Earth-grazing fireball on March 29,2006

Dynamics and Spectroscopy

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Asaka Highschool Earth Science Club, Akira Kawamura, Yasu9999

Survival of Meteoroids

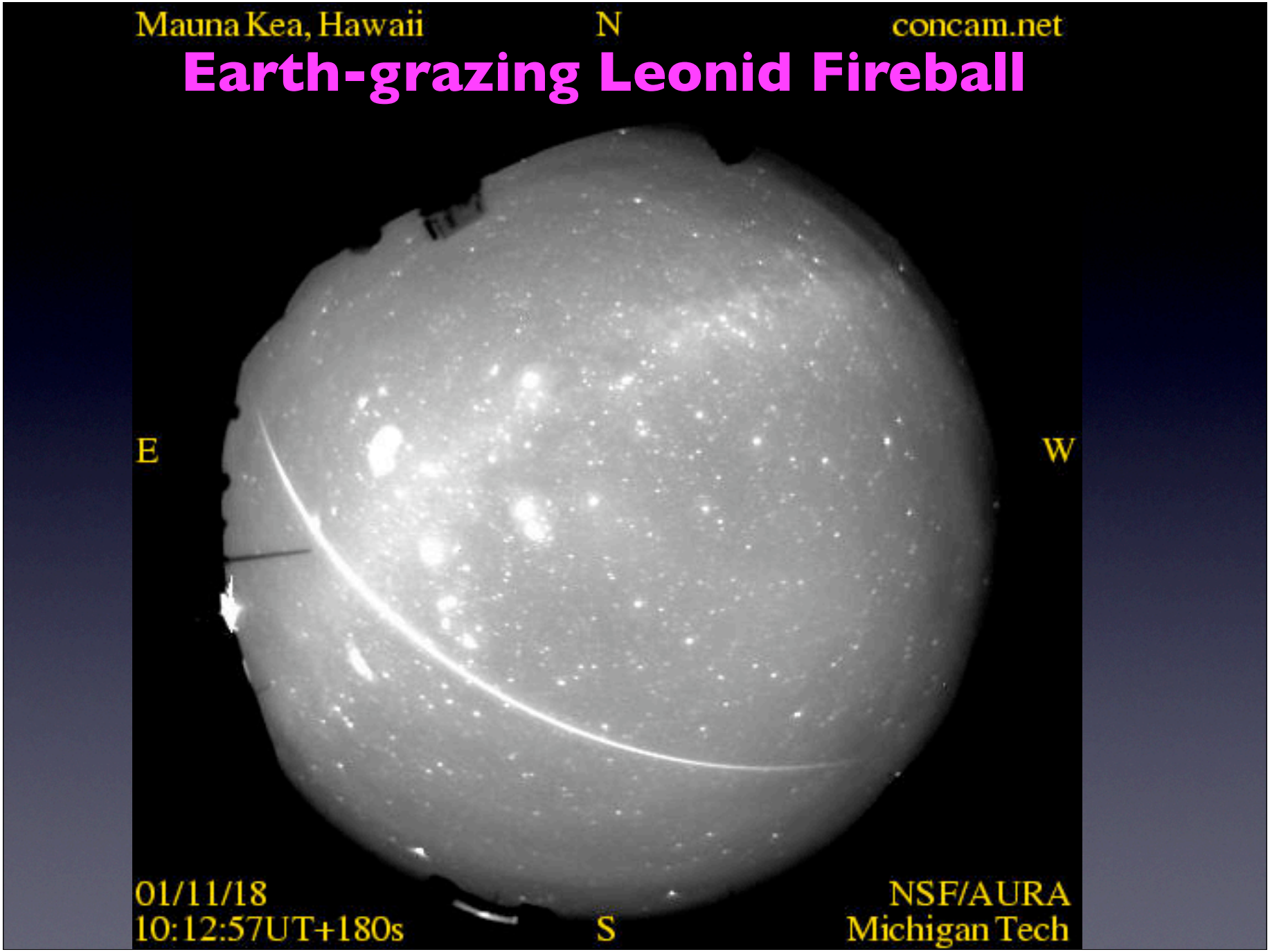
Meteorites

The entry of a meteoroid into the Earth's atmosphere usually terminates by complete ablation of the body well above the Earth's surface. Large bodies can, under suitable circumstances, reach the Earth's surface as meteorites.

Earth-grazing Meteoroids

There is another possibility for a meteoroid survival.

If it enters the atmosphere almost tangentially, then, after appearing as a meteor and losing a part of its mass, it can leave the atmosphere again and return to a modified heliocentric orbit.


Mauna Kea, Hawaii
N
concam.net
Earth-grazing Leonid Fireball
E
W
01/11/18
10:12:57UT+180s
S
NSF/AURA
Michigan Tech

Observed Earth-grazing fireball

★ Feb. 9, 1913 above Canada-N/S-America (O'Keefe(1959))
- geocentric velocity; 11.7 km/s
- in a satellite orbit !

★ Aug. 10, 1972 above US (Jacchia(1974), Ceplecha(1979))
- minimal height; 58 km
- trajectory; 1500 km
- geocentric velocity; 15.0-14.2 km/s
- estimated mass; 10^5 - 10^6 kg
- *first scientifically observed event*

★ Oct. 13, 1990 above Czechoslovakia-Poland (Borovicka&Ceplech(1993))
- minimal height; 98.67 km (103.70-98.67-100.4 km)
- trajectory; 409 km
- duration; 9.8 sec
- geocentric velocity; 41.7 km/s
- estimated mass; 44 kg
- ablated mass; 0.35 kg
- *second scientifically observed event*

A bright fireball of -8 absolute magnitude was observed at 11:24:07(UT) on 29 March 2006 from several stations, which lasted for about 40 seconds traveling about 700 km over Japan, Gif-Nagano-Yamanashi-Tokyo-Chiba prefectures.

The observations were carried out using (a) an automatic meteor detection software, UFOCapture, with high sensitivity CCD camera, Wat-100N(1/2 inch) with 6mm/F0.8 lens(FOV of 56 x 42 deg), in video-rate recording, 30 frames per second(NTSC), (b) All-sky photographs by digital photographic cameras. (c) An ultra wide-field telescope, 62 x 62 deg, for monitoring GRB optical flashes also captured high resolution images. (a') An spectrum with 500 grooves/mm grating was obtained by a station.

From our analysis showed a clear Earth-grazing trajectory which entered the atmosphere almost tangentially.

Through the first and second Earth-grazing fireballs observed on August 10, 1972(Jacchia, 1974; Ceplecha, 1979) and on October 13, 1990 (Borovicka and Ceplecha, 1992), respectively, a special method for computing the eccentric trajectory was developed. From this solution, we present the first results of the Earth-grazing fireball orbit with its spectrum.

