 82288 s. This burst is a Kommers et al. (2001) LE event which was eliminated from the final catalog. It is BATSE trigger 2565, from SGR1806-20.

GRB940710, 35477 s. This event occurred 251 s before BATSE trigger 3071, whose duration is $T90=71$ s. The location of the Kommers et al. (2001) event is RA, Decl. = 99.4°, -33.3°, with uncertainty 3.4°, and that of BATSE 3071 is RA, Decl. = 96.42°, -36.59°, with uncertainty 1.33°. The centers of the two circles are therefore 4.1° apart. The IPN annulus is consistent with both error circles. Thus the Kommers et al. (2001) event may be a precursor to 3071.

GRB950730, 76147 s. This burst is a Kommers et al. (2001) LE event which was eliminated from the final catalog. The IPN annulus is consistent with the position of SGR1806-20.
GRB961119, 21536 s. This burst is a Kommers et al. (2001) LE event which was eliminated from the final catalog. It is probably from SGR1806-20, but it cannot be triangulated with any precision.

GRB961119, 26961 s. This burst is a Kommers et al. (2001) LE event which was eliminated from the final catalog. It is probably from SGR1806-20, but it cannot be triangulated with any precision.

GRB980622, 51085 s. This event is BATSE trigger 6861. It originates from SGR1627-41.
GRB980728, 64911 s. This event is BATSE trigger 6954. It originates from SGR1627-41.
GRB980801, 12920 s. This event is BATSE trigger 6959. It originates from SGR1627-41.
GRB980913 at 19983 s. This is BATSE trigger 7087.
GRB981022, 56447 s. This event is BATSE trigger 7171, from SGR1900+14.
GRB990110, 31141 s. This is BATSE trigger 7315. This burst originates from SGR1900+14.
GRB990429, 35555 s. This event is BATSE trigger 7536. It originates from SGR1900+14.
GRB990507, 71334 s. This is BATSE trigger 7552.
GRB991101, 54480 s. This is BATSE trigger 7835. It is probably a GRB observed with particle contamination.

6. Discussion and Conclusion

The Kommers et al. (2001) and Stern et al. (2001) studies of untriggered BATSE bursts pointed to different conclusions about the GRB population. The sample of Stern et al. provides evidence for a GRB number-intensity relation which continues to increase at low intensities, while the sample of Kommers et al. provides evidence for a flattening. The analysis which we have presented here indicates only that many of the events with peak fluxes above $\sim 0.15$ photon cm$^{-2}$ s$^{-1}$ are likely to be real, and that relatively few of them have been misclassified. The likelihood of reality increases with peak flux (figure 1). As there are hundreds of untriggered bursts below the IPN threshold, the possibility exists that the different conclusions about the number-intensity relation are due to the differences in classifying weak untriggered events. A recent study of untriggered BATSE bursts by Mitrofanov et al. (2004) reinforces and quantifies this idea. While this study is a preliminary one and does not draw any conclusions about the weak events, it should eventually lead to a clearer classification of them. A definitive statement about the weak burst population may
also be forthcoming after the launch of the Swift mission (Gehrels et al. 2004).

7. Acknowledgments

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FIGURE CAPTIONS

Fig. 1.— The IPN efficiency for detecting a BATSE untriggered burst. This is the number of bursts in a flux range detected by the IPN, divided by the number detected by BATSE. The peak fluxes of the untriggered bursts range from 0.06 to 25 photons cm$^{-2}$ s$^{-1}$. The efficiencies are time-averaged.

Fig. 2.— The BATSE 1$\sigma$ (statistical + systematic) error circle for the untriggered event on 980629, and the 3$\sigma$ IPN annulus. Note that in general the curvature of the annulus makes it impossible to describe the resulting error box with only the four annulus/error circle intersection points.

Fig. 3.— The BATSE 1$\sigma$ (statistical + systematic) error circle for the untriggered event on 000403, and the 3$\sigma$ IPN error box, formed by the intersection of the two annuli.
Table 1. BATSE untriggered bursts confirmed by the IPN

| Date UT  | IPN spacecraft         |
|----------|------------------------|
| 910601 62220 | Ulysses                |
| 910830 05148 | Ulysses                |
| 910908 33924 | Ulysses                |
| 910910 14747 | Ulysses                |
| 911029 17453 | Ulysses, PVO\(^a\), Ginga\(^b\) |
| 911120 43957 | Ulysses                |
| 920109 23306 | Ulysses                |
| 920216 58688 | Ulysses                |
| 920303 24523 | Ulysses                |
| 920622 23828 | Ulysses                |
| 920626 64276 | Ulysses                |
| 920717 57852 | Ulysses                |
| 920903\(^c\) 05728 | Ulysses, WATCH/GRANAT\(^d\) |
| 930118 64426 | Ulysses                |
| 930209\(^e\) 15737 | Ulysses, PHEBUS\(^e\) |
| 930408 06847 | PHEBUS\(^e\)          |
| 930424 38888 | Ulysses                |
| 930506 55245 | Ulysses                |
| 930626 07023 | Ulysses                |
| 930710 13810 | Ulysses                |
| 930909 45100 | Ulysses                |
| 940213 07260 | Ulysses                |
| 940222 08083 | Ulysses                |
| 940311 44967 | Ulysses                |
| 940710\(^f\) 35477 | Ulysses                |
| 940712 00070 | Ulysses                |
| 940727 40865 | Ulysses                |
| 940730 39690 | Ulysses, DMSP\(^f\), SROSS-C |
| 940930 23017 | Ulysses                |
| 941104 35178 | Ulysses                |
| 950104 32438 | Konus-Wind             |
Table 1—Continued

