“Superflares on Solar-type Stars and Solar Flares, and Their Impacts on Exoplanets and the Earth.”

<Abstracts>

3/1(Tue)　Observation of Stellar Superflares and Solar White Light Flares

----

Author: Hiroyuki Maehara (NAOJ)

Title: Superflares and starspot activity on solar-type stars

Abstract:

“Superflares” are 10-10,000 times more energetic than the typical X10 class solar flares. Recent high-precision photometry from space enables us to investigate the nature of superflares on solar-type stars (G-type main sequence stars). We searched for superflares on solar-type stars using the Kepler 1-min and 30-min cadence data. We found 187 superflares on 23 stars from 1-min cadence data (Q0-17) and more than 1500 superflares on 279 stars from 30-min cadence data (Q0-6). The bolometric energy of detected superflares ranges from the order of 10^{32} erg to 10^{36} erg. Using these flare data, we found the occurrence frequency (dN/dE) of superflares as a function of flare energy (E) shows the power-law distribution with the power-law index of -1.5 for $10^{33}<E<10^{36}$. Most of superflare stars show quasi-periodic light variations with the amplitude of a few percent which suggest that superflare stars have large starspots. The bolometric energy released by flares is consistent with the magnetic energy stored near the starspots which is estimated from the amplitude of brightness variation.

Both the occurrence frequency of superflares and the fraction of stars showing superflares depend on the rotation period. They increase as the rotation period decreases. However, the energy of the largest flares observed in a given period bin does not show any clear correlation with the rotation period.

Author: Suzanne Hawley (University of Washington)

Title:　Observation of stellar flares

Abstract:

I will review our photometric and spectroscopic observations of stellar flares on low mass M dwarf stars. These observations illustrate many properties of the "white light continuum" during flares.　This observational background will be useful to understand the modeling of the optical spectrum that will be discussed in the following talk by Kowalski.　Also I will discuss some recent work on Kepler observations of both M dwarfs and solar-type stars, and in particular the apparent lack of connection between starspot size and location, and flaring activity.

Author: Adam Kowalski (NASA, GSFC)

Title: Modeling of the optical and NUV spectrum of stellar flares

Abstract:

The optical and near-ultraviolet (white-light) continuum emission is thought to originate from high densities at T~10^4 K, which are conditions in the flare atmosphere that are not easily produced by any standard heating mechanism. In this talk, I discuss the formation of the white-light continuum emission in recent 1D radiative-hydrodynamic models of dMe and solar flares. We present recent progress that we have made with high-flux nonthermal electron beams in reproducing the observed optical continuum color temperature of T~10^4 K and the Balmer jump properties in the near-ultraviolet. These high-flux electron beams produce dense, heated chromospheric condensations, which can explain the shape and strength of the continuum emission in dMe flares and the red-wing asymmetries observed in chromospheric emission lines in solar flares. Future modeling directions and the application of our modeling approach to superflares will also be discussed.

Author: Kyoko Watanabe (National Defense Academy of Japan)

Title: Solar white-light flares

Abstract:

In association with solar flares, we sometimes observe enhancements of visible continuum (white-light; WL) radiation. Such flares are mainly associated with energetic events, and they are still rarely observed. Because many observed events show a close correlation between the time profiles and locations of WL emission, and the hard X- rays and/or radio emission, there is some consensus that the origin of WL emission is due to accelerated particles, especially non-thermal electrons. Hinode/SOT has the capability of observing white-light flares (WLFs). From WLF observations by Hinode/SOT, we found that the power of the WL emission can be explained by greater than 40keV non-thermal electrons. Moreover, we also found that WL emission was emitted from the photosphere.

To understand the conditions that produce enhancements of WL in solar flares, we performed a statistical analysis of Hinode/SOT WL (G-band, Blue, Green and Red) and SDO/HMI (continuum) data. From the analysis of data obtained between 2011 and 2014, we found that the precipitation of large amounts of accelerated electrons into a compact area within a short time plays a key role in generating a WL event. And we also found that the coronal magnetic field strength in the flare region is one of the important factors that can distinguish between WL and non-WL (NWL) events.

