Flux de matière sur Terre avec LSST
micrometeors@LSST

M. Moniez, 21/06/2024

Scientific questions

- **Measure unbiased rate of particules entering atmosphere**

  the main source of matter income on Earth

  - Connect visual count of meteors with particle counts in the collections of micrometeorites
    - Mass distributions
    - Relation ablated mass / emitted light
  - Variation with time (seasonal and longer scale)

- **Directionality / velocity**
  - Dependence with the angle of the line of sight and the Earth orbital velocity
  - Study of known radiants (showers from comet dust) and search for new ones
  - Kinematical distributions (top of atmosphere velocities)
    - Orbitology: asteroidal vs cometary origin?

- **Processus of atmospheric re-entry** (light profile, chromaticity)

Rubin-LSST in a few figures

LSST = Large Survey of Space and Time

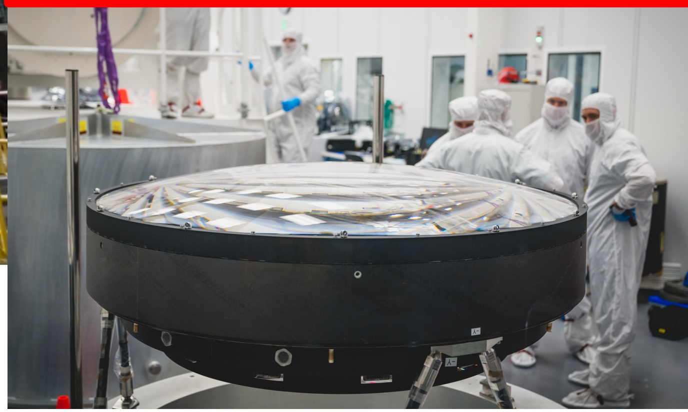
LSST Large Synoptic Survey Telescope

- Optical telescope **8.4 m diameter**
- Wide-field camera : **3.5°, 3.2 Gpixels**
- 6 wide-band filters **u g r i z y**
- Final catalogue: **10 years, 10^{10} galaxies, 10^{10} stars**
- 1,000,000 SNIa up to **z ~ 1**
- Transients with alerts (**10^7/night**)

~ **1000 scientists** in the world (**50% US**)

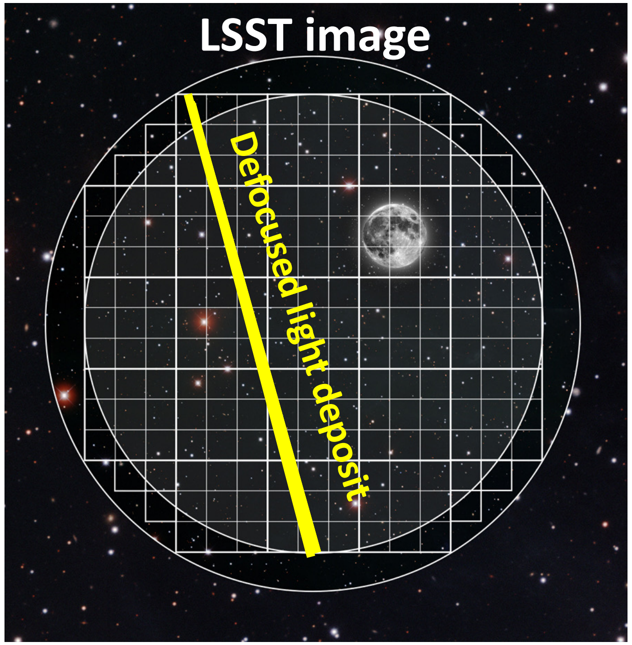
- Only **USA, Chile** (site) & **France-IN2P3** (builder since 2005) will have privileged access to all data

