Introduction Chris Steyaert

- started meteor related activities in the VVS (Flanders, Belgium) 1973
- 1978, 1980: photographic campaigns in Switzerland
- radio work from mid 80's ('East block' FM)
- Founding IMO member
- RMOB text 1993
- RMOB web site 2000 (Pierre Terrier) www.rmob.org
- VVS meteor beacon 2005 (inspired on the Japanese beacon)
- IMO radio commission director 2021, following up J-L. Rault

3 head echo topics

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Topics

- Meteor Trajectory from Multiple Station Head Echo Doppler Observations
- Velocity from single head echo observation
- No head echoes with negative Doppler shift ?

Meteor Trajectory

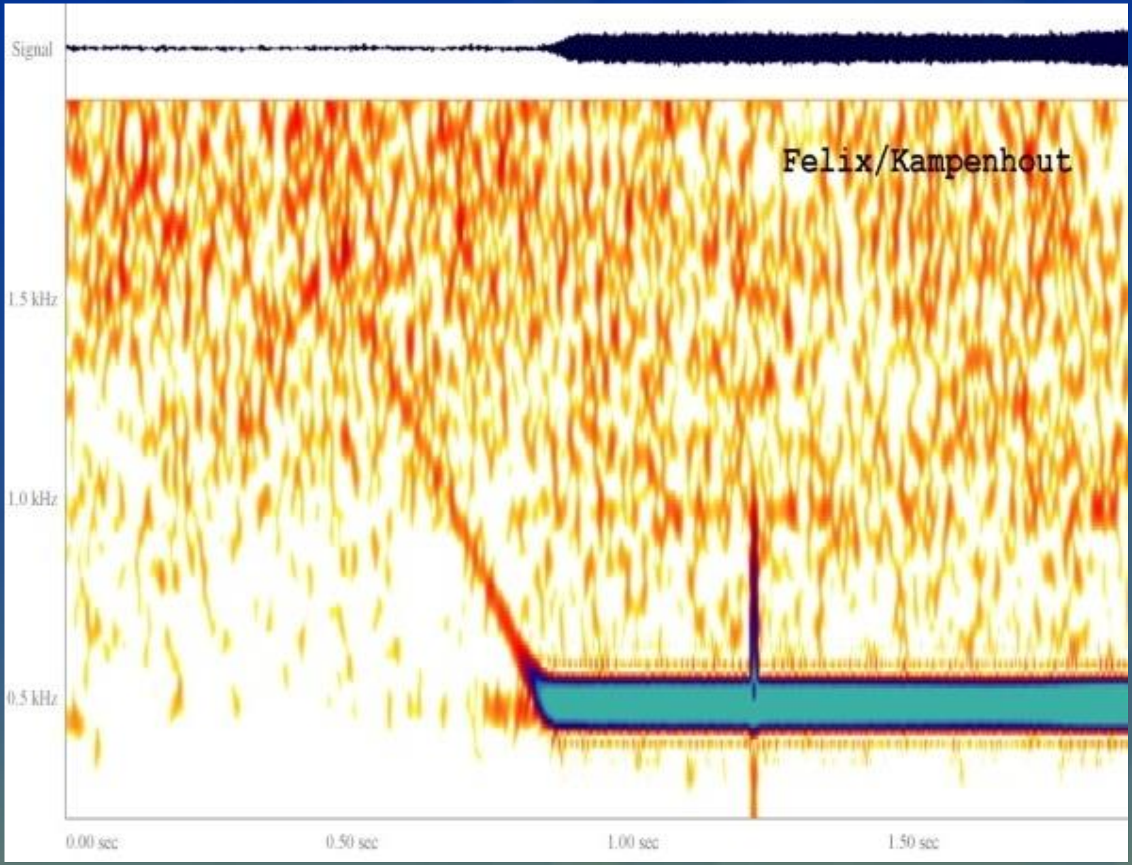
From:

WGN, the Journal of the IMO 38:4 (2010) 123

Meteor Trajectory from Multiple Station Head Echo Doppler Observations

Christian Steyaert, Felix Verbelen, and the VVS Beacon Observers

Meteor Trajectory



Spectrumlab 5 minute recording of Janos Barabas during the Geminids 2009 maximum

Head echo of 12 Dec 2009 20h38m UT Geminid, as recorded by Felix Verbelen

Meteor Trajectory

The purpose is to find the position M and velocity vector $\bar{v}$ from the observed Doppler shifts and Doppler shift derivatives at a given time.

