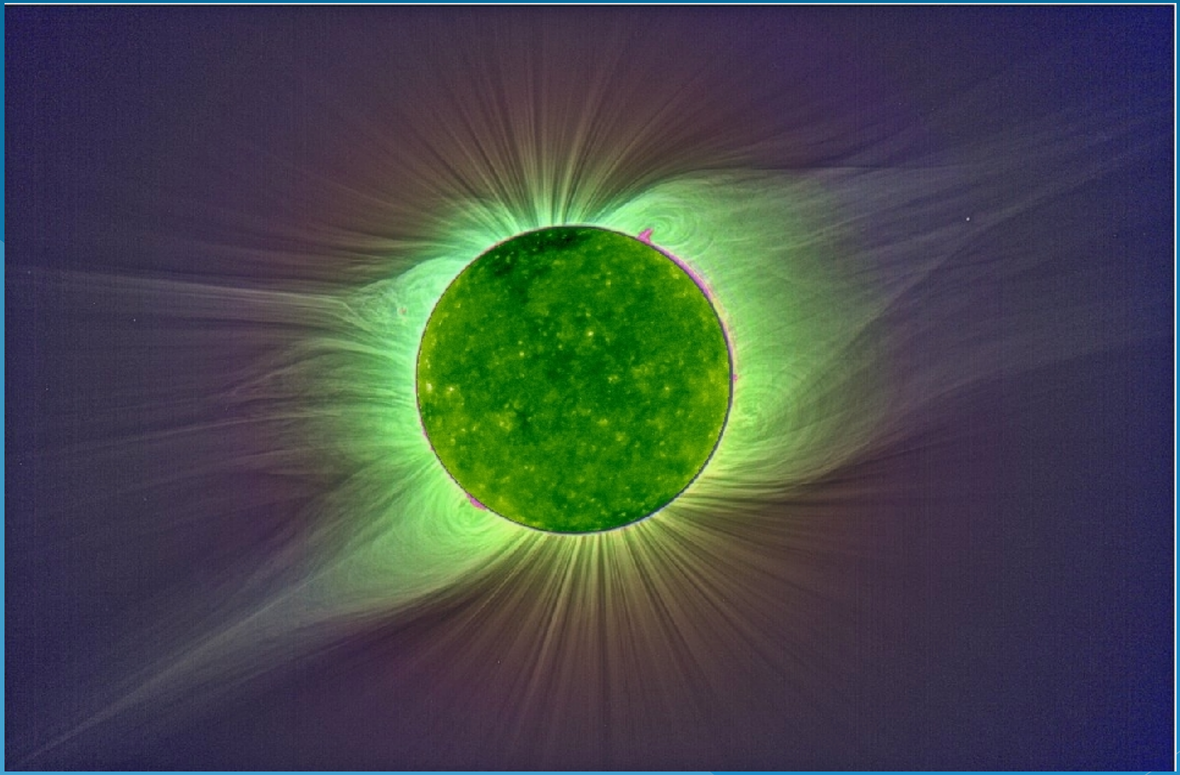
Pulsations in Solar and Stellar Flares and MHD Seismology



A.K. Srivastava
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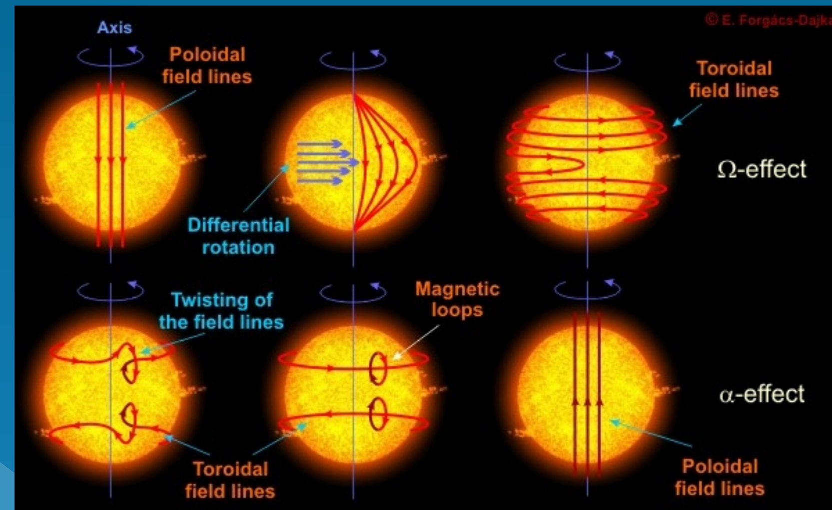
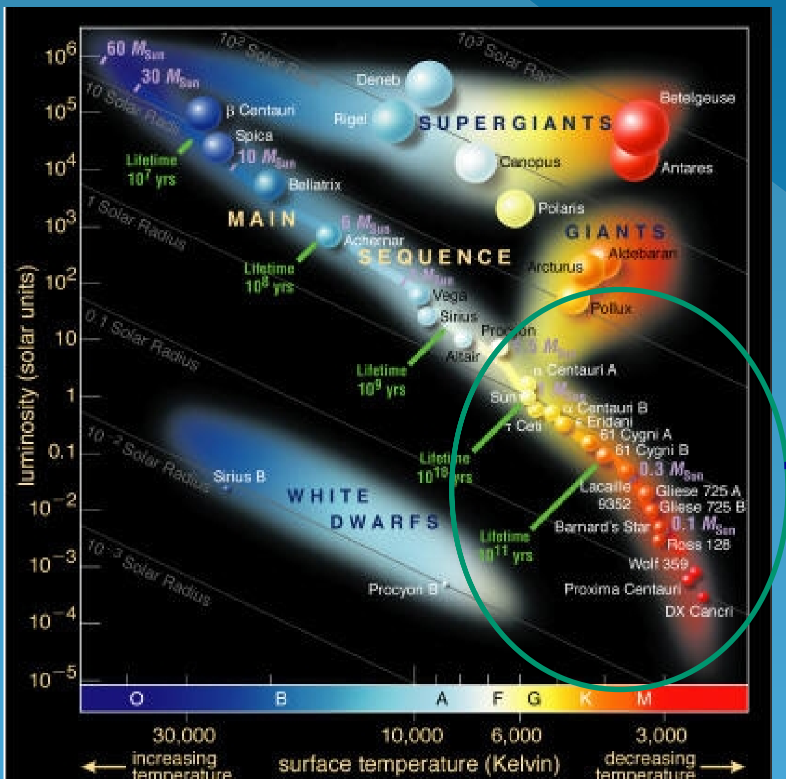
Possibility of Magnetic Activity, Coronae, Flares, QPPs along H-R Diagram

