



1. Bio-data; position

First Name: Ehsan

Family Name: Tavabi

Academic position: Associate Prof. of PNU, Tehran, Iran, Exterior Researcher of Institut d'Astrophysique de Paris, France & Member of Tehran Geophysics Institute, Tehran University, Tehran, Iran.

E-mail: etavabi@gmail.com , etavabi@yahoo.com, e_tavabi@pnu.ac.ir

International Audience

Exterior Researcher of *Institut d'Astrophysique de Paris (IAP)*,

Member of France Astronomical Union.

Member of *International Astronomical Union (IAU)* / *Division E*.

International Fellowship/Awards:

Scientific member (SOC) of Iranian- Franco International Summer School on Astrophysics, 2018, Tabriz, Iran

Post Doctoral position (sabbatical leaves) in Solar eclipse and space climate project in *CNRS-France*, 2017.

Working on several solar Spectrograph experiments at *Institut d'Astrophysique de Paris (IAP)*, 2017.

Working on the design and construction of the siderostat telescope and 9m Spectrograph at Tabriz University, Lasco C2 & C3 coronagraph and Nicolskii's coronagraph.

1st analysis of chromospheric spicule coherent components including waves using the SOT of **Hinode (Japan)**.

Spectra at eclipses (2010-14), more observations with the XRT of Hinode, TRACE, AIA of SDO and IRIS mission.

P.I. of **Gundishapur** award for French-Iranian cooperative works on fine-scale solar plasma instabilities, etc. 2019-2012.

P.I. of ICRP international project (Iran-French), "Space climate", 2016

Post Doctoral position in solar spicules and jets, **IAP**, 2012, France.

Chairman of *Venus transit international workshop*, 2014, Zanzan, Iran

Premier of the Iranian National "*Movement*" Festival, 2014

Paris Observatory 2007 awards for young scientists (to attend a plasma physics workshop);

NASA 2007 grants for members of Hinode telescope to process the data;

ISSS9 fellowship 2009 for the summer school of space science simulation;

2. Main Contributions and Academic Qualifications

2016-2018 Sabbatical leaves at the **Sorbonne** University of Paris-France, Institut d'Astrophysique de Paris.

2014- 2016 Rector of Payame Noor University of Zanzan

2009-2016 Main adviser (director of the thesis) of more than 3 PhDs (2011- to now) and of more than 20 Master thesis.

- 2010-now** Teaching all courses in B.S. in Physics, Advanced Electrodynamics, statistical Physics, Stellar Structure, and Evolution, in M.S. in Astrophysics, Solar Atmosphere at the Ph.D. level.
- 2011-2014** Director of fundamental science Department of PNU of Zanjan
- 2010-2016** Associated Prof. of PNU, IRAN
- 2007-2011** Ph.D. in Astrophysics (GPA: 18.70), "Dynamical structures in Solar Chromosphere", Institute d'Astrophysique de Paris, France & Tabriz University.
- 2003- 2006** M.S. in Astrophysics (GPA: 18.25), "Solar Atmosphere Magnetograms" Tabriz University.
- 1998-2002** B.S. in physics (GPA: 16.70), Tabriz University

3. Publications in refereed journal or publications

- 2020** Zeighami, S., Tavabi, E., Amirkhanlou, E., **Waves propagation in network and inter-network bright points channels between the chromosphere and transition regions with IRIS observations**, *2020JApA...41...18Z*, [10.1007/s12036-020-09633-y](https://doi.org/10.1007/s12036-020-09633-y)
- 2020** Tavabi, E. & Koutchmy, S., CHROMOSPHERIC PECULIAR SPECTROSCOPIC DYNAMICAL EVENTS FROM IRIS OBSERVATIONS, *Astrophysical Journal (ApJ)*, DOI: [10.3847/1538-4357/ab3730](https://doi.org/10.3847/1538-4357/ab3730)
- 2019** Tavabi, E., Koutchmy, S. and Golub L., Polar Coronal Plumes as Jet-like Tornadoes, *Astrophysical Journal (ApJ, Q1)*, DOI: [10.3847/1538-4357/aadc64](https://doi.org/10.3847/1538-4357/aadc64), <https://doi.org/10.3847/1538-4357/aadc64>.
- 2019** Koutchmy, S., Tavabi, E. & Urtado, O., Observation of galactic cosmic ray Spallation Events from the SoHO mission 20-Year operation of LASCO, *Monthly Notices of the Royal Astronomical Society (MNRAS, Q1)*, DOI: [10.1093/mnras/sty1205](https://doi.org/10.1093/mnras/sty1205), [2018MNRAS.478.1265K](https://doi.org/10.1093/mnras/sty1205).
- 2018** Tavabi, E.; Synchronized Observations of Bright Points from the Solar Photosphere to Corona, (*MNRAS, Q1*), DOI: [10.1093/mnras/sty020](https://doi.org/10.1093/mnras/sty020), [2018MNRAS.476..868T](https://doi.org/10.1093/mnras/sty020).
- 2018** Tavabi, E.; Koutchmy, S.; Bazin, C. Analysis of a Failed Eclipse Plasma Ejection Using EUV Observations, *Solar Physics*, DOI: [10.1007/s11207-018-1257-x](https://doi.org/10.1007/s11207-018-1257-x), [2018SoPh..293...42T](https://doi.org/10.1007/s11207-018-1257-x)
- 2017** Tavabi, E.; Ahangarzadeh Maralani, A. R.; Ajabshirizadeh, A. Evidence for coherent spicule oscillations from correcting Hinode/SOT Ca ii H in the south-east limb of the Sun, (*MNRAS, Q1*), 467, 3, 3393-3398, DOI: [10.1093/mnras/stx300](https://doi.org/10.1093/mnras/stx300), [2017MNRAS.467.3393A](https://doi.org/10.1093/mnras/stx300)
- 2017** Zeighami, S.; Ahangarzadeh Maralani, A. R.; Tavabi, E.; Aabshirizadeh, A. Evidence of Energy Supply by Active-Region Spicules to the Solar Atmosphere, *Solar Physics*, 291, 847, DOI: [10.1007/s11207-016-0866-5](https://doi.org/10.1007/s11207-016-0866-5), [2016SoPh..291..847Z](https://doi.org/10.1007/s11207-016-0866-5)
- 2016** E. Tavabi, S. Koutchmy, and L. Golub, Limb Event Brightenings (LEBs) with fast ejection using IRIS mission Observations. *Solar Physics*. 20, 2781, DOI: [10.1007/s11207-015-0771-3](https://doi.org/10.1007/s11207-015-0771-3), [2015SoPh..290.2871T](https://doi.org/10.1007/s11207-015-0771-3)

