served activity; this possibility does not seem likely, but more measurements are clearly in order.

Our results should be compared with those of Lal and co-workers (*10, 11*), who have independently reported the detection of $Al^{26}$ in two samples of marine sediments, and with those of Fireman and Langway (*12*), who did not detect $Al^{26}$ in particles filtered from melted Greenland ice. The former workers report an $Al^{26}$ activity in their (dry) sediments of 0.46 dpm/kg, whereas our data yield a value of 0.81 dpm/kg. This difference could easily result from the sedimentation rates of their samples being twice the rate of our sample, or from the possibility that $Al^{26}$ had decayed by a larger factor in their samples than in ours because their samples came from deeper within the sediment. The upper limit of Fireman and Langway, $4 \times 10^{-7}$ dpm/liter$^{-1}$, corresponds to a production rate of $Al^{26}$ of $1.2 \times 10^{-8}$ dpm cm$^{-2}$ year$^{-1}$ (30 times smaller than our value). The difference could result if 97 percent of the $Al^{26}$ were in a form that passed through the 3-$\mu$ pores of the filter used by these workers. Certainly, the 50 percent of the dust that may be volatilized (*1*) will result in soluble Al compounds, and a fairly large fraction of the remaining $Al^{26}$ will reside in minerals that are easily soluble, or from which the $Al^{26}$ can be easily leached by the action of $H_2O$. In addition, some large particles may have been lost by settling before filtration.

Lal and Venkatavaradan (*11*) have attempted to use their measurement of $Al^{26}$ to set limits on the flux of solar protons during the last $10^5$ years. Clearly our result can be used similarly, though we do so with some trepidation because of the uncertainties involved. The greatest uncertainty in the production rates probably resides in the values for the sedimentation rates, which may be incorrect by as much as a factor of 2 in either our sample or theirs (*13*). The influx of interplanetary dust is uncertain by at least an order of magnitude (*14*). The shrinkage times of the heliocentric dust-particle orbits may be shorter than previous assumptions; they depend on two unkowns: (i) the size distribution of the dust, and (ii) drag forces other than those due to solar electromagnetic radiation.

Perhaps the safest solution is to note that the apparent production rate due to dust is lower by a factor of 4 than that calculated by Wasson, and to reduce his assumed proton flux by the same factor to 250 cm$^{-2}$ sec$^{-1}$, while keeping the assumed rate of dust influx of $10^{-7}$ g cm$^{-2}$ year. These quantities should be within an order of magnitude of the correct values.

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**References and Notes**

1. E. J. Öpik, personal communication, 1961.
2. J. T. Wasson, *Icarus* **2**, 54 (1963).
3. From Lamont Geological Observatory, whose W. A. Cassidy and associates we thank.
4. W. M. Sackett, *Ann. N.Y. Acad. Sci.* **119**, 339 (1964).
5. E. D. Goldberg and M. Koide, *Geochim. Cosmochim. Acta* **26**, 417 (1962).
6. Procedure developed and carried out by the Extractive Metallurgical Research Div. of the Anaconda Co. We thank F. L. Holderreed, W. H. Foard, and J. K. Grunig who did the work; and R. R. Shrock who enabled our association with Anaconda.
7. M. A. Van Dilla, J. R. Arnold, E. C. Anderson, *Geochim. Cosmochim. Acta* **20**, 115 (1960).
8. E. Anders, *ibid.* **19**, 53 (1960).
9. C. Gfeller, F. G. Houtermans, H. Oeschger, U. Schwarz, *Helv. Phys. Acta* **34**, 466 (1961).
10. B. S. Amin, D. P. Kharkar, D. Lal, *Deep Sea Res.*, in press.
11. D. Lal and V. S. Venkatavaradan, *Science* **151**, 1381 (1966).
12. E. L. Fireman and C. C. Langway, Jr., *Geochim. Cosmochim. Acta* **29**, 21 (1965).
13. D. Lal, personal communication.
14. C. Nilsson, *Science* **153**, 1242 (1966).
15. Aided by NSF grant GP-5309 and by the Swiss National Science Foundation.