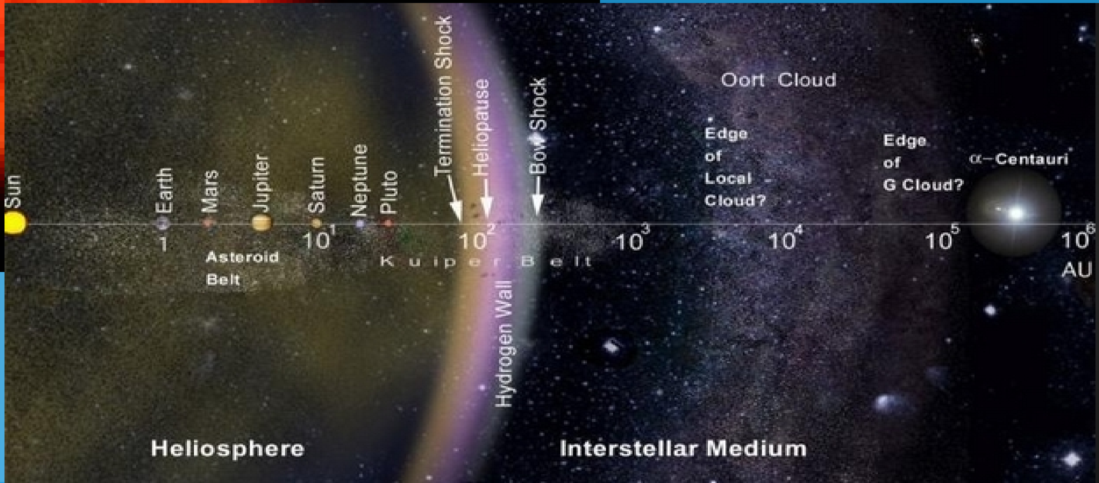




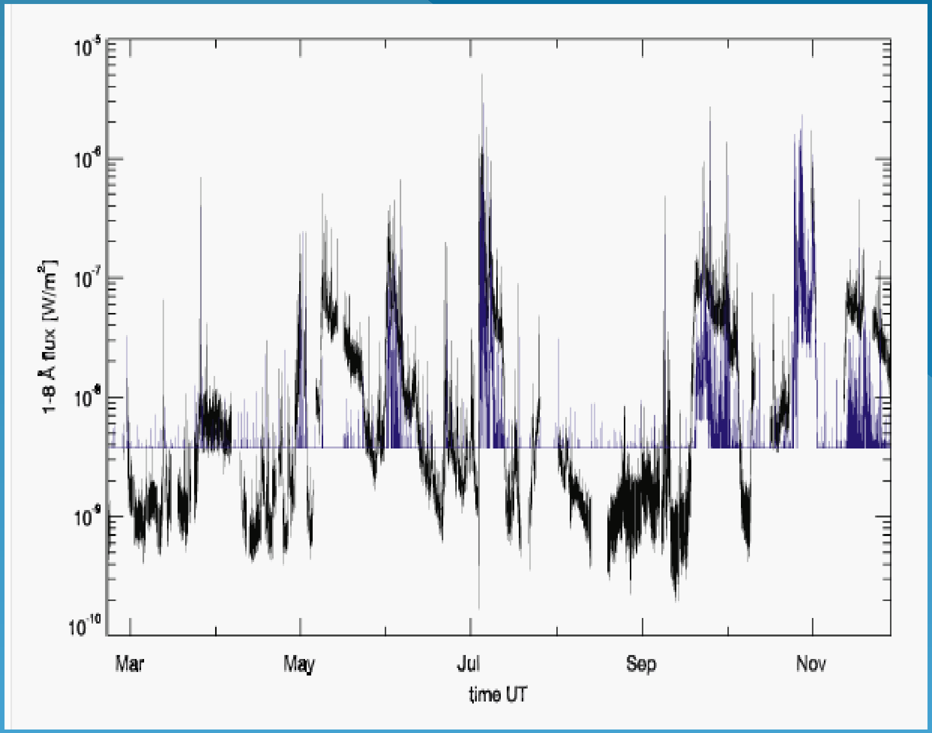
Sun-like Stars

Magnetized, Hot, and Flowing Sun's Corona

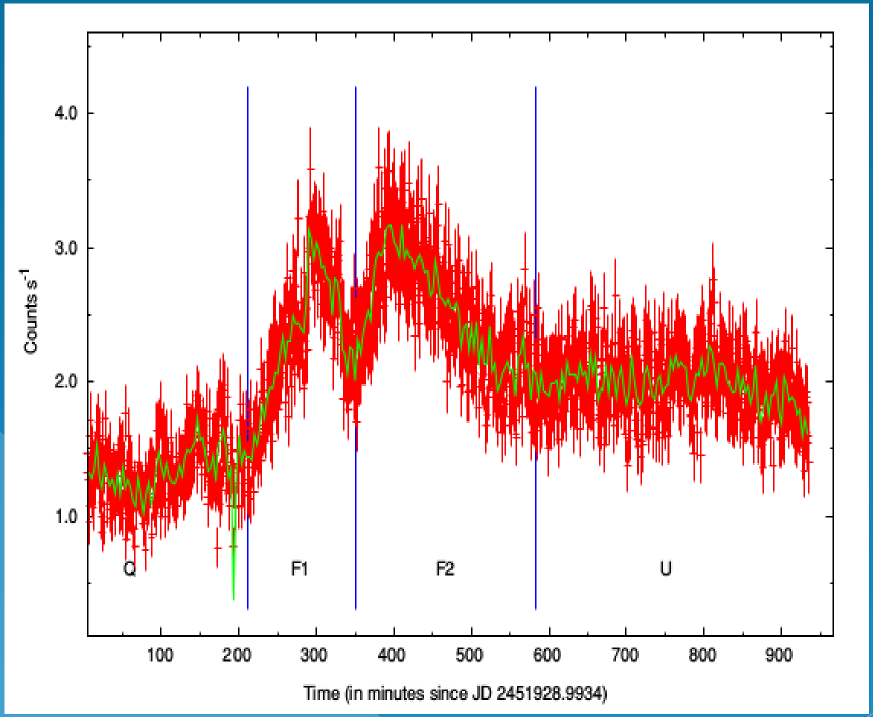
Magnetized, Hot, and Flowing Star's Corona



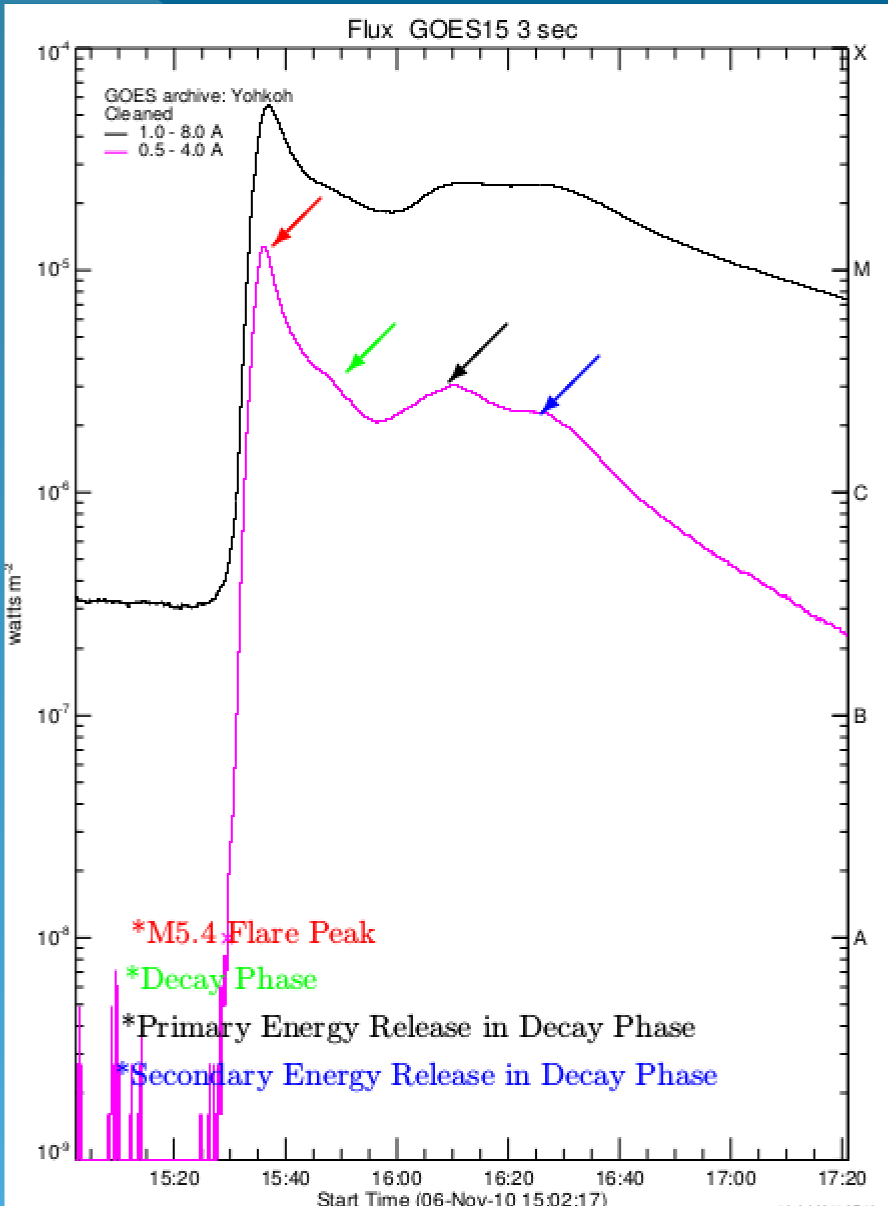
Solar Flares



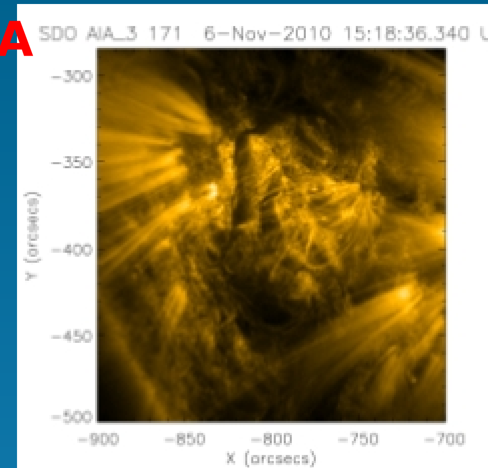
Stellar Flare



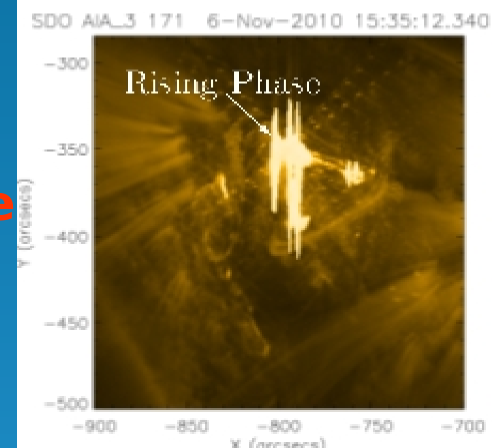
TYPICAL SOLAR FLARE AND VARIABLE CORONA



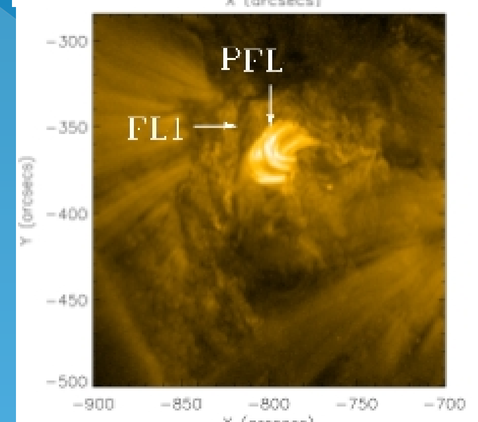
Pre-Flare



Rise of Flare



Post-Flare



While we must take care on use of techniques, we should also take into account
The justifications based on the localized magneto-plasma conditions while studying pulsations

Major Mechanisms of QPPs in the Flaring Regions :