Observed videos

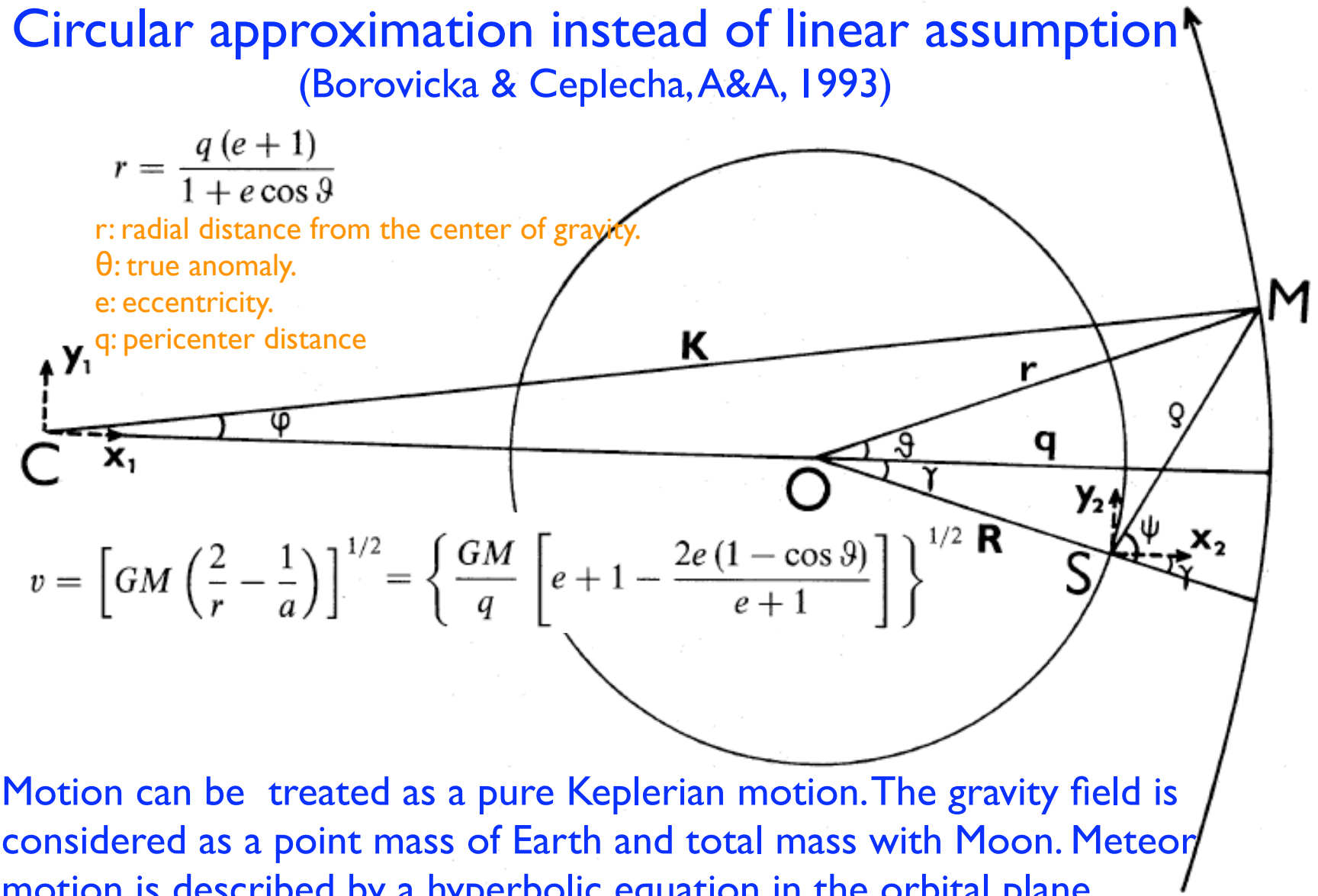
- TV observation from Yokohama(all-sky)
- TV observation from Tokyo(north)
- TV observation from Tokyo(south)
- TV spectrum from Tokyo(south)

Circular approximation instead of linear assumption

(Borovicka & Ceplecha, A&A, 1993)

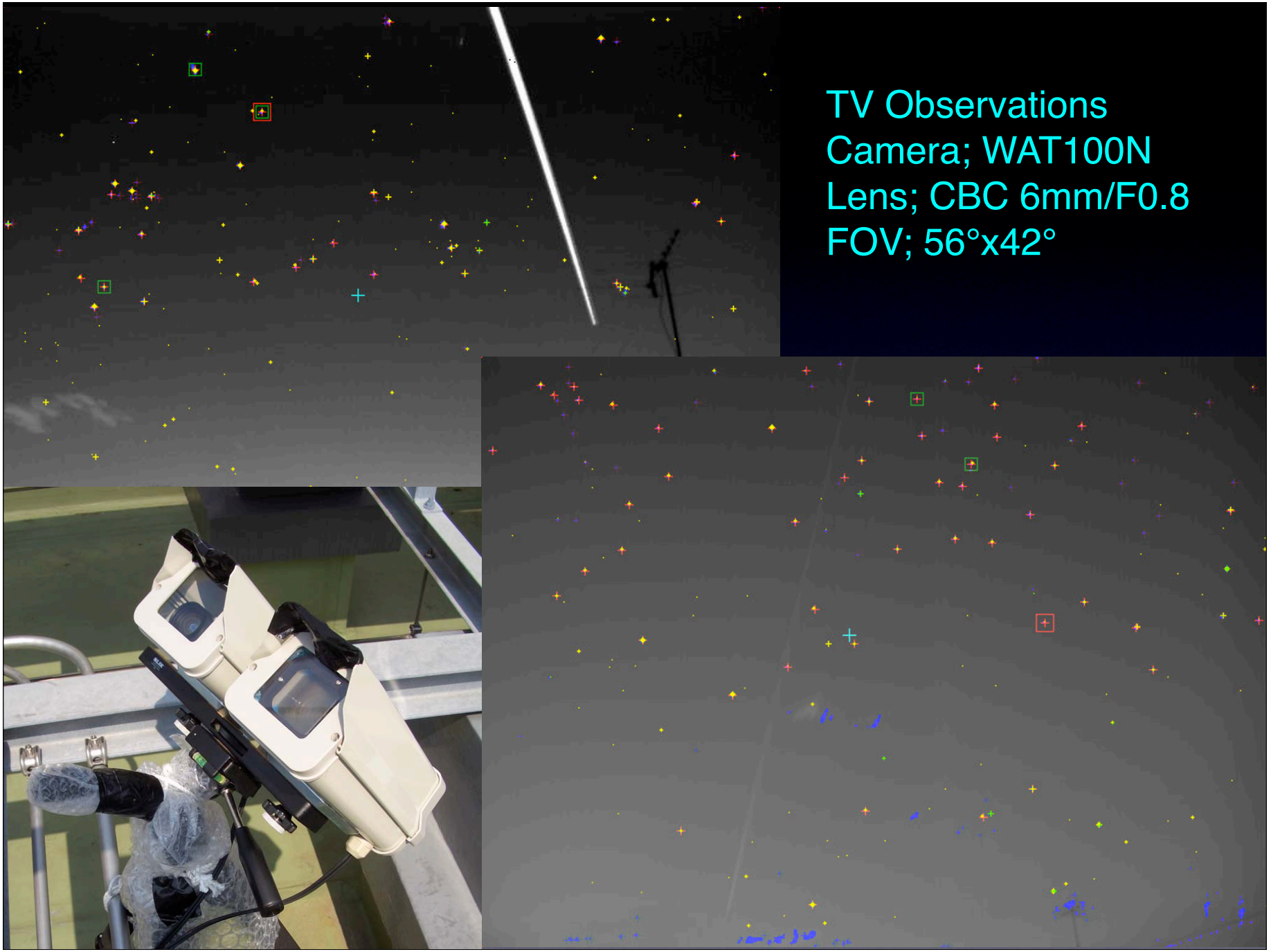
$$r = \frac{q\,(e+1)}{1+e\cos\vartheta}$$

r: radial distance from the center of gravity.
θ: true anomaly.
e: eccentricity.
q: pericenter distance



$$v = \left[GM\left(\frac{2}{r}-\frac{1}{a}\right)\right]^{1/2} = \left\{\frac{GM}{q}\left[e+1-\frac{2e\,(1-\cos\vartheta)}{e+1}\right]\right\}^{1/2}$$

Motion can be treated as a pure Keplerian motion. The gravity field is considered as a point mass of Earth and total mass with Moon. Meteor motion is described by a hyperbolic equation in the orbital plane.

