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) | | Known radio sources in region of search | Sources detected | Limiting flux density (flux units) |
|---|---|---|---|---|
| $\alpha$ | $\delta$ | | | |
| | *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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21 October 1966

## 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 in the area observed and on the color response of the observers' eyes. Most events were brief; most were reported as lasting for a few minutes or (less commonly) hours; they average about 20 minutes. Some events were intermittent or fluctuated in brightness occasionally over periods extending through several nights, although reports of quick fluctuations must be treated with a certain amount of reserve.

"Active" formations — sites where transient phenomena have been reasonably well authenticated — are not distributed at random. There is an association between active areas and the maria Imbrium, Serenitatis, Crisium, and Humorum (Fig. 1). Many sites of lunar events are located along the borders of these maria (in Imbrium, an inner ring also is outlined), and a few peripheral sites also occur near the edges of maria Nubium, Tranquilitatis, and Nectaris.

Association of the events with the borders of maria suggests residual internal activity in dying volcanic fields; terrestrial volcanic arcs associated with folded geosynclinal mountain belts are analogous. Moreover, most of the well-known ray craters (including Tycho, Copernicus, Kepler, Thales, and Philolaus) have shown activity, and a third class of sites contains ring plains with wholly or partially dark floors (Plato, Grimaldi, Schickard, Alphonsus, and Ptolemaeus).

The distribution of black-halo craters, apparently the most recent formations on Moon because they overlie others in the vicinity, correlates strongly with the distribution of sites of events shown in Fig. 1 (*2*). The long line of craters associated with events extending from Clavius through the Walter chain, the Ptolemaeus chain, and down to Plato may be evidence of a lineament that does not otherwise appear in photographs, and it seems likely that the effect is real; Moore (*3*) has pointed out that the main lines of great craters are aligned with Moon's central meridian as seen from Earth. Several of the sites are also members of pairs or groups, notably Atlas and Hercules, Godin and Agrippa, Peirce and Peirce A (*4*), and Messier and Messier A (*4*).

An especially interesting feature is the complete absence of sites from the highland area of the southeast quadrant (southwest in the classical sense). This may be due to observational selection, which seems unlikely over such a long period; a real lack of observable activity in the region is more probable. Observers in the lunar section of the British Astronomical Association and in the Association of Lunar and Planetary Observers have now been asked to keep a careful watch in this area, and it will be interesting to see whether any detections result. We need hardly stress that independent observations greatly increase the reliability of a report. The main need at present is for careful, long-term observations by experienced lunar observers who are adequately equipped telescopically.

Permanent records giving as much

Table 1. Lunar sites in order of frequency of events.

| Feature | Events (No.) | Feature | Events (No.) | Feature | Events (No.) | Feature | Events (No.) |
|---|---|---|---|---|---|---|---|
| Aristarchus | 92 | Pitatus | 3 | Anaximander | 1 | Lambert | 1 |
| Plato | 23 | Promontorium | | Archimedes | 1 | Leibnitz Mts. | 1 |
| Schröter's Valley | | Heraclides | 3 | Arzachel | 1 | Lexell | 1 |
| (and | | Ptolemaeus | 3 | Bessel | 1 | Mare Nectaris* | 1 |
| Cobrahead) | 15 | Riccioli | 3 | Byrgius | 1 | Mare Nubium* | 1 |
| Alphonsus | 13 | Schickard | 3 | Carlini | 1 | Mare Serenitatis* | 1 |
| Tycho | 13 | Theophilus | 3 | Carpathians | 1 | Mare Vaporum* | 1 |
| Mare Crisium* | 11 | Atlas | 2 | Cavendish | 1 | Marius | 1 |
| Eratosthenes | 6 | Calippus | 2 | Censorinus | 1 | Mersenius | 1 |
| Kepler | 6 | Cassini | 2 | Clavius | 1 | Messier | 1 |
| Picard | 5 | Helicon | 2 | Conon | 1 | Mont Blanc | 1 |
| Copernicus | 4 | Hyginus N | | Dawes | 1 | Philolaus | 1 |
| Gassendi | 4 | (Klein N) | 2 | Dionysius | 1 | Plinius | 1 |
| Grimaldi | 4 | Littrow | 2 | Endymion | 1 | Schröter | 1 |
| Lichtenberg | 4 | Macrobius | 2 | Eudoxus | 1 | Sinus Iridum | 1 |
| Piton | 4 | Manilius | 2 | Fracastorius | 1 | South | 1 |
| Posidonius | 4 | Messier A | | Godin | 1 | Sulpicius Gallus | 1 |
| Proclus | 4 | (W. H. Pickering) | 2 | Hansteen | 1 | Struve | 1 |
| Alpetragius | 3 | Peirce A | | Hercules | 1 | Taruntius | 1 |
| Barker's | | (Graham) | 2 | Herschel, W. | 1 | Taurus Mts. | 1 |
| Quadrangle | 3 | Teneriffe Mts. | 2 | Humboldt, W. | 1 | Thales | 1 |
| Herodotus | 3 | Theaetetus | 2 | Kant | 1 | Triesnecker | 1 |
| Mare Humorum* | 3 | Timocharis | 2 | Kunowsky | 1 | Vitruvius | 1 |
| Pico | 3 | Agrippa | 1 | | | Walter | 1 |
| Pico B | 3 | Alps | 1 | | | | |

* Unspecified, or large area.

