Is there a preferred date for a possible impact?

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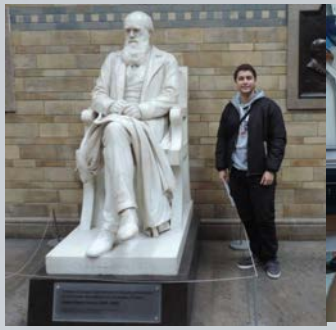

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Meteorites falls and finds

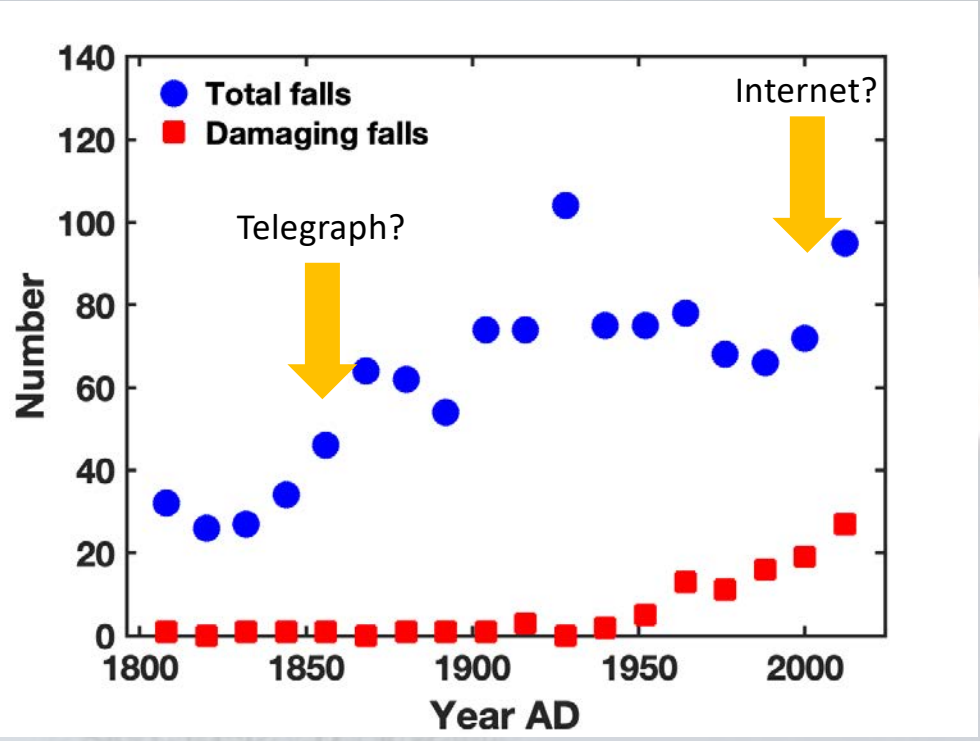
- If any part of the event leading to the delivery of a meteorite to Earth was witnessed, it is called a **fall**. All other meteorites are called **finds**.
- The clearing-house of meteorites is the Meteoritical Society, which maintains the Meteoritical Bulletin Database (MBD).
- Up end of 2018, there are **60779** registered meteorite names.
- There are registered **1174 falls**.
- ***Damaging falls:*** a fall that directly impact human beings or their belongings (house, car, but not pavement).
- There are 105 reports of damaging falls from XVIII century until present.

