Rapid events in the carbon-14 content of tree-rings

FUSA MIYAKE [1], KIMIAKI MASUDA [1], TOSHIO NAKAMURA [2] , FUYUKI TOKANAI [3], KAZUHIRO KATO[3], KATSUHIKO KIMURA [4], AND TAKUMI MITSUTANI [5]

[1] Solar-Terrestrial Environment Laboratory, Nagoya University

[2] Center for Chronological Research, Nagoya University

[3] Faculty of Science, Yamagata University

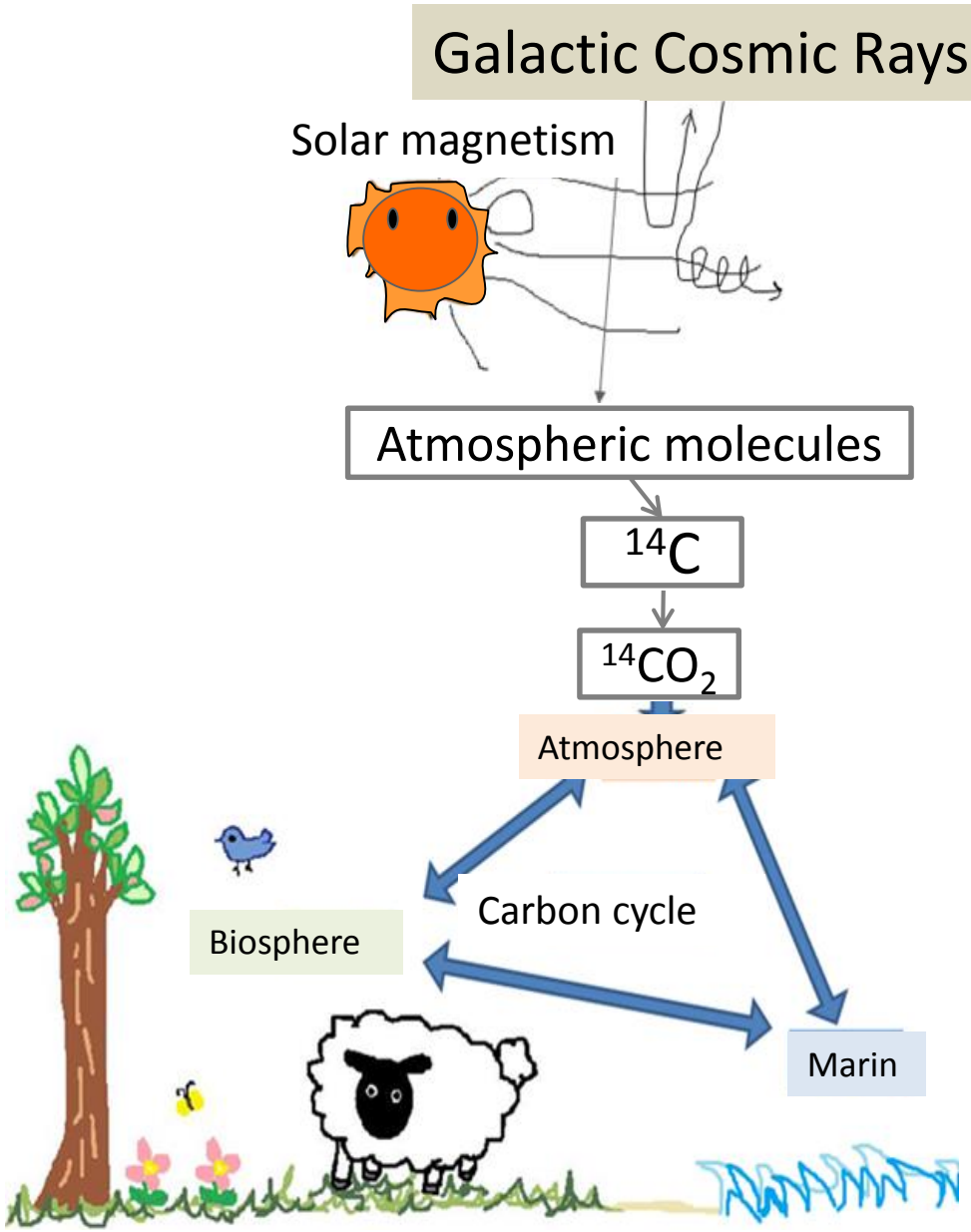
[4] Faculty of Symbiotic Systems Science, Fukushima University

[5] National Institutes for Cultural Heritage, Nara National Research Institute for Cultural Properties

HINODE-7, November 13, 2013

The stump of Tree-A

Past CR intensity…^{14}C measurement



Relation between ^{14}C & CR

Cosmic rays produce ^{14}C
（Neutron capture reaction）

^{14}C is oxidized to form $^{14}CO_2$ and taken by trees during the carbon cycle