The six unknowns x_M, y_M, z_M and v_x, v_y, v_z can in principle be obtained from at least three $Doppl_{Obsi}$ and the corresponding $\frac{\partial Doppl_{Obsi}}{\partial t}$

The general procedure is:

- choose M (x_M, y_M, z_M)
- solve (12) for v_x, v_y, v_z
- calculate for each 'i ' $\frac{\partial Doppl_i}{\partial t}$ with (12)
- calculate $J = \frac{1}{2}\sum_i \left(\frac{\partial Doppl_i}{\partial t} - \frac{\partial Doppl_{Obsi}}{\partial t} \right)^2$ (20)
- iterate M for minimum value J

Meteor Trajectory

The full theory for determining meteor trajectories from multiple Doppler head echo observations has been established.

Numerical results are encouraging, but will only be truly valuable if the timing accuracy of the recordings is improved to a few milliseconds.

Additional observing stations spread around the transmitter would improve the geometry and contribute to better results.

Velocity from single head echo observation

From:

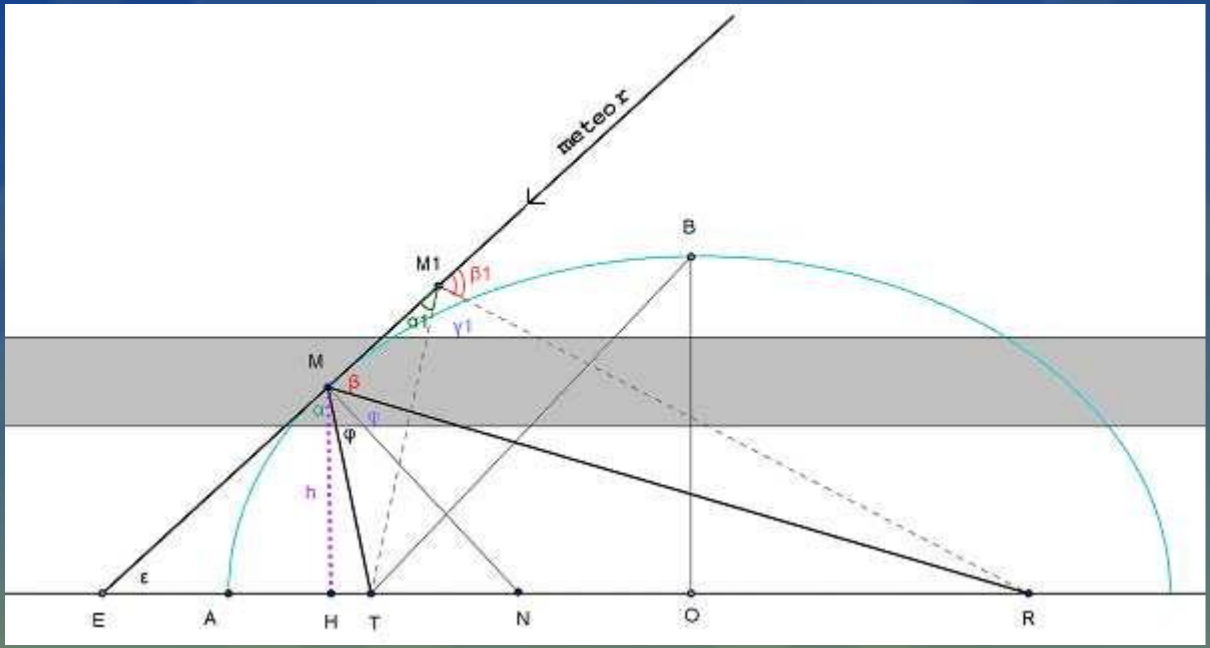
WGN, the Journal of the IMO 47:2 (2019) 49
Meteor velocity derived from head echoes obtained by a single observer using forward scatter from a low powered beacon

Felix Verbelen

Velocity from single head echo observation

Method

- Specular reflection
- Vertical plane
- Locating the specular reflection point M in the vertical plane
- Start 1st Fresnel zone M1



Velocity from single head echo observation

Let Δt_z = time needed to cross the 1st Fresnel zone
Δf_z = frequency change while crossing the 1st Fresnel zone.

Therefore we can directly obtain the meteor's velocity in the vicinity of the specular reflection point as:

$$v = \sqrt{\frac{c \cdot \mathrm{MM}_1 \cdot \tan(\theta)}{f_0 \cdot (\cos(\alpha_1) - \cos(\beta_1))}}$$

Pierre Ernotte (Ernotte, 2018) has shown that this can also be written as: $v = \mathrm{MM}_1 \cdot \sqrt{(-\Delta f_z/\Delta t_z)}$

