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The Adler Planetarium and Astronomical Museum of Chicago*

By PHILIP FOX, Director

Over the world there are many museums of art, where are collected masterpieces from the brush, the chisel, the goldsmith's table, the potter's wheel, or the loom,—things which bear witness to man's age-long striving for the expression of beauty, in form or color or texture. Fewer, however, are the museums where one may look for evidence of man's intellectual awakening expressed in the development of his powers of reason; and fewer still, but of growing importance, are the museums of the physical sciences. These museums come as powerful aids to the great libraries, storehouses of learning.

If all persons could be informed of the successive advances of science, if the phenomena and the laws which govern them and which may be derived from orderly consideration of them could be presented in such way as to win general understanding, the progress of learning would be greatly accelerated. It should be the aim of every museum of science to exhibit its material with this end in view. Such attempts in the natural sciences have perhaps been more extensive and perhaps more successful than those in the physical sciences. One sees many interesting and instructive exhibits in numerous museums of Natural History. It is more difficult to prepare in form for easy comprehension exhibits to illustrate the phenomena and laws of those sciences which walk hand in hand with mathematics.

The Adler Planetarium and Astronomical Museum of Chicago, an institution of type quite new to America, opened its doors to the public on 12 May 1930. The institution had been dedicated, and presented to the South Park Commissioners, on the tenth of May in the presence of a distinguished company. On this occasion Mr. Leo Wormser presided as Chairman. In conformity with the practice of the ancient school of Pythagoras who taught music and mathematics together, there was music by the Dasch String Quartette: "Music of the Spheres" Ruben—

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stein and "Nocturne, Quartette No. 2" Borodine. The Invocation was delivered by Mr. Horace J. Bridges, the Presentation by Mr. Max Adler, the Acceptance by Mr. Philip Graver, an Address and Demonstration by the Director.

It is natural for one interested in astronomy to inquire how this institution came into being, how it is housed, what may be seen there, what is its purpose, and what response the public has given to its offerings.

Its origin may be found in the development at Jena of the optical planetarium and in the generosity of the donor, Mr. Max Adler of Chicago. Mr. Adler's aim is well expressed in the following quotations from his presentation address:

"Chicago has been striving to create, and in large measure has
succeeded in creating, facilities for its citizens of today to live a life richer and more full of meaning than was available for the citizens of yesterday. Toward the creation of such opportunities I have desired to contribute.

"The popular conception of the universe is too meager; the planets and the stars are too far removed from general knowledge. In our reflections, we dwell too little upon the concept that the world and all human endeavor within it are governed by established order and too infrequently upon the truth that under the heavens everything is interrelated, even as each of us to the other."

And again, "The planetarium has been the subject of praise by scientists and educators. One of them has characterized it as 'a schoolroom under the vault of heaven' and as 'a drama with the celestial bodies as actors'.

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“It is my hope that the youth of our city, and indeed of other cities, may through this dramatization find new interests and fresh inspiration and also that with the aid of the Planetarium and Astronomical Museum, science may be advanced.”

Though this Chicago institution bears a double name and is commonly referred to as the Planetarium, it is in reality an Astronomical Museum of which the Planetarium instrument is the principal exhibit.

It stands on an island in Lake Michigan to the east of those neighboring institutions, the Field Museum of Natural History and the Shedd Aquarium. The three are fittingly closely associated and form a trinity dedicated to the study of “The Heavens above; the Earth beneath, and the waters under the Earth.”

The building is an imposing edifice of rainbow granite with copper dome. The plan (Fig. 2) shows that its shape is a regular dodecagon. The exterior diameter is 160 feet. Inset at the exterior corners are bronze plaques of the twelve Signs of the Zodiac by the sculptor, Alfonso Iannelli. Those for Leo and the Gemini have been selected as representative. Usually, when figures of the Zodiacal Signs are used for exterior decoration they are arranged as on a celestial globe, as though the sky were projected upon the surface, in which case they would be placed successively in counter-clockwise order. The sculptor had, however, nearly finished his modelling with the figures reversed, as on the usual map, before the astronomical director saw the plaques. It was therefore necessary to mount them in clockwise sequence, a permissible arrangement if they are regarded as maps held aloft to match the sky. The stars are placed on the sculptured figures in positions fitting the descriptions of Ptolemy, or perhaps it were better to say that the figures were designed to fit the requirement of the fixed framework of stars.

Centrally located within the building is the circular planetarium chamber 72 feet in diameter, carrying a hemispherical dome of 68 feet diameter. This is the diameter recommended by the makers of the
instrument. With a larger dome, the stars lose brilliancy and if much smaller, the illusion of the open sky is lost. The linen of the dome is stretched over horizontal battens circling the dome like almucantars. The whole is suspended by metal straps from the outer dome (see Fig. 3). The outer dome has a diameter of eighty feet and is non-concentric with the linen surface. This arrangement results in favorable acoustics unless the speaker stands too near the center of the chamber.

**Fig. 3. Cross-section of the Building in Elevation.**

About the central hall are the entrance foyer, the museum corridors, offices, library, and auxiliary lecture room. The entrance faces to the west; the offices look to the east on Lake Michigan. Over the offices there is a room for bookstacks and instruments. Below the offices are the heating and ventilating installations, instrument shop and photographic dark room. Below the foyer are the rest rooms. The remainder of the lower floor is being developed as an extension to the Museum. There is a broad upper promenade deck for view of the sky. Portable instruments are carried there on clear evenings. The coelostat for throwing the solar image into the museum chamber below is also on this deck.

The building is regarded as of such merit that for its design the architect, Ernest A. Grunsfeld, Jr., was awarded the 1930 gold medal of the Chicago Chapter of the American Institute of Architects.

Probably the first natural phenomenon to impress itself on man as he began to observe and reason was the orderly succession of day and night. And while he was grateful to the Sun for its light and warmth and the protection and comfort which it afforded, he marvelled no more concerning the Sun than he did about the stars wheeling in the night sky.

"Thinketh he dwelleth i’ the cold o’ the Moon
Thinketh he made it and the Sun to match
But not the stars, The stars came otherwise."

He saw the Moon and traced her course among the stars in recurrent
phases and saw the brighter planets threading their complex ways. It was long before he was able to unify these phenomena into an harmonious scheme of action, in fact, not until Ptolemy (100-170 A.D.) made his Earth-centered hypothesis with its complex system of epicycles. This hypothesis yielded reluctantly to the Sun-centered theory of Copernicus (1473-1543).

