Ricerca di meteoriti con PRISMA

Daniele Gardiol

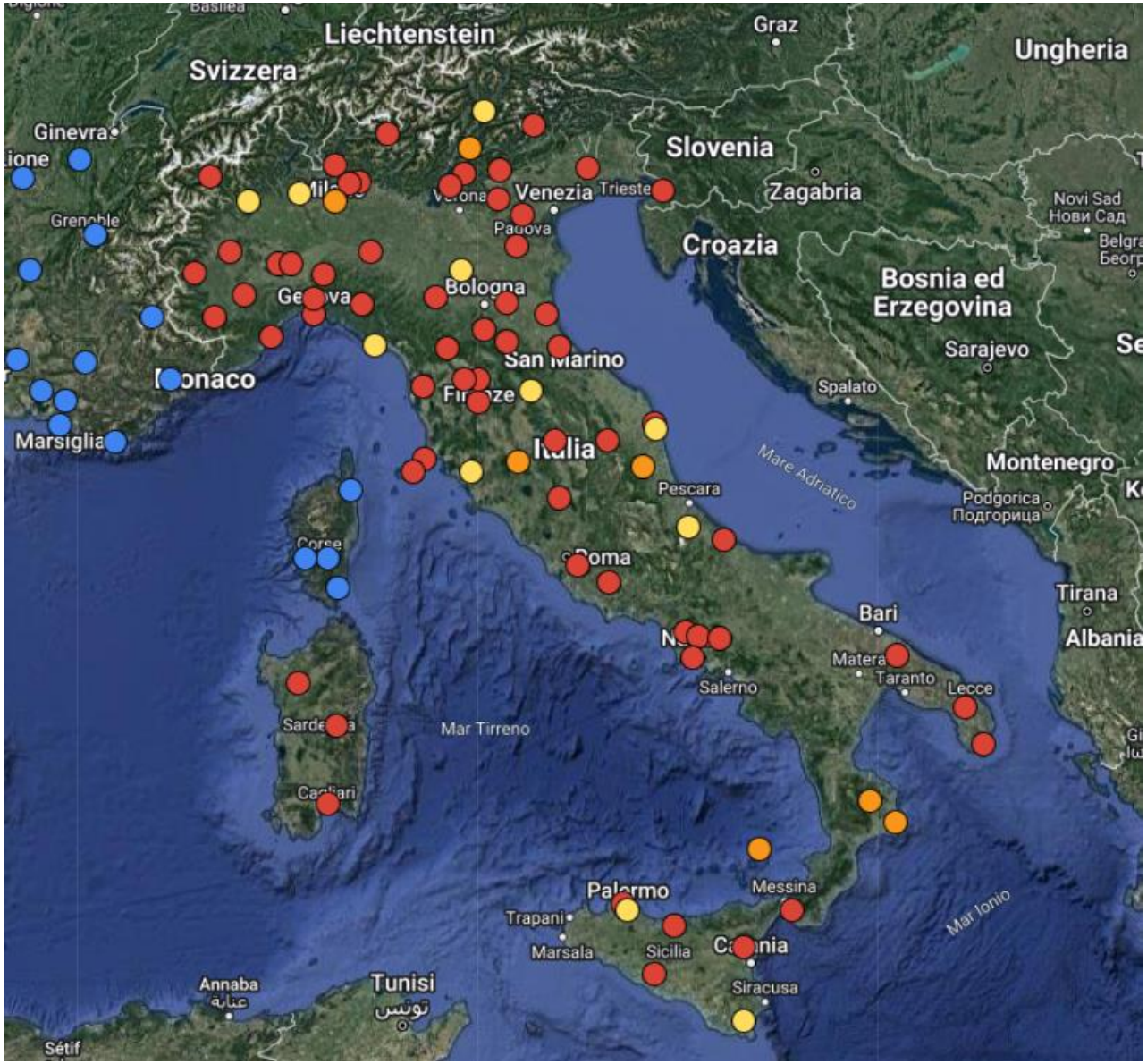
INAF - Osservatorio Astrofisico di Torino

PRISMA DAY 2022 – 25 novembre 2022

Progetto realizzato con il contributo di

Fondazione CRT

PRISMA in a nutshell



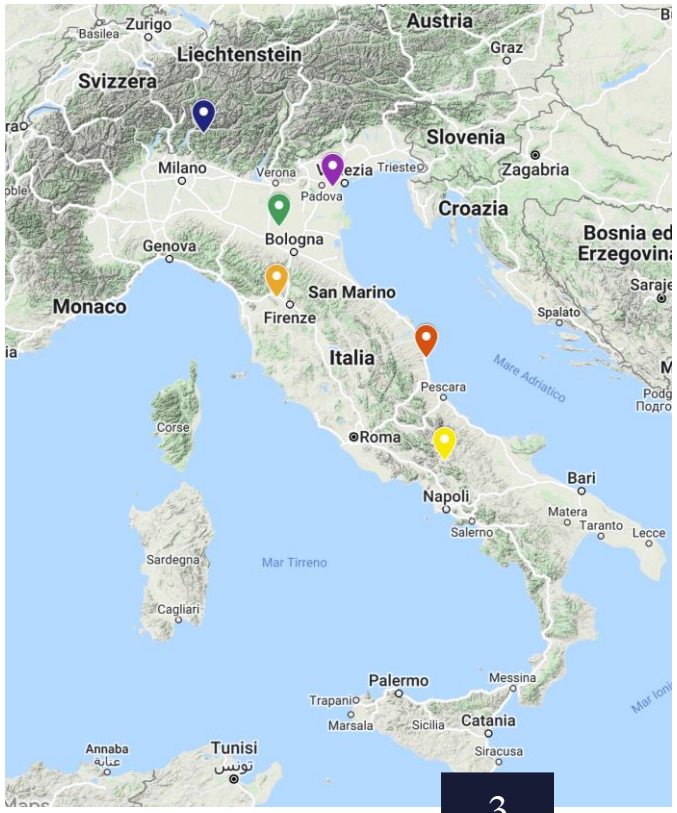
- **5 years of operations**
- 61 **operating** cameras, 7 in **installation** and 12 in **purchasing**
- More than **70 institutions** involved in the project
- More than **130 collaborators**
- More than **2500 observed bolides** in the Italian skies
- Server for **Data processing** (**CRAB** Pino T.se) and **Archive (IA2** Trieste)
- Complete **data reduction pipeline**
- **6** observed potential **meteorite-dropping bolides**
- **1 meteorite recovered** (Cavezzo, 2 fragments)

Recorded potential falls in Italy

- PRISMA has the potential to detect fireballs of **apparent magnitude $m < 0$** (for very dark observational sites, usually -1 is the limiting magnitude)
- This corresponds to a meteoroid size **greater than 1 cm** and mass **above few grams**
- At the same time, we would expect **1 meteorite-dropping fireball per year** over Italy.

So far, this estimation was confirmed

Date	Time UT	Region of fall	N° of cams	Speed [km/s]	Inclin. [deg]	Init. mass [kg]	Fin. mass [kg]
30/05/2017	21:09:26	Padova	2	15.5	29°	4 – 12	0.2 – 4
22/08/2018	21:37:28	Sondrio	6	17.9	72°	2 – 5	0.4 – 1.2
01/01/2020	18:26:54	Modena	8	12.2	68°	10 – 40	0.5 – 1.5
15/03/2021	19:57:32	Isernia	1	14.7	84°	~ 2	~ 1
01/10/2021	01:04:57	Pistoia	8	16.0	31°	3 – 8	0.01 – 0.1
05/03/2022	18:55:52	Ascoli P.	10	15.5	17°	10 – 90	0.3 – 1.5



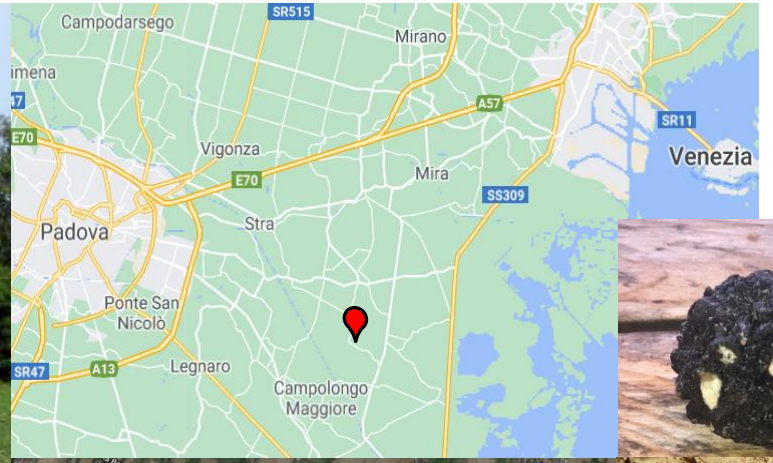
IT20170530 fireball

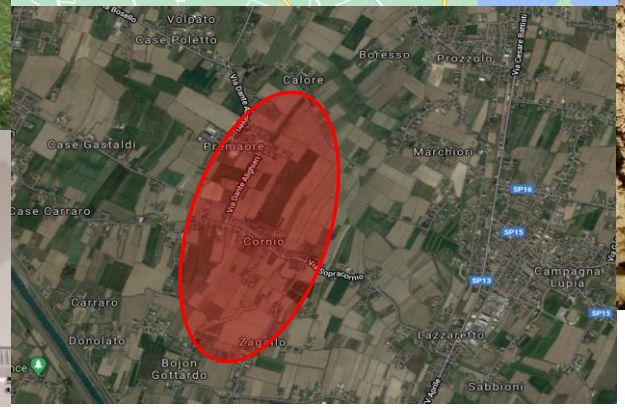
- Only five PRISMA cameras were operative at that time
- Recorded by **two PRISMA cameras** only, Rovigo and Piacenza (very low on the horizon)
- Triangulated also with two cameras (Casteggio and Contigliano) from IMTN – Italian Meteor and TLE network
- 9.5 s flight, **abs. magnitude -8.5,** no visible flares
- Beginning: 82 km height, entered at **~16 km/s** with **31° inclination angle**
- Terminal: 23 km height, went dark at ~3 km/s
- **Terminal mass ~ 0.2-4 kg**

More details can be found in:
Carbognani et al. (2020), *A case study of the May 30, 2017, Italian fireball*, Eur. Phys. J. Plus **135**, p. 255