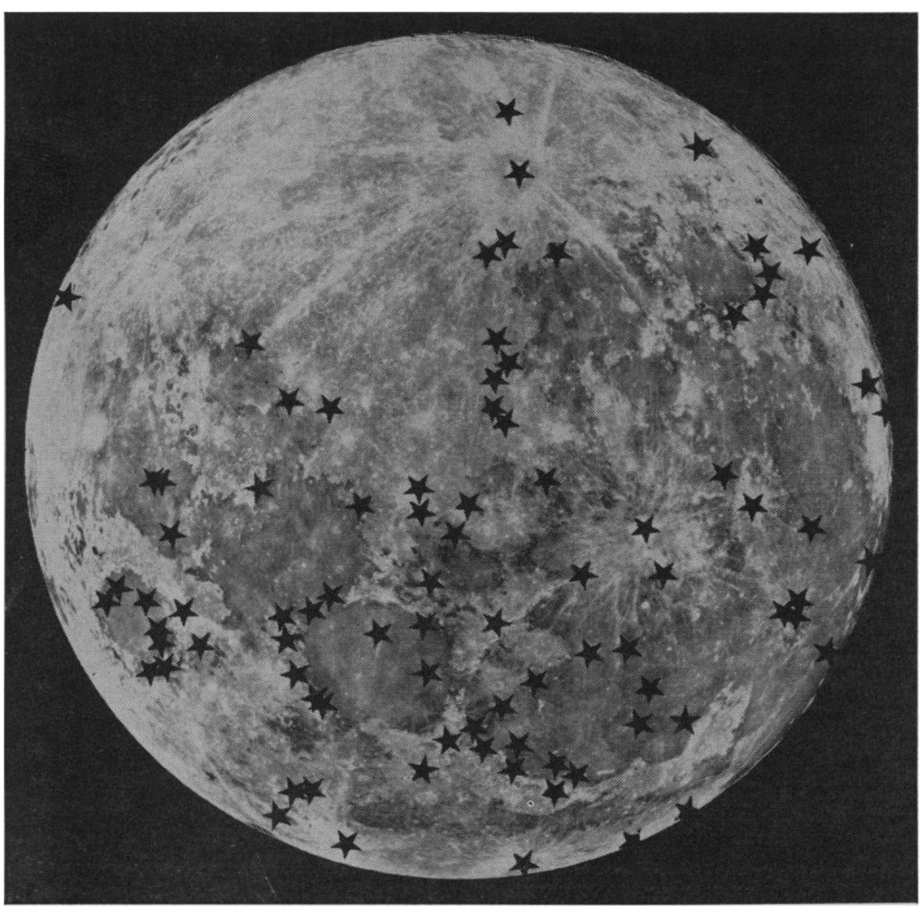

Fig. 1. Stars indicate sites of recorded lunar transient phenomena (Table 1). The top is south. [Lunar Laboratory photograph by Steve Larson]

detailed information as possible are clearly needed, but unfortunately they are not easily obtainable. Direct spectra have been obtained by Kozyrev (*5*), Spinrad (*6*), Dubois (*7*), and others, and spectrophotometric records have been obtained by Grainger and Ring (*8*). Kozyrev identified carbon bands and $H_2^+$ in emission, and unidentified emission features were recorded by Spinrad, and Grainger and Ring. Kozyrev has held to an explanation by outgassing or lunar volcanism, and his identification of carbon is of great interest in connection with the presence of dark areas in our second class of sites and in the black-halo craters. Spinrad, and Grainger and Ring tentatively attributed their anomalies to luminescence, although both stated that all external sources of energy (such as solar particles and cosmic rays) are inadequate by orders of magnitude to produce the observed effects. Notably, however, Scarfe's, Spinrad's, and Grainger and Ring's observations, and one of Kozyrev's, were made within 2 days of perigee, at a time when the recorded events have occurred most frequently; this period and a corresponding period around apogee seem to be the most favorable for recording spectra of events. Another Kozyrev observation was made near apogee; two more, at intermediate dates. The lunar sites indicated by their records, where known, consistently fall into the same three classes (ray craters, ring plains, and craters on the borders of the regular maria) as do the historical events.