Author: Takako T. ISHII (Kyoto University)

Title: White light flares observed at Hida Observatory

Abstract:

In 2011, Flare Imaging System in Continuum and H-alpha (FISCH) was installed on an 25 cm aperture telescope of the Solar Magnetic Activity Research Telescope (SMART) at Hida observatory of Kyoto University. The aim of this system is to diagnose the spatio-temporal evolution of high-energy particles in solar flares by capturing the explosive evolution of chromospheric and photospheric flare kernels. The system acquires flare images covering a field of view of 344 arcsec x 258 arcsec with a spatial sampling of 0.215 arcsec/pixel and a frame rate of 25 frames/s. From the first light on 2011-Aug-18, we observed 12 X-class flares including 5 white light flares with SMART/FISCH. In this talk, I will introduce white light flares observed with FISCH, especitally for X2.1 flare on 2011-Sep-06 and X2.7 flare on 2015-May-05.

Author: Kousuke Namekata (Kyoto University)

Title: Statistical properties of solar white-light flares

Abstract:

Many superflares are generally observed as white-light flares, so it is necessary to know the emission mechanism. We conducted a statistical research on solar white-light flares observed by SDO/HMI Continuum.

First we measured the magnetic field strength and scale of each flare region, using the data of SDO/HMI Magnetogram and AIA 94A. We compared these values with those estimated from GOES soft X-ray data by using the relation suggested by Shibata & Yokoyama (1999). Second, we examined several correlations between its properties (white-light flare energy, duration, GOES soft X-ray flux, and so on). As a result, we found the correlation between energy and duration of solar white-light flares is similar to that of stellar superflares. Moreover we also found the white-light flare energy is roughly proportional to GOES soft X-ray peak flux.

Author: Han-Yuan Chang (National Central University, Taiwan),

Yihan Song, Ali Luo, Li-Ching Huang, Wing-Huen Ip

Title: A LAMOST-Kepler spectrophotometric study of hyper flares of M dwarfs

Abstract:

M dwarfs are known to be magnetically active displaying impulsive energy release effects in terms of stellar flares. In DR1 of LAMOST (Large Sky Area Multi-Object Fibre Spectroscopic Telescope), 11032 M dwarfs are identified and 7179 of them have H alpha emission. The corresponding H alpha (emission) equivalent widths vary between 0.1 and 4.5 (Å). Four of these active M dwarfs have counterparts in the Kepler catalog (KID 2692708, KID 4731525, KID 5791720, KID 6436291). An analysis of their light curves shows that they all have flare activity with explosive energy (E_f) reaching > 0.5 % of the stellar luminosity (L*). One of them, KID 5791720, which EW ≈ 4.5 (Å), is characterized by hyper-flares with E_f comparable to L*. This LAMOST-Kepler spectrophotometric study thus suggests that hyper-flares could be a common phenomenon in M dwarfs. From DR3 we now have more than one hundred LAMOST spectra, an update will be given in this talk.

Author: Li-Ching Huang (National Central University, Taiwan)

Title: Physical Properties of G-type Kepler Eclipsing Binaries

Abstract:

In the 4-year observation (2009-2013), Kepler had observed 2,400 eclipsing binaries. According to Huber's work (2014), which revised the properties of 190,000 Kepler targets, there are 1,057 eclipsing binaries with G-type primary stars. Close binaries have been found to display superflare phenomenon, an interesting question is therefore about the corrsponding probability of flare occurrences. Of the eclipsing G-type binaries detected by Kepler, about 4.07% are with flares. What are the differences between the flaring and non-flaring EBs? To understand how the secondary stars trigger the superflare events, we would like to know the flare timing in their orbital periods, the types of the secondary stars, and the distances between the components in the binary systems. LAMOST has 83 good spectra of Kepler G- type eclipsing binaries until 2014. There are also about 5 binary systems show flare events in the Kepler light curves. Those spectra might help us to understand the spectral types and sizes of the secondary stars. Kepler light curves would help us to find the orbital periods and the distance between the two stars in a system. The light curves also tell us if the flare events are correlated with the position between two stars. This work might help us to know more about the superflare events in the exoplanet (especially Hot-Jupiter) systems.

