Extreme Solar Storms: Occurrence Probability and Implications

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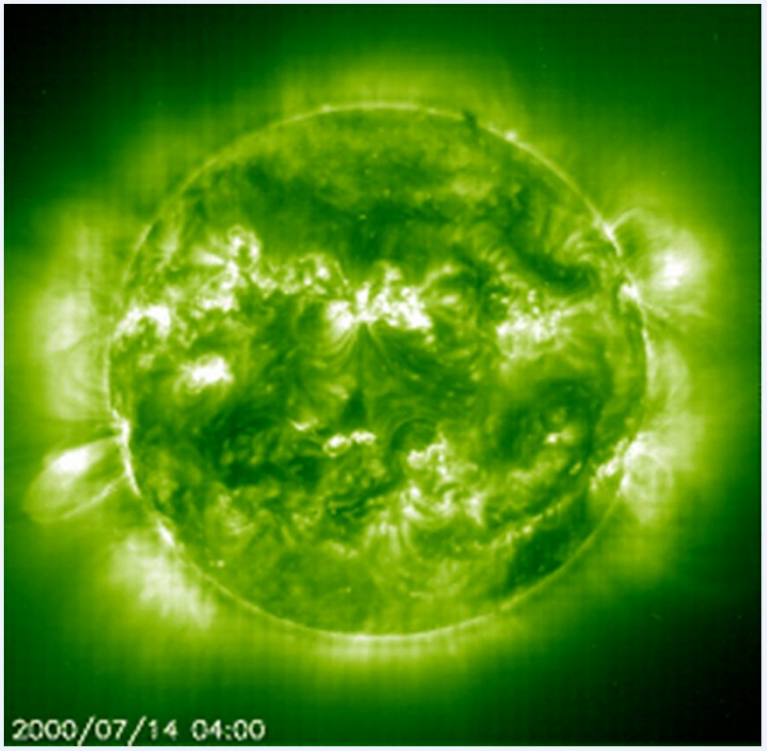
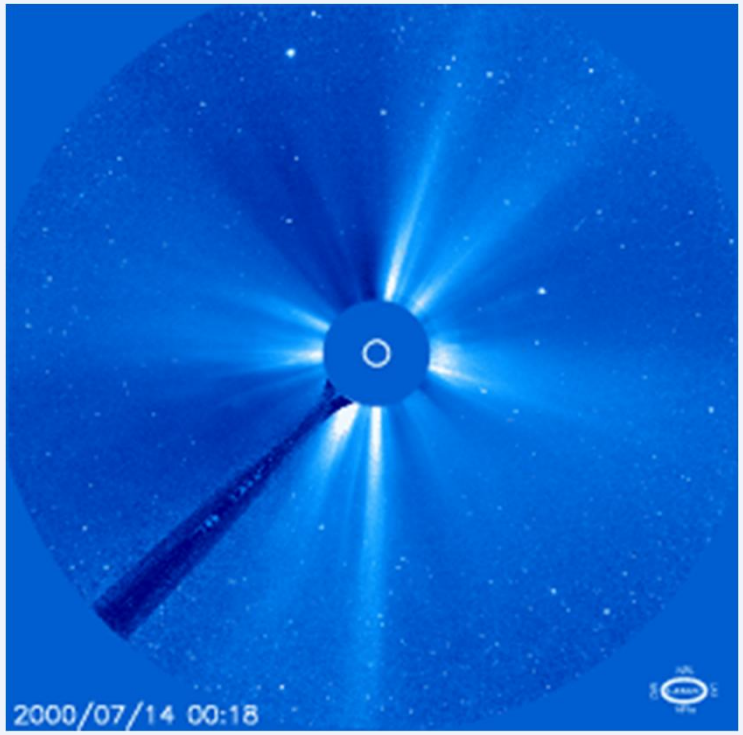
Solar flares and energetic particles



