

ASTRONOMY IN ISRAEL: FROM OG'S CIRCLE TO THE WISE OBSERVATORY

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Supported in part by the U.S.-Israel Binational
Science Foundation

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INTRODUCTION

Colloquium IAU 72 is the first IAU-sponsored activity in this country, and it therefore seemed appropriate to include a paper on Astronomy in Israel. With the highly singular history of this nation, the scene will move from Eretz-Israel* to Babylon (present day Iraq) and to Europe before returning to this area.

MEGALITHS

Prehistoric astronomical activity is represented by a Stonehenge-like megalithic circle and "Observatory" at Rujm-el-Hiri, near Yonathan in the Golan, the Westernmost sector of the historical Bashan plateau¹⁾ dating from the IIIrd Millenium BC. Star worship is mentioned in the Old Testament²⁾ as being common among the Canaanites*, but the Bashan inhabitants who built that Golan megalithic circle antedate the Canaanites. Very little is known about them and the presumably religious role of their edifice. To the XIIIth Century BC Israelites, they appeared as the work of giants (Refa'im, also Anakim, Emim, Zuzim), and this is probably the source of the legends about races of giants that had lived in Eretz-Israel prior to the Israelite conquest - including the characterization "a remnant of the giants" for Og, King of Bashan, in Deuteronomy and Joshua³⁾. Indeed, the Rujm-el-Hiri circle is just one among many megalithic remains in the Bashan, probably at the origin of these tales. Notice that megaliths have given birth to just such stories in Greece and England (the "Giants' Dance" = Stonehenge).

ASTRONOMY IN THE MISHNA

The Israelites' abstract monotheism and their centering of intellectual creativity on ethical issues were detrimental to a natural development of observational science, as did happen in Sumeria or Greece. However, the requirements of agriculture induced a cycle of holidays that were incorporated in time into Judaism and were given Ethnical or National religious significance. There thus developed a need for an understanding of the recurrence of seasons and for a synchronized calendar fitted to Solar, Lunar and Sidereal time⁴⁻⁶⁾. Several of the Mishnaic scholars** were versed in Astronomy, such as the "Tannaim"

Yehohanan ben Zakkai⁷⁾, the Patriarch Gamliel II and in particular Yehoshua (=Joshua) ben Hananiah⁸⁾. In the tractate Horayoth, dealing with errors of Justice, the following anecdote is related⁹⁾: "Rabbi Gamliel and Rabbi Yehoshua went together on a voyage at sea. Rabbi Gamliel carried a supply of bread, Rabbi Yehoshua carried a similar amount of bread and in addition a reserve of flour. At sea, they used up the entire supply of bread and had to utilize Rabbi Yehoshua's flour reserve. Rabbi Gamliel then asked Rabbi Yehoshua - "Did you know that this trip would last longer than usual, when you decided to carry this flour reserve?" Rabbi Yehoshua answered - "There is a star that appears every 70 years and induces navigational errors. I thought it might appear and cause us to go astray." Rabbi Gamliel then exclaimed "You are so knowledgeable and you nevertheless have to travel to make a living?" Rabbi Yehoshua then answered bitterly - "How come you are so surprised? Don't you know that two of your own students Rabbi Eliezer Hisma and Rabbi Yehohanan ben Gudgada who are so smart that they can tell you how many drops there are in the ocean, have neither bread to eat nor clothes to wear?"

This observation is generally interpreted as relating to Halley's Comet¹⁰⁾, with a period approximating 76 years. Observing a comet's periodicity, with such a long period, requires records covering many centuries; it is possible that the Mishnaic scholars did inherit such records from the Great Kneset scholars (before 300 BC) who received them during the Babylonian exile (586-537 BC) from the "Chaldeans" (i.e. from Sumer, Akad etc. going back to the IIIrd Millenium BC). Indeed, the Hebrew agricultural names of the months^{***} were replaced by Sumerian and Akadian names after the Babylonian captivity. However, there is perhaps a difficulty with the dates: Rabbi Yehoshua was born in 35 AD and died in 117 AD. Rabbi Gamliel died in 115 AD. The only appearance of Halley's Comet in the interval 55-115 (when Yehoshua was older than 20), is in 66 AD. Rabbi Gamliel was younger than Rabbi Yehoshua and it has been argued that if he was 20-25 years old, it is doubtful whether he could have had students at the time¹⁰⁾. Still, this is not a strong argument, as Rabbi Gamliel II was also the hereditary Patriarch, and may have had students attached to him formally from the moment he was appointed head of the Sanhedrin.

