«Ядерный университет и духовное наследие Сарова:
Год науки и технологий»
Саров, 22 апреля 2021

WARWICK

МГД сейсмология короны Солнца: от солнечной математики к солнечной физике

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The Sun's corona

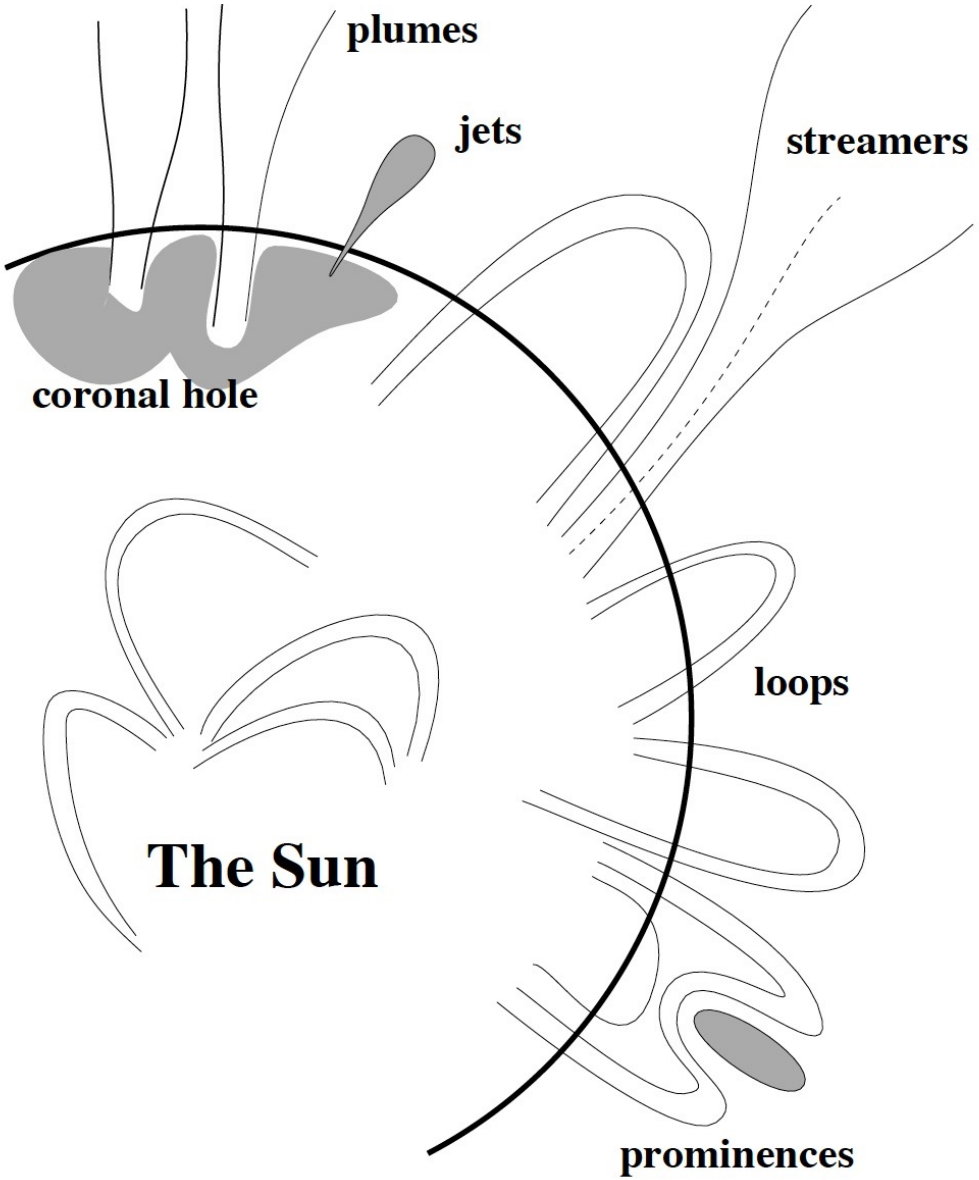
Outer part of the Sun's atmosphere,
Natural laboratory of a fully ionised plasma,

Temperature: 1--10 MK (super hot),
Density: 10^{9}--10^{11} cm^{-3} (super rarified)
Magnetic field: 1--100 G (relatively low)

Usually observed in EUV, radio,
and visible light (during total eclipses
or by coronographs)