^{14}C content in tree rings is retained and shows a record of the past CR intensity

Cosmic ray events

Cosmic high energy phenomenon

(i.e. large solar flare or galactic γ-ray event)

→ Cosmic ray intensity rapidly increases

→ It is possible tree-rings record such an event

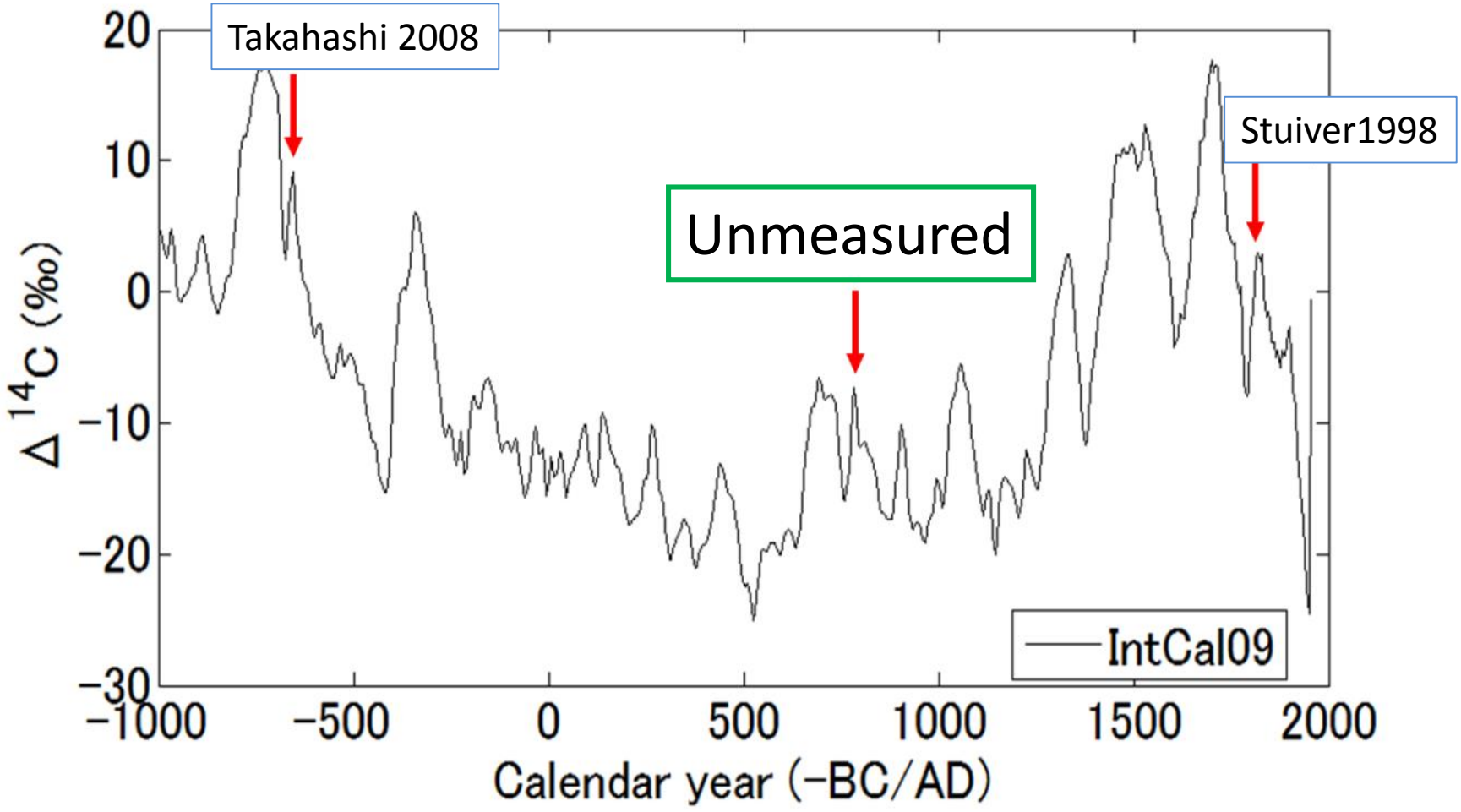
However such events have not been found before

There are a lot of periods of time where there are no yearly ^{14}C content measurements

