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Detection of Jovian decametric radiation by using a short baseline interferometer system

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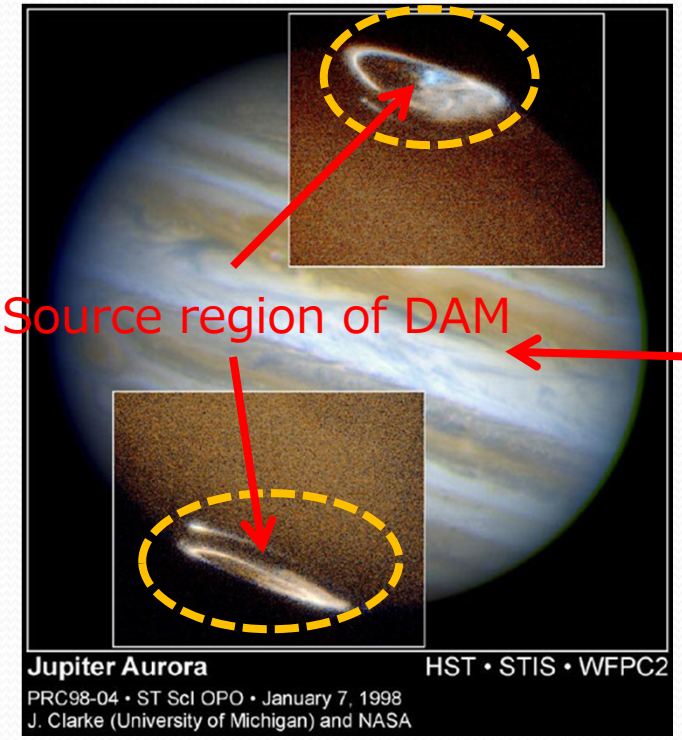
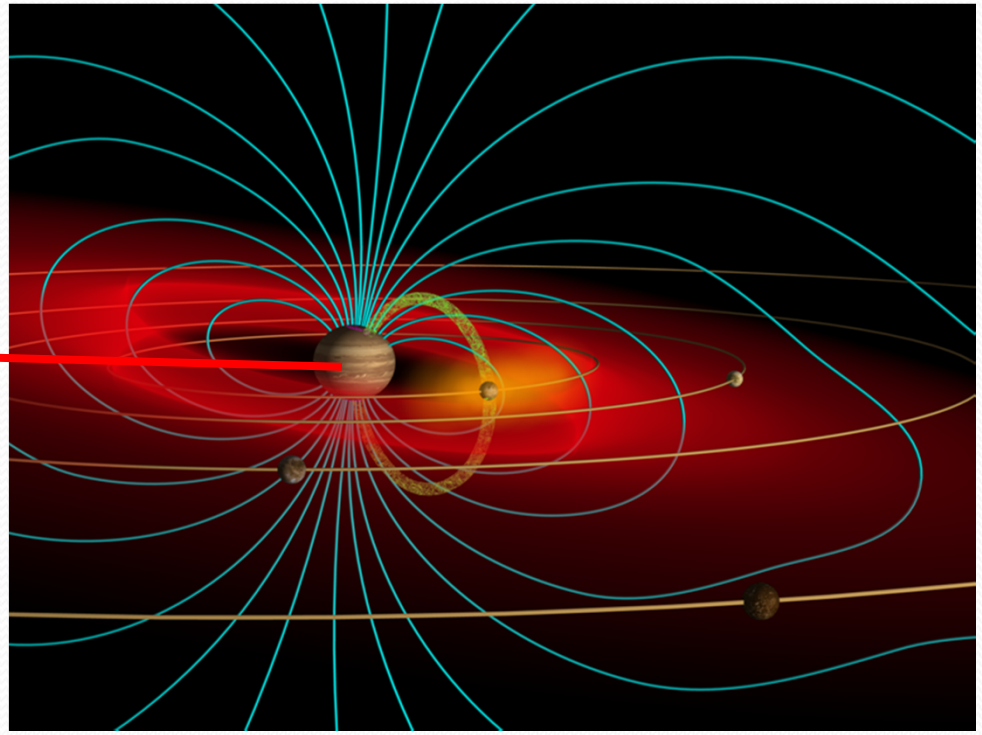
Jovian decametric radiation (DAM)

Jovian aurora



Jovian magnetosphere



- ✓ Source region : auroral region
- ✓ Energy source : Jovian rotational energy, solar wind

One of important indexes for

(i) monitoring the activity of Jovian magnetosphere

(ii) studying the response of Jovian magnetosphere to solar wind

Jovian decametric radiation (DAM)

Activity of Jovian magnetosphere

- ✓ interaction between Jupiter and satellites
- ✓ effect of Io's volcano
- ✓ effect of shoemaker-Levy cometary impact [Oya et al (1997)]

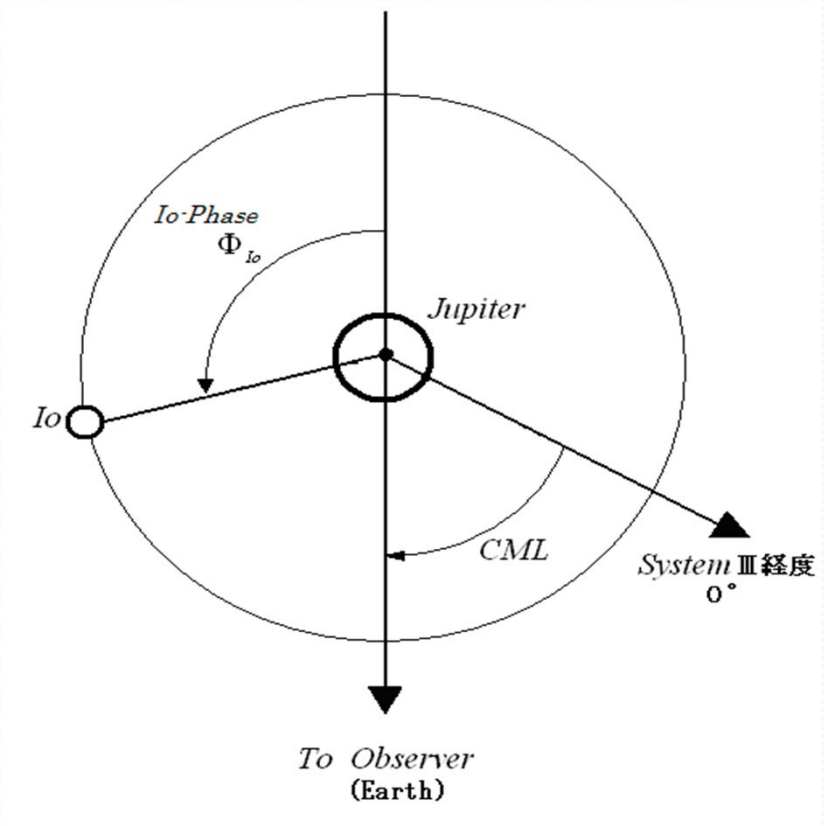
Response of Jovian magnetosphere to solar wind

- ✓ relation between non-Io components and solar wind

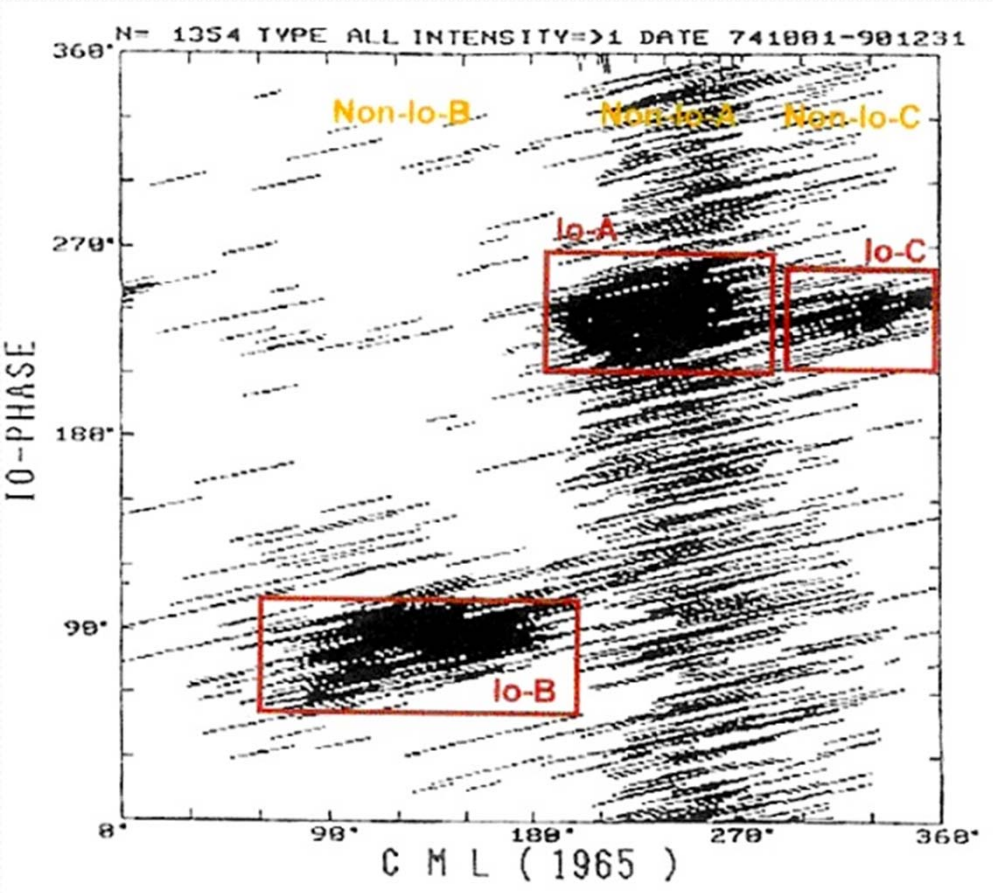
  ⇒ very quick response ? [Morioka et al (2002), Echer et al (2010)]

