Ab initio strewn field for small asteroid impacts

We can predict meteorite strewn fields before asteroids enter atmosphere

Background: The discovery of small asteroids few hours before impacting Earth – also called ***imminent impactors*** – is an increasingly frequent event, thanks to the efficiency of modern surveys for near-Earth asteroids (NEAs).

Soon after discovery, these NEAs are typically tracked by telescopes around the world until they enter the Earth shadow, after which tracking is not possible anymore. Thanks to this follow-up, it is often possible to accurately compute the pre-atmospheric **heliocentric orbit** and the entry point in the atmosphere with good precision.

We introduced a method to compute the ***ab initio strewn field*** of small imminent impactors **using only data from orbit determination** (Carbognani et al. 2025).

This method allows to organize **meteorite search campaigns** in areas not covered by all-sky cameras and can be used to **improve mitigation strategies** and communication in case of impact over a populated area.

The fall model

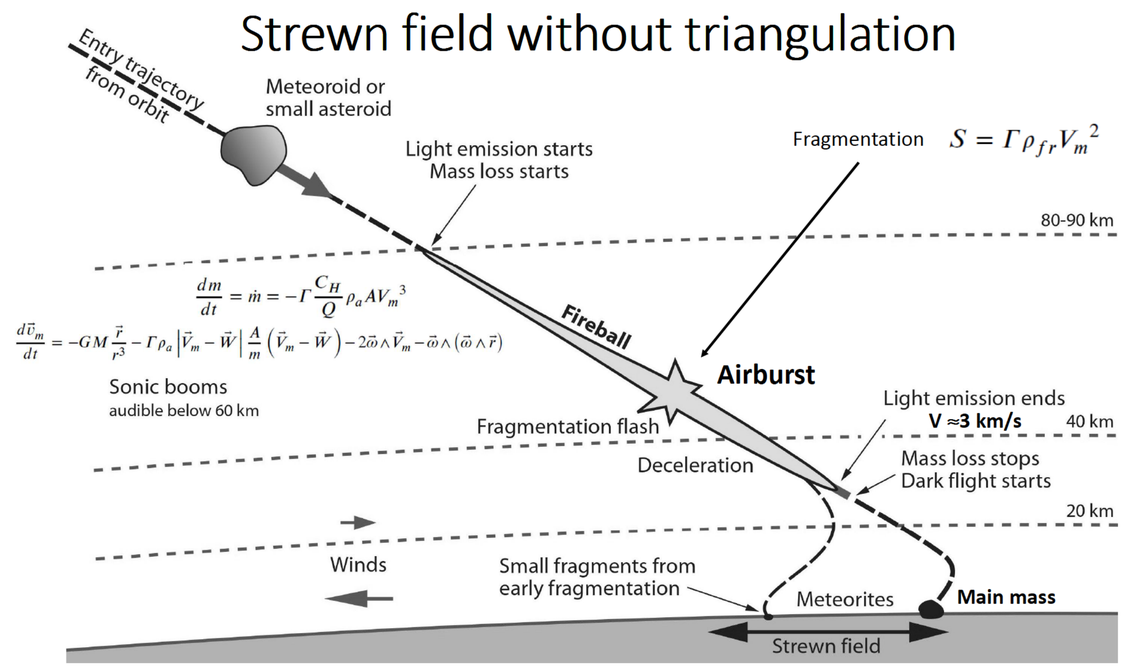

Fig 1 – The fall model of Carbognani et al. 2025 used for the dynamics of a small asteroid during the atmospheric phase. The entry point at 100 km altitude is computed by orbit determination. In the atmospheric phase the dynamics includes atmospheric drag and local winds, while the asteroid undergoes ablation and, eventually, fragmentation. Fragments of different mass follow different paths, and their locations on the ground form the *strewn field*.

Testing on past impactors

The model was tested with **2008 TC3**, **2023 CX1** and **2024 BX1**. Results showed **good agreement** between computed ab initio strewn fields and the locations of recovered meteorites, indicating that this model can be used to make predictions for meteorite search campaigns.