After the announcement of these theories, ingenious men began to make models to represent by means of globes suitably geared together, the observed or calculated motions of the planets and Moon and later also of the other satellites. Not the first, for it is stated that such models date back to Archimedes, but among the earlier of them is that of Christian Huygens constructed in 1682 by the horologist Johannes van Ceulen de la Haye. This may still be seen at the Observatory of Leiden. It is of interest to know that in the calculations for the gearing Huygens came to the invention of continued fractions. These instruments were developed until they became very serviceable in illustrating the phenomena of day and night, of the seasons, of lunar phases, eclipses, transits, occultations, all planetary configurations.

At a date between 1700 and 1710 George Graham, inventor of the compensated pendulum, constructed for Prince Eugene an instrument to show most of the above phenomena. John Rowley copied this instrument with some additions and improvements for the Earl of Orrery. In this lies the origin of the name “orrery” as applied to later elaborate mechanical planetaria. Such instruments varying in size and complexity are to be found widespread. A very interesting one is that made by Eise Eisinga at Franeker, Holland, between 1773 and 1780. In America those of David Rittenhouse, begun in 1767, are worthy of mention: one is at present preserved in Philadelphia. The Rittenhouse planetarium is described in the first volume of the Publications of the American Philosophical Society. Perhaps also should be mentioned an American orrery of T. H. Barlow made in 1851, exhibited at Paris in 1867, and now at Transylvania College, Lexington, Kentucky. In some form these mechanical models are common adjuncts to class-room instruction.

In 1912 Dr. Wallace W. Atwood, then Director of the Museum of the Chicago Academy of Sciences, designed a very different instrument which has been called the Atwood Celestial Globe. It is described in the Bulletin of the Academy, Vol. 4, No. 2, May, 1913. The essential feature is a globe fifteen feet in diameter. Holes of proper size and location are perforated in the sphere to represent the stars. Light thrown on the exterior of the globe shining through the holes, gives the appearance of the starlit sky to the observers standing within. The southern circumpolar region is cut away and from this section the observers enter the globe to stand on a platform inserted through the same opening. The globe may be rotated about the polar axis to reproduce the diurnal motion. This Atwood Globe which has been in daily use since 1913 is

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the progenitor of the new Zeiss Optical Projector. It differs radically from the mechanical planetaria for it is concerned with the appearances of the sky and in no sense is it a mechanical model to explain these appearances.

The Atwood Globe, however, had a much earlier forerunner, for in 1758 Roger Long, Lowndes’s Professor of Astronomy at Cambridge, constructed “an enormous astronomical machine . . . at Pembroke College. It is a hollow sphere, about eighteen feet in diameter, with the polar axis parallel to the mundane axis, upon which it is readily turned by a winch and rack-work; thus it can be made to rotate, while about thirty persons conveniently attend a scientific lecture in the interior and contemplate the orderly march of the constellations painted on the moving concavity above them, the stars being pierced through the metal according to the several magnitudes, so that the light penetrates and each assumes a curious radiated or rather stellated form.”

Professor Max Wolf of Heidelberg had something of this sort in mind in his original suggestion to Dr. Oscar von Miller of the Deutsches Museum at München. Von Miller daring to bring the heavens indoors, turned to the firm of Carl Zeiss, Jena, for the execution of the work. The engineers of Carl Zeiss at first worked on the idea of a great rotating perforated globe. “Much experimental construction work was carried out in Jena . . . but no satisfactory solution . . . to create the illusion of the mysterious, silent march of the worlds of Nature . . . was found.” It is not surprising that an engineer, Dr. W. Bauersfeld, of this firm, which since its foundation in 1846 has been a leader in the development of optical apparatus, should have evolved the following proposition: “The great sphere shall be fixed, its inner white surface shall serve as the projection surface for many small projectors which shall be placed in the center of the sphere. The reciprocal positions and motions of the little projectors shall be interconnected by suitable driving gears in such manner that the little images of the heavenly bodies, thrown upon the fixed hemisphere, shall represent the stars visible to the naked eye, in position and in motion, just as we are accustomed to see them in the natural clear sky.” It took Dr. Bauersfeld and his staff of collaborators and workmen a full five years to demonstrate the practicability of the proposition. No instrument was ever invented more versatile than it for exhibiting the phenomena of a given science. Its success is convincing, even inspiring. It fittingly occupies the central place in the Astronomical Museum of Chicago.

**The Optical Planetarium**

In its essential elements the optical planetarium (Plate IV) is a composite stereopticon with many projectors throwing images on the interior surface of a great hemispherical dome. It is a very complex.

PLATE IV

The Planetarium Instrument in the Chicago Installation.

Popular Astronomy, No. 393.

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FIG. 4. DIAGRAM OF THE PLANETARIUM INSTRUMENT IN PLAN AND ELEVATION.

1-1—Polar Axis. 2-2—Axis of the ecliptic. 3-3—Horizontal axis extending east and west. The whole projection apparatus may be rotated about this axis, producing the changing aspect of the sky consequent on change of latitude. N, S—Two globes, star projector carriers, on which the 22 projectors for the stars are mounted (4, 6, etc.) N primarily for the northern sky, S for the southern. 6, 6—Projectors for the Magellanic Clouds, Sirius, and typical variable stars. 7, 8—Globes which carry 30 projectors for constellation names. 9, 10—Drum projectors for the Milky Way. 11—Cylindrical frame section containing movable projectors for Saturn, Sun, Moon, Gogenschein, and Zodiacal Light. 12—Cylindrical frame section for Mercury, Venus, Mars, and Jupiter. 13, 14—Two globes, each carrying six projectors to throw the equator, ecliptic, sections of numbered hour circles, and arrows to indicate the poles of rotation. 15, 16—Two globes each carrying two projectors to throw the meridian in the sky. 17—Projector to designate the year. 18—Two motors to drive the instrument about the axis (1-1) for diurnal motion. Used singly they give a day in 1° 4' or 3° 12'. 19—Three motors for the annual motion, or more properly speaking the motion of the Sun, Moon, and Planets among the stars. Singly the motors give the year in 5° 5', 61', and 3° 31'. 20—Motor to drive the instrument about axis (2-2) to produce the precessional motion, the 25,600-year precessional cycle in 1° 16'. 21—Motor to rotate the instrument about axis (3-3) for change of terrestrial latitude, period 5° 8'. 22—Commutators to transfer circuits from the fixed frame to the movable parts. 23—Fixed frame or pedestal built of thin, steel bars, care being taken to obstruct as little light as possible. 24—The carriage. The whole instrument can be rolled along a track from its central station under the dome by the cranck and gears at (25). 26—Conduit for electric wires from the instrument to the control deck. One lever engages with one movement the blades for all circuits. 27—Bolt to define the position of the instrument for use. Only when the instrument is in place for this bolt to be shot can the circuit contacts be made at (26). 28—Lamps which throw light upward for the general illumination of the chamber. They are shielded so that no light comes directly into the eyes of the audience. By rheostats these are dimmed or brightened for dusk or dawn, night or day.
instrument for it reproduces the intricate phenomena of the heavens. It shows the naked-eye stars, the Sun, Moon, and planets, all in their proper places for any instant of any year of any century for any terrestrial position. A high order of optical technique, mechanical skill, and astronomical knowledge are merged in its design. It may be best understood by aid of the accompanying diagram (Fig. 4).