Very important to judge correctly whether DAM was emitted from Jupiter

Occurrence probability of DAM



Definition of Io phase and CML

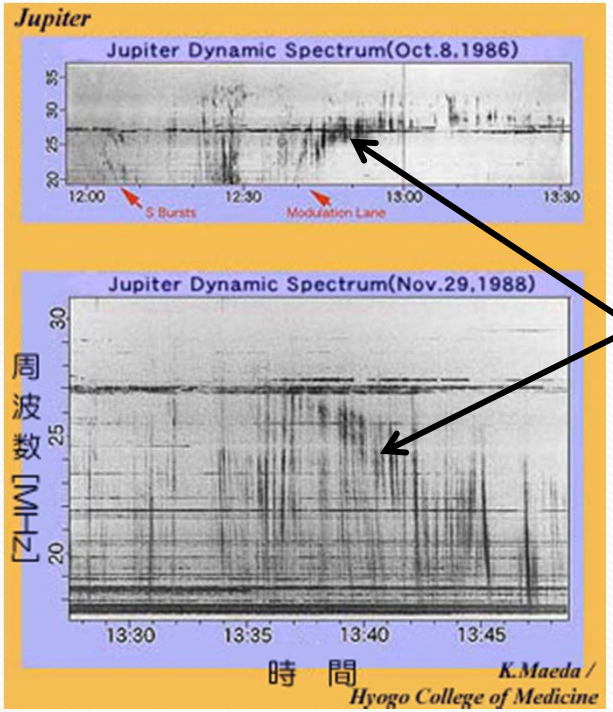


CML- Io phase diagram

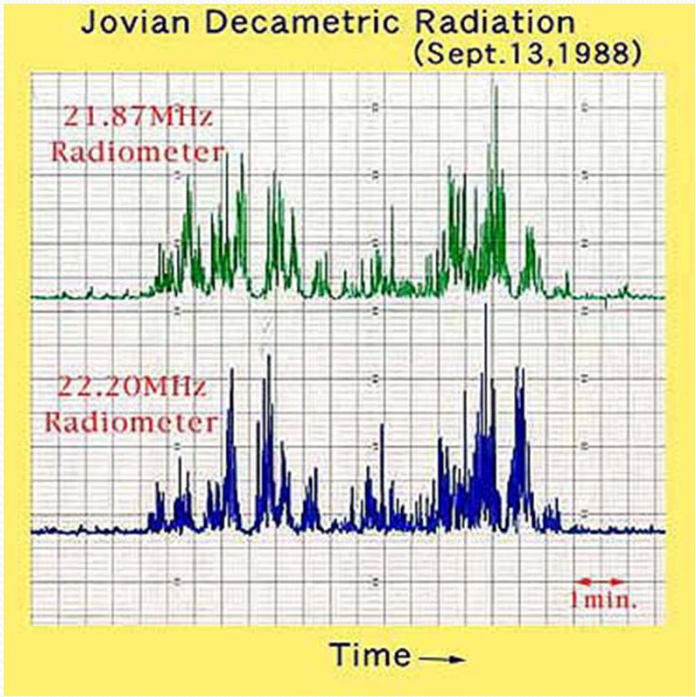
Problem of conventional detection method

Wideband dynamic spectrum

Intensity measurement at fixed frequencies



Arc structure



http://quasar.cc.osaka-kyoiku.ac.jp/~fukue/lecture/cosmo/solar/jupiter_r/jupiter2.htm

- ✓ Basis of judgment is "morphology".
- ✓ Reliable in the case of strong emission
- ✓ Less reliable in the case of weak emission

⇒ Subjective view influences the judgment.

Purpose of this study

Establishment of more objective detection method for weak DAM

Goal

- ✓ relation between non-Io components and solar wind
- ✓ interaction between Jupiter and satellites
- ✓ effect of Io's volcano

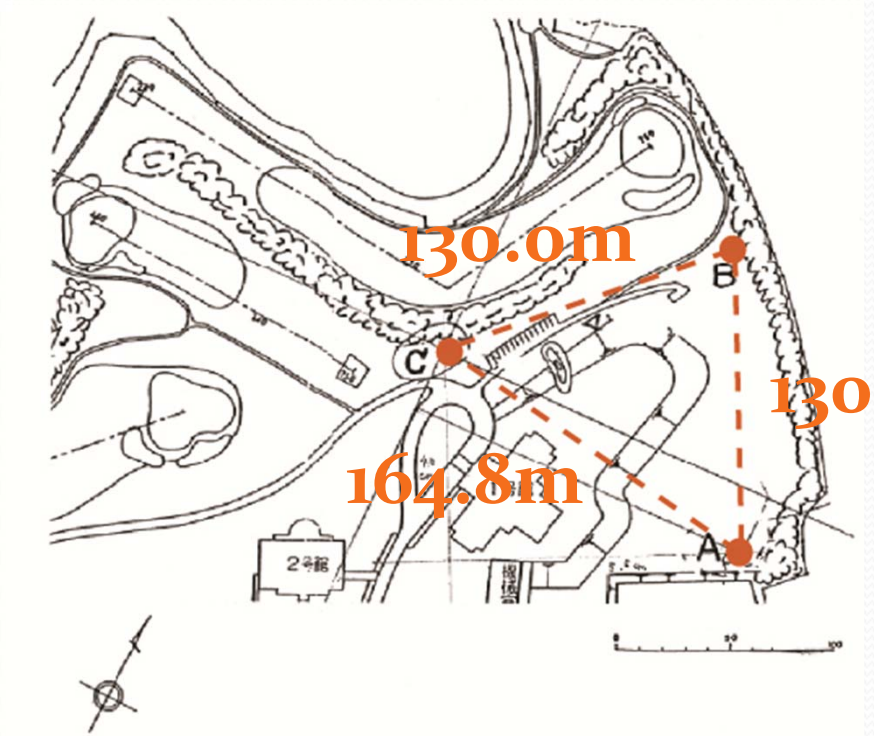
What we performed in this study

- ✓ Observation of DAM by using a short baseline interferometer from 2007 to 2010
- ✓ Trial for detection of weak DAM by fringe correlation method
- ✓ Comparison with

(i) conventional CML-Io phase diagram,
(ii) solar wind data by WIND satellite,
(iii) the result by Nancay observatory.

Observation

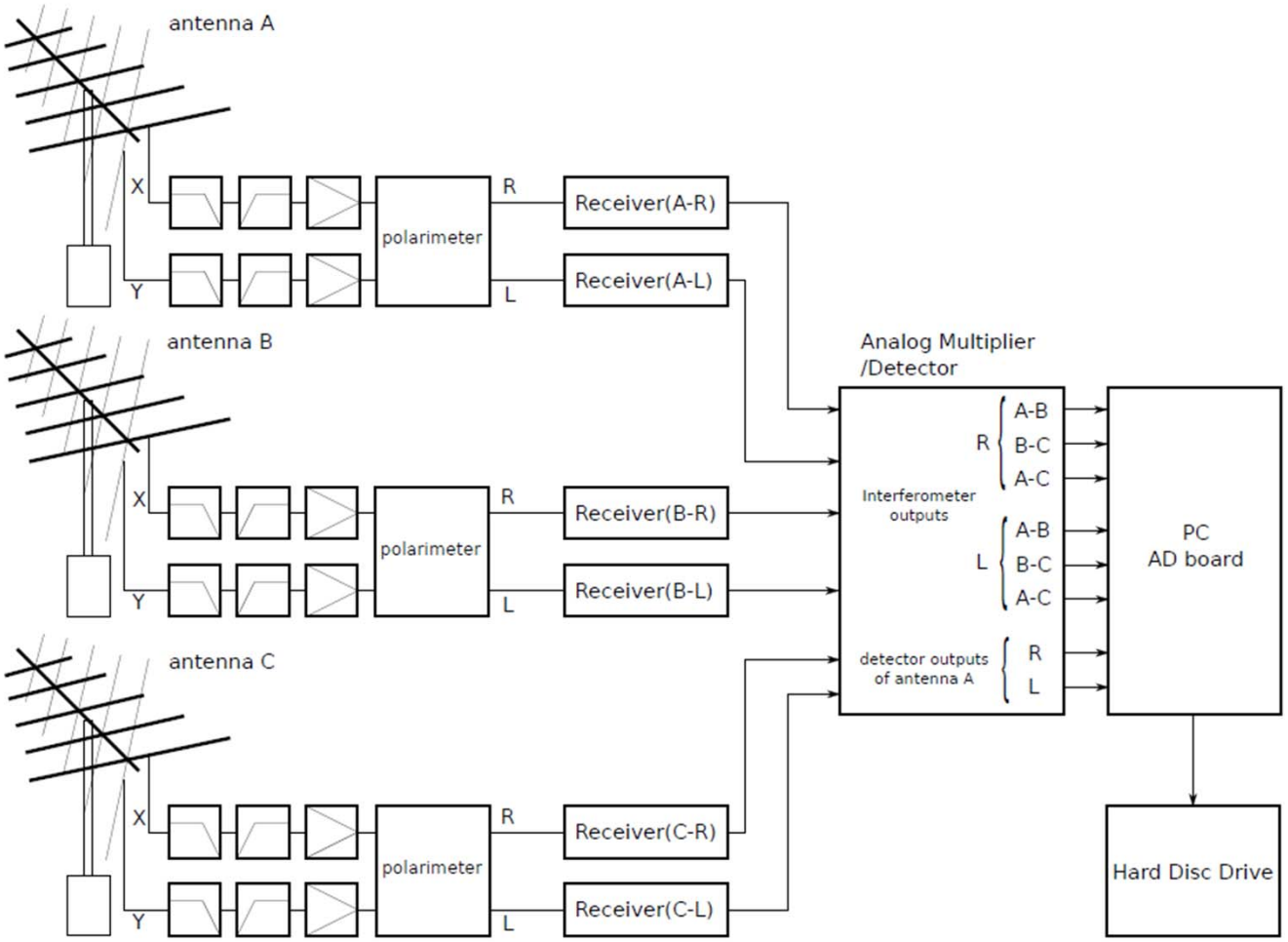
Short baseline interferometer system in Fukui University of Technology



Awara campus at Fukui Univ. of Tech.

