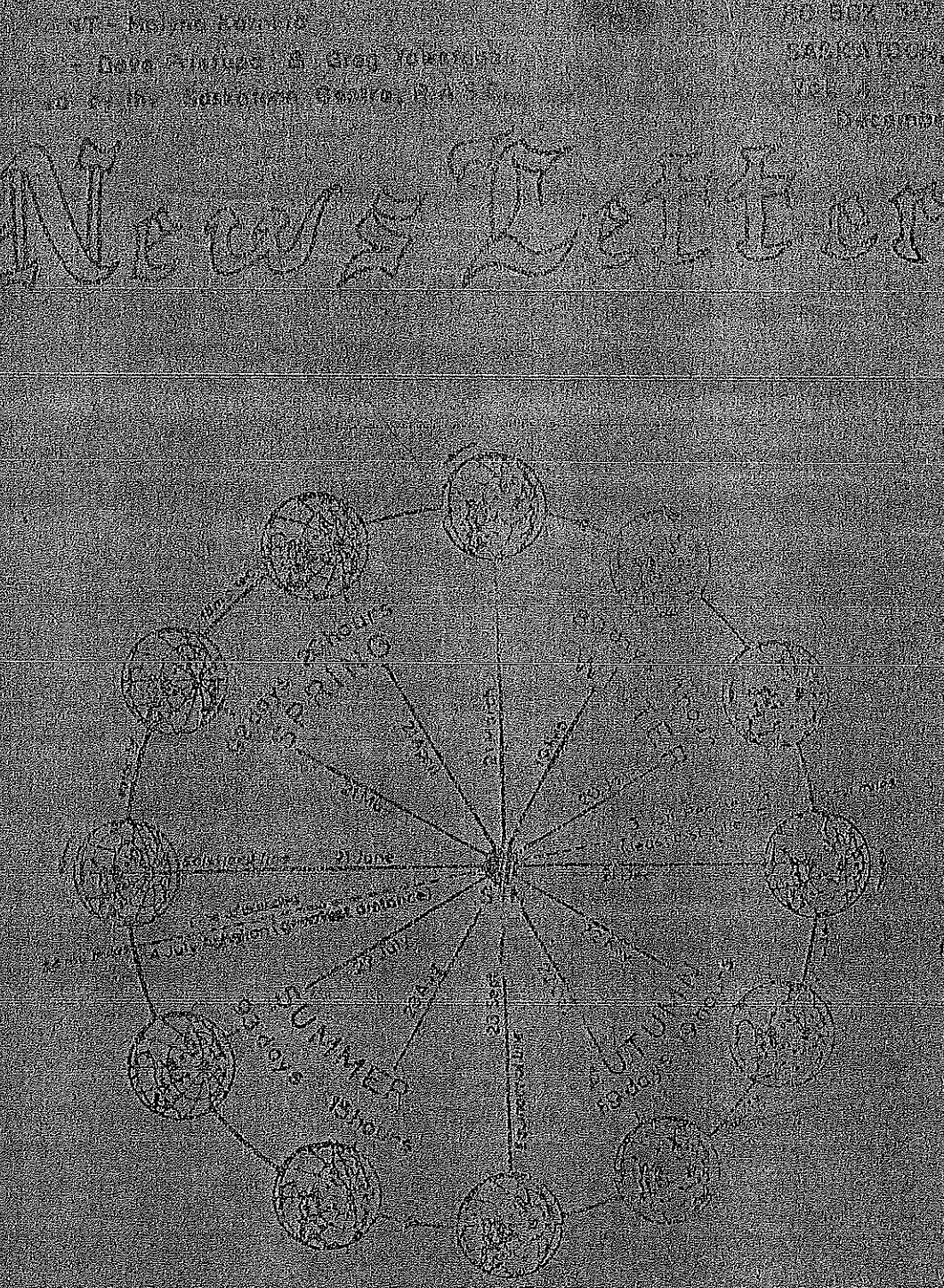


For a complete copy of this map



# THE MANY MOTIONS OF THE PLANET EARTH Part One

G.N.Patterson

Most people unfamiliar with astronomy, and even many amateur astronomers, tend to consider the Earth rotating about its polar axis (the day), and about the Sun (the year) as the only motions of the Earth. Any astronomer using only these two motions would find it very difficult to explain why the stars appear to change positions or to arrive at the correct figure for the proper motions of the stars and galaxies.