| Date  | UT   | IPN spacecraft       |
|-------|------|----------------------|
| 950111| 46528| Ulysses              |
| 950131| 78592| Ulysses, Konus-Wind  |
| 950203| 08456| Ulysses, SROSS-C     |
| 950207| 72568| Konus-Wind           |
| 950211| 15919| Ulysses, Konus-Wind  |
| 950224| 33800| Konus-Wind           |
| 950603| 21257| Konus-Wind           |
| 950611| 21122| Ulysses              |
| 950614| 00779| Konus-Wind           |
| 950615| 12104| Ulysses              |
| 950622| 71470| Ulysses, Konus-Wind  |
| 950625| 09685| Konus-Wind           |
| 950722| 64127| Ulysses, Konus-Wind  |
| 950723| 73608| Konus-Wind           |
| 950728| 45743| Konus-Wind           |
| 950730c| 76147| Ulysses, Konus-Wind  |
| 950904c| 52777| Ulysses              |
| 951001| 41868| Ulysses, Konus-Wind  |
| 951005| 14826| Konus-Wind           |
| 951013| 57096| Konus-Wind           |
| 951112| 67850| Ulysses              |
| 951124| 25132| Ulysses, Konus-Wind  |
| 951213| 32675| Konus-Wind           |
| 951215| 73379| Konus-Wind           |
| 951218| 28745| Ulysses, Konus-Wind  |
| 951231| 77068| Konus-Wind           |
| 960107| 68607| Konus-Wind           |
| 960115| 31956| Ulysses, Konus-Wind  |
| 960123| 43643| Konus-Wind           |
| 960201| 82195| Ulysses              |
| 960202| 05968| Ulysses, Konus-Wind  |
Table 1—Continued

| Date    | UT     | IPN spacecraft |
|---------|--------|----------------|
| 960207  | 65033  | *Ulysses, Konus-Wind* |
| 960304  | 48776  | *Ulysses* |
| 960321  | 19663  | *Konus-Wind* |
| 960418  | 08267  | *Konus-Wind* |
| 960504  | 18779  | *Konus-Wind* |
| 960602  | 42667  | *Konus-Wind* |
| 960603  | 60930  | *Konus-Wind* |
| 960614  | 83621  | *Konus-Wind* |
| 960715  | 58326  | *BeppoSAX* |
| 960725  | 63535  | BeppoSAX* |
| 960817  | 24647  | *Konus-Wind* |
| 960826  | 58072  | *Konus-Wind* |
| 960905  | 02568  | *Konus-Wind* |
| 961017  | 23648  | *Ulysses* |
| 961023  | 07747  | BeppoSAX* |
| 961106  | 43031  | BeppoSAX* |
| 961107  | 12691  | *Konus-Wind* |
| 961110  | 26976  | Konus-Wind, BeppoSAX* |
| 961113  | 80523  | *Konus-Wind* |
| 961119c | 21322  | *Ulysses, Konus-Wind* |
| 961119c | 21536  | *Konus-A* |
| 961119c | 26961  | *Konus-A* |
| 961120  | 30433  | BeppoSAX* |
| 961123  | 59316  | Konus-Wind |
| 961208  | 68232  | BeppoSAX* |
| 961209  | 74677  | *Ulysses* |
| 961213  | 49966  | *Ulysses, Konus-Wind* |
| 961222  | 43207  | BeppoSAX* |
| 961224  | 36648  | Konus-Wind, BeppoSAX* |
| 970116  | 58238  | *Ulysses, Konus-Wind* |
| 970119  | 42607  | *Konus-Wind* |
| Date       | UT   | IPN spacecraft                          |
|-----------|------|----------------------------------------|
| 970221    | 13750| BeppoSAX                               |
| 970223    | 64885| BeppoSAX                               |
| 970311    | 30254| BeppoSAX                               |
| 970406    | 25471| Ulysses, Konus-Wind, BeppoSAX          |
| 970525    | 31783| BeppoSAX                               |
| 970610    | 36151| BeppoSAX                               |
| 970617    | 61459| BeppoSAX                               |
| 970720    | 68515| Konus-Wind                             |
| 970801    | 29048| Ulysses, Konus-Wind                    |
| 970817    | 69692| BeppoSAX                               |
| 970825    | 40632| BeppoSAX                               |
| 970827    | 25872| BeppoSAX                               |
| 970926    | 79655| Konus-Wind                             |
| 971015    | 20356| Konus-Wind                             |
| 971017    | 01897| Konus-Wind                             |
| 971019    | 57427| Konus-Wind                             |
| 971027    | 09808| Ulysses, BeppoSAX                      |
| 971028    | 75126| BeppoSAX                               |
| 971101    | 23483| Ulysses, Konus-Wind                    |
| 971102    | 05581| BeppoSAX                               |
| 971103    | 27090| BeppoSAX                               |
| 971121    | 43992| Ulysses, Konus-Wind                    |
| 971207    | 67900| Ulysses, Konus-Wind                    |
| 971207    | 75492| Ulysses, BeppoSAX                      |
| 971228    | 53605| BeppoSAX                               |
| 971228    | 79012| Konus-Wind, NEAR                       |
| 980106    | 44231| Konus-Wind                             |
| 980205    | 19783| Ulysses, Konus-Wind, BeppoSAX, NEAR    |
| 980207    | 58212| Konus-Wind                             |
| 980223    | 76640| BeppoSAX                               |
| 980226    | 41332| BeppoSAX                               |
Table 1—Continued

