Meteor Observations as a Method of Determining Atmospheric Properties

http://www.space.gc.ca/asc/img/kid_meteor.jpg

Elizabeth Bass, Meers Oppenheim
and Glenn Sugar
Boston University

Jorge Chau
Jicamarca Radio Observatory

ISEA 12 Conference
May 20, 2008

Outline

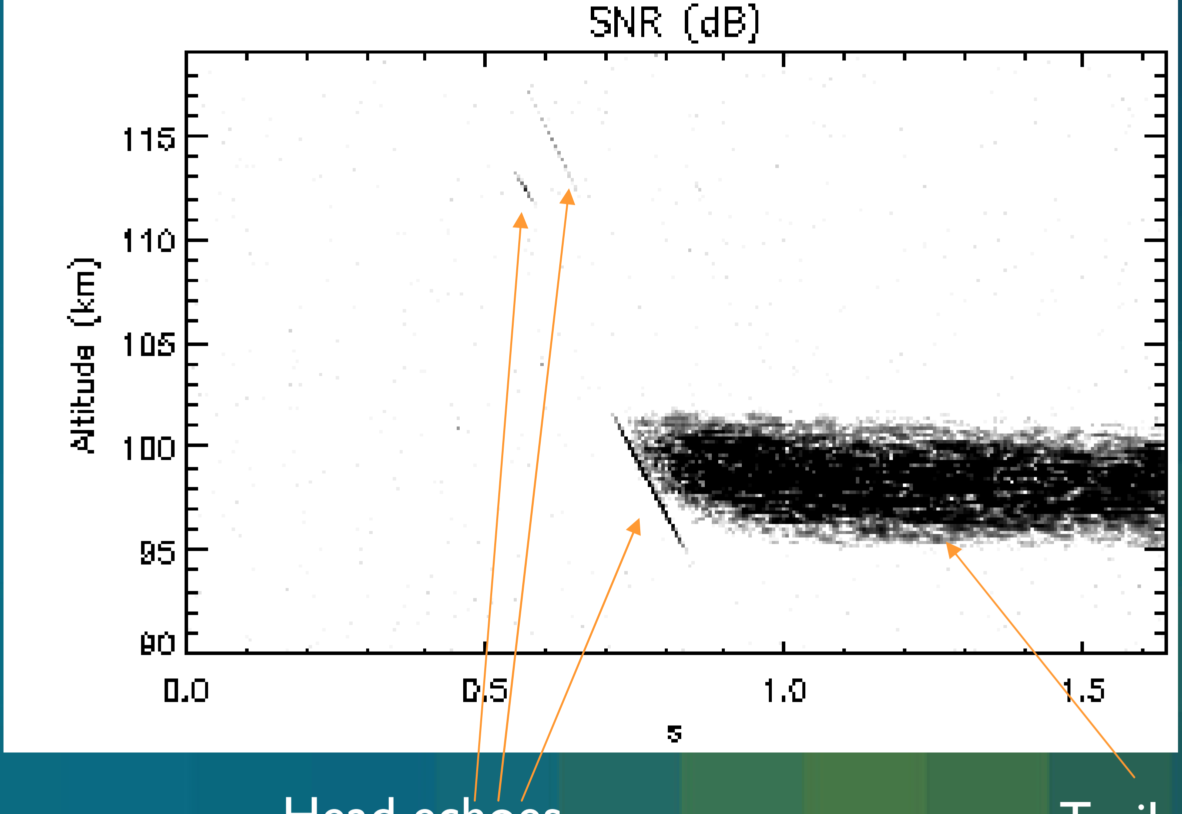
- Introduction
- Ablation model
- Using model to fit to density
- Conclusion

Jicamarca Radio Observatory (JRO)

- Located near Lima, Peru
  - 11.95° S, 76.87° W
- 50 MHz frequency
- Doppler measurements
- Interferometry