⇒It is possible that such events are hidden in these periods

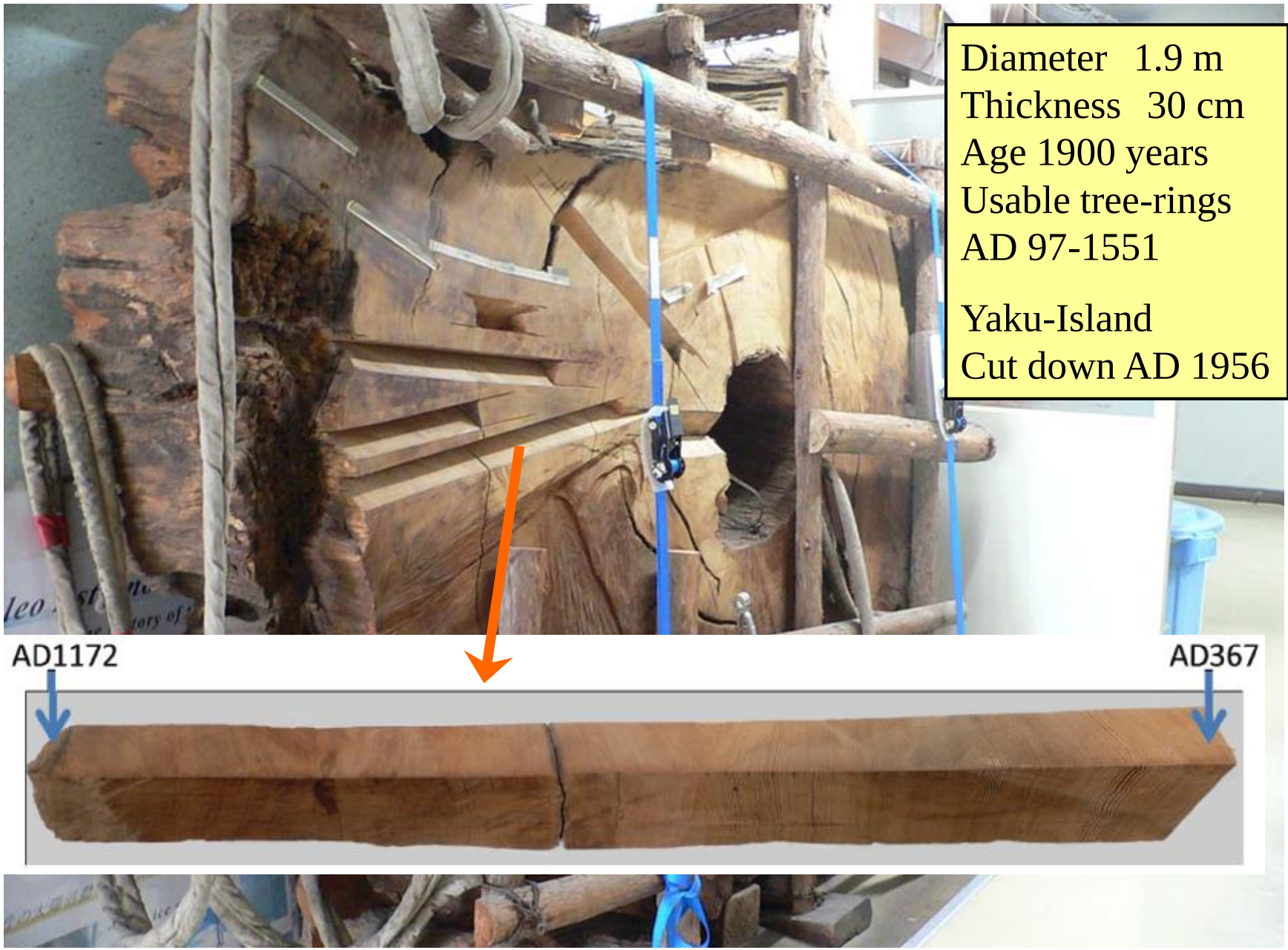
^{14}C content（3000years）

Search for Cosmic Ray events→IntCal decadal ^{14}C dataset

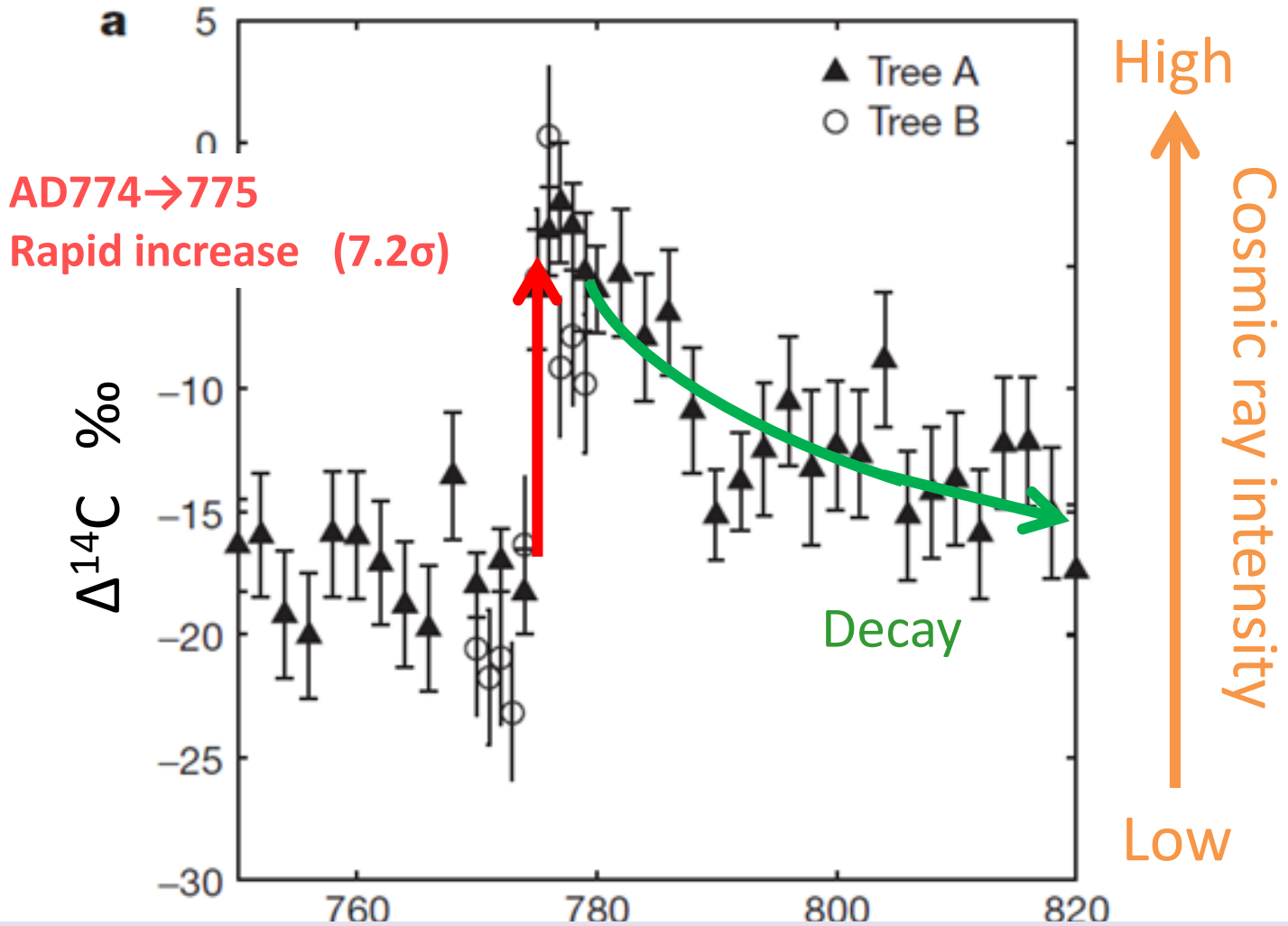


Arrows show rapid increases（＞3‰/10yr）

Sample Tree-A



AD775 Event（Miyake et al. *Nature* 2012）

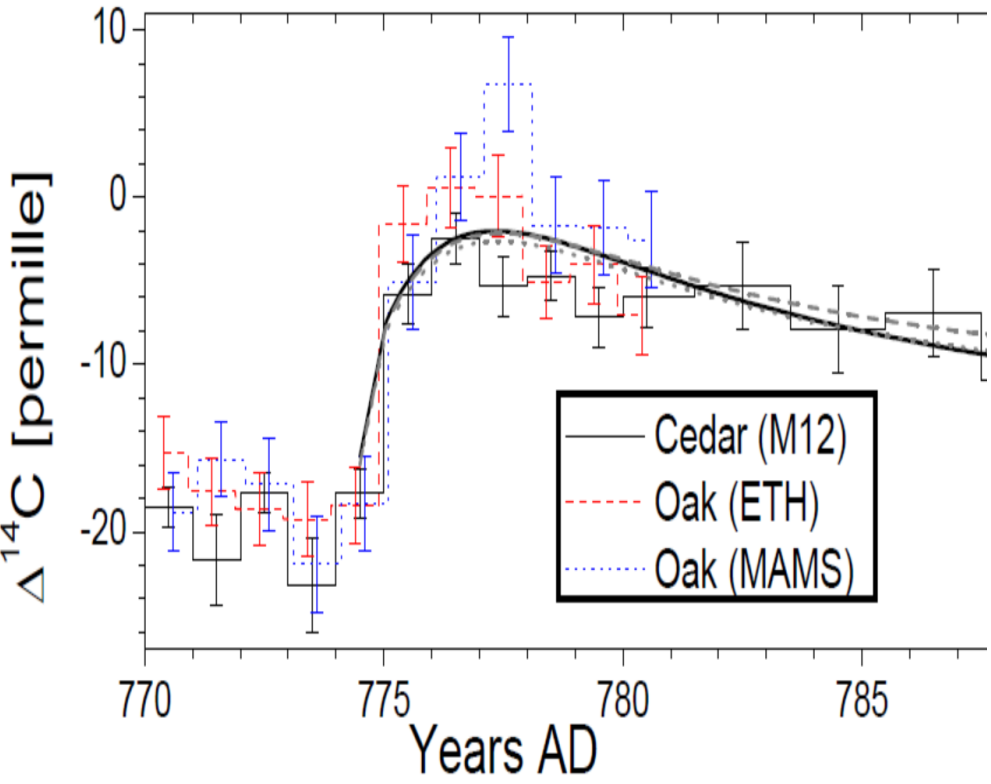


This is the first detection of rapid increase of ^{14}C content by significant amount