| Date UT | IPN spacecraft            |
|---------|---------------------------|
| 980304  | 52863  Konus-Wind, BeppoSAX® |
| 980329  | 55486  BeppoSAX®           |
| 980429  | 20493  Konus-Wind          |
| 980518  | 67488  BeppoSAX®           |
| 980520  | 52002  BeppoSAX®           |
| 980523  | 31208  Ulysses, Konus-Wind |
| 980602  | 46528  Konus-Wind          |
| 980605  | 51131  Konus-Wind, BeppoSAX® |
| 980613  | 17465  BeppoSAX®           |
| 980622c | 51085  Ulysses             |
| 980626  | 70184  Konus-Wind          |
| 980629  | 32377  Ulysses, Konus-Wind |
| 980705  | 23165  BeppoSAX®           |
| 980706  | 63987  Konus-Wind, BeppoSAX® |
| 980709  | 16963  BeppoSAX®           |
| 980712  | 18577  BeppoSAX®           |
| 980713  | 13301  Konus-Wind, BeppoSAX® |
| 980715  | 35282  BeppoSAX®           |
| 980728  | 53879  Konus-Wind          |
| 980728  | 55355  Konus-Wind          |
| 980808  | 78791  BeppoSAX®           |
| 980810  | 15944  BeppoSAX®           |
| 980812  | 17640  BeppoSAX®           |
| 980812  | 18950  Ulysses, Konus-Wind, BeppoSAX® |
| 980907  | 40388  BeppoSAX®           |
| 980908  | 02480  BeppoSAX®           |
| 980913c | 19983  Ulysses, NEAR       |
| 980916  | 73322  BeppoSAX®           |
| 980917  | 35279  BeppoSAX®           |
| 980923  | 30178  BeppoSAX®           |
| 981002  | 05466  BeppoSAX®           |
Table 1—Continued

| Date   | UT    | IPN spacecraft            |
|--------|-------|---------------------------|
| 981018 | 01612 | BeppoSAX                  |
| 981019 | 79603 | *Ulysses*, Konus-Wind, BeppoSAX |
| 981022 | 21682 | BeppoSAX                  |
| 981022 | 56447 | *Ulysses*, Konus-Wind     |
| 981101 | 26940 | *Ulysses*, Konus-Wind, NEAR |
| 981106 | 38479 | BeppoSAX                  |
| 981215 | 80709 | Konus-Wind, NEAR          |
| 981216 | 19755 | BeppoSAX                  |
| 990104 | 39597 | BeppoSAX                  |
| 990109 | 41054 | *Ulysses*, Konus-Wind     |
| 990110 | 31141 | *Ulysses*                 |
| 990128 | 37252 | *Ulysses*, Konus-Wind, BeppoSAX |
| 990204 | 30169 | *Ulysses*, Konus-Wind     |
| 990305 | 34451 | Konus-Wind                |
| 990421 | 65775 | *Ulysses*                 |
| 990504 | 40929 | BeppoSAX                  |
| 990509 | 74345 | *Ulysses*                 |
| 990526 | 47273 | BeppoSAX                  |
| 990603 | 66686 | BeppoSAX                  |
| 990606 | 11124 | Konus-Wind                |
| 990618 | 37636 | BeppoSAX                  |
| 990621 | 43943 | BeppoSAX                  |
| 990705 | 57685 | *Ulysses*, Konus-Wind, BeppoSAX, NEAR |
| 990707 | 54801 | *Ulysses*, Konus-Wind, BeppoSAX |
| 990711 | 49110 | BeppoSAX                  |
| 990719 | 79380 | BeppoSAX                  |
| 990720 | 00025 | BeppoSAX                  |
| 990725 | 41016 | BeppoSAX                  |
| 990727 | 48288 | BeppoSAX                  |
| 990803 | 57565 | BeppoSAX                  |
| 990806 | 60168 | Konus-Wind                |
Table 1—Continued

| Date  | UT   | IPN spacecraft                        |
|-------|------|---------------------------------------|
| 990828| 70019| *Ulysses, Konus-Wind*                 |
| 990917| 52494| *BeppoSAX*                            |
| 990917| 71095| *BeppoSAX*                            |
| 990919| 49338| Konus-Wind, *BeppoSAX*, NEAR          |
| 990919| 86038| Konus-Wind                            |
| 990926| 32653| NEAR                                  |
| 991002| 15031| *BeppoSAX*                            |
| 991004| 22825| *BeppoSAX*                            |
| 991005| 15265| *Ulysses*                             |
| 991011| 35968| Konus-Wind, *BeppoSAX*                |
| 991120| 27069| NEAR                                  |
| 991205| 82651| *BeppoSAX*                            |
| 991217| 21782| *BeppoSAX*                            |
| 000102| 27709| *Ulysses*                             |
| 000205| 45486| *Ulysses, BeppoSAX*                   |
| 000206| 09183| *Ulysses, BeppoSAX*                   |
| 000210| 14030| Konus-Wind                            |
| 000211| 45217| *BeppoSAX*                            |
| 000224| 82209| *BeppoSAX*                            |
| 000318| 12931| Konus-Wind                            |
| 000403| 13199| *Ulysses, Konus-Wind, NEAR*           |
| 000405| 77386| *Ulysses*                             |
| 000420| 61374| *Ulysses, Konus-Wind*                 |
| 000502| 54060| *BeppoSAX*                            |
| 000511| 66298| *Ulysses, Konus-Wind*                 |

