

# KOPERNIK, DOPPLER, MICHELSON AND COSMOLOGY

Andrzej Karbowski, Grzegorz P. Karwasz  
*Institute of Physics, Nicolaus Copernicus University, Torun, Poland*

## Abstract

The negative result of Michelson and Morley's experiment embarrassed scientists for almost 20 years, until Einstein's work on „Electrodynamics of moving objects” and Poincare's postulate of relativity. The precision of that experiment was 1/6 of the predicted Earth's orbital movement. It has been repeated several times, with renewed technical solutions: 1) stabilized temperature within 0.001 K and different paths by Kennedy and Thorndike (1932) who cleared that both time and distance are subject to Lorentz- Einstein contraction, 2) infrared modes of He-Ne laser by Jaseja et al. (1964) who excluded the aether wind within 1/1000 of the Earth's orbital velocity. But starting from 70'ies, i.e. after the discovery of the cosmic 2.725 K microwave background radiation, articles change titles from searching the „aether” drift to the check of “isotropy of space”. A clear dipole Doppler shift of 0.00335 K is seen in this background: the Solar system moves in respect to this background by 368 km/s. Only by subtracting this shift from the measured cosmic background temperature one gets a nice, well known from COBE and WAMP satellites, “spätzle” picture of the initial inhomogenities of early Universe plasma. The Doppler effect allows to establish our place in Universe: Copernicus was right, we are far from being in the centre.

## 1 Nicolaus Copernicus, the relativity principle and the cosmic aether

Mikołaj Kopernik was the first to formulate a scientifically based heliocentric cosmology that displaced the Earth from the center of the universe. His book “*De revolutionibus orbium coelestium*” (On the Revolutions of the Celestial Spheres) is often regarded as the starting point of modern astronomy, although a careful reading shows that it was just the “outline” rather than a complete treaty.

The starting point for Copernicus' arguing was the relativity of motion. In the “*De revolutionibus*” he states: “This impression [i.e. of the whole Universe rotating around Earth] is the same as expressed by Virgilio's Enea [*Eneide* III, 72] – «We leave the harbour and the land and cities travel backward.» [...] The same, really, happens to the day movement of Earth, looking from which into the sky it seems that the whole world spins around”. Secondly, Kopernik notes (from the faint, glimpsing light of stars and the absence of their parallaxial movement) that the dimension of the Universe are infinite. “Why we suppose that the small Earth is in still while all that immense World should move?” – resuming his words. At the end, although putting the center of the Universe “near to Sun” he states that Earth revolves around Sun or *around another star*.

Kopernik mentioned the aether as the “fire-like” medium filling all the space above the air. Renè Descartes in his explanation of planet's movement and later Maxwell, with his electromagnetic waves, came back to this concept.



**Fig. 1** Nicolaus Copernicus, born 19.02.1473 (Toruń, Poland) – died 24.05.1543 (Frombork, Poland)



**Fig. 2** Christian Andreas Doppler: born 29.11.1803 (Salzburg, Austria) – died 17.03.1853 (Venice, Italy)



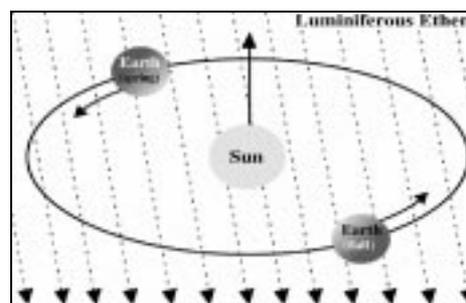
**Fig. 3** Albert Abraham Michelson: born 19.12.1852 (Strzelno near Torun, Poland) – died 9.05.1931 (Pasadena, USA)

## 2 Hypothesis of the aether

Maxwell's equations required that all electromagnetic waves in vacuum propagate at a fixed speed  $c$ . As this can only occur in one reference frame in Newtonian physics, the aether was hypothesized as the absolute and unique frame of reference in which Maxwell's equations hold. That is, the aether must be "still" universally, otherwise  $c$  would vary along with any variations that might occur in its supportive medium. Maxwell himself proposed several mechanical models of aether based on wheels and gears, and George Fitzgerald even constructed a working model of one of them. These models had to agree with the fact that the electromagnetic waves are transverse but never longitudinal.

## 3 Doppler effect and Michelson-Morley experiment

In the late 19th century "aether" was the term used to describe a medium for the propagation of light. It was hypothesised that the Earth moves through a "medium" of aether that carries light. The problem was to solve – does the aether really exist? If yes, in which direction moves the wind of the aether?