Meteor observations with high power large aperture (HPLA) radars

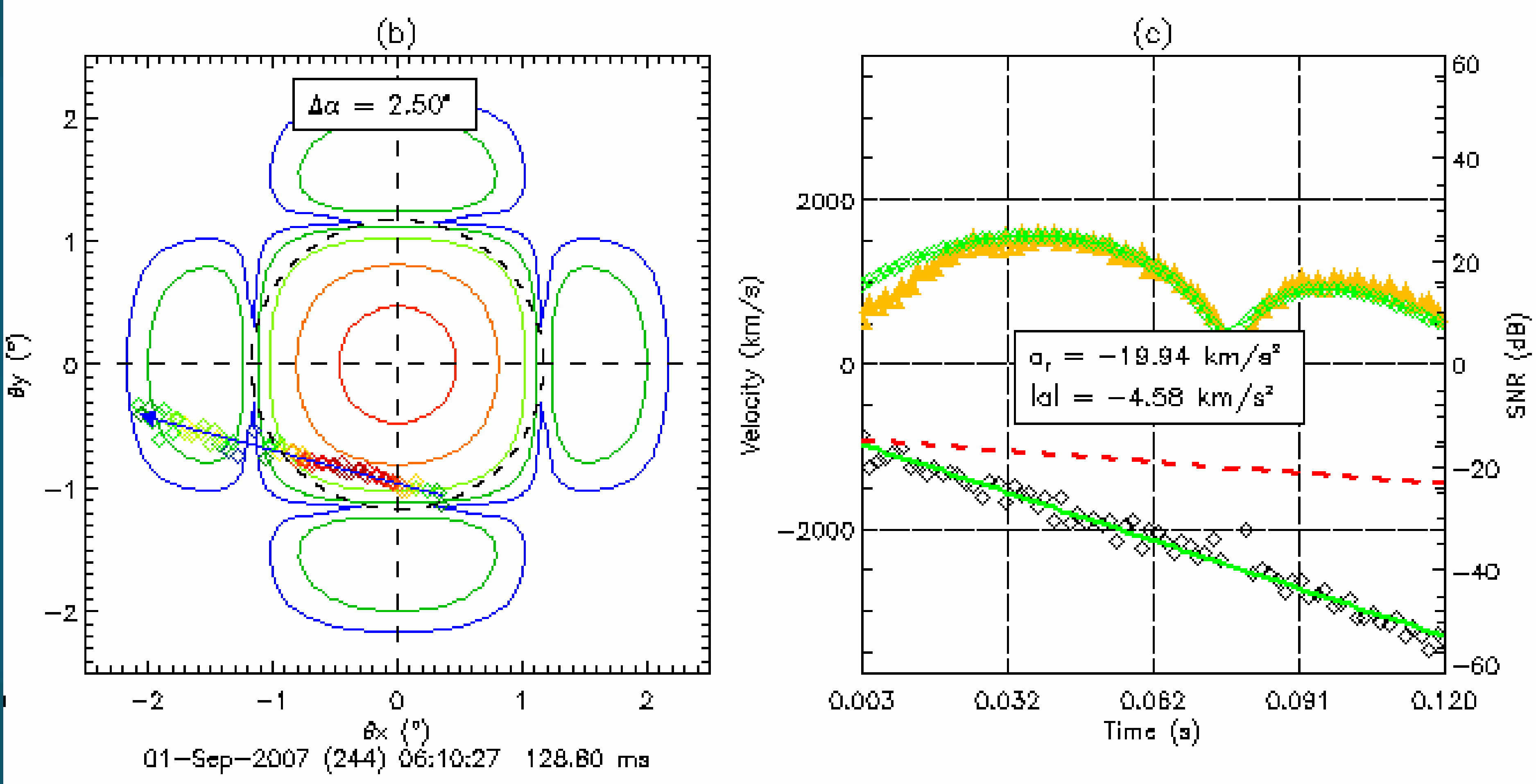
- Head echoes form when meteoroid ablates and plasma forms around it
- HPLA radars detect plasma at altitudes ranging from 70 km to 140 km



Head echoes

Trail

JRO Meteor Data



Simulation

- Meteors evolve according to:

$$\frac{dv}{dt} = \frac{-\Gamma A}{m^{1/3}\rho_m^{2/3}}\rho_{air} v^2$$

$$\frac{dm}{dt} = \underbrace{\frac{-4Am^{2/3}C_1}{\rho_m^{2/3}T^{1/2}}\exp\left(-\frac{C_2}{T}\right)}_{\text{ablation}} - \underbrace{\frac{\Lambda_s A m^{2/3}\rho_{air}v^3}{2Q\rho_m^{2/3}}}_{\text{sputtering}}$$

$$\frac{cm^{1/3}\rho_m^{1/3}}{A}\frac{dT}{dt} = \underbrace{\tfrac{1}{2}\Lambda\rho_{air}v^3}_{\text{friction}} - \underbrace{4\varepsilon(T^4 - T_a^4)}_{\text{radiation}} + \underbrace{\frac{L}{A}\left(\frac{\rho_m}{m}\right)^{2/3}\frac{dm}{dt}}_{\text{ablation}}$$