At first sight it seems strange that the designer did not make the polar axis coincident with the long axis of the dumb-bell. This would have yielded some simplification in the representation of the stars, but the projectors for the Sun, Moon, and planets would then have had high inclinations to this axis and the driving of them would have entailed greater difficulties. Added difficulty would have been encountered in the representation of the precessional motion.

The stars, Milky Way, Sun, planets, and Moon, will be considered in this sequence. The starry heavens are produced by a mosaic of thirty-two separate fields. The plan for the partition of the sky for the individual star fields provided for the geometrical projection of the sky on the faces of a regular icosahedron whose twelve corners have been cut away to give a 32-sided solid with twenty regular hexagonal and twelve regular pentagonal faces. Each of these thirty-two faces then provides a picture which must be projected optically on the dome. At first, glass lantern slides were tried for the plates but later thin (0.0006 inch) copper plates perforated with holes of sixty-five different sizes to represent stars for the visual magnitudes 1 to 6.5 in steps of 0.1 magnitude were adopted. The difference of brightness for the various magnitudes is then accomplished by the different sizes of the star disks shown on the screen. The images of the fainter stars are scarcely one-eighth inch in diameter but the brightest stars are fully two inches and therefore

Fig. 5. Cross-section of Star Projector.
show decided disks. To the objectionable feature that the stars appear as disks instead of points and also to the distortion of constellations due to out-of-center viewpoint in a celestial sphere of restricted radius, the observer readily adapts himself. The unit star projectors are mounted individually and adjustably on the large spherical carriers. The carriers are twenty-nine inches in diameter of thin sheet brass (0.078 inch) and contain each, centrally placed, a 1000-watt lamp which furnishes the illumination for the star images.

Fig. 5 shows one of the star projectors in diagrammatic form and

![Diagram of a star projector with a occulting device.]

**Fig. 6. Assembled Star Projector showing Occulting Device.**

Fig. 6 assembled. (A) is the container, (B) is the condenser, (D) the perforated plate, (C) the Zeiss Tessar projection lens, Aperture = 2.66 cm, F = 12 cm, (M) and (N) are the adjustment rings and (O) the clamp. Inasmuch as only that part of the sky above the horizon is to be shown, an occulting device is provided for each projector to shut off the light when the lens is pointed below the horizon. This is a spherical sector (K) which serves as a mechanical eyelid, not unlike the device used for dolls which open and close their eyes in appropriate posture. Its axis is mounted in the ring (H) which in turn has a ball-bearing mounting in the race (E). The axis is kept level by the weight (J), a
cylinder partially filled with mercury, which provides a delicate sense of level. Moreover, the edge of the shutter (K) is kept parallel to the horizon by the weight (L). The gradual covering of the objectives simulates well the atmospheric absorption near the horizon.

The individual fields, fitted together to give a complete and continuous picture of the sky, are adjusted with respect to each other by moving the projectors within the adjustment rings (M) and (N). This is done once for all when the instrument is erected in the dome. Temporary adjustment marks are provided for the purpose. This adjustment is a matter of great importance and considerable delicacy. No matter how accurately the individual star fields represent the stars within their areas, if they are not in accurate mutual adjustment there will be obvious distortions at the junctions. The position of each perforation in the star plates must be carefully calculated to allow for the distortion of geometrical projection, for optical distortion, and more critically still, for a parallactic displacement that enters because the spherical surfaces of the carriers are not concentric with the dome and also because the axis of diurnal rotation does not pass through the centers of the globes. A star on the equator and one at the pole must be 90° apart on the hemispherical screen but it is readily seen from Fig. 7 that the perforations for them cannot be 90° apart. Neither can two perforations throwing star images to opposite points on the equator be 180° apart on the globes. When it is realized that 9000 stars are represented the amount of preliminary calculation can be appreciated.

On the spherical carriers are mounted also special projectors for the Magellanic Clouds, for Sirius, and on the Chicago instrument, projectors for three typical variable stars, Algol, Mira, and 8 Cephei. A separate
projector for Sirius is provided that the great brightness might be attained by a brighter disk instead of one of excessive size. The lights for the variables are controlled at will by means of rheostats in the demonstrator's desk. Each of these special projectors has its own occulting device.

The spherical carriers bear also the cylindrical or drum projectors for the Milky Way. This feature of the sky is shown very realistically. A negative drawing of the Milky Way was prepared producing the different intensities by stippling with fine dots irregularly placed. This drawing was then photographed on a film. The film is wrapped within a double-walled cylindrical vessel in the center of which is the lamp. By half filling the narrow space between the walls of the vessel with mercury, the occulting of the part of the Milky Way below the horizon is neatly accomplished.

![Front and Back Views of the Solar Projector]

It is not necessary to comment at length on the projectors for constellation names for they operate in the same manner as the star projectors even to the occulters. The names in general fall in vacant parts of the constellations. They may be turned on or off at will. That projector which covers the north pole of the ecliptic shows also the location of the poles of the planetary orbits and the circle described by the pole of rotation as a result of precession, dated to indicate the position of the pole in the different chilliads.

The images of the members of the solar system are thrown on the dome by individual projectors. These are located in the cage-like framework between the globes and the mid-section (Fig. 4). In all cases they are in pairs and of large aperture to minimize the effects of obstruc-
tion of the struts of the cages in which they are placed. Optically the planetary projectors are alike except that the images have distinguishing character. Mars is red, Jupiter has belts, Saturn has rings, Mercury and Venus are distinguishable by size. The Sun and Moon offer some optical differences.