IT20170530 strewn-field

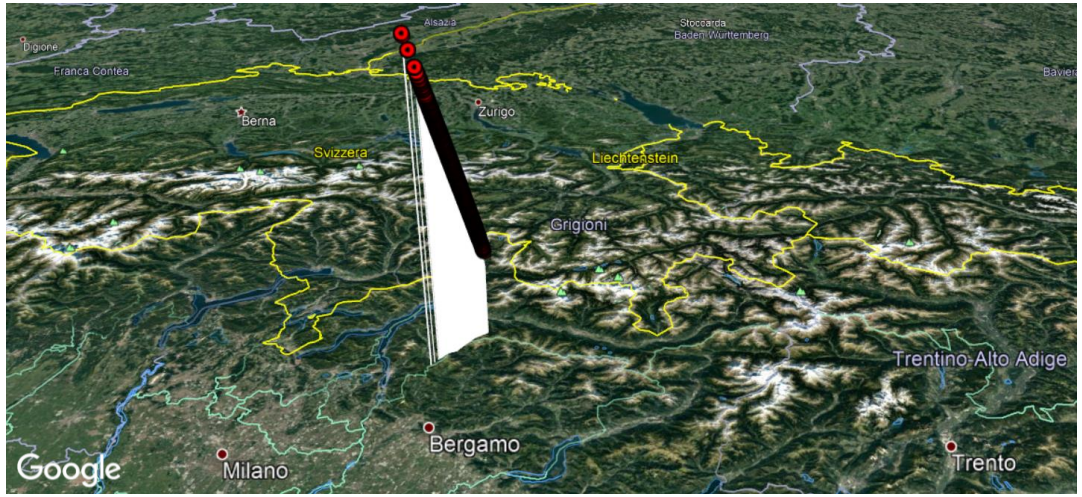
- The strewn-field is about **1.7 km x 0.6 km** around **Cornio** in the territory of municipality of Camponogara (Venezia, Veneto), mostly over cultivated fields
- Volunteers and hunters from PRISMA organized on-field search campaigns

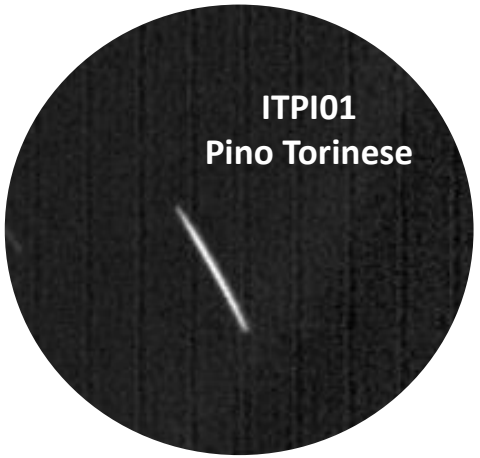




IT20180822 fireball

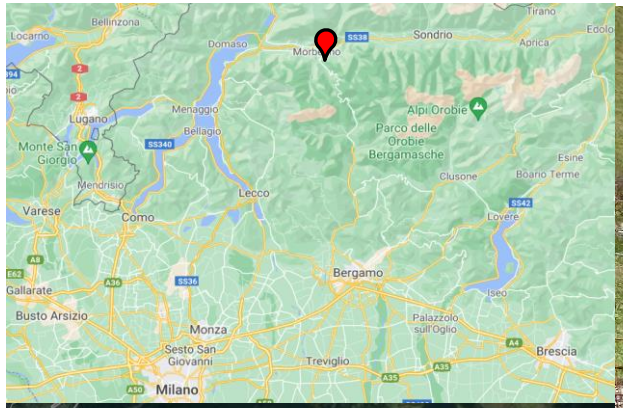
- Recorded by **six PRISMA cameras** (Alessandria, Brembate di Sopra, Piacenza, Pino Torinese, Ponte in Valtellina, Sormano)
- 4.4 s flight, **abs. magnitude -8**, no visible flares
- Beginning: 75 km height, entered at **~18 km/s** with **72° inclination angle**
- Terminal: 25 km height, went dark at ~4 km/s
- **Terminal mass ~ 0.4-1.2 kg**

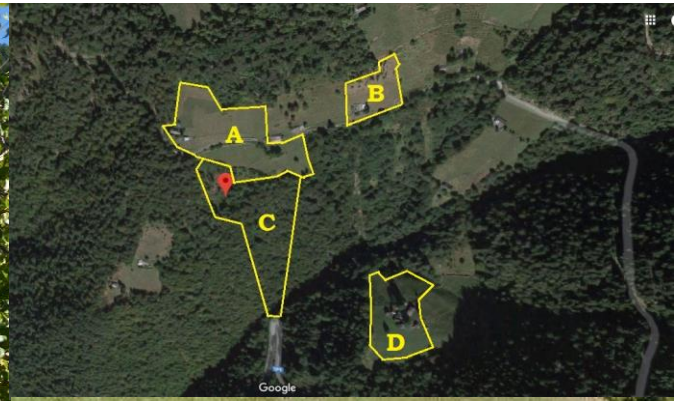




IT20180822 strewn-field

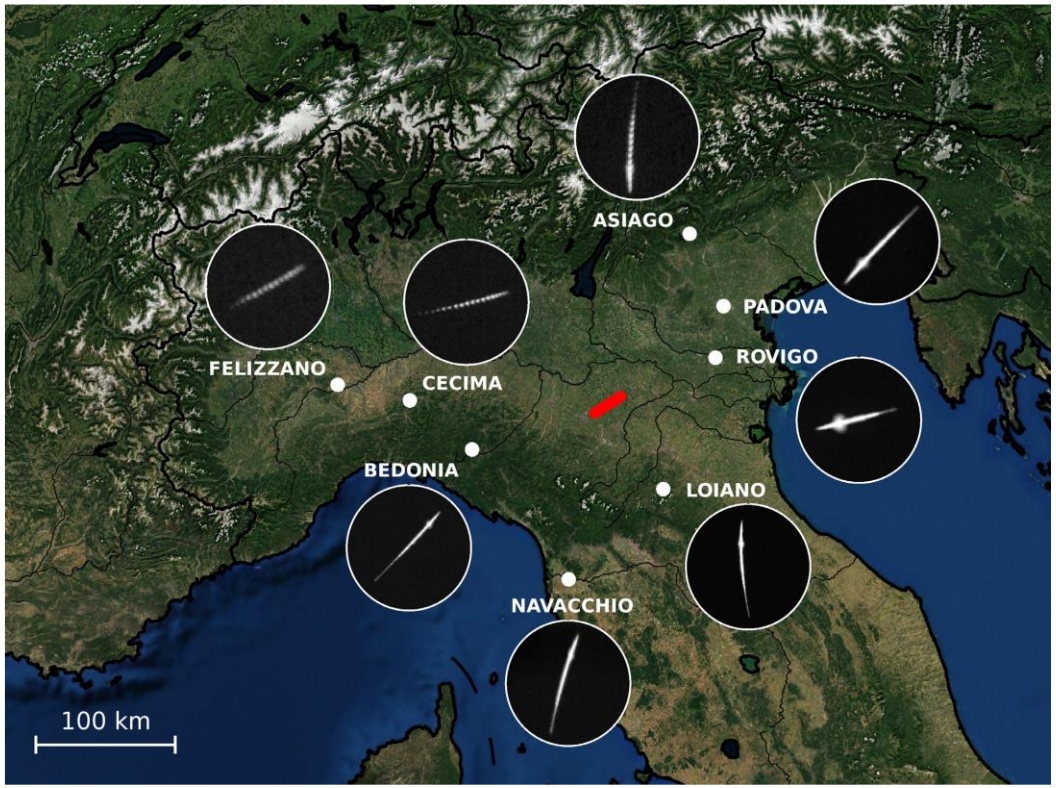
- The strewn-field is about **1.5 km x 0.5** km centered ~1 km East of the town of **Albaredo per San Marco** (Sondrio, Lombardia)
- On-site researches were unsuccessful. The strewn-field lies over an **impervious ridge of Alpi Orobie**, at 1000 to 1600 m altitude





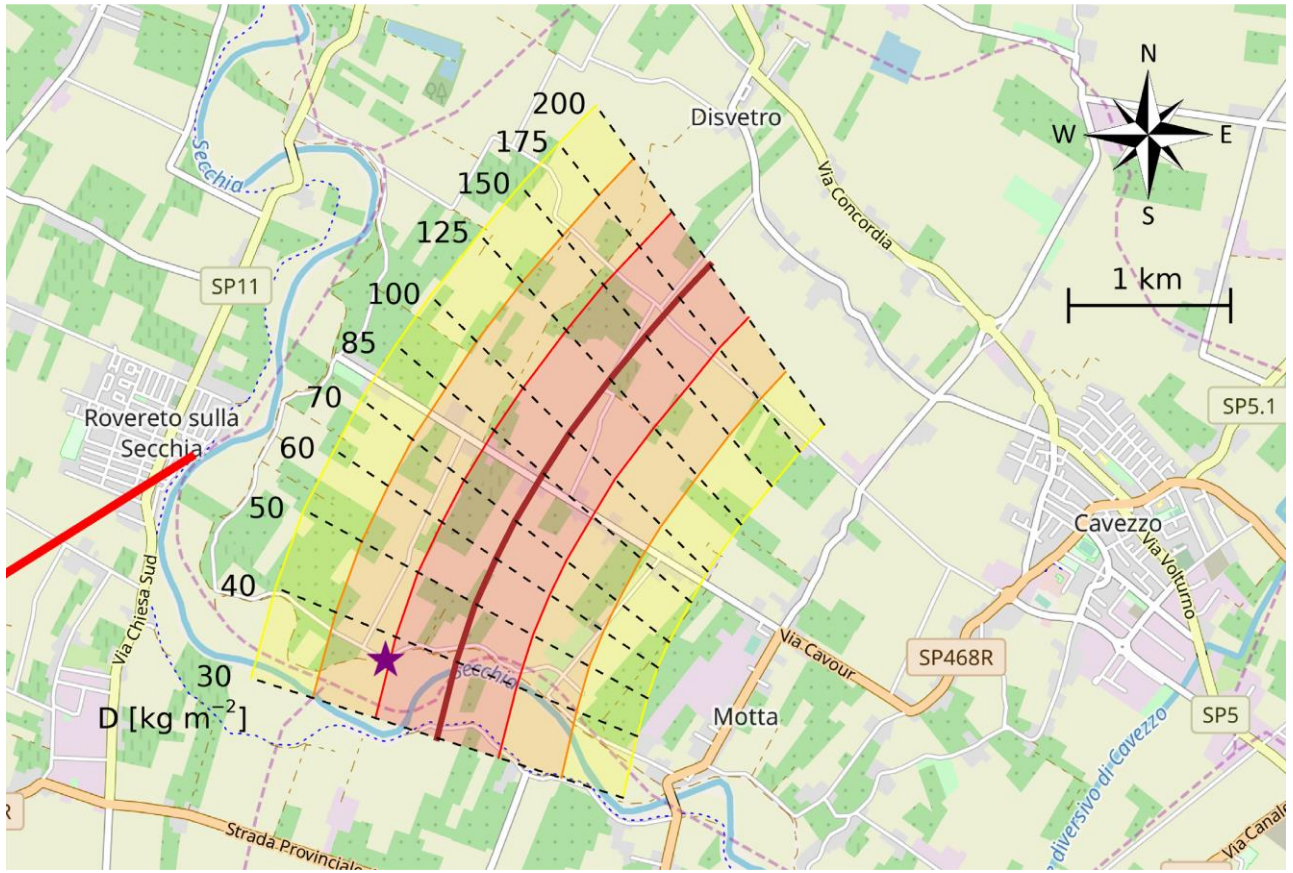
IT20200101 fireball (Cavezzo)

- Recorded by **eight PRISMA cameras** (Asiago, Bedonia, Cecima, Felizzano, Loiano, Navacchio, Padova, Rovigo)
- 5.6 s flight, **abs. magnitude -9.5**, two visible flares
- Beginning: 76 km height, entered at **~13 km/s** with **68° inclination angle**
- Terminal: 22 km height, went dark at ~4 km/s
- **Terminal mass ~1.5 kg**



Cavezzo strewn-field

- Due to **intense winds** of that night, the area of probable fall was shifted to East with respect to ground trajectory
- PRISMA informed and **reached the attention of the local population** by press releases. The event was extensively covered by local and national media
- **Two meteorite pieces** were recovered by a local inhabitant, Mr. Davide Gaddi, **less than three days after the fall** on the afternoon of 04/01/2020 in the municipality of Cavezzo (MO)



More details can be found in:
Gardiol et al. (2021), *Cavezzo, the first Italian meteorite recovered by the PRISMA fireball network. Orbit, trajectory, and strewn-field*, Mon. Not. R. Astron. Soc. **501**, p. 1215

Cavezzo recovery

In the **early afternoon of 4th January** Davide Gaddi send us an e-mail claiming the recovery of **two suspected meteorites**. We immediately organise a meeting with Romano Serra on the spot. The two fragments are indeed **freshly fallen meteorite fragments**.