2015 Tavabi, E.; Ajabshirizadeh, A.; Ahangarzadeh Maralani, A. R.; Zeighami, S.; Spicules Intensity Oscillations in SOT/Hinode Observations, **Journal of Astrophysics and Astronomy**, 36, 307, DOI: [10.1007/s12036-015-9335-z](https://doi.org/10.1007/s12036-015-9335-z), [2015JApA...36..307T](#)

2015 E. Tavabi & S. Koutchmy, et al., Alfvénic waves in polar spicules, **Astronomy & Astrophysics (A&A)**, 573, 4, DOI: [10.1051/0004-6361/201423385](https://doi.org/10.1051/0004-6361/201423385), [2015A&A...573A...4T](#)

2014 E. Tavabi; S. Koutchmy, Oscillations in solar jets observed with the SOT of Hinode: viscous effects during reconnection, **Astrophysics & Space Science (AP&SS)**, DOI: [10.1007/s10509-014-1875-1](https://doi.org/10.1007/s10509-014-1875-1) , [2014Ap&SS.352....7T](#)

2014 E. Tavabi, Power spectrum analysis of limb and disk spicule using Hinode Ca H-line broadband filter, **AP&SS**, DOI: [10.1007/s10509-014-1901-3](https://doi.org/10.1007/s10509-014-1901-3) , [2014Ap&SS.352...43T](#).

2014 E. Tavabi, On vortex motion in chromospheric network boundaries, **Astrophysics and space science**, DOI: [10.1007/s10509-014-1807-0](https://doi.org/10.1007/s10509-014-1807-0) , [2014Ap&SS.350..489T](#).

2014 Koutchmy, B. Filippov, E. Tavabi, C. Bazin, S. Weiller, 3D dynamical structuring of a high latitude erupting prominence: II- Analysis of the coronal context and eruption. **IAU**, DOI: [10.1017/S1743921313011411](https://doi.org/10.1017/S1743921313011411), [2014IAUS..300..430K](#)

2013 S. Koutchmy, B. Filippov, E. Tavabi, C. Bazin, S. Weiller, 3D dynamical structuring of a high latitude erupting prominence: I- Analysis of the cool plasma flows before the eruption, **IAU**, DOI: [10.1017/S1743921313011423](https://doi.org/10.1017/S1743921313011423), [2014IAUS..300..433K](#)

2013 S. Koutchmy, L. Golub and E. Tavabi, Very High-Resolution Structures of a Coronal Active Region using Hi-C: Moss Cells and Filament Channels”, **SCLW**, 6, 2013, [2014cosp...40E2970S](#)

2013 E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, Increasing the Fine Structure Visibility of Filtergrams with application to the HCaII SOT- Hinode observations., **Solar Phys.** DOI: [10.1007/s11207-012-0011-z](https://doi.org/10.1007/s11207-012-0011-z), [2013SoPh..283..187T](#).

2013 B. Filippov, S. Koutchmy and E. Tavabi, Formation of the white-light jet in the quadrupolar magnetic configuration, **Solar Phys.** DOI: [10.1007/s11207-011-9911-6](https://doi.org/10.1007/s11207-011-9911-6) , [2013SoPh..286..143F](#)

2013 Bazin, C.; Koutchmy, S.; Tavabi, E. Prominence-cavity regions observed using SWAP 17.4 nm filtergrams and simultaneous eclipse flash spectra, **solar Phys.** DOI: [10.1007/s11207-012-0188-1](https://doi.org/10.1007/s11207-012-0188-1), [2013SoPh..286..255B](#).