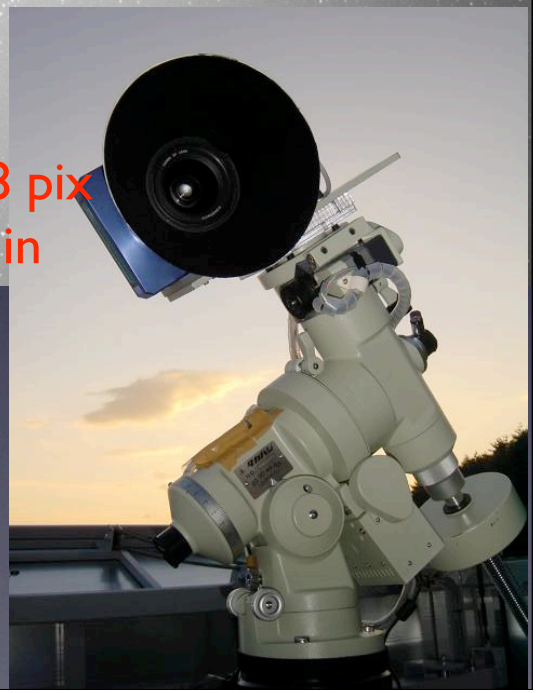

TV Observations
Camera; WAT100N
Lens; CBC 6mm/F0.8
FOV; 56°x42°

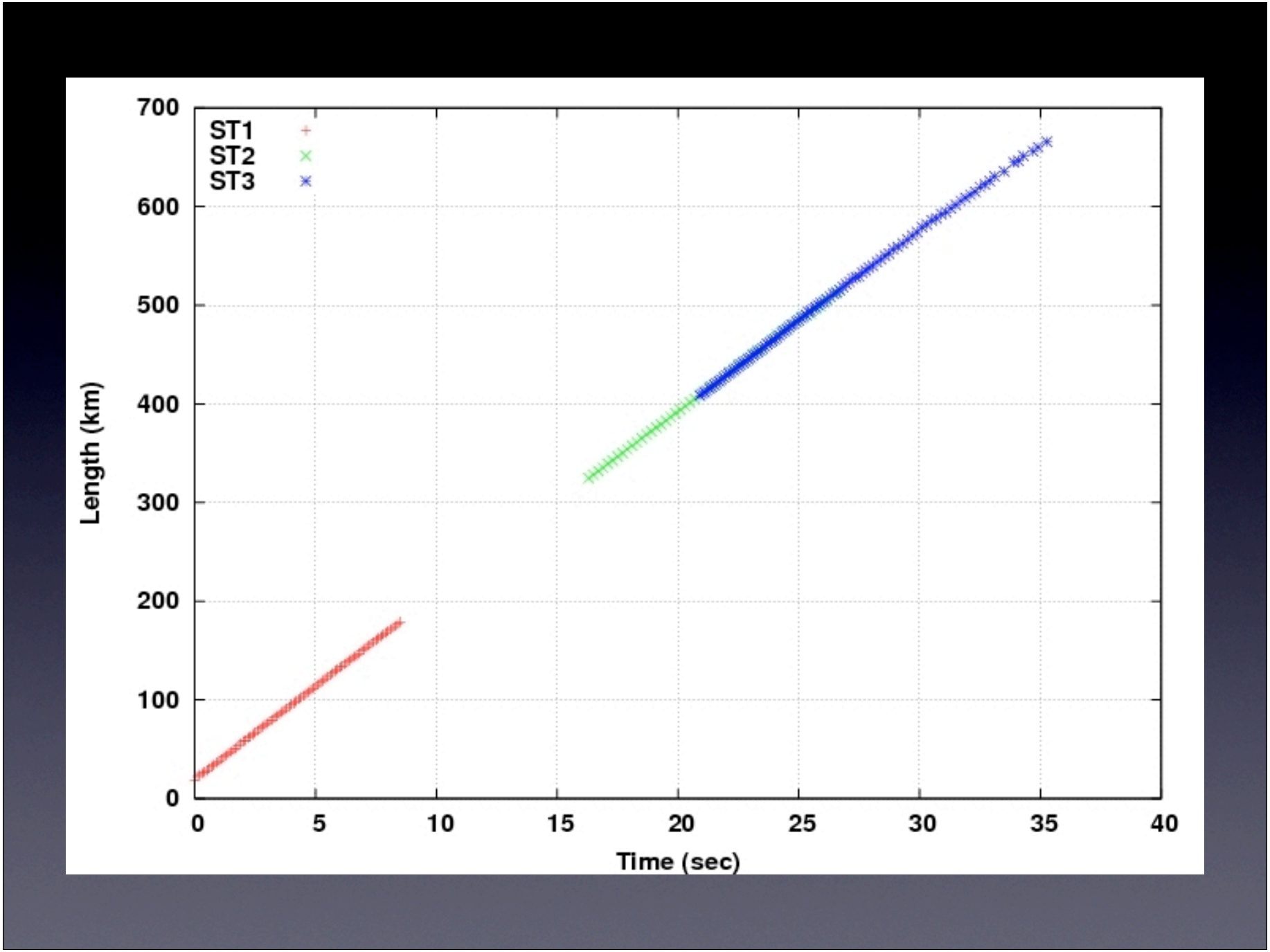
Digital Photograph
Camera; FinePix S3 Pro
Lens; SIGMA 8mm/F4 EX DG
(CIRCULAR FISHEYE)