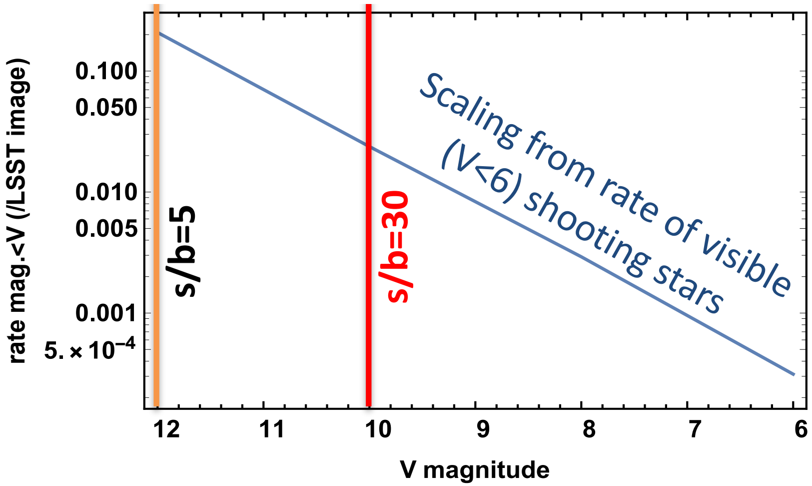

Mount commissioning (on-going work)

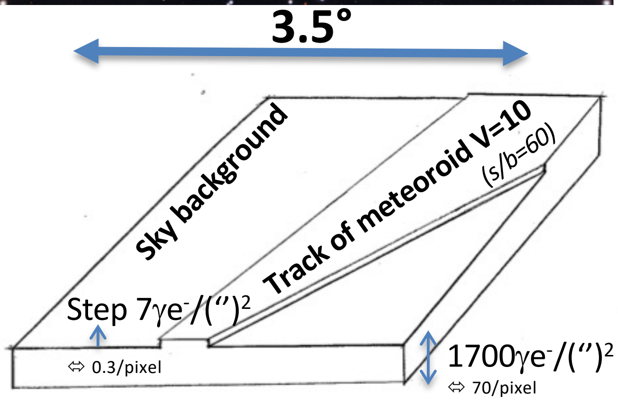


http://www.lsst.org/

micrometeors@LSST







Light trace crossing the LSST field

- <track length in LSST> = **2.75°** (10000 pixels) (4.8km at 100km altitude)
- Light deposited in ~ **0.16s**
- ***Out of focus***: 16'' (80 pixels) width@100km. Wider where object is closer
- Appears like apparent increase of sky background in a band

Conservative detection limit @LSST

Detection magnitude limit (30σ) of a meteoroid track of 2.75°x16''

u = 9.6; g = 10.8; r = 10.3; I = 9.8; z = 9.1; y = 7.7

(airmass = 1.2, no moon)

Event rate / faisibility

- Detection rate of **>25μg** micrometeors:

[1/40 – 10] per LSST image -> depends on extrapolation: shooting stars, micrometeorites flux or observed falls

- Needs analysis of (10x10pixels) rebinned LSST images taken during dark nights in **g** (no moon) -> **40Gb/night**

Science

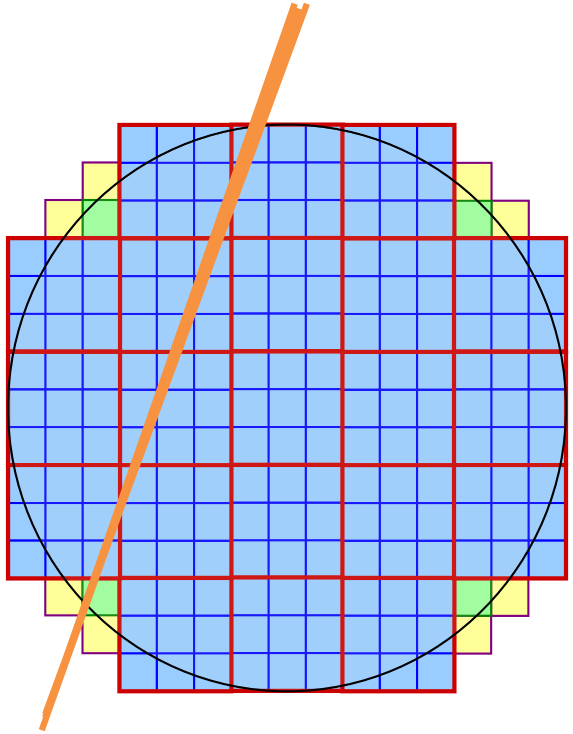
Unbiased rate of particules entering atmosphere, Directionality, Processus of atmospheric re-entry