Philippe Veron has, however, come up¹¹⁾ recently with a different identification of Rabbi Yehoshua's star, and argues that this was the variable Mira Ceti.

Mar Samuel, who became around 220 AD the Dean of the Talmudic Academy of Nehardea in Babylonia, was an astronomer who could calculate and adjust the calendar with great precision, intercalating an extra month or reassigning the length of a month. The prescriptions for the calendar adjustments were written down in a special Baraita^{**}. They include the 19 years synchronization cycle used to this very day in the Jewish Calendar.

SPAIN AND PROVENCE¹²⁾

Science spreads by convection. When Khushru Anushirvan, Sassanid Emperor of Persia, signed a ten year truce with Justinian of Byzance, he ensured the continuity of science by requesting that the teachers of the recently abolished Academy of Athens be transferred to Persia. In his fanaticism, Justinian was then trying hard to put an end to Judaism at the sametime eradicating Neo-Platonicism and what was left of Greek science. The Neo-Platonacists settled in Mesopotamia under Persian rule, and their school was already flourishing when Persia was conquered by Islam. Mathematics and Astronomy thrived (e.g. Omar Khayyam, whose Rubayat were just a hobby, his professional creativity having yielded methods for solving factorizable cubic equations etc.) and spread all over the new Mohammedon Empire. The Jews were active participants, and the first Arabic-language treatise on the Astrolabe was written by the Jew Joel, known as Masha-Allah of Basra (Iraq) around the year 800. This is the treatise that was translated into English by Geoffrey Chaucer ("The Treatise on the Astrolabe") around 1380, from a prior Latin translation. Masha-Allah also wrote a book on Lunar and Solar Eclipses, that was later translated into Hebrew by Abraham Ibn Ezra ("sefer be kadrut ha levana ve ha shemesh").

Sind ben Ali, a heretic Jew, was the main contributor (~830) to the astronomical tables of the Caliph Maimun. The scene now shifts to Spain, where Abraham bar Hiyya Hanasi ("The Prince") of Barcelona (d.1136) improved on these tables, using calculations performed by the Arab astronomer Al-Battani (d. 929). Abraham bar Hiyya was a prominent mathematician and astronomer, and wrote famous textbooks in both fields. He introduced Europe to (Arab) trigonometry in his "Treatise on Mensuration and Calculations". The Hebrew was translated by Plato of Tivoli into Latin in 1145 and the book served as main source material for the later work of Leonardo Fibonacci of Pisa. In Astronomy, his book "The Shape of the Earth" is based upon the Ptolemaic system, contains a roughly correct estimate of the distance to the Moon (but the wrong distance to the Sun). The principles for Calendar intercalation make up yet another book.

His student, Abraham Ibn Ezra (1089-1164), poet, philosopher, Biblical commentator and Astronomer, spent the last part of his life travelling in Italy and France, ending up in Eretz-Israel. He continued the publication of tables, mostly on the movement of the planets. The "Toledo Tables" were compiled by 12 Jewish astronomers led by the Cordovan Arab astronomer Ibn Arzarkali ("Azarchel"). The Latin version (translated by John of Brescia and Jacob Ibn Tibbon) was further improved in 1272 by a group of astronomers led by Isaac Ibn Said, and is known as the "Alphonsine Tables".

Rabbi Moshe ben Maimon's (=Maimonides) main contribution to Astronomy is his complete rejection of Astrology (1194). He is unique, throughout the Centuries, in making this clear-cut. Remember that Kepler was still drawing horoscopes! Perhaps this should justify a visit to Maimonides' tomb in Tiberias.....

Rabbi Levi ben Gershom (= Gersonides, also Maestre Leo de Bagnols, Maestre Leo Hebraeus; 1288-1344), was one of the greatest of Medieval astronomers. He lived in Provence, mostly at Orange. As a mathematician, he rediscovered the law of sines and published a sine table, correct to the 5th decimal. As an astronomer (he wrote 136 "chapters"!), he is the first to have relied on his own observations (in his studies of eclipses) rather than on Ptolemy's. He invented "Jacob's staff", a navigational instrument which was widely used for 3 centuries, and was the first person known to have used a Camera Obscura for his observations.

Rabbi Levi is also the first scientist to derive more realistic estimates of the distance to the fixed stars. Ptolemy's estimate was of the order of 10^{-5} light years (a million times smaller than the distance to the nearest star), whereas Rabbi Levi reached a figure of about 10^5 light years, 10 times our present estimate for the distance to an average star in the Galaxy. Gersonides was also one of the greatest Medieval philosophers and published Commentaries to the Bible.