[Prisma_po] Meteorite Posta in arrivo ×

Davide Gaddi [redacted] tramite inaf.it

a prisma_po

4 gen 2020, 15:

inglese › italiano Traduci messaggio Dis

Salve.. Ritrovato questo frammento in zona Disvetro_Rovere[redacted]chia in provincia di Modena. Dalle descrizioni si av
frammento di meteorite.. O sbaglio? Per informazioni o indicazioni 347997896.Grazie.Gaddi Davide

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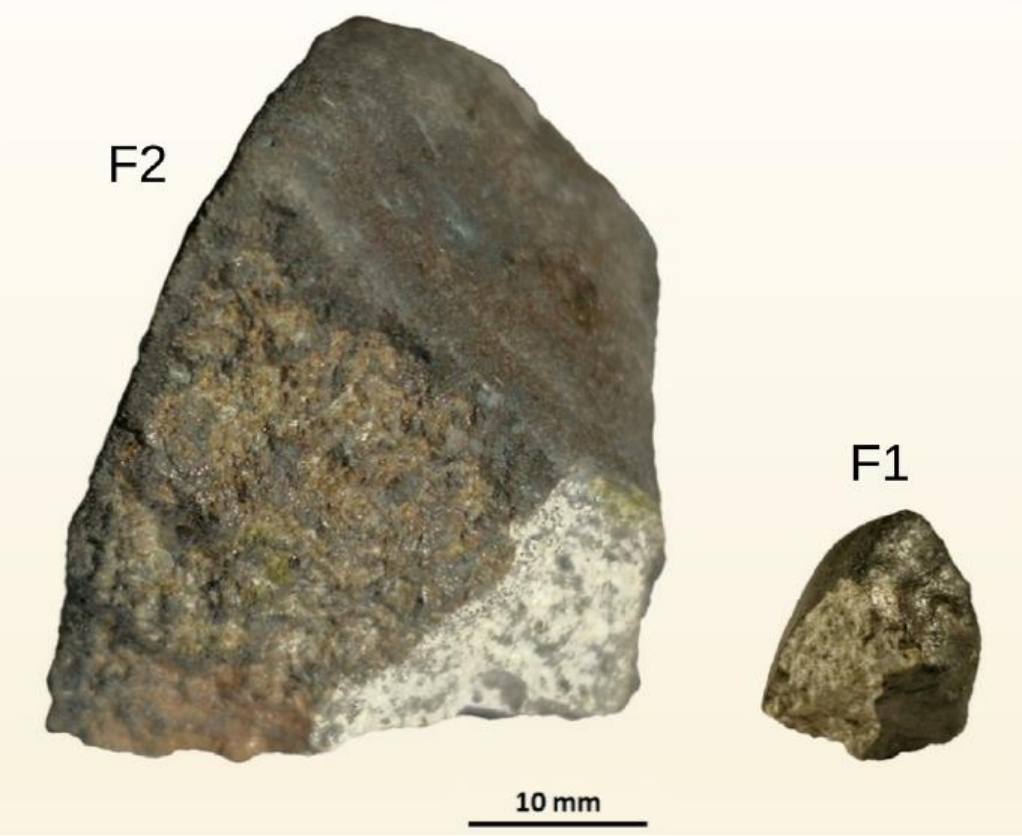
Prisma_po mailing list
Prisma_po@inaf.it
http://www.sedecentrale.inaf.it/mailman/listinfo/prisma_po

2 allegati

IMG-20200104-WA0012.jpeg
633 KB

Cavezzo recovery

The two fragments have been recovered along the **Secchia river**, near Ponte Motta, in the municipality of Cavezzo, fairly **inside the strewn-field** computed by the PRISMA researchers. The first fragment has been spotted by Pimpa.



Impact on the media

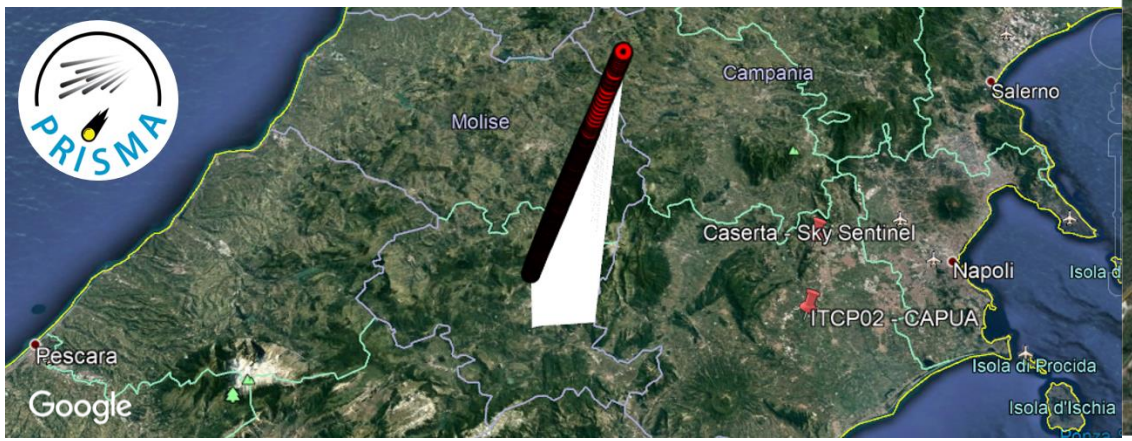
La notizia sul sito MEDIA INAF è stata **la più cliccata di sempre**, superando di oltre 5 volte i *click* della precedente notizia più cliccata (immagine del buco nero).

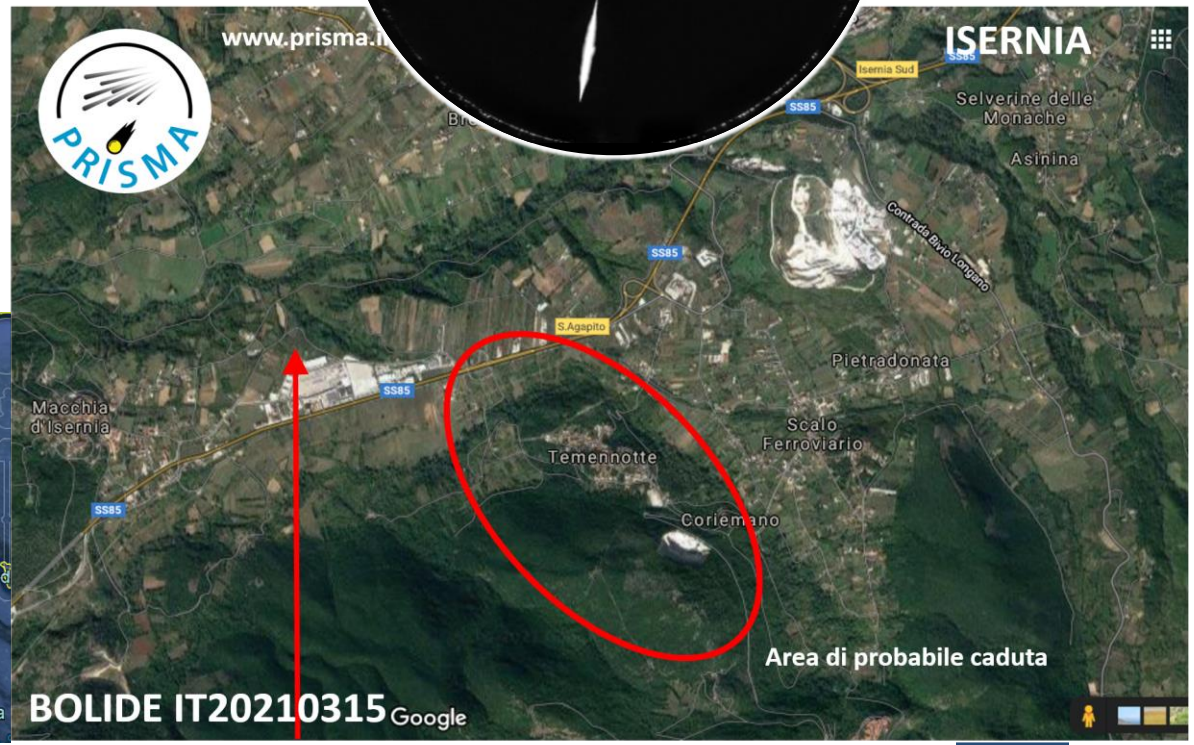
Presenza costante su TV, Radio e Giornali. *Highlights*:

- RAI1 – Superquark *(2.000.000 di ascolti)*
- RAI2 – I fatti vostri
- RAI3 – Tg Leonardo
- Notiziari: Tg1, TgR, Rainews, Tg5, TgCom24, SkyTG24, Studio Aperto
- Radio 2 – Il ruggito del Coniglio
- Radio 2 - Caterpillar
- Radio 3 Scienza
- Canale 5 – Pomeriggio cinque
- Testate giornalistiche: Il Messaggero, La Repubblica, La Stampa, Il Corriere della Sera, Il Giornale, Il Mattino, Il Secolo XIX, Il Resto del Carlino, Il Secolo d'Italia, ecc..
- Innumerevoli TV, Radio e testate locali e sul web

IT20210315 fireball

- Only one camera was operative that night in that region (ITCP02 – CAPUA). Triangulated with two cameras of Associazione Arma Aeronautica (Caserta) and IMTN (Tortoreto)
- 5.3 s flight, **abs. magnitude -9.5**, one faint flare
- Beginning: 80 km height, entered at **~15 km/s** with **84° inclination angle**
- Terminal: 20 km height, went dark at ~3 km/s
- **Terminal mass ~1 kg**





