Triton's atmosphere in 1989: new lab data, new profiles

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Start with the Summary

Radio occultation, ϕ vs. r
N2 refractivity, ν_{STP}
UVS occultation 800-1000 Å, T vs. r, λ
N2 line cross sections, $\sigma(\lambda)$ **NEW**
UVS occultation 550-650 Å, T vs. r, λ
N2 continuum cross sections, $\sigma(\lambda)$

→ Solve for line of sight number density (N_{los}) point-by-point →

N_{los}
0-20 km
139-322 km
474-703 km

→ Invert N_{los} →

Initial
number density, n(r)
pressure, p(r)
temperature, T(r)

Initial
number density, n(r)
pressure, p(r)
temperature, T(r)

→ detailed modeling →

Improved
number density, n(r)
pressure, p(r)
temperature, T(r)

→ Thermal models →

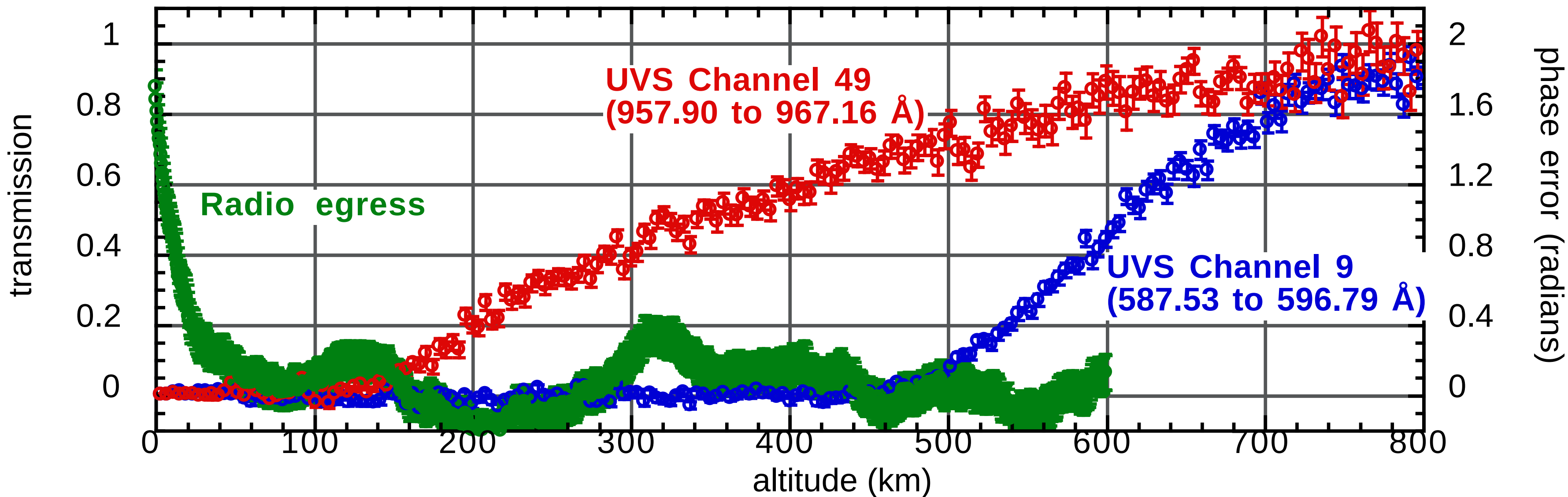
Energy sources, sinks

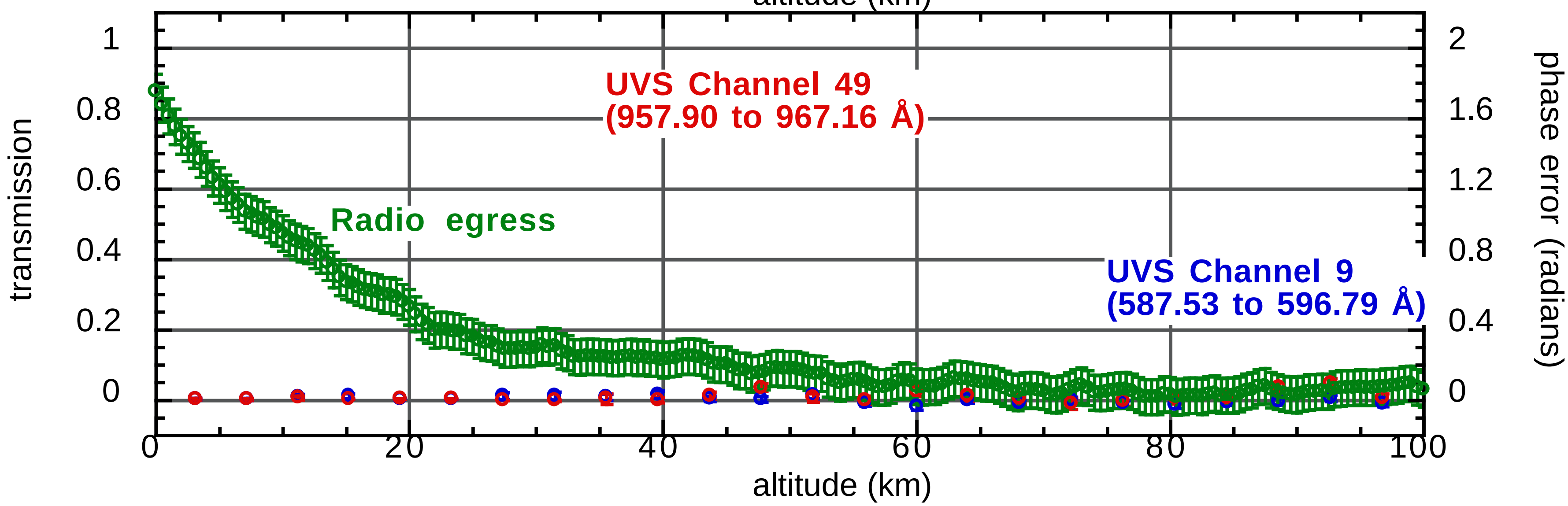
Initial
number density, n(r)
pressure, p(r)
temperature, T(r)