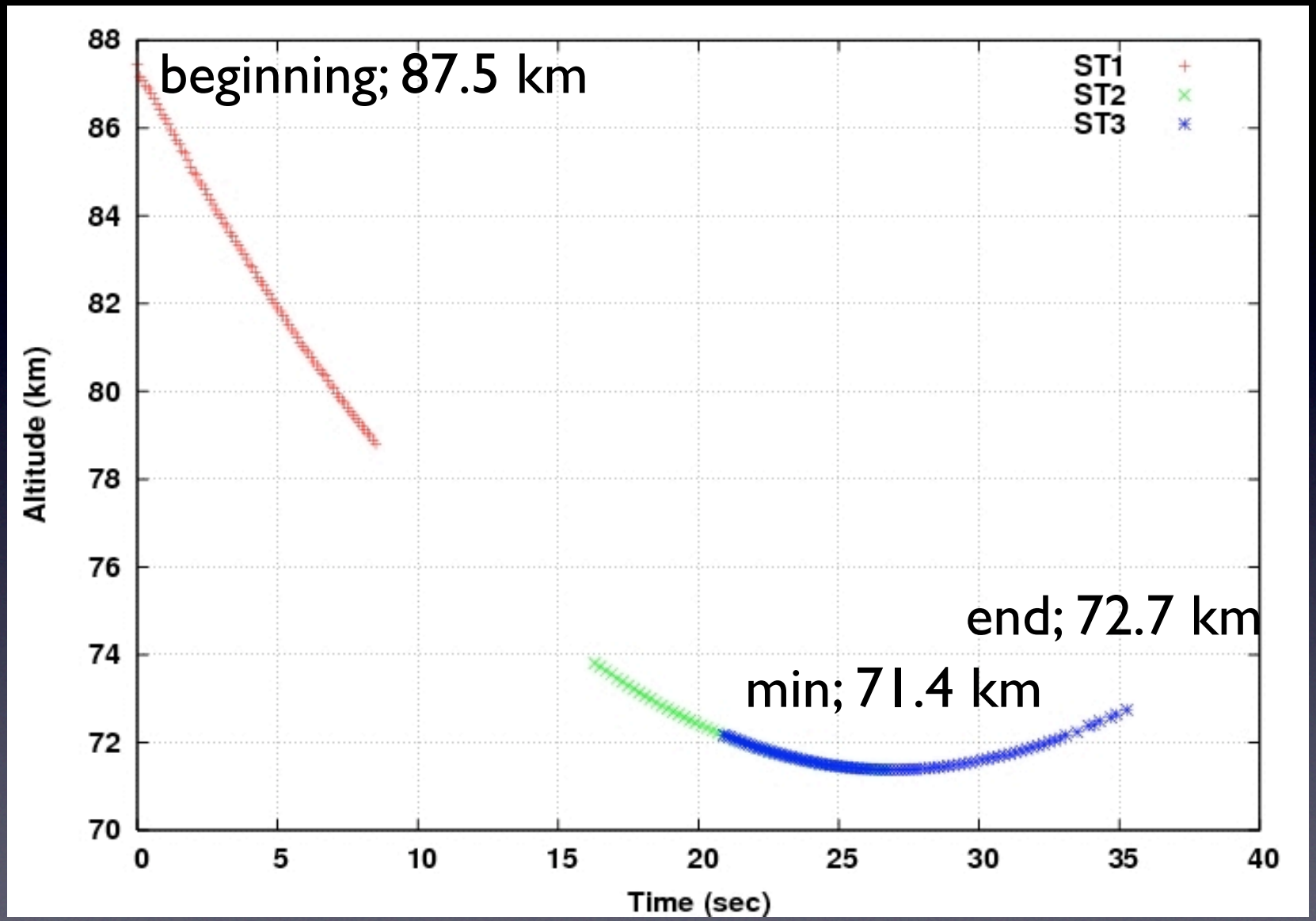
CCD Observation
WIDGET
FOV; 62°x62°

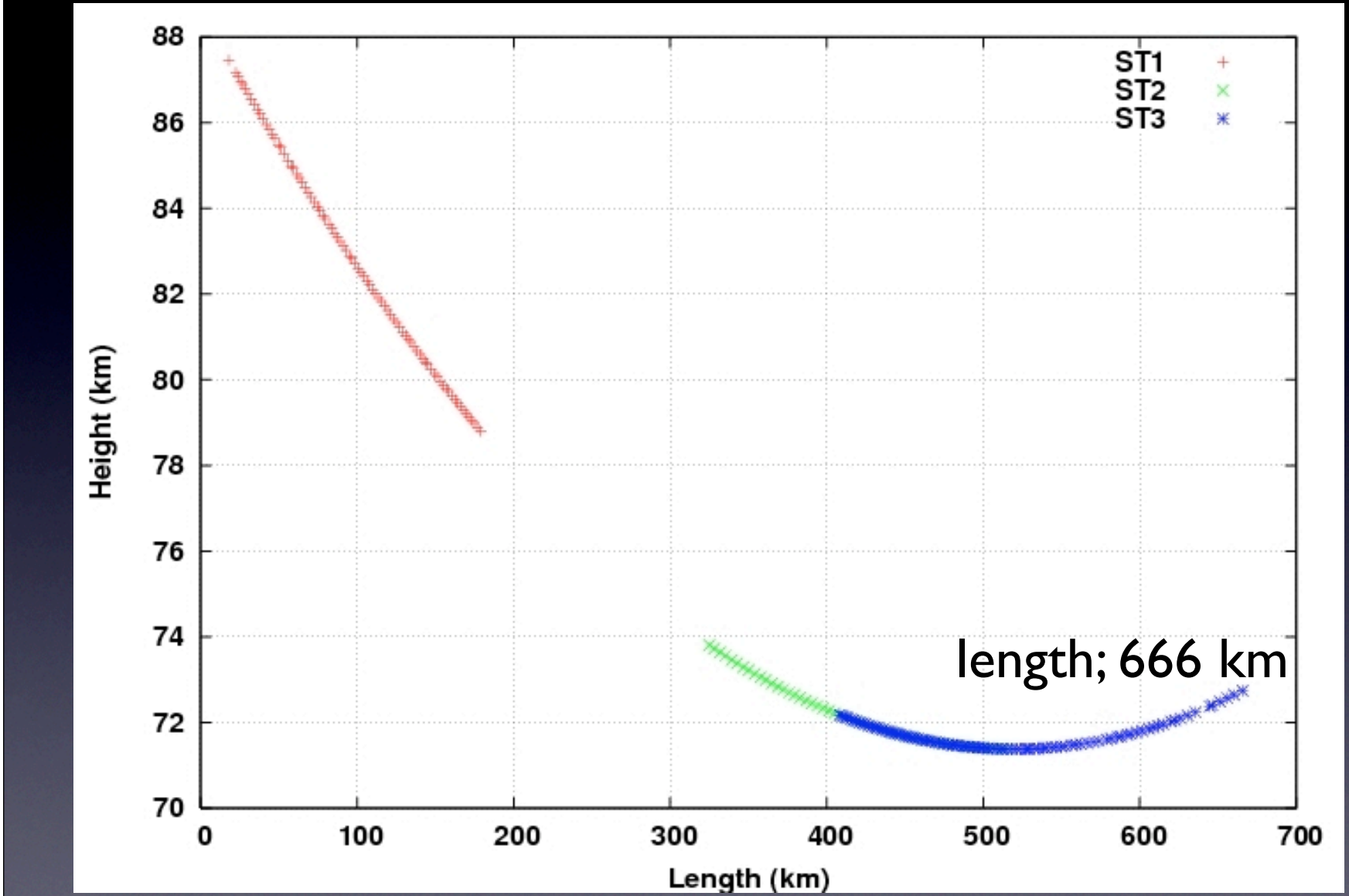
WIDGET is a robotic telescope for monitoring the HETE-2 field-of-view to detect Gamma-ray Burst optical flashes or possible optical precursors.