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## Search for 21-Centimeter Radiation near Cosmic X-Ray Sources

Abstract. *A search was made for 21-centimeter wavelength radiation in the regions of seven of the cosmic x-ray sources. No new sources with flux densities greater than 5.5 flux units were found.*

The location of various cosmic x-ray sources have been reported by Giacconi *et al.* (*1*), Bowyer *et al.* (*2*), and by Fisher *et al.* (*3*). Positions (within 1.5°) and relative intensities of ten x-ray sources have been determined by Bowyer and his co-workers (*2*). Of the sources in this list, Tau XR-1 seemed to be associated with the Crab nebula; Oph XR-1, with Kepler's supernova (SN); and Sgr XR-1, possibly associated with the galactic center. The remaining sources did not seem to be associated with optical or radio objects. In January 1965 a search was made for 21-cm continuum radiation in the regions of seven of the x-ray sources in the list of Bowyer *et al.* (*2*) to determine if there were radio sources, previously undetected, at the positions of the x-ray sources. (The search was made at 21-cm because of the availability of equipment at this wavelength.) Table 1 lists the x-ray sources studied here; Taurus XR-1 was not included in the survey because of its identification with the Crab nebula; and Sco XR-2 and Sco XR-3 were too far south in declination to be observed. No new sources were found in our initial scans of the regions, and, because of the limited time available for this experiment, it was decided to discontinue the search until better positions for the x-ray sources and more time for the search were available.

More recent rocket experiments have shown, however, that Oph XR-1 does not exist at present, that Sgr XR-1 is at a position different from that originally determined, and that Sgr XR-2 is possibly variable (*4*). Because x-ray sources may be variable, it now seems that the 21-cm measurements made in January 1965 should be described.

Observations were made with the 84-foot parabolic reflector of the Naval Research Laboratory, located at the Maryland Point Observatory. The radiometer, which has been described previously (*5*), has a center frequency of 1414 Mc/sec and a bandwidth of 3.3 Mc. With a 6-second integration time, the peak-to-peak noise is 0.5 degree Kelvin. The antenna efficiency is 45 percent (*6*), which results in a minimum detectable flux density of 5.5 flux units [1 flux unit is $10^{-26}$ watt m$^{-2}$ (cy/sec)$^{-1}$] for a source small with respect to the 36-minute-of-arc beam. This value for limiting flux density was determined by assuming that a source giving a deflection equal to the peak-to-peak noise could be detected in a single drift curve. For a source of size comparable to or larger than the beam, the minimum detectable flux density would be greater than 5.5 flux units.

Observations consisted of drift curves in right ascension, centered on the right ascension of the x-ray sources (*2*) and taken at intervals of 18 minutes of arc in declination (half beamwidth.) The range over which the search was carried out and the known radio sources

Table 1. Summary of results of search for cosmic radio sources near cosmic x-ray sources. Positions of x-ray sources are for epoch 1950.0.

| Region of search (epoch 1950.0) $\alpha$ | Region of search (epoch 1950.0) $\delta$ | Known radio sources in region of search | Sources detected | Limiting flux density (flux units) |
|---|---|---|---|---|
| | *Sco XR-1* ($\alpha = 16^h15^m \pm 6^m$; $\delta = -15.2° \pm 1.5°$) | | | |
| $16^h14^m \pm 5^m$ | $-15.2° \pm 0.8°$ | | | 5.5 |
| | *Oph XR-1* ($\alpha = 17^h32^m \pm 6^m$; $\delta = -20.7 \pm 1.5°$)* | | | |
| $17^h31^m \pm 6^m$ | $-21.0° \pm 0.8°$ | Kepler's SN 1604<br>MSH 17-212 | Kepler's SN 1604 | 5.5 |
| | *Sgr XR-1* ($\alpha = 17^h55^m \pm 6^m$; $\delta = -29.2° \pm 1.5°$)† | | | |
| $17^h52.5^m \pm 5.5^m$ | $-29.35° \pm 0.6°$ | Galactic plane | Galactic plane | 5.5 |
| | *Sgr XR-2* ($\alpha = 18^h10^m \pm 6^m$; $\delta = -17.1° \pm 1.5°$)‡ | | | |
| $18^h13^m \pm 11^m$ | $-17.0° \pm 1.2°$ | W33 (IC 4701)<br>M17<br>Galactic plane<br>MSH 18-13 | W33<br>M17<br>Galactic plane | 11 |
| | *Ser XR-1* ($\alpha = 18^h45^m \pm 6^m$; $\delta = +5.3° \pm 1.5°$) | | | |
| $18^h53^m \pm 16^m$ | $+5.6° \pm 0.5°$ | Galactic plane | Galactic plane | 5.5 |
| | *Cyg XR-1* ($\alpha = 19^h53^m \pm 6^m$; $\delta = +34.6° \pm 1.5°$) | | | |
| $19^h51.5^m \pm 7.5^m$ | $+34.7° \pm 1.2°$ | | | 5.5 |
| | *Cyg XR-2* ($\alpha = 21^h43^m \pm 6^m$; $\delta = +38.8° \pm 1.5°$) | | | |
| $21^h42.5^m \pm 5.5^m$ | $+38.9° \pm 1.2°$ | | | 5.5 |

*Does not appear in recent survey (*4*). †Most probable position has changed in recent x-ray survey (*4*). ‡May be variable (*4*).

in the regions covered by the 21-cm search are given in Table 1. Known radio sources, except the galactic plane, were taken from Howard and Maran (*7*). Instead of using the catalog numbers assigned to the sources by these investigators, we give the most familiar name. The position of the galactic plane was determined from Westerhout (*8*).