IT20210315 strewn-field

- The strewn-field is about 2 km x 1 km around the territory of **Temennotte** in the municipality of **Sant'Agapito** (Isernia, Molise)
- Following the success of the previous year with Cavezzo, PRISMA organized on-site search activities involving and informing the local population
- The event had an extensive media coverage on local and national newspapers, television and on the web
- Volunteers were asked to **track their researches via GPS** on their phones to know which parts of the strewn-field were already covered

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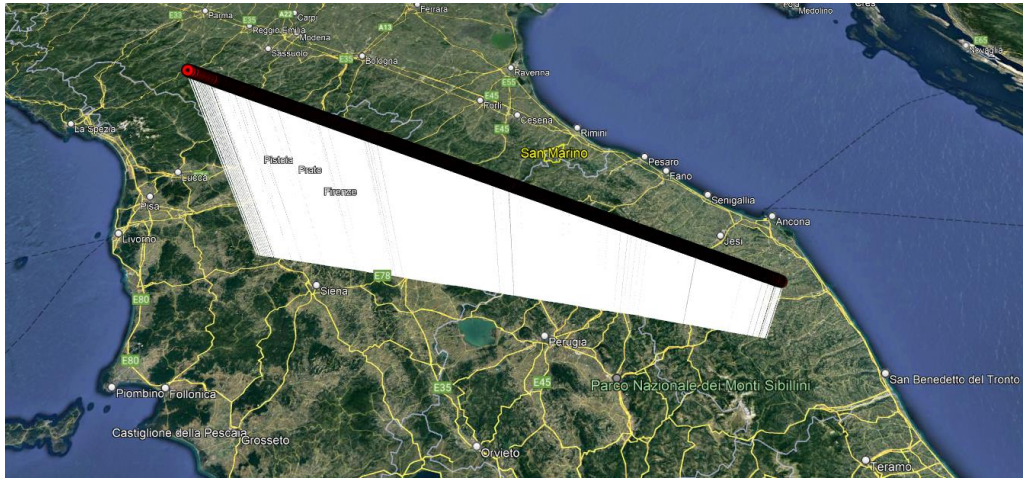
IT20211001 fireball

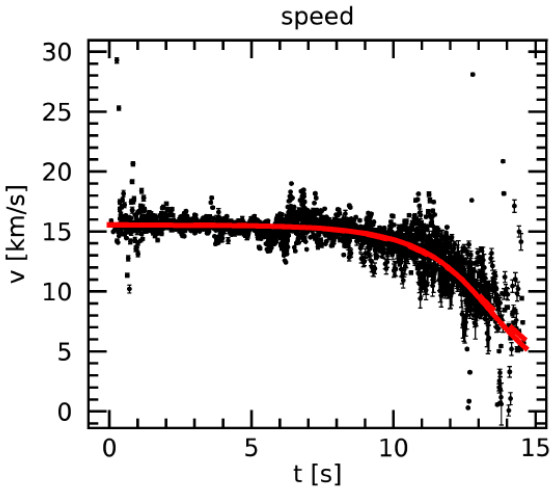
- Recorded by **eight PRISMA cameras** (Camerino, Cecima, Chianti, Navacchio, Perugia, Piombino, San Marcello Pistoiese, Scandiano)
- 6.3 s flight, **abs. magnitude -8.5**, with three visible peaks

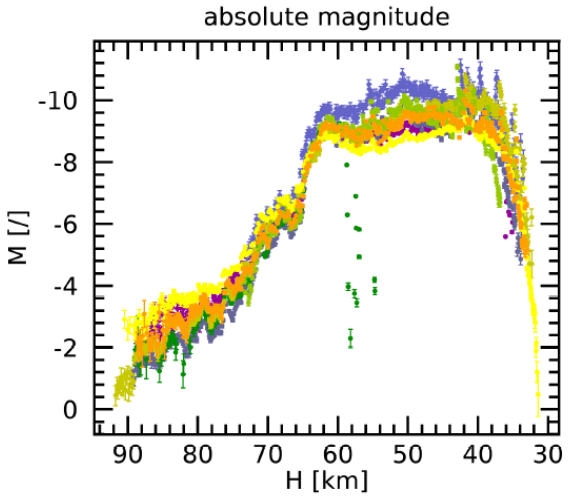
- Beginning: 77 km height, entered at **~16.6 km/s** with **32° inclination angle**
- Terminal: 32 km height, went dark at ~6 km/s

IT20220305 fireball

- Recorded by **ten PRISMA cameras** (Amelia, Arcetri, Chions, Loiano, Montelupo Fiorentino, Navacchio, Perugia, Ravenna, San Marcello Pistoiese, Vicenza)
- 14.7 s flight, **abs. magnitude -11**, with more than 5 visible flares
- Beginning: 90 km height, entered at **~15.5 km/s** with **17° inclination angle**
- Terminal: 32 km height, went dark at ~5 km/s







IT20220305 strewn-field

- Initial mass **10 – 90 kg**, estimated **20 – 30 cm** of size
- Final mass **0.3 – 1.5 kg**
- Due to the very low inclination, the **strewn-field is quite elongated** (~20 km) and half of it falls on the sea in front of **Cupra Marittima, Marche**. Also the nominal impact point falls into the sea.
- **On-field searches were unsuccessful**

Grazie per l'attenzione

Buon PRISMA Day a tutti!

Per le scuole

Istituti scolastici che partecipano a PRISMA

(attività svolte in collaborazione con i docenti, es: PCTO)

- Liceo Peano-Pellico di Cuneo
- Liceo P. Paleocapa di Rovigo
- Istituto d'Istruzione Superiore L. da Vinci di Civitanova Marche (MC)
- Liceo A. Issel di Finale Ligure (SV)
- Liceo Manzoni di Caserta
- Istituto d'Istruzione Superiore E. Fermi di Montesarchio (BN)
- Istituto Nautico di Crotone
- Istituto d'Istruzione Superiore Follador-De Rossi di Agordo (BL)
- Liceo Scientifico G.B Quadri di Vicenza
- Scuola Media Statale A. Pisano di Caldiero (VR)
- Istituto d'Istruzione Superiore Marie Curie di Savignano sul Rubicone (FC)
- Liceo Scientifico-Classico G. Stampacchia di Tricase (LE)
- Istituto d'Istruzione Superiore M.Ciliberto A.Lucifero di Crotone

Laboratori hands-on (didattica esperienziale).

Maggiori info nella sezione *Didattica* del sito web di PRISMA

Altri Istituti coinvolti in attività:

negli a.s. 17/18 e 18/19 **33 interventi** in

7 Istituti secondaria superiore

negli a.s. 19/20 e 20/21 oltre **80 interventi** in

10 Istituti secondaria superiore

4 Istituti secondaria inferiore

23 Istituti primaria

1 Scuola infanzia

nell'a.s. 2021/22 **89 interventi** in

3 Istituti secondaria superiore

5 Istituti secondaria inferiore

11 Istituti primaria

2 Scuola infanzia

Raggiunti circa 4000 studenti e 200 docenti

Per il pubblico

Conferenze rivolte al pubblico:

2016 e 2017: **14 interventi**

2018 e 2019: **18 interventi**

2020 e 2021: **26 interventi**

2022: **4 interventi**

Scuole di formazione: 4

PRISMA Day

2017 Firenze

2018 Bologna

2020 on-line

2022 Torino

Eventi, Festival, Mostre:

2016 e 2017: **12 eventi**

2018 e 2019: **3 eventi**

2020 e 2021: **4 eventi**

2022: **4 eventi**

Tra cui

Star Party St. Barthelemy (2016)

Festival dello Spazio di Busalla (2017, 2021)

Festival di Genova (2017)

Bergamo Scienza (2017)

Sito WEB:

www.prisma.inaf.it

Newsletter:

220 iscritti, c'è posto!

prisma.imo.net

Segnalazioni visuali

Finanziamenti e collaborazioni

FONTI DI FINANZIAMENTO:

2016: Contributo di Fondazione CRT (25 k€) – per acquisto prime camere e attività nelle scuole

2018: Cofinanziamento DS INAF (35 k€) – per borsa di dottorato triennale Università di Torino

2019: Contributo di Fondazione CRT (25 k€) – per realizzazione server analisi dati e attività nelle scuole

2020: Contributo di Fondazione CRT (20 k€) – per valorizzazione meteorite Cavezzo pubblico/scuole

2022: Contributo di Fondazione CRT (40 k€) – per sfruttamento scientifico database e

2022: Finanziamento DS INAF (35 k€) – per Assegno di Ricerca post-dottorato

Acquisto camere: finanziamento proviene da enti/istituzioni/associazioni/scuole che partecipano alla rete

Non esiste ad oggi uno specifico finanziamento da **INAF**

COLLABORAZIONI CON ALTRI PROGETTI DI D&D:

Sorvegliati spaziali – consulenza per meteore e meteoriti (3k€ stanziati per videopillole teatrali)

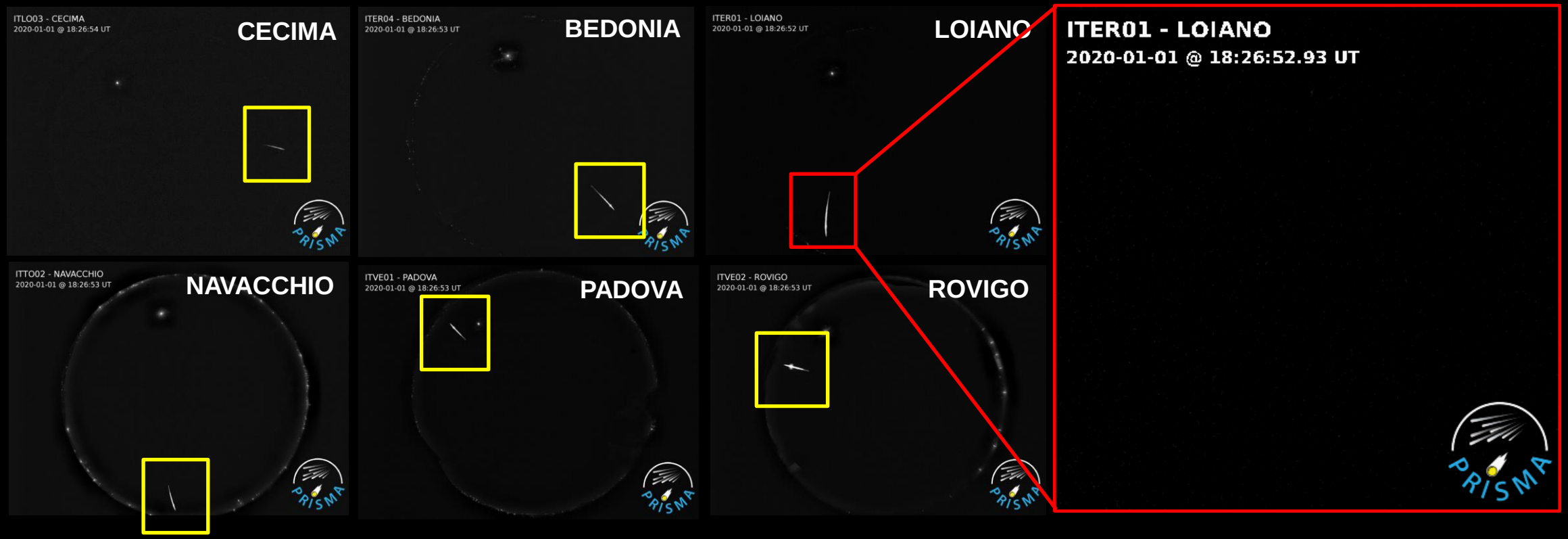
Gruppo Storie – collaborazione a progetto Rodari e realizzazione fumetto su PRISMA (1.5k€ investiti)