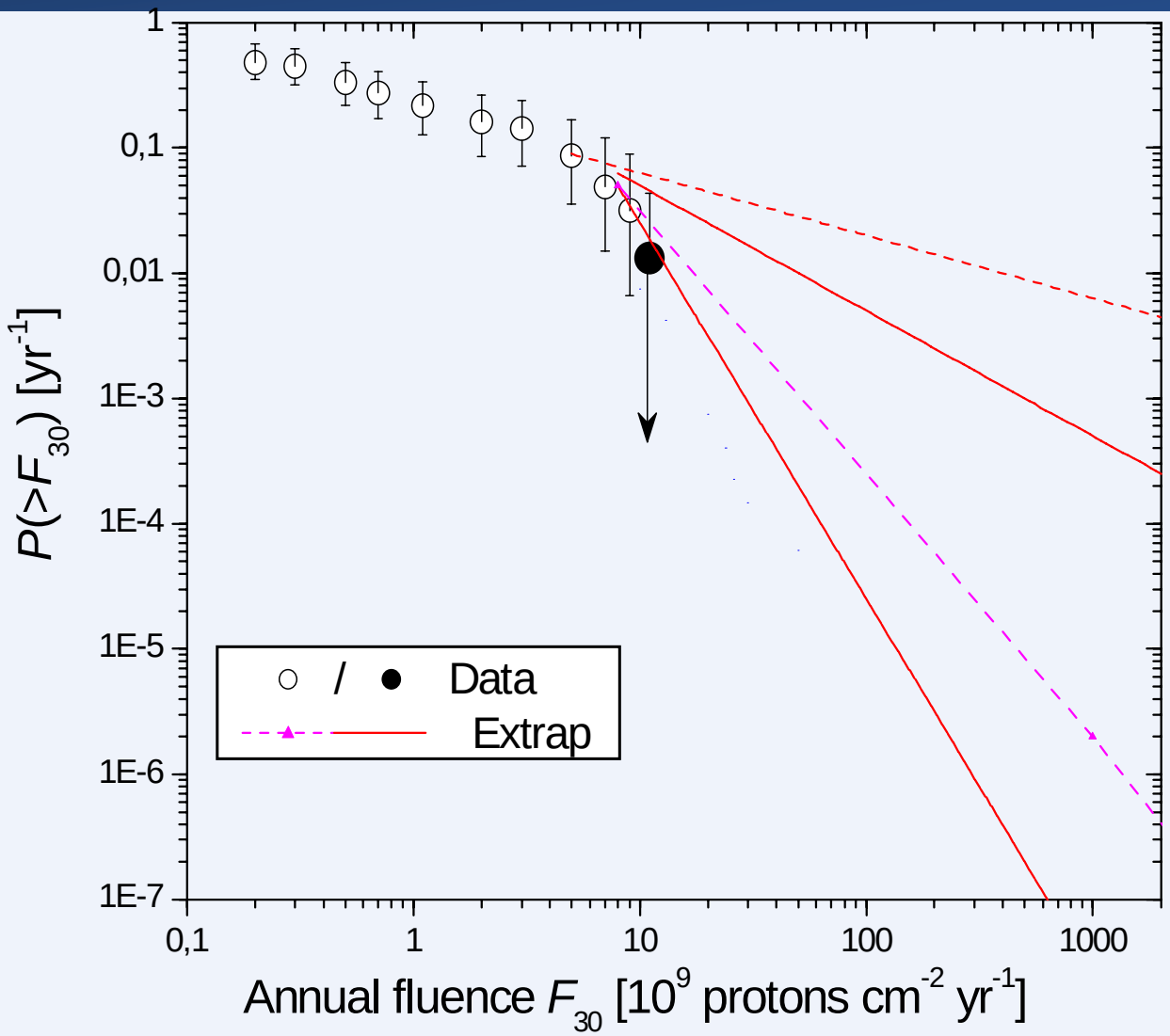
EIT 195 Å



LASCO C3

SOHO (Credit NASA)