*a* J. Laros, private communication, 1991

*b* T. Murakami, private communication, 1991

*c* See section 5
dSazonov et al. 1998

eTkachenko et al. 1998

fJ. Terrell, private communication, 1995

gGuidorzi et al. 2004

hPiro & Costa 1998
| Date   | UT     | $\alpha_{2000,\text{IPN}}$ | $\delta_{2000,\text{IPN}}$ | $R_{\text{IPN}}$ | $\delta R_{\text{IPN}}$ |
|--------|--------|-----------------------------|-----------------------------|-----------------|----------------------|
| 910601 | 62220  | 307.008                     | -20.544                     | 31.555          | 0.602                |
| 910830 | 05148  | 152.409                     | 12.566                      | 48.690          | 0.306                |
| 910908 | 33924  | 154.638                     | 11.730                      | 84.755          | 0.092                |
| 910910 | 14747  | 155.049                     | 11.574                      | 19.634          | 0.072                |
| 911029 | 17453  | 344.478                     | -7.880                      | 29.352          | 0.050                |
| 911120 | 43957  | 167.141                     | 6.825                       | 86.994          | 0.049                |
| 920109 | 23306  | 347.750                     | -6.711                      | 47.721          | 0.173                |
| 920216 | 58688  | 342.389                     | -8.336                      | 32.244          | 0.135                |
| 920303 | 24523  | 338.881                     | -8.709                      | 21.076          | 0.083                |
| 920622 | 23828  | 150.168                     | 6.668                       | 48.411          | 0.135                |
| 920626 | 64276  | 330.525                     | -6.378                      | 65.379          | 0.045                |
| 920717 | 57852  | 152.612                     | 4.858                       | 77.394          | 0.050                |
| 920903 | 05728  | 338.736                     | -0.545                      | 54.228          | 0.063                |
| 930118 | 64426  | 163.857                     | -13.874                     | 54.969          | 0.035                |
| 930209 | 15737  | 159.547                     | -14.829                     | 70.983          | 0.050                |
| 930424 | 38888  | 144.212                     | -12.262                     | 78.603          | 0.549                |
| 930506 | 55245  | 323.364                     | 11.717                      | 66.872          | 0.992                |
| 930626 | 07023  | 325.198                     | 11.491                      | 67.667          | 0.374                |
| 930710 | 13810  | 326.814                     | 12.090                      | 82.054          | 0.024                |
| 930909 | 45100  | 336.355                     | 17.978                      | 87.746          | 0.038                |
| 940213 | 07260  | 151.385                     | -51.418                     | 39.877          | 0.189                |
| 940222 | 08083  | 146.406                     | -52.260                     | 86.434          | 0.118                |
| 940311 | 44967  | 136.417                     | -52.192                     | 85.580          | 0.439                |
| 940710 | 35477  | 128.502                     | -39.575                     | 25.746          | 0.750                |
| 940712 | 00070  | 128.902                     | -39.677                     | 44.911          | 0.058                |
| 940727 | 40865  | 313.160                     | 41.197                      | 47.661          | 0.206                |
| 940730 | 39690  | 134.062                     | -41.599                     | 35.990          | 0.072                |
| 940930 | 23017  | 341.171                     | 58.806                      | 65.096          | 0.510                |
| 941104 | 35178  | 26.375                      | 73.600                      | 57.376          | 0.187                |
| 950111 | 46528  | 322.648                     | -44.901                     | 66.079          | 0.119                |
| 950131 | 78592  | 331.984                     | -31.567                     | 29.273          | 0.527                |

Table 2. *IPN annuli*
Table 2—Continued

| Date UT | $\alpha_{2000,IPN}$ | $\delta_{2000,IPN}$ | $R_{IPN1}$ | $\delta R_{IPN}$ |
|---------|----------------------|----------------------|------------|-----------------|
| 950203  | 08456                | 332.839              | -30.167    | 89.992          | 0.030           |
| 950211  | 15919                | 335.834              | -25.077    | 30.200          | 0.130           |
| 950611  | 21122                | 196.445              | -57.824    | 26.966          | 1.033           |
| 950615  | 12104                | 198.715              | -60.874    | 56.631          | 0.518           |
| 950622  | 71470                | 204.112              | -66.756    | 68.801          | 0.141           |
| 950722  | 64127                | 98.551               | 83.396     | 57.905          | 0.379           |
| 950730  | 76147                | 320.422              | -82.230    | 77.858          | 0.039           |
| 950904  | 52777                | 190.636              | 67.767     | 36.463          | 0.144           |
| 951001  | 41868                | 202.666              | 60.024     | 80.559          | 0.068           |
| 951112  | 67850                | 216.222              | 54.930     | 39.289          | 0.202           |
| 951124  | 25132                | 219.201              | 55.029     | 38.194          | 1.044           |
| 951218  | 28745                | 44.049               | -57.317    | 39.343          | 0.089           |
| 960115  | 31956                | 45.389               | -63.277    | 45.746          | 0.090           |
| 960201  | 82195                | 41.130               | -68.152    | 88.655          | 0.146           |
| 960202  | 05968                | 221.086              | 68.185     | 49.051          | 0.164           |
| 960207  | 65033                | 218.206              | 69.749     | 73.961          | 0.089           |
| 960304  | 48776                | 192.220              | 74.434     | 75.937          | 0.404           |
| 961017  | 23648                | 174.945              | 32.043     | 15.768          | 0.302           |
| 961209  | 74677                | 179.842              | 31.294     | 2.542           | 5.564           |
| 961213  | 49966                | 179.845              | 31.446     | 24.486          | 0.129           |
| 970116  | 58238                | 176.897              | 33.808     | 84.760          | 0.143           |
| 970406  | 25471                | 335.943              | -35.323    | 42.658          | 0.277           |
| 970801  | 29048                | 337.672              | -22.111    | 38.624          | 0.222           |
| 971027  | 09808                | 169.177              | 13.952     | 58.403          | 0.013           |
| 971101  | 23483                | 349.656              | -13.606    | 27.793          | 0.014           |
| 971121  | 43992                | 351.033              | -12.487    | 73.989          | 0.115           |
| 971207  | 67900                | 171.412              | 11.889     | 75.290          | 0.226           |
| 971207  | 75492                | 171.412              | 11.887     | 62.197          | 0.051           |
| 971228  | 79012                | 83.395               | 20.899     | 81.666          | 2.305           |
| 980205  | 19783                | 165.363              | 12.132     | 53.914          | 0.040           |
|         | 183.317              | 72.020               | 38.790     | 2.212           |
Table 2—Continued