Because of limited time, the ranges of observations in the vicinity of Sgr XR-1 and Ser XR-1 were restricted in order to avoid the confusing effects of the galactic plane. Radio source MSH 17-217 is within 1.5° of the most probable position of Sgr XR-1, and 3C 390.1 is within 1.5° of Ser XR-1, but neither is in the range covered by the 21-cm search. No source, other than the galactic plane, with flux density greater than the limiting flux density of 5.5 flux units was observed in the vicinity of these sources.

Several strong previously known radio sources in the vicinity of Sgr XR-2 limited the sensitivity of the search in this region. The only sources observed were known sources with flux densities greater than the limiting flux density, which in this case was 11 flux units.

In the region near Oph XR-1 that was covered by this search, Kepler's 1604 supernova is the only known source that has a flux density greater than 5.5 flux units at 21-cm wavelength. This was the only source detected.

No radio sources are known to exist in the vicinity of Sco XR-1, Cyg XR-1, and Cyg XR-2. In our search no sources with flux density greater than 5.5 flux units were detected. The Sco XR-1 result agrees with the results obtained by Hogg and reported by Johnson (*9*).

A summary of this search is given in Table 1. All the known sources for which the flux density is greater than the limiting value were detected, but no new sources were discovered.

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#### References

1. R. Giacconi, H. Gursky, J. R. Waters, G. Clark, B. B. Rossi, *Nature* **204**, 981 (1964).
2. S. Bowyer E. T. Byram, T. A. Chubb, H. Friedman, *Science* **147**, 394 (1965).
3. P. C. Fisher, H. M. Johnson, W. C. Jordan, A. J. Meyerott, L. W. Acton, *Astrophys. J.* **143**, 203 (1966).
4. H. Friedman, private communication.
5. E. D. Goldberg and M. Koide, *Geochim. Cos-Instrum.* **35**, 1227 (1964).
6. A. C. Miller and J. Griffin, *Astron. J.* **7**, 744 (1966).
7. W. E. Howard, III, and S. P. Maran, *Astrophys. J. Suppl. Ser.* **10**, 1 (1965).
8. G. Westerhout, *Bull. Astron. Inst. Neth.* **14**, 215 (1958).
9. H. M. Johnson, *Astrophys. J.* **144**, 635 (1966).

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## Lunar Transient Phenomena: Topographical Distribution

Abstract: *The sites named in nearly 400 reports of lunar transient phenomena fall into three classes: (i) sites peripheral to the maria, (ii) ray craters, and (iii) ring plains with dark or partially dark floors; none are known in the rugged highland area of the southeast (International Astronomical Union, 1964; classically southwest) quadrant. Permanent records are few; the sites where known are consistent with the visual records.*

A recent survey (*1*) of the literature collected about 400 reports of transient lunar phenomena occurring over a period longer than 400 years. Many of the older observations were made with small instruments, and at least some of the reports, especially the older ones, may reflect errors in observation. Careful checking of the details, and the consistency with which the locations of the sites divide into three classes, make it probable that the number of errors is not high; we do not believe that inclusion of a few possibly incorrect reports substantially influences our findings.

Many of the famous astronomical names of the 18th and 19th centuries appear in our catalogue (*1*), and virtually all the experienced lunar observers. Nineteen of J. H. Schröter's observations are listed. Piazzi is on record as having seen bright spots on seven occasions. W. Herschel, Bode, Olbers, Argelander, J. Schmidt, Tempel, Barnard, Flammarion, and many others have contributed reports.

One of us (P.M.) has observed a color phenomenon; reddish glows in the crater Gassendi, 30 April–1 May 1966; it was first seen just before 2200 hours on 30 April by P. Sartory with a blink device using color filters, and was confirmed by T. Moseley. Further color events in Gassendi were seen by several observers between 1930 hours 1 May and 0021 hours 2 May and in September 1966. Details (such as color, areal extent, and duration) were quite similar to those reported in 1963 for events in the Aristarchus region by observers in Flagstaff, Arizona.

Color events abound throughout the catalogue; also included are reports of obscurations and bright spots on the dark side, as the reports depend in a subjective way on lighting conditions