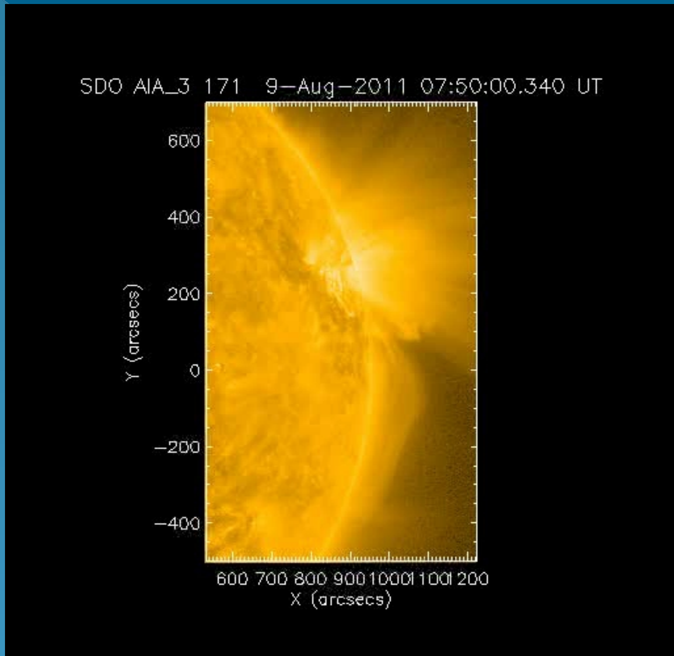
(1) Periodic motions of energetic Particles in flaring loops !

(2) External Driver and Periodic Re-connection ;

(3) Triggered MHD Modes;

(2)-----> If it is present, a novel chance to determine the local plasma Conditions of the localized solar and stellar coronae, e.g., magnetic field; scale height/expansion factor (using period ratio); transport phenomena, etc.

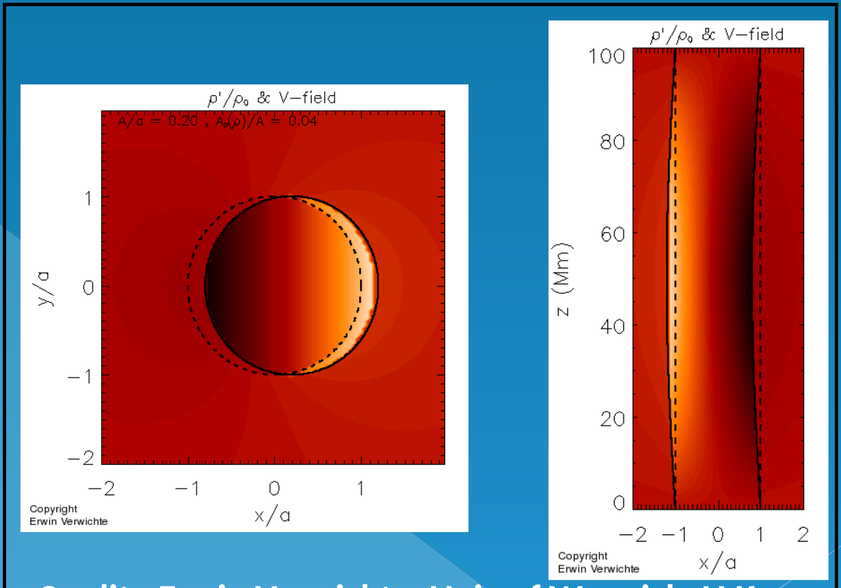
MHD-Modes



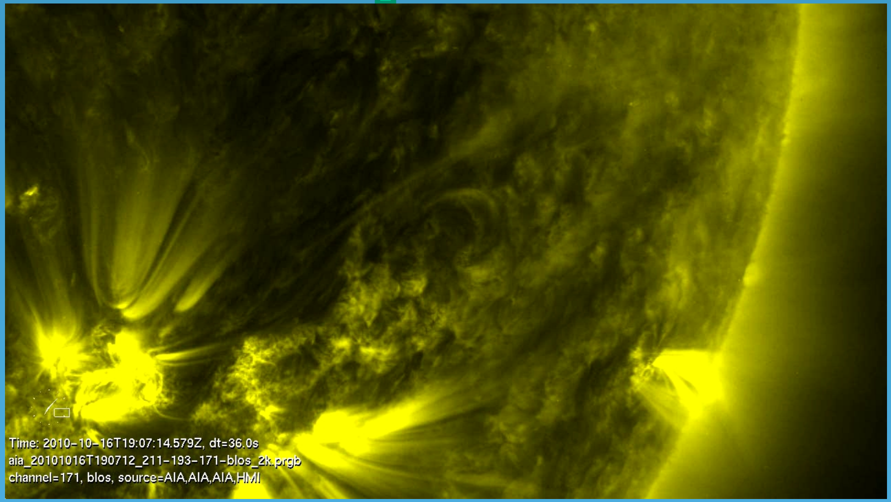
Straighten the curved loop and excite the perturbations

Vertical modes

Srivastava & Goossens, 2013, ApJ



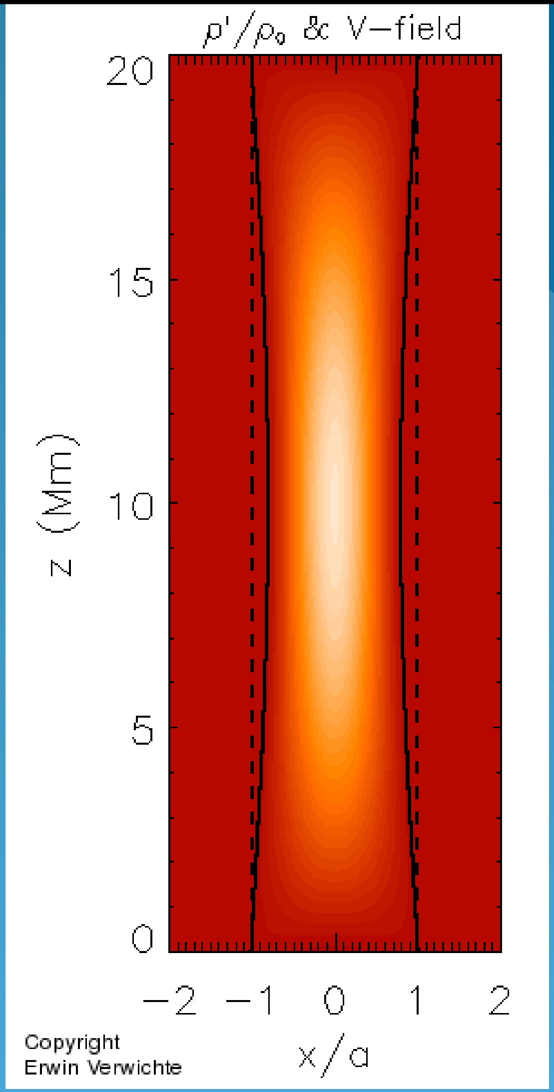
Credit : Erwin Verwichte, Univ of Warwick, U.K.