The true motion of the Earth is a much more complex movement, but can be broken down into several major individual motions which can be summarized as follows:

- a) Daily rotation about the polar axis,
- b) "Monthly" rotation about the Barycentre,
- c) Annual rotation about the Sun,
- d) Nutation of the Polar Axis,
- e) Precession of the Polar Axis,
- f) Rotation about the Galactic Center, and,
- g) Movement of our Galaxy.

Let us look at each motion separately and in detail.

## I. DAILY ROTATION ABOUT THE POLAR AXIS

Here there are two different time intervals of rotation to consider. The time period from 12:00 noon one day to 12:00 noon the next day, i.e., the shortest interval between the Sun being in the same position in the sky, is the solar day with a mean time of 24 hours. If instead we consider the time for the Earth to rotate from a star at the zenith one night until the same star is at the zenith the next night we find the time is only 23 hours, 56 minutes, 4.09 seconds of mean solar time, about 3 minutes, 56 seconds less than the solar day. This lesser time is the sidereal day and represents a true  $360^{\circ}$  rotation of the Earth. Why then the extra time of 3 minutes, 56 seconds in the solar day? To understand this we must realize that the Earth has changed position in its solar orbit during one "day", and hence must turn nearly one degree ( $0.986^{\circ}$ ) further to bring the same point on its surface under the Sun again. Figure 1 illustrates this requirement.

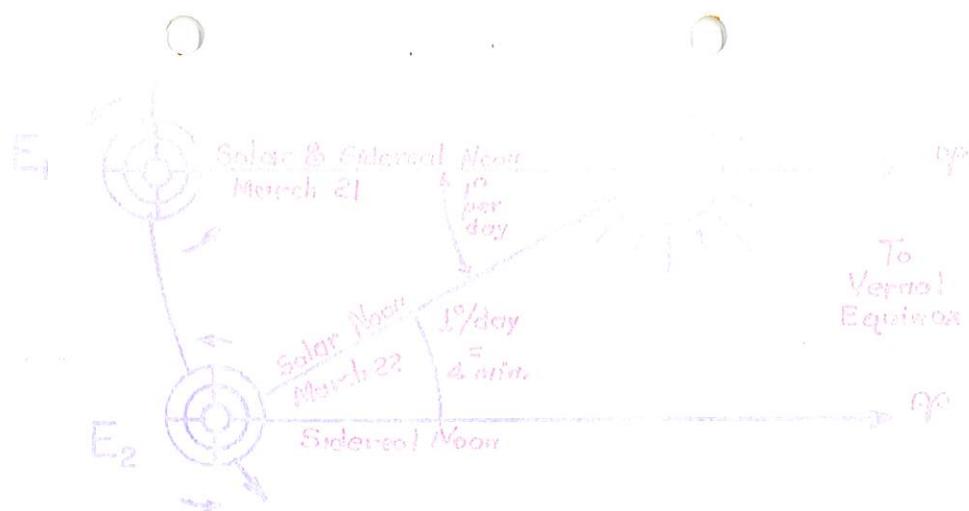


Figure 1: Diagram showing rotation of Earth and revolution about the Sun. The angle of  $1^\circ$  is highly exaggerated. The Earth, starting at  $E_1$ , rises at  $E_2$  a day later. Sidereal noon occurs when the Normal Equinox (sign of Aries) lies directly overhead, but the Sun will not be overhead until approximately four more minutes have elapsed.

## 2. ROTATION OF THE EARTH ABOUT THE BARYCENTRE

The Earth-Moon may be considered as a two-planet system which rotates about a common center-of-mass. To visualize this, consider two masses, one equal to the Earth, the other the Moon, equalling 0.0123 Earth mass, each mounted at opposite ends of a ruler 238,900 miles long. (Figure 2). The object is to find the point of balance or center-of-mass of this system.



Figure 2: Location of the Barycentre

$$Mx = m(238,900 - x) = 0.0123M(238,900 - x)$$

Solving for "x" gives a figure of 2902.766 miles from the Earth's center. This is a mean figure since the orbit of the Moon is elliptical, varying from 221,463 miles at perigee to 252,710 miles at apogee, so "x" varies from 2690.88 to 3070.55 miles from the Earth's center. This rotation point is known as the Barycentre, and actually shifts around below the Earth's surface to keep in line with the Moon, so this motion is very complex in itself. The period of time for one such rotation is 29 days,

12 hours, 44 minutes, 3 seconds.