3/2(Wed) Observation of Stellar Superflares and Spectroscopic Observations

---

Author: L. A. Balona (South African Astronomical Observatory)

Title: FLARE STARS ACROSS THE H-R DIAGRAM

Abstract:

Stars cooler than F5 have convective envelopes. Such stars develop surface magnetic fields due to dynamo action. This, in turn, allows starspots and flares to develop. On the other hand, magnetic fields are thought to be absent in stars hotter than F5 since they have radiative envelopes. Such stars should not have starspots nor flares. While this is our current perception, high-precision photometric observations of A and B stars from the Kepler satellite show light variations which can only be interpreted as starspots. Furthermore, flares are seen in many A stars which cannot originate in a cool companion. In this talk I present a summary of magnetic fields, spots and flares on stars across the H-R diagram and show that our current understanding needs to be modified. Furthermore, I argue that far from being an attribute of mostly K and M dwarfs, flare stars are a common property of all stars across the H-R diagram. Using short-cadence data from Kepler, I present various properties of flares seen in both cool and hot stars and some ideas on how magnetic fields can be generated in stars with radiative envelopes.

Author: Nakariakov, V.M. (University of Warwick)

Title: Oscillations of stellar flares

Abstract:

Quasi-periodic pulsations (QPP) with the periods ranging from a fraction of a second to several tens of minutes are often detected in thermal and non-thermal emission produced in solar flares. Physical mechanisms for QPP can be divided in two groups: related to magnetohydrodynamic (MHD) oscillations and quasi-periodic regimes of magnetic reconnection ("magnetic dripping"). QPP are also detected in light curves of stellar superflares. We analysed 3106 flares on 216 different stars, detected with Kepler in the short-cadence data. 56 flares are found to have pronounced QPP-like signatures in the light curve, of which 11 show evidence of stable decaying oscillations. No correlation is found between the QPP period and the stellar temperature, radius, rotation period and surface gravity, suggesting that the QPPs are independent of global stellar parameters, and hence are the result of processes occurring in the local environment. There is also no significant correlation between the QPP period and flare energy. The QPP decay time is found to scale linearly with the QPP period.

Also, an example with a clear presence of two significant periodic patterns was found. The results obtained indicate that QPP in stellar flares are likely to be produced by local MHD oscillations, and hence are likely to be similar cooperating in at least some of solar flares.

Author: Yuta Notsu (Kyoto University)

Title: Spectroscopic observations of solar-type superflare stars

Abstract:

Solar-type superflare stars found from Kepler data show quasi-periodic brightness variations withthe typical period of from one to a few tens of days.Such variations are thought to be caused by the rotation of the star with large starspots.However, spectroscopic observations are needed in order to confirm whether the variation is really due to the rotation and whether superflares can occur on ordinary single stars similar to our Sun.

We have carried out spectroscopic observations for 50 solar-type superflare stars with Subaru/HDS. As a result, more than half (34 stars) of the target stars show no evidence of the binary system, and we confirmed stellar atmospheric parameters of these stars are roughly in the range of solar-type stars on the basis of our spectroscopic data.

We then conducted the detailed analyses for these 34 stars. First, the value of the "v sin i" (projected rotational velocity) measured from spectroscopic results is consistent with the rotational velocity estimated from the brightness variation. Second, there is a correlation between the amplitude of the brightness variation and the intensity of Ca II IR triplet line. All the targets expected to have large starspots because of their large amplitude of the brightness variation show high chromospheric activities compared to the Sun. These support that the brightness variation discussed above is explained by the rotation of a star with large starspots.(ref: Notsu et al. 2015a&2015b PASJ)

In addition, in this talk I also quickly discuss the results of Lithium (Li) abundance analyses of superflare stars, on the basis of the above spectroscopic data. Li is a key element to understand the evolution of the stellar convection zone, which reflects the age of solar-type stars. (ref: Honda et al. 2015 PASJ)

Author: Satoshi Honda (University of Hyogo)

Title: Spectroscopic observations of flare star EV Lac at NHAO

Abstract:

It is known that the EV Lac is one of the M-dwarf flare stars. In 2008, Swift satellite detected the superflare in this star. This star will be a good target for investigations of the stellar flare. We have carried out the monitor of the Halpha line by Nayuta/MALLS at Nishi-Harima Astronomical Observatory from Aug.to Nov.in 2015. I will introduce the obtained medium-dispersion spectra and discuss the asymmetry of the line profile.

Author: Yoichi Takeda (NAOJ)

Title: Activities and related properties of solar-type stars

Abstract:

Observational charactristics and statistical trends of various activity indicators along with the related properties (e.g., rotation, age, Li abundance, ...) for FGK-type main-sequece stars (especially solar-analog G dwarfs) are reviewed in comparison with the Sun. I would also discuss the traditional problems such as "Can we find any perfect solar twin?" or "Is our Sun typical or peculiar among solar analogs?"