→ Atmospheric heating is 200 km lower and ~5x stronger than previously thought →

Heady excitement and wild speculation

Voyager (1989) occultation data

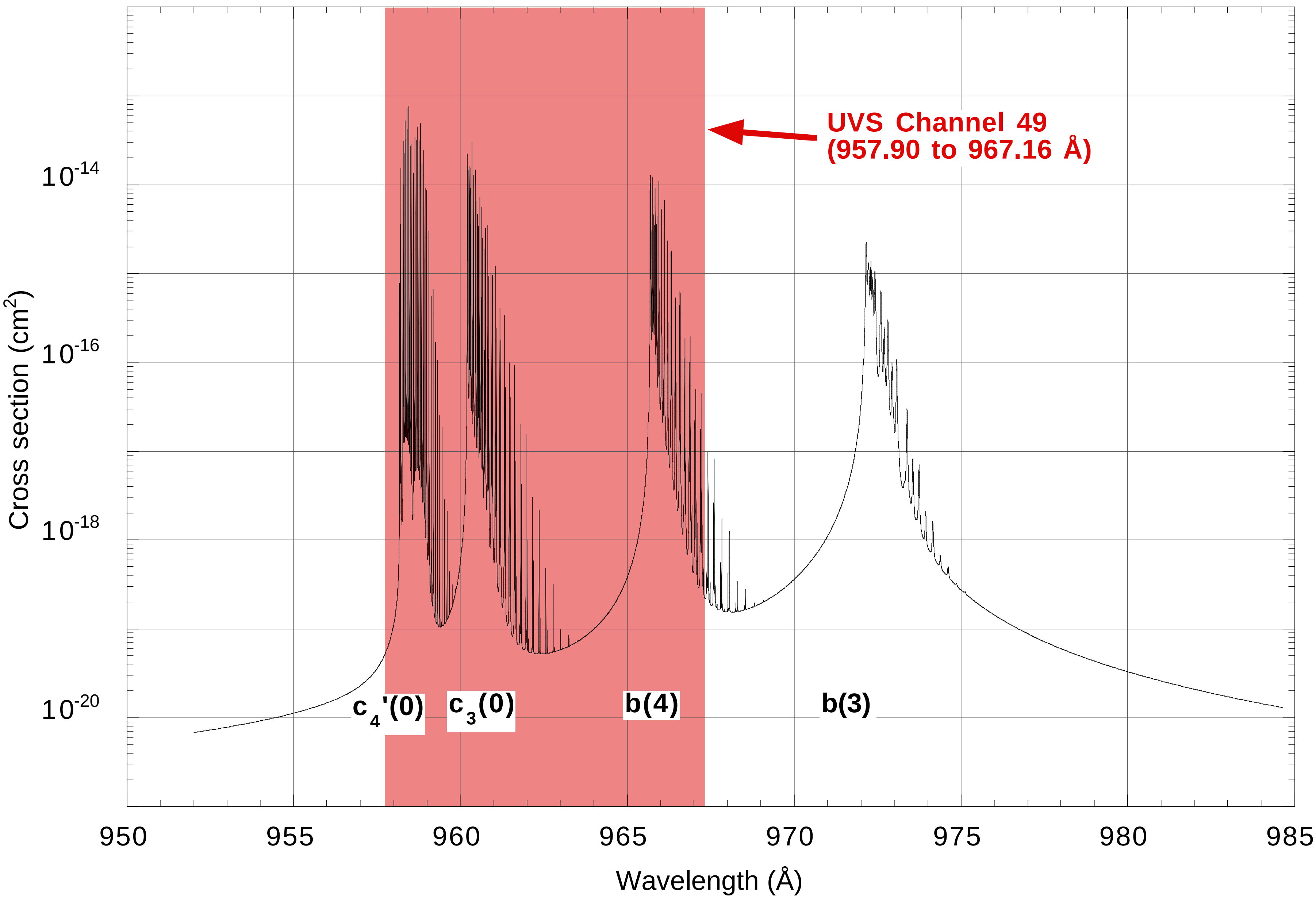




Voyager data details

- UVS transmission vs. altitude and wavelength
  - Use Ron Vervack's most recent reduction (~1992)
  - Use only odd channels
  - Account for wavelength shifts with altitude by shifting the transmissions
  - Estimate errors by comparing ingress and egress transmissions at the same wavelength, altitude
- Radio phase delay vs. altitude
  - Using most recent reduction: Gurrola, E. M. 1995. *Interpretation of Radar Data from the Icy Galilean Satellites and Triton*. Ph.D. Thesis, Stanford University, Fig 6.2, as preserved in Planetary Data System
  - Gurrola estimates errors at 0.1 radian; however, errors are highly correlated
  - Use the background estimated by Gurrola, taking into account this correlation; this is the background in Gurrola Table 8.3.