It is the Barycentre that follows the elliptical path, and not the center of the Earth. As a result the center of the Earth oscillates back and forth in roughly a sinusoidal path, the synodic month to complete each cycle. The path of the Moon in outer space is epicyclic in motion, including retrograde motion. This is shown in Figure 3.

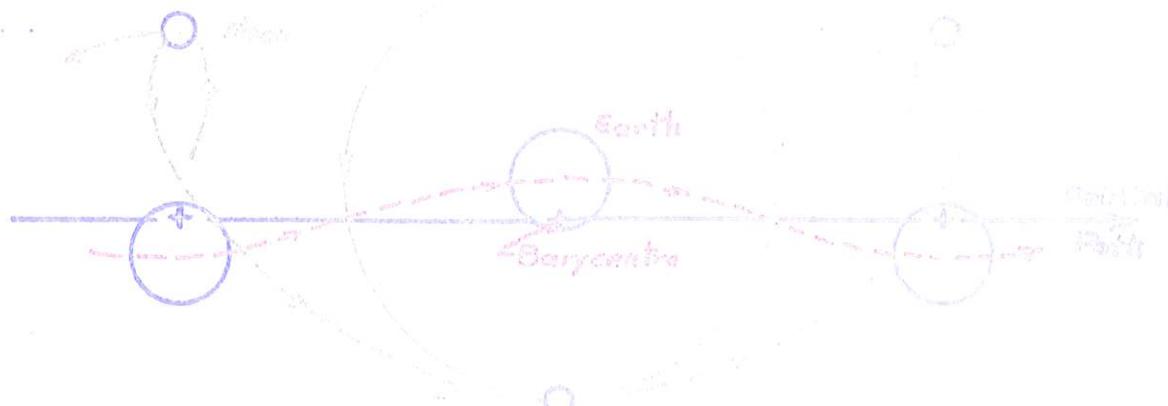


Figure 3: Path of the Earth and Moon, seen from above

### 3. MOTION OF THE EARTH ABOUT THE SUN

The path of the Earth (Barycentre) about the Sun is an ellipse with a semi-major axis of 92.96 million miles and an eccentricity of 0.017. At perihelion (closest to the Sun) the Earth is 91.10 million miles from the Sun, and at aphelion (furthest from the Sun) the distance is 94,52 million miles. The total orbital path is approximately 580 million miles, and the mean orbital velocity is 18.5 miles per second. In accordance with Kepler's Second Law, this orbital velocity is greater at perihelion and less at aphelion. The time taken to complete one orbit is one sidereal year, or 365 days, 6 hours, 9 minutes and 10 seconds. This is shown in Figure 4 (Cover Page) where an elliptical orbit is assumed for Earth. This, in fact, is not totally correct - it is the center-of-mass of the Earth-Moon system that follows the elliptical path. The center of the Earth oscillates about this elliptical path in a somewhat sinusoidal motion as shown in Figure 3.