SPE: space era

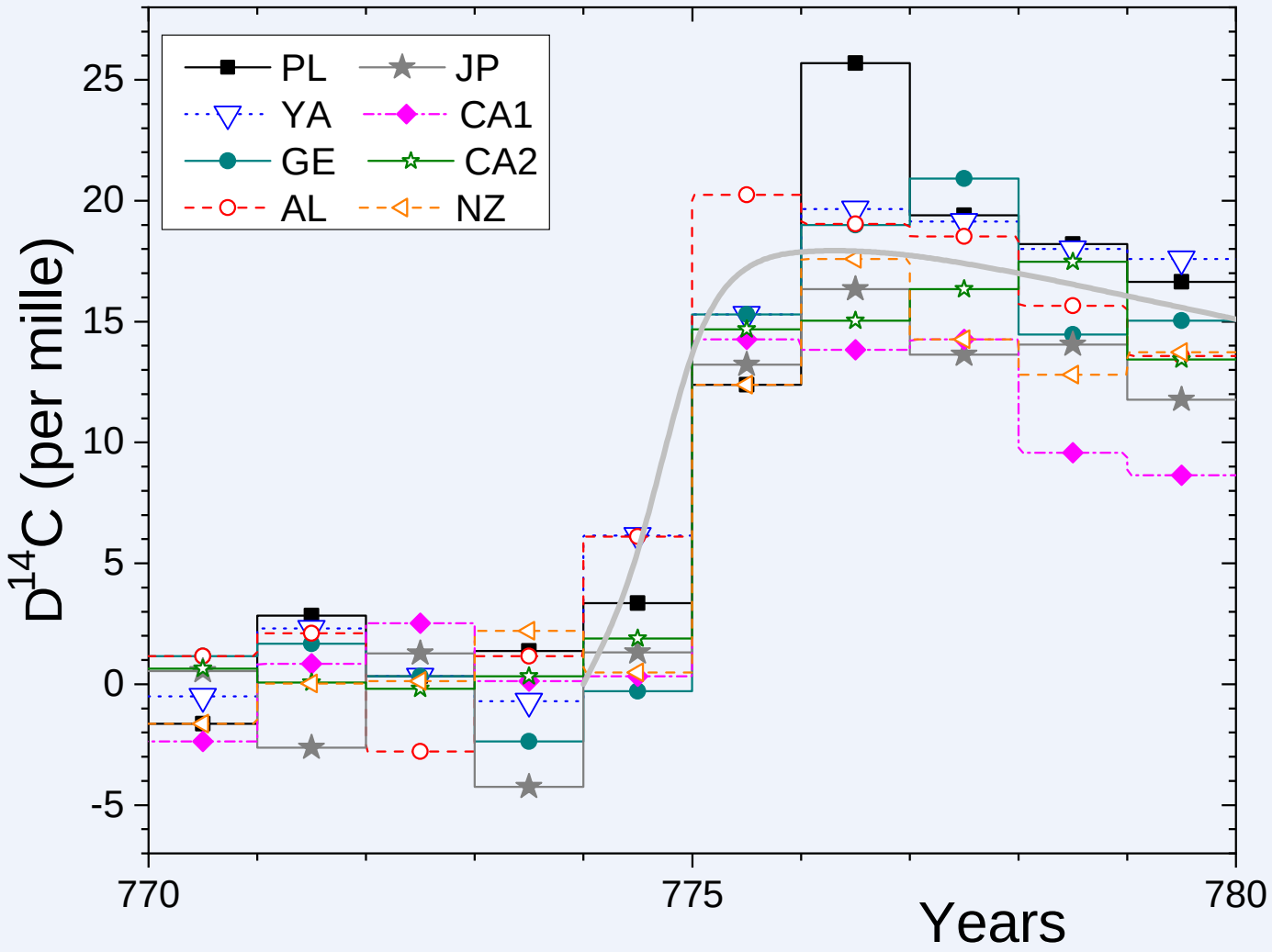


Data: Shea & Smart (1990, 2012), Reedy (2012), No events with $F_{30}>10^{10}$ cm^{-2} during last 70 years.