The Zohar, a compilation of Jewish mystic writings drawn in Spain in the XIIIth Century anticipates Copernicus by stating that "the whole earth spins in a circle like a ball; the one part is up when the other part is down; the one part is light when the other is dark; it is day in the one part and night in the other".

Jewish astronomers played a key role in the theoretical preparation of the great voyages of discovery in the XVth Century. Judah Cresques, forced to adopt Christianity in the massacres of 1391, later became the Director of the Prince Henry of Portugal's ("The Navigator") Nautical Academy at Sagres. Abraham Zacuto ("Zacut", 1452-1515) worked first at Salamanca but moved to Portugal after the expulsion from Spain. As Court Astronomer to Kings John II and Manuel I, he prepared the voyage of Vasco da Gama (1496) and supplied instrumentation (including his newly perfected copper astrolabe), improved tables, charts, instruction and briefs. He developed the first copper astrolabe. His very precise predictions of eclipses were used by Columbus to threaten the natives at a dangerous moment. Like all Jews, Zacut had to flee Portugal in 1497 and went to Tunis. He died in Eretz-Israel.

MODERN TIMES

The XVI-XVIIth Centuries were centuries of Jewish sufferings, and contributions to Astronomy are less prominent, except perhaps for the Herschel family, of Jewish origin. It was only when Alexander von Humboldt became President of the Prussian Academy of Sciences, that he abolished the requirement of a Christian Oath by a Professor at his ordination. Karl-Gustav Jacobi was the first Jew who did not have to abjure his faith to become a Professor. The oath was re-established by von Humboldt's successor, but it was no more in existence when Einstein, Minkowski and Schwarzschild were ordained.

MODERN ISRAEL

Until 1965, observational astronomy was entirely a matter of amateurs. In that year we started astronomical research at Tel Aviv University, and by 1969 we had a Department of Physics and Astronomy,

still the only one in the country in 1982. In 1971 we inaugurated, with the help of the Smithsonian Astrophysical Observatory, the Florence and George Wise Observatory¹³) at Mitspe-Ramon (altitude 950m.) in the Negev. The telescope is a 40" Wide Angle Ritchie-Chretien reflector. European astronomers have often used the instrument. The more important observations at the Wise Observatory have been (1) the first optical identification¹⁴) of an X-ray pulsar, Hercules X-1 (J. and N. Bahcall, 1972); (2) the first direct verification¹⁵) of Whipple's conjecture about comet-tails being composed of water (P. Wehinger and S. Wycoft, together with G. Herbig at Lick Observatory and G. Hertberg and H. Liu in Canada, 1974); (3) the discovery of Sodium¹⁶) and Sulphur¹⁷) clouds around Jupiter, along the orbit of its satellite 10. (Y. Mekler, A. Eviathar and I. Kupo, 1974); (4) the precise observation¹⁸) of a recurrent Nova leading to a better understanding of the Nova mechanism (N. Brosh, I. Leibowitz, 1978); (5) the discovery¹⁹) of the 13-day period in SS433 (I. Leibowitz, T. Mazeh, in coll. with the University of Oregon, 1979).

We now have theoretical groups in almost all institutions in Israel. The late G. Racah was honoured by the IAU for his work in Spectroscopy by giving his name to a crater on the Moon, where he has thus joined the company of Ibn Ezra, Rabbi Levi, Zacut, Jacobi and Einstein.

BIBLIOGRAPHY

1. Z. Vilnay, Ariel - an Eretz-Israel Encyclopaedia, p. 7344.
2. See for example, Deuteronomy 4, 19.
3. See for example, Genesis 14, 5; *ibid* 15,20; Numbers 13, 33; Deuteronomy 2,10-11; *ibid* 3,11-13; *ibid* 9,2; Joshua 12,4; *ibid* 13,12; *ibid* 17,15; etc...
4. See for example, Jeremiah 33,25; Job 38,33; Ecclesiastes 1,5-6.
5. See for example, in the Apocrypha, the Book of Enoch.
6. In the Mishna, see for example, the tractate Shabath 75a.
7. See the tractate Sukkoth 28a.
8. J. Podro "The Last Pharisee: the life and times of Rabbi Joshua ben Hananyah", Valentine Mitchell, London (1969).
9. Horayoth, 10a.
10. S. Brodetsky, "Astronomy in the Babylonian Talmud", Jewish Review May 1911, p. 60.
11. P. Veron, L'Astronomie (1982), 351.
12. For the astronomers mentioned in this section, see the relevant entries in Encyclopaedia Judaica 13.
13. "The Florence and George Wise Observatory" - Tel Aviv University, Department of Information, P.R., 1978.
14. J.N. and N.A. Bahcall, "The period and light curve of HZ Herculis", *Ap. J.* 178 (1972), L1.
15. P.A. Wehinger et al., "Identification of H₂O⁺ in the tail of comet Kohoutek", *Ap. J.* 190 (1974), L43.
16. Y. Mekler & A. Eviatar, "Spectroscopic observations of Io", *Ap. J.* 193 (1974), L151.