| Date UT  | $\alpha_{2000, IPN}$ | $\delta_{2000, IPN}$ | $R_{IPN1}$ | $\delta R_{IPN}$ |
|----------|----------------------|----------------------|------------|-----------------|
| 980523 31208 | 329.478              | -11.682              | 36.270     | 0.183           |
| 980622 51085 | 330.752              | -9.840               | 77.221     | 0.029           |
| 980629 32377 | 331.305              | -9.351               | 80.020     | 0.019           |
| 980812 18950 | 336.276              | -5.670               | 38.173     | 0.061           |
| 980913 19983 | 340.559              | -2.546               | 31.980     | 0.278           |
|           |                      | 67.928               | 25.235     | 56.955          | 0.483           |
| 981019 79603 | 344.985              | 1.273                | 45.039     | 0.029           |
| 981022 56447 | 345.260              | 1.560                | 58.633     | 0.012           |
| 981101 26940 | 346.143              | 2.571                | 61.551     | 0.180           |
|           |                      | 275.722              | -23.305    | 44.973          | 0.085           |
| 981215 80709 | 301.383              | -18.295              | 16.297     | 0.223           |
| 990109 41054 | 345.757              | 8.751                | 60.734     | 0.016           |
| 990110 31141 | 345.649              | 8.805                | 58.037     | 0.004           |
| 990128 37252 | 342.818              | 9.649                | 62.261     | 0.007           |
| 990204 30169 | 161.450              | -9.832               | 73.846     | 0.169           |
| 990421 65775 | 146.070              | -7.792               | 55.096     | 0.026           |
| 990509 74345 | 144.820              | -7.244               | 81.947     | 0.375           |
| 990705 57685 | 147.515              | -8.031               | 76.306     | 0.004           |
|           |                      | 167.925              | -19.482    | 71.632          | 0.008           |
| 990707 54801 | 147.737              | -8.132               | 56.409     | 0.010           |
| 990828 70019 | 155.115              | -12.504              | 67.522     | 0.024           |
| 990919 49338 | 149.773              | 12.594               | 74.222     | 0.082           |
| 990926 32653 | 335.529              | -9.725               | 14.580     | 1.019           |
| 991005 15265 | 340.866              | 17.520               | 18.198     | 0.110           |
| 991120 27069 | 198.957              | -13.840              | 45.024     | 0.095           |
| 000102 27709 | 165.147              | -34.791              | 51.204     | 0.236           |
| 000205 45486 | 156.800              | -40.955              | 70.209     | 0.128           |
| 000206 09183 | 336.592              | 41.031               | 51.005     | 0.395           |
| 000403 13199 | 314.499              | 40.072               | 63.855     | 0.040           |
|           |                      | 308.246              | 19.750     | 46.194          | 0.167           |
| 000405 77386 | 133.665              | -39.692              | 57.653     | 0.304           |
Table 2—Continued

| Date  | UT  | $\alpha_{2000,IPN}$ | $\delta_{2000,IPN}$ | $R_{IPN1}$ | $\delta R_{IPN}$ |
|-------|-----|---------------------|---------------------|------------|-----------------|
| 000420| 61374| 310.666             | 37.563              | 86.354     | 0.181           |
| 000511| 66298| 309.117             | 34.756              | 75.388     | 0.712           |
Table 3. *IPN error boxes*

| Date   | UT   | α_{2000} | δ_{2000} | σ_{sys+stat,B} |
|--------|------|----------|----------|----------------|
| 910601 | 6220 | 297.900  | 8.300    | 2.330          |
|        |      | 296.058  | 9.756    |                |
|        |      | 298.589  | 10.529   |                |
|        |      | 295.545  | 8.284    |                |
|        |      | 299.858  | 9.600    |                |
| 910830 | 5148 | 202.100  | 14.700   | 2.130          |
|        |      | 202.699  | 12.651   |                |
|        |      | 202.991  | 16.650   |                |
|        |      | 202.060  | 12.570   |                |
|        |      | 202.358  | 16.815   |                |
| 910908 | 33924| 230.800  | -32.000  | 2.260          |
|        |      | 230.053  | -34.172  |                |
|        |      | 231.638  | -29.857  |                |
|        |      | 229.842  | -34.113  |                |
|        |      | 231.434  | -29.806  |                |
| 910910 | 14747| 150.700  | 30.300   | 2.000          |
|        |      | 148.384  | 30.285   |                |
|        |      | 152.795  | 31.170   |                |
|        |      | 148.393  | 30.134   |                |
|        |      | 152.864  | 31.031   |                |
| 911029 | 17453| 11.300   | -18.700  | 2.130          |
|        |      | 11.838   | -20.769  |                |
|        |      | 13.048   | -17.368  |                |
|        |      | 11.712   | -20.794  |                |
|        |      | 12.966   | -17.277  |                |
| 911120 | 43957| 74.300   | 35.100   | 3.050          |
|        |      | 76.296   | 32.540   |                |
|        |      | 75.564   | 37.976   |                |
|        |      | 76.405   | 32.601   |                |
|        |      | 75.694   | 37.937   |                |
| 920109 | 23306| 345.500  | 33.800   | 11.410         |
|        |      | 332.965  | 39.182   |                |
|        |      | 357.208  | 40.384   |                |
|        |      | 332.720  | 38.745   |                |
|        |      | 357.521  | 39.973   |                |
| 920216 | 58688| 322.900  | 18.200   | 2.260          |
|        |      | 321.367  | 16.478   |                |
|        |      | 325.055  | 19.170   |                |
|        |      | 321.597  | 16.313   |                |
|        |      | 325.162  | 18.913   |                |
| 920303 | 24523| 318.400  | -10.900  | 4.220          |
|        |      | 318.255  | -15.118  |                |
|        |      | 317.616  | -6.752   |                |
|        |      | 318.434  | -15.120  |                |
|        |      | 317.788  | -6.724   |                |
| 920622 | 23828| 147.100  | -39.400  | 2.720          |
Table 3—Continued