Verification by other trees

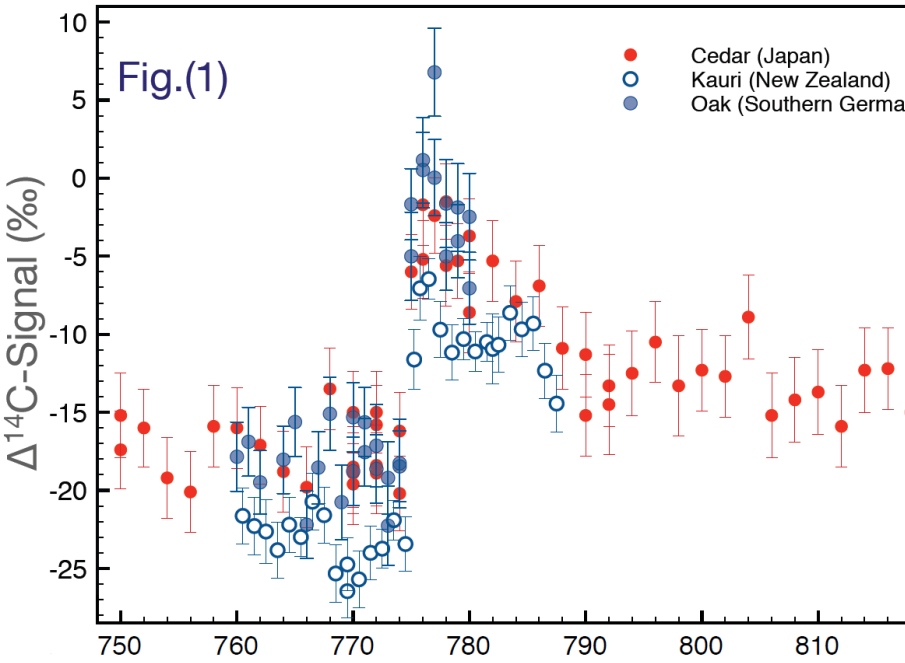
Germany Oak sample

Usoskin et al. 2013



New Zealander Kauri sample

Güttler et al. 2013



This strongly indicates that the anomaly is triggered by cosmic outbursts that affected the whole planet.

^{14}C production rate [atoms/cm^2]

<Production rate for this event>

- Miyake et al. 2012: $(6.0 \pm 1.3) \times 10^8$ atoms/cm^2
  ^{14}C atoms/(π R^2)
- Usoskin et al. 2012&2013: $(1.3 \pm 0.2) \times 10^8$ atoms/cm^2
  ^{14}C atoms/(**4**π R^2)

→Their estimation is 5 times smaller than ours

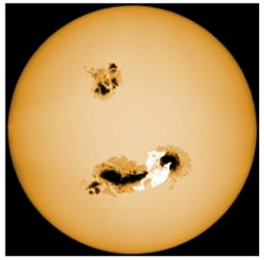
↓ Definition of production rate is different!

Our production rate is consistent with Usoskin et al.

↓ : $(1.5 \pm 0.3) \times 10^8$ atoms/cm^2 (Miyake)
: $(1.3 \pm 0.2) \times 10^8$ atoms/cm^2 (Usoskin)

Total ^{14}C production (total incoming cosmic ray) is consistent with theirs!

Maehara et al. 2012



Cause of these events?