The solar projector, of which front and back views are shown in Fig. 8, is complicated by serving a manifold function. With it is combined a device (D) for a halo of diffuse light centered on the Sun which by contrast blots out the fainter neighboring stars and which gives a glow at dawn forewarning of sunrise and at dusk above the hidden Sun. At (C) a series of prisms like steps of a stairway (see also Fig. 13) throws a faint glow along the ecliptic for the Zodiacal Light and at (B) are two small projectors to throw a faint patch of light to the opposition point for the Gegenschein.
Since the eccentricity of the Earth's orbit is slight, no account is taken of it in reproducing the Sun's apparent motion along the ecliptic. The solar projector is centered on the axis (2-2) of Fig. 4 and is driven uniformly by spur gears from the main annual driving shaft (Z) (Fig. 9). Inasmuch as the solar projectors are north of the plane of the ecliptic they are given a fixed inclination to bring the solar image upon that circle. The projectors for the Gegenschein are tilted similarly toward the opposition point. The brightness of the Sun may be varied by rheostat control but even at its maximum permits the view of the stars and accordingly the Sun's course among them.

![Diagram of planetary projector](image)

**Fig. 10. To show the Principle of the Alignment of a Planetary Projector.**

Since in the sky we view the moving planets from a moving Earth their apparent motions are compounded of their own and the Earth's. In the planetarium the optical axes of the projectors in all cases and at all times must be directed along lines through the position of the planet and the Earth. All the vicissitudes that the different inclinations, non-commensurable periods, non-uniformity of speed introduce in the sky must be reproduced in the planetarium. Also, since none of these projectors can be in the plane of the ecliptic each must be given a tilt to bring the planet on the ecliptic when it should be at the nodes.

Each pair of projectors (Fig. 9) firmly bound together by a collar (C) is pivoted in the yoke (Y) free to rock about the long axis of the

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collar. The yoke (Y) can be rotated about an axis (A). Figs. 10 and 11 show the principle by which the alignment of the projector is maintained in the case of an outer planet. The same principle holds for an inner planet Mercury or Venus with the roles (E) and (P) reversed.

Consider now just one planet. The aligning rod (R) passes through a sliding bearing carried on a universal joint at (E), the position of the Earth. The position of the planet (P) is on the axis (A) on the yoke mentioned above. As the positions of (E) and (P) change and their distance apart changes, the aligning rod (R) slips through the bearing at (E) which rotates and tilts, accommodating itself in all directions. At the same time the collar bearing the projectors tilts in the yoke which the while turns back and forth about the axis (A). In the planetarium the points (E) and (P) are carried on disks on opposite faces of the cage-chambers, one on the floor and the other on the ceiling. The terrestrial disk carrying the point (E) is centered on the axis (2-2) and is perpendicular to it. It is driven at uniform speed from the main planetary driving shaft (Z) by means of suitable reduction gears. A stud mounted on this disk carries the universal slide bearing (E) which may be raised or lowered to adjust the aligning rod (R) that it will point the projector to the ecliptic at the moments of nodal passages. Moreover, this stud is offset from the axis of the disk an amount (D) proportional to the Earth’s distance from the Sun. The planetary disks for Venus, Jupiter, and Saturn, whose orbits have low eccentricities, are essentially like the terrestrial disk. Their centers are slightly offset from (2-2) to partially compensate for eccentricity, with the point (P) on the yoke-axis (A) at a distance (X) from the disk center in the proportion that D/X = ratio of the distances of the Earth and Planet from the Sun. The planetary disk is inclined to the terrestrial at an angle equal to the inclination of the orbit to the ecliptic. The terrestrial and planetary disks are not borne on central axes but are supported at the rims by three small sheaves. In general this device affords rigidity. It permits the use of fairly light disks without attendant tremors. It is of course apparent that any vibration of the axis of projection produces a greatly multiplied displacement on the dome, nearly a hundredfold.

For Mercury and Mars, where the orbital eccentricities are high (0.2056 and 0.0933) the angular velocity, which varies in the orbit inversely as the square of the radius vector, changes so considerably that it is not permissible to regard it as constant. A modification of the
simple planetary disk was adopted, whereby though still using a combination of crank motions with the initial disk driven at uniform speed, the point (P) moves in a circle and still changes its angular position in close agreement to true anomaly of the elliptic orbit. Three disks are employed. The upper, let us say, carries the axis (A) of the yoke, that is, the point (P). It is centered on the orbit's center, properly offset from (2-2), even as are the simpler planetary disks. The lower disk, which is the one driven from the main driving shaft (Z) is offset from (2-2) in the same direction but by twice the amount. The intermediate disk (I) is centered midway between. These three disks are (U), (I), and (L), in Fig. 12. A pin on the upper side of (L) engages in a slot in (I); also a pin from the lower side of (U) engages in this same slot. When (L) is driven uniformly, a point on the periphery of (U) describes an angular motion about (2-2) in close approximation to the variation of true anomaly. The greatest deviation from true position of Mercury, which is the most critical case, is less than one degree. This deviation is of course not cumulative. This triple planetary disk is tilted to provide for the inclination of the orbit as in the simpler cases.

In the southern cage an element of simplification and mechanical
economy is provided by having the terrestrial disks for Mercury and Venus back to back on opposite sides of the separating diaphragm between their chambers. The diaphragm is perforated and the disks are then one body with but one set of driving gears from the main shaft (Z). A similar economy is found for Mars and Jupiter. In the northern cage the annual drive of the Sun is carried similarly into the cage for Saturn and also into the lunar cage where it is applied to the gear train of the lunar phase meniscus to be described later.

**FIG. 13. Northern Cage Containing the Projectors for the Moon, the Sun, and Saturn.**

As stated in an early paragraph, Huygens discovered the principle of continued fractions in designing his mechanical planetarium in 1682. Since that time this principle has been employed in all similar gear problems where it is desired to approximate the ratio of incommensurable periods. Application of the principle to Mercury yields, after some
adjustment, for the number of teeth of the gears

\[ \frac{45 \times 66 \times 86}{(65 \times 91 \times 104)} = 0.41520905 \]

This figure when divided by 1/10, the ratio of speed of the terrestrial disk to the main planetary shaft (Z), gives 4.1520905 which is a close approximation to the true ratio of the Earth's and Mercury's sidereal periods, 4.15209106 : 1. The teeth numbers are large enough to give smooth motion and yet not so large as to require large gears or, to avoid that, small teeth. The error in the ratio is so small that the accumulated residual will amount to one degree only after five thousand planetarium years. For the other planets an accuracy of the same order is attained.