**Fig. 4** The concept of the ether [8].

### 3.1 Doppler effect

The Doppler effect is the change in frequency and wavelength of a wave as perceived by an observer moving relative to the source of the waves. The Doppler effect for electromagnetic waves such as light, is of great use in astronomy, and results in either a so-called redshift or blueshift. It has been used to measure the speed at which stars and galaxies are approaching toward or receding from us, that is, the radial velocity. This is used to detect if a single star is, in fact, a close binary and even to measure the speed of rotation of stars and galaxies.

If, in the reference frame of the observer, the source is moving away with velocity  $v$  at an angle  $\theta$  relative to the direction from the observer to the source (at the time when the light is emitted), the frequency changes.

$$f_o = f_s \frac{1}{\gamma \left(1 - \frac{v \cos \theta}{c}\right)} \quad (1)$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \quad (2)$$

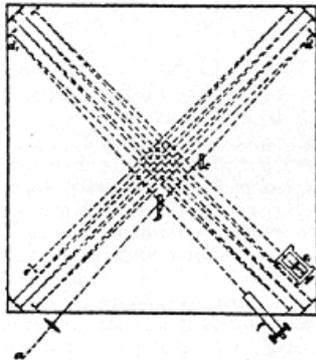
where:  $f_s$  – frequency of the emitted wave and  $f_o$  – observed frequency of the light.

The Doppler type correction to the speed of the light coming from “aether wind”, as calculated by Maxwell himself, should be proportional to the wind velocity - it means for the orbital motion of the Earth it should be in the  $10^{-8}$  range.

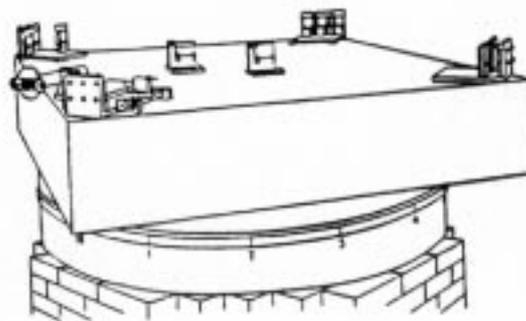
### 3.2 Michelson’s experiments

Michelson performed early measurements of the velocity of light in Potsdam. In 1881 he invented an interferometer for the purpose of discovering the effect of the Earth’s motion [1]. The split light beam travels in to perpendicular directions and the merges back, subject to interference. In 1887 Michelson collaborated with Edward Williams Morley in the modified version of the experiment.

Any slight change in the amount of time the beams spent in transit would then be observed as a shift in the positions of the interference fringes. If the ether were stationary relative to the sun, then the Earth’s motion (about 30 km/s) would produce a fringe shift 0.04 the size of a single fringe.

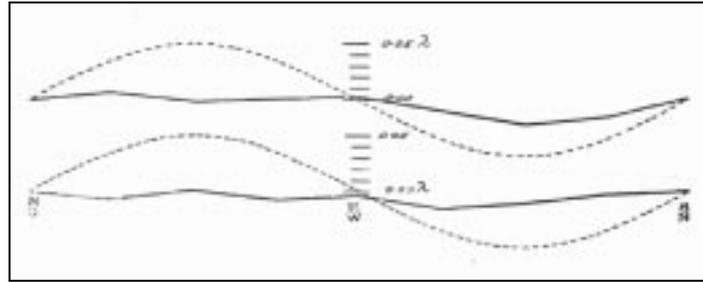


**Fig. 5** At each corner of the stone were placed 4 mirrors.



**Fig. 6** The scheme of Michelson-Morley’s apparatus.

In the Michelson-Morley experiment, the light was repeatedly reflected back and forth along the arms, increasing the path length to 11 m [2] (see Fig. 5). At this length, the drift would be about 0.4 fringes. To make that easily detectable, the apparatus was located in a closed room in the basement of a stone building, eliminating most thermal and vibrational effects (see Fig. 6). Vibrations were further reduced by building the apparatus on top of a huge block of marble, which was then floated in a pool of mercury. They calculated that effects of about 1/100th of a fringe would be detectable. The mercury pool allowed the device to be turned, so that it could be rotated through the entire range of possible angles to the “aether wind.”



**Fig. 7** The results of the observations of Michelson and Morley from the paper „On the relative motion of the Earth and the luminiferous ether” [2]. The upper is the curve of observations at noon, and the lower for the evening observations. The dotted curves represent the theoretical displacements.

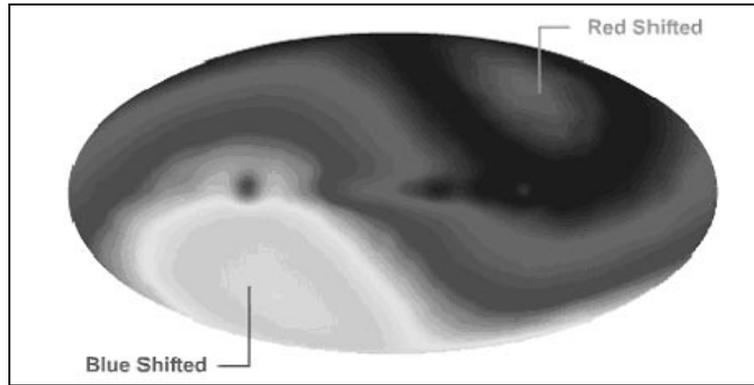
The result was **negative**: there was **no aether wind**!

