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Birjandī: ʿAbd al-ʿAlī ibn Muḥammad ibn Ḥusayn al-Birjandī

Died **1525/1526**

Birjandī, a pupil of Manṣūr ibn Muʿīn al-Dīn al-Kāshī (who was a staff member of the Samarqand Observatory) and of Sayf al-Dīn Taftāzānī, was known for his numerous astronomical commentaries and supercommentaries. He wrote several commentaries on the works of **Naṣīr al-Dīn al-Ṭūsī**, including Ṭūsī's *al-Tadhkira fī ʿilm al-hayʾa*, his *Taḥrīr al-Majisṭī* (recension of **Ptolemy**'s *Almagest*), and Ṭūsī's book on astrolabes. In the preface to the last book Birjandī mentions some tables of the positions of stars that he calculated for the year 853 Yazdigird (1484). In addition, Birjandī wrote a commentary on **Kāshī**'s *Zīj-i Khāqānī*, which was Kāshī's attempt to correct Ṭūsī's *Īlkhānī Zīj*. Birjandī was also known for his commentary on the *Zīj* of **Ulugh Beg** (the last date provided in it being 929 H = 1523) as well as for his supercommentary *(ḥāshiya)* on **Qāḍīzāde**'s commentary *(sharḥ)* to **Maḥmūd al-Jaghmīnī's** *al-Mulakhkhaṣ fī ʿilm al-hayʾa al-basīṭa.*

In addition to these commentaries, Birjandī wrote several independent astronomical works, whose subjects included cosmology, ephemeredes, instruments of observation, as well as a treatise on the distances and sizes of the planets that was dedicated to Ḥabīb Allāh, and another work on the construction of almanacs completed in 1478/1479.

Birjandī completed his *Sharḥ al-Tadhkira* (Commentary on the *Tadhkira*) in 1507/1508. Nayanasukha translated the 11th chapter of the second book of this work into Sanskrit. This is the chapter in which Ṭūsī deals with the device called the "Ṭūsī couple" and its applications, mainly to the lunar theory. From the colophon of the Sanskrit translation we learn that a Persian, Muḥammad Ābida, dictated it (presumably in a vernacular language) to Nayanasukha as he composed it in Sanskrit. Muḥammad Ābida had been at **Jai Singh**'s court since at least 1725.

Birjandī's commentary on the *Tadhkira* is a good example of the commentary tradition within Islam. In analyzing Ṭūsī's work, Birjandī provides the reader with explanations of meanings, shows variants, provides grammatical explanations, and engages in philosophical discussions. He also provides different interpretations and examines the objections of his predecessors against Ṭūsī. In Book II, Chapter 11, Birjandī cites the following authors and works: Ṭūsī's *Risālah-i muʿīniyya*; Ptolemy's *Almagest*; **Ibn al-Haytham**; Euclid's *Elements*; **Quṭb al-Dīn al-Shīrāzī**'s *Tuḥfa* and *Nihāya*; **Theodosius**'s *Sphaerica*; **Menelaus**; and **Autolycus**.

In his commentary, Birjandī seems to follow Shīrāzī's opinions and his devices. For example, Birjandī mentions an objection against the application of the Ṭūsī couple to the celestial spheres regarding the necessity of rest between two motions; such a discussion about rest between ascending and descending motions is given by Shīrāzī as well as **Shams al-Dīn al-Khafrī** (Ragep, pp. 432–433). Also when Birjandī discusses an application of the curvilinear or spherical version of the Ṭūsī couple, he mentions that this version produces a slight longitudinal inclination, which had been discussed by Shīrāzī in his *Tuḥfa* (Kusuba and Pingree, pp. 246–247). Finally we note that Birjandī gives a proof for a device that G. Saliba has called the "ʿUrḍī lemma," after **Muʾayyad al-Dīn al-ʿUrḍī**, but the proof is similar to that given by Shīrāzī rather than ʿUrḍī's original in his *Kitāb al-Hayʾa*.

Takanori Kusuba

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Birkeland, Kristian Olaf Bernhard

Born **Christiania (Oslo, Norway), 13 December 1867**
Died **Tokyo, Japan, 15 June 1917**

Kristian Birkeland, perhaps Norway's most famous scientist, produced the first artificial aurorae, organized polar expeditions to collect auroral data, and contributed to the theoretical understanding of these upper atmospheric phenomena.

Birkeland was the son of Reinart Birkeland and Ingeborg (*née* Ege). His one brother, Tonnes Gunnar, was a medical doctor, and one of his cousins, Richard Birkeland, became professor of mathematics at the University of Oslo. Kristian Birkeland received his early education in Norway, at the University of Oslo, was appointed to a position there in 1893, and became full professor at the age of 31. He was elected to the Norwegian Academy of Science and Letters and received an honorary doctorate from the Technical University of Dresden, Germany, in 1909.