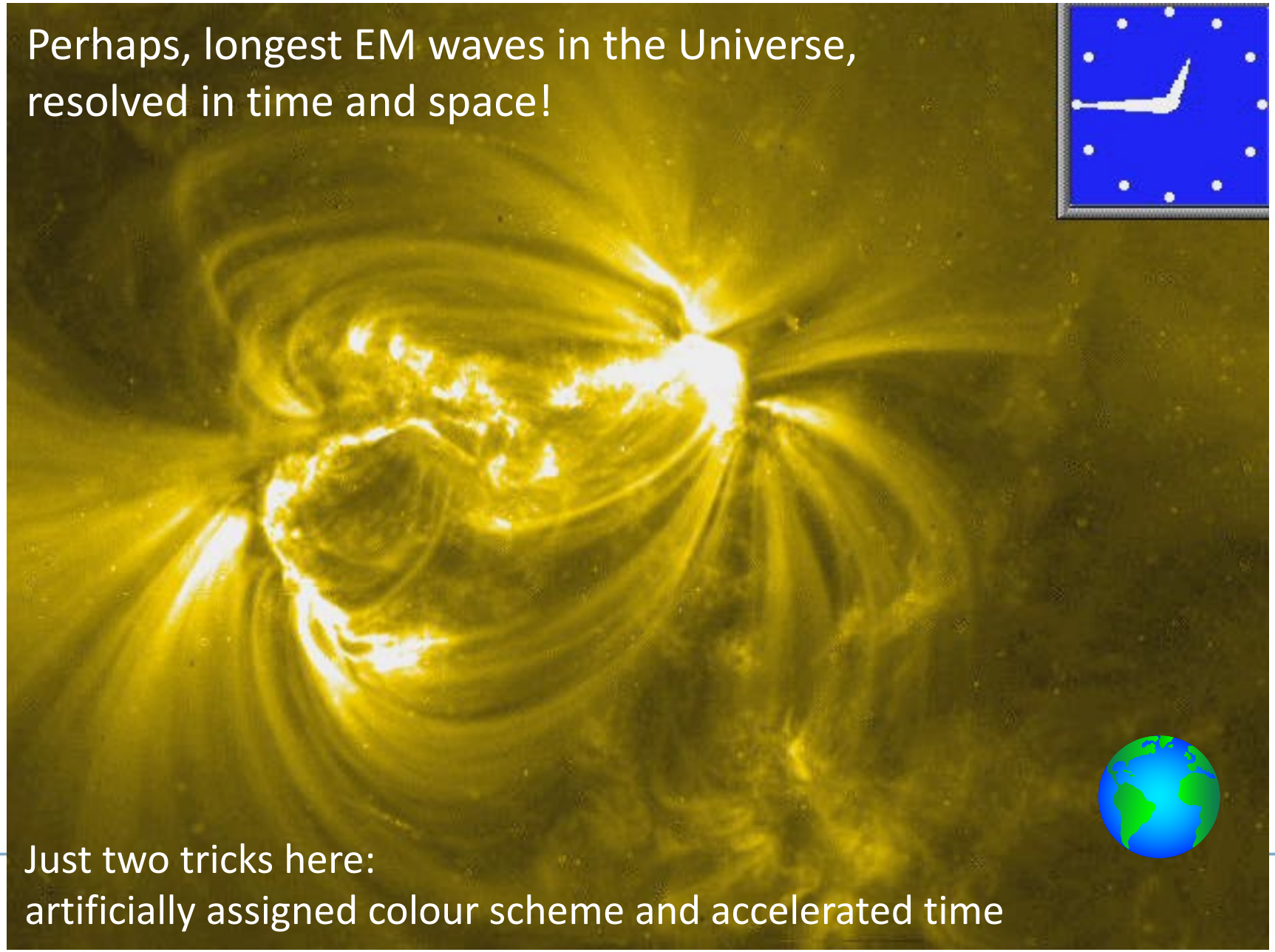
Just sit and stare…

Typical plasma structures in the corona

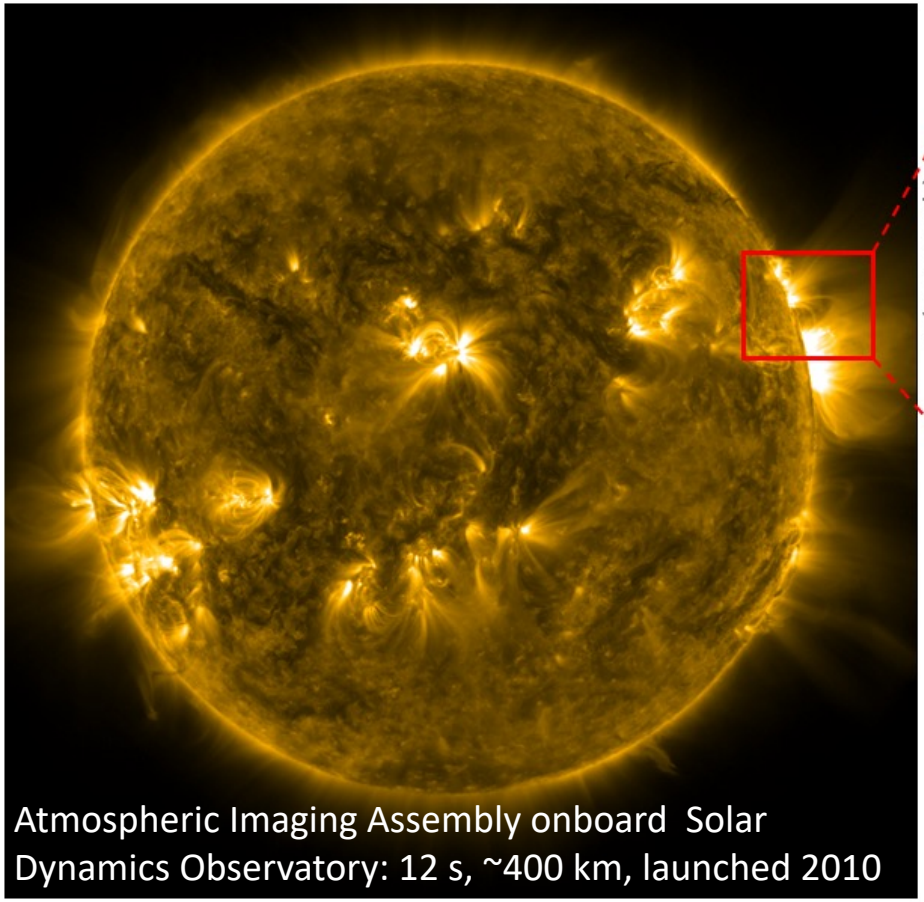


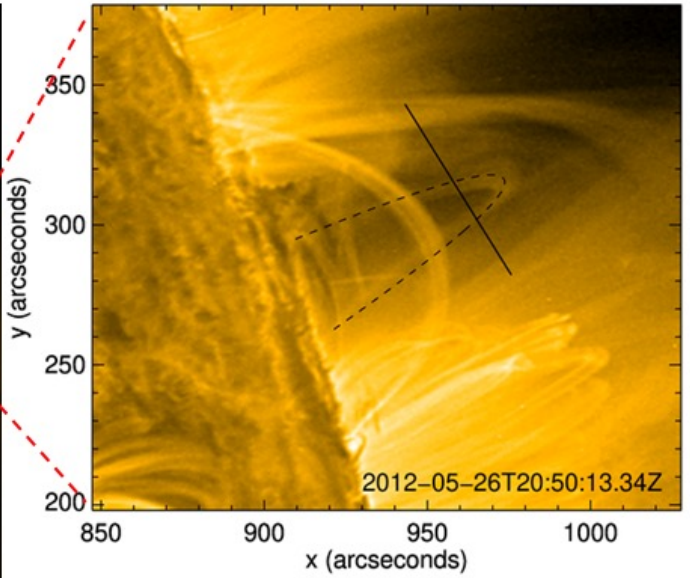
The intrinsically highly filamented nature of the corona allows for the existence of various waveguides and resonators!

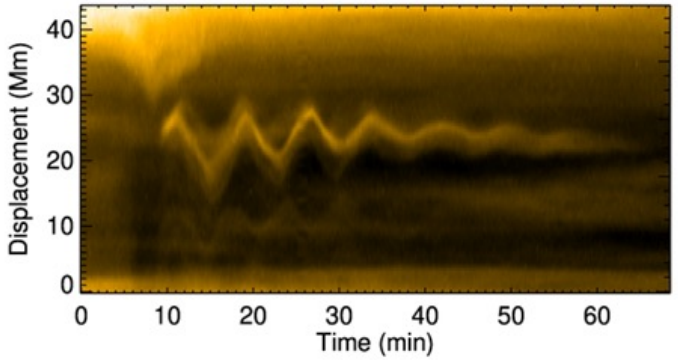
Direct observations of waves in the corona