2013 Tavabi, E.; Koutchmy, S.; Ajabshirizadeh, A., Hough Transform to study the magnetic confinement of Solar Spicules, **Journal of Modern Physics**, DOI: [10.4236/jmp.2012.311223](https://doi.org/10.4236/jmp.2012.311223), [2012JMPh....3.1786T](#)

2012 Koutchmy, S.; Bazin, C.; Berghmans, D.; De Groof, A.; Druckmüller, M.; Tavabi, E.; Engell, A.; Filippov, B.; Golub, L.; Lamy, Ph.; and 6 coauthors, Plasmoid Ejection at a Solar Total Eclipse, 55, 223, DOI: [10.1051/eas/1255031](https://doi.org/10.1051/eas/1255031), [2012EAS....55..223K](#)

2012 Bocchialini, K.; Koutchmy, S.; Solomon, J.; Tavabi, E., Homologous flares inducing EUV filament oscillations with subsequent eruption, **EDP Sciences**, 55, 335, [10.1051/eas/1255046](https://doi.org/10.1051/eas/1255046), [2012EAS....55..335B](#)

2012 Koutchmy, S.; Bazin, C.; Damerrore, L.; Rochain, S.; Tavabi, E., New Technology Solar Coronagraphs, **EDP Sciences**, 33, 375, DOI: [10.1051/eas/1255053](https://doi.org/10.1051/eas/1255053), [2012EAS....55..375K](#)

- 2012** E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, Oscillation of CaII H cool Jet Observed with the SOT (Hinode): Viscous Effects, New Astronomy. 352, 7, DOI: [10.1007/s10509-014-1875-1](https://doi.org/10.1007/s10509-014-1875-1), [10.1007/s10509-014-1875-1](https://doi.org/10.1007/s10509-014-1875-1).
- 2011** E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, A statistical analysis of the SOT-Hinode observations of solar spicules and their wave-like behavior, New Astronomy, (Hot paper) 16, 296, DOI: [10.1016/j.newast.2010.11.005](https://doi.org/10.1016/j.newast.2010.11.005), [2011NewA...16..296T](https://doi.org/10.1016/j.newast.2010.11.005)
- 2011** E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, Null-Point Oscillations of Chromospheric Large Cool Jets, American Institute of Physics, 1356, 99, DOI: [10.1063/1.3598098](https://doi.org/10.1063/1.3598098), [2011AIPC.1356...99T](https://doi.org/10.1063/1.3598098).
- 2011** E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, The 3D behavior of a twisted flux tube expanding in the corona: reconnection, writhe, and jets, 2011, IEEE Transactions on Plasma Science, 39, 2436, DOI: [10.1109/TPS.2011.2134110](https://doi.org/10.1109/TPS.2011.2134110), [10.1109/TPS.2011.2134110](https://doi.org/10.1109/TPS.2011.2134110)
- 2011** E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, Contribution to the modeling of solar spicules, 2011, Advance research in Astronomy and Astrophysics, 47, 2019, DOI: [10.1007/s10509-008-9951-z](https://doi.org/10.1007/s10509-008-9951-z), [2009Ap&SS.319...31A](https://doi.org/10.1007/s10509-008-9951-z)
- 2010** C. Bazin, S. Koutchmy and E. Tavabi, The He I and He II chromospheric shells and the Transition Region, IAGA II Conference, Cairo Dec 2009, Proceedings, Dame and Hady Ed, [2010arXiv1008.0404B](https://arxiv.org/abs/2010arXiv1008.0404B)
- 2008** A. Ajabshirizadeh, S. Koutchmy, E. Tavabi, Magneto-acoustic wave oscillations in solar spicules, Astrophysics & space science, 16,32, DOI: [10.1007/s10509-008-9951-z](https://doi.org/10.1007/s10509-008-9951-z), [2009Ap&SS.319...31A](https://doi.org/10.1007/s10509-008-9951-z)
- 2008** A. Ajabshirizadeh, S. Koutchmy, E. Tavabi, Wavelet analysis of solar macro-spicule recurrences, New Astronomy, 13, 93, DOI: [10.1016/j.newast.2007.07.001](https://doi.org/10.1016/j.newast.2007.07.001), [2008NewA...13...93A](https://doi.org/10.1016/j.newast.2007.07.001)

4- Conference Presentations, poster papers etc.

- 2017** Tavabi & Koutchmy, Lasco (SoHO mission) observations of galactic cosmic ray spallation reactions” Russian, *Yalta*
- 2017** Koutchmy, Tavabi, Urtado and Boileau, Galactic Cosmic Rays, Medoun, French
- 2016** Tavabi, Filippov, Koutchmy, Ajabshirizadeh, A Quadrupolar Jet, Damghan, Iran.
- 2015** Tavabi & Koutchmy, FOURIER ANALYSIS OF LIMB SPICULES AND DISK MOTTLES, Russian, Moscow
- 2014** Tavabi, Golub, Koutchmy, Bazin OBSERVATION OF NANO-FLARES AND TRANSIENT CORONAL HEATING, Russian Moscow
- 2013** Tavabi, Koutchmy, Ajabshirizadeh On Alfvenic waves in thread-spicules, Belgium, Belgium
- 2013** Koutchmy, Glolub, Tavabi, Very High-resolution structures of...., Belgium, Belgium
- 2013** Tavabi, Koutchmy, Evidence of several null points Oscillation, Bulgarian, Kitten
- 2011** E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, Oscillation of Ca H Emission Observed by SOT: Viscous Effects, 2011, EGU.
- 2011** E. Tavabi, S. Koutchmy, A. Ajabshirizadeh, Oscillation of Ca H Emission Observed by SOT, 2011, 15th Iranian Astronomy and Astrophysics.