Horizontal modes

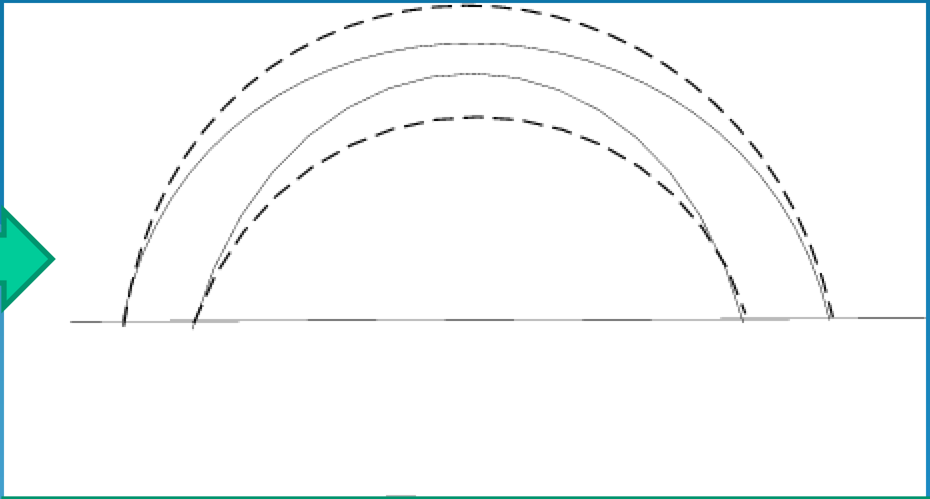
Aschwanden & Schrijver, 2011, ApJ

Sausage Oscillations



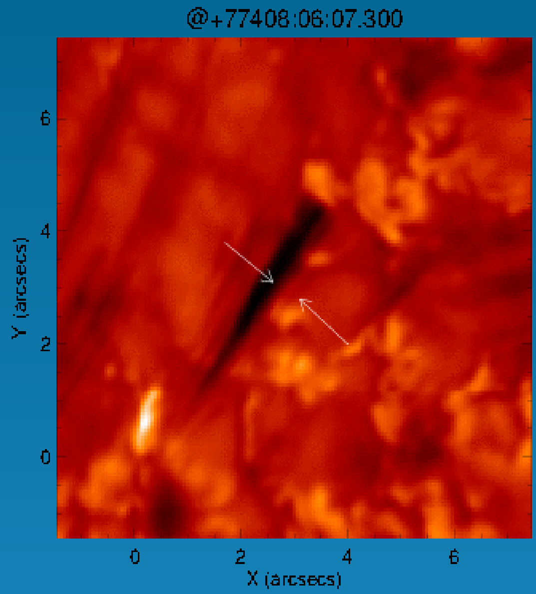
Straight Tube

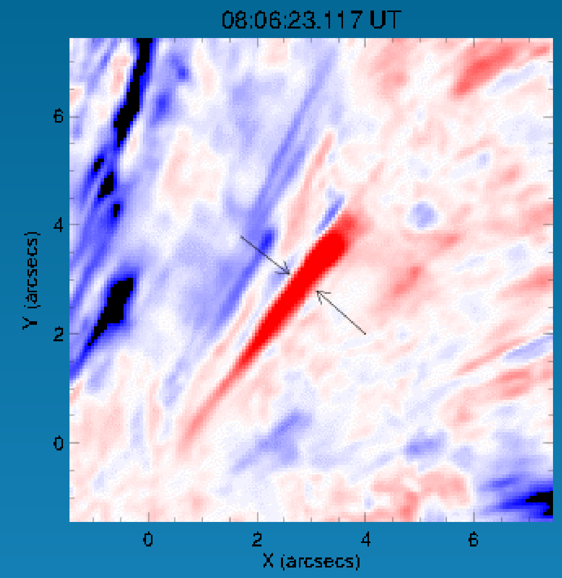
Curved Tube

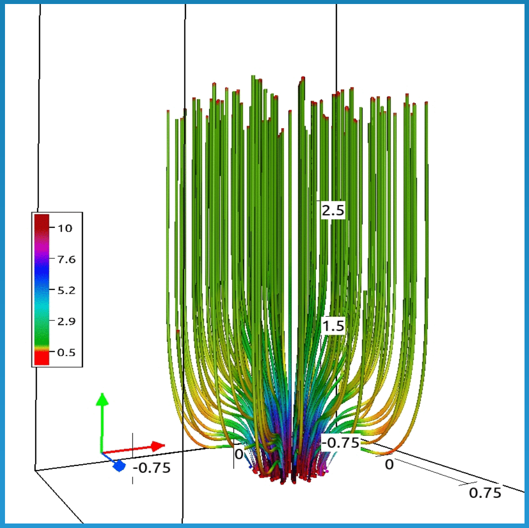


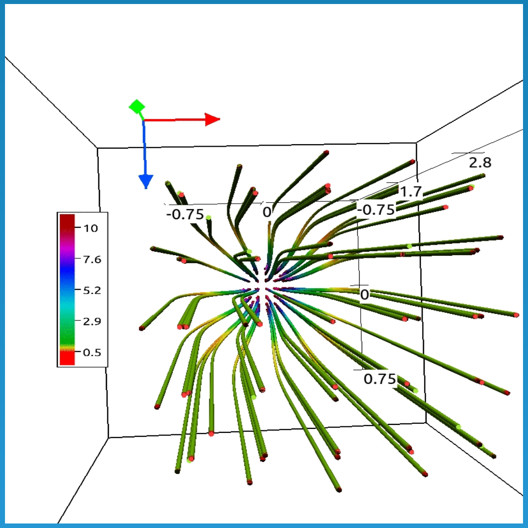
Longitudinal and compressive fundamental-mode sausage oscillations in a magnetic fluxtube

Torsional Alfven Waves in the Solar Flux-tubes









Srivastava, A.K., Shetye, J., Murawski, K., Doyle, J.G., Stangalini, M., Scullion, E., Ray, T., Wojcowik, D
Dwivedi, B.N., 2017, Nature Sci. Rep., 7, 15547.

Pulsations in Stellar Flares and Possible Diagnostics

Few Confirmed Detection on Stellar Pulsation

Star	Periodicity	MHD Candidates	Reference
YZ Cmin	Few seconds to few mins in optical band	???	Contadakis et al., 2012, AN, 333, 583
Red-Dwarf Binary	QPOs	??	Qian et al., 2012, MNRAS, 423, 3646
EQ-Peg B	10 s optical	Sausage Oscillations	Tsap, Y.T., Stepanov, A.V., et al., AstL., 2011, 37, 49
XI-BOO	1019 s in post-flare phase of X-ray emissions	Fast Magnetoacoustic Kink Waves	Pandey, J.C., Srivastava, A.K., 2009, ApJL, 697, L153
EQ Peg B	10 s optical	Fast Modes or Periodic Reconnections	Mathioudakis, M. et al., 2006, A&A, 456, 323
AT Mic	750 s in X-ray	Standing Slow Waves	Mitra-Kraev et al., 2005, A&A, 1041, 436.
RS CVn binary II Peg	220 s in optical	Standing Kink Modes	Mathioudakis et al., 2003, A&A, 403, 1101
dMe star YZ CMi	**32 minutes**	**Slow modes and kink waves**	**Anfinogentov et al., 2013, ApJ, 773, 156**
Proxima Centauri	**X-rays**	**Multiple slow oscillations an d MHD seismology**	**A.K. Srivastava, L. Sairam, J.C. Pandey, ApJL, 778, L28**

+ The recent works done by group of Warwick (UK) + Kyoto (Japan)

THE ASTROPHYSICAL JOURNAL, 697:L153–L157, 2009 June 1 doi:10.1088/0004-637X/697/2/L153

OBSERVATIONS OF X-RAY OSCILLATIONS IN ξ BOO: EVIDENCE OF A FAST-KINK MODE IN THE STELLAR LOOPS

XI BOO-A : 22 Light Years Away; 5551 K surface temperature, binary star, 6.2 times larger rotation than Sun; Young star of MYR age.

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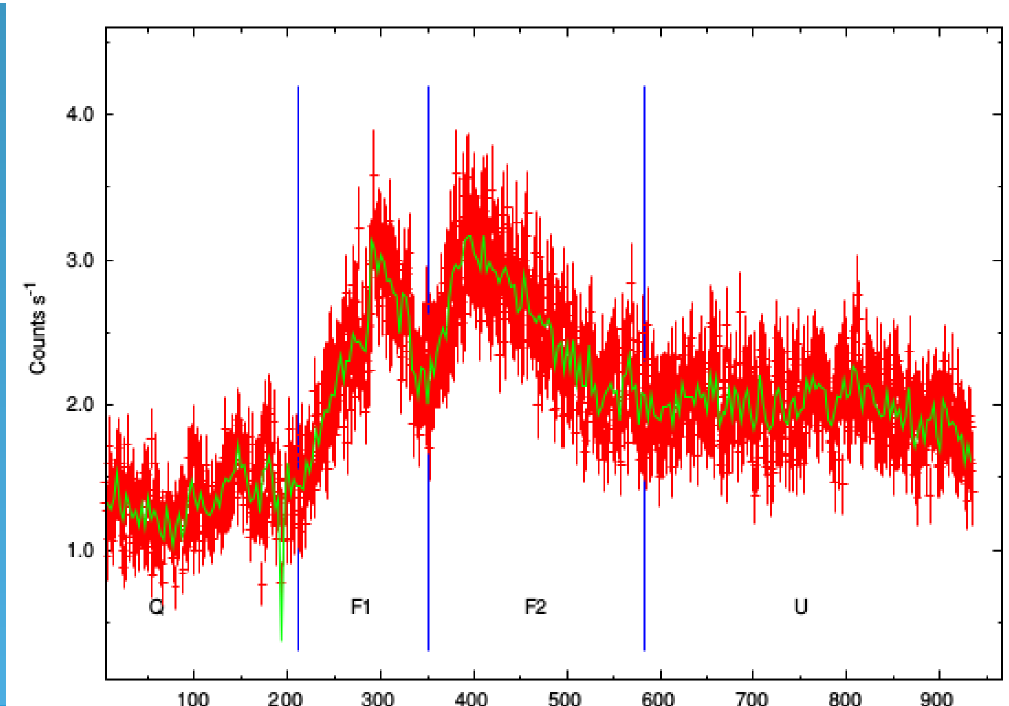
Received 2009 February 13; accepted 2009 April 27; published 2009 May 12

ABSTRACT

We report the observations of X-ray oscillations during the flare in a cool active star ξ Boo for the first time. ξ Boo was observed by EPIC/MOS of the *XMM-Newton* satellite. The X-ray light curve is investigated with wavelet and periodogram analyses. Both analyses clearly show oscillations of the period of ∼1019 s. We interpret these oscillations as a fundamental fast-kink mode of magnetoacoustic waves.