| Date UT | α2000 | δ2000 | σ_{sys+stat,B} |
|---------|-------|-------|-----------------|
| 920626  | 64276 | 1.000 | 50.900          |
|         |       | 0.000 | 0.000           |
|         |       | 0.000 | 0.000           |
|         |       | 0.000 | 0.000           |
|         |       | 0.000 | 0.000           |
| 920717  | 57852 | 159.300| -71.600         |
|         |       | 153.631| -72.582         |
|         |       | 165.497| -72.133         |
|         |       | 165.564| -72.026         |
| 920903  | 05728 | 299.100| 28.800          |
|         |       | 295.016| 35.387          |
|         |       | 295.583| 36.120          |
|         |       | 295.067| 35.214          |
|         |       | 295.799| 36.158          |
| 930118  | 64426 | 219.200| -32.600         |
|         |       | 220.633| -34.866         |
|         |       | 221.151| -30.652         |
|         |       | 220.541| -34.904         |
|         |       | 221.075| -30.599         |
| 930209  | 15737 | 239.300| -58.200         |
|         |       | 237.240| -59.590         |
|         |       | 237.460| -56.756         |
|         |       | 237.051| -59.508         |
|         |       | 237.272| -56.830         |
| 930424  | 38888 | 230.100| -57.600         |
|         |       | 233.507| -58.979         |
|         |       | 232.932| -55.956         |
|         |       | 231.473| -59.744         |
|         |       | 230.887| -55.382         |
| 930506  | 55245 | 259.300| 34.400          |
|         |       | 252.549| 24.267          |
|         |       | 253.061| 45.092          |
|         |       | 254.773| 23.377          |
|         |       | 256.039| 45.844          |
| 930626  | 07023 | 21.800 | -40.200         |
|         |       | 8.784 | -43.846         |
|         |       | 21.353| -29.886         |
|         |       | 8.494 | -42.978         |
|         |       | 20.326| -29.950         |
| 930710  | 13810 | 316.500| -69.200         |
|         |       | 322.028| -69.921         |
Table 3—Continued

| Date UT | α2000 | δ2000 | σ_{sys+stat,B} |
|---------|-------|-------|-----------------|
| 930909  45100 | 310.697 | -69.198 | 2.000 |
| 940213  07260 | 244.000 | 9.400 | 2.130 |
| 940222  8083  | 200.200 | 22.500 | 4.400 |
| 940311  44967 | 105.200 | 26.400 | 2.130 |
| 940710  35477 | 99.400 | -33.300 | 3.760 |
| 940712  00070 | 66.700 | -73.100 | 2.800 |
| 940727  40865 | 312.500 | -1.900 | 2.260 |
| 940730  39690 | 79.700 | -61.400 | 1.750 |
| 940930  23017 | 78.700 | 32.000 | 3.760 |
Table 3—Continued

| Date UT | $\alpha_{2000}$ | $\delta_{2000}$ | $\sigma_{sys+stat,B}$ |
|---------|----------------|-----------------|----------------------|
| 941104 | 74.207 | 31.968 | 80.379 | 35.492 |
| 35178  | 345.300 | 18.500 | 5.920 |
| 351.494 | 19.349 |
| 340.023 | 21.742 |
| 351.427 | 19.743 |
| 340.265 | 22.072 |
| 950111 | 24.300 | -5.800 | 1.790 |
| 46528  | 25.708 | -6.916 |
| 23.085 | -4.481 |
| 25.546 | -7.092 |
| 22.919 | -4.654 |
| 950131 | 319.400 | -58.800 | 6.790 |
| 78592  | 332.034 | -61.367 |
| 307.773 | -56.126 |
| 332.489 | -60.312 |
| 308.789 | -55.212 |
| 950203 | 274.600 | 42.700 | 2.000 |
| 08456  | 273.162 | 41.011 |
| 276.802 | 43.897 |
| 273.232 | 40.979 |
| 276.851 | 43.846 |
| 950211 | 325.600 | 3.300 | 1.750 |
| 15919  | 323.883 | 2.949 |
| 327.178 | 4.064 |
| 323.955 | 2.698 |
| 327.274 | 3.822 |
| 950611 | 269.800 | -69.500 | 2.480 |
| 21122  | 0.000 | 0.000 |
| 0.000 | 0.000 |
| 0.000 | 0.000 |
| 0.000 | 0.000 |
| 950615 | 310.200 | -48.500 | 6.110 |
| 12104  | 317.991 | -52.050 |
| 302.386 | -45.503 |
| 316.943 | -52.875 |
| 301.692 | -46.428 |
| 950622 | 213.400 | -1.500 | 4.680 |
| 71470  | 216.922 | 1.582 |
| 210.342 | 2.043 |
| 217.169 | 1.275 |
| 210.055 | 1.773 |
| 950722 | 74.200 | 25.800 | 3.580 |
| 64127  | 78.163 | 25.551 |
| 70.224 | 25.950 |
| 78.144 | 26.310 |
Table 3—Continued