Table 1– List of damaging falls

Date	Meteorite name	Place	Meteorite type	Ref.	Description
24 jul 1790	Barbotan	Barbotan, France	H5	2	There is a report of a crushed cottage, a killed farmer and some cattle.
26 abr 1803	L'Agle	Orne, France	L6	2	The roof ridge of a house was hit and a wirepuller was hit on the arm by a small stone.
14 jul 1847	Braunau	Bohemia, Czech Republic	Iron Hex. IIA	1	One mass of 17.2 kg fell upon a house, pierce the roof, struck the beam, passed through a ceiling composed of white clay and straw, and entered a room where several persons were assembled, but, no one was hurt.
01 may 1860	New Concord	Ohio, USA	L6	2	A stone struck and killed a young horse.
19 nov 1881	Grossliebenthal	Odessa, Ukraine	L6	2	Sources cite a building being struck and a man was injured.
4 nov 1906	Diep River	Cape Province, South Africa	L5	2	A 910 g stone fell and crashed through a metal roof of a house.
28 jun 1911	Nakhla	Al Buhayrah, Egypt	Martian nakhlite	2	A dog was struck and killed.
30 jun 1918	Richardton	North Dakota, USA	H5	2	A single stone struck a building.
02 abr 1936	Yurtuk	Lubimov, Ukraine	Howardite	2	One stone of 509 g fell through the roof of a house.
11 jun 1949	Kunashak	Kunashak, Russia	L6	2	A stone blasted through the roof of a very modest house.
10 dic 1950	St.	Missouri, USA	H4	1	A stone crashed through the top of an automobile as a man was driving.
30 nov 1954	Sylacauga	Alabama, USA	H4	1	A lady was asleep on her sofa when a 3.86 kg stony meteorite crashed through her roof (struck the radio, bounced off the floor) and hit her, causing abdominal injuries which, fortunately, were not serious.
19 feb 1956	Sinnai	Sardegna, Italy	H6	1	A stone penetrated through the roof and floor of a hut and buried to a depth of 25 cm.
29 feb 1956	Centerville	South Dakota, USA	H5	1	After penetrating the aluminium roof, it struck a corn planter stored in the shed and four small pieces were chipped off.
13 oct 1959	Hamlet	Indiana, USA	LL3-4	1	A single stone of 2.045 kg struck a house, ripping off the rain gutter of the roof.
05 mar 1960	Gao-Guenie	Gao, Burkina Faso	H5	2	16 pieces were recovered after falling through the roofs of some huts.
09 sep 1961	Bells	Texas, USA	C2-ung	1	A fragment hit the roof of a house.
26 abr 1962	Kiel	Schleswig-Holstein, Germany	L6	1	A stone hit the roof of a house and made a hole about 10 x 10 cm.
24 dic 1965	Barwell	Leicestershire, England	L6	2	A piece smashed through a factory roof, another tiny fragment was found later in a vase and another landed on the bonnet of a car.
12 abr 1968	Schenectady	New York, USA	H5	1	Some damage to the roof.
25 abr 1969	Bovedy	Northern Ireland, UK	L3	2	Press reports of scorching of the asbestos roof and desks.
07 ago 1969	Andreevka	Donetsk, Ukraine	L3	1	A stone made a hole in a slate roof of a house and fell on the floor of the garret.
28 sep 1969	Murchison	Victoria, Australia	CM2	1	One stone burst through a barn roof, landing in the hay.
08 abr 1971	Wethersfield	Connecticut, USA	L6	1	A stone fell through the roof and was found in the early morning suspended in a ceiling.
02 ago 1971	HaverÖ	Turku Ja Pori, Finland	Ureilite	1	A stone fell through the roof of a storehouse.
15 oct 1972	Valera	Trujillo, Venezuela	L5	1	A single stone struck and killed a cow. The stone had broken into three pieces weighing 38, 8, and 4 kg, respectively.

A lot of funny anecdotes

The number of reports



Period of 12 yr	# Total falls	# Damaging falls	% Damaging /Total
1959-1970	78	13	17
1971-1982	68	11	16
1983-1994	66	16	24
1995-2006	72	19	26
2007-2018	95	27	28
TOTAL	1174	105	

~1/4 of the reported meteorite falls are damaging ones

In the last 12 years there has been 95 reports of falls and 27 of damaging falls, implying a rate of 7.9 and 2.3 reports per year, respectively.

We do not expect a large increase in the number of reported falls and damaging falls, since the numbers have not dramatically change in the last decades, in spite of the improvements in communications.

How many meteorite falls are per year?