Key words: stars: activity – stars: coronae – stars: flare – MHD – waves



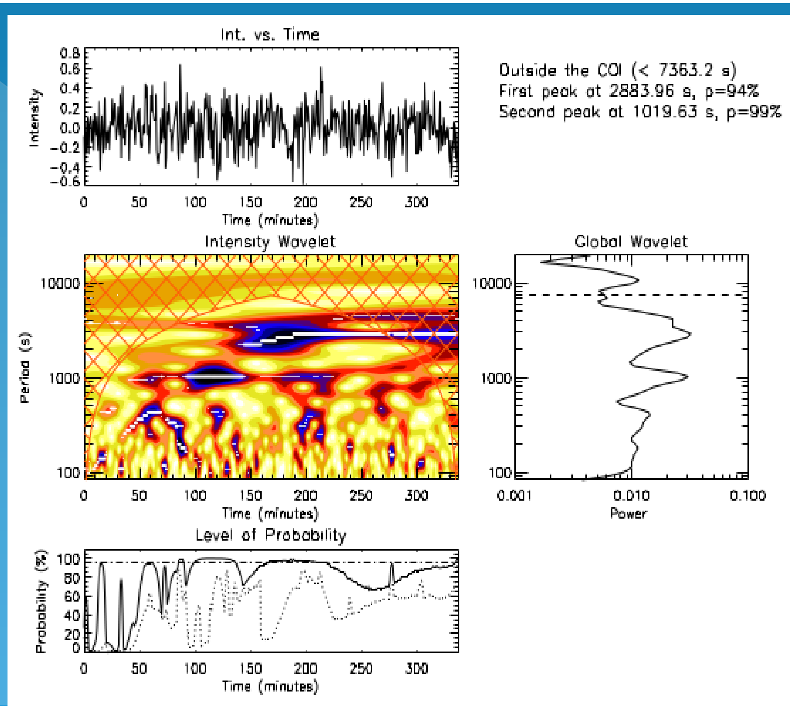


Table 2
Derived Parameters

Model	Loop Length (10^{10} cm)	Theoretically Estimated Period: Slow Mode (s)	Fast-Kink Mode[a,b] (s)	Fast Sausage Mode[b] (s)	Observationally Estimated Period (s)
Hydrodynamic	3.6 ± 0.8	1586 ± 353	1004 ± 391	313 ± 121	
Rise and decay	3.9 ± 0.5	1718 ± 222	1087 ± 374	339 ± 116	
Pressure balance	3.6 ± 0.9	1586 ± 377	1004 ± 407	313 ± 127	1019
Haisch's approach	3.8 ± 0.2	1674 ± 92	1059 ± 343	330 ± 107	

Notes.
[a] Large error bars are due to the large density error.
[b] Loop width was determined by assuming $a/L = 0.1$.

Remarks: [1] One of the earlier works on stellar coronal pulsations !

[2] An approach though considering the possibility of MHD modes.

[3] Clues of decay-less oscillations are mentioned in this paper, more prior before they are observed in solar corona !!!.

[4] Opens further the search of MHD modes in stellar coronae !

First Detection of Multiple Slow Waves in the Proxima Centauri and Its MHD Seismology

The Astrophysical Journal Letters, 778:L28 (5pp), 2013 December 1
doi:10.1088/2041-8205/778/2/L28

EVIDENCE OF MULTIPLE SLOW ACOUSTIC OSCILLATIONS IN THE STELLAR FLARING LOOPS OF PROXIMA CENTAURI

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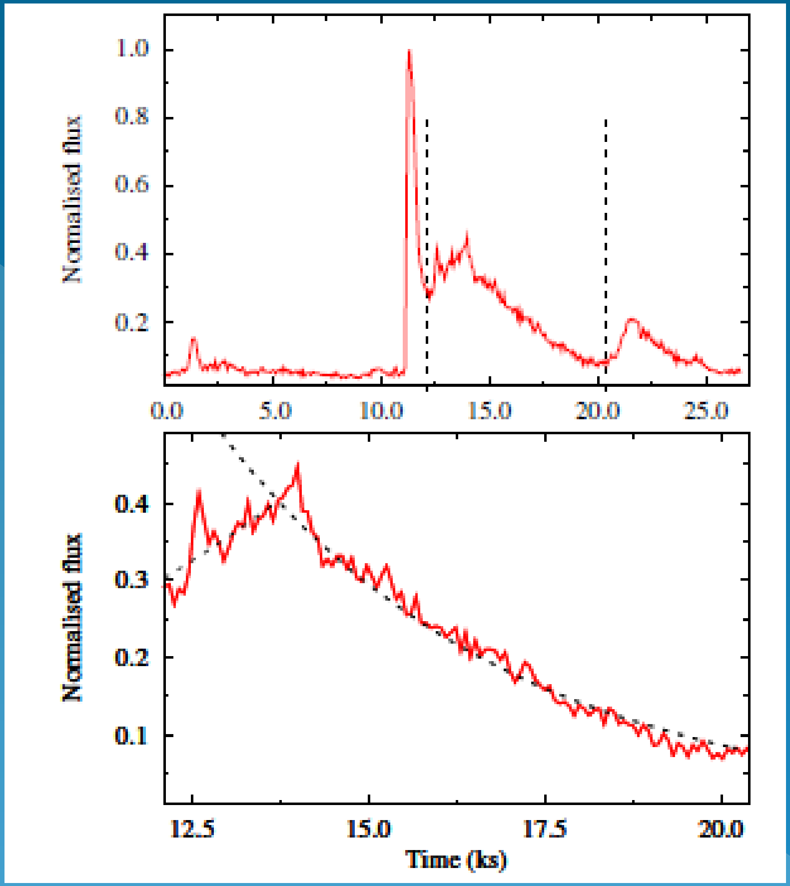
Received 2013 August 19; accepted 2013 October 24; published 2013 November 12

ABSTRACT

We present the first observational evidence of multiple slow acoustic oscillations in the post-flaring loops of the corona of Proxima Centauri using *XMM-Newton* observations. We find the signature of periodic oscillations localized in the decay phase of the flare in its soft (0.3–10.0 keV) X-ray emissions. Using the standard wavelet tool, we find multiple periodicities of 1261 s and 687 s. These bursty oscillations persist for durations of 90 minutes and 50 minutes, respectively, for more than three cycles. The intensity oscillations with a period of 1261 s may be the signature of the fundamental mode of slow magnetoacoustic waves with a phase speed of 119 km s^{-1} in a loop of length 7.5×10^9 cm, which is initially heated, producing the flare peak temperature of 33 MK and later cooled down in the decay phase and maintained at an average temperature of 7.2 MK. The other period of 687 s may be associated with the first overtone of slow magnetoacoustic oscillations in the flaring loop. The fundamental mode oscillations show dissipation with a damping time of 47 minutes. The period ratio P_1/P_2 is found to be 1.83, indicating that such oscillations are most likely excited in longitudinal density stratified stellar loops. We estimate the density scale height of the stellar loop system as ~23 Mm, which is smaller than the hydrostatic scale height of the hot loop system, and implies the existence of non-equilibrium conditions.

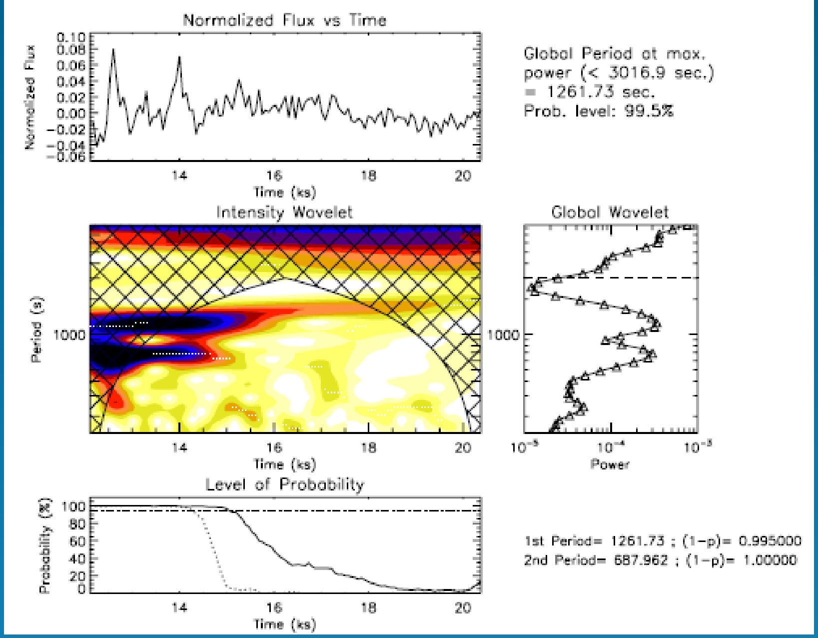
Nearest Sun-like star to us; 4.25 (or 1.3 pc) away from us; 0.1 Msun; 0.1 Rsun; 82 days rotation period.