| Date  | UT   | $\alpha_{2000}$ | $\delta_{2000}$ | $\sigma_{sys+stat,B}$ |
|-------|------|-----------------|-----------------|-----------------------|
| 950730| 76147| 70.337          | 26.703          | 2.193                 |
|       |      | 218.300         | -13.400         |                       |
|       |      | 216.499         | -14.090         |                       |
|       |      | 220.702         | -13.533         |                       |
|       |      | 216.511         | -14.168         |                       |
|       |      | 220.711         | -13.611         |                       |
| 950904| 52777| 197.100         | 33.300          | 2.190                 |
|       |      | 196.048         | 31.299          |                       |
|       |      | 198.492         | 31.452          |                       |
|       |      | 195.522         | 31.561          |                       |
|       |      | 198.968         | 31.778          |                       |
| 951001| 41868| 127.100         | -0.300          | 2.970                 |
|       |      | 129.732         | 1.076           |                       |
|       |      | 126.889         | 2.663           |                       |
|       |      | 129.600         | 1.304           |                       |
|       |      | 127.153         | 2.670           |                       |
| 951112| 67850| 225.700         | 16.900          | 1.940                 |
|       |      | 223.970         | 15.896          |                       |
|       |      | 227.667         | 16.437          |                       |
|       |      | 223.782         | 16.281          |                       |
|       |      | 227.727         | 16.858          |                       |
| 951124| 25132| 157.300         | 47.600          | 2.190                 |
|       |      | 157.526         | 45.416          |                       |
|       |      | 154.289         | 48.462          |                       |
|       |      | 160.092         | 46.514          |                       |
|       |      | 156.796         | 49.765          |                       |
| 951218| 28745| 20.700          | -20.700         | 2.000                 |
|       |      | 19.312          | -22.227         |                       |
|       |      | 22.801          | -21.085         |                       |
|       |      | 19.491          | -22.354         |                       |
|       |      | 22.748          | -21.288         |                       |
| 960115| 31956| 132.300         | -50.200         | 4.030                 |
|       |      | 137.695         | -52.409         |                       |
|       |      | 127.935         | -47.375         |                       |
|       |      | 137.535         | -52.562         |                       |
|       |      | 127.746         | -47.594         |                       |
| 960201| 82195| 170.700         | -15.600         | 6.400                 |
|       |      | 177.126         | -17.328         |                       |
|       |      | 164.395         | -13.665         |                       |
|       |      | 177.042         | -17.609         |                       |
|       |      | 164.306         | -13.944         |                       |
| 960202| 05968| 104.400         | 54.600          | 2.060                 |
|       |      | 107.037         | 53.246          |                       |
|       |      | 100.892         | 54.993          |                       |
|       |      | 107.379         | 53.511          |                       |
|       |      | 101.036         | 55.318          |                       |
Table 3—Continued

| Date UT | α 2000 | δ 2000 | σ sys+stat,B |
|---------|--------|--------|--------------|
| 960207  | 65033  | 9.800  | 35.800       | 2.260 |
|         | 8.257  | 33.928 |
|         | 12.029 | 34.464 |
|         | 8.022  | 34.072 |
|         | 12.193 | 34.665 |
| 960304  | 48776  | 72.800 | 23.400       | 3.050 |
|         | 75.184 | 21.292 |
|         | 69.613 | 22.567 |
|         | 75.734 | 21.995 |
|         | 69.476 | 23.427 |
| 961017  | 23648  | 162.800| 42.400       | 4.030 |
|         | 157.992| 40.590 |
|         | 164.912| 46.136 |
|         | 158.495| 40.001 |
|         | 165.805| 45.805 |
| 961209  | 74677  | 188.600| 33.400       | 5.630 |
|         | 188.241| 27.778 |
|         | 184.992| 38.211 |
|         | 183.130| 30.222 |
|         | 181.856| 33.794 |
| 961213  | 49966  | 186.300| 57.300       | 2.720 |
|         | 189.274| 55.140 |
|         | 181.933| 56.019 |
|         | 188.793| 54.961 |
|         | 182.254| 55.744 |
| 970116  | 58238  | 181.300| -49.300      | 2.560 |
|         | 178.432| -51.084|
|         | 184.499| -50.830|
|         | 178.071| -50.803|
|         | 184.795| -50.520|
| 970406  | 25471  | 287.300| -28.200      | 4.120 |
|         | 284.199| -31.319|
|         | 287.704| -24.096|
|         | 284.742| -31.673|
|         | 288.335| -24.186|
| 970801  | 29048  | 311.600| -54.200      | 2.260 |
|         | 312.760| -56.361|
|         | 307.838| -53.740|
|         | 313.585| -56.156|
|         | 308.119| -53.267|
| 971027  | 09808  | 194.600| 67.500       | 1.630 |
|         | 0.000  | 0.000  |
|         | 0.000  | 0.000  |
|         | 0.000  | 0.000  |
|         | 0.000  | 0.000  |
| 971101  | 23483  | 359.000| 13.100       | 1.840 |
Table 3—Continued

| Date UT  | α2000 | δ2000 | σ_{sys+stat,B} |
|----------|-------|-------|----------------|
| 0.531    | 12.026|       |                |
| 357.113  | 13.202|       |                |
| 0.513    | 12.003|       |                |
| 357.112  | 13.173|       |                |
| 971121   | 43992 | -71.000| 3.310         |
| 0.000    | 0.000 |       |                |
| 0.000    | 0.000 |       |                |
| 0.000    | 0.000 |       |                |
| 971207   | 67900 | 56.000 | 5.150         |
| 89.818   | 50.916|       |                |
| 89.893   | 61.105|       |                |
| 90.537   | 50.865|       |                |
| 90.833   | 61.146|       |                |
| 971207   | 75492 | 71.100 | 5.540         |
| 125.571  | 65.980|       |                |
| 148.573  | 72.644|       |                |
| 125.820  | 65.945|       |                |
| 148.619  | 72.537|       |                |
| 971228   | 79012 | -58.100| 3.580         |
| 56.348   | -60.131|       |                |
| 44.681   | -56.488|       |                |
| 0.000    | 0.000  |       |                |
| 980205   | 19783 | -37.400| 2.449         |
| 141.408  | -36.889|       |                |
| 149.002  | -39.630|       |                |
| 141.537  | -36.855|       |                |
| 149.169  | -39.591|       |                |
| 980523   | 31208 | -50.600| 5.440         |
| 328.652  | -48.129|       |                |
| 341.734  | -46.631|       |                |
| 328.989  | -47.767|       |                |
| 341.252  | -46.362|       |                |
| 980622   | 51085 | -49.900| 5.350         |
| 247.000  | -41.315|       |                |
| 249.092  | -44.724|       |                |
| 249.068  | -55.100|       |                |
| 249.083  | -44.739|       |                |
| 980629   | 32377 | 53.600 | 1.840         |
| 271.700  | 54.937|       |                |
| 270.855  | 51.833|       |                |
| 273.931  | 54.899|       |                |
| 270.917  | 51.822|       |                |
| 273.978  | 54.870|       |                |
| 980812   | 18950 | 33.900 | 3.140         |
| 337.300  | 32.346|       |                |
| 340.558  | 32.346|       |                |
Table 3—Continued