**Fig. 14. Schematic Drawing of Lunar Projector Showing the Location of the Phase Meniscus and the Device for Accomplishing the Regression of the Nodes.**

The projector for the Moon (Fig. 13) provides the only perturbation that is represented, the 18.5995-year period of regression of the nodes. The lunar projector carriage is centered on the axis (2-2) and is driven about this axis in a period of one sidereal month. Under the projector and centered also on (2-2) is an inclined plane member (I) (Fig. 14) which controls the inclination, 5° 9'. If for a moment we neglect the regression of the nodes the lunar projector would rotate about (2-2) changing its tilt by rocking in the bearing perpendicular to (2-2) and to the line of projection, being constrained so to do because the guide rod (R) is attached to a plane rolling on ball bearings on the inclined plane (I). In one rotation the Moon would make its migration above and below the ecliptic and would always reach its nodes at the same
longitudes and come to the points of maximum latitude among the same stars. If now the gears which make the monthly revolution are dis-engaged and the inclined plane member is set to rotating in its equivalent period of 18.5995 years, the inclination of the lunar projector would slowly change until in the half-period the projector would be pointing as far above the ecliptic as nine years earlier it had pointed below. The bearing on the guide rod (H) must be a universal slide bearing. Both the lunar projector and the inclined block are driven from the main planetary shaft (Z) through independent gear trains (G₁) and (G₂). With the monthly and nodal regression motions both in operation, the Moon will go through its configurations and stations with the nodal points slowly moving westward along the ecliptic. This is a very necessary feature of the instrument for without it the planetarium would be wholly useless for reproduction of eclipse configurations.

Another interesting mechanical and optical device provides that the Moon appear in phase appropriate to its configuration. In Fig. 15 the path of the beam from the lamp may be easily followed through lenses and totally reflecting prisms until it strikes a small metallic concave mirror (X). Projection of the image of this mirror when fully illuminated gives full moon; fractional illumination yields the lesser phases. Pivoted on an axis (T₁) aligned with the reflecting face of the mirror and perpendicular to the ecliptic is a closely fitting hemispherical meniscus or cup (T₂) which rotates on its axis in a period of one synodic month. Since the edge of this hemispherical shell will project always as an ellipse, it will properly represent the terminator.

As noted previously the annual motion of the Sun is transmitted directly into the lunar cage. The central axis carrying the solar projector and aligned on (Z) protrudes into the lunar chamber and there carries a spur gear (A) (Figs. 14 and 16). Meshed with this gear through idlers (B, B), mounted on the lunar projector carrier are others (C, C) having the same number of teeth as (A), their axes carrying in prolongation the axes of the occulting cups which, as noted above, are therefore perpendicular to the ecliptic. The design has placed the cups.
in prolongation of the axes about which the lunar projectors oscillate perpendicularly to the ecliptic so that they stand always at a fixed distance from the top of the cage. If the gear (A) (Figs. 14 and 16) from the solar projector were fixed instead of in motion the lunar drive carrying the projectors through an angle \(1/M\) would rotate the cups a like amount and in one rotation, that is, in a sidereal month, would rotate the cups through 360°. But, because (A) is rotating with a period of one year it automatically and with the utmost simplicity lengthens the period to one synodic month, for in one day it would turn through an angle \(1/E\) thereby retarding (C) by a like amount. The relation \(1/M - 1/E = 1/S\), where \(E\) is the year, \(M\) the sidereal month, and \(S\) the synodic period, is maintained. The horns of the crescent Moon point along the ecliptic and not exactly away from the Sun but the error is not perceptible except when the Moon is very near the Sun and only then when near its greatest celestial latitude. But since the Moon is scarcely to be seen within one day of conjunction the malposition of the terminator will in general escape notice.

The main planetary driving shaft (Z) in its two sections provides that the solar, lunar, and planetary motions take place in perfect synchronization for the gears are all interlocked. The terrestrial disks all rotate with one-tenth the speed of the shaft (Z), the planetary disks in strict proportion.

The locations of the sets of projectors which throw the principal astronomical reference circles on the dome are indicated on the diagram of the instrument (Fig. 4). The projectors for the equator and ecliptic (13, 14) must of course move with the instrument and the circles which
they project travel with the stars, being displaced only by precessional motion. By a series of lenses full circles are projected on the sky, the ecliptic graduated in daily dated stations of the Sun, the equator graduated to indicate right ascension. The projectors for the meridian (15, 16), on the contrary, are fixed on the standard. As our horizon is always with us, fixed in the chamber, so are the zenith and meridian. Illuminated letters, N, E, S, W, faint of course so as not to be obtrusive, stand along the horizon at the cardinal points. At each point is also the letter of the opposite point for as one travels on a meridian over the pole all directions reverse. These graduated reference circles are useful for instruction in the coordinate systems and their interrelation, and even for the solution of simple problems in practical astronomy and navigation.

The over-all length of the great dumbbell is twelve feet. The center of motion which is in the plane of the horizon is 9.81 feet above the floor. The weight of the movable parts approaches a ton. The support for it is built of steel in lattice-work fashion of the thinnest allowable members consistent with the demand for freedom from vibration or oscillation, just as in the planetary cages the struts are thin and placed edge-on to the line of projection that the obstruction shall be as slight as possible.

There are four distinct types of motion: that for change of latitude; the diurnal motion; the interlocked motions of the Sun, Moon, and planets; and the precessional motion.

The first of these is wholly independent of the others. The motor drives the whole movable part of the instrument about the axis (3-3) (Fig. 4) perpendicular to the meridian, thereby changing the inclination of the polar axis (1-1) and producing a change in the aspect of the sky like that resulting from change of latitude. The arrow-head markers for the poles move along the graduated meridian and permit the latitude to be read directly by the polar altitude. The alternative method of reading the zenith distance of the intersection of meridian and equator is also available. The period for the 360° circuit is 5° 8′.

There are two motors for the diurnal motion which rotate the instrument about the axis (1-1) (Fig. 4) in periods for the sidereal day of 3° 12′ or 1° 4′. These motors can be operated together or opposed, yielding periods of 48′ or 1° 36′.