- **Large SPE (Solar Proton Event)?**

  Melott & Thomas 2012, Usoskin et al. 2012&2013, Thomas et al. 2013

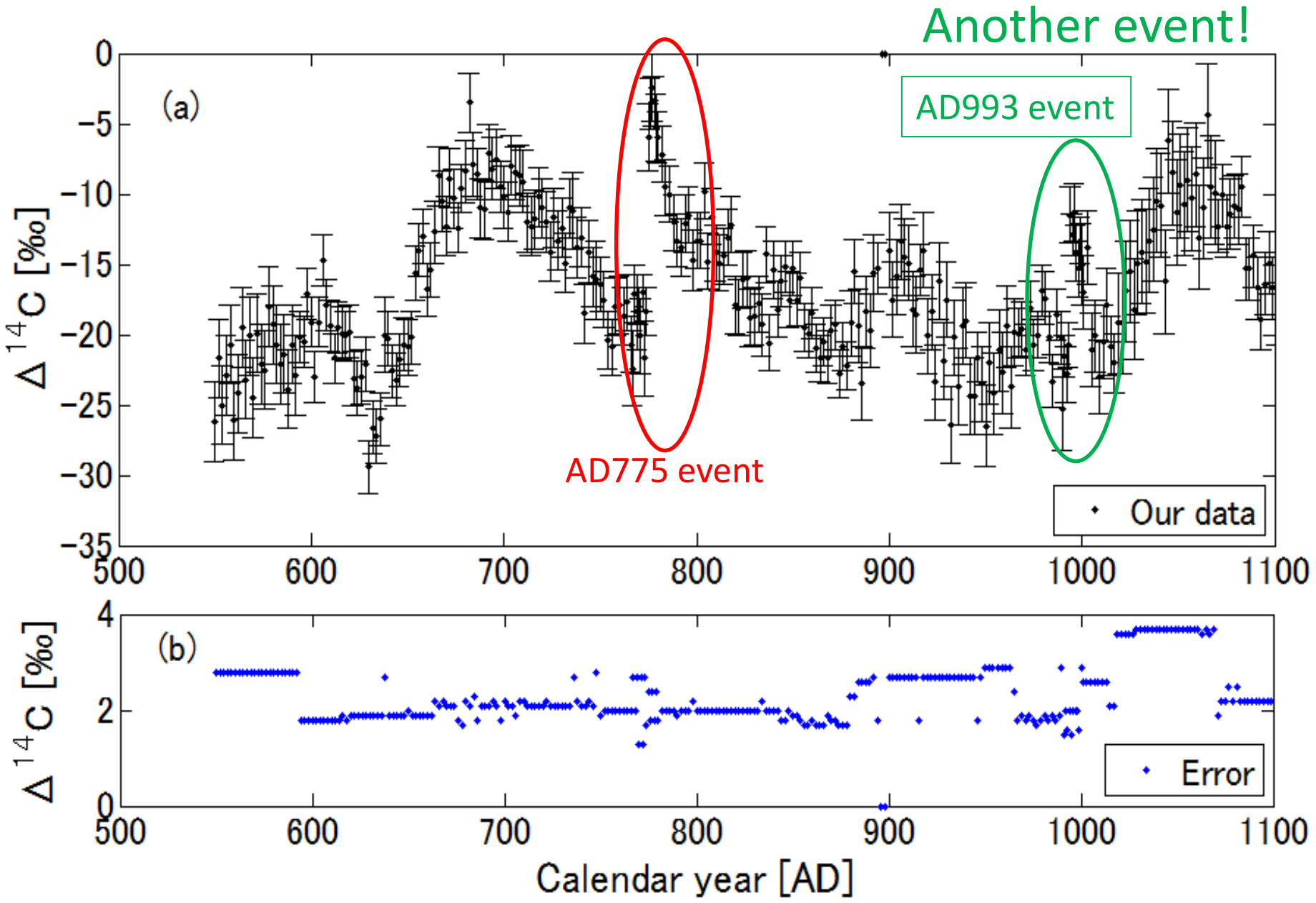
- **Short GRB (gamma-ray burst)?**