- 2010 C. Bazin, S. Koutchmy and E. Tavabi**, The extreme limb of the Sun at very high spatial resolution and without parasitic scattered light, EST-France 2010 EST-Workshop, Meudon, 19-21 May
- 2010 E. Tavabi, S. Koutchmy, A. Ajabshirizadeh**, Chromospheric large scale Ca Jet a Result of propagation waves at Multiple Nullpoints Reconnection, 2010, BUKS 2010, Leuven, Poster
- 2010 E. Tavabi, S. Koutchmy, A. Ajabshirizadeh**, Chromospheric large scale Ca Jet as evidence of propagation waves at Multiple Nullpoints Reconnection 2010, 14th meeting of Astronomy Research in Zanzan, May 13&14 2010, Proceedings, p.60
- 2009 S. Koutchmy, E. Tavabi, A. Ajabshirizadeh**, About the Size Distribution of Diameter of Solar Spicules, CAS-IAU “the Dynamical Solar Corona” 2009, China
- 2009 C. Bazin, S. Koutchmy and E. Tavabi**, Transitions Region with spicules and helium shells, Poster, 26-28/09/2009; PNST meeting in Ecole Polytechnique, Palaiseau.
- 2009 A. Ajabshirizadeh , E. Tavabi, S. Koutchmy**, Contribution to the modeling of solar spicules, the 9th international school of space simulation (ISSS9), 2009
- 2009 A. Ajabshirizadeh , E. Tavabi, S. Koutchmy**, NUMBER EFFECT IN THE SOLAR DARK MOTTLES RECURRENCE, BUKS2009,
- 2008 A. Ajabshirizadeh , S. Koutchmy, E. Tavabi**, RESOLUTION EFFECT IN THE SOLAR SPICULES OSCILLATIONS, ESPM12
- 2008 A. Ajabshirizadeh , S. Koutchmy, E. Tavabi**, KINK WAVE OSCILLATIONS IN SOLAR SPICULES, MEARIM, First Middle East-Africa, Regional IAU Meeting, Cairo, Egypt, April 5-10
- 2007 A. Ajabshirizadeh , S. Koutchmy, E. Tavabi**, WAVELET ANALYSIS OF SOLAR MACRO-SPICULE OSCILLATIONS, 11th Conference on Astrophysics at the international University of Ghazvin.
- 2006 Ajabshirizadeh, A. and Tavabi, E.**, Simultaneous Measurement Of Magnetic & Velocity Fields In The Layers Of Photosphere And The chromosphere, IAU Symposium233, 31 March – 4 April 2006, Cairo, Egypt.
- Ajabshirizadeh, A. and Tavabi, E.**, Magnetogram & Dopplergram in the Photosphere and Chromosphere, Turkey eclipse.
- 2004 Ajabshirizadeh, A. and Tavabi, E.** Study of Magnetogram & Dopplergram in 8th Conference on Astrophysics in the Ferdousi University of Mashhad & International Conference of Physics (ICP).

5. Work Experience and Research Activity:

- 2009-2014** Teaching Physics in Ba.c, Ms.C, in Payame Noor University of Tehran.
- 2009-2011** Research by Programming in image and data processing, Payame Noor University of Tehran.
- 2004-2007** Lecturer, Physics & Engineering Faculty, Tabriz Azad University, Tabriz, Iran.
- 2000 2004** Physics Instructor, Ministry of Education, Tabriz.

6. Computing Skills

Programming and Systems: C, Visual Basic, LATEX, Matlab, IDL, SSW, Maple

Image processing, Fourier and Wavelet Analyzing methods and space data analysis and PFSS model computing and MHD simulation.

7. Interests:

- 1- The role of turbulence in atmospheric dynamics and MHD plasma.
- 2- Instabilities in magnetic fields.
- 3- Looking for the helical-kink mode in multicomponent spicules.
- 4- Find a correlation between disc dark mottles and limb spicules to understand the origin of TR heating and mass supply and also Alfvénic wave propagation inside the spicules,
- 5- Study of polar plumes and relation between these structures and solar fast wind and acceleration method,

Past research activities and Cover letter

Ehsan Tavabi_2021

Aims & Vision

The vision is greatly enhance our understanding of several crucial aspects of the physics of the solar atmosphere. The aim is to study the connections between different layers of the atmosphere. In the past decade, ground- and space-based observations and MHD simulations have revealed that magnetic fields measured in the Sun's photosphere may change rapidly during a flare. Longer-term changes exhibit over the solar cycle.

The observation of a time difference between the hot linear jet-like feature and the ensuing tornado-like cool event suggests that the tornado helical formation is closely related to the precursor hot component that occurs when a release of energy occurs with the acceleration inside the tornado plasma vortex near the reconnection site. The SDO/AIA temporal and spatial resolution allows us to resolve some uncertainty concerning the relationship of hot line ejections and the cold tornado events at their footpoints. The detailed analysis of the behavior of different components of our event strongly supports the rather new suggestion that polar plumes (e.g. see Figure 1) are made of simple cylindrical structures of 10" to 25" diameter with an expansion in time, height and width. A more detailed comparison with the sub- structure and the behavior of eclipse white-light polar-plumes is needed (work in progress) to understand these structures. The forthcoming launch by ESA of a novel coronagraph system (PROBA3 mission) permitting a total solar eclipse in space for several hours (Lamy et al. 2008) is another opportunity for making progress on this very old and classical question of explaining magnetic solar coronal polar plumes.