The synchronized solar, lunar, and planetary motions, commonly referred to as the annual motions, take place within the body of the instrument. There are three motors which in the Chicago instrument used singly operate at the rates of a year in 3° 3′, 61′, and 5° 8′. They may be run in any combination forward or backward. The shortest possible year with all in either forward or backward motion is 5° 1′.

The remaining motion is that about the axis (2-2). This reproduces the precession of the equinoxes, for it changes the direction in which the ecliptic faces with respect to the equator and sends their points of inter-
section, the equinoxes, in westward motion. The stars move parallel to
the ecliptic changing right ascension, declination, and celestial longitude,
but with celestial latitude unchanging. In nature the precessional cycle
requires 25,800 years; in the planetarium 1° 16′. As the equinoxes
move, the pointer at the equatorial pole moves about the pole of the
ecliptic in a circle of radius equal to the obliquity of the ecliptic. As
noted earlier this circle graduated in chiliads is thrown on the dome by
a projector in (7) (Fig. 4).

FIG. 17. COMPLETE DESIGN OF MOTOR DRIVE IN SCHEMATIC FORM.

The diurnal, annual, and precessional motions are not wholly inde-
dependent but are interconnected in some operations mandatorily but not
necessarily reciprocally. Thus the operation of the diurnal motion
carries with it the commensurate annual and precessional motions, but
neither the annual nor precessional carries the corresponding diurnal.
The operation of the annual motion requires the proportional precession-
al change but the reverse is not true. So in general, the motions which in nature are of short period carry with them in the planetarium operation those of longer period and this of course either backward or forward in time but the reciprocal action does not hold. This does not imply that the daily motion may not be operated when the annual is on, or when the precessional is on, nor that the annual may not be used when the precession is in operation, nor that the independent precessional or annual motions may not be superposed on the proportional automatic ones. Various combinations are possible but the automatic connections are as stated. Some combinations give very curious results.

**Fig. 18. Detail of the Annual and Precessional Drives.**

Since diurnal and annual speeds of nearly equal periods are provided it is possible by using the two together to have perpetual noon day. Also, with a backward precessional motion and a forward annual motion one may have perpetual spring. Fig. 17 shows the general course of transmission of the motions and Fig. 18 some interesting details of the transmission.

It is not necessary to elaborate on the change of latitude drive. As noted before, this motion is entirely independent. Its method of applica-
tion from the motor (1) through two worm gears is apparent in Fig. 17.

The three annual motion motors (4, 5, 6) (Fig. 17) transmit by
\( (J_i, K_i, H_i) \) to the planetary shaft in the north cage and by \( (M_i) \) and
a shaft through the perforated precessional axis \( (2-2) \) to the planetary
shaft in the south cage. The planetary shaft is here number \( (4, 4) \).
Heretofore it has been designated \( (Z) \).

At \( (D_i) \) a shaft is taken from \( (K_i) \) to transfer the annual motion to
the precessional axis for proportional motion. A multiple reduction in-
volving a 3000-fold step-down is shown in Fig. 18 at \( (D_i) \). Thirteen
gears are involved between \( (K_i) \) and the bevel gear \( (K) \). The bevel
gear \( (M) \) is mounted on the head of the precessional driving worm shaft
which turns the worm wheel \( (W_z) \) and thereby rotates the instrument
about the axis \( (2-2) \). The worm shaft is perforated and the shaft \( (T_z) \)
from the precession motor \( (7) \) passes through it (Fig. 19). The motion

![Fig. 19. Detail for Precessional Motion and the Annual Increment Thereof.](image)

from the annual train and from the precession motor \( (7) \) are both ap-
plied to the gear \( (M) \) through the intermediate bevel gear \( (S) \), the axis
of which is a pin through the shaft \( (T_z) \). If the annual motion is run-
ning, the gear \( (K) \) will drive \( (S) \) and thereby \( (M) \) and the worm
\( (W_z) \) in the proper ratio to the year. The axis of \( (S) \) will remain
fixed in direction. If, however, the precessional motor \( (7) \) is running,
the shaft \( (T_z) \) will turn and with it of course the axis of the gear \( (S) \),
entailing motion of \( (K) \) or \( (M) \) or both. But since \( (K) \) is practically
locked by the manifold gear reduction it stands fast and \( (M) \) is driven.
The annual motors then deliver automatically the attendant precession
but the reverse does not apply.

The diurnal motors (2) and (3) (or 18 in Fig. 4) transmit their
motions through the shafts \( (Z_i) \) and \( (M) \) to a worm \( (W_z) \) mounted as
an integral part of the cradle which carries the whole instrument in its
bearing on the axis \( (3-3) \). With either or both of these motors in opera-
tion the instrument is driven about the polar axis \( (1-1) \). The bevel
gear \( (T) \) turns with \( (W_z) \) and through the pinion \( (V) \) and shafts
\( (Z_i, T_z) \) drives the main annual motion shaft \( (J_i) \) and so through the
whole train for the proportional increment of annual motion and even
the precessional motion.

From the rapidly turning annual motion motor to the creeping pre-
cession requires extraordinary gear reduction. There are 25,800 years
in the precessional cycle. If the motor makes 1600 RPM and if the year required exactly one minute, the reduction would be 41,280,000 to 1. For the 5°8 annual motion this would be 3,990,400 to 1. The greatest reduction is from the slowest diurnal motion by the circuitous route through the annual motion to precession, where the reduction, providing the motors run at 1600 RPM, would be 48,248,064,000 to 1.

The wiring for the electric circuits is another interesting feature of the instrument. The lamps in the great globes for the star projectors are 110 volts, 1000 watts. For the other multiple projectors for constellation names, circles, etc., they are 30 volts, 100 watts; and for Sun, Moon, planets, Sirius, variable stars, etc., they are 6 volts, 10 watts. The commutators on axis (3-3) may be seen in Fig. 4 at (22). There are thirty rings for the distribution from the pedestal to the movable parts of the instrument at this stage. There are other distribution rings on the great plate in the equatorial plane and also on either side of this in the plane of the ecliptic. They provide unbroken circuits with entire freedom of motion about the axes (1-1), (2-2), and (3-3). For the planets there are individual rings with sliding spring contacts. The electric circuits are led down the frame in small tubes and make contacts with the cable leading to the control board by a many bladed knife switch under the standard at (26) (Fig. 4).