Artifacts

- **Planes**: bright, dotted lines, stronger defocus
- **Satellites**: bright, dotted / uniform lines
- **Detector defects**: sensitivity to bright lines of the CCD -> x or y axis
- **Optics**: egrets, ghosts? A priori curved structures or known directions

Going further

- **More detailed feasibility studies**
  - Simulate meteor tracks on a LSST-type image and study detection as a function of peak magnitude.
    - Variable light profile
    - Possibility to find the origin (defocus increases with time)
    - Emission spectrum
  - Estimate data management / computation costs
  - Refine strategy: use only darkest nights, focus on g filter…
  - Precursor studies on archived images (PanSTARRS, ZTF… Any wide field camera)
- All these studies mainly need **manpower** with little money investment but a limited computing support



COMPLEMENTS

Challenges

- **Process LSST images** (20 Tbytes/night)
  - Because of defocusing, bin the data (10x10 pixels)
    - 1 rebinned image would be 32Mpix (like a smartphone)
    - Limit to images with dark sky (and g/r filters?) -> divide data volume to process by ~5
  - > 40 Gbytes/night. **Sustainable**
- **Detection of (weakly) overluminous bands extended on several CCDs**
  - Hough transform on a merged image; consider also differential imaging

Detection limit / event rate

Signal ⇔ light deposited by a star during 0.16s
(instead of 30s), spread over the track on a single image

Noise: fluctuation of the sky background light
under the track (~ 7 photoelectrons/(”)) -> integrate

Detection magnitude limit (5σ) of a meteoroid track of 2.75°x16”:

- **u = 11.5; g = 12.7; r = 12.4; I = 11.7; z = 11.0; y = 9.8**

(airmass median = 1.2, low moon)

Detection magnitude limit (30σ) of a meteoroid track of 2.75°x16”:

- **u = 9.6; g = 10.8; r = 10.3; I = 9.8; z = 9.1; y = 7.7**

(airmass median = 1.2, low moon)

Event rate (1): from shooting stars

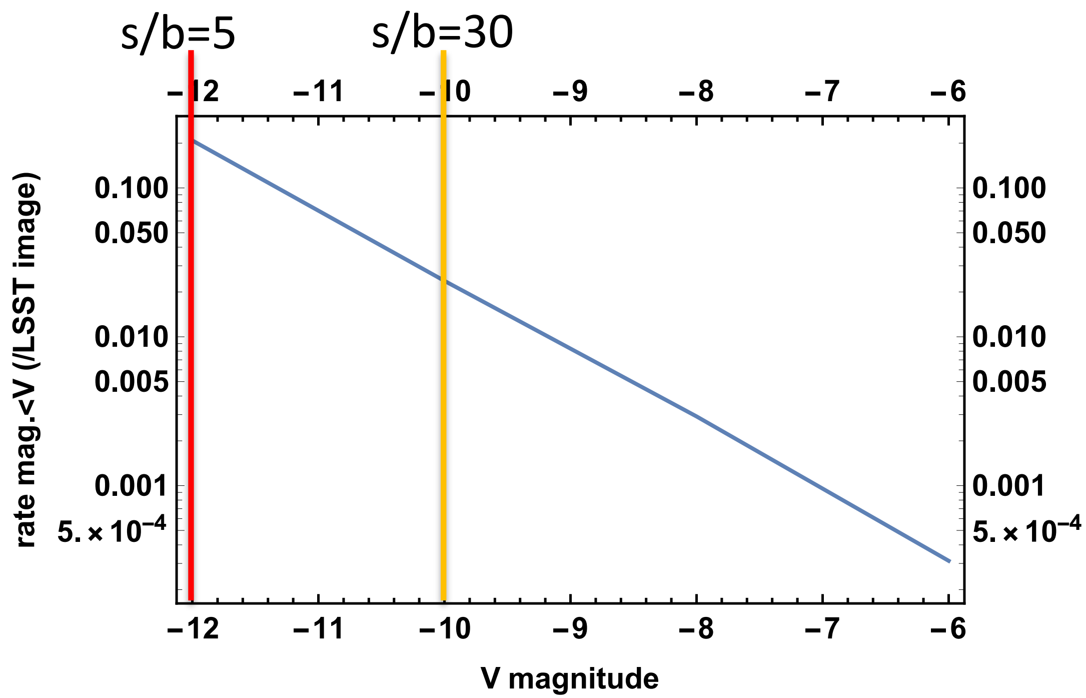
Scaling from the rate of visible (V<6) shooting stars (0.075/hour in LSST)