International Meteor Organization– collaborazione al sistema di segnalazioni visuali

Fripon – collaborazione con le attività di divulgazione del progetto francese

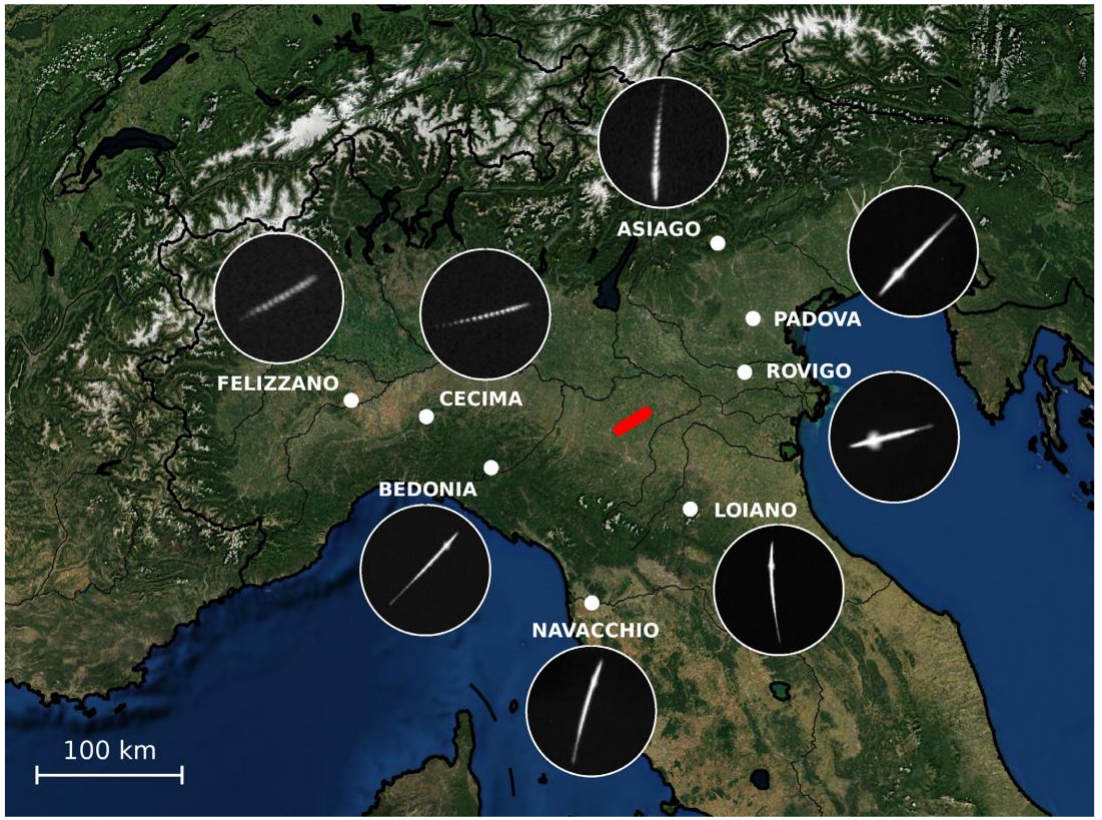
Il bolide di Capodanno 2020

Il 1˚ gennaio 2020 alle 18:26:53 UT otto stazioni PRISMA rilevano un brillante bolide nei cieli del nord Italia. Il meteoroide penetra fino a una quota di circa 22 km, indicando che c'è la concreta possibilità che dei frammenti siano giunti a terra



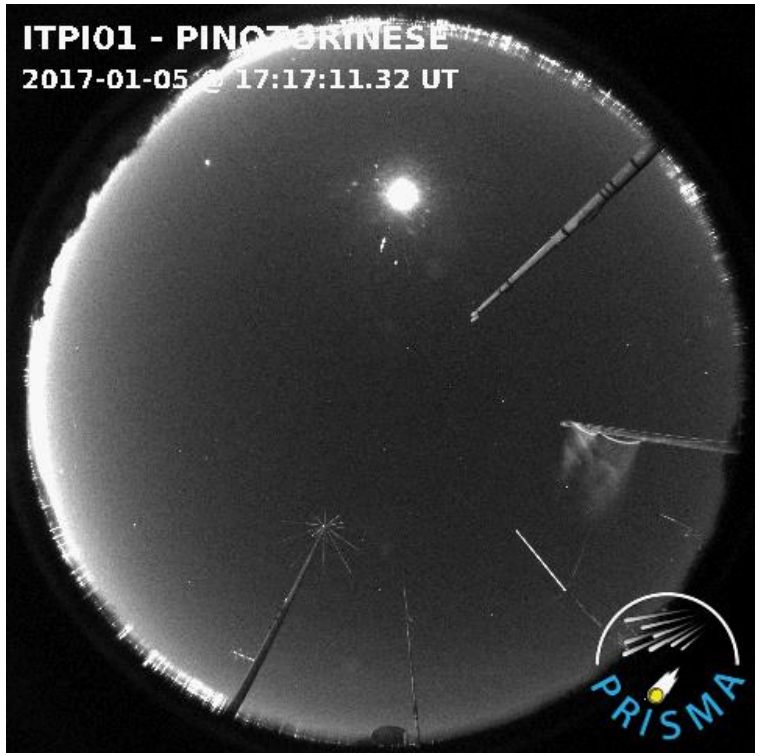
Il bolide di Capodanno 2020

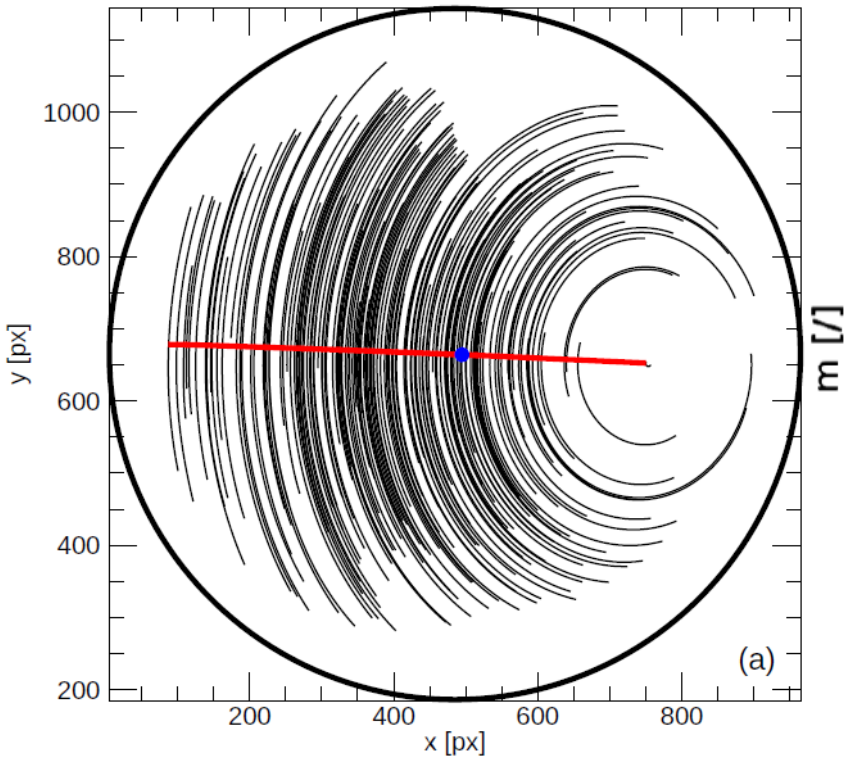
- Registrato da **8 camere PRISMA** (Asiago, Bedonia, Cecima, Felizzano, Loiano, Navacchio, Padova, Rovigo)
- Tempo di volo 5.6 s, **magnitudine assoluta -9.5**, due *flares* visibili
- Inizio: quota 76 km, velocità **~12 km/s** con **inclinazione ~68°**
- Fine: quota 22 km, velocità **~4 km/s**
- **Massa finale ~1.5 kg**