Author: Steven Saar (Harvard-Smithsonian Center for Astrophysics)

Title: Observations of Magnetic Cycles in Late-type Single Dwarfs: What are They Telling Us?

Abstract:

I present a fresh analysis of (apparent) magnetic cycles in single dwarf stars, using an updated sample of data drawn from the literature. I stress why stars must be carefully vetted to be bona-fide single (or effectively so) and unevolved dwarfs in order not to muddy the sample and confuse the results. With the new sample, I study a subset of high quality detections for correlations with stellar physical and activity-related properties, and speculate about what it all may mean.

Authors: Mark Cheung (LMSAL), Marc DeRosa (LMSAL) , Sandra Jeffers (U. Goettingen) & Benjamin Beeck (MPI for Solar System Research, U. Goettingen)

Title: Evolving Models of Stellar Photospheric and Coronal Magnetic Fields

Abstract:

I will describe a new project to investigate photospheric and coronal magnetic fields of stars. In this project, we run a series of surface flux transport (SFT) models of starspot evolution. SFT models are used as lower boundary conditions to drive evolving models of stellar coronal magnetic fields. The coronal magnetic fields are modeled by magnetofriction (MF), which allows us to construct force-free coronal fields evolving in response to starspot evolution. The combined SFT/MF simulations are used to synthesize dynamic Stokes spectra to serve as inputs for Zeeman Doppler Imaging (ZDI) inversions. Photometric light curves modulated by starspot evolution and stellar rotation are also synthesized. The aims are to test the validity of inversions, and to examine the correspondence between inferred stellar magnetic properties with the input SFT parameters governing flux emergence, differential rotation and turbulent dispersal. This project is part the Solar-Stellar Connection Focus Science Team funded by NASA's Living With A Star program.

3/3(Thu) Possibility of superflares on the Sun

Author: Kazunari Shibata (Kwasan and Hida Observatories, Kyoto University)

Title: Can Superflares Occur on Our Sun?

Abstract:

I will mainly introduce the results of the paper by Shibata et al. (2013, PASJ , 65, 49). Namely, we examine whether superflares with energy of 10^{33}–10^{35} erg could occur on the present Sun through the use of simple order-of-magnitude estimates based on current ideas related to the mechanisms of the solar dynamo. If magnetic flux is generated by differential rotation at the base of the convection zone, as assumed in typical dynamo models, it is possible that the present Sun would generate a large sunspot with a total magnetic flux of ~ 2 x 10^{23} Mx (= G cm^2) within one solar cycle period, and lead to superflares with an energy of 10^{34} erg. To store a total magnetic flux of ~ 10^{24} Mx, necessary for generating 10^{35} erg superflares, it would take ~ 40 yr. Hot Jupiters have often been argued to be a necessary ingredient for the generation of superflares, but we found that they do not play any essential role in the generation of magnetic flux in the star itself, if we consider only the magnetic interaction between the star and the hot Jupiter. This seems to be consistent with Maehara et al.'s finding of 148 superflare-generating solar-type stars that do not have a hot Jupiter-like companion. Altogether, our simple calculations, combined with Maehara et al.'s analysis of superflares on Sun-like stars, show that there is a possibility that superflares of 10^{34} erg would occur once in 800 yr on our present Sun.

Author: Hideyuki Hotta (Chiba University)

Title: Current understanding of solar global scale magnetic field and dynamo

Abstract:

Recent advances on the solar dynamo theory using numerical calculation is reviewed. The sun has sunspots and the number of the sunspots has 11-year cycle. The solar magnetic cycle is thought to be maintained by differential rotation and helical turbulence. Since the turbulent thermal convection is a highly non-linear phenomenon, numerical approaches have importance role on the research. In the presentation, I mainly focus on the mechanism that makes large-scale coherent magnetic field from turbulent small-scale convection. In the final part, I discuss the influence of super flare sunspot on the solar cycle.

Author: Hisashi Hayakawa, Harufumi Tamazawa, Akito D Kawamura (Kyoto Univeristy)

Title: World-Wide Records of Solar Flare Candidates in the 10th century and the 18th century

Abstract:

Recent studies indicate a possibility for the sun to cause extreme space weathers such as super flares. Surveys on isotopes in tree-rings or ice cores discover possible extreme space weathers in 775 and 994. In the same time, solar activity would be traceable by records of auroras as a indirect proxy, and sunspots as a direct proxy in historical documents. While carrying out the survey on the historical documents, we found world-wide simultaneous observations of auroras in 994 and 1770. In such cases, we found records of not only red auroras but also white auroras which are usually not observed at low-latitude. This finding is potentially important to understand the impact on the Earth under a super flare.