- 29 % of the surface of the Earth is covered by land (CIA, 2017)
- Urban land is defined as “areas dominated by built environment (>50%), with minimum mapping unit > 1 km^2.”
- Urban land (computed from satellite images) is 0.13% of the total area of the Earth, and 0.44 % of the area covered by land. (Schneider et al., 2009)
- ~55% of the Earth’s population lives in urban areas (UN 2014).
- The urban land corresponds to a large fraction of the area where there are witnesses of a fall.
- There is no estimate of the total area actually covered by buildings.

How many meteorite falls are per year?

$$\text{Total Number of falls per year} = \frac{\text{Number of falls in urban land}}{\text{Fraction of urban land}}$$

- **7.9/0.0013 ≈ 6100 meteorite falls per year over the entire Earth**
- **and 7.9/0.0044 ≈ 1800 over the land.**

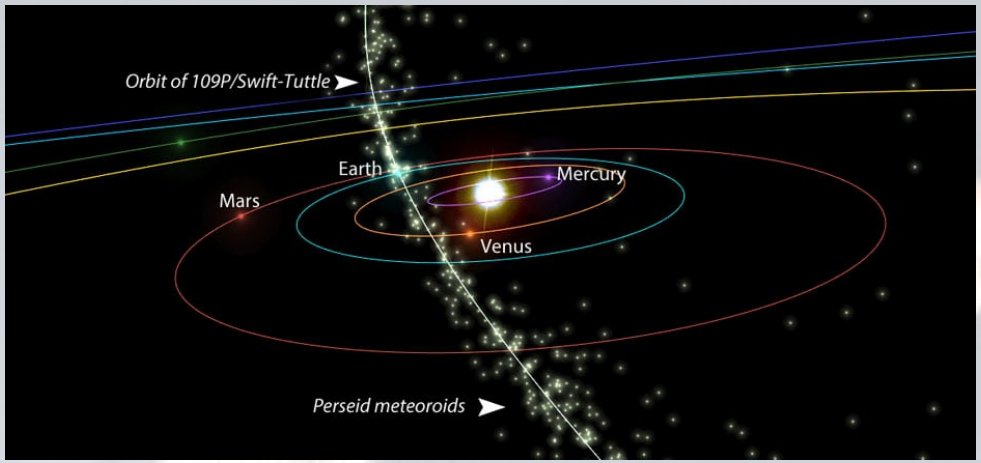
- Halliday (1984) estimated 4100 meteorite falls over the Earth, based on photographic observations of fireballs and estimates of the delivered mass using meteor physics laws (several assumptions).
- Our values are 50% higher (with far less assumptions)

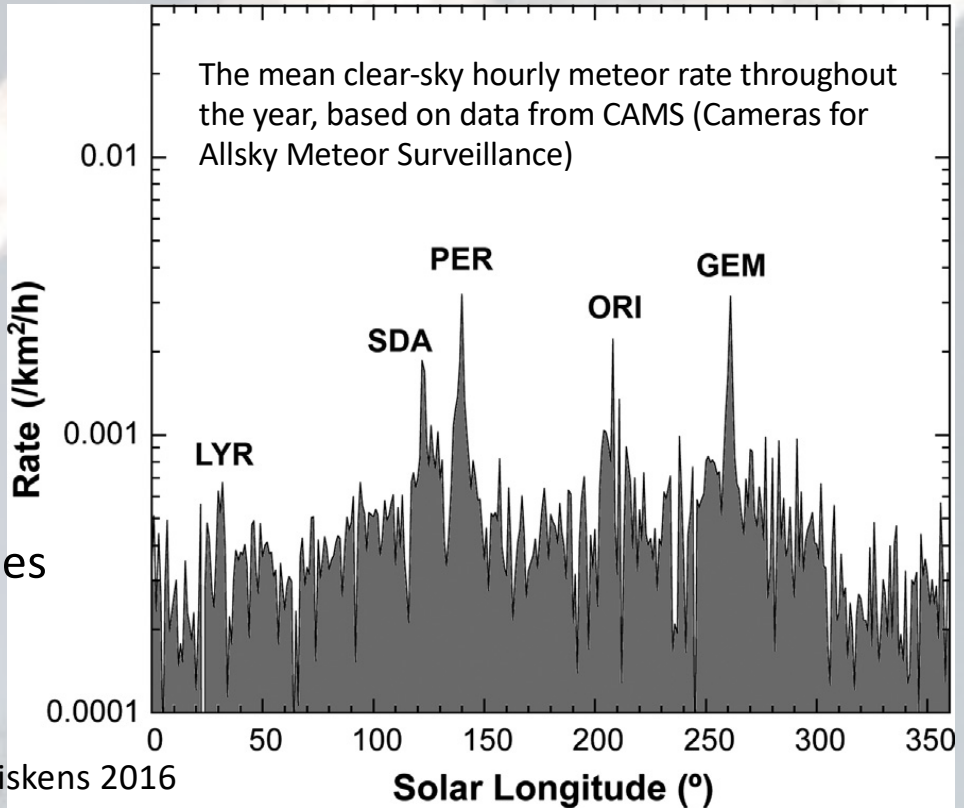
- The fraction of damaging falls as a proxy for the fraction of the urban land covered by buildings.

