The mean molecular mass of Titan's atmosphere

an *in situ* measurement from Huygens without using the mass spectrometer

proof of concept for a useful technique

Paul Withers
Boston University
(withers@bu.edu)

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Previous Journal Club Talks

- 2004 September – Mars magnetic field/ionosphere
- 2005 October – Solar flare effects on ionospheres of Mars and Earth
- 2006 March – Space physics at Mars
- 2006 October – Aerobraking at Mars

- Mars, Mars, Mars, Mars, Mars, Mars, Mars

Science Questions

- Mean molecular mass (μ) -> Chemical composition
- How did Titan form?
- Current reservoirs of volatiles
- Ethane/methane puddles/ocean
- Thermal structure of atmosphere

Motivation

- Determination of atmospheric composition was a major Huygens goal – N_2 / CH_4
- Huygens carried six instruments (GCMS, ACP, DISR, SSP, HASI, DWE)
  - Instruments to determine μ were massive, expensive, delicate, etc
  - T/p sensors are simple, cheap, reliable
- Is it possible to know μ based on simple measurements only?

Method

Start at parachute deployment
End at surface impact

- Know p(t), T(t), z(t=0)
  - NOT μ(t)
- Want z(t), p(z), T(z)

http://images.businessweek.com/ss/05/05/eurospace/image/sequence.jpg

- $p = \rho \, k \, T / \mu$ (ideal gas law)
- $dp / dz = - \rho \, g$ (hydrostatic equilibrium)
- Need one more piece of information if μ is not known (Paul, explain the usual technique)

Terminal Velocity

- mg = ρ A v^2 C / 2 (drag equation)
- v = dz / dt (velocity - vertical)
- Rearranging…

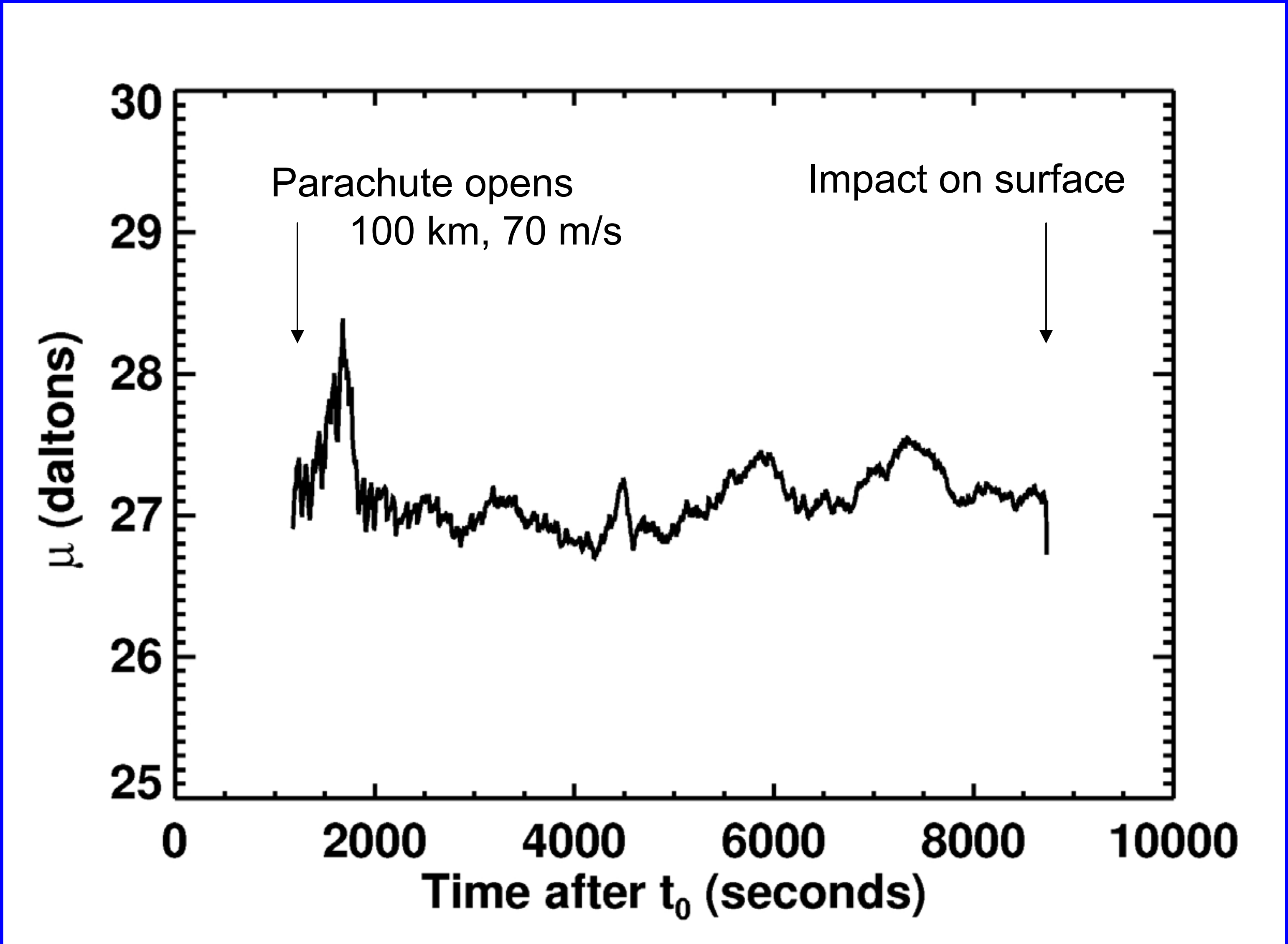
$$v = \left(\frac{-2mg_0^2}{(dp/dt)AC} \right) \left(\frac{R}{R+z} \right)^4$$

- Anyway, use these to get z(t) and v(t)
- Then get ρ(z) from hydrostatic equation and μ(z) from ideal gas law

Nasty Problem – And Its Solution

- C = ?
- Wind tunnels and numerical modelling made preflight predictions for C~0.5

- Select C, find z_{impact}, did impact occur at known surface, R = 2575 km?
  - If yes, C good; if not, C bad
- C = 0.65 (consistent with other analyses of the flight data)
  - C=0.66 has impact at z = +1.4 km
  - C=0.65 has impact at z = -0.2 km
  - C=0.64 has impact at z = -2.0 km



N_2 = 28

CH_4 = 16

My mean value differs from that of GCMS by 2%

Huygens GCMS found:	μ = 27.9 (low t, hi z)	1.41% CH_4
	μ = 27.4 (hi t, low z)	4.90% CH_4
Mean value in this work is	μ = 27.1	7.50% CH_4

So what? Huygens GCMS worked

- H / He ratio in giant planets uncertain by few percent
- CO_2 / N_2 ratio in Venus is uncertain by at least one percent
- CH_4 / N_2 ratio on Titan could vary in space and time

- Predictions of C must improve, need accuracies of 1%.

The End