Block diagram of observation system

- ✓ 6 fringe waveforms are outputted by analog multiplier.
- ✓ The fringe waveforms are digitized with 5 Hz sampling frequency.



Observation condition

year	2007	2008	2009	2010
observing period	03/02-09/04	02/24-10/18	03/23-11/29	03/27-10/07
total observation time [hours]	552	702	808	628
opposition date	06/02	07/12	08/17	09/23
sunspot number [1/day]	7.1	3.1	2.9	15.2
DE [°]	−2.9	−1.5	0.4	2.2
maximum elevation [°]	29	31	39	52
H.A. from galactic center [hour]	-1	+1	+4	+6

Detection of weak DAM by fringe correlation method

Fringe correlation method [Oya and Iizima, 2003]

Correlation between observational and theoretical fringes

Observational fringe　　Theoretical fringe

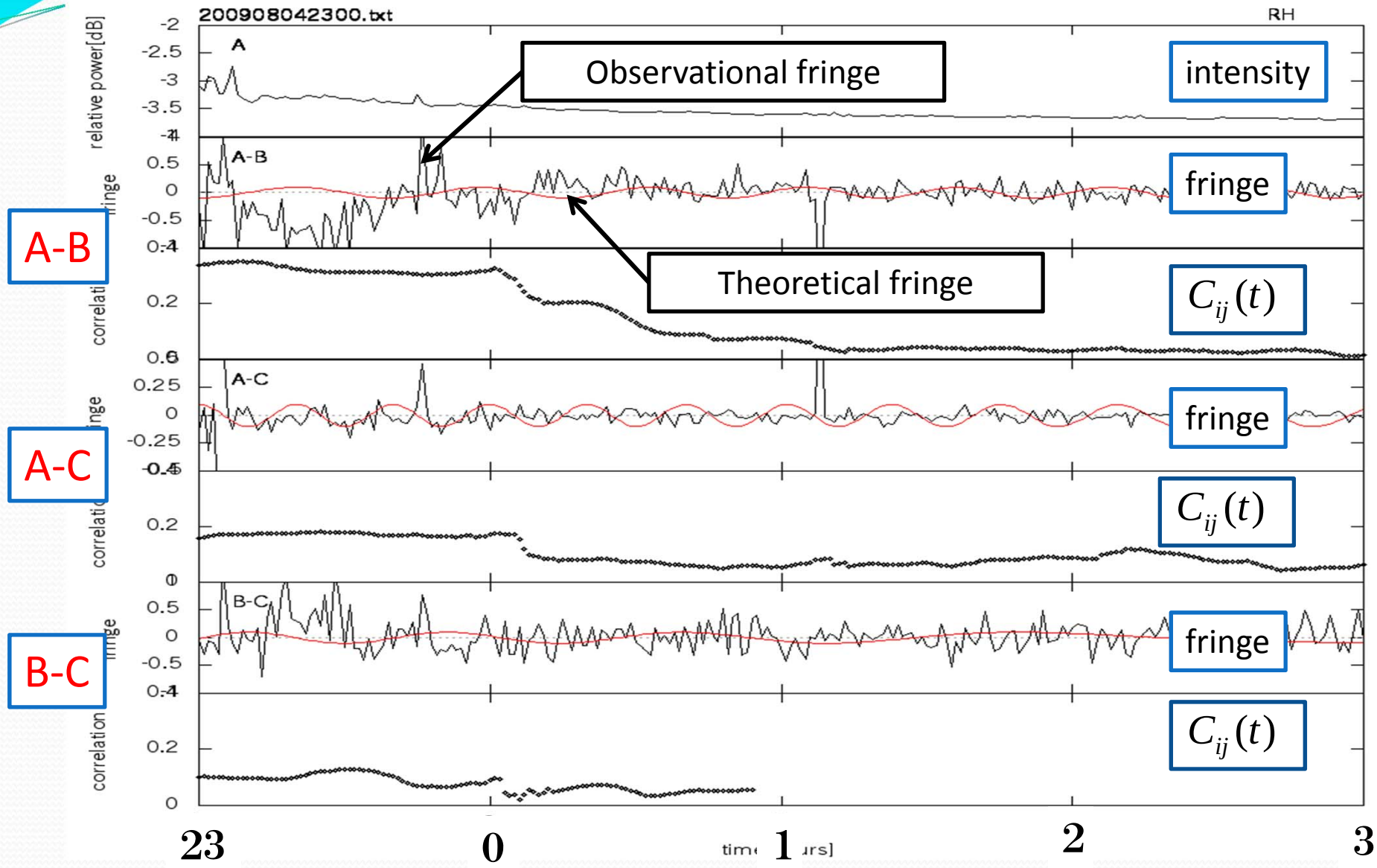
$$C_{ij}(t) = \left| \frac{\left\langle F_{ij}^{obs}(t) F_{ij}^{theory}(t) \right\rangle}{\sqrt{\left\langle \left(F_{ij}^{obs}(t)\right)^2 \right\rangle} \sqrt{\left\langle \left(F_{ij}^{theory}(t)\right)^2 \right\rangle}} \right|$$

i, j : indexes for antenna
<> : time integration

Caution in this study

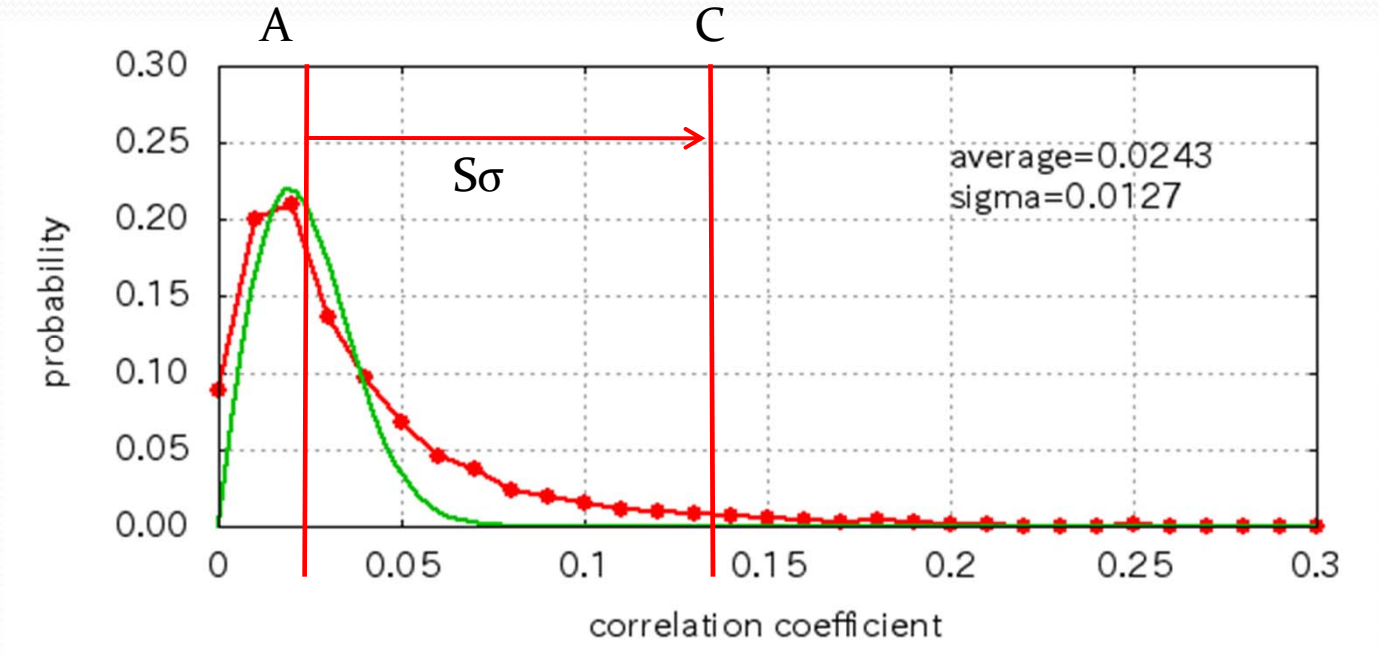
- ✓ Integration time (= 2 hours) seems to be too long.
- ✓ We can detect only long duration DAM.

An example of analysis result



How to set the threshold value

Example of Probability distribution of correlation coefficients (2010, A-B)



- Red line : observational result
- Green line : fitting result (Raileigh distribution)

$$S = \frac{C - A}{\sigma}$$

- C：correlation coefficient
- A：average of distribution
- σ：standard deviation

Criteria for judging the occurrence of DAM

✓ We used only the data obtained
(i) at night (from 19:00 to 6:00),
(ii) under the condition that elevation of Jupiter is more than 10 deg,
(iii) under the condition that fringe period is less than 60 min.