17. I. Kupo, Y. Mekler & A. Eviatar, "Detection of ionized sulphur in the Jovian magnetosphere", *Ap. J.* 205 (1976), L51.
18. N. Brosch et al., "A spectroscopic study of WZ Sagittae during the 1978 outburst", *Ap. J. Lett.* 236 (1980), L29.
19. J.C. Kemp et al., "SS 433 Intensive 4 month Light Curve", *Ap. J. Lett.* 238 (1980), L133.

FOOTNOTE

*This is the name of this country since the XIIIth Century BC. Outside of the Bible, it is first mentioned in a 1225 BC monument put up by Pharaoh Merneptah at Beit-She'an in the Jordan Valley (now at the Jerusalem Rockefeller Museum). Before, it was known as Canaan. The Canaanites, called Phenicians by the Greeks, spoke the same language as the Hebrews, but worshipped Baal and other deities instead of Yahveh. They continued to live along the coast of present Lebanon to Roman times. Canaanites who settled in present-day Tunisia at the end of the VIIIth Century BC built Keret-Hadashat (the new city), pronounced Carthage by the Romans. Hannibal (or Hananbal) thus spoke a dialect of Hebrew. His name means "Baal has forgiven" just as John (Johanan=Yehohanan also Hanan-Yahu=Hananiah means "Yahveh has forgiven". The magistrates of Carthage were known as Shofetim ("Suffetes"), "Judges". ("Patriarchs", then Shofetim=Judges and then Kings).

The first Jewish Commonwealth lasted in various forms between 1700-586 BC. King David installed his capital in Jerusalem around 1000 BC. The second Commonwealth started as an autonomous province of the Persian Empire, Judea with Cyrus the Great's declaration in 537 BC. The Hashmonean (or Maccabean, then Herodian) independent state of Judea lasted from 167 BC to 44 AD (91 AD in the Golan), when it was replaced by the Roman province of Judea, of New Testament renown. After the Bar-Kochba rebellion of 135 AD, the Emperor Hadrian changed the name of the province to Palestine, to erase its connections with the Judean (= Jewish) nation. Palestine and Judea appear as synonyms during the Crusades. Jewish autonomy in Galilee (the "Patriarchate") lasted till 425, when the Byzantine Emperor refused to recognize a successor to Gamliel VI. It was renewed for a short spell in 607-614. Galilee with its schools and religious leadership was again central to the Jewish world in the VII-Xth Centuries AD, and again in the XVI Century. Modern Jewish resettlement started in 1777 and accelerated after 1870. Political Zionism was created by Herzl in 1897 and received its Charter over the land in the Balfour Declaration (1917) and the League of Nations Mandate (1921). The Third Commonwealth became in 1948 the State of Israel.

**The Bible (in particular the Old Testament) represents a selection of Hebrew literature, poetry, history, philosophy, etc. between ~ 1300-400 BC. The Apocrypha are works that existed around 100 AD, when the Old Testament was edited, and were not included. The Mishna is an

extensive legal code, (divided into six "Orders"), edited ~ 200 AD by the Patriarch Yehuda the Prince in Tiberias, and representing a selection from the Proceedings of the Rabbinical academies in Eretz-Israel between 300 BC and 200 AD. Its authors are known as Tannaim. The Gmara is a similar but much more extensive code, organized as a Commentary on the Mishna. It was written in the academies of Galilee ("The Jerusalem Talmud" stopping, though unedited, around 350 AD) and Babylonia ("The Babylonian Talmud" edited by Rav Ashi around 400 AD). Its authors are known as Amoraim. The Term Talmud covers both Mishna and Gmara but often denotes the latter. The Talmud is divided into "Tractatea". Discussions that were left out when the Mishna was edited are known as Baraitoth, "externals".

***The months in the Gezer (Halfway between Tel Aviv and Jerusalem) calendar (1000 BC, now in the Istanbul museum) carry names such as "the month of the oat harvest" etc. The months of the present Jewish calendar represent the Babylonian Zodiac appellations, sometimes named after Sumerian or Akadian deities (Tammuz, etc.).