MHD nature of coronal waves

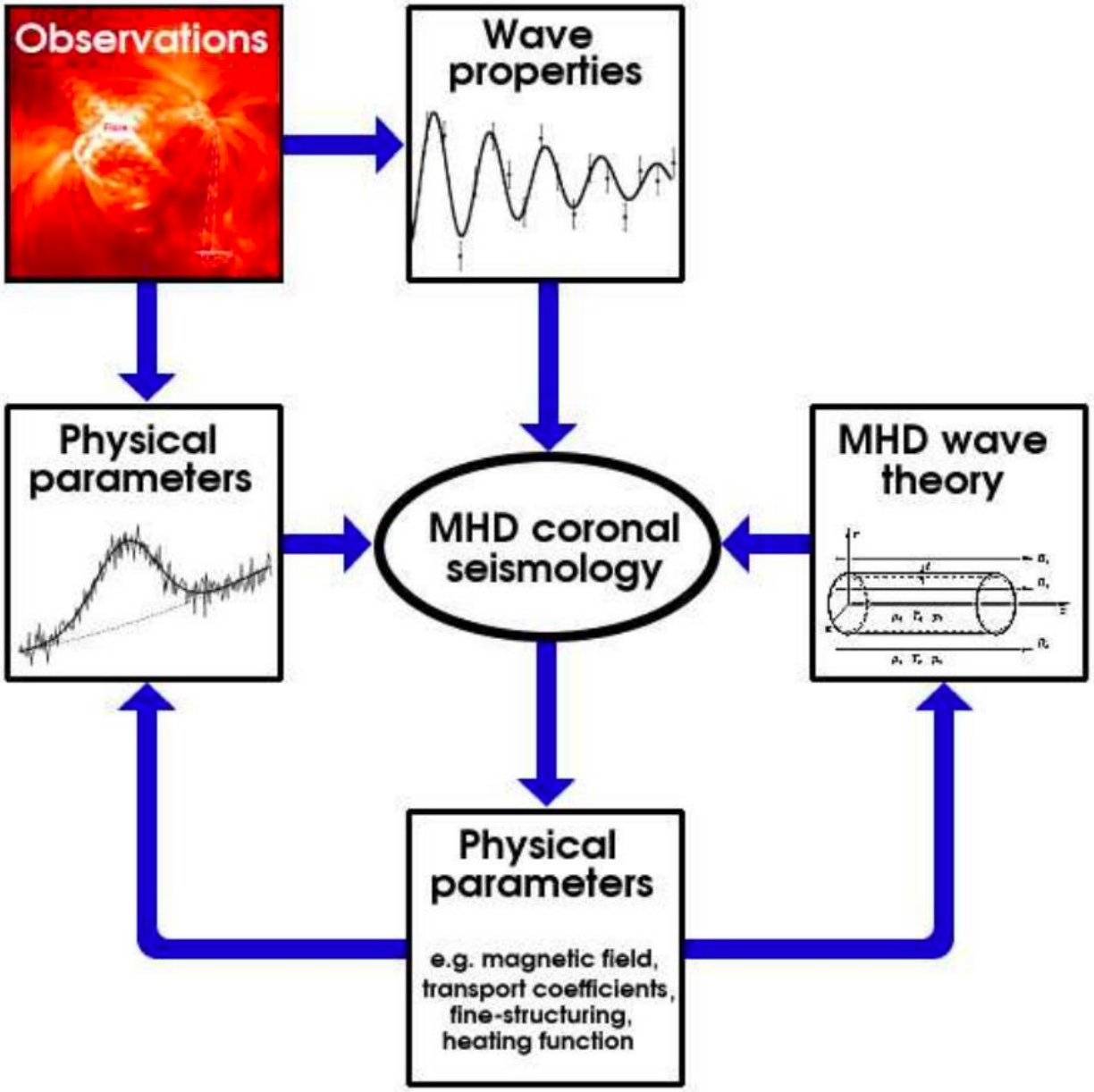




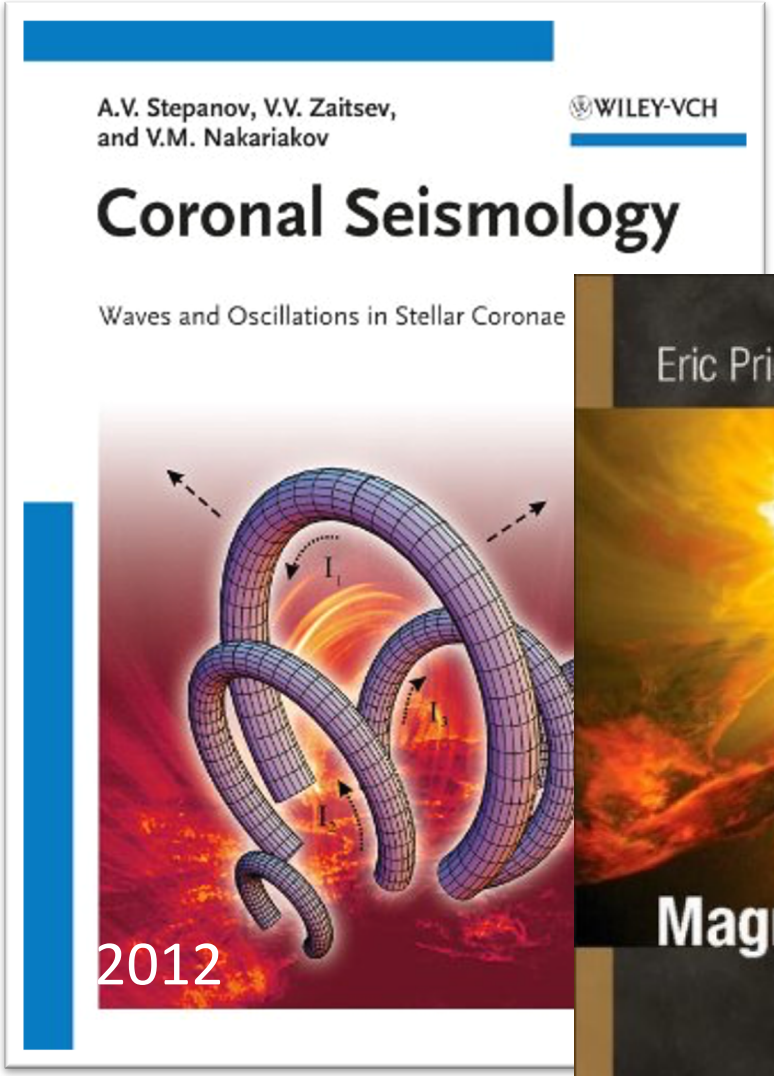


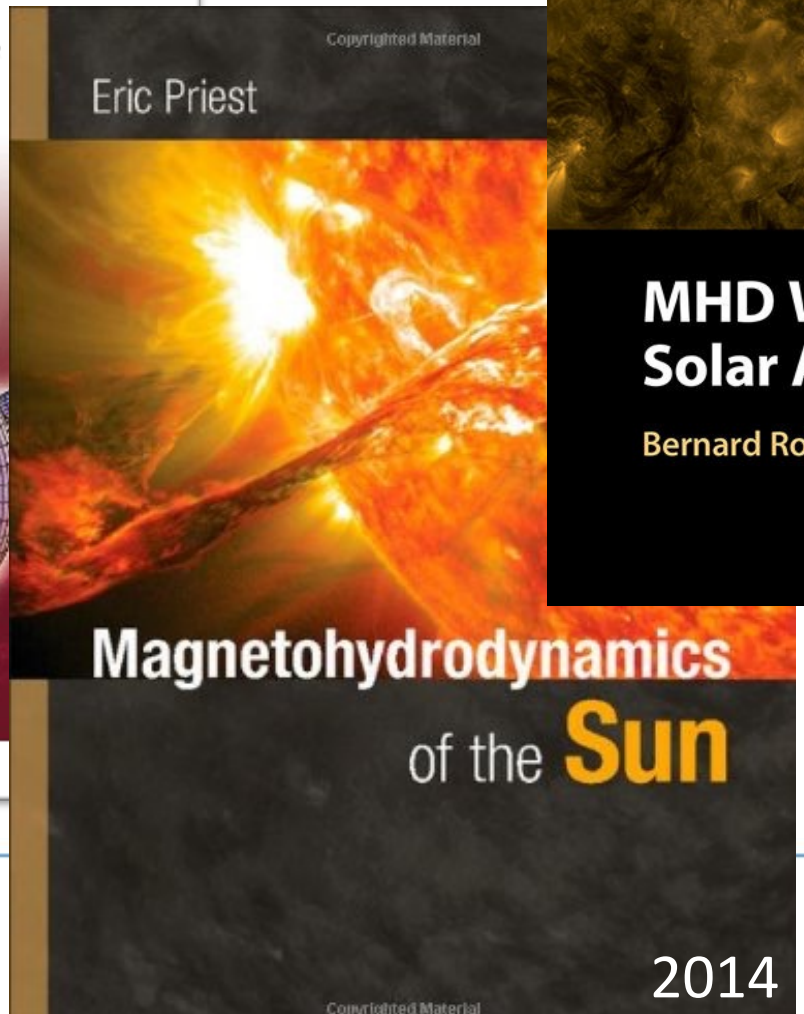
Wave speed:	~ 100--1000 km/s	<<	speed of light
Wavelength:	~ 1--100 Mm	>>	ion gyroradius (< 1 km) & mean free path length (~ 100 km)
Periods:	~ 1 s to tens of min	>>	ion gyroperiod (< 0.001 s)

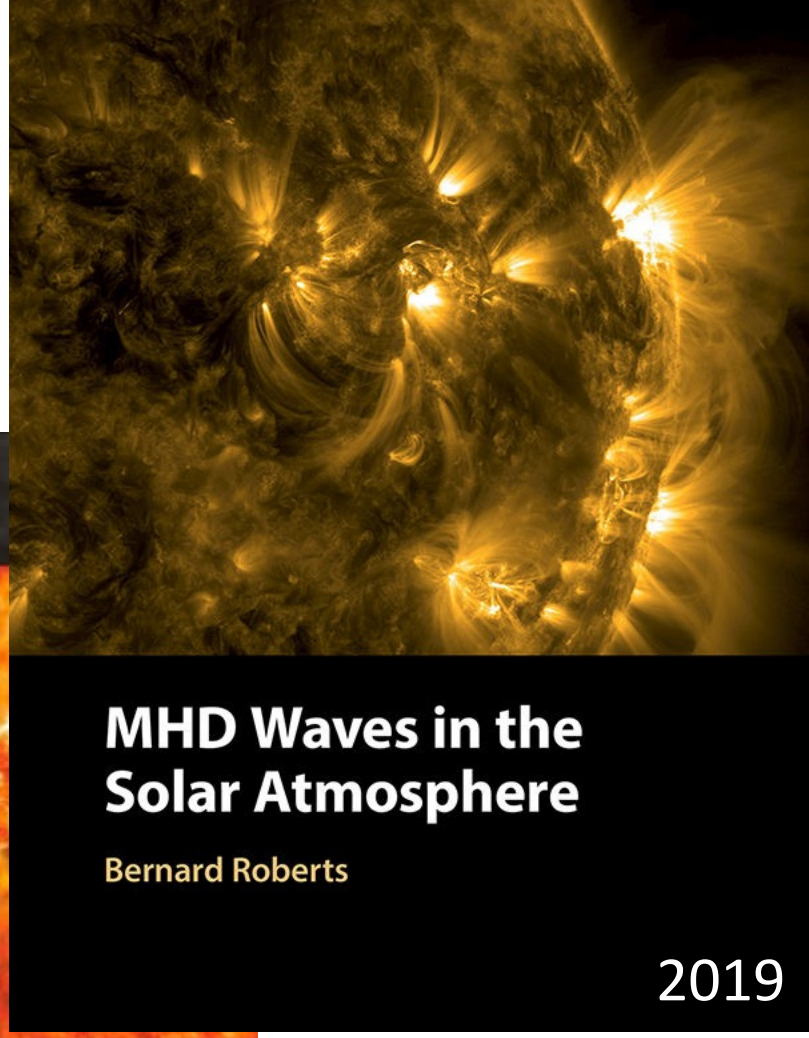
Coronal MHD seismology:



Recent monographs…







And review papers…

Magnetohydrodynamic Waves in the Solar Corona

Annual Review of Astronomy and Astrophysics 2020

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КВАЗИПЕРИОДИЧЕСКИЕ ПУЛЬСАЦИИ В СОЛНЕЧНЫХ И ЗВЕЗДНЫХ ВСПЫШКАХ. ОБЗОР

Журнал: СОЛНЕЧНО-ЗЕМНАЯ ФИЗИКА / SOLNECHNO-ZEMNAYA FIZIKA/ SOLAR-TERRESTRIAL PHYSICS
Том 6 № 1 ,2020
Рубрики: ОБЗОРЫ

УДК 52 Астрономия. Астрофизика. Исследование космического пространства. Геодезия

Куприянова Елена Геннадьевна [1] Колотков Дмитрий Юрьевич [2]
Накаряков Валерий Михайлович [3] Кауфман Анастасия Сергеевна [4]

Информация об авторах и публикац

Аннотация и ключевые слова

Аннотация (русский):
В статье представлен обзор современного со
процессов в солнечных и звездных вспышка
наземных и космических инструментов с вы
спектральным разрешением в разных диапа
Рассматриваются механизмы генерации вспы
квазипериодической модуляции. Обсуждают
звездных вспышек, а также связанные с эти
космической погоды. Показано, что квазипе
излучения являются эффективным инструме
процессов, так и параметров тепловой плазм
виды КПП, их статистические свойства и ме
параметров КПП. Сделан обзор предполагае

Ключевые слова:
Солнце, солнечная активность, солнечные в
квазипериодические пульсации