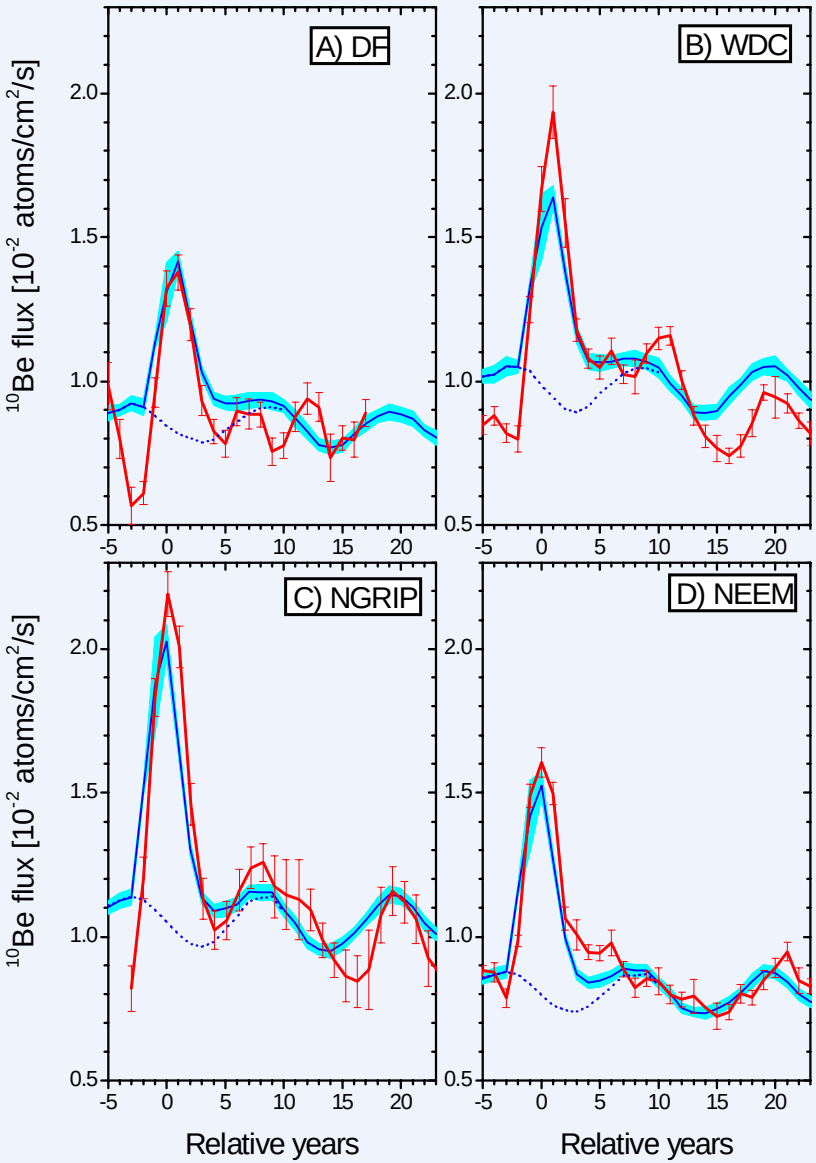
Extrapolations: Lingenfelter & Ramaty (1980); Nymmik & Miroshnichenko (2014)