The control board (Fig. 20) at first glance seems fairly complex but it is logically arranged and sufficient mastery to enable the demonstrator to operate it in the dark or with dim light is soon acquired. Considerable experience and practice are needed, however, before the demonstrator can without hesitation make the correct contacts. If from inexperience he must divert attention from the thought of his lecture to consider the operation of the switch-board, his discourse is interrupted or perhaps incoherent. A novice should not drive an automobile in city traffic. Fortunately in the planetarium no damage can result from turning the wrong switch except that to the speaker's complacency. It is a matter of chagrin to prepare an audience for the approaching trip to the pole and find instead the equinox moving among the stars with swiftly rolling centuries. An obvious solution is to have a trained operator and free the lecturer from the responsibility. But more freedom, more elasticity, more spontaneity are available if the demonstrator manipulates the controls.

A considerable number of astronomers have presided at the control board of the Adler Planetarium in public demonstration. The Director has given 554 lectures, the Assistant Director Miss Maude Bennet 420, Demonstrator F. W. Schlesinger 151. Besides these regular members of the staff, the following have participated as guest lecturers: Walter J. Bartky 171, Dinsmore Alter 122, W. D. MacMillan 63, C. H. Gingrich 34, R. H. Baker 33, D. W. Morehouse 26, Elliott Smith 18, E. A. Fath 10, W. H. Garrett 9, James Stokley 7, Joel Stebbins 6, Ralph C. Huffer 5, H. T. Stetson 3, E. J. Moulton 3, Giorgio Abetti 1, Clyde Fisher 1.
Fig. 20. Control Board at the Demonstrator's Desk, which is enclosed to confine its faint illumination.

m—Meridian. A push button for momentary presentation (extinguishes on release) and switch for longer showing. c—Equator, ecliptic, and sections of hour circles. Button and switch. y—A button for the year counter. n—Constellation names. S—The stars. C—Moon. P1—Planets. O—Sun. c—Cardinal points. b—Switch for control-board lights. The lamps are seen at the top of the board. Ordinarily these are hooded. P—Precessional motion. L—Change of latitude. A—Annual motion, slow at the left, intermediate in the center, and fast at the right. D—Diurnal motions, slow at the left and fast at the right. Rb—Rheostat for adjustment of control-board illumination, the lights (b). RO—Rheostat to control the brightness of the Sun. Rp—Rheostat to control the brightness of the optical pointer. p—Plug for optical pointer. x—Extra line. f—Fuse plugs. M—Master switch.
The master switch for connecting all circuits is at the bottom of the board (M) (Fig. 20). All switches for projectors are in the top section of the board; all for motions are in the row (P, L, A, D) across the upper center of the board.

By reversing the plugs above the seven switches (P, L, A, D), the directions of motion are reversed. The seven motors under instant control by the several switches may be operated in as many different ways as there are possible combinations, having in mind that any or all of them may be arrested or reversed. Mathematically there are 2187 possible combinations, including the one when all circuits are dead. The vast majority of combinations serve no logical or illustrative purpose. For example the use of all seven in any possible combination of direct or reverse would produce an almost meaningless phantasmagoria. The combinations actually used are comparatively few, less than two score. Certain interesting combinations to give perpetual noonday or eternal spring have been previously cited. Just as certain combinations are of interest so also certain sequences of motion are of value; for example, the change of latitude to bring the pole to the zenith to be followed by diurnal motion to show the movement of the stars on the “parallel sphere.”

Ready to the hand of the demonstrator is an optical pointer (Fig. 21). It is plugged into the switchboard at (p). Its brightness may be controlled by (Rp). It is a focusing lamp which throws an image of an arrow on the dome. As it is held in the hand any point of interest can be indicated. Care must be exercised to use it sparingly, to move it slowly, to hold it steadily on the object, to extinguish it when it has served its purpose. Rapid motion of this arrow or unsteady holding
or excessive brightness is annoying.

The remaining features of the control station are the switches and rheostats for the lights (28) (Fig. 4) which furnish the general illumination of the chamber, and the rheostats to produce the change of brilliancy of typical variable stars. This feature of variable stars is new with the Chicago instrument.

Near the demonstrator's desk there is an auxiliary projector for showing lantern slides. These may be flashed on the dome as in any ordinary illustrated lecture. In pointing out the Great Cluster in Hercules, for example, a picture of it might be projected on the dome to show its appearance in a great telescope. For such purpose the lantern is of great value.

In the Adler Planetarium certain accessory apparatus has been developed for use with the stereopticon to reproduce the phenomena of eclipses, meteoric showers, aurora, etc.

The planetarium affords means for illustration of a great variety of astronomical phenomena, too many to present in a single lecture. At the Adler Planetarium twelve topics have been selected which serve fairly well as vehicles to show the various possibilities of the instrument. The topics rotate, each one serving for a month.

February—Time and Place.
March—The Calendar.
April—The Moon and Its Motions.
May—The Way of the Planets.
June—The Midnight Sun; the Heavens at the North Pole.
July—Summer Constellations of the Home Sky.
August—The Southern Sky; the Southern Cross.
September—The Seasons; the Annual Journey of the Sun.
October—The Great Precessional Cycle.
November—Objects of Special Interest in the Sky.
December—Architecture of the Heavens.

In devising a program it is obvious that the method of presentation must differ in several respects from that of the university class room. For the audience there are no intellectual prerequisites; there is mixture of age and interest through wide range; there are some making their initial visits, others who have been frequently in attendance. There can be, therefore, no strictly formulated progression. Each lecture must be measurably self-contained. Some features are common to all demonstrations for each includes a brief description of the instrument and exhibits the phenomena of diurnal and annual motions. Beyond this, emphasis is placed on items particularly associated with the topic for the month. What these must be is obvious in most cases but even so, careful consideration is necessary if repetition is to be avoided and discourse and sequence of events are to fit in orderly and natural fashion.
January and July are devoted to constellation study. Methods and history of nomenclature are discussed. The ancient star groups and the principal stars are pointed out; where they may be seen at different hours at different seasons. The lantern lends its aid with slides of the constellation figures, slides of paintings or sculptures portraying the old stories of mythology and of temples oriented to certain stars, and slides of interesting astronomical objects in the constellations. No Chicago youth can in later years cry out with Carlyle: "Why did not someone teach me the constellations and make me at home in the starry heavens?"

*Time and Place* brings emphasis to the systems of reference circles and coordinates. The circles are projected on the dome. Solar time, sidereal time and their relation; the inequality of apparent solar days; the equation of time and need of mean time can be exhibited very simply. The change in aspect of the sky with change of latitude may be seen; the altitude of the pole or meridian zenith distance of the equator can be read directly.