  Hambaryan & Neuhäuser 2013

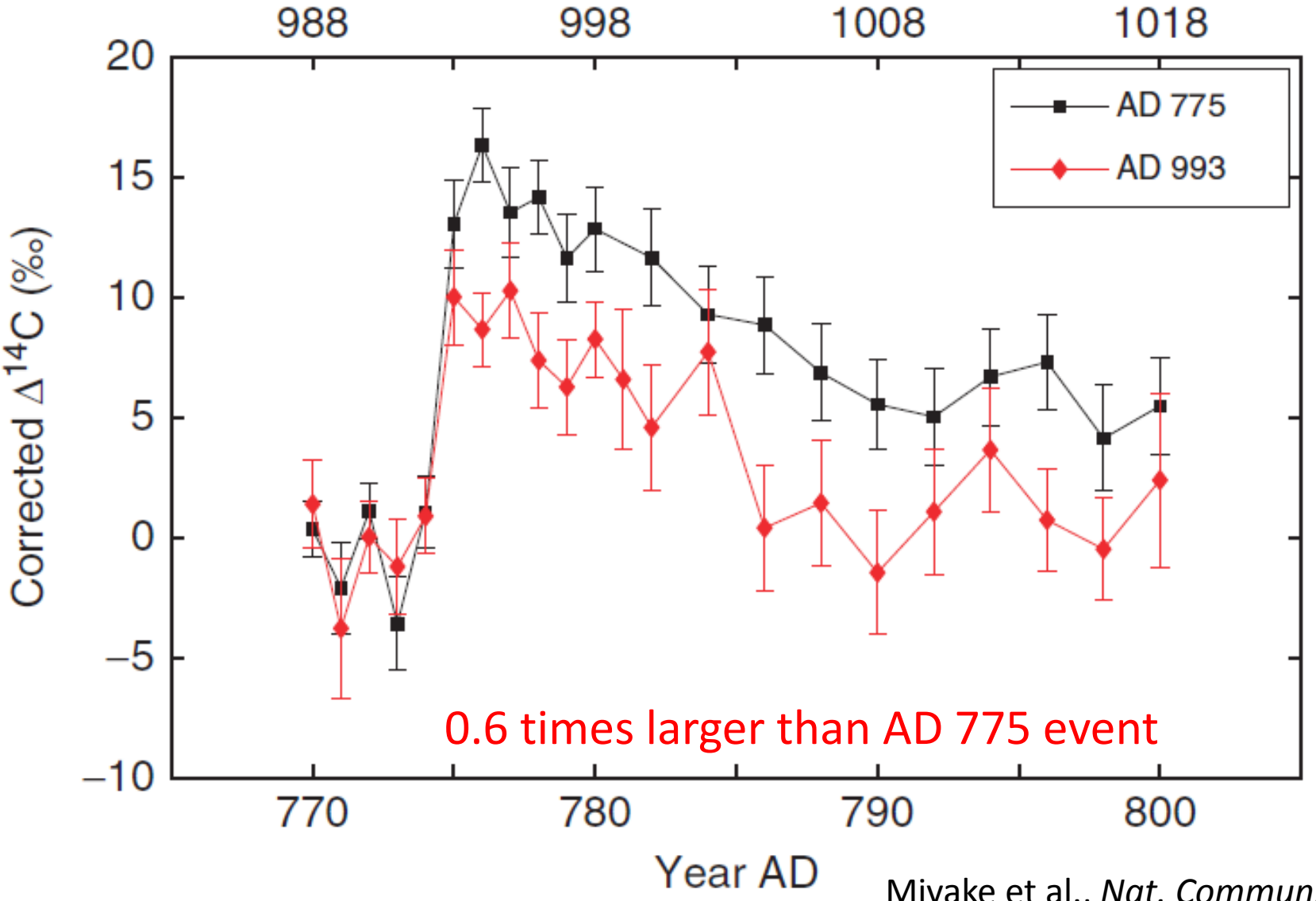
→Observed rate of short GRB is very low: $1/(3.7 \times 10^6)$ [1/yr]

^{14}C event rate is very important!