(*Jérémie Vaubaillon*)

⇒ **1 per 5 exposures** of 15s with V<12 within the LSST field (1/2143 of the visible sky)

⇒ Above LSST detection limit for all filters

⇒ **0.025/exposure**
with mass > 25μg (V<10)

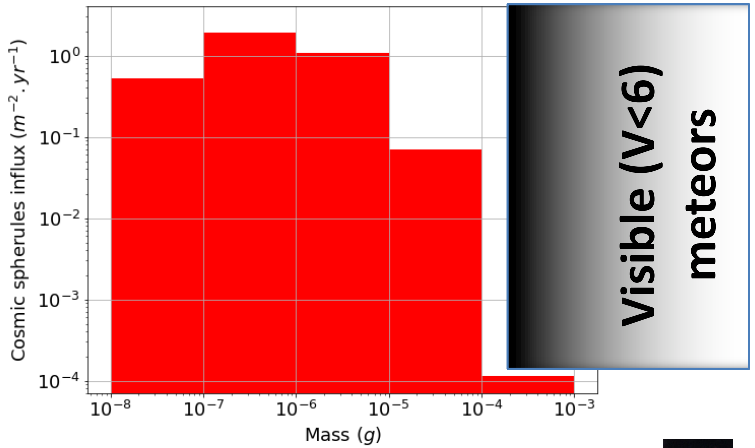


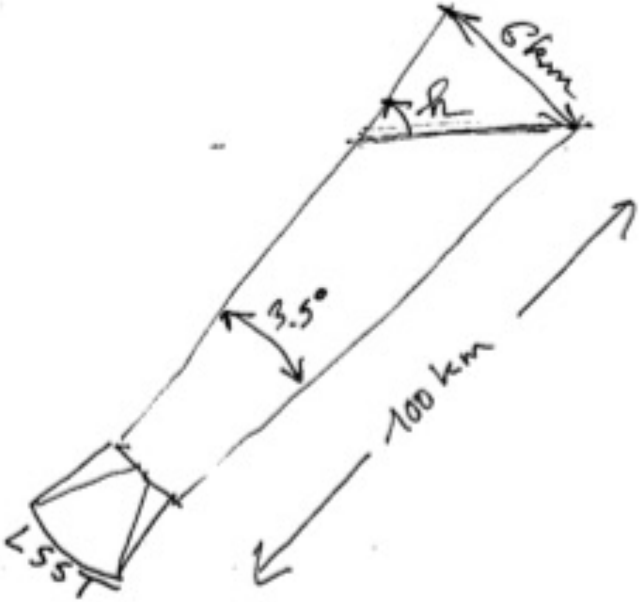
Event rate (2)
Link LSST <-> micrometeorites counting