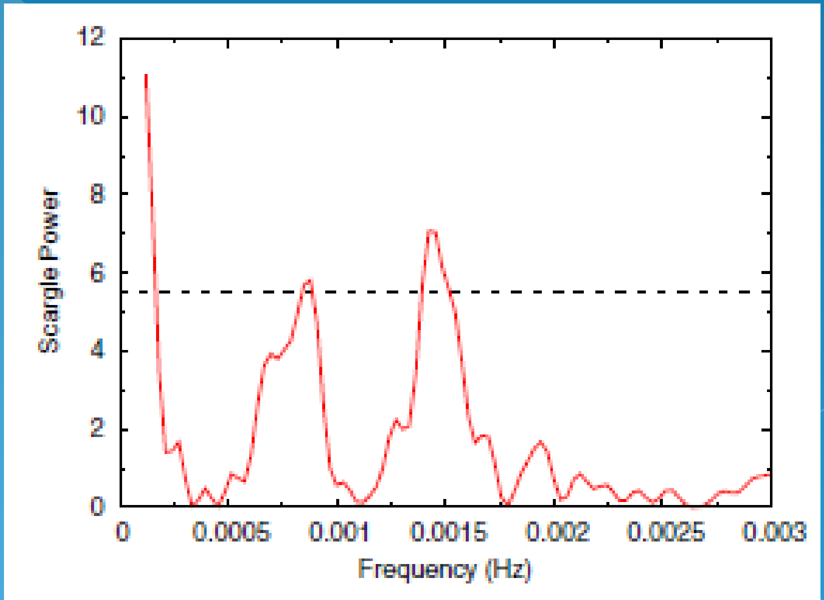


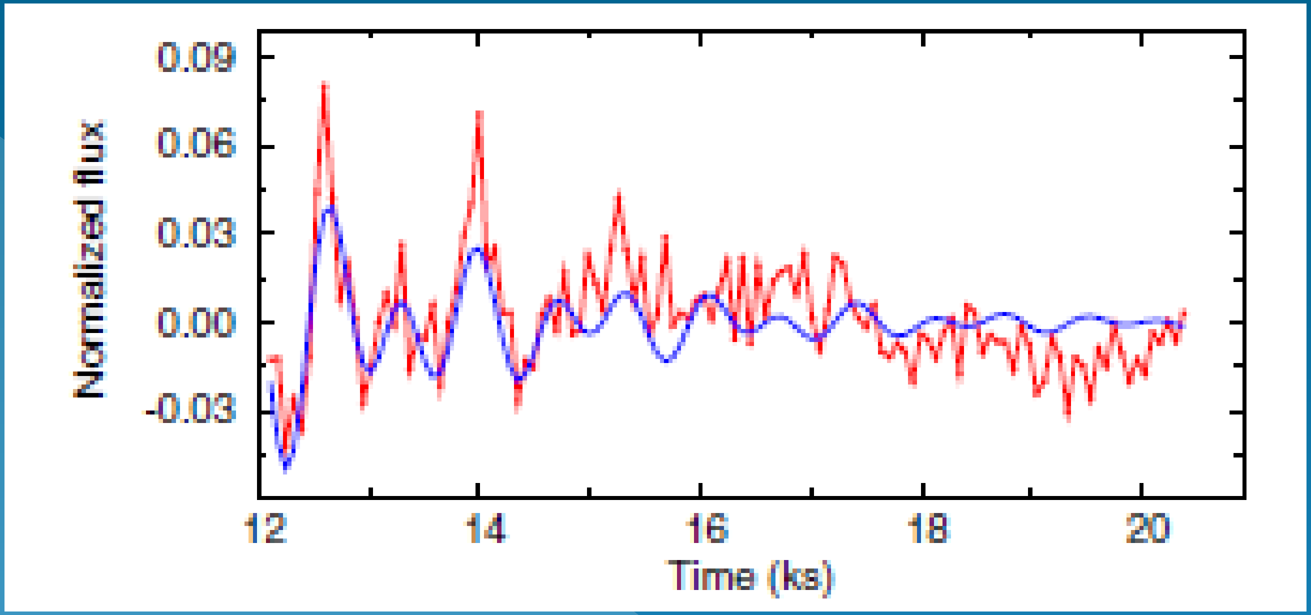
X-ray light curve of 0.3-10 keV range with 70 s binning

Table 1
The Summary of Detected Periodicities using Wavelet Analysis

Binning Time (s)	Cycles	Periods (s)	Probability (%)
50	>3	1274 and 694	>99
60	>3	1286 and 701	>99
70	>3	1261 and 687	>99
90	>3	1250 and 682	>97







$$F(t) = \sum_{i=1}^{2} A_i \cos\left(\frac{2\pi}{P_i} t + \phi_i\right) e^{-\frac{1}{\tau_i} t},$$

Summary of Results :

[1] We derive the loop length by knowing volume emission measure (VEM), density (ne) , number of loops (N=100 here), and aspect ration. In our case it turned out 7.5 x 10^9 cm.

[2] Phase speed is turning out 116 km/s based on loop length and detected Period, which is found to be sub-sonic during the post flare temperature Of 7.5 MK.

[3] Period ratio is 1.834, which suggests for the stratified loops.

[4] Density scale height is 23 Mm, which is well below the hydrostatic scale height and indicates the non-equilibrium.

I propose the following works to the ISSI team with their slight description and underlying objectives

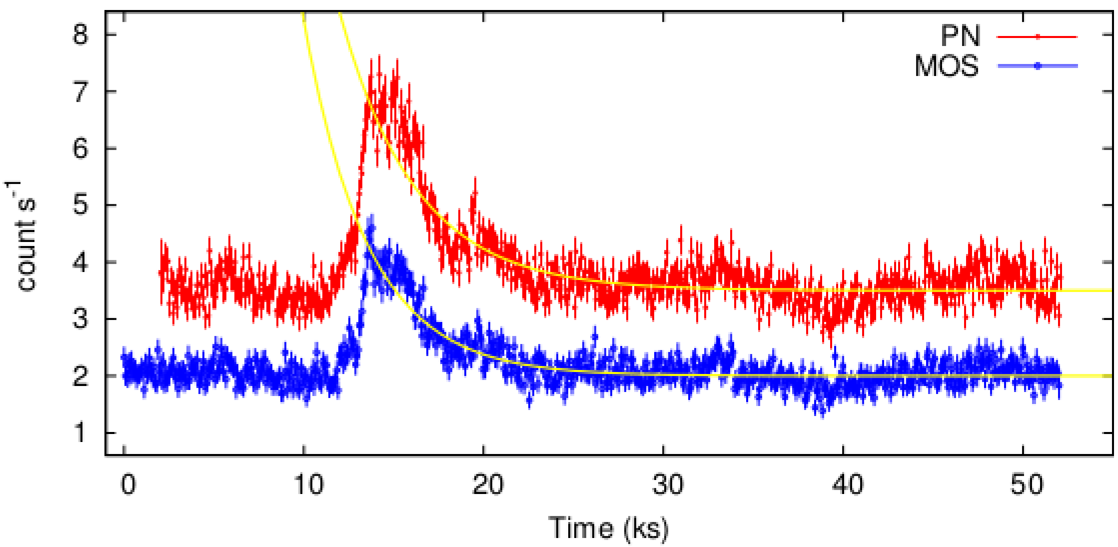
(i) The present ISSI team focus on the solar flare QPPs and related physics. However, as we know that recently the another ISSI team (Broomhall et al.) have been explored the stellar flares and related oscillations. Therefore, we must also make some linkage on solar-stellar connection !

(ii) We can revert back even some idea from these QPPs back to the solar flaring regions in order to diagnose them !

(iii) These works can open a window that our group is in major dealing with solar flare QPPS, but we are open with a parallel forum to deal with solar stellar connections !

(iv) I would like to invite the interested ISSI team members to these works. !! + More contributions in solar flare QPP stuffs.

PROPOSAL 1: Sun-like Wave Propagation on EK DRA



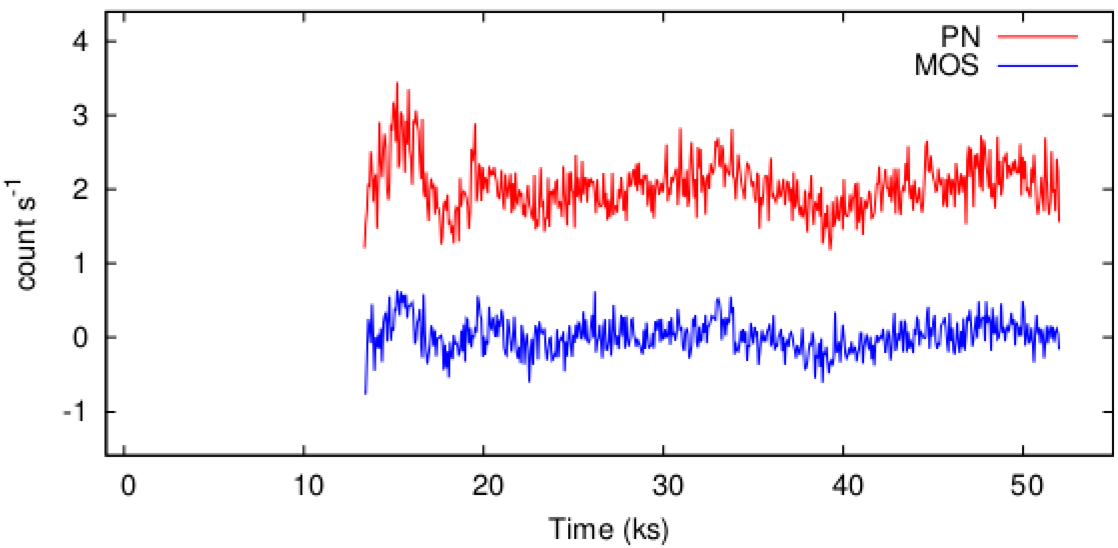


Table 1: Loop parameters of EK Dra

Parameters	Value
Decay Time (τ_d)	4234 ± 98s
T_{max}	$9.1 \pm 2.7 \times 10^7$ K
$T^\star_{eq}$	8.6×10^6 K
Loop Length(L)	$9.9 \pm 3.1 \times 10^{10}$ cm
Electron Density (n_e)	2.5×10^{10} cm^{-3}
Pressure ($p = 2n_ekT$)	628 dyne cm^{-2}
Magnetic Field (B)[1]	126 Gauss