$$\frac{dh}{dt} = -v\cos\chi$$

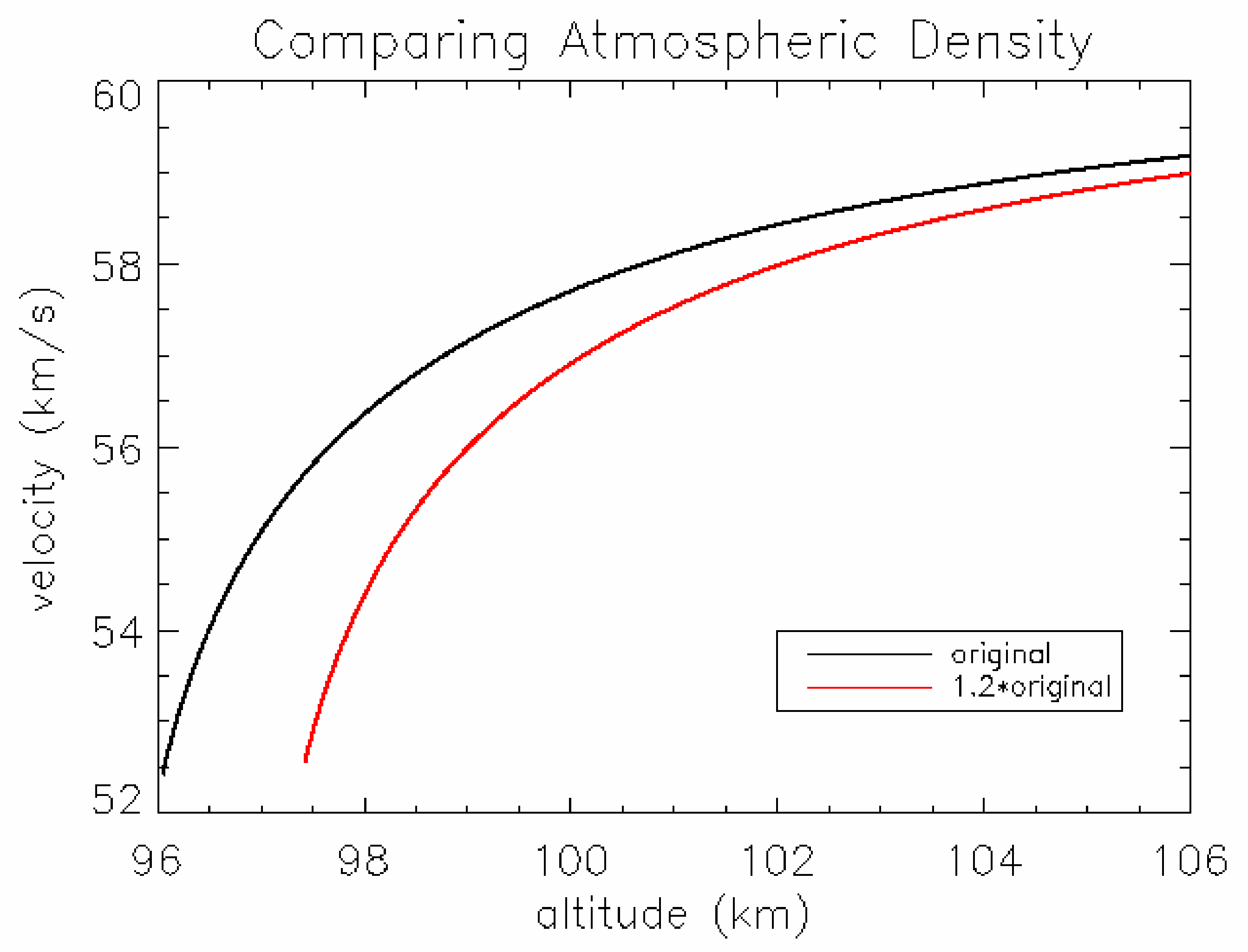
Here, *h* is height, *v* is velocity, χ is zenith angle, ρ_m is meteoroid density, ρ_{air} is atmospheric density, m is meteoroid mass, T is temperature, A is shape factor, Λ_s is sputtering coefficient, Λ is heat transfer coefficient, Q is energy of evaporation, ε is emissivity, c is specific heat, L is latent heat of fusion plus vaporization