It is not understood what causes these changes, and what is the energetic consequence in the atmosphere. This research will use unprecedented spectro-image capabilities and high temporal and spatial resolutions to advance our understanding of the physics of solar magnetic field changes by addressing:

1. What exactly is changed, field strength or direction or both? What is the change at different depth of the lower atmosphere? What are the temporal and spatial scales of these changes? Are these changes ubiquitous or selective?
2. What causes the localized, rapid change of photospheric magnetic field during a flare? Is the origin of this change in the lower atmosphere, or is it a direct response to the change in the corona? This question has direct consequences to our understanding of space weather.
3. What is the energetic consequence of these changes, and how are they related to flares or even sunquakes? Do flare-generated heating and dynamics of the lower atmospheric plasma cause the observed change of the magnetic field locally? Or does the change of the magnetic field in the lower atmosphere produce heating and particle energization?

The source region of the wind, at chromospheric and transition region heights, is extremely structured and dynamic. The chromosphere is permeated by spicules, cool and dense jets of chromospheric plasma. Spicules have been thought to be too slow and cold to contribute significantly to the solar wind, but a more dynamic type of spicule, with shorter lifetimes, faster motions, and a hotter plasma component has recently been discovered

by *Hinode*. Such spicules also support waves, possibly with sufficient energy to accelerate fast wind streams in coronal holes (Tavabi et al. 2009, 2011 & 2014).

Hinode has also observed the frequent occurrence of very small-scale X-ray jets in polar coronal holes (Tavabi & Koutchmy, 2013 & 2014). Given the high velocities and frequency of these events, it has been suggested that they contribute to the fast solar wind. Their relation to the photospheric magnetic field, however, has not been established as the high latitudes at which they are observed hamper the accurate determination of their photospheric footpoints from the ecliptic plane. Other fine-scale ray-like structures – coronal plumes – permeate coronal holes and are correlated with small-scale bipolar structures inside the hole. Ultraviolet measurements show that these structures are cooler than the surrounding background hole plasma, and have slower, but denser outflows. However, composition measurements tend to call this notion into question: a significant elemental fractionation is observed in the solar wind plasma relative to that of

the photosphere, which scales with the first ionization potential (**FIP**). Metallic ions, with **low FIP**, are more abundant in the solar wind than mid- or high-FIP elements when compared with their photospheric compositions.

Science Objectives

In this project I will address (i) Which types of non-thermal energy dominate in the chromosphere and beyond?, (ii) How does the chromosphere regulate mass and energy supply to the corona and heliosphere? And (iii) How do magnetic flux and matter rise through the lower atmosphere and what role does flux emergence play in flares and mass ejections? (iv) Find the chromosphere activities cycles?

Answering questions about the long term behavior of the Sun will benefit from repeated measurements of specific targets using these instruments over many years and could improve our knowledge including:

1. Does the small scale magnetization of the quietest internetwork show cycle variations?
2. Does the quietest granulation itself show any statistical variation with the cycle?
3. Does the existence or nonexistence of a penumbra (pore to sunspot transition) depend on the global field configuration or just the local field strength?

The Sun exhibits remarkable changes over decadal time scales. These are most apparent at large spatial scales because they reflect the underlying global solar dynamo. However, cycle-related changes have been observed on the Sun at scales as small as supergranulation. Flares get larger when the Sun is more active, and careful synoptic observations at a higher resolution will likely reveal cycle-dependent dynamics at smaller scales. Assessing variations in the statistical properties of small scale processes over long time scales could provide important insights into the coupled multi-scale dynamics of the Sun.

My studies will contribute to answering the following science questions:

1. Do precursors precede all solar flares or only a subset of flares and **the most popular jet-like structures named by spicule, macrospicules, jets, and nano-flare**? What is that subset?
2. What are the temporal, spatial and temperature structure of the precursors?
3. When and how do magnetic channel structures form? What are the correlation between flare precursor – brightenings and/or flows and magnetic channel structures?
4. What is the role of small-scale magnetic reconnection in triggering flares?
5. If and how the observed shear and converging flows contribute to building up the magnetic free energy and trigger eruptions?
6. Are precursors associated with the onset of flares?
7. Do precursors fit the existing flare and eruption models? Do they manifest internal (flux rope formation) or external (flux rope release) reconnection?

To tackle these problems, the analysis of very small scale dynamical phenomena is required. This is timely because a number of new space missions brought a lot of data concerning phenomena like macro- spicules and X-ray jets. The former problem of chromospheric "cool" spicules, believe to explain the storage of plasma in the corona, is now completely renewed and can be more extensively analyzed. New diagnostics should also be considered to understand the processes going on inside the extended in the radial direction transition region (TR) where magnetic energy is released. A larger number of the HMI magnetic bright points, which are dominated by small scale bright dots, tend to recur at roughly the same location in the photosphere. These characteristics, associated with TR dopplergrams with areas of high line-of-sight velocities, suggest that some of these bright points may result from magnetic reconnections of loops (Tavabi et al. 2015) at source regions in the lower layers of TR and chromosphere. Since the measurement of the coronal magnetic field is almost inaccessible, understanding the real magnetic structure and properties only through the characteristics of the surrounding magnetic structure is indirectly delineated. Filippov et al. (2009) illustrated the geometrical shape of the jets that show a frozen vertical ejection of hot plasma into the higher atmosphere that could introduce rapid heating of corona and mass source into the solar wind flow. One may expect that these CBPs could also be traced throughout the TR and chromosphere given that the photospheric magnetic field lines keep continuously expanding towards the corona.