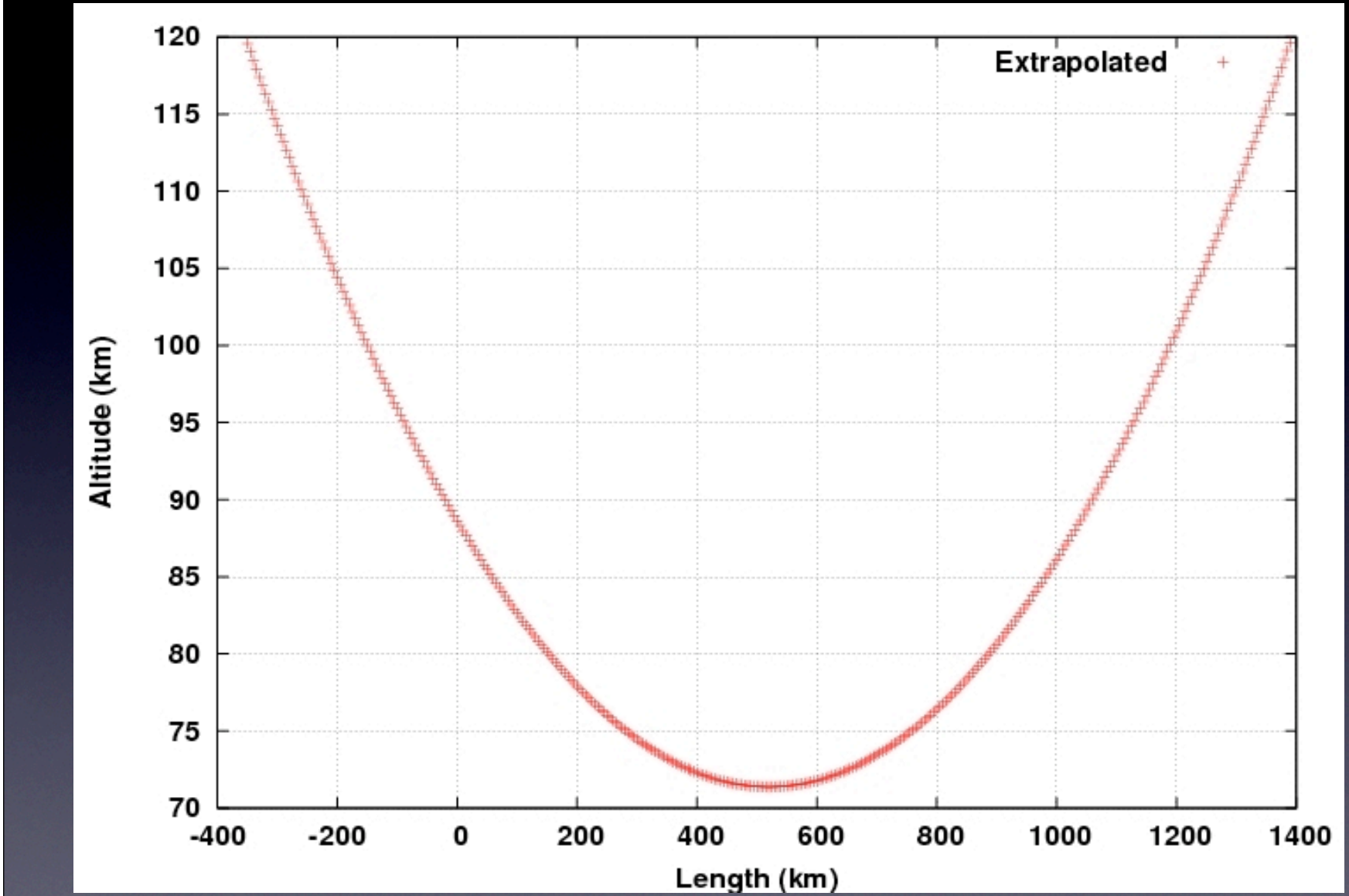
format; 2048 x 2048 pix
resolution; 1.8 arcmin