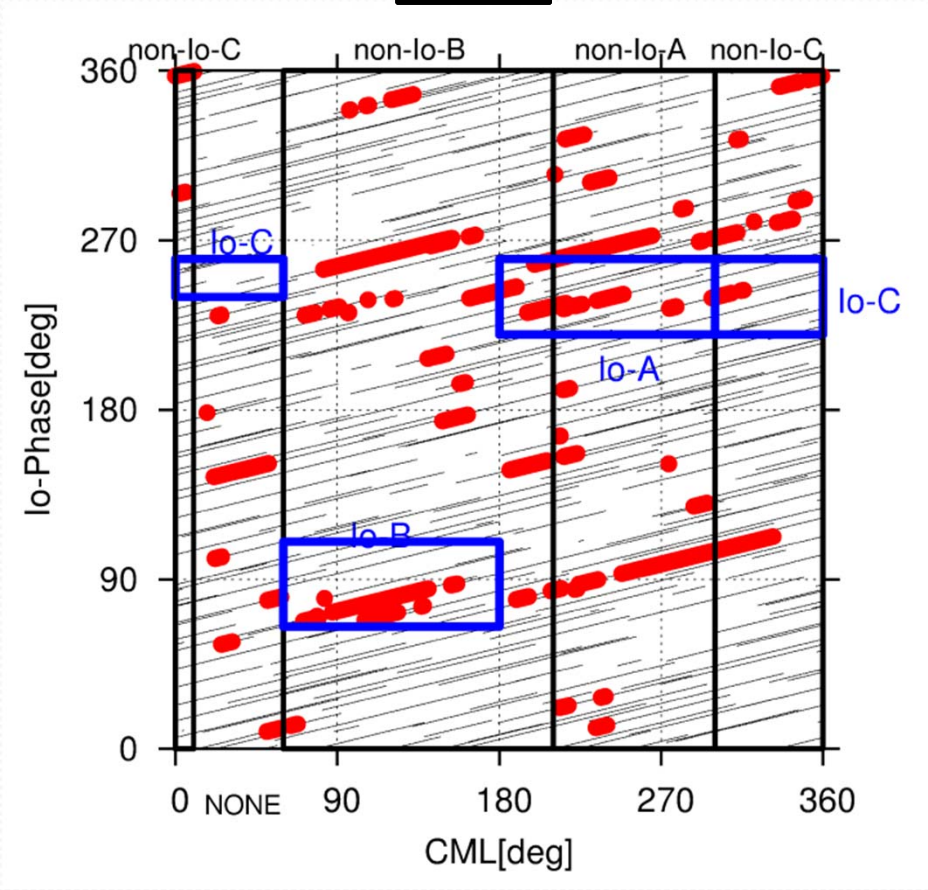
✓ We judged the received signals as DAM when all the coefficients exceed the given threshold value.

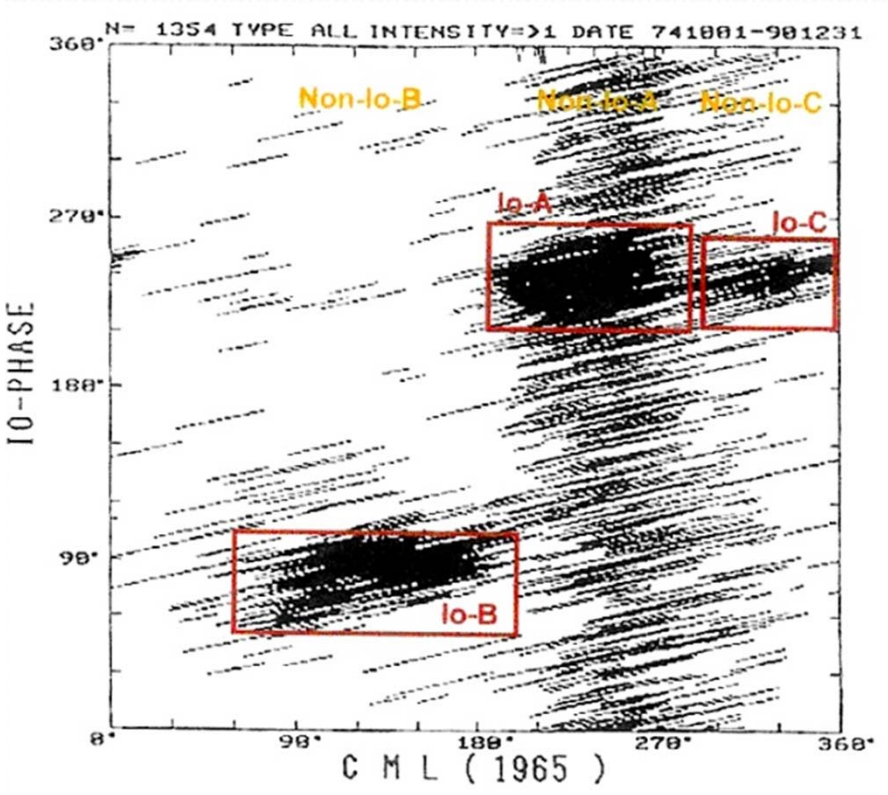
✓ In the case that fringe period of a baseline exceeds 60 min
we judged the received signals as DAM in the case that other 2 fringe periods exceed the given threshold value.

Validity of the fringe correlation method

Comparison with the conventional CML-Io phase diagram

S=4

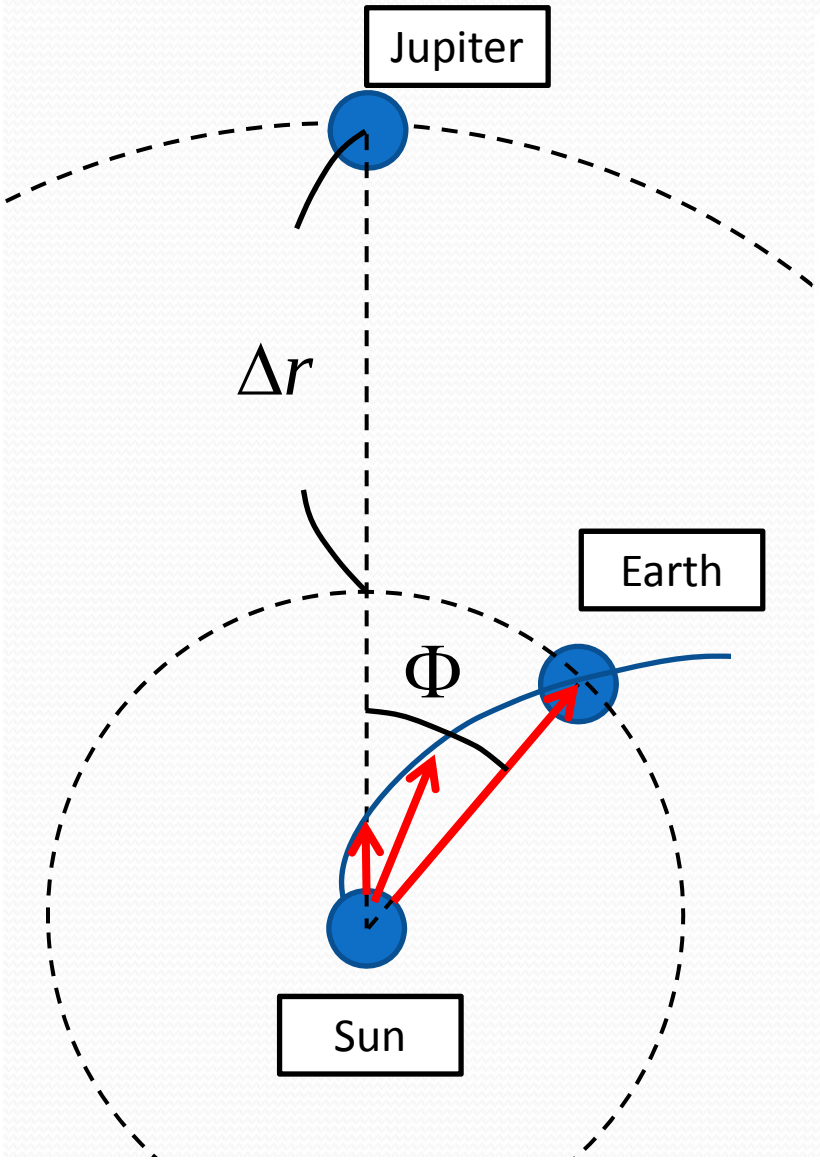




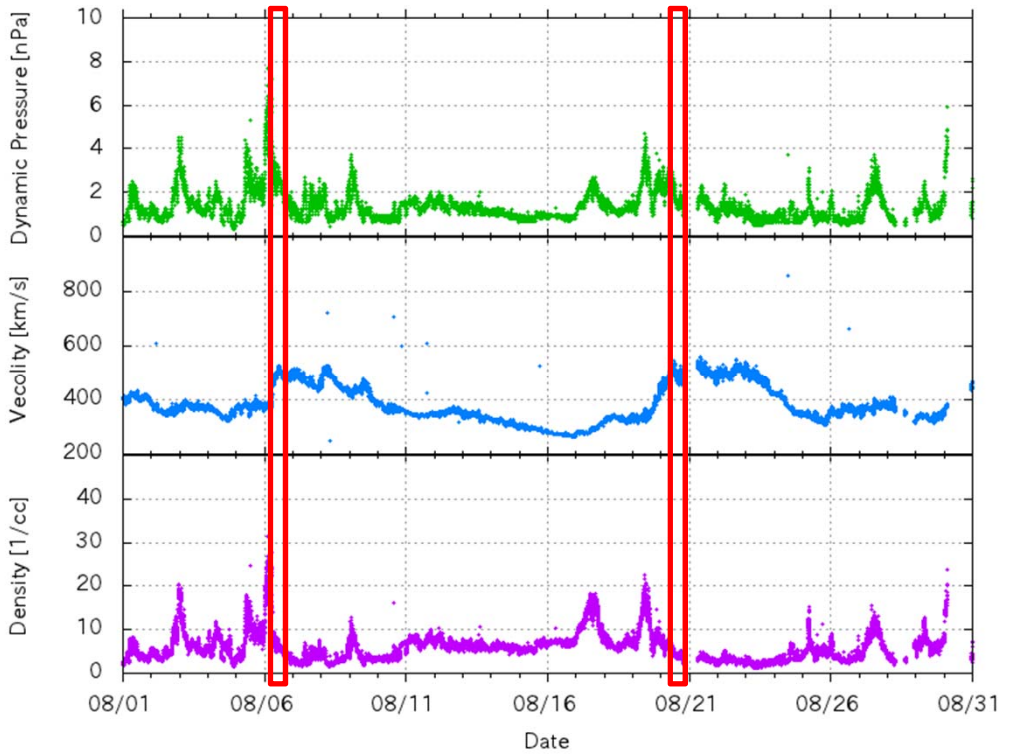
Both are well alike.