Michelson and Morley’s experiment was repeated at distances of decades, making them more sophisticated (performing measurement for long time, with good temperature stabilization, uneven arms length of the interferometer [3] and using new technologies, like He-Ne laser [4]. The result was always the same: no special reference frame can be defined.

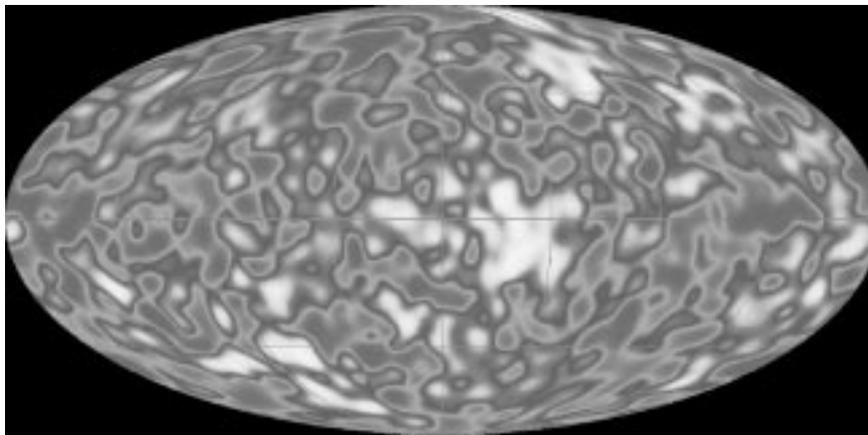
## 5. Doppler effect in cosmology and Cosmic Microwave Background Anisotropy

Our Universe started somewhat 14.5 billion years ago. It took less than one millionth of a second to make disappear heavy quarks, one hundredth of a second to make protons and three minutes to make hydrogen and helium but 300000 years to decouple the light from the matter.

The anisotropy of the cosmic microwave background (CMB) consists of the small temperature fluctuations in the blackbody radiation left over from the Big Bang. The average temperature of this radiation is 2.725 K as measured by the COBE satellite. There are small temperature fluctuations superimposed on this average. One pattern is a plus or minus 0.00335 K variation with one hot pole and one cold pole: a dipole pattern. A velocity of the observer with respect to the Universe produces a dipole pattern with  $dT/T = v/c$  by the Doppler shift. The observed dipole indicates that the Solar System is moving at  $368 \pm 2$  km/s relative to the observable Universe in the direction galactic longitude  $l=263.85^\circ$  and latitude  $b=48.25^\circ$  with an uncertainty slightly smaller than  $0.1^\circ$  [6]. COBE in 1990 and WMAP in 2003 showed not only that Universe started as a ball of wriggly plasma but also that it is flat to the most remote corner (see Fig. 9).



**Fig. 8** The changes of the temperature ( $\pm 3$  mK) of the Cosmic Microwave Background measured by COBE.  
 COBE Dipole: Speeding Through the Universe  
<http://csep10.phys.utk.edu/astr162/lect/cosmology/cbr.html>



**Fig. 9** The changes of the temperature ( $\pm 27$   $\mu$ K) of the Microwave Background Radiation measured by COBE Differential Microwave Radiometer (DMR).  
[http://map.gsfc.nasa.gov/m\\_mm.html](http://map.gsfc.nasa.gov/m_mm.html)

Kopernik, Michelson and Smoot form a kind of Hegel's triad: moving Earth for Kopernik, undistinguishable movement from still for Michelson and the whole Universe moving somewhere for Smoot (but not knowing why?). Remains the question if the Universe is limited and maybe non-unique. But as Kopernik wrote: "Let's leave the question to philosophers" (Book I, Chapter VIII),

**References:**

- [1] Michelson A. A. 1881 American Journal of Science **22** 120
- [2] Michelson A. A., Morley E. W. 1887 American Journal of Science **34** 333
- [3] Kennedy R. J., Thorndike E. M. 1932 Phys. Rev. **42** 400
- [4] Jaseja T. S. et al. 1964 Phys. Rev. **133** A 1221
- [5] Brillot A., Hall J. L. 1979 Phys. Rev. Lett. **42** 549
- [6] Smoot G. F., Gorenstein M. V., Muller R. A. 1977 Phys. Rev. Lett. **39** 898
- [7] Smoot G. F., Nobel Lecture, December 8, 2006.