| Date UT  | α2000 | δ2000 | σ_{sys+stat,B} |
|----------|-------|-------|----------------|
| 980913 19983 | 333.941 | 32.499 | 3.580 |
| 980913 19983 | 340.474 | 32.231 |            |
| 980913 19983 | 334.018 | 32.381 |            |
| 981019 79603 | 318.700 | -36.700 | 3.220 |
| 981019 79603 | 322.038 | -38.539 |            |
| 981019 79603 | 315.772 | -34.531 |            |
| 981019 79603 | 322.079 | -38.490 |            |
| 981019 79603 | 315.821 | -34.489 |            |
| 981022 56447 | 287.900 | 8.000 | 6.110 |
| 981022 56447 | 286.585 | 2.032 |            |
| 981022 56447 | 287.253 | 14.077 |            |
| 981022 56447 | 286.609 | 2.027 |            |
| 981022 56447 | 287.278 | 14.079 |            |
| 981101 26940 | 290.700 | 18.400 | 2.260 |
| 981101 26940 | 285.480 | 20.739 |            |
| 981101 26940 | 285.453 | 20.570 |            |
| 981101 26940 | 285.856 | 20.658 |            |
| 981101 26940 | 285.829 | 20.489 |            |
| 981215 80709 | 298.000 | -2.800 | 2.720 |
| 981215 80709 | 295.278 | -2.895 |            |
| 981215 80709 | 300.530 | -1.796 |            |
| 981215 80709 | 295.333 | -3.352 |            |
| 981215 80709 | 300.663 | -2.236 |            |
| 990109 41054 | 319.500 | -49.200 | 1.940 |
| 990109 41054 | 322.111 | -48.305 |            |
| 990109 41054 | 319.282 | -47.265 |            |
| 990109 41054 | 322.068 | -48.254 |            |
| 990109 41054 | 319.369 | -47.262 |            |
| 990110 31141 | 287.100 | 63.200 | 3.490 |
| 990110 31141 | 287.081 | 6.477 |            |
| 990110 31141 | 286.582 | 12.883 |            |
| 990110 31141 | 287.088 | 6.477 |            |
| 990110 31141 | 286.589 | 12.884 |            |
| 990128 37252 | 304.900 | -41.900 | 1.680 |
| 990128 37252 | 306.488 | -43.105 |            |
| 990128 37252 | 303.203 | -40.804 |            |
| 990128 37252 | 306.503 | -43.094 |            |
| 990128 37252 | 303.216 | -40.793 |            |
| 990204 30169 | 131.600 | 63.200 | 3.490 |
| 990204 30169 | 130.012 | 59.793 |            |
| 990204 30169 | 138.763 | 62.040 |            |
Table 3—Continued

| Date   | UT   | $\alpha_{2000}$ | $\delta_{2000}$ | $\sigma_{sys+stat,B}$ |
|--------|------|-----------------|-----------------|----------------------|
| 990421 | 65775| 131.050         | 59.720          |                      |
|        |      | 138.262         | 61.569          |                      |
| 990509 | 74345| 93.000          | -44.000         | 2.640                |
|        |      | 0.000           | 0.000           |                      |
|        |      | 0.000           | 0.000           |                      |
|        |      | 0.000           | 0.000           |                      |
|        |      | 0.000           | 0.000           |                      |
| 990705 | 57685| 79.100          | -72.300         | 1.750                |
|        |      | 77.451          | -72.112         |                      |
|        |      | 77.488          | -72.150         |                      |
|        |      | 77.460          | -72.090         |                      |
|        |      | 77.497          | -72.127         |                      |
| 990707 | 54801| 102.700         | -53.000         | 1.840                |
|        |      | 105.730         | -53.289         |                      |
|        |      | 103.292         | -51.196         |                      |
|        |      | 105.730         | -53.261         |                      |
|        |      | 103.336         | -51.202         |                      |
| 990828 | 70019| 221.000         | -66.600         | 2.560                |
|        |      | 215.426         | -67.990         |                      |
|        |      | 219.021         | -64.176         |                      |
|        |      | 215.346         | -67.937         |                      |
|        |      | 218.889         | -64.195         |                      |
| 990919 | 49338| 69.400          | 74.000          | 2.720                |
|        |      | 71.601          | 71.360          |                      |
|        |      | 74.556          | 76.382          |                      |
|        |      | 72.134          | 71.404          |                      |
|        |      | 75.176          | 76.285          |                      |
| 990926 | 32653| 350.600         | -6.100          | 3.760                |
|        |      | 351.358         | -9.784          |                      |
|        |      | 349.452         | -2.518          |                      |
|        |      | 349.287         | -9.628          |                      |
|        |      | 347.741         | -3.646          |                      |
| 991005 | 15265| 329.000         | 37.900          | 1.840                |
|        |      | 0.000           | 0.000           |                      |
|        |      | 0.000           | 0.000           |                      |
|        |      | 0.000           | 0.000           |                      |
|        |      | 0.000           | 0.000           |                      |
| 991120 | 27069| 153.400         | -28.700         | 2.060                |
|        |      | 153.311         | -30.759         |                      |
|        |      | 152.564         | -26.777         |                      |
|        |      | 153.536         | -30.757         |                      |
Table 3—Continued

| Date UT | α 2000 | δ 2000 | σ sys+stat,B |
|---------|--------|--------|--------------|
| 000102 27709 | 152.770 | -26.717 | 2.720 |
| 000205 45486 | 203.000 | 14.600 | 2.000 |
| 000206 09183 | 28.100 | 18.200 | 2.130 |
| 000403 13199 | 275.100 | -10.700 | 1.710 |
| 000405 77386 | 226.900 | -52.500 | 2.640 |
| 000420 61374 | 104.100 | 54.200 | 1.840 |
| 000511 66298 | 48.700 | 38.000 | 2.260 |