Dopplergrams are the oldest used technique to find supergranulation. The first detection was made by Hart (1954), and the typical length of this structure ranges between around 20 and 30 Mm. We investigate the relationship between the photospheric magnetic-field, chromospheric, and TR dopplergrams in NUV and FUV channels with coronal EUV filtergrams.

This proposal is a program designed to understand the causes of solar variability and its impacts on Earth. The results help us understand the Sun's influence on Earth and Near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously.

The main goal is to understand, driving towards a predictive capability, the solar variations that influence life on Earth and humanity's technological systems by determining how the Sun's magnetic field is generated and structured how this stored magnetic energy is converted and released into the heliosphere and geospace in the form of the solar wind, energetic particles, and variations in the solar irradiance.

We will study how solar activity is created and how Space Weather comes from that activity. Measurements of the interior of the Sun, the Sun's magnetic field, the hot plasma of the solar corona, and the irradiance that creates the ionospheres of the planets are our primary data products.

The quiet Sun observed in chromosphere layers is dominated by magnetic bright points (MBPs) or magnetic network at rosettes of supergranule cells (Tavabi 2014 & 2018). They may not definitely correspond to the photosphere bright point elements.

Today, this relationship is rough accepted, suggesting that the magnetic network formation is strongly associated with supergranulation flows. SDO measures the properties of the Sun and solar activity includes the chromosphere thickness variations (in 304 Å He II thick line) which correspond to the macrospicules and type II more dynamical spicules. There are few types of measurements but many of them will be taken. For example, the surface velocity is measured by HMI. This data can be used in many different studies. One is the surface rotation rate, which must be removed to study the others. After subtracting the rotation, you have the oscillation and convective velocities. The latter look like billows of storm clouds covering the Sun. Hot gas moves outward at the center of the billows and downward at the edges, just like boiling water. By looking at these velocities you can see how sunspots affect the convection zone. By looking at a long sequence of data (more than 30 days), you see the oscillations of the Sun (like the picture). These patterns can be used to look into and through the Sun.

When will activity occurs, and is it possible to make accurate and reliable forecasts of space weather and climate?

All but a few percent of the non-radiative energy leaving the Sun is converted into heat and radiation within the chromosphere and transition region (TR). Here, the magnetic field and plasma exert comparable forces, resulting in a complex, dynamic interface region between photosphere and corona whose understanding remains a challenge.

- Feature studies using IRIS fills a crucial gap in our ability to advance Sun-Earth connection studies by tracing the flow of energy and plasma through this foundation of the corona and heliosphere for which no suitable observations exist.
- The IRIS investigation combines advanced numerical modeling with a uniquely capable observatory: IRIS obtains UV spectra and images with high resolution in space (1/3 arcsec) and time (1s) focused on the chromosphere and TR.
- An ideal opportunity: scientific need; near sunspot minimum; complementing observatories; powerful numerical tools.

By addressing them, we expect to make major advances in our understanding of how the inner solar system works and is driven by solar activity. To answer these questions, it is essential to make *in-situ* measurements of the solar wind plasma, fields, waves, and energetic particles close enough to the Sun that they are still relatively pristine and have not had their properties modified by subsequent transport and propagation processes. This is one of the fundamental drivers for the *Solar Orbiter* mission, which will approach the Sun to as close as 0.28 AU.

Solar Orbiter's imaging of the properties and dynamics of the polar region during the out-of-the-ecliptic phase of the mission (reaching heliographic latitudes of 25° during the nominal mission and as high as 34° during the extended mission) will provide badly needed constraints on our knowledge about the polar regions dynamical structures.

Different wavelengths and viewpoints will be available after the Solar Orbiter mission for providing a wide range of filtergrams and spectrums with best spatial (~ 80 km) and temporal resolution from out of the ecliptic plane at closest distance.

We deeply believed with Combining Solar Orbiter data from the in-situ and remote-sensing instruments taken at different intervals will make it possible to determine the relative contributions of plumes, jets, and marospicules to the slow and fast wind.

Summary of research activities in the past

Outreach- our team members (Institut Astrophysique de Paris) regularly collaborated in several total eclipses and designed several instruments and collaborate with space mission telescopes data processing and calibration and give public talks and lectures and participate in many science outreach activities include the Hinode/SOT, Proba/SWAP, IRIS workshops and conferences. I am a leading figure in the field of Alfvén wave propagations along the solar spicules as in our 1st analysis of chromospheric spicule coherent components and jets including magneto acoustic waves in the solar outer atmosphere using the space telescopes. The results were a significant advance in our understanding of the physics of solar magnetic field changes by addressing several guidelines as multicomponent threads structures of chromospheric jets and their helical motions. To have the best image processing to increase the visibility and auto detection of chromospheric fine structures we developed a non-linear operator selecting maxima of convexities computed in multiple directions around each pixel rewritten in IDL & MatLab so-called “MadMax”.

Summary of research activities in the past

Magnetic fields, radiation transfer, and plasma dynamics play crucial complex roles in the energy balance of the solar atmosphere. The magnitude and direction of the magnetic fields in the solar atmosphere are assumed, but unmeasured. The flow and deposition of energy in different regions of the solar atmosphere has been modeled and predicted, but current observations support a variety of interpretations. The dynamics of the chromosphere and corona, where some multi-temperature structures are stable for weeks at a time while others erupt, is poorly understood. The chromosphere (in the classical, stratified, and highly oversimplified view) is an intermediate region in the atmosphere of the Sun, lying above the photosphere and below the corona.