N_2 cross sections

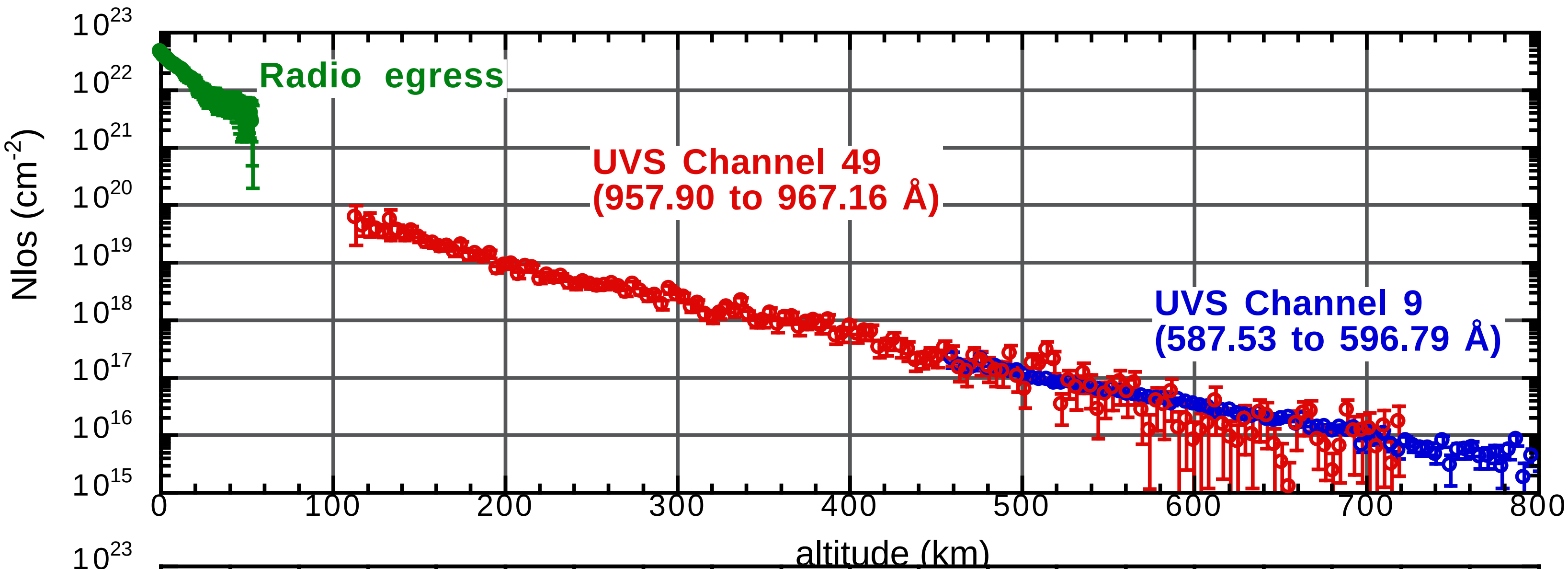


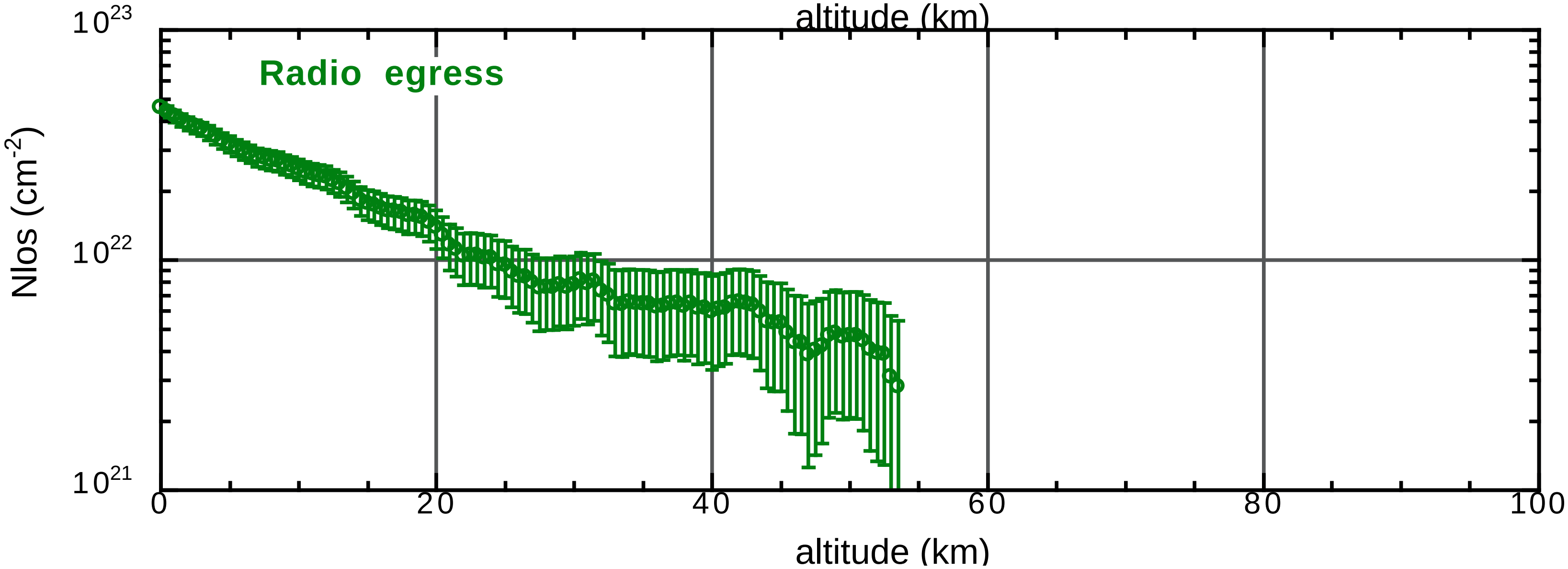
N_2 cross section details

- Four bands used in this analysis ($c_4'(0)$, $c_3(0)$, b(4), b(3))
  - N_2 photoabsorption measured by Stark and others at the Photon Factory synchrotron radiation facility at the High Energy Accelerator Research Organization in Tsukuba, Japan, 1997, 1998, 1999
  - Predissociation widths from Stark's measurements, or from Ubachs (e.g., Ubachs, W. 1997. Predissociative decay of the $c_4'\ ^1\Sigma_u^+$ v=0 state of N_2, *Chem. Phys. Lett.* **268**, 201.)
  - Use Hönl-London factors to derive individual line strengths, and use one predissociation width for each band.
  - Use cross sections for T=95 K

