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THE SEARCH FOR THE NINTH PLANET, PLUTO

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At the beginning of the 20th century, a few investigators, particularly Dr. Percival Lowell, became interested in the possible existence of an unseen planet beyond Neptune. Certain small residual perturbations of Uranus were interpreted by Lowell as indications of the presence of another, more distant planet. Dr. Lowell started a search program in 1906, at Flagstaff, using a camera 5 inches in aperture to record photographically the positions of the many thousands of faint stars, for purposes of comparison. About 200 plates were obtained by E. C. Slipher and 50 by K. P. Williams. This series of 3-hour exposures was centered along the invariable plane of the solar system, at every 5° of longitude. Dr. Lowell examined these plates with a hand magnifier by laying one plate of a pair over the other. The new planet could not be found, for, as is now known, the inclination of its orbit placed its images just off the south edge of the plates.

Next, a series of plates was made with the 42-inch reflecting telescope. Its small field rendered this instrument unsuitable for searching. The comparison of plates was greatly facilitated, however, by the use of a Zeiss blink comparator.

The search was resumed in 1914, as a result of the loan of a 9-inch telescope by the Sproul Observatory. From 1914 to 1916, a great many plates were taken with this instrument. The plates were examined under the blink comparator by Dr. Lowell and C. O. Lampland. Nothing was seen of the elusive "Planet X." This fact was a keen disappointment to Dr. Lowell, as he felt that theory had lent all the aid it could.

The search work from 1906 to 1916 was at some disadvantage, because Pluto was moving slowly on the more remote part of its orbit and was consequently about a half magnitude fainter than it was at the time of discovery.

In 1915, Dr. Lowell published his 125-page "Memoir on a Trans-Neptunian Planet." His solutions indicated that "Planet X" had a mass 1/50,000 that of the Sun, or 7 times that of the Earth, and a mean distance of 43 astronomical units from the Sun. Dr. Lowell assumed the unseen planet to have a low density and a high albedo, like the four giant planets, and hence a disk subtending an angle of one second of arc with a stellar magnitude between 12 and 13. On November 16, 1916, Dr. Lowell died suddenly and the search was discontinued for 13 years.

In 1919, W. H. Pickering, from discrepancies in the motion of Neptune, found indications of a planet in the same region of the sky and predicted that the new planet would be of the 15th magnitude. Four photographs were taken with a 10-inch telescope on Mount Wilson in December, 1919, of the region in which the unseen planet was supposed to be. Portions of these plates were pretty carefully examined, but nothing was found, for Pluto's images were outside the area of close scrutiny. Moreover, some of the images of Pluto were nearly obliterated by accidental defects in the emulsion. It was natural, then, for the astronomical world to doubt the existence of a trans-Neptunian planet.

The Lowell Observatory still courageously persevered with the search. In 1925, glass disks were procured for a 13-inch photographic telescope with a wide field. Percival Lowell's brother, Dr. A., Lawrence Lowell, generously provided the funds to complete the instrument. Great credit is due the skillful optician, Mr. C. A. R. Lundin, who succeeded in making a search instrument of superior quality. In January, 1929, the Director of the Lowell Observatory, Dr. V. M. Slipher, invited me to join the Observatory staff. In a few weeks, the 13-inch objective arrived from the East, and was promptly installed in its tube. In the next few weeks, tests were performed to ascertain the properties of the instrument.

The 13-inch Lawrence Lowell telescope has a focal length of 66 inches and a plate scale of 30 millimeters per degree; it gives good images over almost the entire area of a plate, 14 by 17 inches, covering an area of the sky nearly 12° by 14°. Success in using so large a plate effectively is attained by the use of special plateholders which bend the plates into a slightly concave form by a controlled amount. Every plate was tested and made to conform to a standard curvature, so as to insure a homogeneously focussed series of plates. The images of the faintest stars were consistently less than 1/30th of a millimeter in diameter.

Every precaution was taken to match perfectly the plates of each pair, so as to facilitate thorough and rapid examination under the blink comparator—a laborious work at best. Other precautions included: selecting plates of like age and sensitivity, careful judging of sky transparency and sky light, equal exposure times, same guide star, similar steadiness of seeing, same hour angle, careful guiding, avoiding moonlight, and uniform development. A 7-inch refractor was used as a guide telescope, so that the guide star occupied the center of the plate. A 5-inch camera was attached to check the brighter planet suspects. The standard exposure time was one hour, recording stars to the 17th magnitude, except at the extreme ends and corners of the plates. Guide stars, seldom fainter than the 7th magnitude, were carefully chosen on or very near the ecliptic so as to provide sufficient overlap for planetary motion when adjacent plates were not taken at the same dates and also for some loss in magnitude near the edges of the plates.

Since planets move slowly in the sky with reference to the stars, it should be evident that the basic technique in searching for new planets is to photograph a given region of the sky, then take a second photograph of the same region at a later time for the purpose of comparison. The scale of the 13-inch plates is such that, for a planet beyond the orbit of Neptune, the shift of the image is suitable for detection after an interval of 2 or 3 days.