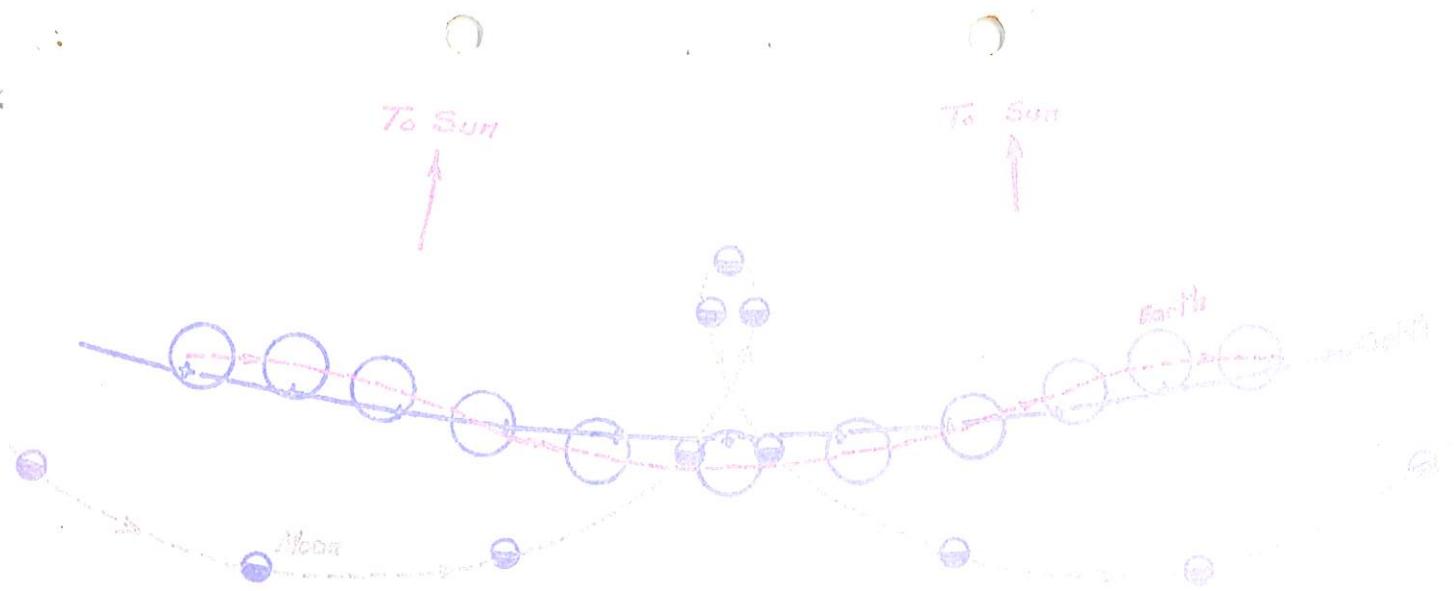


Figure 5: Path of the Earth-Moon system in Solar Orbit

#### 4. NUTATION OF THE POLAR AXIS

Nutation means nodding, and this is literally the motion transmitted to the Earth's axis by the movement of the Moon in a North-South direction. The Earth's axis is inclined approximately  $23.5^\circ$  to the ecliptic but the Moon's orbital plane is inclined only  $5^\circ$  to the ecliptic. This results in the Moon's orbit oscillating North and South of the Earth's equatorial plane between  $\pm(23.5^\circ \pm 5^\circ)$ , or between  $\pm 28.5^\circ$  of Declination. A complete cycle of the Moon between these limits takes place over a period of 18.61 years, and results in a total movement of the Earth's polar axis of 9.2 seconds of arc, or approximately one nine-thousandth ( $1/9000$ ) of the  $23.5^\circ$  declination angle. The shift of the polar axis on the Earth's surface at the pole amounts to approximately a 940-foot diameter circle.

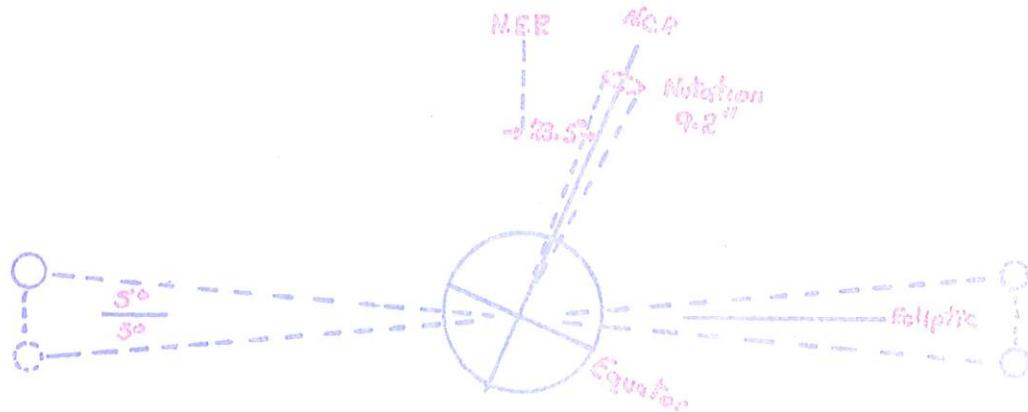


Figure 6: Nutation of the Polar Axis

The Nutation of the polar axis is closely connected with the Saros or eclipse cycle which takes place in approximately the same time, i.e., 18.03 years. Nutation is coincident with the next motion, Precession.

As a benefit of our subscription to ASTRONOMY magazine, we get two free 40 word advertisements in the Astro-Mart section, each year. If any member has something to advertise, he could use this. See the President or Treasurer if you are interested.