Band	Integrated cross section (cm^2 Å)	Predissociation width (Å)
$c_4'(0)$	1.11×10^{-15}	0.0001
$c_3(0)$	4.57×10^{-16}	0.00067
b(4)	5.03×10^{-16}	0.0029
b(3)	4.57×10^{-15}	0.03

Line-of-sight number density

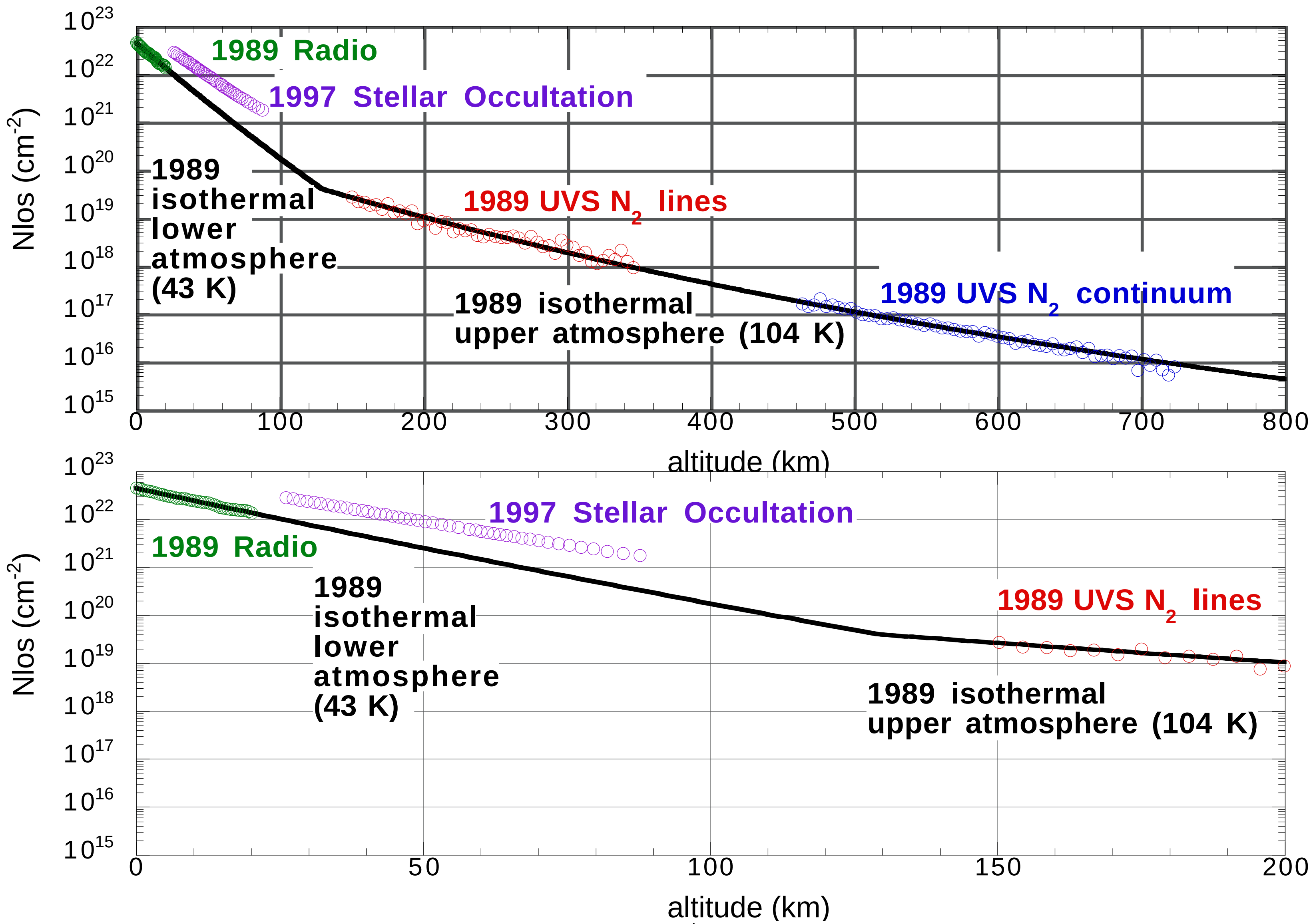




Line-of-sight density details

- N_{los} from N_2 continuum transmission
  - Simple Beer's law
  - $transmission = e^{-N_{los}\bar{\sigma}}$, where $\bar{\sigma} \approx \dfrac{\int_{\lambda_0}^{\lambda_0+\Delta\lambda} F_{\odot}\sigma_\lambda \, d\lambda}{\int_{\lambda_0}^{\lambda_0+\Delta\lambda} F_{\odot} \, d\lambda}$
- N_{los} from N_2 line transmission
  - Explicit averaging over wavelength
  - Consistent with N_{los} from N_2 continuum transmission
  - $transmission \approx \int_{\lambda_0}^{\lambda_0+\Delta\lambda} e^{-N_{los}\sigma_\lambda} d\lambda$
- N_{los} from radio phase
  - $phase\ delay = \dfrac{4\pi\nu_{STP}}{\lambda N_L} N_{los}$