Space Sci Rev (2016) 200:75–203
DOI 10.1007/s11214-015-0233-0

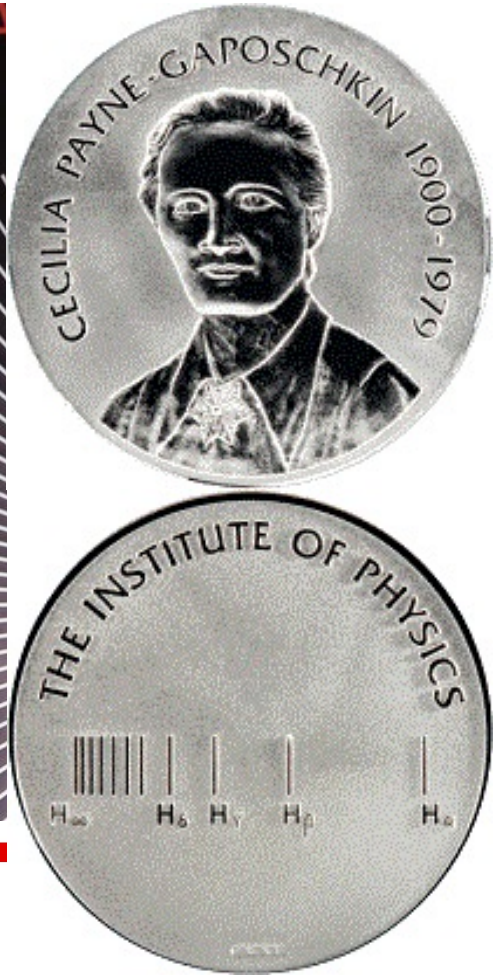
CrossM

Magnetohydrodynamic Oscillations in the Solar Corona and Earth's Magnetosphere: Towards Consolidated Understanding

V.M. Nakariakov[1,2,3] · V. Pilipenko[4] · B. Heilig[5] · P. Jelínek[6] · M. Karlický[7] · D.Y. Klimushkin[8] · D.Y. Kolotkov[1] · D.-H. Lee[2] · G. Nisticò[1] · T. Van Doorsselaere[9] · G. Verth[10] · I.V. Zimovets[4,11,12]

Received: 4 May 2015 / Accepted: 29 December 2015 / Published online: 2 February 2016

Abstract Magnetohydrodynamic (MHD) oscillatory processes in different plasma system such as the corona of the Sun and the Earth's magnetosphere, show interesting similariti and differences, which so far received little attention and remain under-exploited. The su cessful commissioning within the past ten years of THEMIS, Hinode, STEREO and SD spacecraft, in combination with matured analysis of data from earlier spacecraft (Wi



Payne-Gaposchkin medal recipients

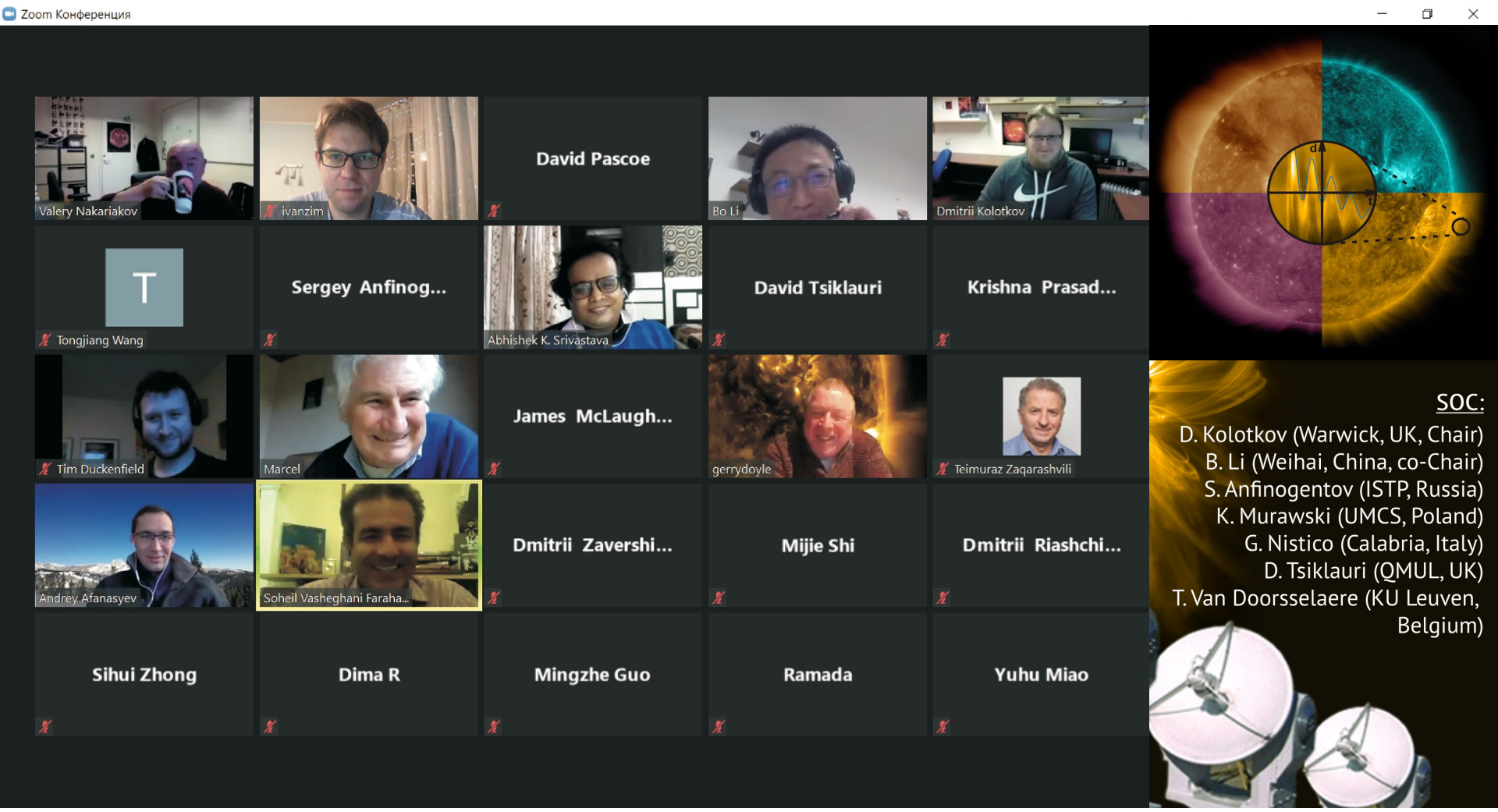
2015

Professor Valery Nakariakov *(born in Nizhny Novgorod, graduated from Gorky State University)*

University of Warwick

For his leadership and major contribution to the discovery of magnetohydrodynamic (MHD) activity of the solar corona, which led to transformative changes in our understanding of the solar atmosphere, and to the creation and successful implementation of a new branch of solar physics, MHD coronal seismology.

A recent major conference (Dec 2020): “MHD Coronal Seismology in 2020”



About 100 participants from 5 continents and 17 time zones!