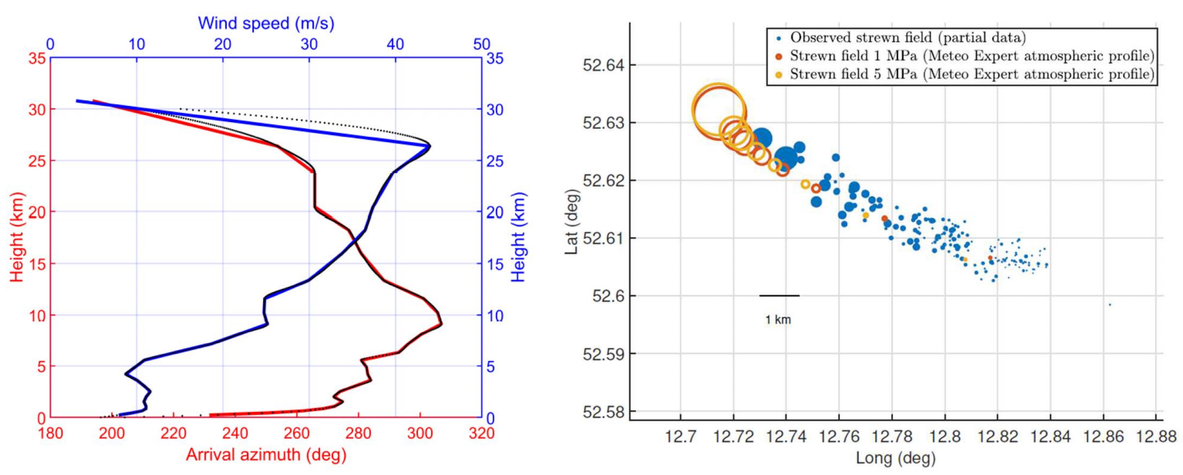

Fig 2 – Wind profile (left panel) and ab initio strewn field of 2024 BX1 (right panel), with location of recovered meteorites.

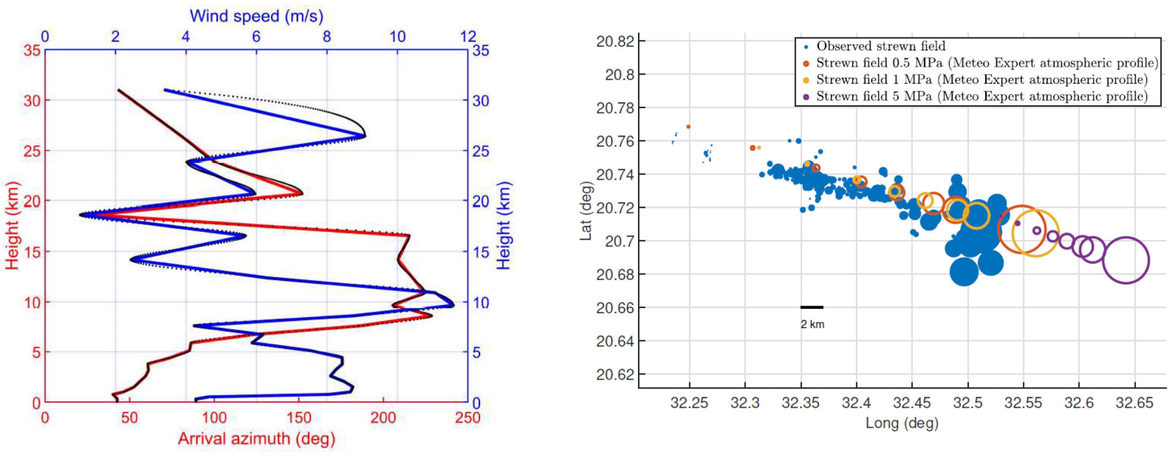

Fig 3 – Wind profile (left panel) and ab initio strewn field of 2008 TC3 (right panel), with location of recovered meteorites.

The fall of 2024 XA1

Asteroid **2024 XA1** was discovered on 3 Dec. 2024 about 10 hours before impacting over Russia. We were able to compute *live ab initio strewn fields* prior to impact. We also give the **final strewn field**, which can be used for future meteorite search campaigns (Gianotto et al. 2025).

Fig 4 – Asteroid 2024 XA1 during the atmospheric entry, as imaged by a live webcam in the town of Lensk (Russia).

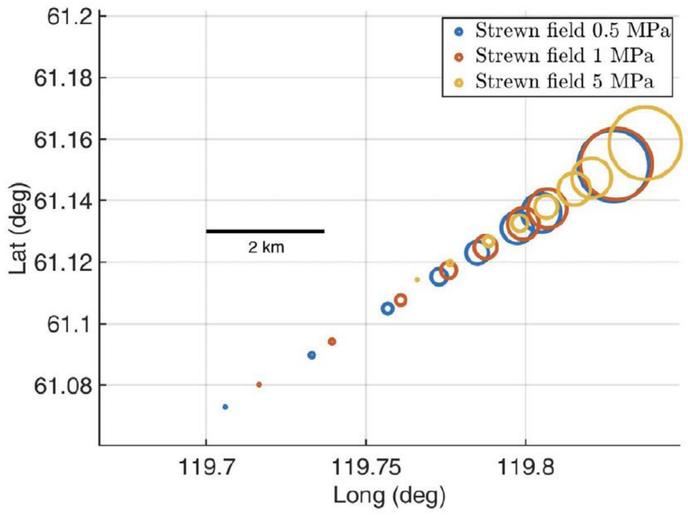

Fig 5 – The final ab initio strewn field of steroid 2024 XA1. A table with full coordinates of the estimated strewn field is available in Gianotto et al. 2025.

Scan QR code to access:

NEOCC Portal | Carbognani et al. 2025 | Gianotto et al. 2025

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