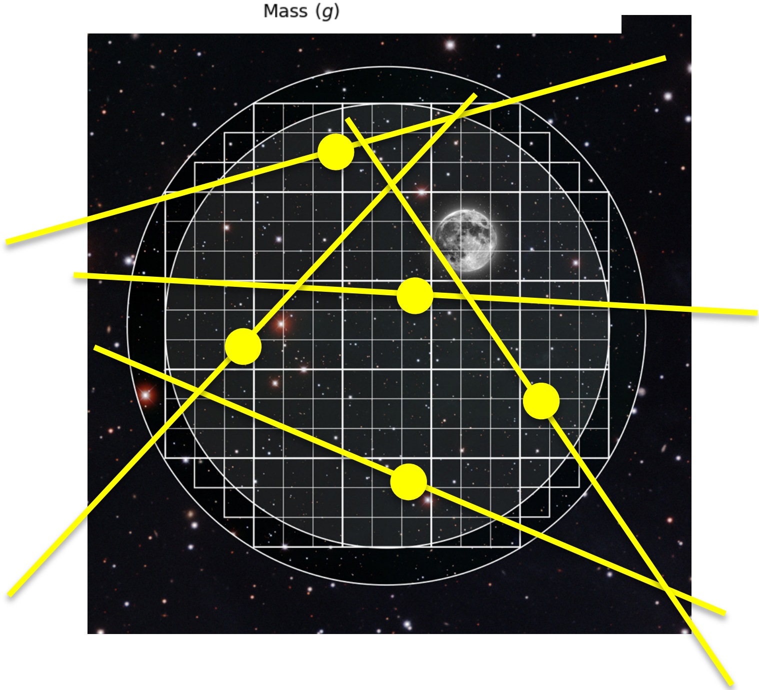
- From counting: deposition rate / time unit / surface unit (@100km altitude)
- (pessimistic) hypothesis:

  \# of tracks in LSST field =

  \# of spherules in the surface covered at 100km altitude ($30km^2/\sin h$)
- LSST 15s exposure > $14m^2.yr$