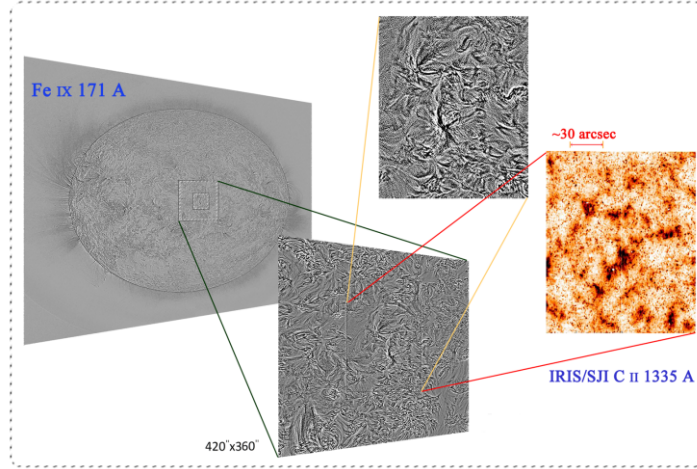


Fig 1. Full disk observation of AIA/SDO in Fe IX 171 Å line after summing over 30 min, with 12 sec. cadence in 2014 June 2 beginning at 12:12 U.T. (left panel). The region was observed simultaneously by IRIS (right panel) in several TR layers (Tavabi 2018, MNRAS).

This proposal deals with the interesting problem of the coupling of different layers of the solar atmosphere. Tracking the complex processes within these layers of the solar atmosphere requires instrument and modeling capabilities that are within technological reach for the first time. Complimentary high-resolution observations of the photosphere, chromosphere, transition region and corona were taken by Hinode/SOT, *IRIS* and *SDO* will be used (see figure 1). *IRIS* is the first mission designed to simultaneously observe the range of temperatures specific to the chromosphere and transition region at very high spatial and temporal resolution, beyond earlier missions that were a lower resolution or did not cover a wide temperature range.

Applicant's Track Record

I have had a key or lead role in several international collaborations that have led to key insight into several aspects of solar atmospheric dynamics and heating. I am a leading figure in the field of Alfvén wave propagations along solar spicules following my first analysis of chromospheric spicule coherent components, waves, and jets using SOT/Hinode, selected as the 'hot paper' of the *New Astronomy* journal in 2011. For this project, I had a lead role in an international collaboration with the Institute of Astrophysics de Paris and Tabriz university to detect magnetic wave propagating into the solar corona (Tavabi et al. 2011, Tavabi 2014). The results were a significant advance in understanding changes in the solar magnetic field by addressing several problems involving multicomponent thread-like structures of chromospheric jets. I have developed advanced analysis methods to reveal and auto-detect chromospheric fine structures, including a non-linear operator that selects local maxima of convexities computed in multiple directions (the widely-used 'madmax' operator: Tavabi et al. 2012, 2013). I had a leading role in finding the quadrupolar saddle-like magnetic configuration and a possibility for plasma to escape along open field lines into the outer corona and forming a white-light jet in cooperation with Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russian Academy of Sciences (Filippov, Tavabi and Koutchmy 2013). More recently, I was among the first to use *IRIS* observations for new science, in collaboration with the Harvard-Smithsonian Center for Astrophysics. We showed a large Doppler shift, with a pair of redshifted elements together with a faster-blueshifted element from almost the same position, corresponding to velocities of up to 100 km/s in projection on the plane of the sky. Erupting spicules and macrospicules from these regions are visible in images taken before and after the spectra. The bidirectional plasma jets ejected from a small reconnection site are interpreted to be the result of coronal loop-loop interactions that lead to reconnection in nearby sites using the *IRIS* raster data (Tavabi, Koutchmy and Golub 2015). Tavabi et al. (2015) showed the surge-like behavior of solar polar region spicules supporting the untwisting multicomponent interpretation of spicules exhibiting helical dynamics. The curvature along the spicule corresponds to a low turn number similar to a transverse kink mode oscillation along threads. All these advances suggest that the energy flux carried by coherent waves into the corona and heliosphere may be several times larger than previous estimates that were based solely on constant velocities. I provide compelling evidence for the

existence of upwardly propagating coherent waves (Tavabi et al. 2017). Tavabi (2018) applied simultaneous observations of the magnetic network from HMI and found a strong relationship between the network bright points in all levels of the solar atmosphere. Coronal bright point emission, accompanied by the magnetic origins in the photosphere, suggests that magnetic field concentrations in the network rosettes could help to couple the inner and outer solar atmosphere. A recent collaboration between the IAP team and Harvard-Smithsonian Center for Astrophysics (Tavabi, Koutchmy, and Golub) studies dynamic behavior using space-time diagrams that reveal a large amount of fast ejected material originates from the plume footpoints.

Method

When, where and how does the Sun release a large burst of matter and magnetic disturbance and study of the mechanism of flare magnetic field structure and CMEs. HINODE/SOT and magnetograms, SDO/AIA and HMI data simultaneous with the IRIS transition region Slit-Jaw-Images and spectra will be used. Requires some software development as well as an adaptation of existing 'Solarsoft' packages.

A study of the source regions of solar explosive events, with emphasis on the photospheric and chromospheric layers using magnetographs (V-stokes parameter) and velocity maps (produced by IRIS Dopplergrams) using SDO/AIA & HMI, IRIS, DKIST, SOLAR_C, and Hinode/SOT.