[1] mimimum magnetic field to confine the plasma

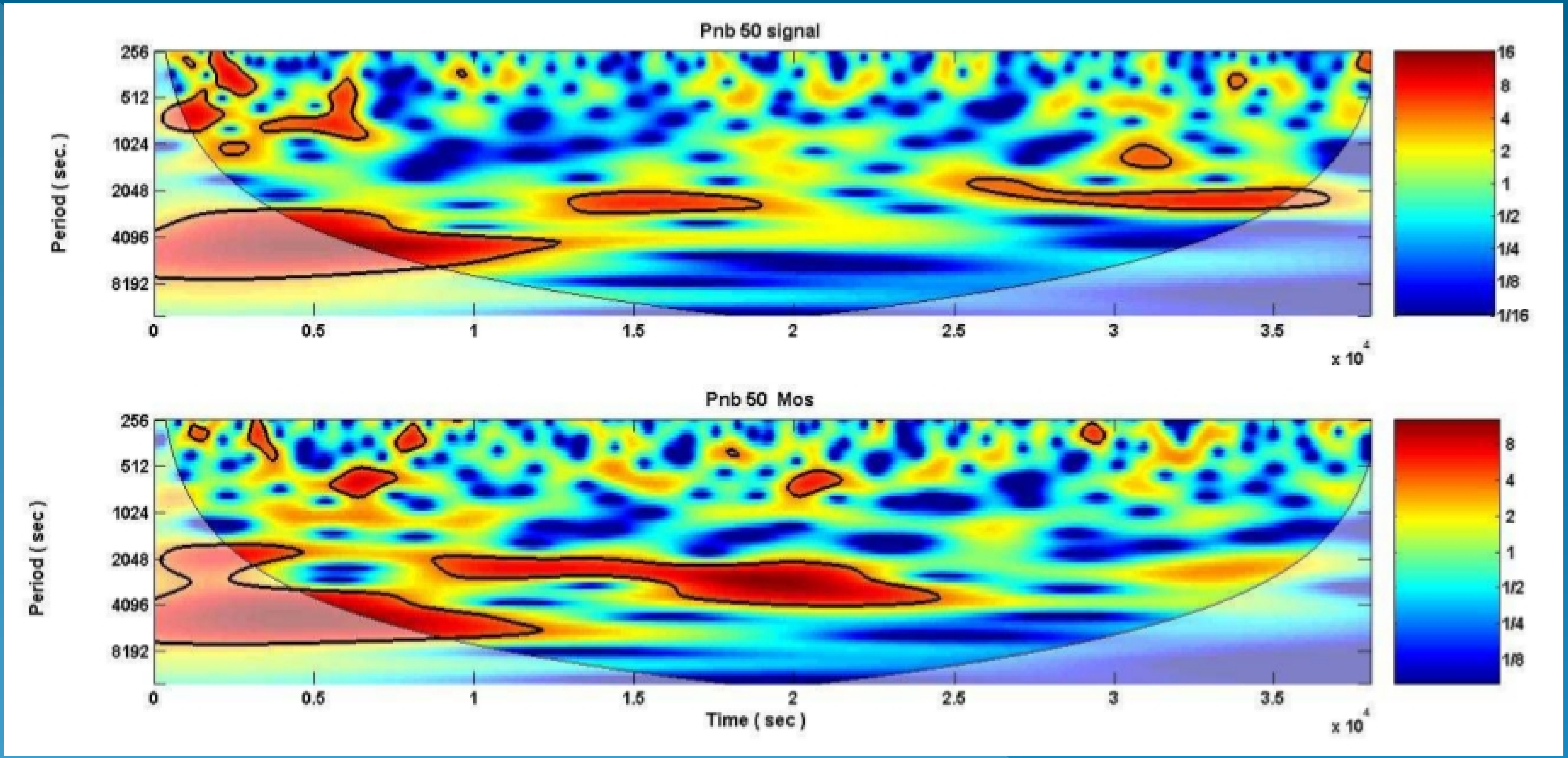
(Scelsi et al. 2005)

Srivastava et al (in prep for ApJL)

+ ISSI-BJ Team

(Interested members may join)

Note: A parallel work by the team of BroomHall (including Valery Nakariakov) is being done On it with different scientific aspects. We are open to each other and in touch to finalize two different science cases.



[1] We got that equilibrium atmosphere changes with the near Gaussian shaped change of the temperature.

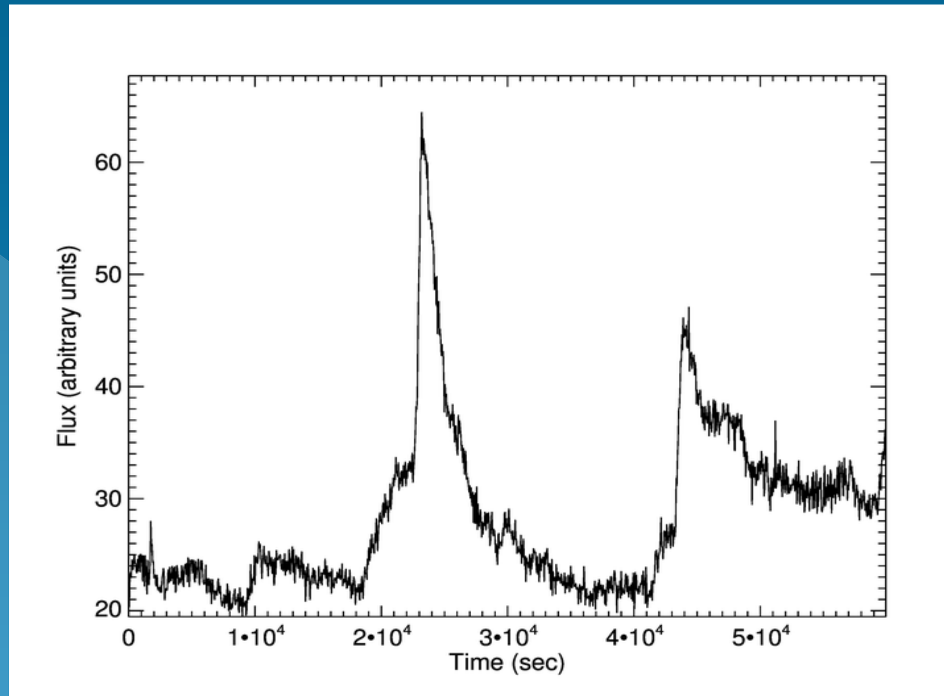
[2] Scale-height of the atmosphere will change with temperature, which in turn change the Acoustic Cutoff Frequency !

[3] It will change the behavior of the medium for the wave, and later short period waves will channel over the flaring region.

PROPOSAL 2 : Sun-like QPPs in ABDOR (in Progress)

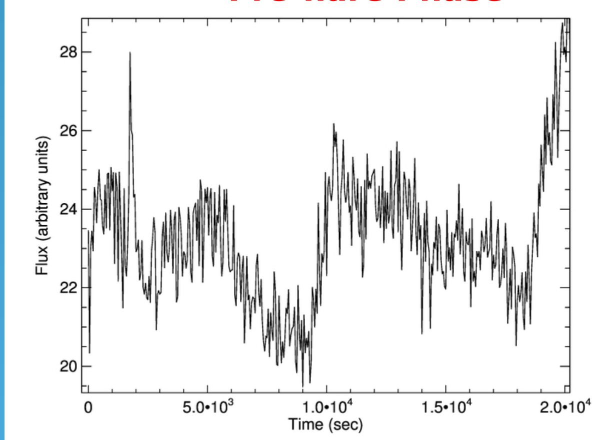
*We have analyzed> 30 Flares and their QPPs on a single star

* We have enough statistics to check the scaling law in P vs Damping time as seen in solar flares.

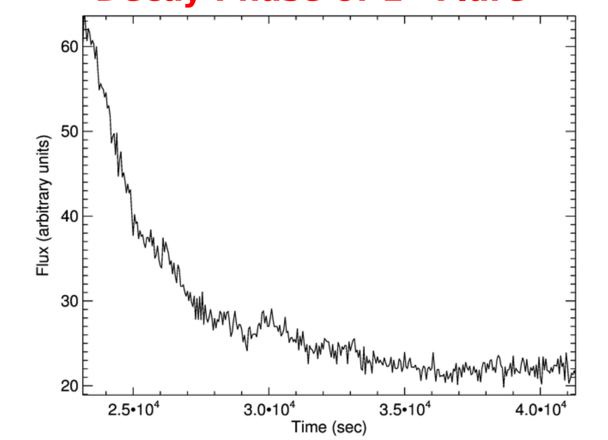


* We have spectral observations, plasma parameter estimation, and estimated loop parameters to understand the physical scenarios underlying the oscillations.