Velocity from single head echo observation

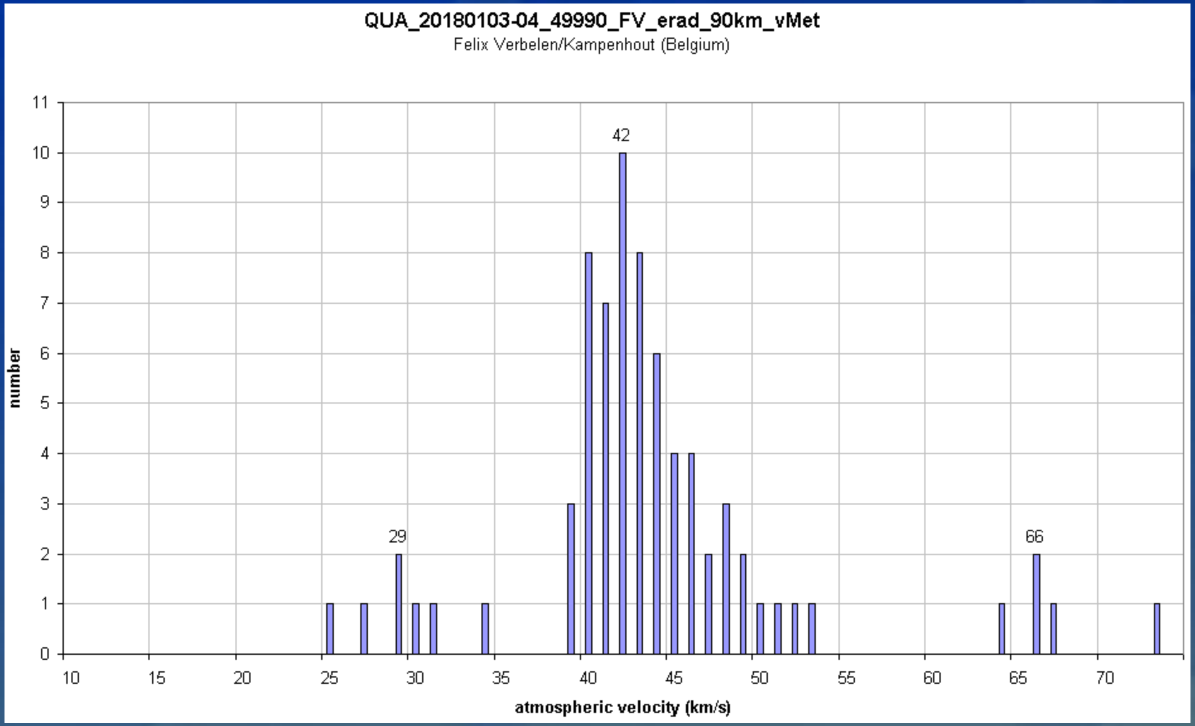


Figure 4 – Velocities (km/s) derived from head echoes on 2018 January 03–04 (VVS beacon near Ypres). Apart from the Quadrantids with typical velocities of 42 km/s, other showers with meteor velocities around 29 and 66 km/s seem to be active.