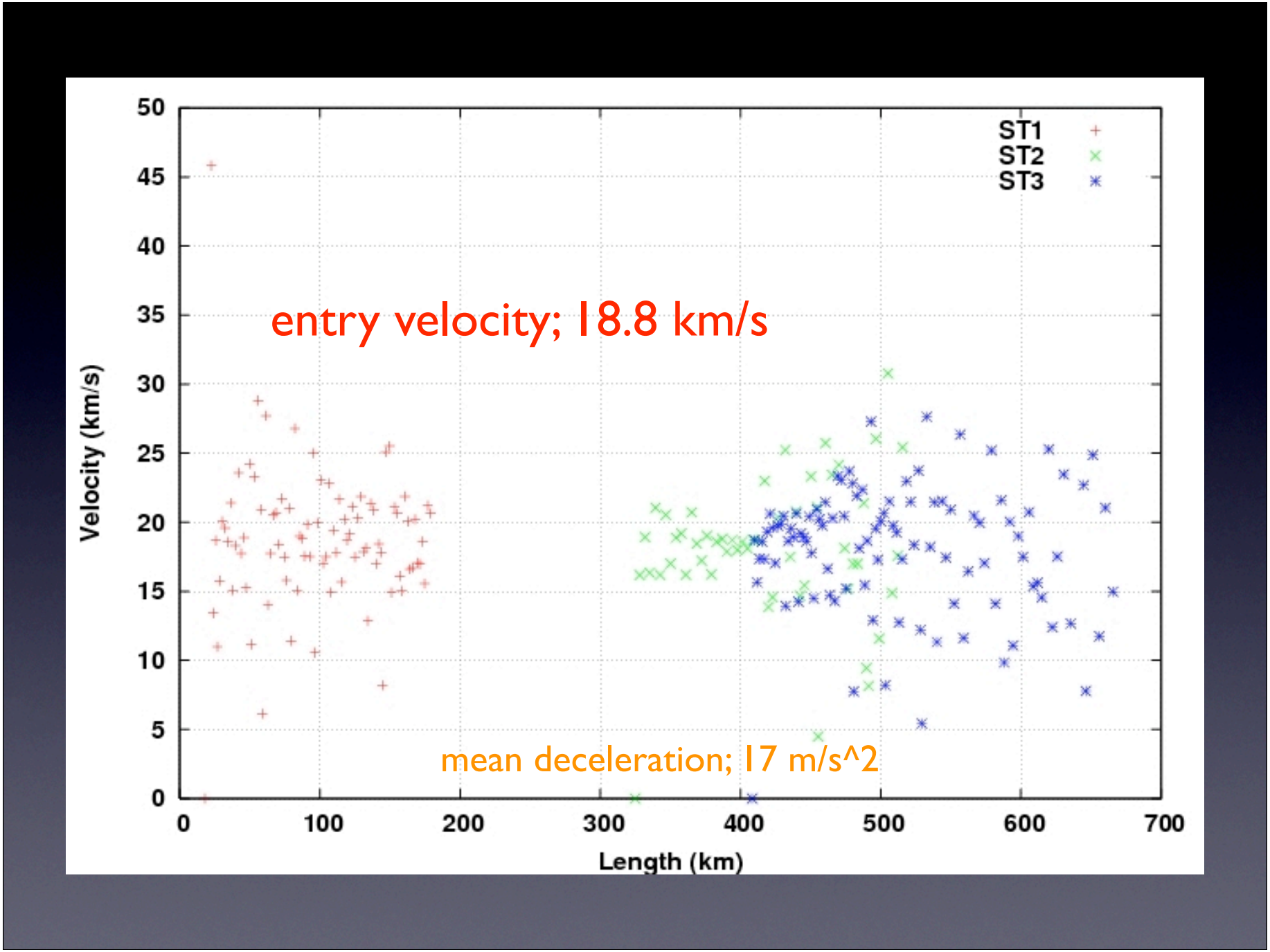


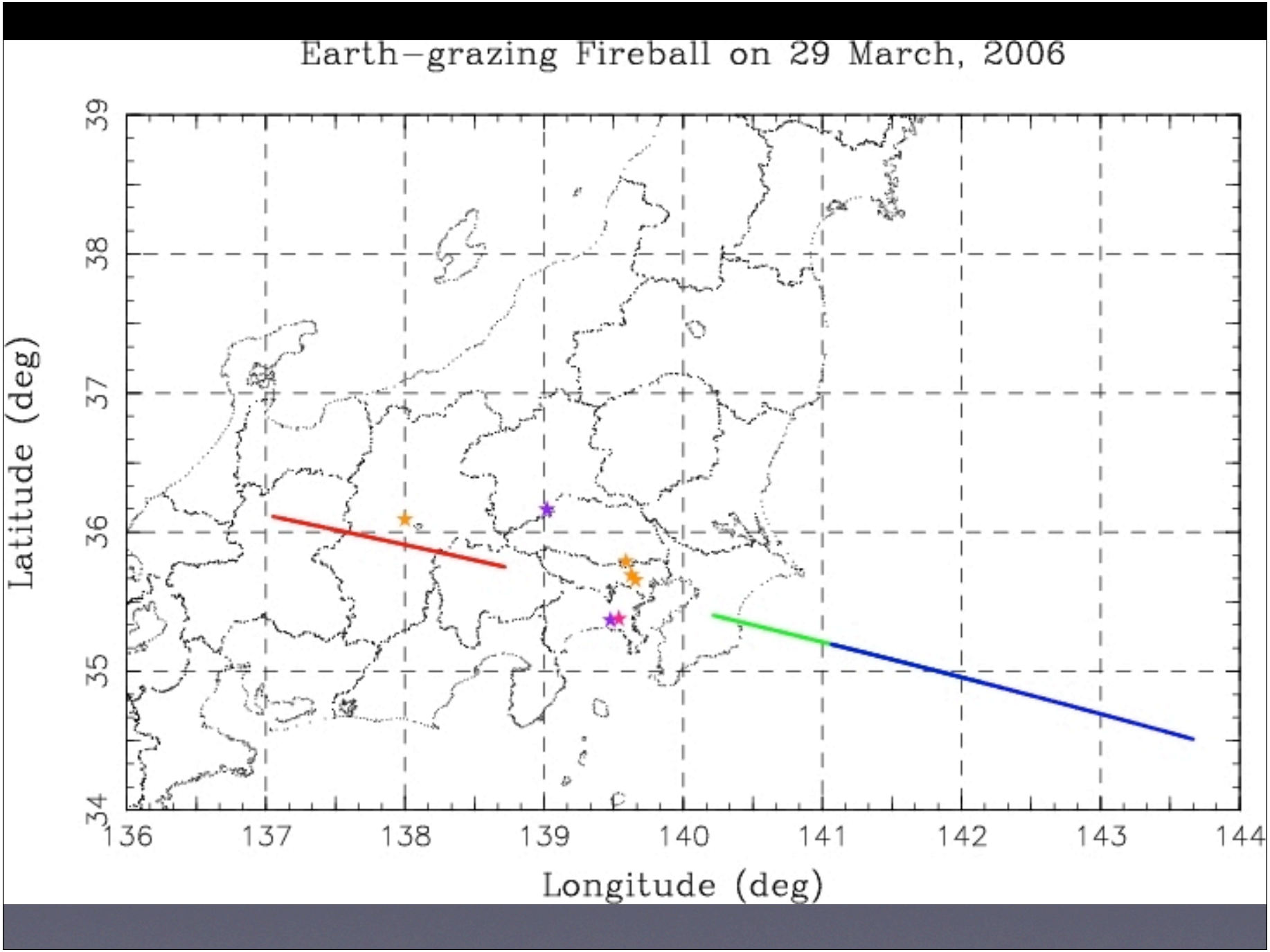

ST1
ST2
ST3
Length (km)
Time (sec)
0
100
200
300
400
500
600
700
0
5
10
15
20
25
30
35
40


beginning; 87.5 km
end; 72.7 km
min; 71.4 km
ST1
ST2
ST3
Altitude (km)
Time (sec)
88
86
84
82
80
78
76
74
72
70
0
5
10
15
20
25
30
35
40


ST1
ST2
ST3
Height (km)
88
86
84
82
80
78
76
74
72
70
0
100
200
300
400
500
600
700
Length (km)
length; 666 km


Extrapolated
Altitude (km)
120
115
110
105
100
95
90
85
80
75
70
-400
-200
0
200
400
600
800
1000
1200
1400
Length (km)