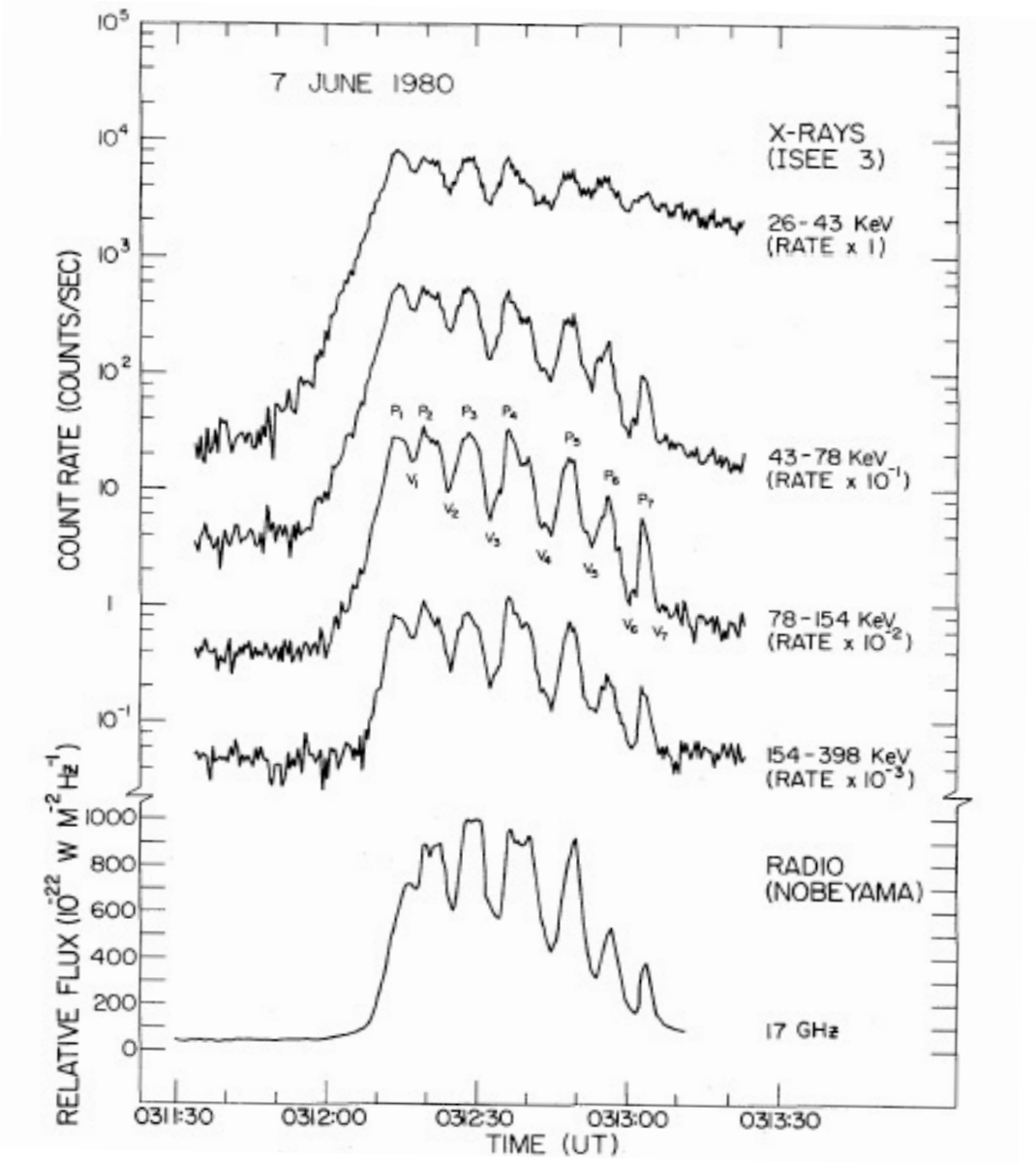
In “prehistoric” times (1970s to 1980s)…

Indirect signatures of coronal waves were observed as quasi-periodic modulations of the EM emission intensity from solar flares.

Typical examples:

“The Seven Sisters Flare” by ISEE-3 and Nobeyama Radiopolarimeter.

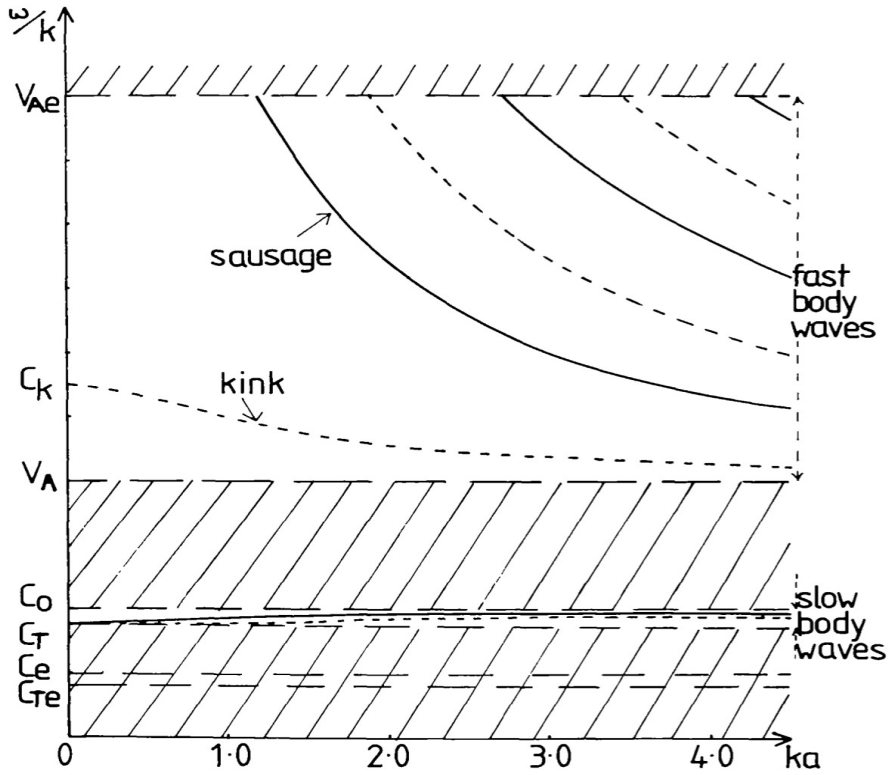
Period about 8 s.