Cosmogenic radionuclides ^{14}C and ^{10}Be: last 11 millennia

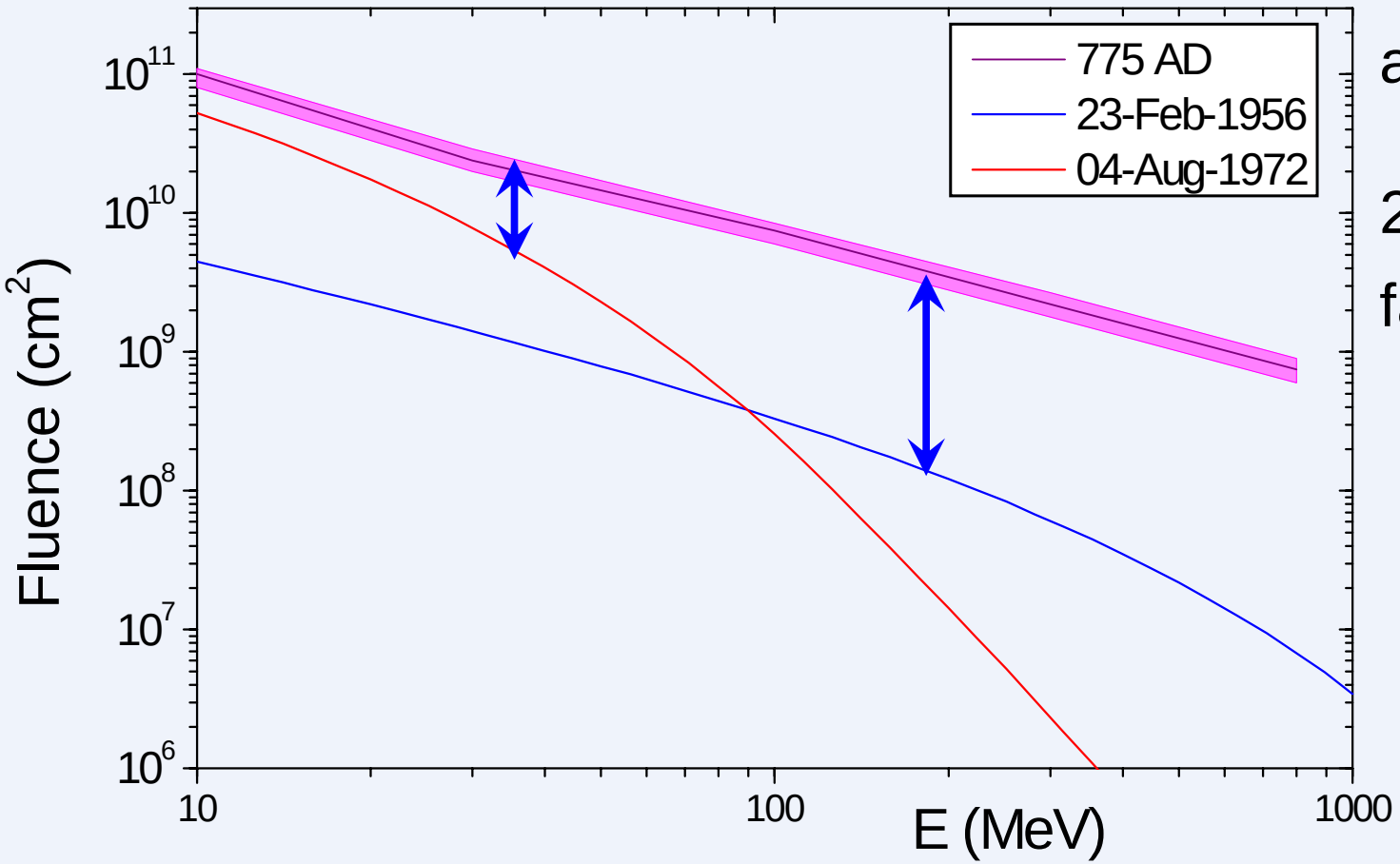
775 AD event: ^{14}C



775 AD event: ^{10}Be



Energy spectrum of 775 AD event