Table 1 lists sites in order of frequency of events. It is difficult to assess the recovery rate, either total or for any given site, since the rate must be very strongly affected by observational selection and by other factors. For example, the size of the aperture used controlled the size of the field. Instruments with large mirrors of good reflectivity demand high magnification for comfortable viewing, with consequent reduction of the field of view. Thus it is not surprising that very few 20th-century records deal with events on the dark side (about six, compared with more than 40 before 1900 for a comparable number of records); most lunar observers are interested primarily in the details on the illuminated side that are thrown into relief by shadows.

Our catalogue (*1*) lists no events between 1800 and 1821, and only one earlier record outside Europe is known to us (New England, 1668); Europe was then unsettled by the Napoleonic wars. Numbers of events recorded have recently increased considerably; about 24 have been listed during 1965 and 1966. So far as we know, the Gassendi events of April and May 1966 were not seen anywhere in the United States although they were well confirmed in Britain—more probably because American observers then happened to be looking elsewhere on Moon than because no activity occurred in Gassendi while Moon was visible in the United States. A round-the-clock watch, subject to weather conditions, is now possible as observers in Japan, Australia, Europe, and America are interested, and the frequency of recorded events probably will be even higher than the average of two per month during 1965 and 1966.

Only one instance of an event occurring in the uplands has been reported (Hammes, 1878); so many details in the report proved to be false or dubious that we rejected it as a fabrication. Otherwise, the sites recorded visually, and those indicated by the few spectra and other permanent records, fall consistently into the three classes mentioned, and we believe that the results of this analysis are undoubtedly significant. We consider that the topographical distribution of sites that we have discussed supports the conclusion that most lunar transient events result from internal causes—possibly of volcanic nature. Other evidence in favor of internal activity has been presented elsewhere (*9*).

Our finding may be open to some criticism because we used many old records. On the other hand, nearly all of the early observers are known to have been scientists of integrity. Modern reports are coming in with greater frequency as a result of the Moon Blink and other programs, and it will be interesting to see whether the new data support the hypothesis of internal activity.

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3 October 1966

## Niningerite: A New Meteoritic Sulfide

Abstract. *Niningerite, a new meteoritic sulfide ranging in composition from* $(Fe_{0.19}Mg_{0.66}Mn_{0.14}Ca_{0.007}Cr_{0.002})S$ *to* $(Fe_{0.52}Mg_{0.33}Mn_{0.06}Ca_{0.06}Cr_{0.03}Zn_{0.004})S$, *from the type-I enstatite chondrites Abee, Saint Sauveur, Adhi-Kot, Indarch, St. Mark's, and Kota-Kota, is described. It is named in honor of H. H. Nininger.*

During a systematic study of the enstatite chondrites (*1*) it was found that the highly recrystallized type-II enstatite chondrites Jajh deh Kot Lalu, Hvittis, Atlanta, Pillistfer, Ufana, Blithfield, Khairpur, and Daniel's Kuil (Fig. 1, 7–14, respectively) contain ferroan alabandite (*2*), whereas the less–extensively metamorphosed type-I enstatite chondrites Abee, Saint Sauveur, Adhi-Kot, Indarch, St. Mark's, and Kota-Kota (Fig. 1, 1–6, respectively) contain a cubic iron-magnesium-manganese sulfide that is compositionally quite distinct

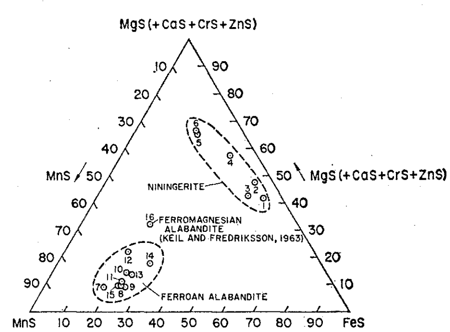


Fig. 1. Compositions (mole percent) of niningerite (points 1–6), ferroan alabandite (points 7–15), and ferromagnesian alabandite (point 16) plotted in a MnS–FeS–MgS (+CaS+CrS+ZnS) concentration triangle. Points 1–6 correspond to type-I enstatite chondrites Abee, Saint Sauveur, Adhi-Kot, Indarch, St. Mark's, and Kota-Kota, respectively; points 7–14 correspond to the type-II enstatite chondrites Jajh deh Kot Lalu, Hvittis, Atlanta, Pillistfer, Ufana, Blithfield, Khairpur, and Daniel's Kuil, respectively; points 15 and 16 correspond to the enstatite achondrites Pesyanoe and Norton County, respectively.