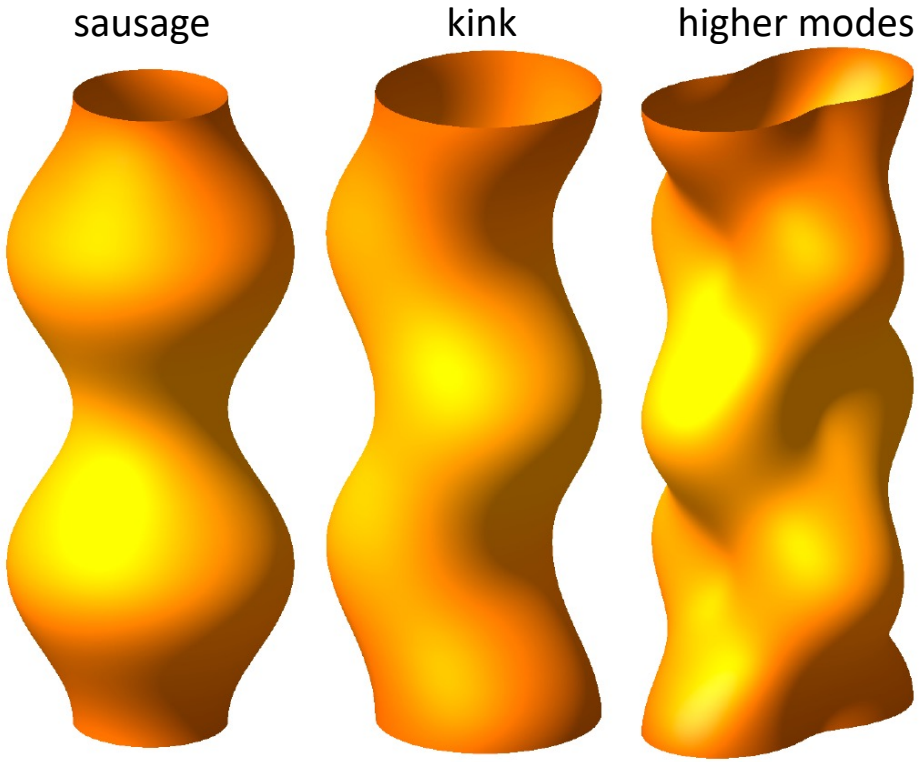


MHD modes of a straight plasma cylinder: Zaitsev-Stepanov-Edwin-Roberts model

Valery **Zaitsev** (NIRFI, Gorky State University) & Alexander **Stepanov** (Institute of Solar-Terrestrial Physics, Irkutsk), *"On the origin of pulsations of type IV solar radio emission. Plasma cylinder oscillations"*, Issled. Geomagn. Aeron. Fiz. Solntsa, (1975)

Patricia **Edwin** & Bernard **Roberts** (both at the University of St Andrews), *"Wave propagation in a magnetic cylinder"*, Solar Physics (1983)





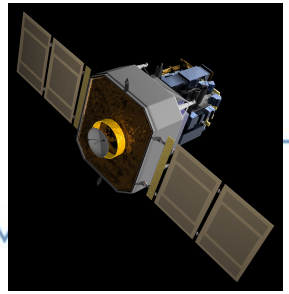
B. Roberts, "MHD Waves in the Solar Atmosphere", 2019:

I can readily recall my own early involvement in coronal seismology. In the summer of 1982, I was visiting the Astronomy Department in ETH, Zurich, working principally with Professor J. O. Stenflo on photospheric magnetic fields. On one occasion, Dr. Arnold Benz (a well known solar radio astronomer) asked me to join him for lunch and, without preamble, posed to me the question: 'how do you explain a one second oscillation in the solar corona?'. Without hesitation, I replied it must be 'a magnetic wave within a coronal magnetic field', a coronal loop oscillating therein. 'But why such a *short* time as a second?', challenged Benz. 'That must be the *transverse* timescale of the oscillation, the period or timescale being determined by the transverse spatial scale and not the longitudinal one', I responded. Benz then told me, casually, that this was a major problem in coronal physics, with many authors using the length of a loop to determine timescales. Anyway, I agreed

The truth is out there – late 90s…

Professor Eric Priest from the University of St Andrews, mathematician, at the National Astronomy Meeting 1996:

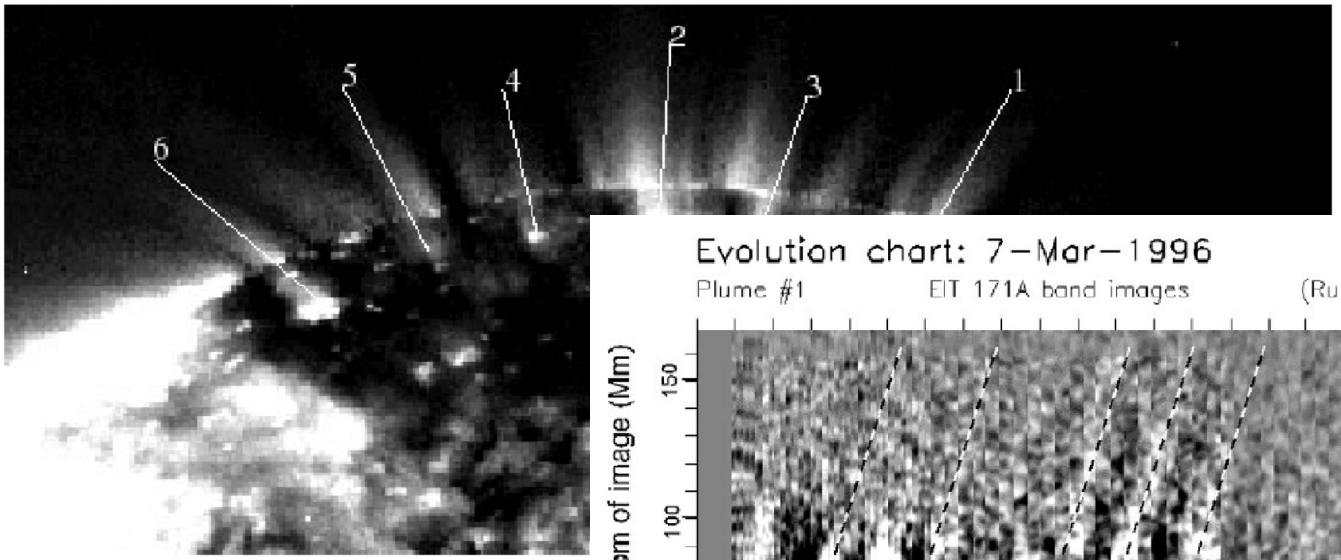
"Using observations of the corona from SOHO/EIT[1], Robert Walsh and Jack Ireland [his postdocs] showed that there are NO waves in the solar corona…"