Comparison with solar wind data by WIND spacecraft

Estimation of arrival date of shock structure in solar wind



Example of WIND data

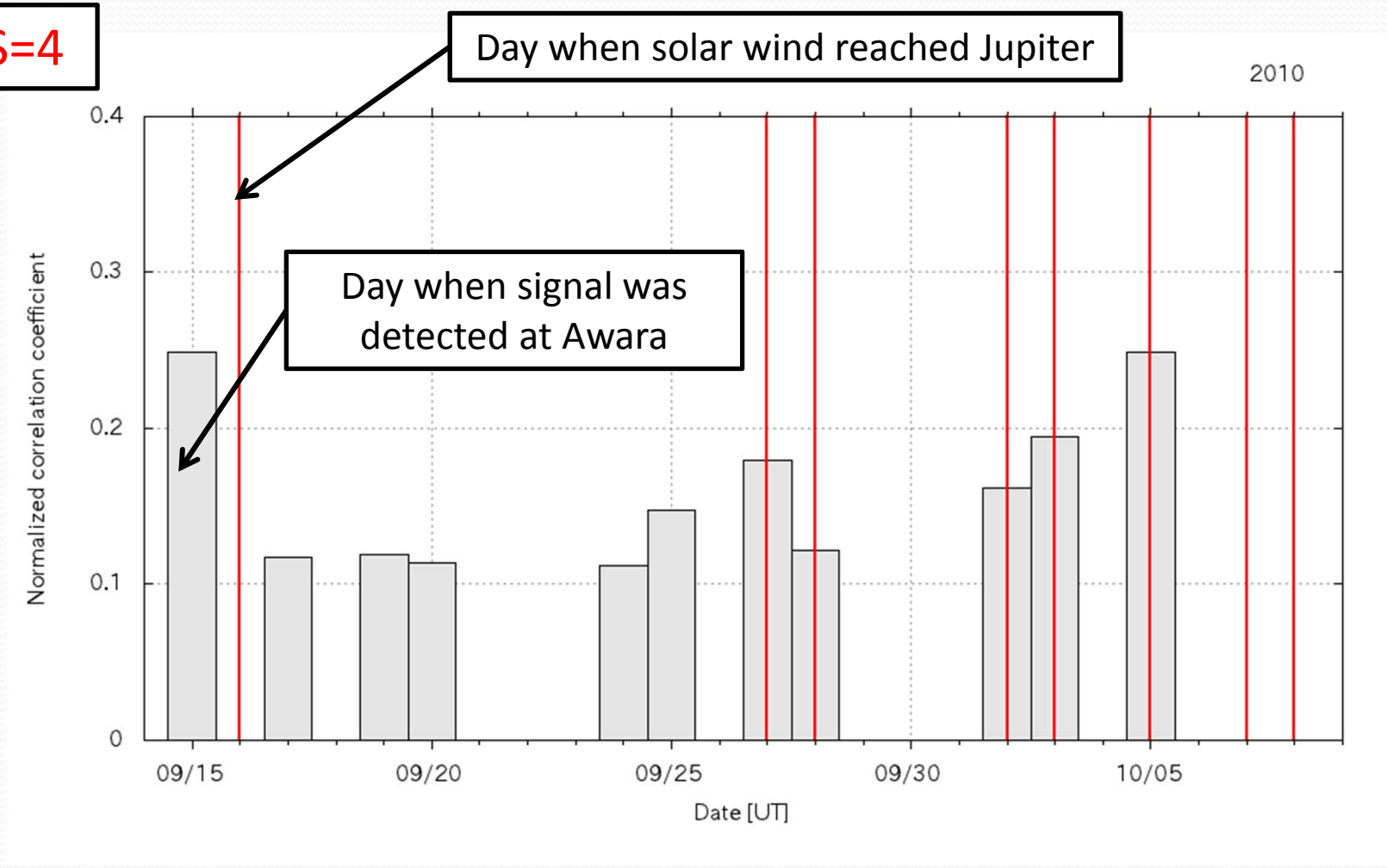


$$t_J = t_E + \frac{\Delta r}{V_{SW}} + \frac{\Phi}{\Omega_{sun}}$$

Comparison with solar wind data by WIND spacecraft

2010, within 1 month before and after the opposition

S=4

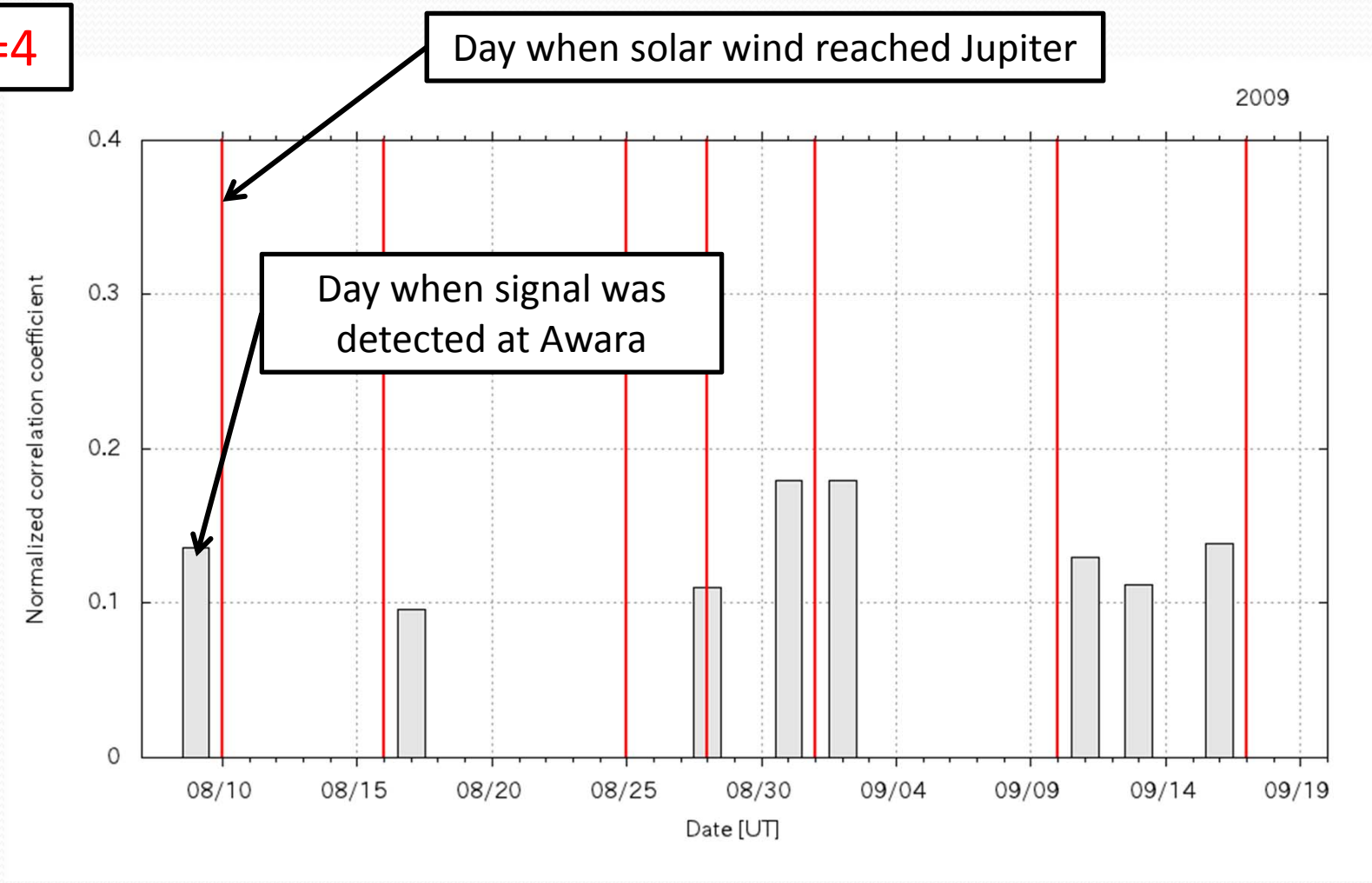


Both are mostly in agreement.