30 MeV – a factor of **3**;

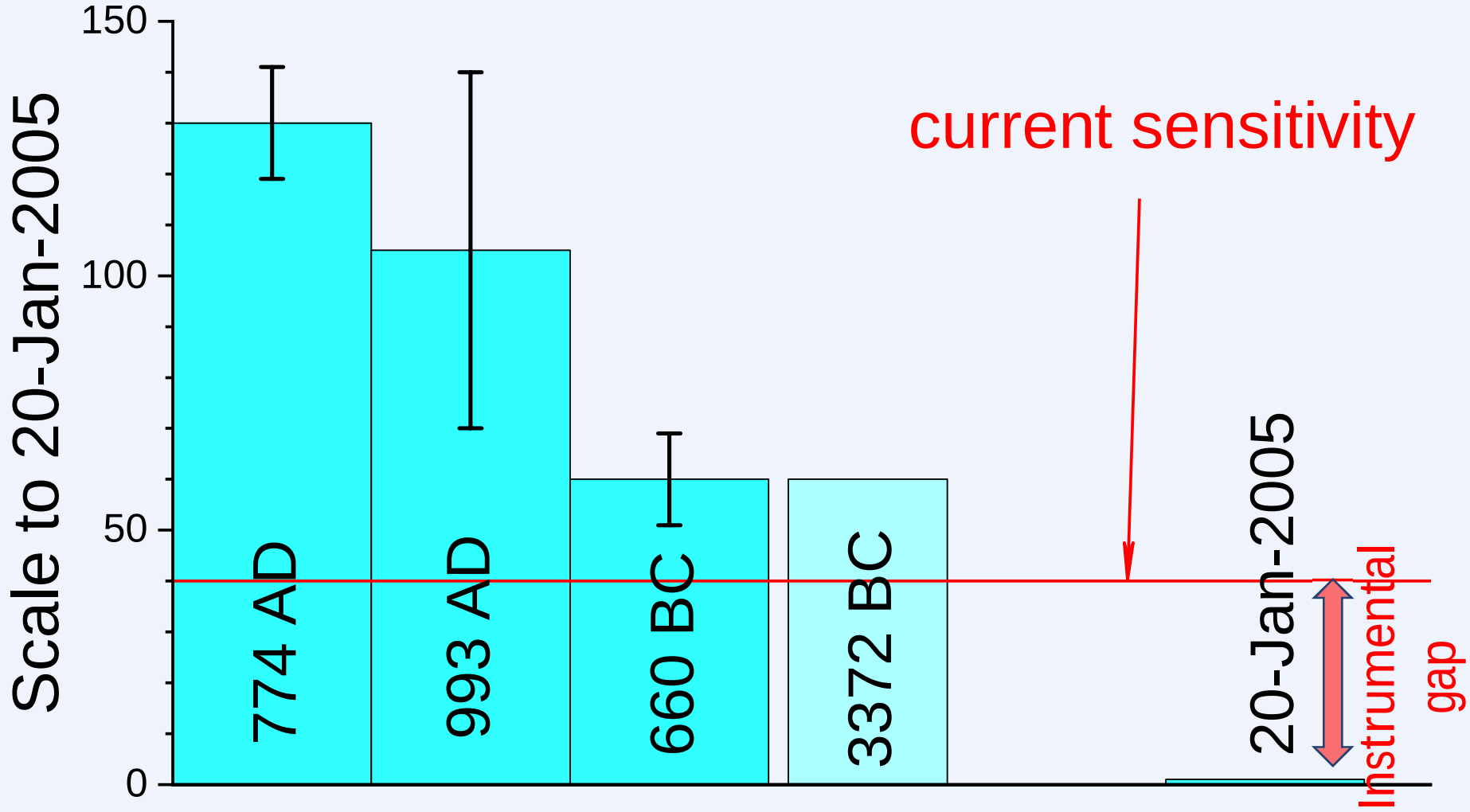
200 MeV – a factor of **50**

Mekhaldi et al. (2015)

Other similar but slightly weaker events:

994 AD; 660 BC & 3372 BC

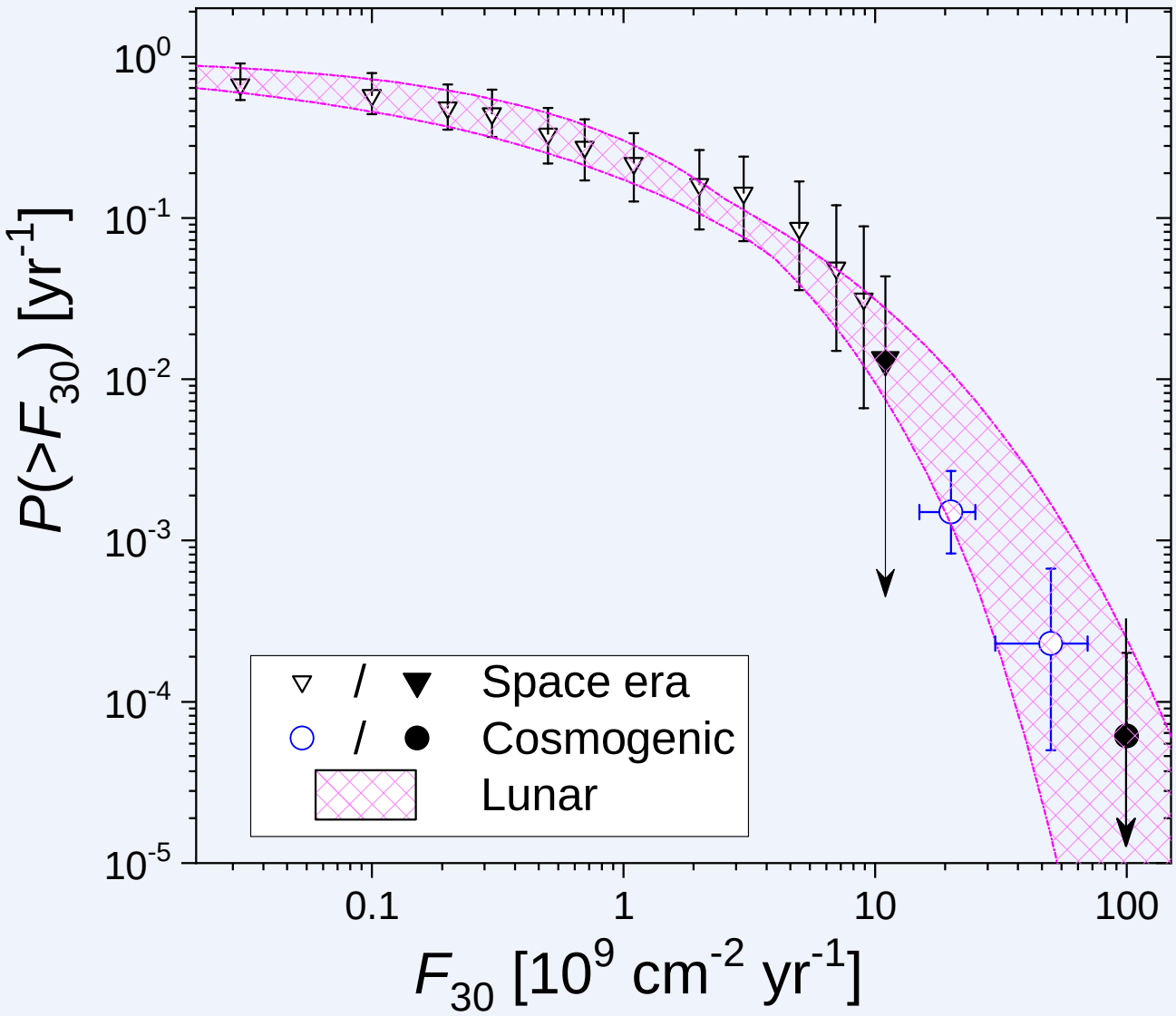
Ranking of extreme SPEs



Mehaldi et al. (2015); O'Hare et al. (2019)

