Abstract. This paper covers some aspects of the life and work of the Estonian astronomer Ernst Öpik (1893–1985), who contributed to a very wide range of astronomical disciplines, and whose publications span more than 70 years. He worked in Estonia, the Soviet Union, the United States, Germany and Northern Ireland. His visions on the role of solar variability in global climate change are emphasized, and his opinions on modelling in science are explained, in addition to his views about scientific refereeing and publishing.

Key words: history of astronomy – Sun: variability – Earth: climate change

1. INTRODUCTION

This meeting offers an exquisite blend of historical astronomy and modern science. Before proceeding with the topic of my talk, I wish to share a short anecdote. In 1999, I participated at a meeting with a very similar concept, viz., “The legacy of J. C. Kapteyn. Studies on Kapteyn and the development of modern astronomy” (van der Kruit & van Berkel 2000 – see also the preface of their book). As I entered the lecture hall, I encountered Michael W. Feast, who said to me: “you are too young to be here”.

I was in my mid-fifties at that time, nevertheless I was since long convinced that the history of science can be very useful as an educational tool, because understanding historical science may help young (as well as seasoned) researchers to recognise the shortcomings and errors in their data and models: we can learn an awful lot from reading historical papers, especially with regard to the limitations and systematic shortcomings of experimental data and models. In fact, the better our insights in the past are, the more reliable any looking forward in time can be, and this is particularly true for climate research, which incorporates a very strong predictive component.

2. ÖPIK’S PERIPATETIC LIFE

Ernst Julius Öpik was born on October 22, 1893 in the Estonian coastal town of Kunda. After graduating at a gymnasium in Tallinn in 1911, he entered Moscow University in 1912. From 1916 to 1920 he worked at Moscow University Observatory. The Russian Revolution of 1917 led to the creation of the Soviet Union ruled
by the Bolsheviks, who decided in 1919 to found a university in Tashkent. Over 100 professors and other teaching staff volunteered to leave Moscow and start a new life at what was then known as Turkestan University. The 3000 km trek by train from Moscow to Tashkent took a full 70 days, and Öpik (1977) describes that the academics even had to saw and split raw timber to fuel the locomotive.

Öpik was the only astronomer in the group, so he became Chairman of astronomy and put new life in Tashkent Observatory, a former military geodetic observatory. In 1921 he returned to Tartu Observatory for a period of nine years (where he obtained his PhD diploma in 1923), after which he resided at Harvard University during 1930–1934. He worked another 10 years in Tartu, and fled in 1944 to Germany, where he became the first rector at the Baltic University in Hamburg.¹ In 1948 he moved to Armagh Observatory, where he spent an unusually long period of time as Editor of the *Irish Astronomical Journal*. He passed away on September 10, 1985 in Bangor (Northern Ireland). Figure 1 displays the above-mentioned information on a timeline. Figures 2 and 3 show vintage photographs of Ernst Öpik.

![Timeline of Ernst Julius Öpik's professional appointments.](image)

3. ÖPIK’S SCIENTIFIC INTERESTS

The SAO/NASA ADS lists about 400 entries for E. J. Öpik, and a quick inspection of the titles of the papers reveals a very broad area of scientific interest and astronomical research activity, as is illustrated by the list below.

- stellar energy sources and nucleosynthesis, life in the universe,
- stellar models, stellar (and solar) structure and evolution, cosmology,
- dark matter, spiral nebulae (galaxies), clusters, observational techniques,
- star formation in supernova shells, interstellar extinction, interstellar dust,
- origin of asteroids, meteorites and comets, impact and explosion cratering,

¹ The *Baltic University in Exile* was established in 1946 by exiled Estonian, Latvian, and Lithuanian faculty to educate refugees from these countries in the aftermath of the Second World War. The project was a very early model of international cooperation in academic life (50 Year Anniversary of the Baltic University in Exile, Washington University Baltic Fund News. [http://depts.washington.edu/baltic/newsletter/spring96.html](http://depts.washington.edu/baltic/newsletter/spring96.html)).
Earth–Moon system, comets, planetary astronomy & planetary exploration,
scientific publishing, science writing, popularisation, research methodology,
solar variability, celestial mechanics and the Earth’s orbit, climate change.

These topics were not items he just touched on: some of his researches were
really cornerstone contributions to the solution of the key astronomical problems
of his times – and also of today. Ōpik was described by Jaan Einasto and Mihkel

4. AN ENCOUNTER WITH ŌPIK

In August 1976, Mart de Groot was appointed director of Armagh Observa-
tory. Mart worked and lived for several years at the La Silla site of the European
Southern Observatory in Chile, and he soon worked out an ingenious method for
augmenting the number of visitors to Armagh Observatory. In those days, airfare
regulations allowed any passenger holding a return ticket between Europe and
Chile to fly a limited amount of extra miles, and make a stopover at no cost. So,
Mart invited me to come to Armagh on one of my trips home, and as such I gave
a lecture on October 22, 1979 on the topic of photometric variability of early-type
supergiants.