$$\frac{\text{Area covered by buildings}}{\text{Area covered by urban land}} \approx \frac{\text{Number of damaging falls}}{\text{Number of registered falls}} \approx 1/4$$

Meteor showers

Meteor showers are formed by particles released by a comet. Small particles spread around the nominal orbit due to non-gravitational effects.





Note the peaks with values several times over the background

Jenniskens 2016

Is there any meteorite streams?

Meteor shower ≠ Meteorite stream

- Meteorite stream: a group of meteorites sharing a similar orbit
- Meteorite falls are produced by at least a few tons meteoroid (larger 1m).
- A few tons meteoroids are not affected by small particles non-gravitational forces: radiation pressure and Poynting-Roberston effect.
- Yarkovsky effect works in long-time scale.

- Recent Meteorite streams (if they exist) should be very compact

Why meteorite streams are relevant?

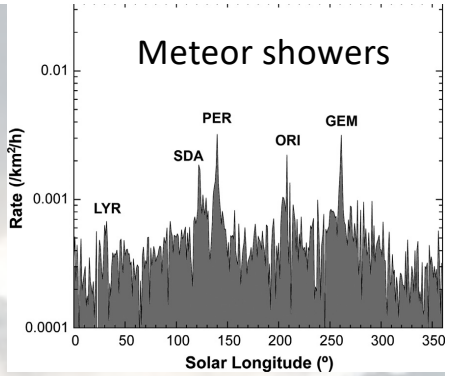
- If a meteorite stream exists, there should be a distribution of meteoroids with similar Earth-crossing orbits.
- An ensemble of hazardous objects.
- A much bigger one (hundred of m or km-size object) could exist.
- A dedicated search could be performed to look for the stream members (e.g. Micheli & Tholen 2015).