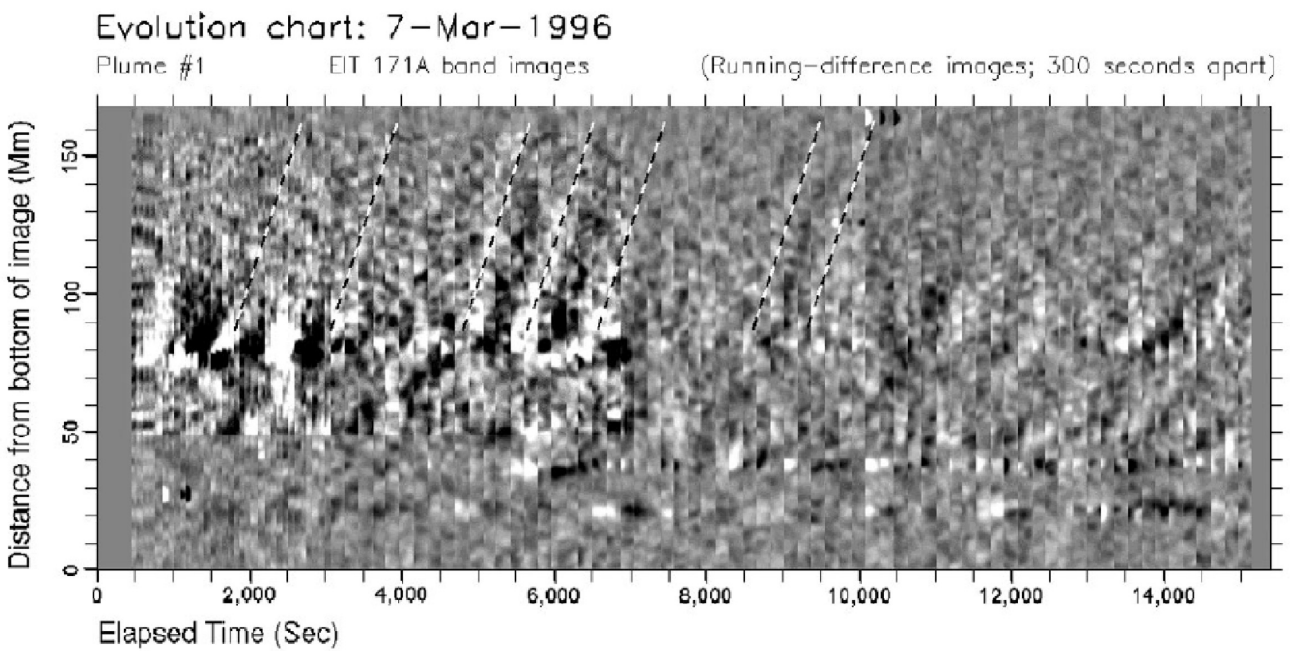


[1]EUV Imaging Telescope (EIT) onboard Solar and Heliospheric Observatory (SOHO): from half a minute to several minutes, ~1700 km, launched 1995

Leon Ofman (NASA) et al. 1997 using SOHO/UVCS: *"Ultraviolet Coronagraph Spectrometer Observations of Density Fluctuations in the Solar Wind"*

Craig DeForest & Joseph Gurman (NASA) 1998 using SOHO/EIT: *"Observation of Quasi-periodic Compressive Waves in Solar Polar Plumes"*





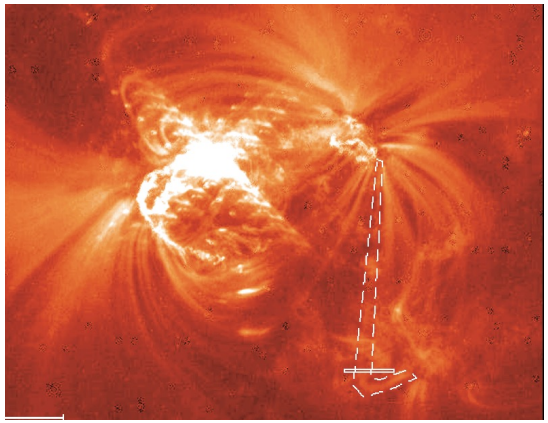
New direct observations and the pioneering work on a practical coronal seismology

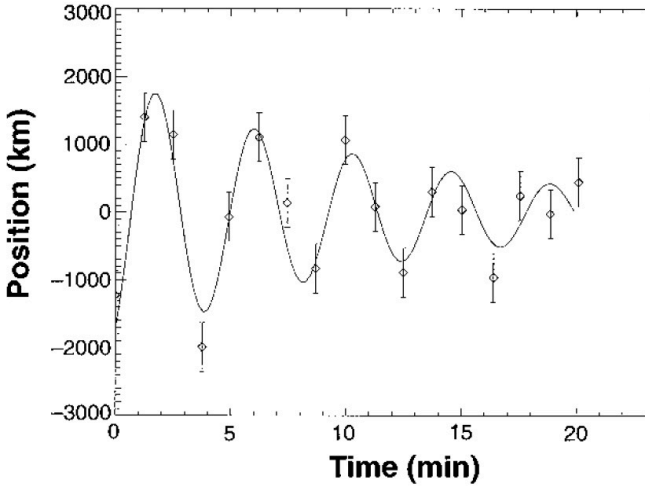
Valery Nakariakov (Univ. of St. Andrews) et al. 1999: *"TRACE[1] Observation of Damped Coronal Loop Oscillations: Implications for Coronal Heating"*

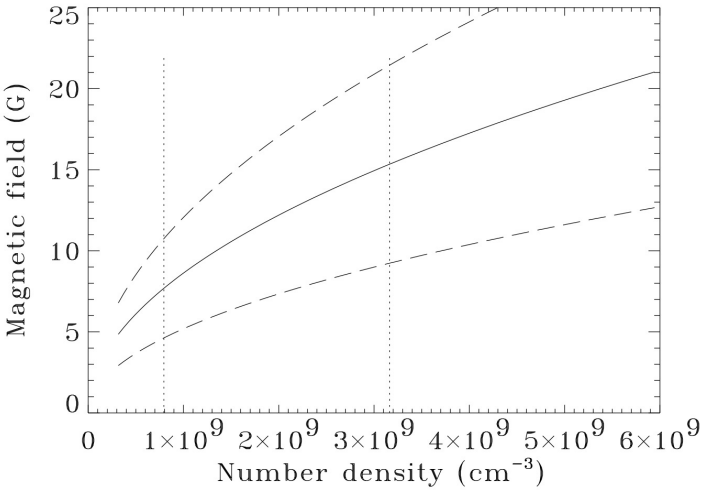
Valery Nakariakov (Univ. of Warwick) & Leon Ofman (NASA) 2001:
"Determination of the coronal magnetic field by coronal loop oscillations"

Using ZSER theory of MHD modes in a plasma cylinder:

$$B_0 = (4\pi\rho_0)^{1/2} C_{A0} = \frac{\sqrt{2}\,\pi^{3/2} L}{P} \sqrt{\rho_0 (1 + \rho_e/\rho_0)}.$$







[1]Transition Region and Coronal Explorer (TRACE): ~ 75 s, ~ 360 km, launched 1998

Conclusions

- ✓ The development of the field is possible only when the combination of a theoretical ground and experimental data or observations is available!
- ✓ Experimentalists/observers need a simple formula!
- ✓ Coffee chats and informal organic interactions in general are extremely important!
- ✓ Writing a good paper is not sufficient. It must be actively presented and promoted!

Dishes of a new Siberian Radioheliograph, Institute of Solar-Terrestrial Physics, Irkutsk

Have itchy questions or want more information to read?
Please feel free to email me: D.Kolotkov.1@warwick.ac.uk