Birkeland published his first three scientific papers (in mathematics) before he was 20. Among his early contributions to physics was his work on Maxwell's equations with the first solution in 1894 as well as a general expression – still valid – for the Poynting vector in 1895.

In 1896, Birkeland published, through the French Academy journal *Comptes rendus de l'Académie des sciences*, the first realistic auroral theory. His idea was that electrically charged particles (which he called cathode rays, because the electron had not yet been discovered) streamed out from sunspots at such high velocity that, guided by the Earth's magnetic field, they could penetrate far into the polar atmosphere. *Via* collisions with the atmospheric gases, visible aurorae would be produced.

Birkeland produced the first artificial aurorae in his laboratory in 1896. In order to substantiate his theory, Birkeland began rather complicated calculations of charged particles in magnetic fields.

He also built the world's first permanent auroral observatory, in northern Norway, in 1899.

Birkeland organized expeditions to polar regions where he established a network of observatories under the auroral regions to collect aurora and magnetic field data. The results of the Norwegian polar expedition conducted from 1899 to 1900 contained the first determination of the global pattern of electric currents in the polar region from ground magnetic field measurements.

Birkeland suggested that the polar electric currents – today referred to as auroral electrojets – were connected to a system of currents that flowed along geomagnetic field lines into and away from the polar region. He provided a diagram of field-aligned currents in his famous book, *The Norwegian Aurora Polaris Expedition 1902–1903*. The book also contains chapters on magnetic storms and their relationship to the Sun, the origin of the sunspots themselves, comet 1P/Halley, and the rings of Saturn.

Birkeland's vision of field-aligned currents became the source of a controversy that continued for half a century, because their existence could not be confirmed from ground-based measurements alone. The absolute proof of Birkeland's field-aligned currents could only come from observations made above the ionosphere with satellites. A magnetometer onboard a US satellite, launched in 1963, observed magnetic disturbances on nearly every pass over the high-latitude regions of the Earth. The magnetic disturbances were originally interpreted as hydromagnetic waves, but it was soon realized that they were due to field-aligned or Birkeland currents, as they are called today. Birkeland even estimated the total currents at 10^6 A – still a realistic value.

The scale of Birkeland's research enterprises was such that the time-honored matter of funding became an overwhelming obstacle. Recognizing that technical invention could bring wealth, he spent much time on applied science. In 1900, he obtained patents on what we now call an electromagnetic rail gun and, with some investors, formed a firearms company. The rail gun worked, except the high muzzle velocities he predicted (600 m/s) were not produced. At one demonstration, the coils in the rail gun shorted and produced a sensational inductive arc complete with noise, flame, and smoke. It easily could have been repaired and another demonstration organized.

However, fate intervened in the form of an engineer named Sam Eyde. Eyde told Birkeland that there was an industrial need for the biggest flash of lightning that can be brought down to Earth in order to make artificial fertilizer. Birkeland's climactic reply was "I have it." He worked long enough to build a (the Birkeland–Eyde) plasma-arc device for the first industrial nitrogen-fixation process. Thus, the Birkeland fixation method was the founding of Norsk Hydro, still today a major industrial enterprise, and one of Norway's largest companies. Birkeland then enjoyed adequate funding for his only real interest, basic research.

Birkeland continued with industrial inventions and had altogether 60 different patents. Today, Birkeland's plasma torches find application in the steel industry, tool hardening, and nitrification of radioactive waste.

In his last years, Birkeland's main scientific work was an extension of his theory on aurorae and geomagnetic disturbances to a more general theory of the cosmos. He concluded, in 1908, that charged particles are continuously emitted from the Sun and that electromagnetic forces are as important as gravity in the Universe.

Birkeland based most of his ideas on models from the results of laboratory experiments. He contributed greatly to the study of solar-terrestrial physics. He introduced many ideas that still remain central to these fields. His work was truly the foundation for modern space physics.

In the field of basic physics Birkeland had nearly 70 publications plus three books. His main contribution remains *The Norwegian Aurora Polaris Expedition 1902–1903*. It was published in two volumes in 1908 and 1913, respectively, and is nearly 850 pages long. It is still a good reference book for solar-terrestrial physics.

Birkeland's pioneering work underlies many of our present ideas concerning the three-dimensional nature of the Earth's magnetosphere, the workings of polar geomagnetic activity, the aurora, and the connection of the Sun to the magnetosphere. His students included additional auroral observers and theorists Lars Vegard, Ole Andreas Krogness, and Olaf Devik, as well as professors of mathematics (Thoralf Sklem) and physics (Sem Saeland) at the University of Oslo. The Norwegian government (in 1994) honored its most famous scientist with a 200 kr banknote (equivalent to approximately US $30) bearing Birkeland's likeness.

Alv Egeland

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Birkhoff, George David

Born **Overisel, Michigan, USA, 21 March 1884**
Died **Cambridge, Massachusetts, USA, 12 November 1944**

American mathematician George Birkhoff developed two theorems with astronomical applications, one (the ergodic theorem) relevant to systems where one wants to take averages over time