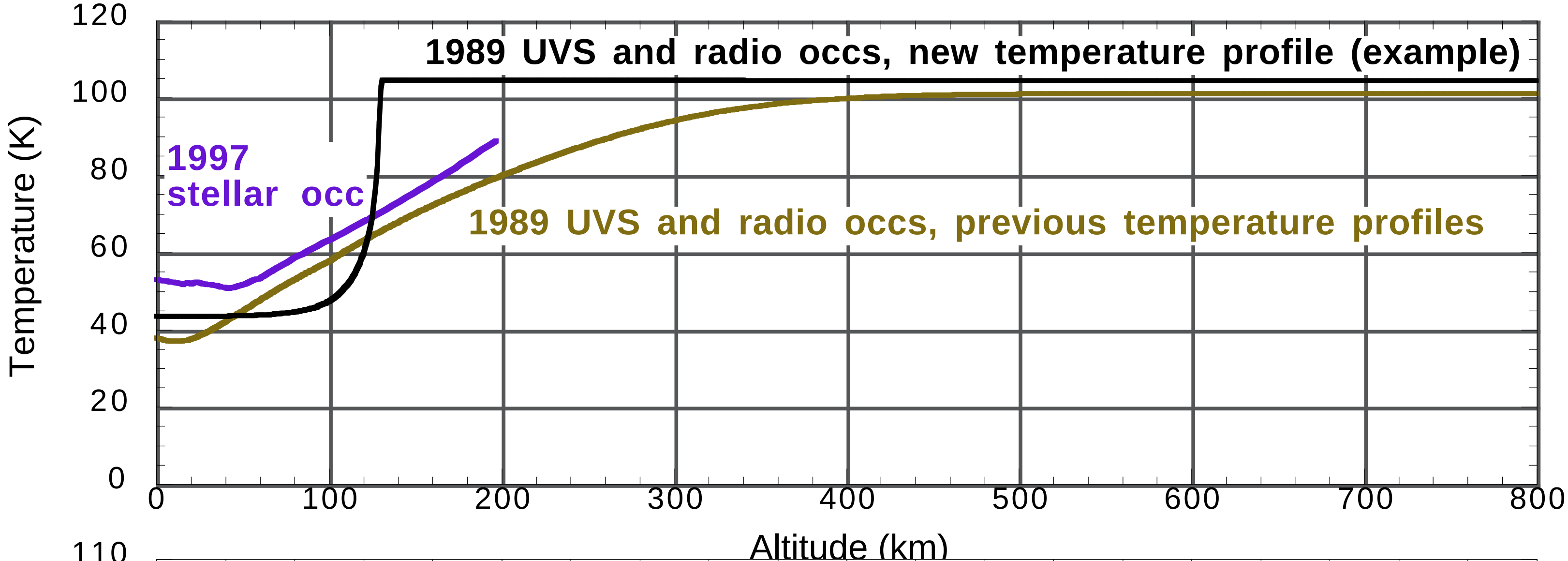
N_{los} interpretation

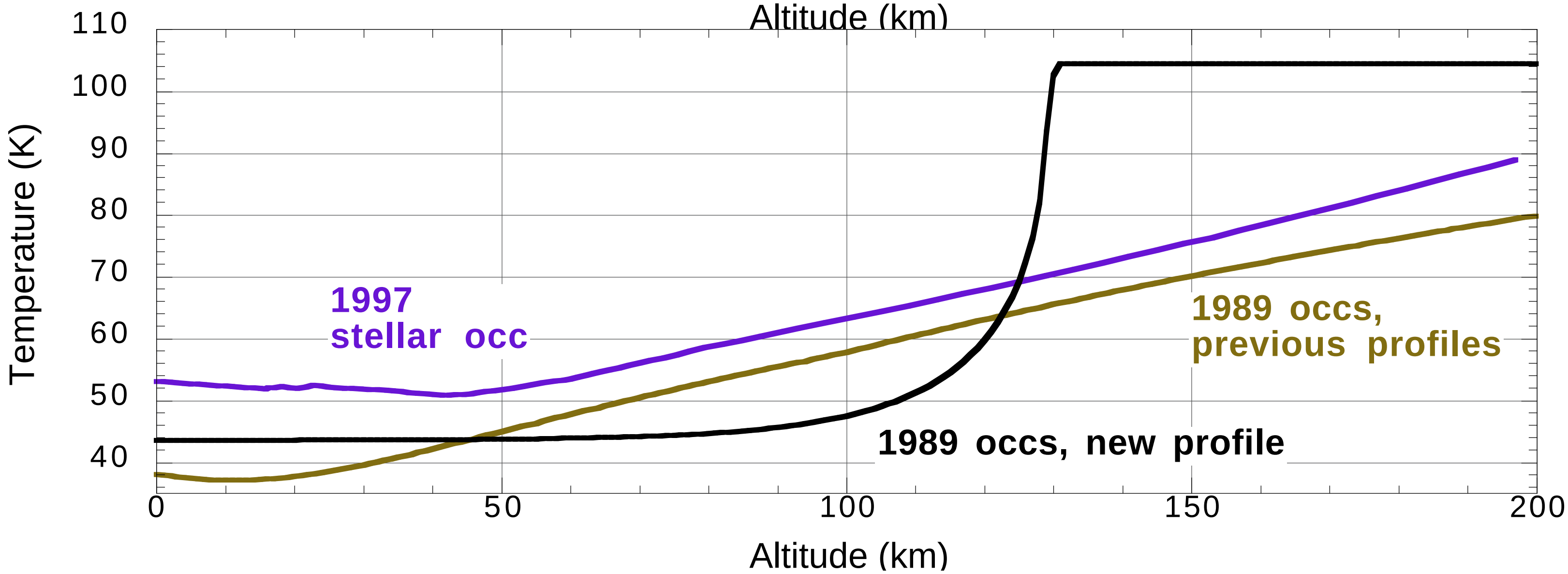


N_{los} interpretation details

- Fit UVS and radio with (small-planet) isothermal models
  - $N_{los} = N_{los}(r_o)\left(\frac{r}{r_0}\right)^{3/2} \exp\left[\frac{r}{H} - \frac{r_0}{H_0}\right]\left[1 + \frac{9}{8}\left(\frac{H}{r} - \frac{H_0}{r_0}\right)\right]$
- Upper atmosphere
  - All of the SNR>5 UVS N_{los} can be fit with single temperature
  - T=104 K (c.f. Krasnopolsky et al. 1993; T=102±3 K)
- Lower atmosphere
  - All of the SNR>5 radio N_{los} consistent with single temperature
  - T=44 K (c.f. Gurolla 1995; T=42±8 K)
- Comparison with 1997
  - Calculate N_{los} from temperature profile (Elliot et al. 2000)
  - N_{los} has increased between 1989 and 1997

Temperature profiles





Temperature profile details

- Invert the "spliced isothermal" N_{los} profile from above
  - Use the "small planet" Abel transform
  - $n(r) = -\frac{1}{\pi r^2}\int_0^\infty \frac{dsN_{los}(s)}{ds}\frac{s\,ds}{\sqrt{s^2-r^2}}$
- Implied heating differs from previous models
  - Stevens et al. 1992; Yelle et al. 1991
  - Main heating is below 150 km (c.f. Stevens et al 1992; 300-400 km)
  - Gradients may be as high as 1.4 K/km for fluxes as high as 8×10^{-3} erg/cm^2/s
  - Heating by chemical recombination or energetic particle precipitation?
  - Thermal models may not split the atmosphere into "upper" and "lower"
- Lower atmosphere (<90 km): colder in 1989 than in 1997
  - As reported by Elliot et al. 2000
  - Higher conductive flux will affect thermal models of the 1997 occultation, which are currently unsatisfactory.