(Lebedinets et al. 1973 and Rogers et al. 2005)

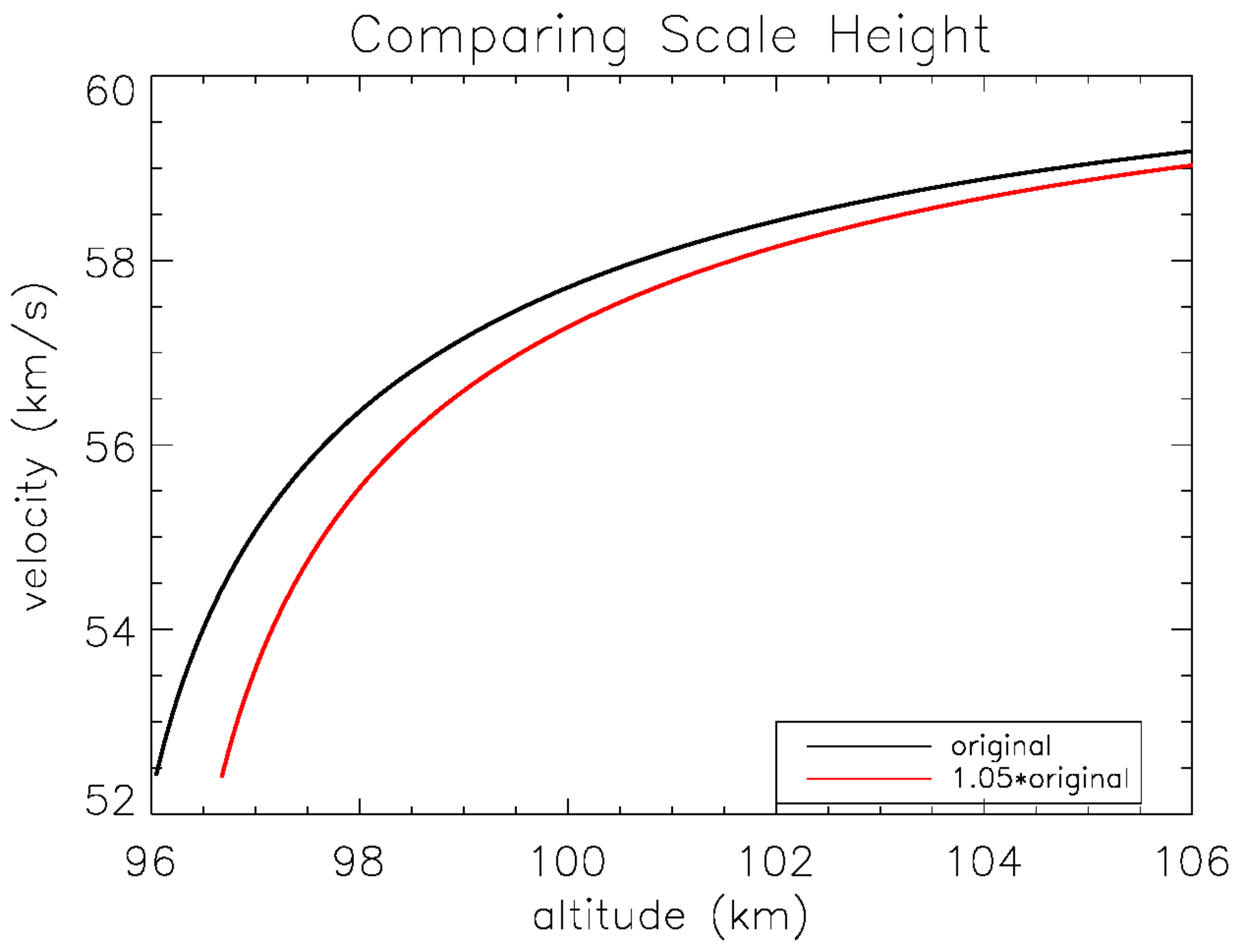
Using model fitting to calculate atmospheric properties

- Equations governing motion sensitive to atmospheric density
- Approach
  - allow density/scale height to be a free parameter
  - run ablation model iteratively to find best fit to altitude and velocity measurements