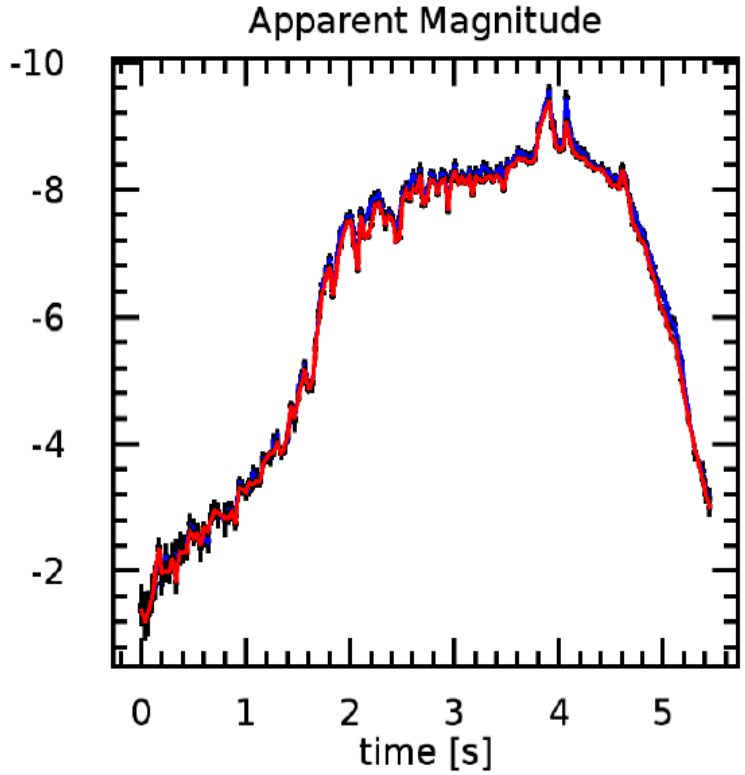


Astrometria e fotometria

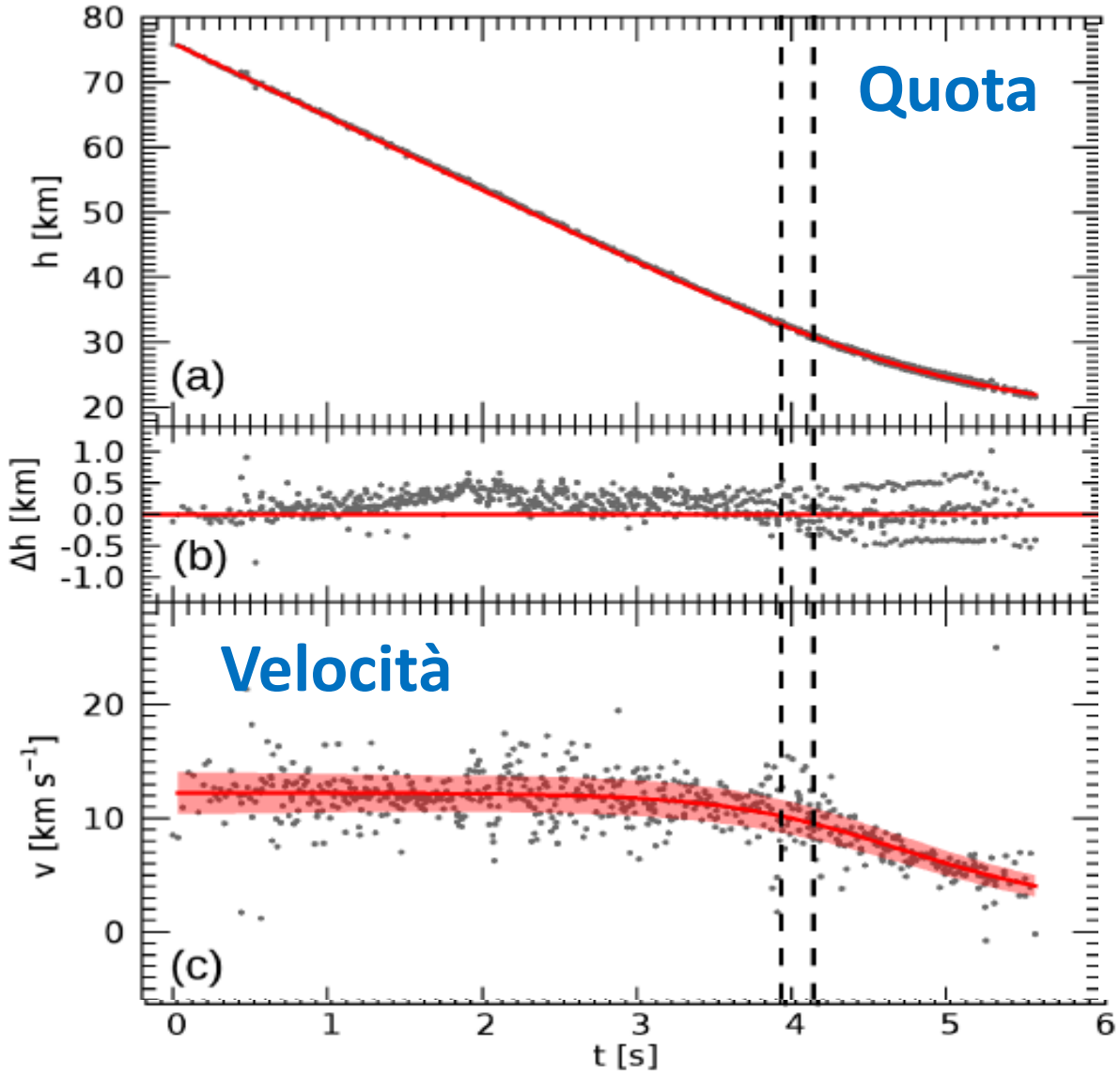
La **calibrazione** astrometrica e fotometrica è ottenuta per mezzo di osservazioni dedicate delle **stelle** più **brillanti** (fino a $M_V \sim 4$). La posizione del bolide in coordinate celesti e la sua curva di luce è determinata per ogni video disponibile.

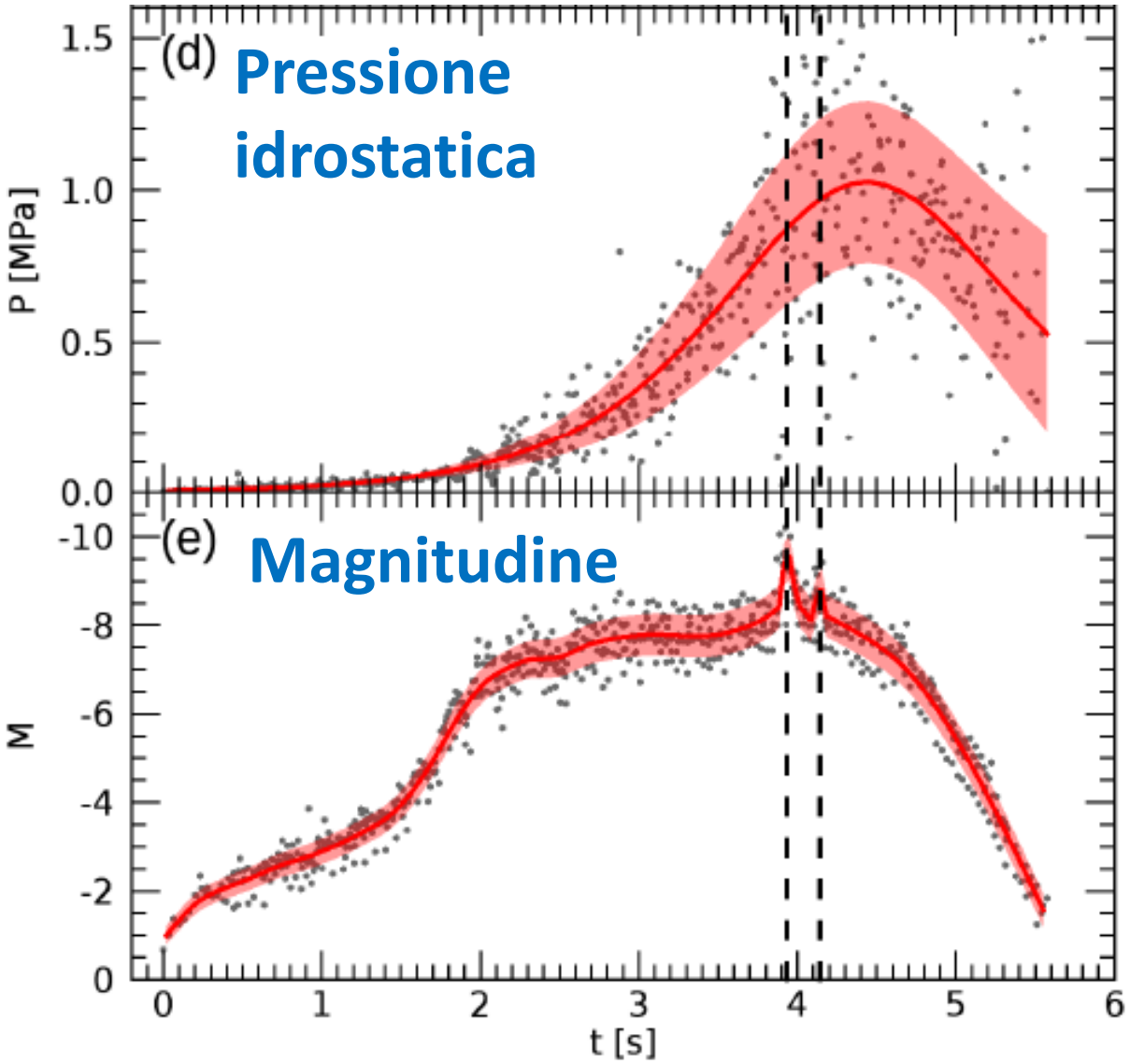






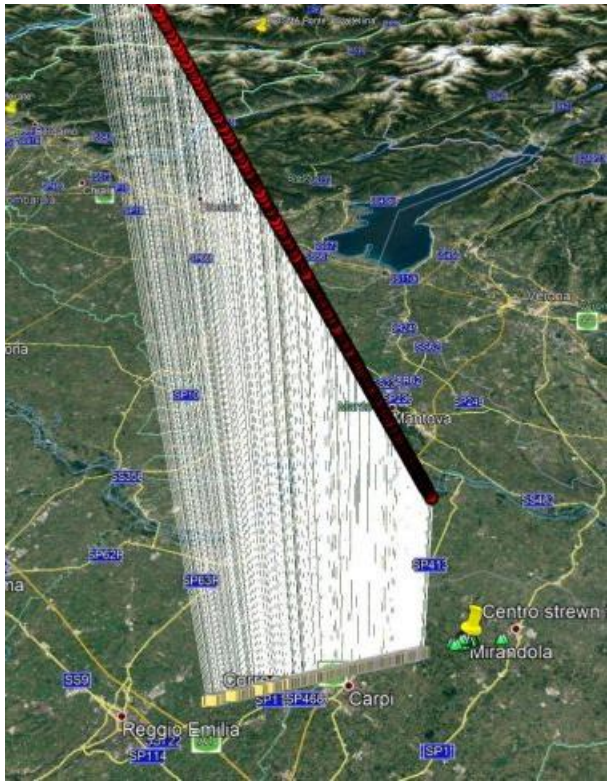
Modello cinematico





Traiettoria e Orbita

La **traiettoria** è ottenuta con il metodo della **triangolazione**. La velocità di ingresso è piuttosto bassa. Due **brillamenti** avvenuti all'altezza di circa 30 km indicano una probabile frammentazione. Gli **elementi orbitali** sono quelli di un asteroide della fascia interna.