Study of solar polar coronal hole regions (which dominate at the solar minimum activity) and the jets and the polar plumes contained within, and compare with the solar maximum coronal holes near the equatorial regions, to find the best candidates for solar fast wind energetic particles sources and introduce a proper mechanism for their acceleration process. The magnetic reconnection shearing will be investigated theoretically. This phase needs data for several years during the maximum and minimum of solar activity. Planning and proposing for ground- and space-based observing campaigns in the highest spatio-temporal resolution of a selected active region to look at huge flares or huge explosive events, and preparing the space telescopes observation request according to the suggested proposal.

Try to find the long-term variations of solar magnetic cycles and their relationships with space weather and effects on Earth's climate. This last phase is the most significant in the context of societal and economic impact since it can lead to a greater understanding of space weather variations. The solar activity cycle modulates the UV, EUV and X-Ray radiation environment in the inner solar system, and there may be a link to Earth climate in localized regions. Global temperatures have risen by about 1.5 degrees since 1880, with more warming expected due to anthropological effects. The importance of this alarming trend demands a more complete understanding of the link between solar activity and Earth climate...

How Solar Orbiter (closer to the Sun than ever before) could help to resolve?

By addressing them, we expect to make major advances in our understanding of how the inner solar system works and is driven by solar activity. To answer these questions, it is essential to make *in-situ* measurements of the solar wind plasma, fields, waves, and energetic particles close enough to the Sun that they are still relatively pristine and have not had their properties modified by subsequent transport and propagation processes. This is one of the fundamental drivers for the *Solar Orbiter* mission, which will approach the Sun to as close as 0.28 AU.

Solar Orbiter's imaging of the properties and dynamics of the polar region during the out-of-the-ecliptic phase of the mission (reaching heliographic latitudes of 25° during the nominal mission and as high as 34° during the extended mission) will provide badly needed constraints on our knowledge about the polar regions dynamical structures.

Different wavelengths and viewpoints will be available after Solar Orbiter mission for a wide range of filtergrams and spectrums with the best spatial (~80 km) and temporal resolution from out of the ecliptic phase at the closest distance.

Full-disk & high-resolution maps of the photospheric magnetic field and local and convective flows, maps of rotation, differential rotation, and meridional circulation, the structure of subduction areas, properties of sub-surface convection cells (using Polarimetric and Helioseismic Imager, PHI) could answer these questions: How is magnetic flux transported to and reprocessed at high solar latitudes?, What are the properties of the magnetic field at high solar latitudes? & Are there separate dynamo processes acting in the Sun?

The mechanisms heat and accelerate the fast solar wind seem to originate from polar coronal holes, Solar Orbiter mission instruments simultaneous data (includes the High-resolution, high-cadence maps of photospheric magnetic field (PHI) at the poles, and from remote (SPICE) and in-situ (SWA) observations) could help us to figure out their formation and evolving procedures.

We genuinely believed with Combining Solar Orbiter data from the in-situ and remote-sensing instruments taken at different intervals will make it possible to determine the relative contributions of plumes, jets, and marospicules to the slow and fast wind.

The Multi Element Telescope for Imaging and Spectroscopy (METIS/COR) will employ broad-band, polarized imaging of the visible K-corona and narrow-band imaging of the UV (HI Ly α , 121.6 nm) and EUV (He II Ly α , 30.4 nm) corona to study the structure and dynamics of the full corona with unprecedented temporal coverage and spatial resolution. Especially for looking to the base of corona jet and spic. **This coronagraph give us the significant opportunity to know the dynamical behavior of corona polar plumes tiny jets as a plausible source for solar fast wind acceleration region. In addition, METIS is an externally occulted coronagraph having an annular FOV between 1.2 and 3.0 RS at a solar distance of 0.23 AU (1.8 to 5.3 RS at a distance of 0.3 AU). This region of the corona is crucial in linking the solar atmospheric phenomena to their evolution in the inner heliosphere including the chromosphere and transition regions.**

The unique capability of imaging the solar corona in three different wavelength bands by means of a single telescope is achieved by a combination of multilayer coatings of the mirrors, optimised to enhance reflectivity in the He II line, and spectral band-pass filters. Coronal light enters METIS through the external occulter aperture that provides occultation of the solar disk for both thermal protection and stray light rejection. An annular sector shaped Sun-disk rejection mirror reflects the light from the solar disk back through the front aperture. The hole in the heat rejection mirror is the aperture stop through which the coronal light enters the telescope. The telescope consists of aspherical primary and secondary mirrors in an off-axis Gregorian mount.

A door that is part of the spacecraft heat shield closes the instrument when it is not operating to protect it and to reduce the thermal load on the spacecraft. A filter wheel accommodates two filters: a narrow band interference filter (HF) optimized to transmit the HI 121.6 nm line and to reflect visible light, and an aluminium low pass filter (HeF) to block the wavelengths above the He II 30.4 nm line. With HF, the UV HI 121.6 nm corona and the VL K-corona are imaged simultaneously.

With HeF, only the EUV He II 30.4 nm is imaged on the UV detector. The visible light channel includes a polarimeter assembly to observe the linearly polarized component of the K-corona. The polarimeter assembly uses a nematic liquid crystal variable retarder plates (LCVR) and a colour filter to select the spectral operation band. METIS has two detectors: one optimised for observations in visible light (450 – 650 nm), the other dedicated to UV (121.6 nm) and EUV(30.4 nm) detection.