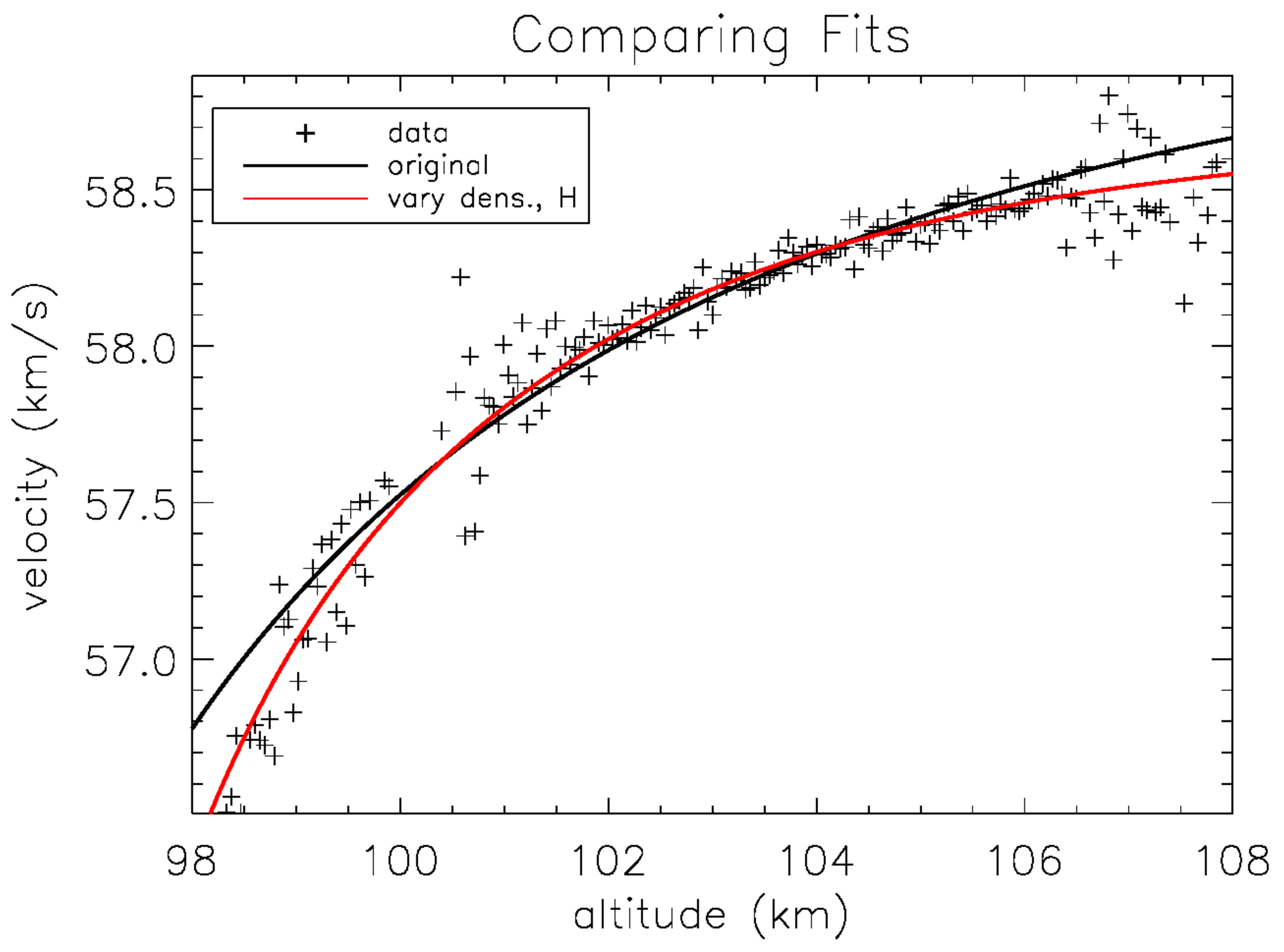
Effects of atmospheric density



Effects of atmospheric density (2)



Example with data



Preliminary results

- 14 strong meteors
  - within 10 minute period
- Possible trend:
  - 7 showed increased density and decreased scale height for best fit
  - 1 showed increased density but increased scale height
  - 2 had decreased density and scale height
  - 4 had fits which did not improve by varying density and scale height
- Preliminary conclusions:
  - strong hint that MSIS temperature is too high
  - weaker hint that density is too low

Conclusions

- Varying density and scale height allows greater improvement of fit
- Possible trends in sample
- Technique needs to be refined
  - apply to hundreds of meteors
  - a work in progress!