Cosmogenic radionuclides in lunar rocks: 1 Myr

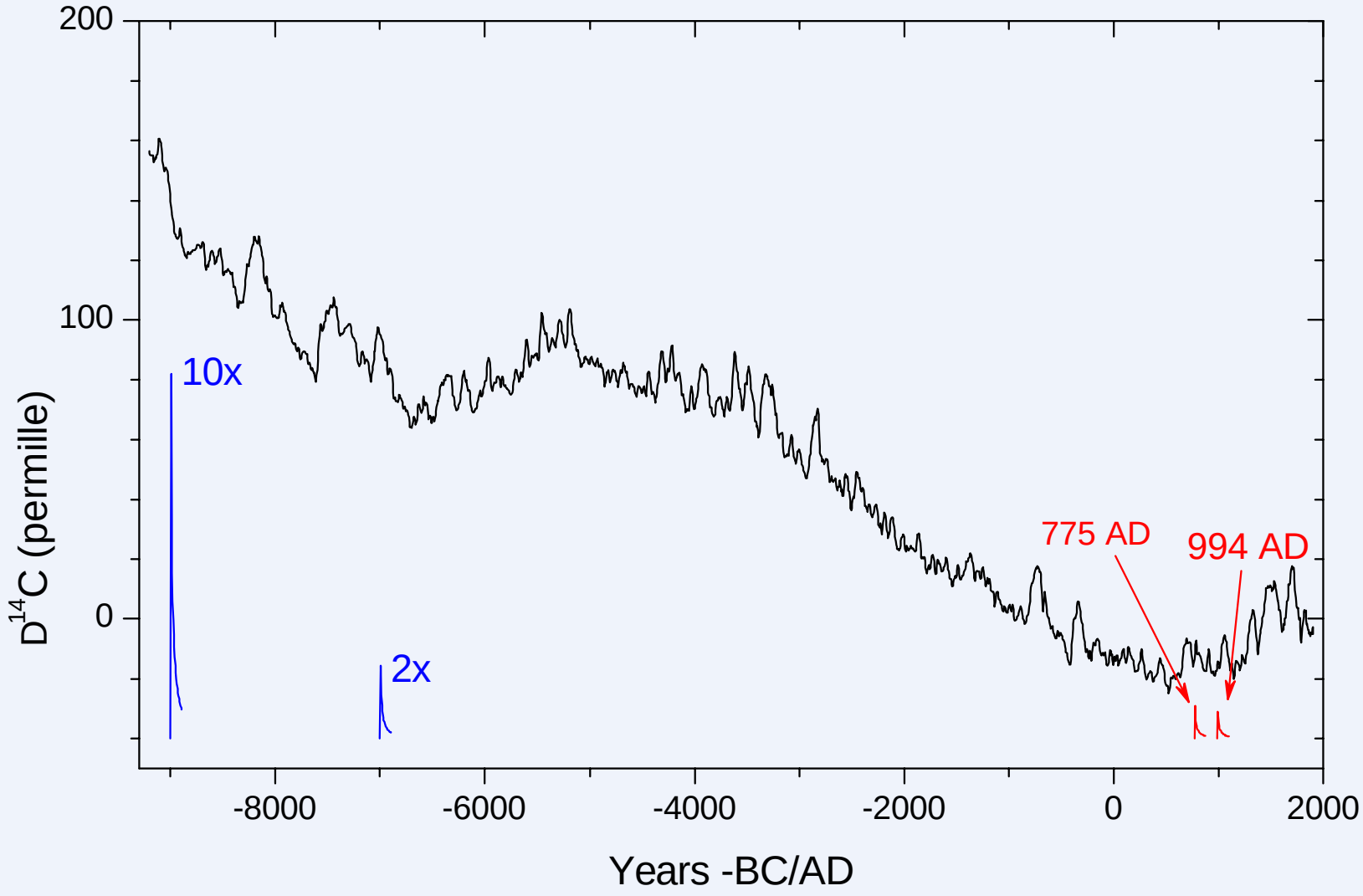
OPDF



Poluianov et al. (2018)

The worst case scenario?

Events to look for in $\Delta^{14}C$



Summary

- Practical limits are: F_{30}≈1, 2÷3, 5*10^{10} and 10^{11} cm^{-2} for the occurrence probability ≈ 10^{-2}, 10^{-3}, 10^{-4} and 10^{-6} $year^{-1}$, respectively.

- Three (+1) extreme SEP events are know. The greatest event was in 774 AD F_{30}~(5-8)*10^{10} cm^{-2}. It may serve as the worst-case scenario. Other events: 660 BC, 993 AD, 3372 DC (?).

- There is an observational gap between those and instrumental-era events.

- Possible climatic effects are notable at the regional scale, but not dramatic. Technological effects can be dramatic.

THANK YOU !