By the way, if you have any thoughts about the usefulness of the magazine, please mention it to some executive member. It is important that we spend our small budget for subscriptions on things that you like.

Evan Beveridge, a member in Porcupine Plain who does not often get into meetings, reports that he has recently completed and put into operation two telescopes: a 4.25 inch f/12.2 Newtonian and an 8 inch f/7 Newtonian. He writes, "actually, the long focus 4-½ is almost as good on bright objects like Jupiter as the 8" is at low powers. We have not yet added worm gear controls, brakes or setting circles to the 8" and I am using only low power with a small damaged diagonal." He also reports that he observed the sediment light about September 20.

- - - submitted by Alan Blackwell.

## GENERAL MEETING

DATE: December 19, 1974.  
TIME: 8:00 P.M.  
PLACE: Room 211, Health Sciences Building,  
(across from observatory)  
AGENDA: Regular business, Film: "The Strange Case of  
the Cosmic Rays"

### NOTICE TO ALL MEMBERS:

The Handbooks have arrived and all members who have not yet received one can get their copy at the general meeting.

### FUNDAMENTALS CLASSES:

The December 24 Fundamentals class is to be cancelled. The next class will be held on January 14, 1975.

### PHYSICS FOR FUN FILM SERIES:

The Physics for Fun film and lecture series is once again being held. The next activity in the series will be a lecture on January 8 on "Automation and Society".

All are welcome.

### LIBRARY:

Help will be needed to get our library cleaned up. The date is January 11 (Saturday) at 2:30 P.M.

THE EXECUTIVE WISHES YOU A MERRY CHRISTMAS

AND

A HAPPY NEW YEAR.

Minutes of the Executive Meeting  
Saskatoon Centre, R.A.S.C.  
Held in the Observatory  
November 3, 1974 3:00 p.m.

Present: Old and New Executive

Wandel Frenzel - Past President - Activities  
Halyna Kornuta - President - Past Editor  
Melodie Andrews - Secretary  
Alan Blackwell - Treasurer  
Gordon Patterson - (Past) Activities  
Jim Young - VP/PR  
Ron Waldron - Past VP/PR  
Hugh Hunter - Librarian  
Dr. Holden - Centre Rep. Programming  
Merly Melby - Councillor  
Greg Towstego Dave Pristupa - Editor  
Doug Beck - Bruce Fulton - Councillors

Item	Detail	Action
10.	The meeting was opened. 3:30 p.m.	
11.	The duplicator is now bought and put in the library.	
12.	Positions of the new executive were discussed among the past and present executive members.	
13.	Fundamental class are being held the 2nd and 4th Tuesdays in the observatory at 7:30 to 10:00 p.m.	
14.	Saturdays - Astrophotography classes are being held at Gordon Patterson's home (79 Baldwin Cres.) starting 8:00 p.m. weather permitting.	
15.	Saturday November 23, 2:00 p.m. Library inventory. Please return books.	
16.	The position of Centre Representative is now open, and a member to replace Dr. Holden is being looked into.	
17.	Motion for adjournment.	Doug Beck Hugh Hunter Carried

Minutes of the General Meeting  
Saskatoon Centre, R.A.S.C.  
Held in the Health Science Bldg. Rm. 111  
November 19, 1974 8:00 p.m.

Present: President - Halyna Kornuta  
Secretary - Melodie Andrews  
Treasurer - Alan Blackwell  
Editors - Greg Towstego  
  
Sub-Councillors - Merly Melby  
Doug Beck  
Bruce Fulton

VP/PR - Jim Young  
Library - Hugh Hunter  
Activities - Wandel Frenzel  
Programming - Dr. Briden

Absent: Editor - Dave Pristupa

Item	Detail	Action
18.	The meeting was opened at 8:00 p.m.	

18. Motion for adoption of October minutes  
Bill McDonald  
Gordon Patterson
20. Please note that fees are due.  
21. Nominations for Centre Representative.  
Motion for Centre Representative to be Wendel Frenzel.  
Gordon Patterson  
Jim Young Carried
22. The meteor shower October 20-21 was very good. Wendel Frenzel was the only member who turned out.
23. A lecture by Gordon Patterson on the "Various Motions of the Earth," was given.
24. Handbooks have arrived and were given out at the end of the meeting.
25. Motion for adjournment.

Marilyn Melby  
Doug Beck Carried