Initial height: 75.9 ± 0.2 km

Inclination: 68.4 ± 0.3 deg

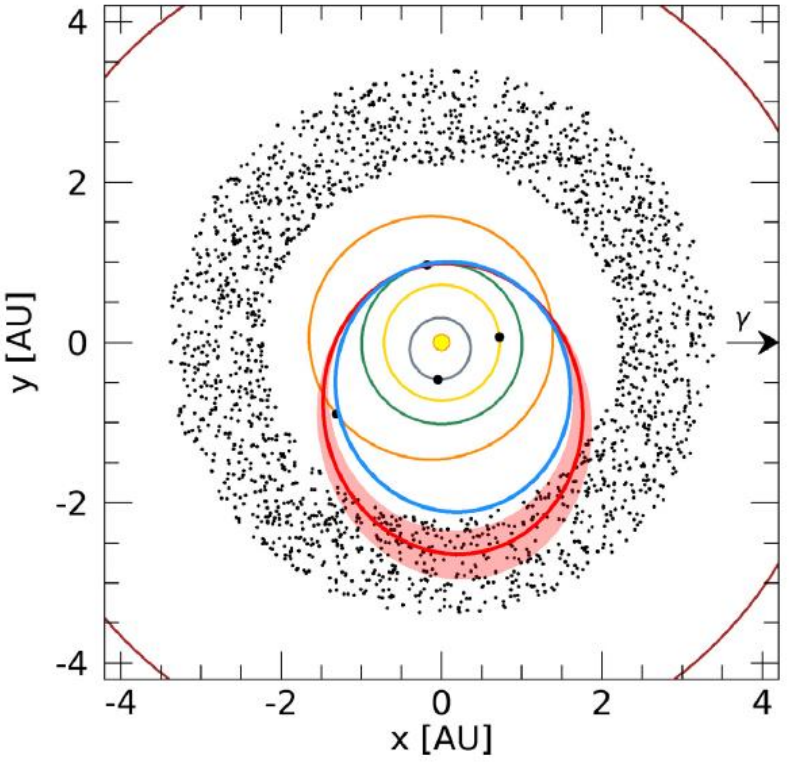
Entry velocity: 12.2 ± 0.2 km/s

Min. abs. Mag.: -9.5 ± 0.5

Final height: 21.5 ± 0.1 km

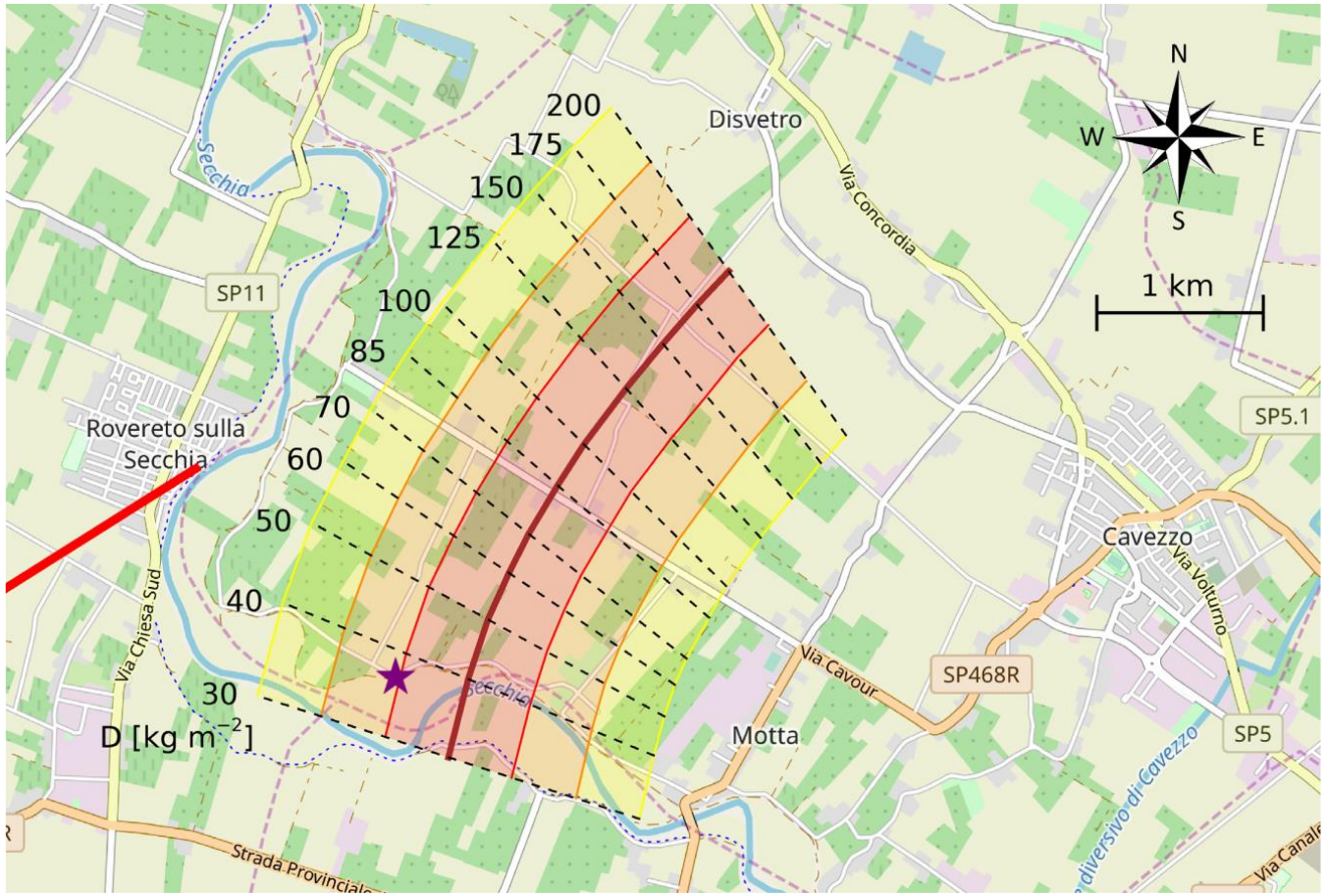
Duration: 5.6 sec

Final velocity: 4.0 ± 0.2 km/s



Volo buio e Strewn-field: Cavezzo

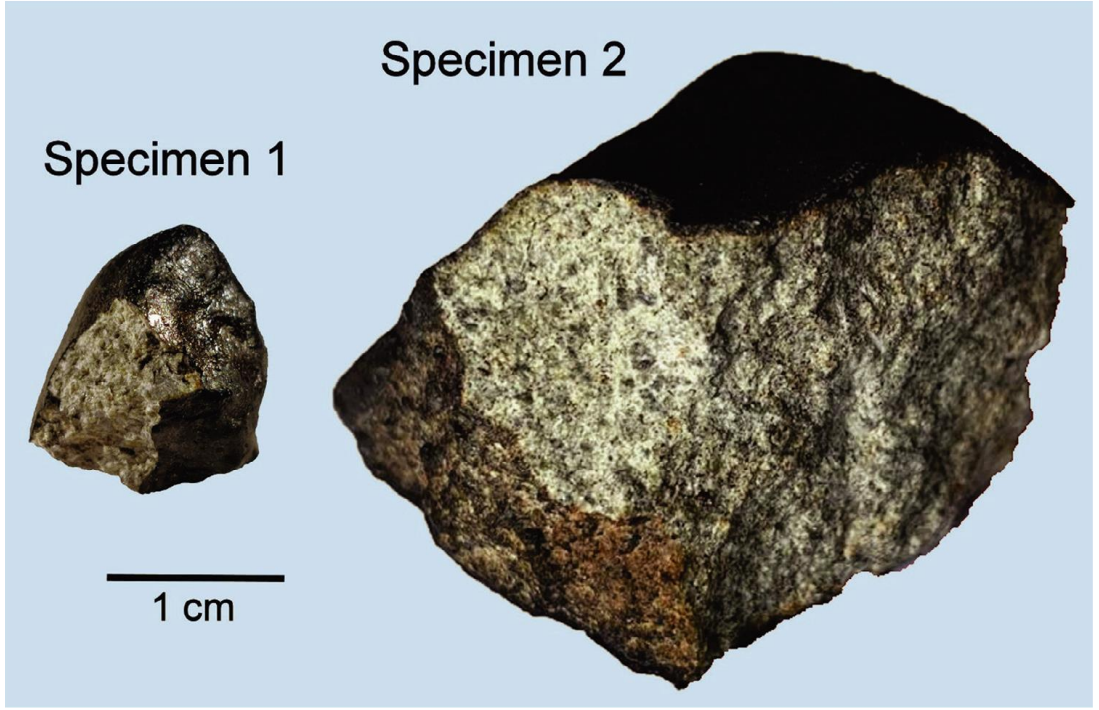
- A causa degli **intensi venti in quota** l'area di probabile caduta è spostata verso sud-est rispetto alla traiettoria prolungata a terra.
- PRISMA ha informato e ottenuto l'attenzione della **popolazione locale** tramite comunicati stampa, ampiamente ripresi da media locali e nazionali.
- **Due frammenti di meteorite** recuperati dal Sig. Davide Gaddi, **meno di tre giorni dopo la caduta**, nel pomeriggio del 04/01/2020 nel territorio del comune di Cavezzo (MO).



Dettagli in:
Gardiol et al. (2021), *Cavezzo, the first Italian meteorite recovered by the PRISMA fireball network. Orbit, trajectory, and strewn-field*, Mon. Not. R. Astron. Soc. **501**, p. 1215

La meteorite Cavezzo

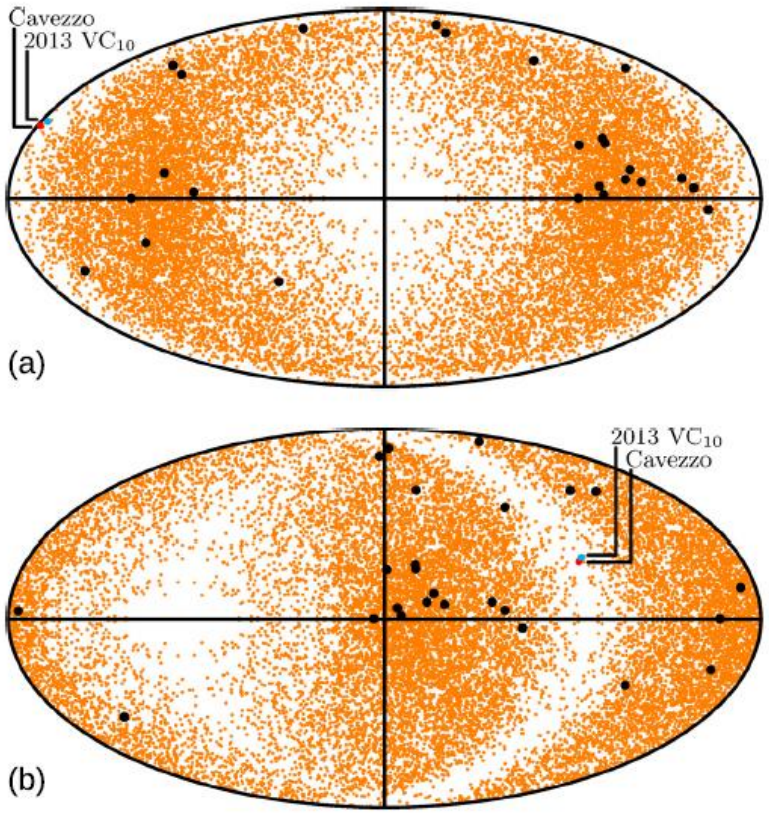
- Data la morfologia, **altri frammenti avrebbero dovuto essere trovati** nell'area di caduta, ma ulteriori campagne di ricerca sono state infruttuose, anche per le difficoltà dovute alla pandemia.
- Entrambi i frammenti sono stati **donati a INAF dal ritrovatore**.
- Il 05/09/2020, la meteorite è stata approvata dalla *Meteoritical Society* con il nome di "Cavezzo" e classificata come **Condrite L5 anomala**.
- I due frammenti recuperati, F1 (3.12 g) and F2 (52.19 g) sono significativamente differenti per petrologia, mineralogia modale e composizione isotopica.
- **Misure dell'attività Gamma** effettuate sulla *main mass* F2 hanno rivelato la presenza di radionuclidi instabili a vita breve (per esempio ^{48}V, $T_{1/2}$ = 16 giorni) dimostrando in maniera certa che i frammenti ritrovati appartengono all'oggetto caduto il 1° gennaio 2020.