Comparison with solar wind data by WIND spacecraft

2009, within 1 month before and after the opposition

S=4

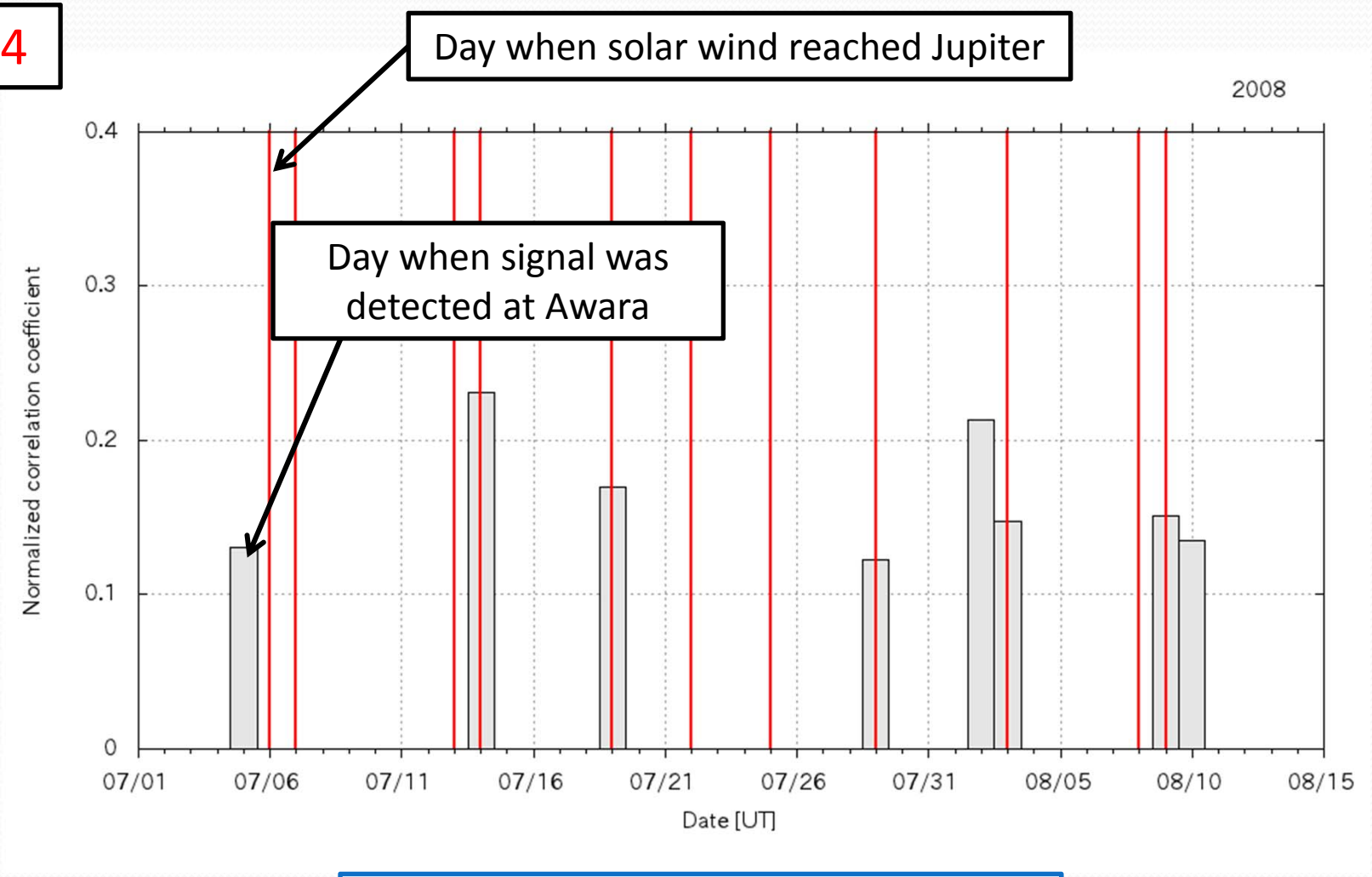


Both are mostly in agreement.

Comparison with solar wind data by WIND spacecraft

2008, within 1 month before and after the opposition

S=4

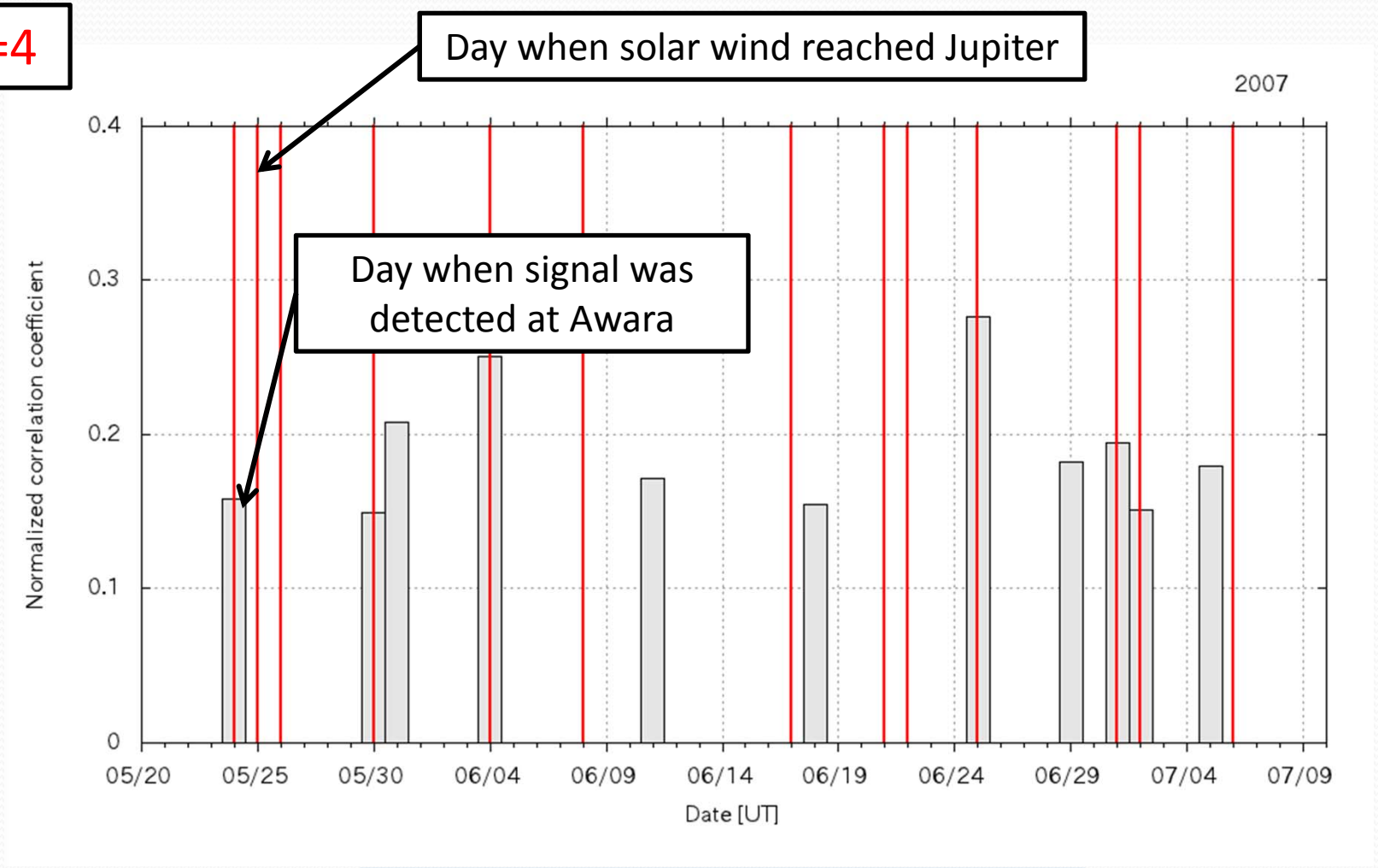


Both are mostly in agreement.

Comparison with solar wind data by WIND spacecraft

2007, within 1 month before and after the opposition

S=4

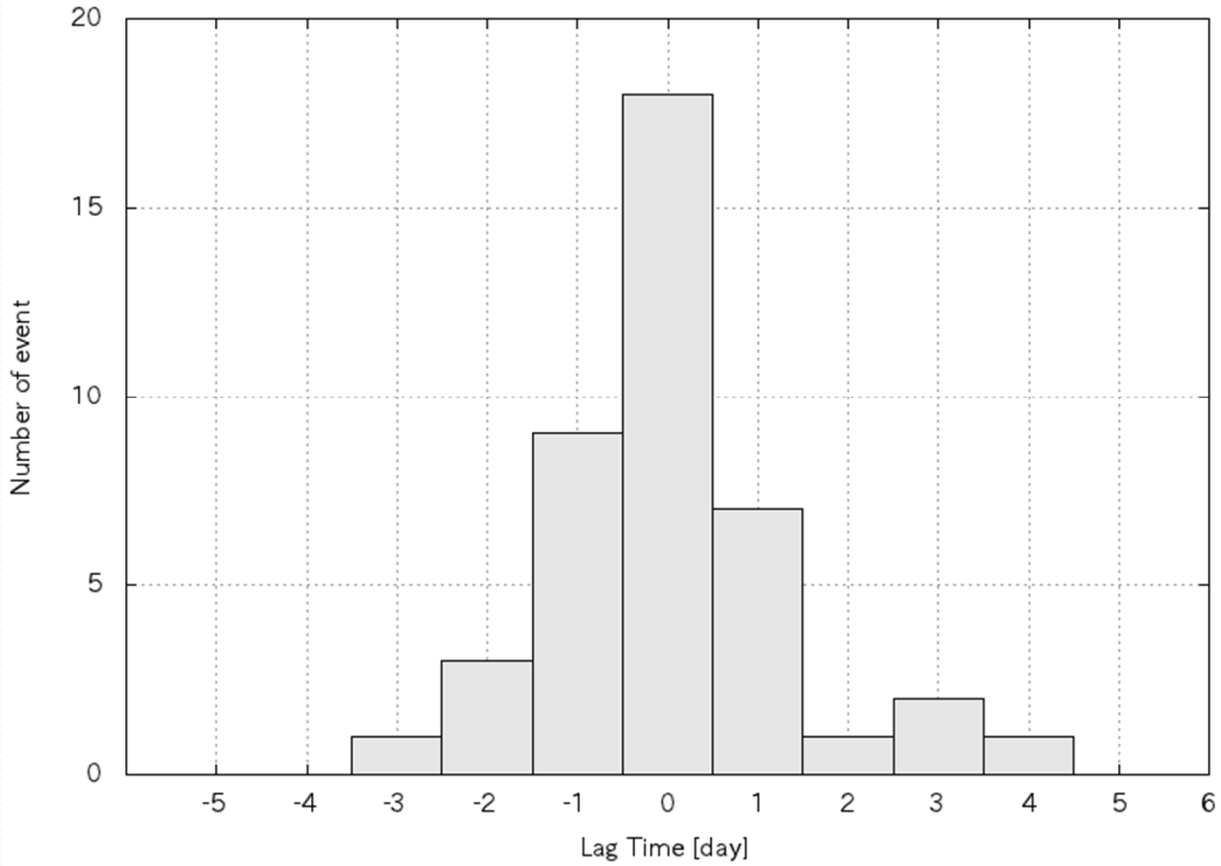


Both are mostly in agreement.