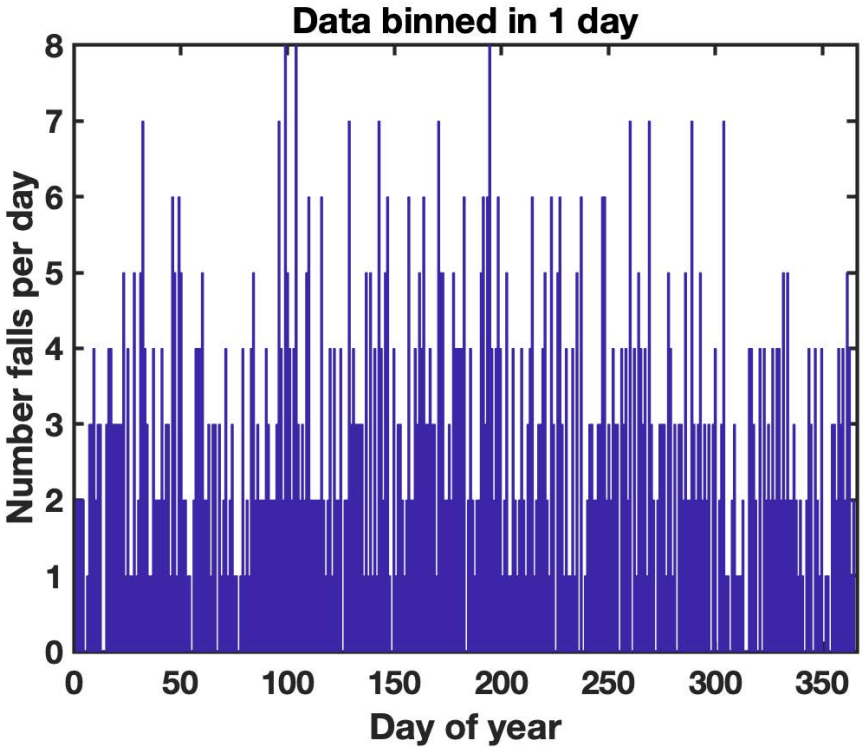
Databases to look for meteorite streams

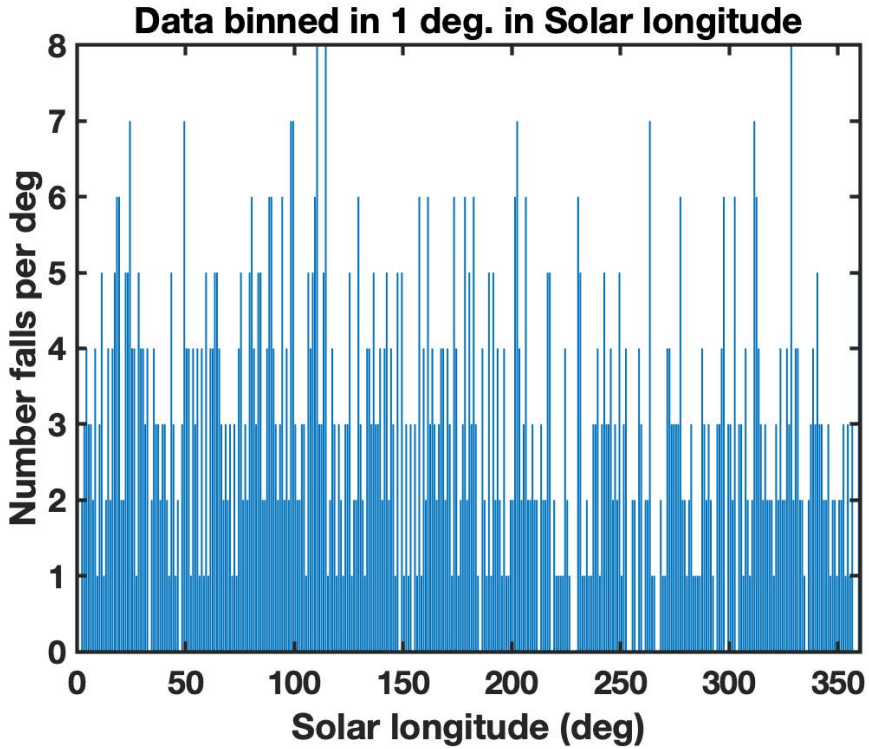
- IAU Meteor showers database: look for asteroidal orbits (~40)
- Meteorites with photographic orbits
- Meteoritical Bulletin Database
- Fireballs:
  - American Meteor Society
  - US Government Sensors

Using the Meteoritical Bulletin Database

- 1032 falls with confirmed dates (the students went through every record and checked the literature)
- 60 % of the falls are in s XX & XXI