By the end of March, 1929, final adjustments having been made, I embarked upon the long, hard, tedious task of taking many plates at the telescope each month and of examining them under the blink comparator. The favored region in Gemini was sinking in the western evening sky—soon it would be behind the Sun. Accordingly, these regions were promptly photographed, then regions to the east along the ecliptic, as rapidly as possible. Various improvements in the technique suggested themselves, as the work progressed. Two proved to be very important. (1) Much time, effort and expense may be lost in running down planet-suspects that turn out to be only asteroids near their apparent stationary points where they imitate the slow motion of a more distant planet. The simple expedient was to photograph each region near its "opposition point" (180° from the

Sun), where the apparent retrograde motion is a maximum for all planets outside the Earth's orbit, and the daily shift in position against the star background is roughly inversely proportional to the distance of the object. As a consequence, the asteroids, on the average, moved about 7 millimeters per day on the plates, and exhibited short trails during the hour's time of exposure, whereas Pluto moved only ½ millimeter per day. This criterion was useful in estimating at sight the distance of any suspicious object, and extremely convenient in computing a rough ephemeris when it was necessary to re-photograph a region later in running down a promising planet suspect. The known asteroids number a few thousand and are widely scattered between the orbits of Mars and Jupiter. The angular distances of the stationary points from opposition for Mars and Jupiter are, respectively, 36° and 64°. Accordingly, the areas of the sky between these limits were scrupulously avoided. On account of the revolution of the Earth around the Sun, the opposition longitude moves eastward through the constellations at the rate of 30° per month. From September, 1929, to the end of the search, the practice of photographing each region of the heavens at opposition was strictly followed.

There are two other advantages to photographing at opposition. The opposition point is on the local meridian at midnight, and so allows the observer enough observing hours to obtain the necessary number of plates, without running into unfavorably low altitudes in the sky. Moreover, the Earth is nearest the planet then, although for a planet as distant as Pluto, the difference in brightness between opposition and conjunction is only 0.1 of a magnitude. (2) Experience in examining pairs of plates under the blink comparator early revealed that the greatest number of planet suspects were very faint and beyond the reach of the 5-inch camera plates for checking. Almost every pair of plates had a few faint planet suspects, which were only plate defects. Some pairs had over a hundred of them. If the search program was to be thorough and worth anything, this problem had to be met in a practical way. Accordingly, the second important improvement in the technique consisted in taking 3 plates of each region within a total time of one week. This procedure increased the photographic work by 50 per cent, but it was well worth it. The planet suspects were marked as the "blinking" progressed. At the end of a panel, the unmarked plate was removed and the third plate slipped into place. Only a few out of several thousand suspects survived the crucial test of the third plate; thus, only a few regions had to be re-photographed. The practice of taking 3 plates of each region was advantageous in that the best matched 2 of the 3 plates were selected for blink examination.

I entertained the possibility that a new planet might be found in any part of the zodiac. After catching up with the opposition point in September, 1929, the blink examination began in real earnest on plates taken in Aquarius. The search progressed eastward through Pisces and Aries. On each of the plates the images of about 50,000 stars appeared. A pair could be thoroughly examined in 3 days. The number of stars increased in Taurus as the Milky Way was approached. The work of examination of each pair became more tedious and more prolonged. The plates taken in western Gemini contained over 300,000 star images each! Since the time spent in the blink examination of plates is proportional to the number of star images, this work fell behind that of taking the plates.

Three plates centered on Delta Geminorum were taken on 1930 January 21, 23, and 29, respectively. After laboriously finishing the easternmost pair in Taurus, I happily decided to postpone the two very rich regions in Gemini and started blinking the Delta Geminorum pair. When one-fourth of the way through this pair of plates, on the afternoon of February 18, 1930, I suddenly came upon the images of Pluto! The experience was an intense thrill, because the nature of the object was apparent at first sight. The shift in position between January 23 and 29 was about right for an object a billion miles beyond Neptune's orbit. Since the plates had been taken at opposition, I was confident that the object was not an asteroid. The images were sharp, not diffuse; hence, there was no suggestion that the object was a comet. In all of the 2 million stars examined thus far, nothing had been found that was as promising as this object. It was about two magnitudes brighter than the faintest stars recorded on the plates. At once the 5-inch plates, taken simultaneously, were inspected with a hand magnifier. There too were the images of Pluto, clearly confirmed, exactly in the same positions! The images were quickly found on both plates of January 21, the positions conforming with the motion indicated by the plates of January 23 and 29. Thereupon, I informed the Director and other members of the staff, who came to take a look.

The night of February 18 was cloudy, but the following night was clear, and the Delta Geminorum region was photographed again with the 13-inch telescope. The new plate was put under the comparator. Within a minute, the image of the planet was found, after 3 weeks' motion, just where it was expected. On February 20, with the aid of a film print of the immediate star field from this negative, the planet was soon picked out among the faint stars in the field of view of the 24-inch visual refractor. It was disappointing that no disk was visible—merely a faint, star-like object of the 15th magnitude was seen, which had moved a small distance from the photographic position of the night before. Dr. C. O. Lampland started photographing the new planet with the 42-inch reflector. The rate of motion continued to be satisfactory, and proved beyond doubt that the object was a trans-Neptunian planet.

News of the discovery was telegraphed to the Harvard College Observatory on March 13, 1930; from there it was announced to the world. A few months later the planet was named Pluto.

Pluto was discovered at the time it was crossing the ecliptic. Had it been far from its node, it would have been outside the first photographic belt and might not have been found until 1932, when two more belts, one on each side of, and parallel to, the first, were completed.

After the discovery of Pluto, I was urged to continue this thorough and systematic search over a wide area of the sky for other possible distant planets. This immense and tedious task continued at Flagstaff until three-fourths of the entire heavens had been explored, and 90 million star images had passed in review in the eyepiece of the blink comparator!

Some doubt has arisen as to whether Pluto is really Dr. Lowell's predicted "Planet X" because of the apparent smallness of its mass. On the other hand Pluto was found within 6° of his predicted place, and the predicted and actual elements of the planet's orbit are in remarkably good agreement.

Thus, Pluto, a planet barely visible in a 12-inch telescope, was singled out from 20 million other equally bright, or brighter, objects in the sky.

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