![Image of Ōpik giving a lecture at the University of Maryland in 1956 (Leppik 2011).]

In the audience was an attentive listener: Ernst Ōpik. After my talk, he in-
terrogated me about the very long cycles of variability (now known as S Doradus
cycles) of these massive stars, and he incidentally pondered what kind of observa-
tional training I had received during my master education. I told him that there
had been no such training, since I held an MSc in mathematics for which I made
a master thesis on the topic of mathematical climatology and the astronomical
theory of climate variation (Sterken 1969) – i.e., the mathematical theory of the
ice ages, as described by Milankovitch (1930). To my great surprise, Ōpik was
deeply interested in that matter, and he expressed his strong opinions about the
mathematical model as the basis for explaining long-term climate variability. In
fact, very few astronomers worked on this topic (see, for example, van den Heuvel
& Buurman 1974).
5. CLIMATE MODELING, AND THE CONSENSUS ON GLOBAL WARMING

The long-term variability of Earth's climate is a long-standing scientific problem, and the mystery of the coming and going of the ice ages, in particular, has puzzled climatologists for long. Some apparently minor external and internal causes seem to trigger dramatic climatic changes. The former comprise insolation changes due to orbital forcing, the latter embrace CO$_2$ and albedo effects, the planet’s nat-

Fig. 3. Ernst Őpik (leftmost person) with Tartu Observatory employees at the Fraunhofer refractor. The lady in the middle is Alide, Őpik’s wife. Source: Leppik (2011).
ural greenhouse effect, and the still vaguely understood anthropogenic forcing due to human fossil burning contributing to the man-made greenhouse effect.

5.1. Orbital climate forcing

Orbital climate forcing rests on the assumption that the solar-radiation output is constant, and that the fluctuations in insolation (solar radiation received at the top of the Earth’s atmosphere) are entirely due to changes in the obliquity $\epsilon$ of the Earth’s axis and the eccentricity $e$ of its orbit, and is a function solely of $\epsilon$ and $e \sin \omega$, where $\omega$ is the longitude of perihelion. Each of these orbital elements is quasi-periodic, and the combined effect leads to a series of maxima and minima in the insolation curve, as shown in Figure 4. Such orbital forcing may trigger a climatic response that seems to explain the series of glacial-interglacial cycles. This theory is corroborated by geological evidence that some of these minima correspond to periods of glaciation during the Pleistocene².

![Fig. 4. Insolation curve of the Earth (arbitrary caloric units, some of the minima correspond to glacial periods). Based on Sterken (1969).](image)

The interpretations in the mathematical theory mainly rest on correlation, in the absence of deep knowledge of the climatic response mechanisms. The strong “belief” in the mathematical models in the 1960s and 1970s was partly due to an insufficient understanding of the limited time spans that insolation could be calculated backwards, coupled to the very restricted computational abilities of these times.

The first 10,000 years in Figure 4 (i.e., from $-11,000$ to $0$) remarkably suggest that the Earth’s climate is on a cooling course, a view that led to a fixation of the 1970s on global cooling. Imbrie & Imbrie’s (1980) model, for example, predicts that “the long-term cooling trend which began 6000 years ago will continue for the next 23,000 years”. These opinions were also fed by some media panic about the question whether we are heading for a new glacial period. Very soon afterwards, the scientific consensus tossed to global warming.

5.2. Øpik’s approach

Øpik always insisted on one very basic observational fact that Milankovitch’s theory could not possibly explain: the geological evidence for more than 100 million years of warm climate (without polar glaciations) that lasted till about 2.5 million years ago. Moreover, he was of the opinion that the theory’s basic assumption – the constancy of the Sun’s energy output – was flawed. In a seminal 79-pages paper entitled “A climatological and astronomical interpretation of the ice ages

² The Pleistocene is the geological epoch from 2.5 million to 12,000 years BC that spans the world’s recent period of repeated glaciations.
and of the past variations of terrestrial climate”, Ōpik (1953) summarised his explanations of the ice ages by non-static changes in the Sun, and supplemented his previous work with a new climatological method of quantitative analysis of the climatic heat balance.

**Fig. 5.** Sample variation of central hydrogen content of the Sun \( (X_c) \) and of mean temperature of the Earth \( (t\odot) \) with time. Scale of x-axis is millions of years from our era. Based on Ōpik (1953).

For the variability of the Sun, he identifies two main types of variation caused by convective disturbances that account for both the general trend of, and the fluctuations during, a major ice age: disturbances around the central regions of the Sun with a period of decay of 0.5 million years superimposed by successive discrete “pulses”. Figure 5 illustrates this principle, and shows the variation of the central hydrogen content of the Sun \( (X_c) \), and of the mean temperature of the Earth \( (t\odot) \) with time. The arrows pointing down are meant to indicate the ice ages corresponding to the pulses in energy generation shown in the upper curve \( (Q \) refers to the Quaternary or present “ice age”). The shape of the \( t\odot \) curve still stands today, although the prediction for the future (the region leading to the fast change in 1 billion years) strongly depends on the model assumptions (for example, mass loss effects that could not be taken into account half a century ago). The time interval shown in Figure 4 corresponds to only about 3 mm in Figure 5.