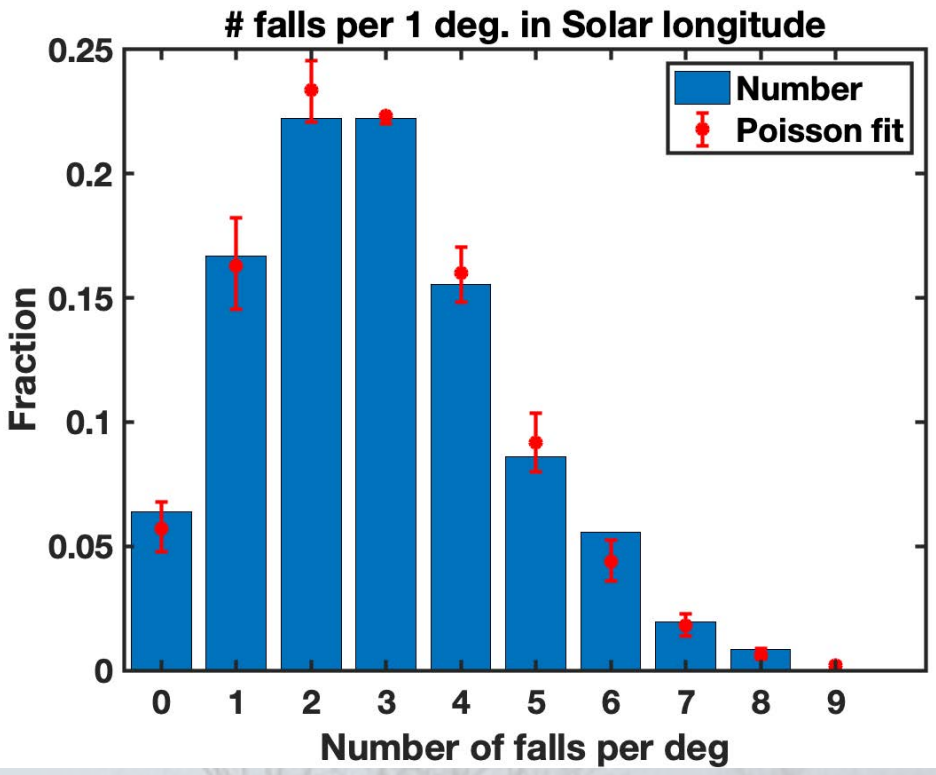
Meteorite falls: a Poisson process

- A Poisson point process has the property that each point is stochastically independent to all the other points in the process.
- Valid for counting the occurrences of random events at a certain rate.
- The probability that the number of events *N(t),* in a finite interval of length *t,* equals *n* is given by the Poisson distribution:

$$P\{N(t) = n\} = \frac{(\lambda t)^n}{n!} e^{-\lambda t}$$

- λ is the mean rate of events per interval t (e.g. number of falls per day or deg)

Meteorite falls: a Poisson process



The data was fitted with a Poisson distribution with

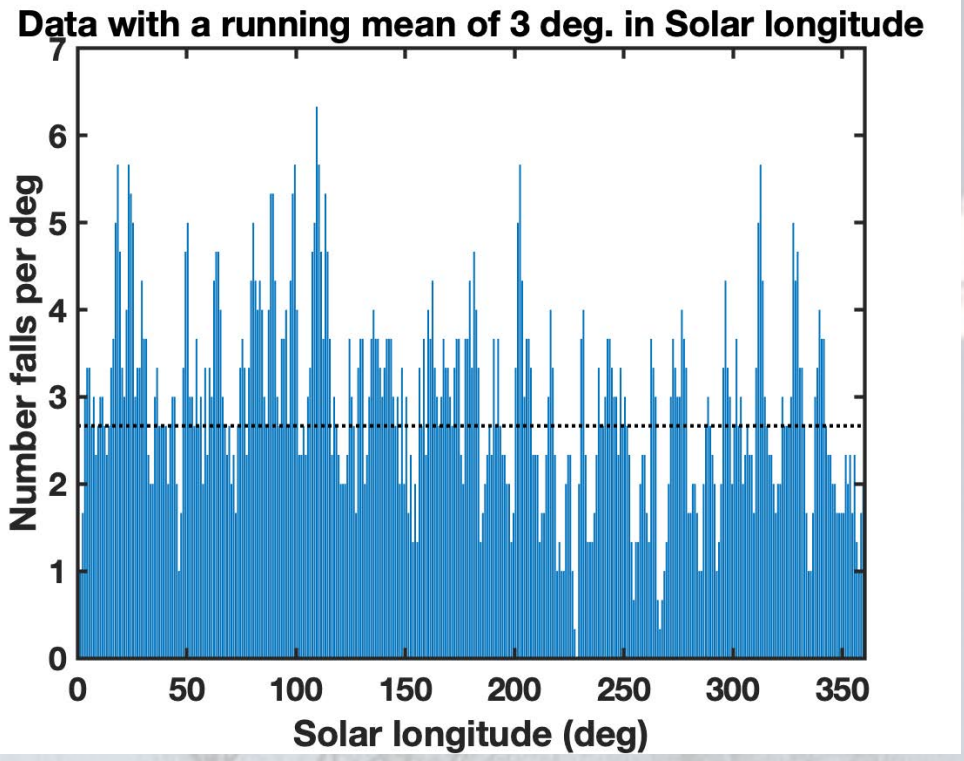
$\lambda = 2.89^{3.04}_{2.69}$ per deg.