Event rate (2): from micrometeorite flux

Extrapolation from the estimated flux of micrometeorites

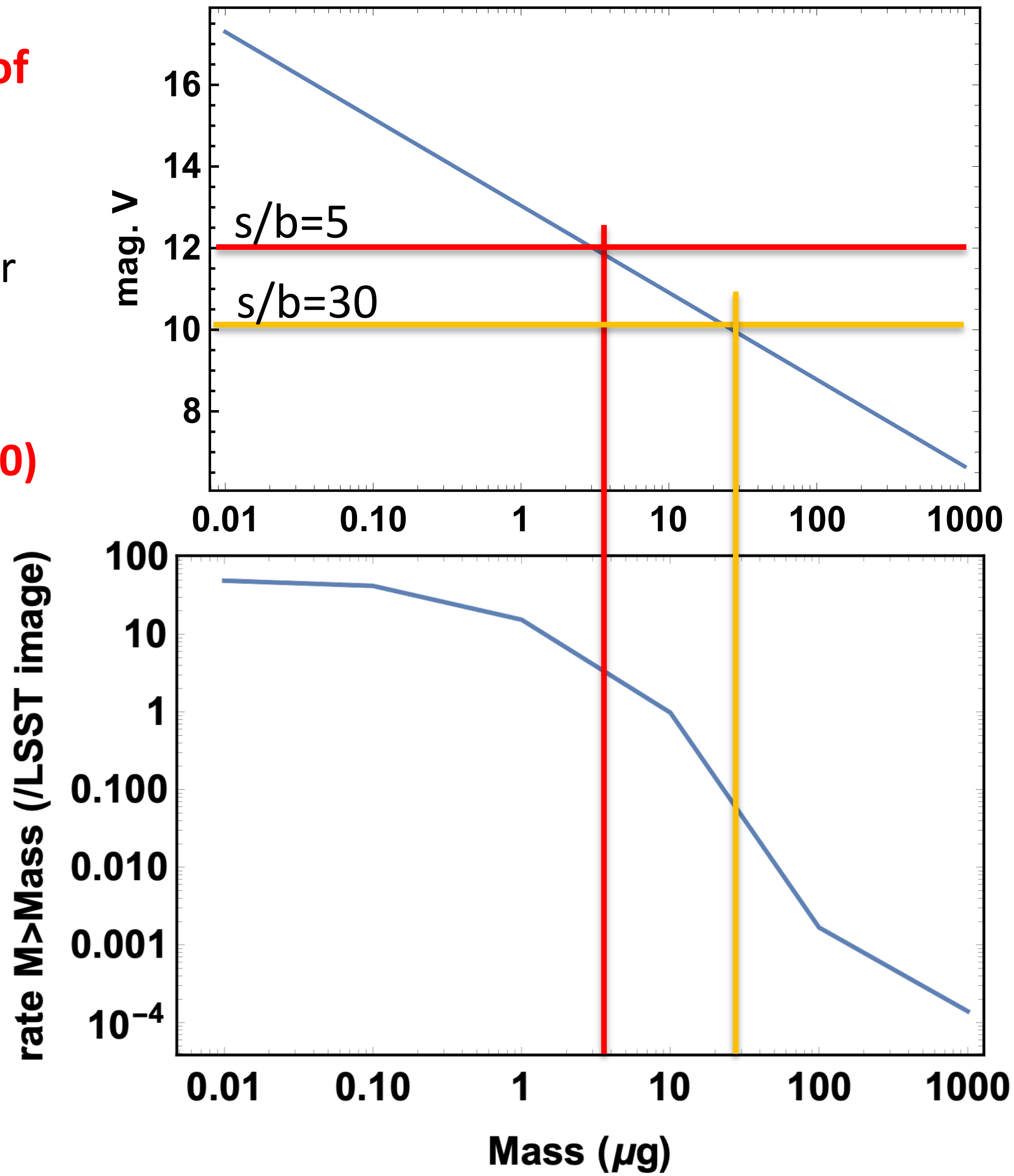
~ 0.3 spherule/m²/yr with mass> 3µg

⇒ 15s LSST ⇔ exposure of 14/sin(h) m²yr

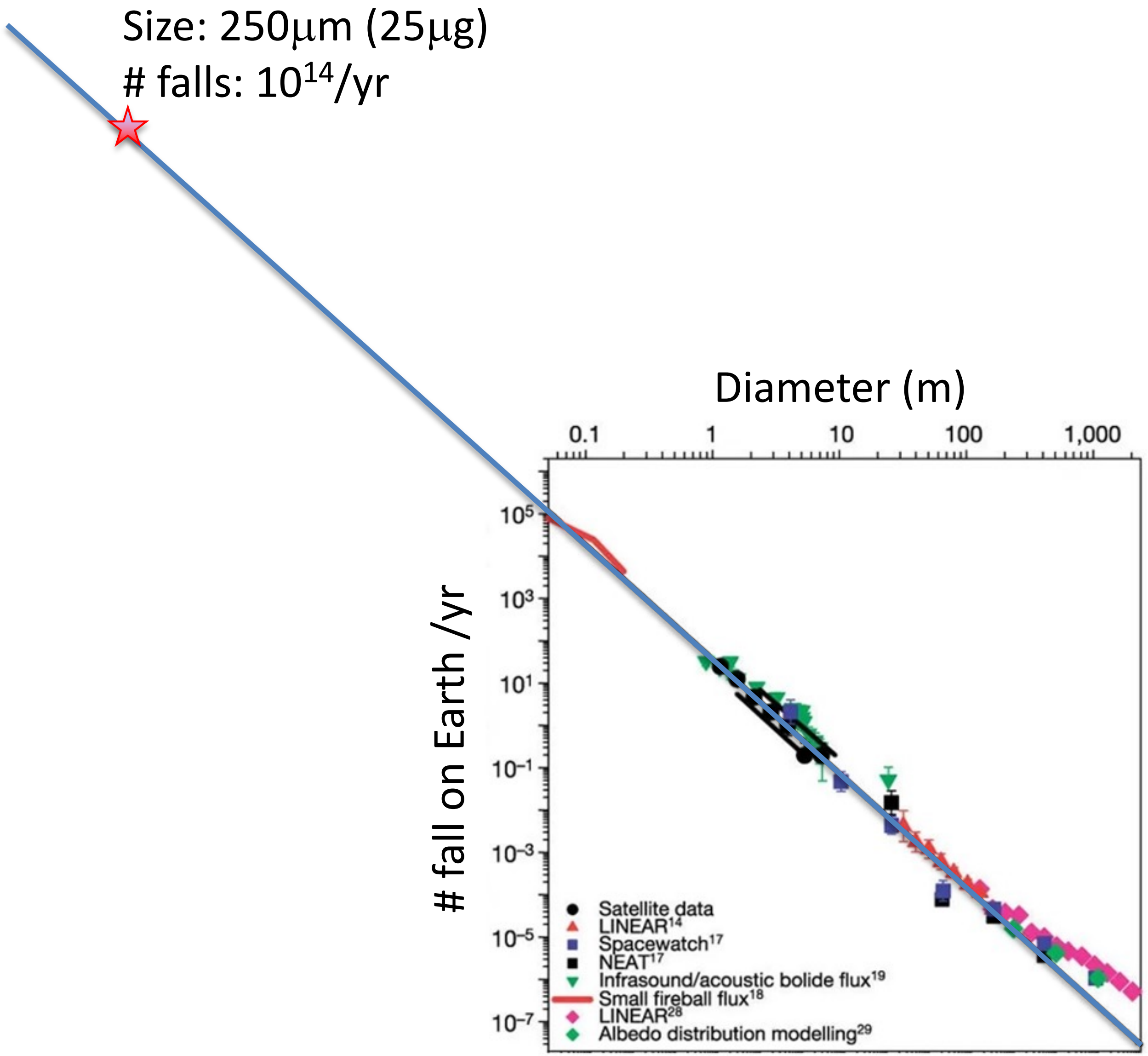
⇒ Expect **4 meteors** with mass > 3µg (V<12) **in each LSST 15s exposure**