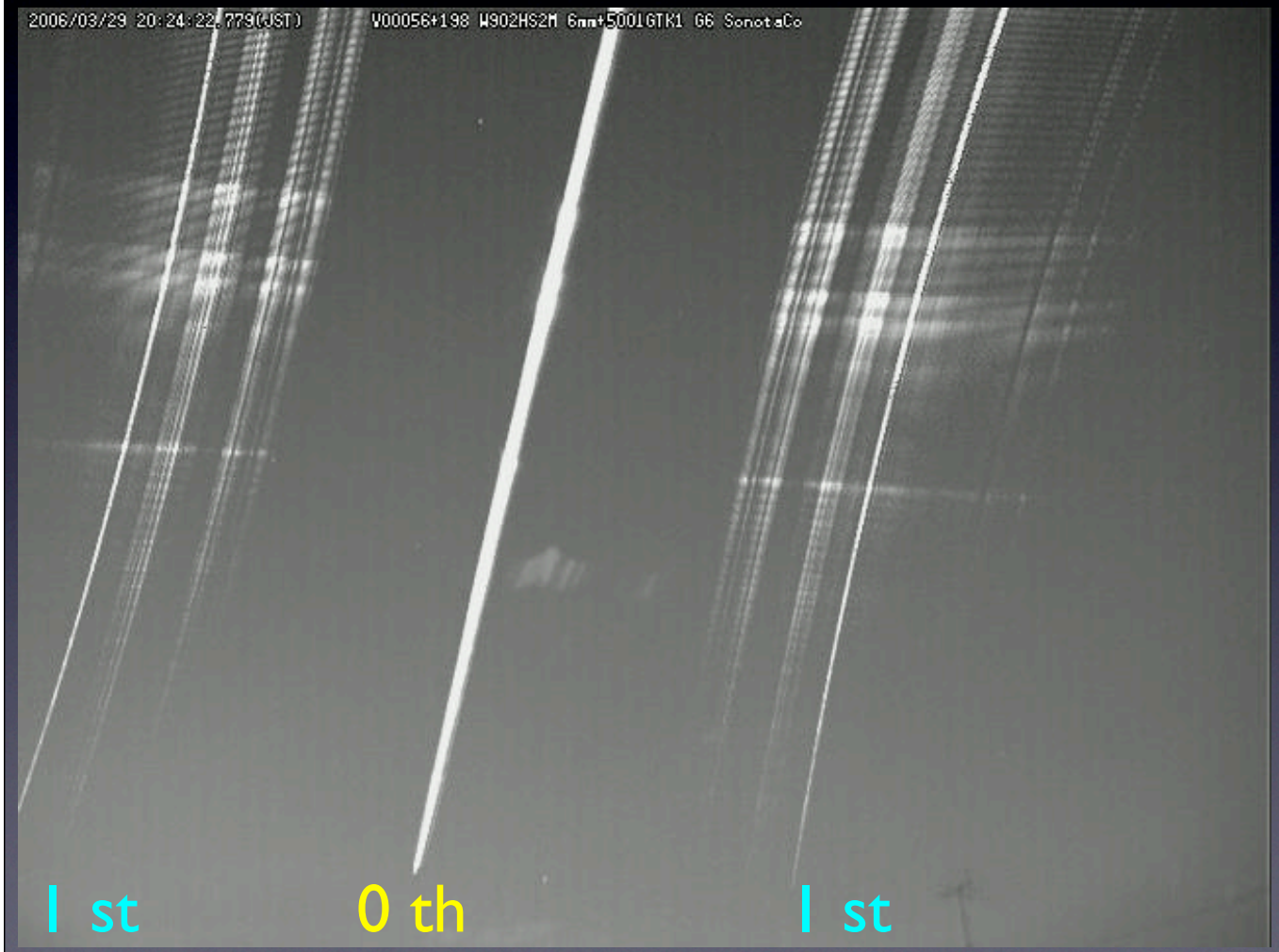

ST1
ST2
ST3
entry velocity; 18.8 km/s
mean deceleration; 17 m/s^2
Velocity (km/s)
Length (km)
0
5
10
15
20
25
30
35
40
45
50
0
100
200
300
400
500
600
700


Earth−grazing Fireball on 29 March, 2006
Latitude (deg)
39
38
37
36
35
34
136
137
138
139
140
141
142
143
144
Longitude (deg)

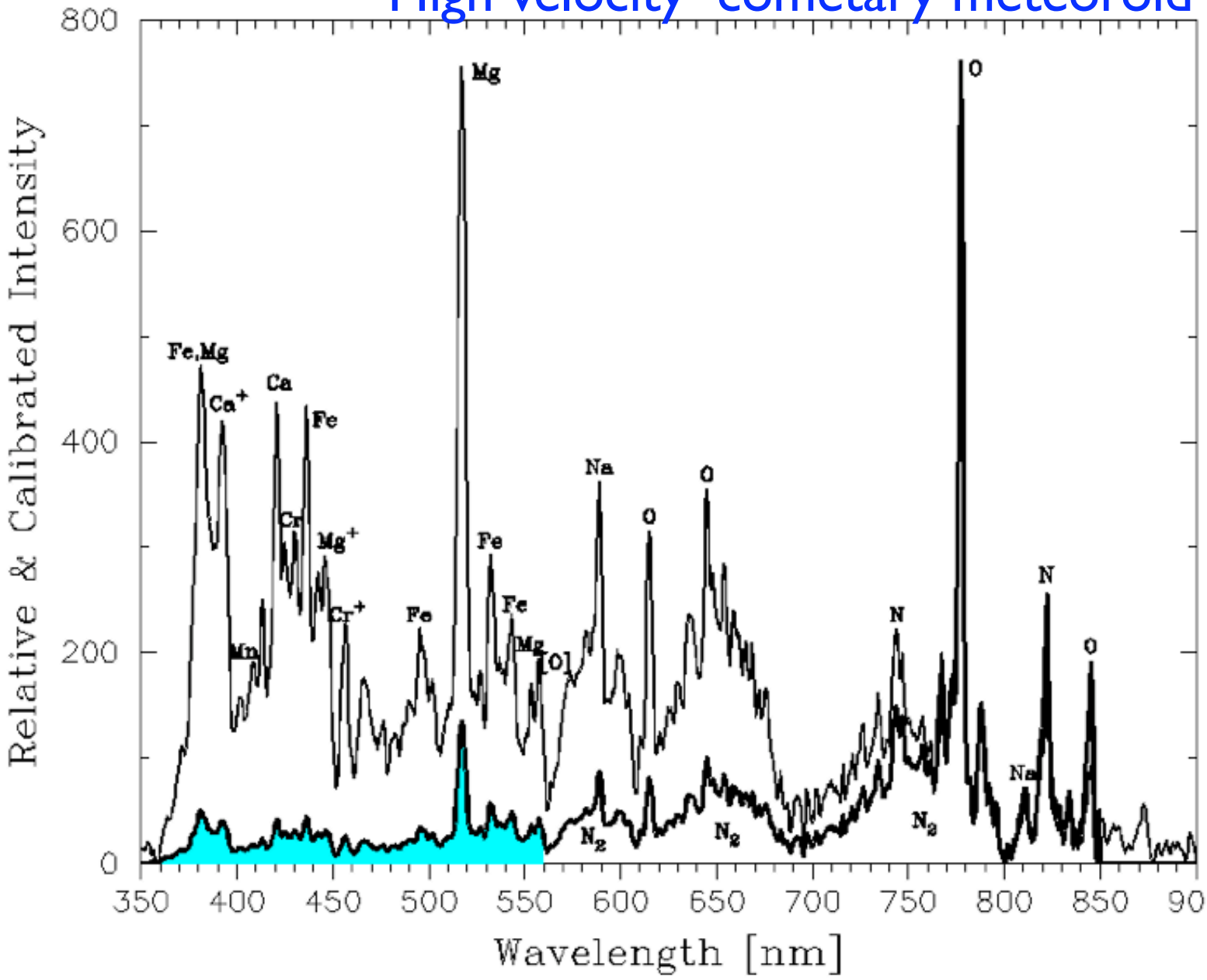
Spectrum of Earth-grazing fireball

TV spectrum
Camera; WAT902H2S
Lens; CBC 6mm/F0.8
Grating; 500 grooves/mm
FOV; 56°x42°