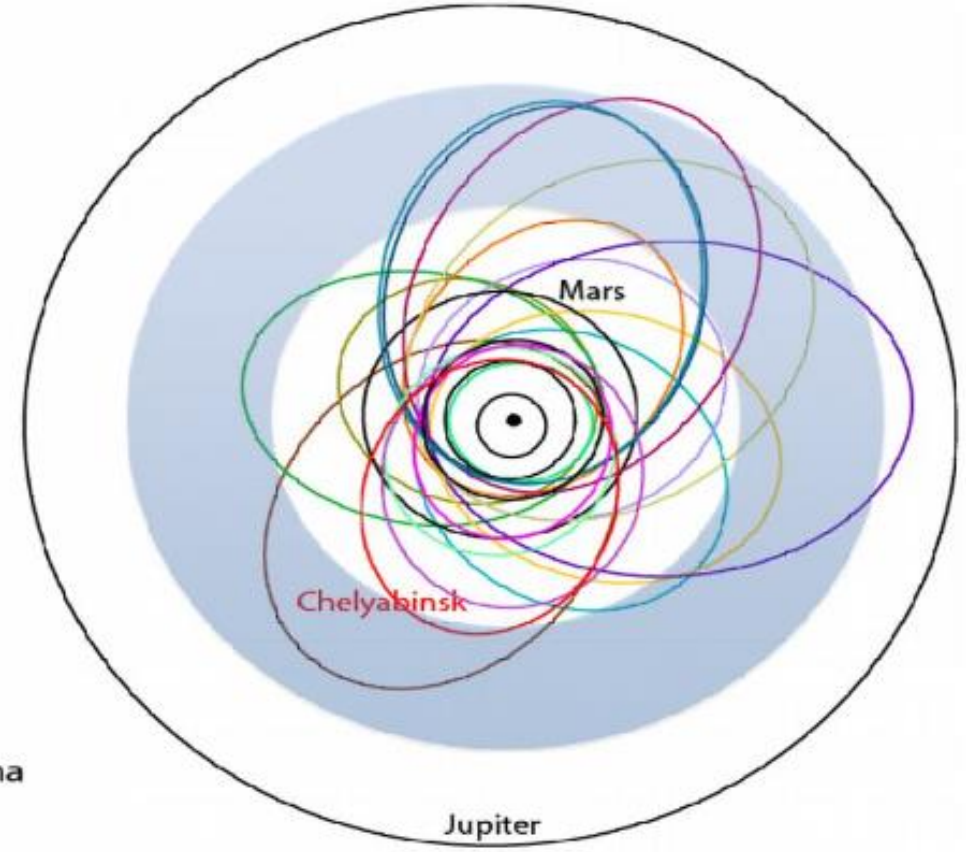


Dettagli in:
Pratesi et al. (2021), *Cavezzo – The double face of a meteorite: Mineralogy, petrography, and geochemistry of a very unusual chondrite*, Met. Planet. Sci., **56**, p. 1125

Importanza della Cavezzo

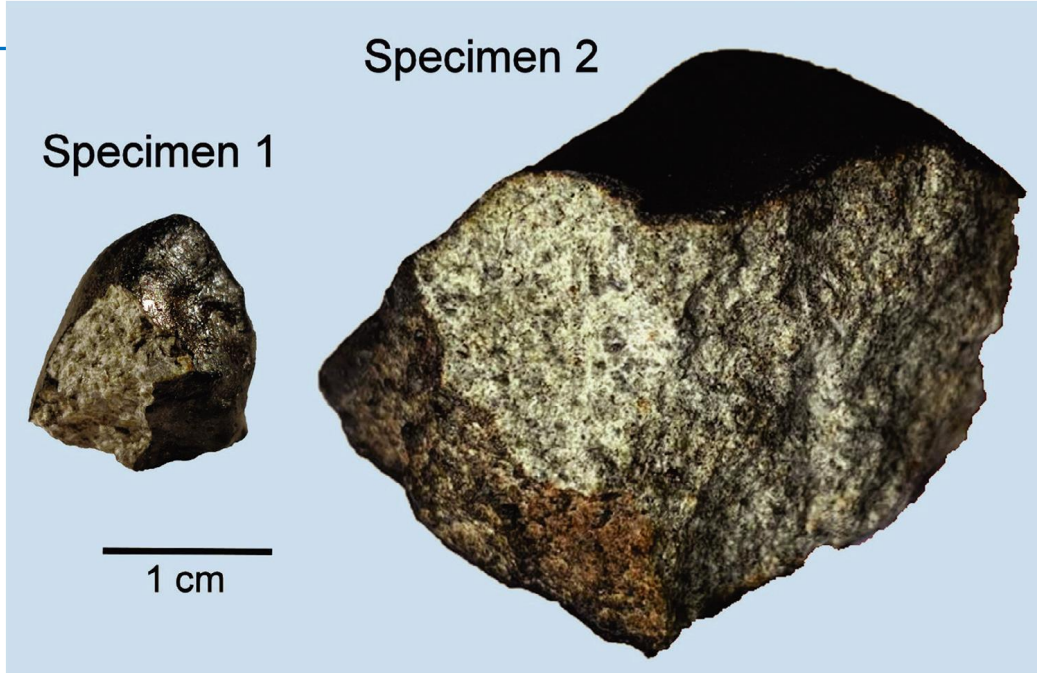
Cavezzo è la prima meteorite italiana recuperata da PRISMA. Solo 20 meteoriti con «pedigree» sono state recuperate con questi metodi nel mondo. L'asteroide 2013 VC10 potrebbe essere il corpo progenitore. È anomala, unica nel suo genere.





Cavezzo, an anomalous L5 chondrite

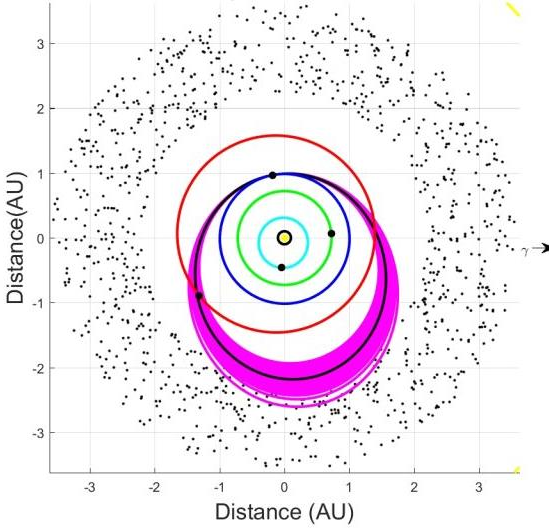
- Due to the morphology of the two recovered pieces, **other fragments should have been found** on site, but further campaigns were unsuccessful up until now
- Both fragments have been **donated to INAF by the finder**
- On 05/09/2020, the meteorite was approved with the name “Cavezzo” and classified as a **L5-anomalous chondrite**
- The two recovered fragments, F1 (3.12 g) and F2 (52.19 g) were found to be quite different in their petrology, modal mineralogy and oxygen isotopes composition
- **Gamma activity measurements** were performed on the main mass F2. The detection of short-lived radionuclides (like ^{48}V, $T_{1/2}$ = 16 d) gave indisputable proof of the very fresh fall of Cavezzo

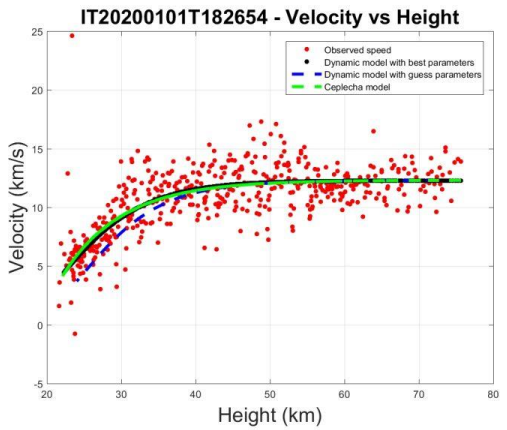


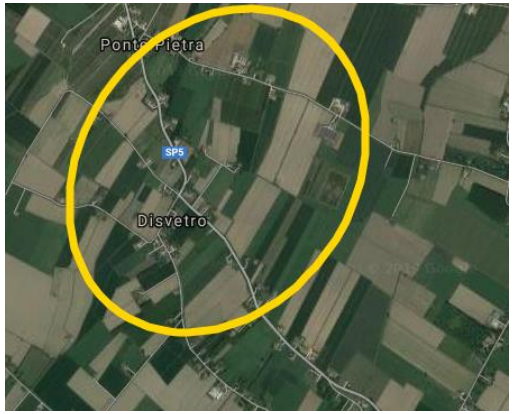
More details can be found in:
Pratesi et al. (2021), *Cavezzo – The double face of a meteorite: Mineralogy, petrography, and geochemistry of a very unusual chondrite*, Met. Planet. Sci., **56**, p. 1125

Campi di applicazione di PRISMA

- Calcolo del punto di caduta di eventuali frammenti per il **recupero e l'analisi di meteoriti fresche**
- Studio della dinamica e delle proprietà fisiche dei **bolidi**
- Determinazione dei **parametri orbitali** dei corpi progenitori
- Identificazione di **nuove famiglie asteroidali**
- Formazione ed evoluzione del Sistema Solare
- Monitoraggio dell'**inquinamento luminoso**
- Monitoraggio dei **detriti spaziali** brillanti (LEO)
- **Meteorologia**







Scientific production and outreach

Scientific papers (selected list):

- Gardiol et al. (2021), *Cavezzo, the first Italian meteorite recovered by the PRISMA fireball network. Orbit, trajectory, and strewn-field*, MNRAS **501**, p. 1215
- Pratesi et al. (2021), *Cavezzo – The double face of a meteorite: Mineralogy, petrography, and geochemistry of a very unusual chondrite*, MPS., **56**, p. 1125
- Barghini et al. (2019), *Astrometric calibration for all-sky cameras revisited*, A&A, **626**, A105
- Carbognani et al. (2020), *A case study of the May 30, 2017, Italian fireball,* EPJP Plus, **135**, A255
- Colas et al. (2020), *FRIPON: a worldwide network to track incoming meteoroids*, A&A, **644**, A53
- Gardiol et al. (2017), *Improvement of the extraction method of faint signals in gamma activity measurements of meteorites*, EPJP Plus, **132**, A269
- Drolshagen et al. (2021), *Luminous efficiency based on FRIPON meteors and limitations of ablation models*, A&A, **650**, A159
- Jeanne et al. (2019), *Calibration of fish-eye lens and error estimation on fireball trajectories: application to the FRIPON network*, A&A, **627**, A78
- Gardiol et al. (2020), *PRISMA and the finding of the Cavezzo meteorite: the success of a close collaboration among professional astronomers, amateurs and citizens*, EPSC 2020, 1051
- Barghini et al. (2020), *PRISMA: an Italian network for the recovery of freshly fallen meteorites*, EPSC 2020, 201
- Gardiol et al. (2016), *PRISMA, Italian network for meteors and atmospheric studies*, IMO, ISBN 9778-2-87355-030-1

Scientific symposiums

Educational activities in schools and talks for the general public

Events, scientific festivals, exhibitions

Website, Newsletter, Social, PRISMA Day