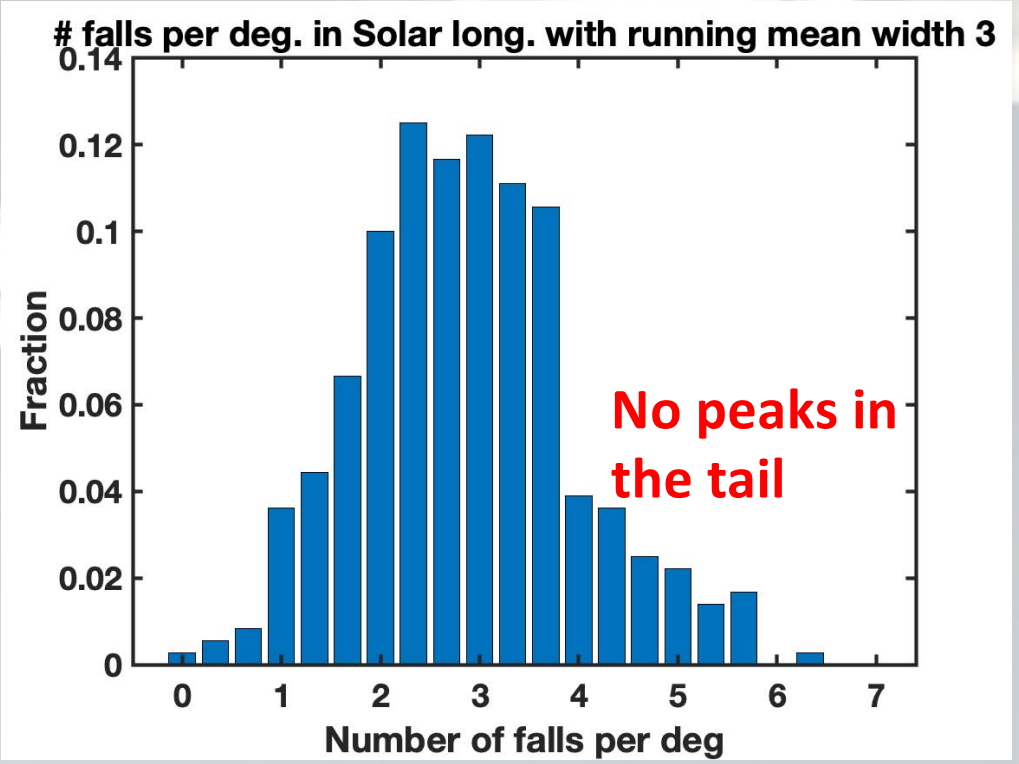
All the data points are within the error bars.

→ The meteorite falls occur randomly throughout the year.

- CAVEAT: The reports have a 1-day resolution, but a correction for the time difference has not been introduced.

Meteorite falls with a running mean





Poisson statistics can not be applied because the data points are not independent

Conclusions

- ~6100 meteorite falls per year over the entire Earth, and ~1800 over the land.

- There are several ~40 meteor showers with asteroidal orbits.
- There is no clear indication of an excess in the distribution of falling meteorites and fireballs with date or solar longitude.
- Heavily populated meteorite streams do not exist.

- There is no particular date of the year to be outdoors with a helmet.

There is no preferred date for Doomsday!