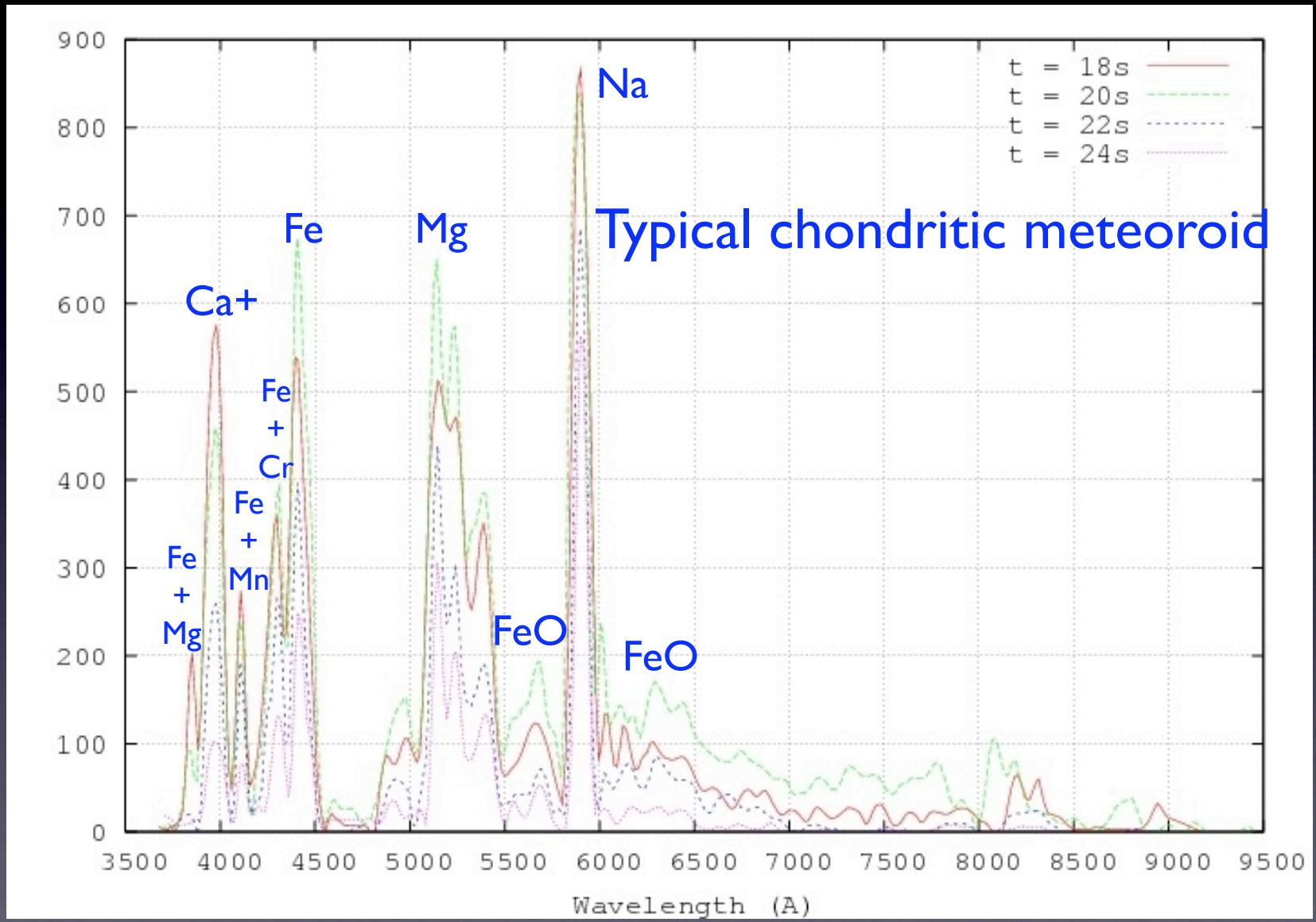
height; 73.1～71.5 km



High velocity cometary meteoroid

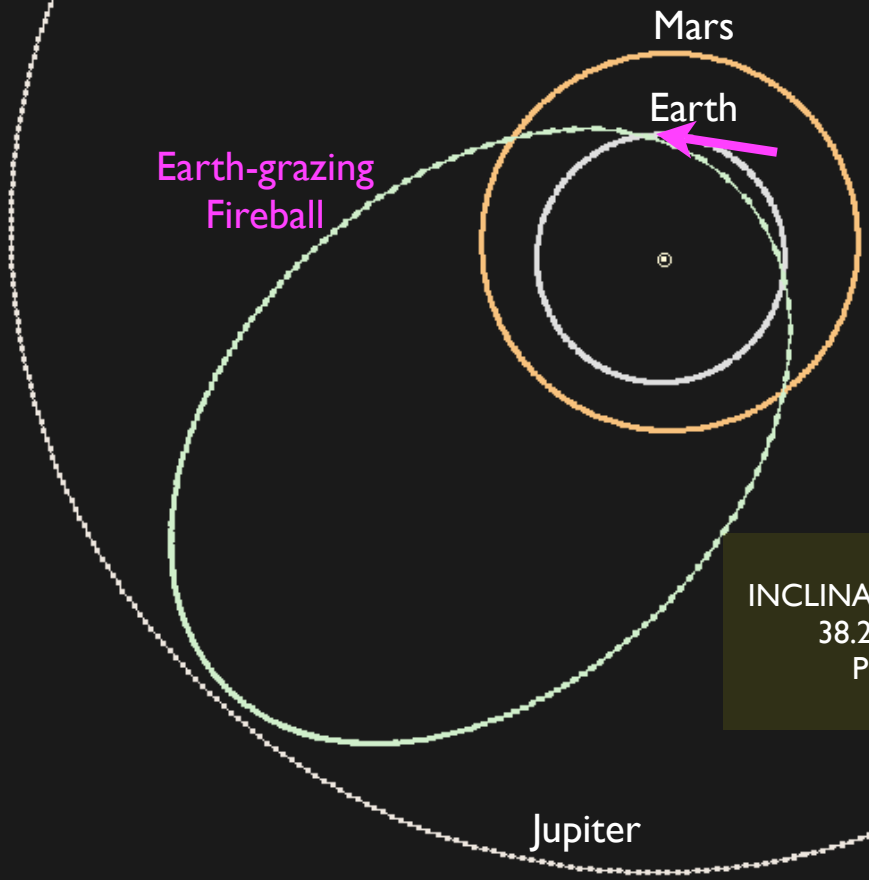


Shinsuke Abe, PhD Thesis, 2001; Shinsuke. Abe et al., EMP, 82/83, 369, 2000.


Typical chondritic meteoroid
Na
Fe
Mg
Ca+
Fe + Cr
Fe + Mn
Fe + Mg
FeO
FeO
t = 18s
t = 20s
t = 22s
t = 24s
900
800
700
600
500
400
300
200
100
0
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
Wavelength (A)

HELIOCENTRIC ORBIT

A	E	Q PER	Q APH	OMEGA	ASC NODE	INCL
2.8839	0.7139	0.8252	4.9426	305.6884	188.5451	2.2421
±0.0569	±0.0057	±0.0014	±0.1140	±0.2538	±0.0002	±0.0861



GEOCENTRIC ORBIT

INCLINATION	RA ASC NODE	LONG PERICENTER
38.263	21.596	113.027

PERICENTER (km)	ECCENTRICITY
6442.552	4.74307

Summary

- *Earth-grazing fireball (3rd case), with spectrum (1st case)*
- March 29, 2006 above Japan
  - minimal height; 71.4 km (87.45 - 71.38 - 72.74 km)
  - trajectory; 666 km
  - duration; 35- sec
  - entry velocity; 18.8 km/s
  - mean deceleration; 17 m/s^2
  - estimated mass; ~100 kg (assuming density of 3g/cc)
  - ablated and terminal mass; not yet determined
  - orbital changes; not yet determined
  - geocentric radiant; α=30.159°, δ=6.698°
- Heliocentric orbit shows low inclination.
- Spectrum shows chondritic material.