*The Calendar* continues the previous topic with the consideration of the adjustment of the incommensurable units of day and year. An interesting feature in this lecture is the demonstration of the Metonic Cycle, the equality of 235 months to nineteen years.

*The Moon and Its Motions* includes an explanation of the phases, the reason for great meridian altitude of the full Moon of winter and *vice versa*, the orbital inclination, the Harvest Moon, the regression of the nodes, eclipse of the Sun and Moon. For the exhibition of eclipses special apparatus has been devised and constructed.

In *The Way of the Planets* the phenomena of planetary motions are considered more thoroughly. The rapid annual motions are here of greatest value. The looping of the apparent paths in the sky, the retrograde motions, critical or multiple conjunctions are exhibited very vividly. It is beautiful to see the planets describing their rhythmic arabesques among the stars. The triple conjunction of Jupiter and Saturn in 1940-41 is nicely shown. The agreement of the dates with those yielded by calculation demonstrates the usefulness of the instrument for approximate computation.

*The Midnight Sun* of course requires that the Sun be at the summer solstice and that the observer be on the arctic circle or still farther north if the solar declination is less. The place and time for the Sun's setting are observed, first in the latitude of Chicago, then farther north until the phenomenon of the Midnight Sun is revealed. The hour of sunset can be read by the projected coordinates, its place can be noted by the buildings of the Chicago skyline cut in silhouette along the horizon. At the pole the circling of the Sun, planets, and stars along almucantars, with the pole star near the zenith, shows the parallel sphere. The Sun sets at the autumnal equinox and in the arctic night the aurora borealis appears. For this a simple piece of apparatus (also designed here) serves admirably.
The Southern Sky: the Southern Cross is treated in much the same manner as the lectures on constellation study. On the way south a pause is made at the equator to show the right sphere.

The Seasons: the Annual Journey of the Sun is one of the most effective lectures. The course of the Sun along the ecliptic, the low short arc of the Sun in the winter day (counting the hours), the long night, and reciprocal conditions in summer, give convincing explanation of summer's heat and winter's cold. The changing meridian altitude of the Sun through the year is neatly shown by running the diurnal and annual motions together, using the nearly equal periods, so adjusted as to give perpetual noonday, itself an interesting phenomenon.

The Great Precessional Cycle is the topic perhaps of greatest interest to astronomers because the change of the sky from precession in a human lifetime is so slight that acquaintance with it, while of great interest, is generally encountered as an annoying consideration in dealing with star positions. It is very strange to see the swift motion of the stars in circles parallel to the ecliptic, to see the equinox moving among them and the pole reeling about the pole of the ecliptic. It is curious to see the sky of 3000 B.C. with Thuban (Alpha Draconis) as the pole star, with the Vernal Equinox in Taurus, the Southern Cross appearing above the Chicago horizon; or leaping far into the future, 14000 A.D., to see Vega as the pole star, the Vernal Equinox in Virgo, Sagittarius high in the sky and holding the summer solstitial point, Alpha Ursae Minoris setting, the Southern Cross again appearing, and Orion far from the Equator, at upper culmination only half above the horizon. An interesting variation can be accomplished by running the precession against the synchronized annual motion and thereby attaining perpetual spring or eternal summer. The lecturer with simple apparatus shows the relationship of astronomical precession to the familiar gyroscopic motion of spinning objects here on Earth.

Objects of Special Interest in the Sky takes up in sequence the different kinds of objects: proper motion stars, double stars, giant and dwarf stars, variables, multiple stars, clusters, nebulae, pointing them out, showing slides of them and about them. The rheostat control of the variables is used very effectively here. In this lecture (partly because it is given in November) a meteoric shower is projected realistically on the screen with the radiant in Leo. This is produced by a device which has been made in the instrument shop of this institution.

The Architecture of the Heavens may serve either as an introduction to the series or a summary of the whole. The method of star counts to demonstrate galactic concentration is illustrated. The Milky Way, so beautifully portrayed, takes on its true significance. By putting the nodes of the galactic plane at the east and west points and then changing latitude, it is possible to bring first one pole of the galaxy then the other to the zenith. When this is done our solar system is shown to be well to the north of the median plane.
It is possible to vary these lectures for any purpose at will. For example, on two different occasions Officers of the U. S. Navy stationed in the vicinity of Chicago, Naval Reserve Officers, the Naval R.O.T.C. Unit of Northwestern University, and Army Officers of the Air Service, have attended special demonstrations for instruction in the astronomical phases of navigation, or perhaps it were better to say, demonstrations to illustrate the applicability of the planetarium for such instruction. While the contents of the lectures may be varied ad libitum the twelve topics outlined above have been adopted for the scheduled demonstrations.

The minimum schedule of demonstrations of the Planetarium, operative in winter, offers lectures each week-day at eleven o'clock in the morning and at three in the afternoon. In addition there are lectures at eight in the evening on Tuesdays and Fridays; on Sunday afternoons lectures are given at three and four. In summer this program is expanded by additional lectures in the afternoons and evenings.

The response of the public has been very gratifying. The attendance during the first year was 731,108. The million mark was passed on the twenty-first day of the sixteenth month. The average daily attendance for the first nineteen months was 1,951. No record is available to show how many of the total have made more than a single visit. Certain it is that there are many who attend frequently and many who announce that they are attending each month to hear the complete cycle of lectures, some oftener than once a month. The large attendance is the more gratifying when it is realized that the building is more than a mile from street car or elevated transportation; only busses and taxis are available for public conveyance. Moreover, the approach to the building is as yet none too inviting. The way to the island leads across the lagoon by a temporary wooden bridge, which in rough weather may be swept by waves, and then a bleak third of a mile on a dirt and cinder road or path. The installation of the great bridge and the completion of the landscaping will totally change this aspect.

The visitors come to see a stirring spectacle, the heavens brought within the confines of museum walls. Not a trivial plaything, a mimic aping firmament, but the heavens portrayed in great dignity and splendor, dynamic, inspiring, in a way that dispels the mystery but retains the majesty, a revelation of the sky so beautiful that with Milton one may say “...fragrant the fertile Earth
After soft showers, and sweet the coming on
Of grateful evening mild; then silent night
With this her solemn bird and this fair Moon
And then the gems of heaven, her starry train.”

(A second paper, pertaining specifically to the Astronomical Museum, will follow in an early issue of this magazine.)

Adler Planetarium and Astronomical Museum,
Chicago, Illinois, 1 January 1932.