3/4(Fri) Planets (AM) & Future Plans (PM)

Author: Masashi Omiya (NAOJ)

Title: Observations of exoplanets and stellar activity

Abstract:

Stellar activity gives large noises on searches for Earth-like exoplanets around late-type stars because it adds mimic variations of planetary signals to observations for exoplanet searches using indirect methods. To cancel the noises caused by the stellar activity (rotational modulation, pulsation, magnetic cycle), it is necessary to exclude active stars from sample of the searches, and trace the activity by monitoring observations of activity indicators, such as chromospheric lines (H alpha, Ca II HK etc.) and spectral line shapes. I'd like to talk about effects of the stellar activity on the searches and other exoplanet observations, and discuss stellar surface diagnostics for InfraRed Doppler (IRD) planet searches to look for Earth-like planets.

Author:Takuya Takahashi (Kyoto University)

Title: CMEs of solar superflares

Abstract:

Recent discovery of many super flares on Sun-like stars (Maehara et al. 2012) attracted solar and stellar researchers to the question 'Can our Sun produce super flares?'.On the other hand, more practical questions arise, that is, 'How extreme will the space weather storms become when solar super flares occur?'.One of the key to answer the latter question is the mechanism that determine the physical quantities of CMEs associated with solar super flares. For example, strong shock waves formed at the nose of super fast CMEs propagating in the interstellar medium will result in extreme increase of high energy proton flux in space. Intense westward electric field caused by fast CME passage at the earth with its strong magnetic field with result in extreme geomagnetic storm. In our talk, we will introduce some scaling laws connecting important physical quantities (such as magnetic field strength, density, velocity) of CMEs and flare size (namely, sunspot length scale) based on studies of solar flares, and discuss the application of these scaling relations to solar proton events and geomagnetic storms caused by solar super flares.

Author: Daisaku Nogami (Kyoto University)

Title: Kyoto 3.8m telescope and future plans of our superflare studies

Abstract:

We, department of astronomy and Kwasan and Hida observatories are carrying forward the 3.8m telescope project. This telescope is placed at Okayama, Japan, and will be one of the largest telesocpes in Asia. The half of the telescope time will be assigned for Kyoto University, and the other half will be assigned for jouint use. I will make a general introduction of thie telescope project, especially new technologies developed for this telescope, the plan of instrument, and scientific aims. I will also talk about the plans of our superflare studies utilising our long telescope time, and the optical high dispersion spectrograph.

Discussions ~Future plans of superflare studies~

(Moderators: Daisaku Nogami and Kazunari Shibata)

Short comments & Topics

- -Daisaku Nogami: Future plans of our superflare studies
- -Hiroyuki Ishikawa: Comment on the habitability of M-type stars
- -Fumihide Iwamuro: Short comment on spectrograph of Kyoto 3.8m telescope
- -Bun'ei Sato: Comment on spectroscopic observations with Kyoto 3.8m telescope (Introduction of TESS)

-Possibility of International Collaboration

Short comments (~5 min) are welcome.

Short comments : Impacts of superflares on the planets around M-type stars

Author: Hiroyuki Ishikawa

Abstract

Main sequence M-type stars are often regarded as the primary targets in the search for habitable planets because of their abundance, their long life, and the high detectability of planets in their habitable zones close to the star. However, M-type stars often have high chromospheric activity, which can be detrimental to life or detection of life. The high-energy radiation and charged particles produced by large flares and proton events would lead to the destruction of ozone in the atmosphere. Ozone is the important molecule that protects life on the Earth and is the promising biosignature of exoplanets. Segura et al. (2010) studied about the impact of flares on the atmosphere of planets around M-type stars. They concluded that large flare is not necessarily direct hazard to life. However, they did not take into account the high frequency of the flare production for M-type stars. We estimated the effects of multi flares to the planets using the frequency distribution proposed by Superflare Group in Kyoto University. We found that ozone must be destructed constantly so that it could not exist in the atmosphere on the planets in the habitable zones of M-type stars. We also discussed the impacts on the planetary atmosphere around Sun-like stars.