Comparison with solar wind data by WIND spacecraft

Detection day on the basis of arrival date of solar wind

2007-2010, within 1 month before and after the opposition



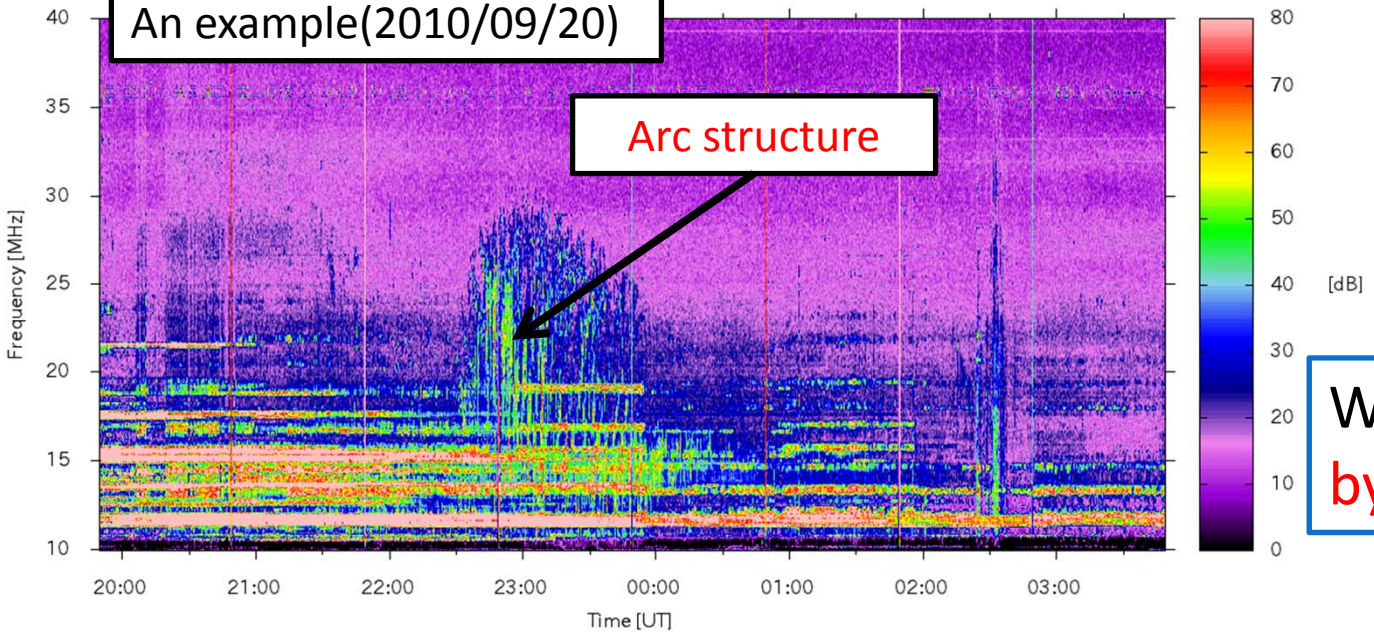
80% of signals are detected within one day
before or after the day when a solar wind arrives at Jupiter.

Comparison with the result by Nancay observatory

- ✓ France
- ✓ 144 helical antennas
- ✓ High sensitive wideband dynamic spectrum
- ✓ The data is released on WEB.
- ✓ We downloaded the data for the period from 2007 to 2010.

http://satorchi.net/nancay/rd/2006apr01/index.php?p4015301

An example(2010/09/20)



We detected DAM by visual judgment

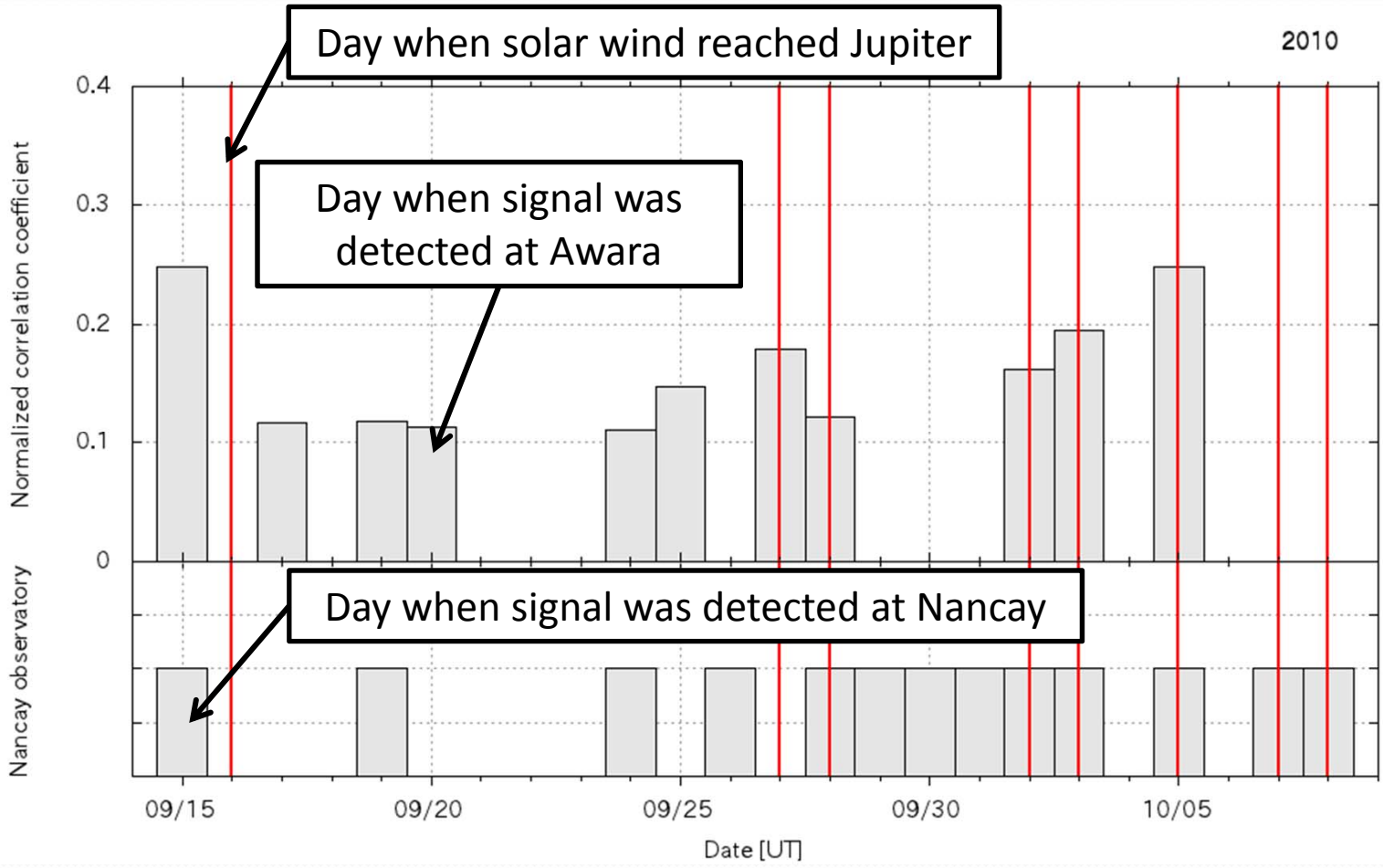
Comparison with the result by Nancay observatory

2010, within 1 month before and after the opposition

Awara

S=4

Nancay



Both are complementary or mostly in agreement.

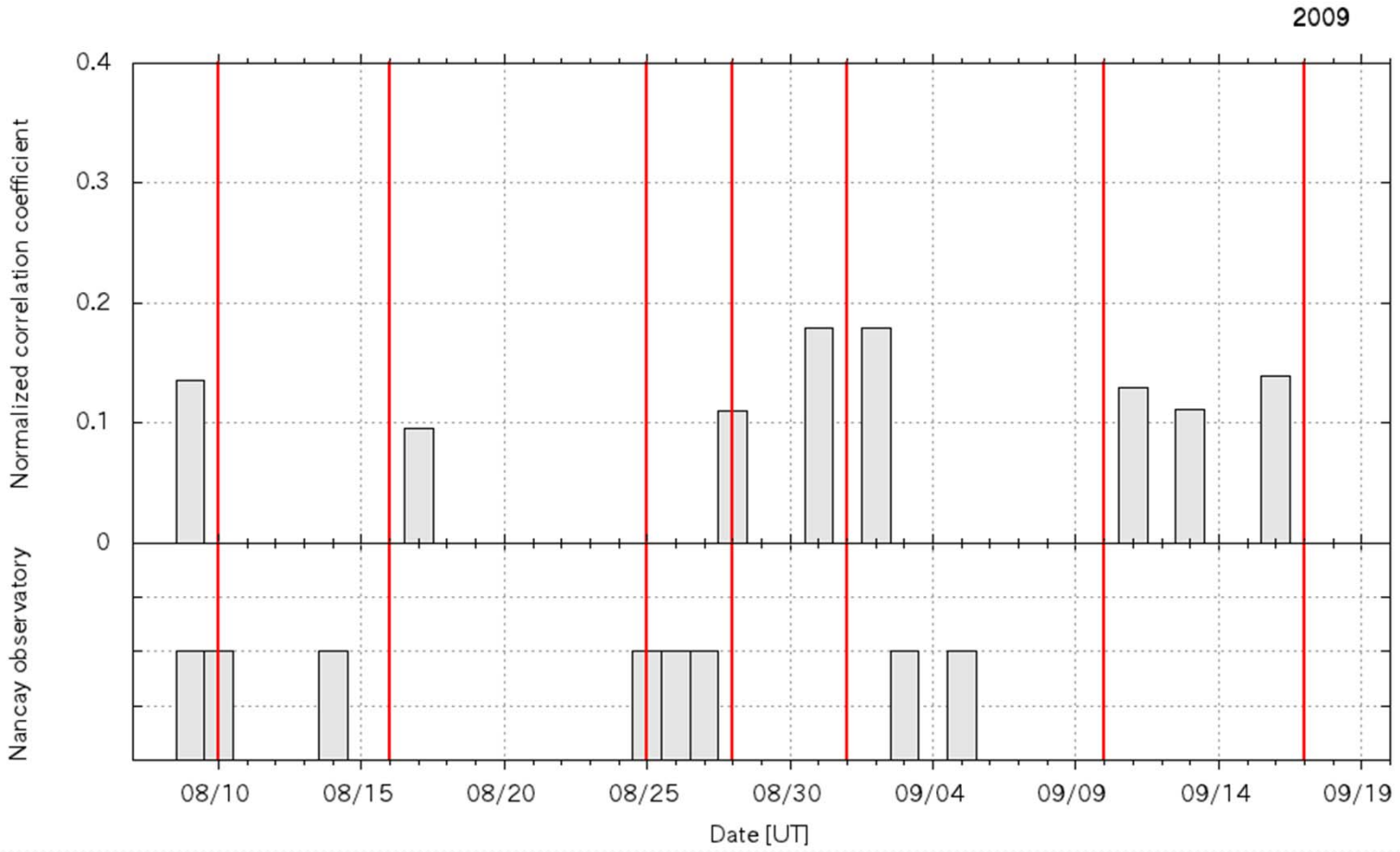
Comparison with the result by Nancay observatory

2009, within 1 month before and after the opposition

Awara

S=4

Nancay



Both are complementary or mostly in agreement.