The latter point about the predictive uncertainties was very clearly anticipated by Ōpik: the last Section of his paper dealt with the uncertainties in the interpretation of the geological criteria as we go back in time. He mentions two problem areas: (1) the forms of organic life strongly differed in the past, and (2) the possibility of continental drift (and polar wandering) that introduces a good deal of arbitrariness in any attempts to trace climatic zones of the past. The last point
simply asks the question if the available data really are what we really think they
are, or in Opik’s words “the latitude where at present a fossil is found may
considerably differ from the latitude of its origin”.

What about anthropogenic climate forcing? Well, that was not much of an
urgent issue in the 1950s. Nevertheless, Opik (1953) is a beautiful example that
long-term climate research needs reliable historical data, refined theoretical mod-
els, and, above all, a generalist view.

5.3. The Sun’s unusual activity today

Solanki et al. (2004) combined dendrochronologically dated radiocarbon
\(^{14}\)C concentrations with sunspot numbers and physics-based models to extend the his-
torical sunspot curve over the Holocene\(^3\). These authors note that solar activity
reconstructions tell us that only a minor fraction of the recent global warming
can be explained by the variable Sun, and that the current period of high solar
activity is unique within the period of the last millennium.

![Atmospheric radiocarbon \(^{14}\)C differential concentrations (expressed as deviation, in \(\%\), from the \(\Delta^{14}\)C long-term decline curve shown in Figure 1 of Solanki et al. 2004). The \(\Delta^{14}\)C measurement precision is generally 2–3\(\%\), although in the earlier part of the time series it can reach up to 4–5\(\%\). The peaks are significant at the 4\(\sigma\) level.](image)

Figure 6 illustrates the short-term fluctuations of the Sun (duration one to two
centuries) that reflect changes of the atmospheric radiocarbon \(^{14}\)C production rate
due to solar variability. These data show beyond doubt that (non-evolutionary)
short-term solar activity is not a key factor in the climate debate, and that solar
variability – at this timescale – is rather of a stochastic nature.

6. OPIK’S PERSONALITY

Opik had an outspoken character, and he always used direct speech, what arouse
the image of him being a troublemaker. Yet, in 1979, at the age of 86, and
more than half a century my senior, he very carefully interrogated the junior
speaker, and kindly explained his own strong points of view. to Merton (1995)
on the so-called Thomas Theorem, (an axiom in the sociology of knowledge: “If
men define situations as real, they are real in their consequences”). But when
under unjustified attack, he would respond with vigour. For example, when one
critic first completely misrepresented Opik’s work, and then set out to destroy this

\(^3\) The Holocene is a geological epoch which began 11 500 years ago and continues to the
present.
fantasy of his own imagination (which was just the very opposite of what Öpik was saying), he immediately published a letter of rectification in *Science* (Öpik 1976) in order to avoid the creation of a myth on the basis of second-hand information. He also took strong stands in public, for example at age 84, during a lecture at the University of Maryland (October 5, 1977), he proclaimed

“...some famous cosmic age estimates (of the Earth and of the Galaxy) turned out to be wrong because authors substituted mathematical models for reality, ignoring well-known observational facts that were available to them. ... The dislike of climatologists to consider real variations of solar luminosity as the cause of climatic change is remarkable. ... Yet from our analysis it follows that intrinsic solar variability is unquestionably the main factor.”

As an Editor, he held views that were quite exceptional:

1. on accessibility of scientific literature: “good science is always read, whatever the prestige of the journal, provided the paper is accessible to the community” (Öpik 1977) – in other words, provided that the paper is in Open Access, and

2. on anonymity in refereeing: “Anonymity in refereeing is like kicking somebody in the dark, without a chance of response; it ‘protects’ the reviewer but not the author. The sooner this scourge of anonymity is abandoned, the better for the honest pursuit of research. If fewer referees can be found when there is no anonymity, it will be only to an advantage: those who consent will be a more qualified selection for the job of critics.” (Öpik 1977).

7. EPILOGUE

Peeter Saari, during the inaugural address of this bicentenary celebration, quoted Taavet Rootsmäe (1885–1959, the first astronomer of Estonian origin and former director of Tartu Observatory):

“Science is carried by the quest for Truth that is just as sincere and honest as Nature itself.”

It is such sincere quest for Truth that was one of the great qualities of Ernst Öpik.

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4 *Astronoomia ja Eesti* (Astronomy and Estonia), Tartu University on 27 April 2011.
5 *Teadust kannab tõe otsimine, mis on nitsama sirus ja aus kui loodus ise*, translated by Taavi Tuvikene. See also Victor Abalakin’s paper in these Proceedings.
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