Velocity from single head echo observation

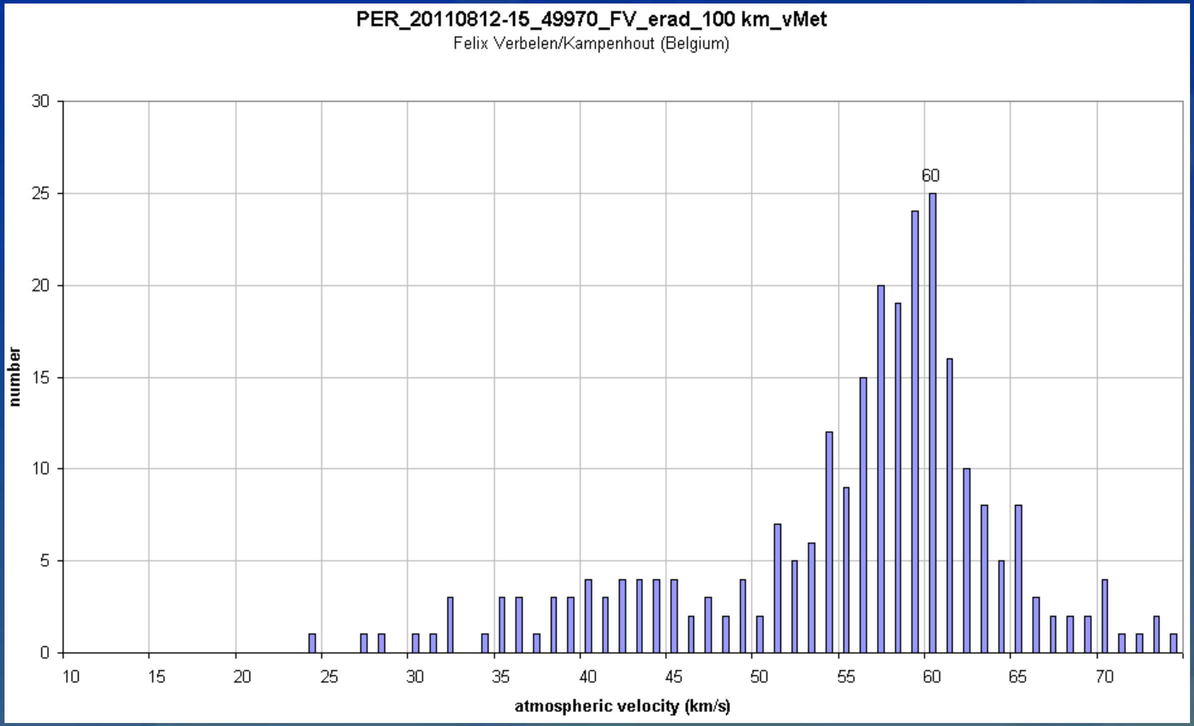


Figure 6 – Velocities (km/s) derived from head echoes on 2011 August 12–15 (BRAMS beacon at Dourbes). The Perseids show typical velocities of 60 km/s.

Velocity from single head echo observation

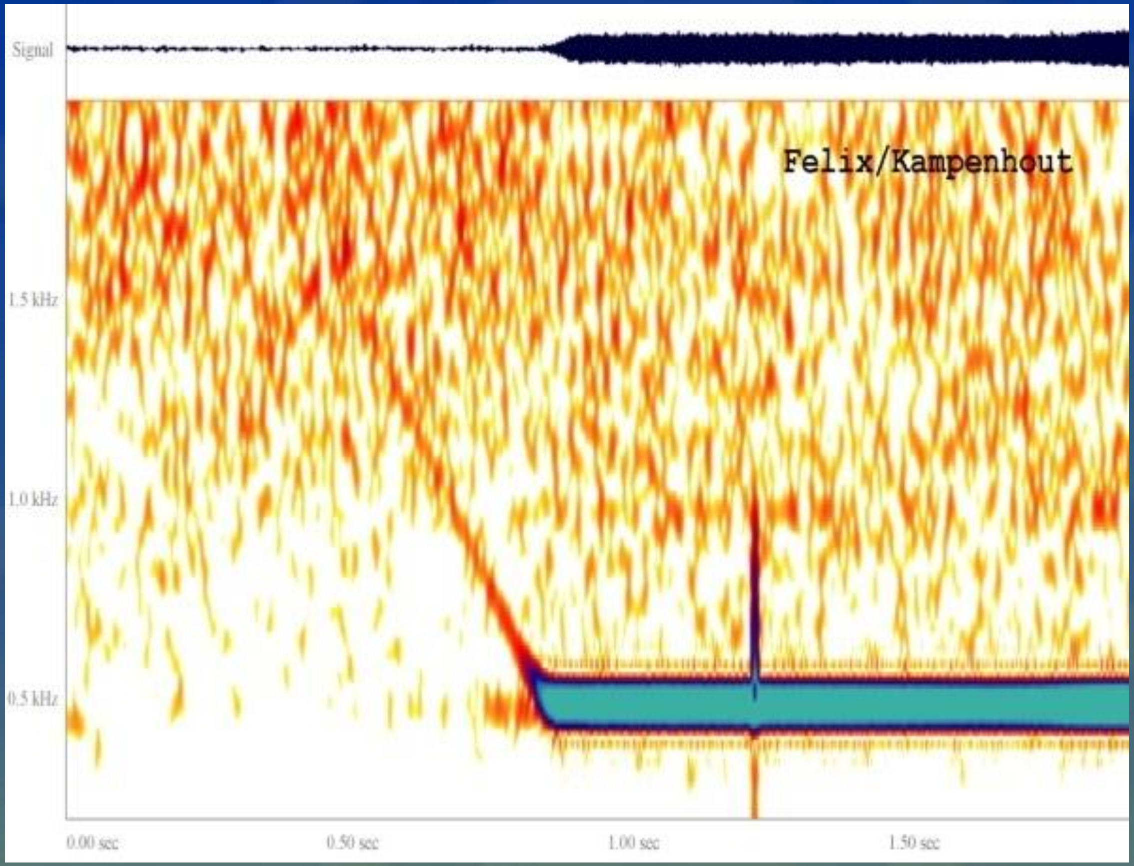
Conclusion

Using a single forward scatter receiver as described above and knowing only:

- the distance (TR) between transmitter and receiver,
- the beacon's frequency (f_0)
- the "slope" of the head echo (tan(theta)), and, if possible,
- the radiant's elevation (epsilon)

and assuming a reasonable ionisation height (h), it is possible to calculate the meteor's velocity in the immediate vicinity of the specular reflection point.

No head echoes with negative Doppler shift ?



Thanks to

- Felix Verbelen
- Cis Verbeeck
- Pierre Terrier
- BRAMS