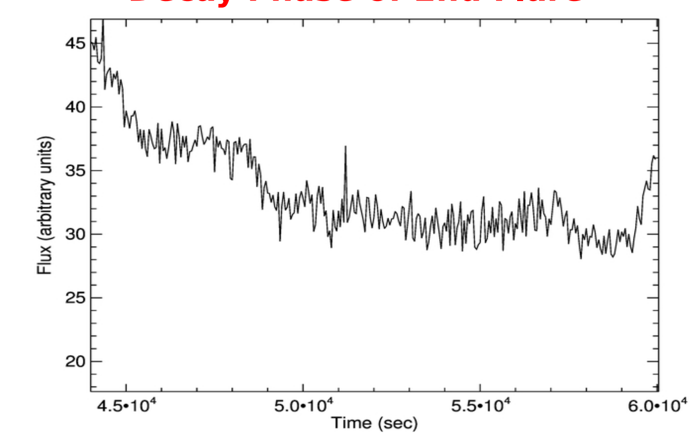
Pre-flare Phase



Decay Phase of 1st Flare

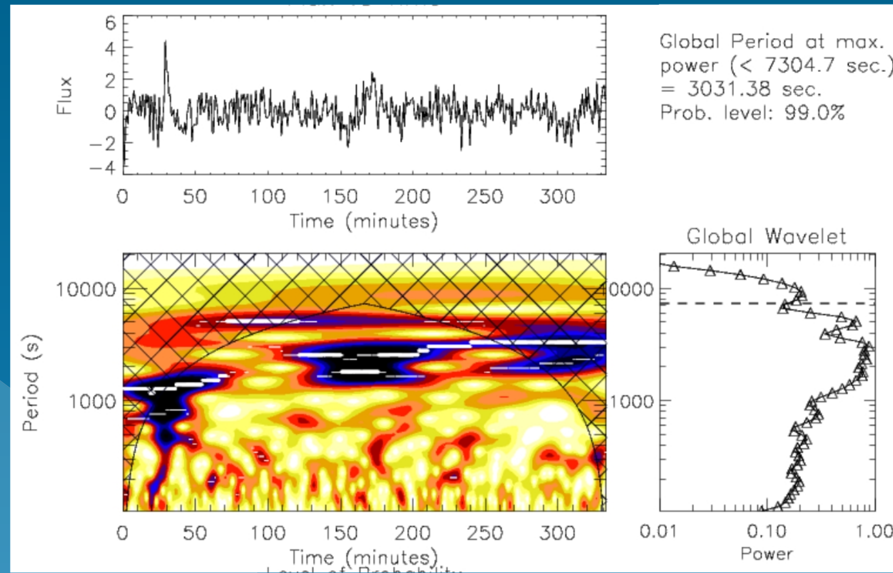


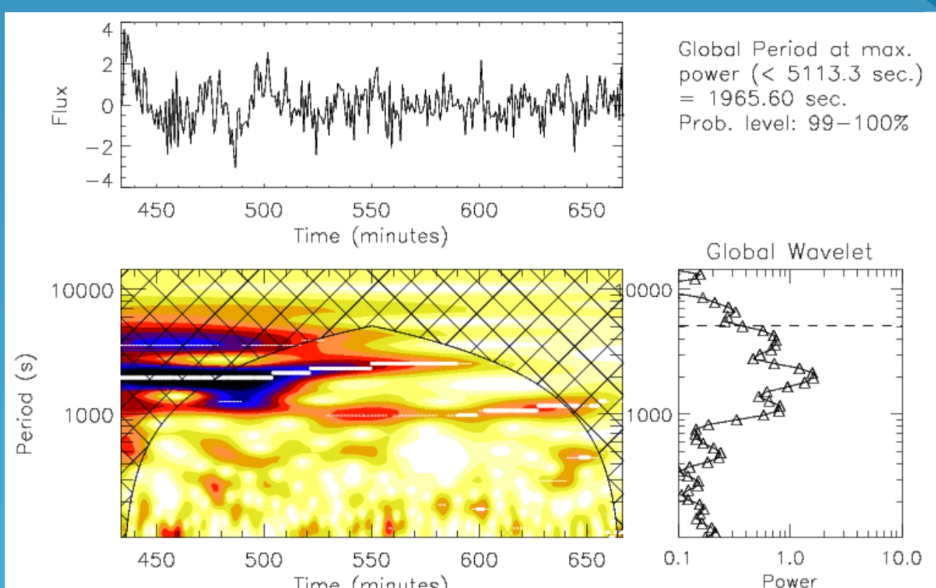
Decay Phase of 2nd Flare

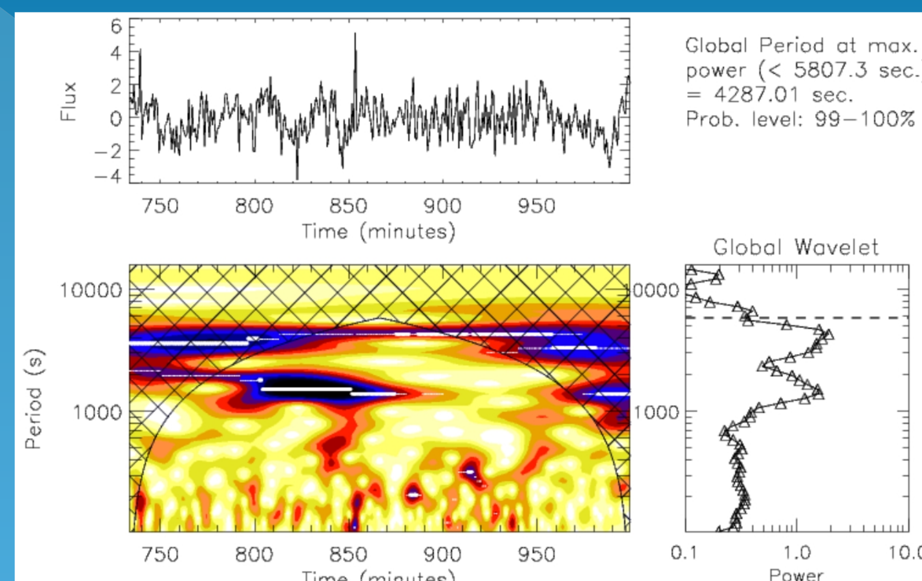


Srivastava et al (in prep for MNRAS); + ISSI-BJ Team (Interested members may join)

Pre-flare







Post-Flare 1

Post-Flare 2

Conclusions and Proposal:

[1] While, we focus on the solar flare and associated QPPs, the stellar coronal pulsations and related projects will bring additional elements to our ISSI-BJ team.

[2] Exploitation of these oscillations, keeping the view of solar analogy, will diagnose the local properties and dynamics of the plasma there. This is still an important task as far as the solar and stellar pulsations are constrained as it constrain the existing theories.

[3] My proposition to the group are herewith :

(a) Sub-groups with broader themes we have discussed;

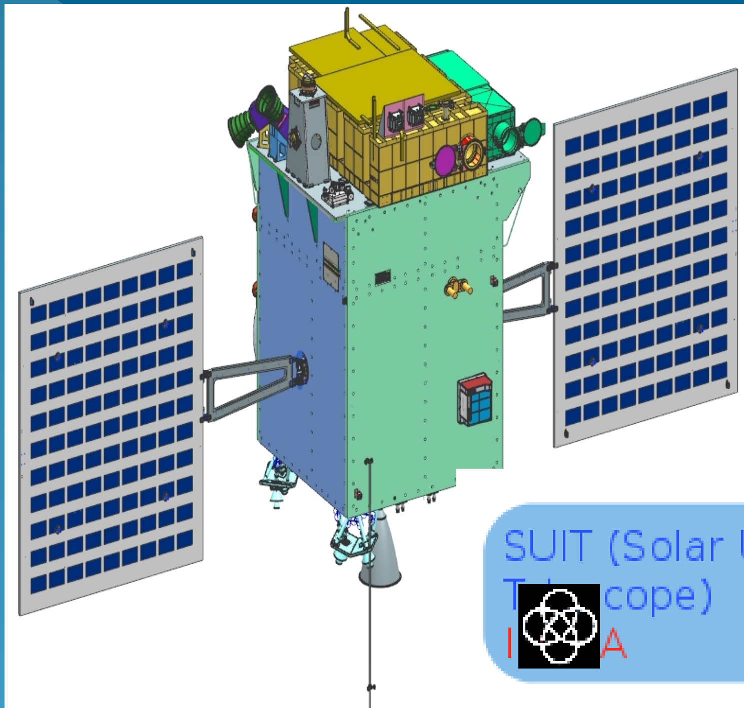
(b) Cross-talk between subgroups;

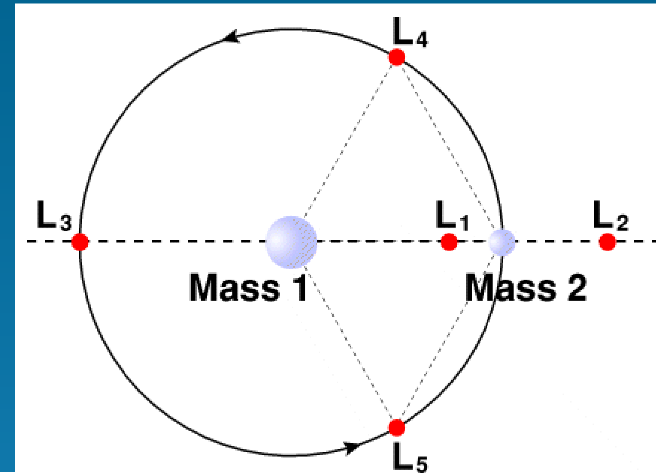
(c) Master Event list based on the objectives of all sub-groups;

(d) Solar-stellar connection as an additional project (s) [To make a bridge between Broomhall's group and stellar community.];

(e) Topical issue (lets say in Solar Physics) : All the papers can be published in a single volume and it will be a visibility to the ISSI-BJ Team.

Indian Aditya-L1 Space Mission (Time-Line: 2019)





Future

Synergy at the core scientific level with the ground (e.g., DKIST, NLST, EST, SST), and space (e.g., Solar Orbiter, IRIS, SDO)observatories lying in the same time-line.

SUIT (Solar Ultraviolet Imaging T cope)
I A

VELC (Visible Emission Line C onagraph)

SOLEXS (Soft X-ray Low rgy X-ray Spectrometer)
D - ISAC

HEL1OS (High Energy L1 ting X-ray Spectrometer)
D - ISAC

PAPA (Plasma Analyser oad For Aditya)
D - VSSC

ASPEX (Aditya Solar Wind cle Experiment)

netometer
D - LEOS

The University Of Sheffield.

northumbria UNIVERSITY NEWCASTLE

DYNAMIC SUN II. SOLAR MAGNETISM FROM INTERIOR TO THE CORONA

HOME | Scientific Programme | Registration & Accommodation | Participants | Venue & Transportation | SOC & LOC | About |