^{14}C content（AD550-1100）



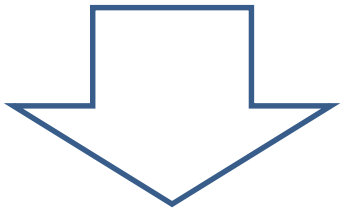
Comparison of AD775 & 993



Miyake et al., *Nat. Commun.* 2013

Cause of ^{14}C event

Occurrence rate of ^{14}C event: 1 event / 800 years

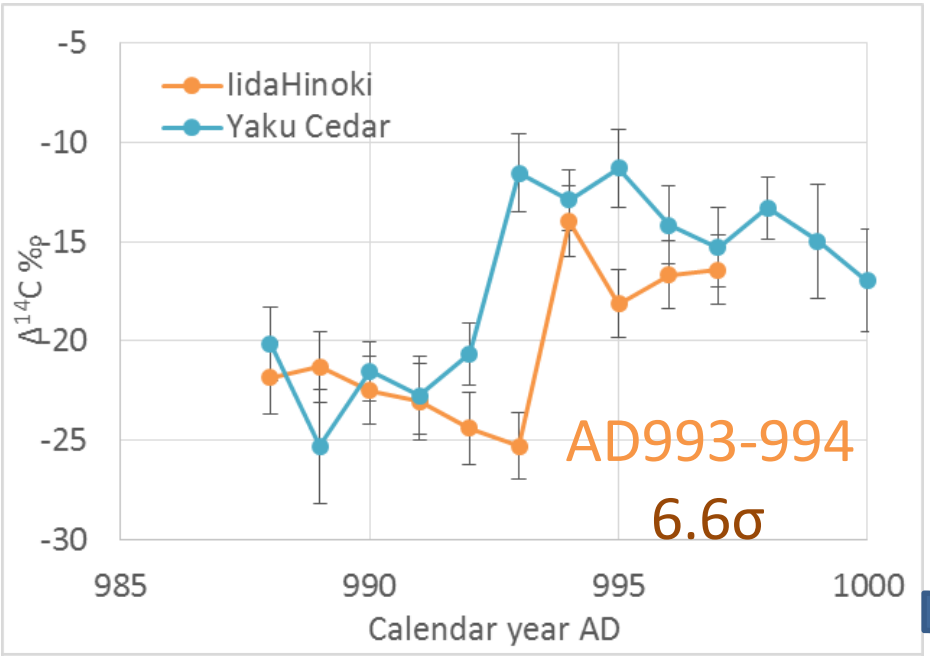


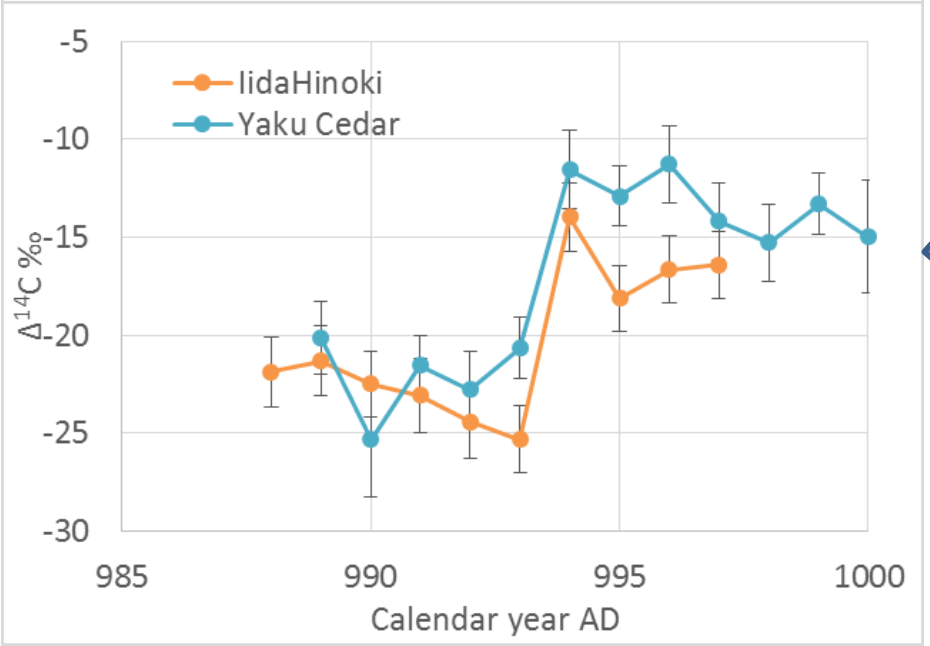
Inconsistency between
a short GRB rate and ^{14}C event rate

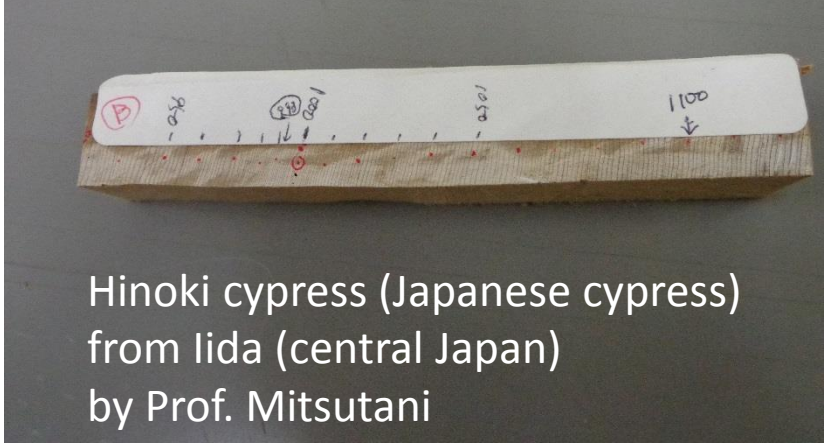
Large SPE is a more plausible cause!
(more than 10 times larger than the largest SPE like the Carrington event)

→This indicates the possibility that such large SPEs will occur in the future.

Latest result






Hinoki cypress (Japanese cypress)
from Iida (central Japan)
by Prof. Mitsutani

The ^{14}C increment of the 993 event is reproduced by another tree!

If we shift either for one year, the two series are almost consistent

Age determination mistake was found in ad 946

Summary

- We measured ^{14}C content from AD 550 to 1100
- We found two rapid increases in the ^{14}C content (AD775, AD994)
- These ^{14}C events are supported by some measurements of several trees
  (German, New Zealander, & other Japanese trees)
- Considering the occurrence rate of ^{14}C events, the cause of ^{14}C events must be due to large Solar Proton Events (> 10 × the Carrington event)
- **This indicates the possibility that such large SPEs will occur in the future.**