OR **0.05/exposure with mass > 25µg (V<10)**

⇒ Reasonable excursion between the 2 extrapolations (<1 order)



Event rate (3): from observed falls

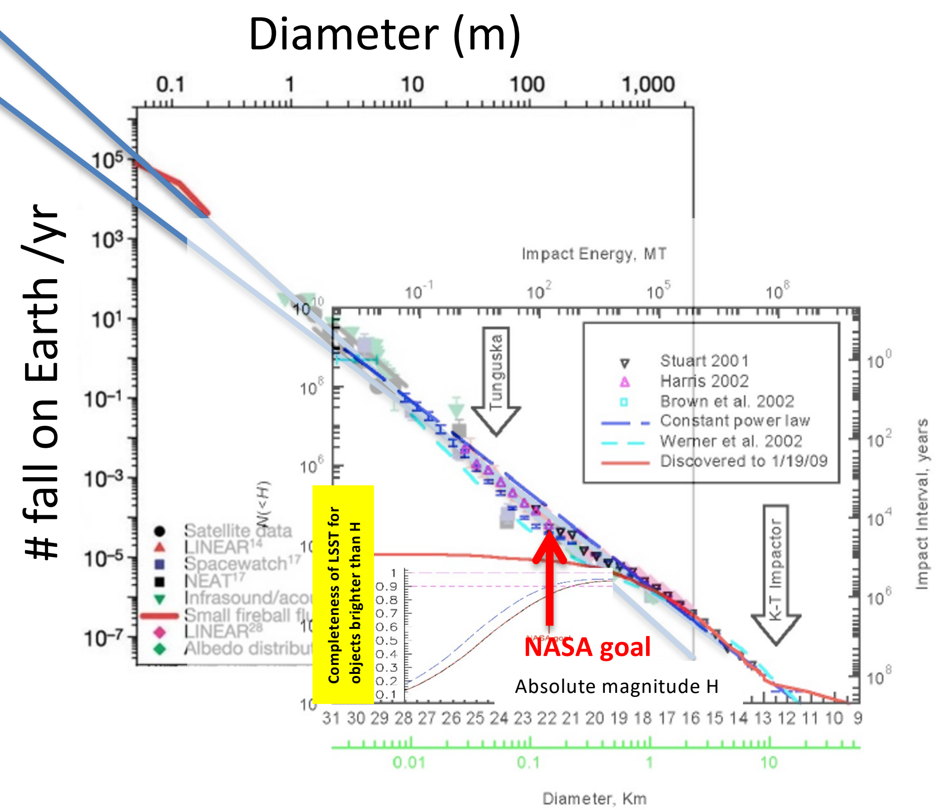


Brown et al, 2002

Event rate (3)

Size: 250μm (25μg)
falls: 10^{14}/yr

10^{12}/yr



- Scaling from the observed rate of individual falls
- Extrapolation meteors with V<10
  - High: 60 per LSST exposure
  - Low: **0.6 /LSST exposure with mass > 25μg**