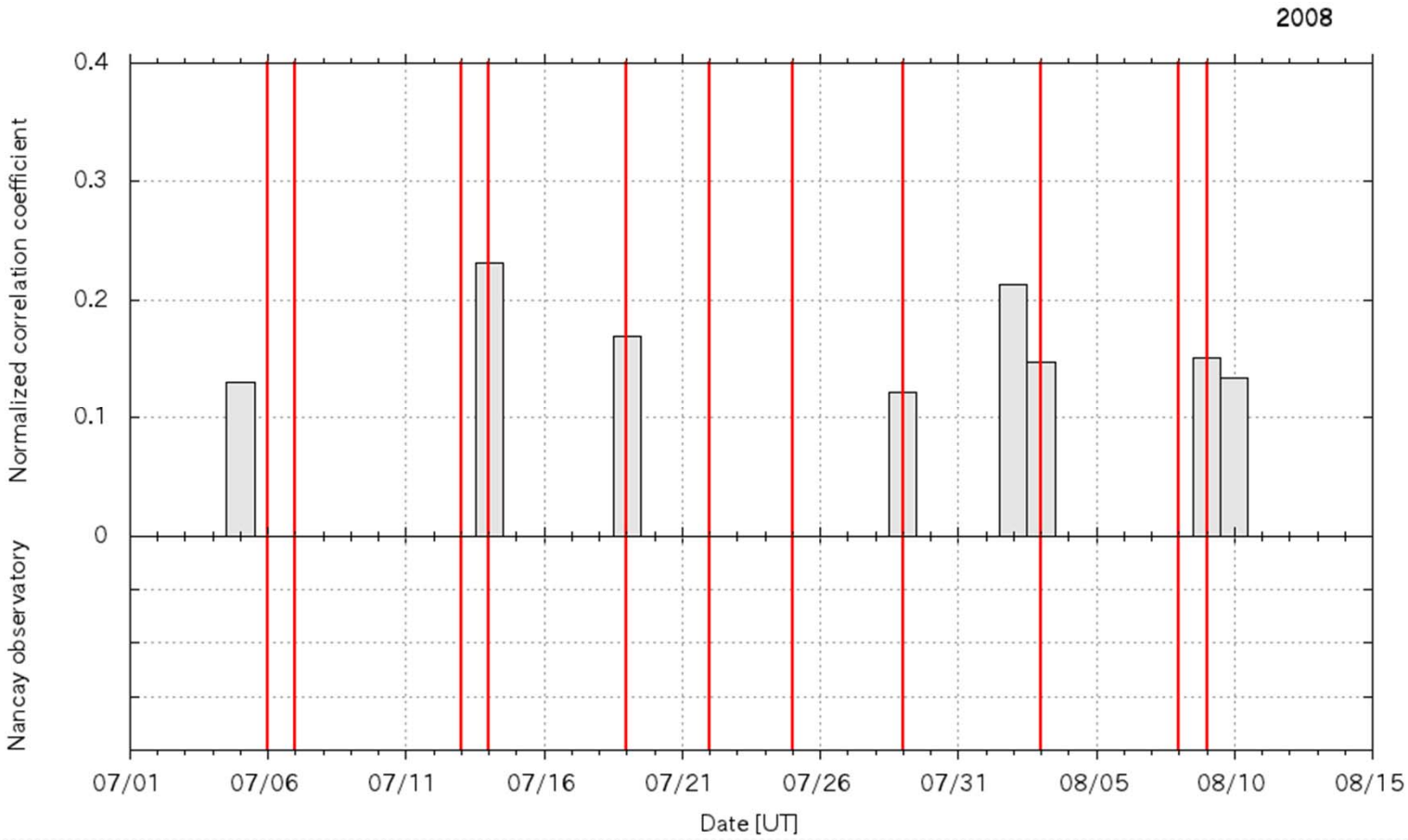
Comparison with the result by Nancay observatory

2008, within 1 month before and after the opposition

Awara

S=4

Nancay



We could not detect DAM in Nancay data.

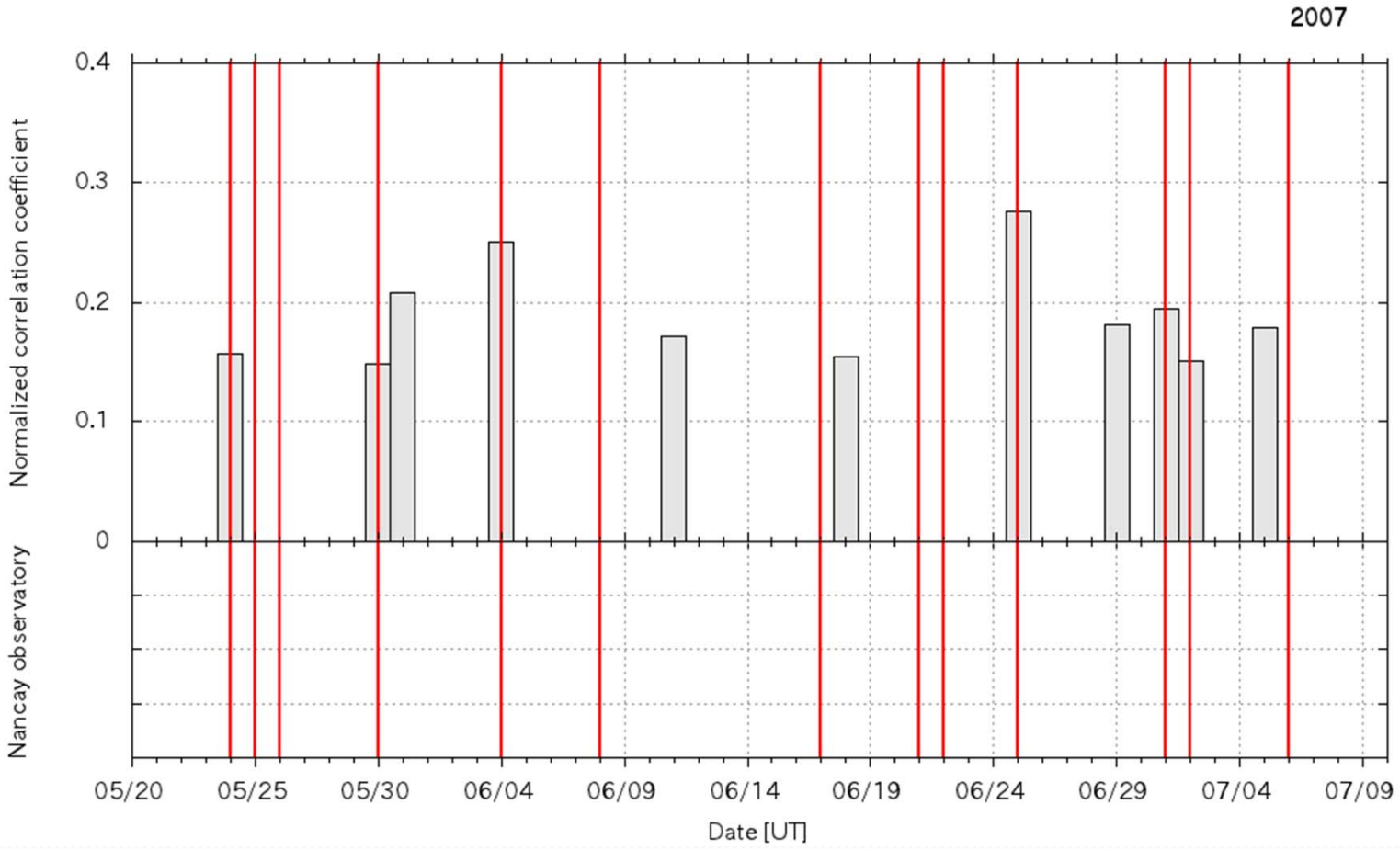
Comparison with the result by Nancay observatory

2007, within 1 month before and after the opposition

Awara

S=4

Nancay



Sensitivity of Awara is higher than that of Nancay.

Conclusion

✓ We tried to detect weak DAM emissions by using a short baseline interferometer.

✓ Most signals detected by fringe correlation method is considered to be DAM because
(i) CML-Io phase diagram based on this study corresponds to the conventional one,
(ii) Most signals detected in non-Io region are observed when shock structure of solar wind arrives at Jupiter,
(iii) Detection period in this study is complementarily in agreement with that in Nancay observatory in 2009 and 2010.

✓ Fringe correlation method is very useful for detection of weak DAM emission.

Disccussion and future study

✓ The results of data analyses show that

(i) non-Io components with long duration may be radiated by the interaction between Jovian magnetosphere and solar wind,

(ii) Jovian magnetosphere responds very quickly to variation of dynamic pressure of solar wind,

(iii) A part of weak DAM emissions detected in this study may be radiated from southern polar region.

✓ For the future study, we need to develop a new interferometer system with a few km baseline length which enables us to perform the fringe correlation method with short integration time.