Anomalous equatorial vertical winds?

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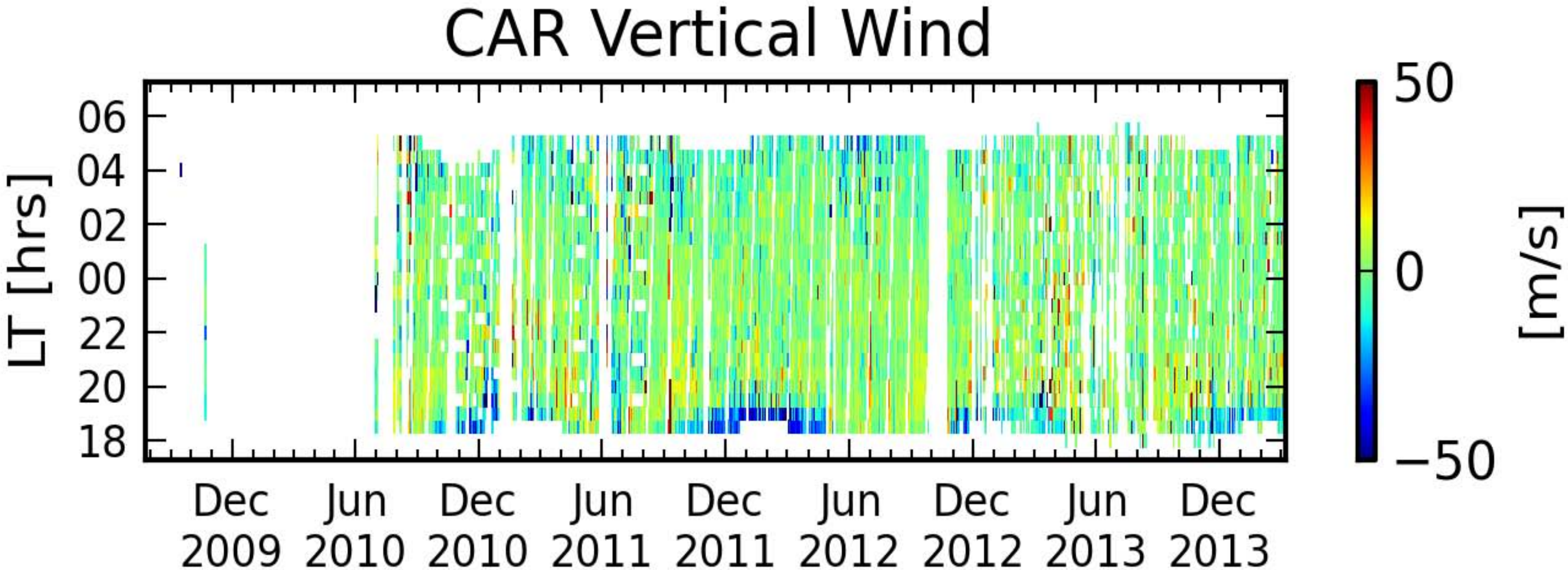

RENOIR observations of seasonal twilight vertical winds repeated over four years

Question: How to account for the downward vertical winds of 20-25 ms^{-1} in evening twilight?

not likely to be dynamical in origin!

To account for the observed fast production of atoms in the laboratory by Biondi, Bates (1950) proposed the mechanism of dissociative recombination (DR):

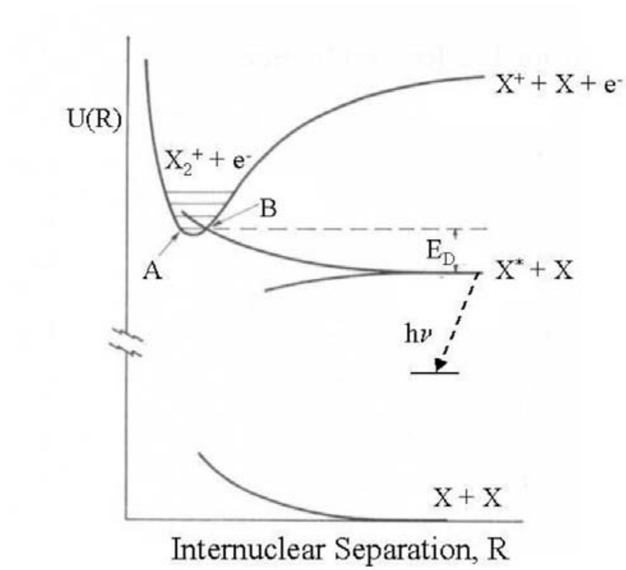

Figure 3. Simplified potential energy curves for the dissociative recombinati

This is based upon

a) molecular ions are formed by charge exchange, i.e.,
b) $O^+ + O_2 = O_2^+ + O$
c) Recombination of these molecular ions produces excited atoms
d) These atoms carry the kinetic energy of dissociation

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Interferometric Study of Dissociative Recombination Radiation in Neon and Argon Afterglows*

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A photoelectric recording, pressure-tuned Fabry-Perot interferometer of high resolution is used to determine the spectral line profiles of 22 neon and 5 argon ($2p_n \rightarrow 1s_m$) lines emitted from a microwave discharge and during the ensuing afterglow. All afterglow line profiles are broader than the corresponding discharge lines, and in most cases the afterglow line shapes are consistent with a dissociative origin of the excited atoms, indicating that the $2p_n$ excited states of neon and argon are produced by dissociative recombination of electrons with Ne_2^+ and Ar_2^+ ions, respectively. Detailed examination of the line profiles in neon indicates a "multishouldered" structure corresponding to several different dissociation kinetic energies, suggesting that different initial states of the Ne_2^+ ion are involved in the dissociative recombination process. From the deduced molecular ion energy levels it appears that, in addition to the Ne_2^+ ion state with a dissociation energy $D = 1.35$ eV reported by Connor and Biondi, there may be a more weakly bound state with $D \sim 0.5$ eV which contributes to the recombination.

Laboratory studies by Biondi showed the line shapes of emission from DR reaction product (atoms) to be non-thermal

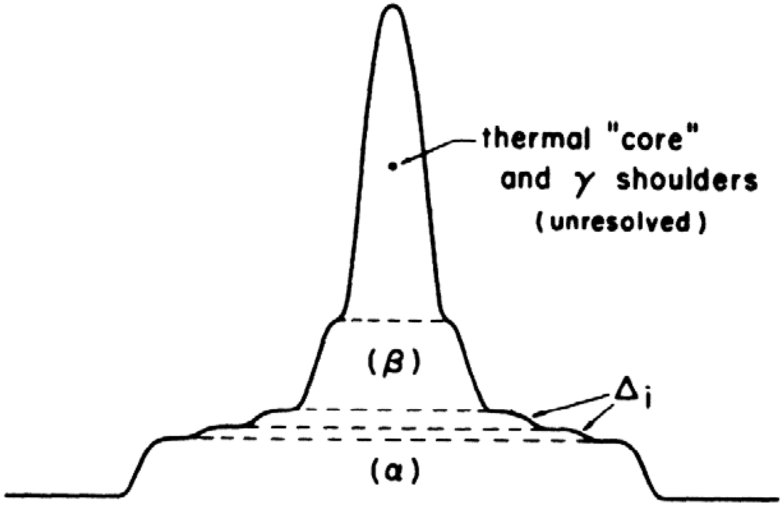
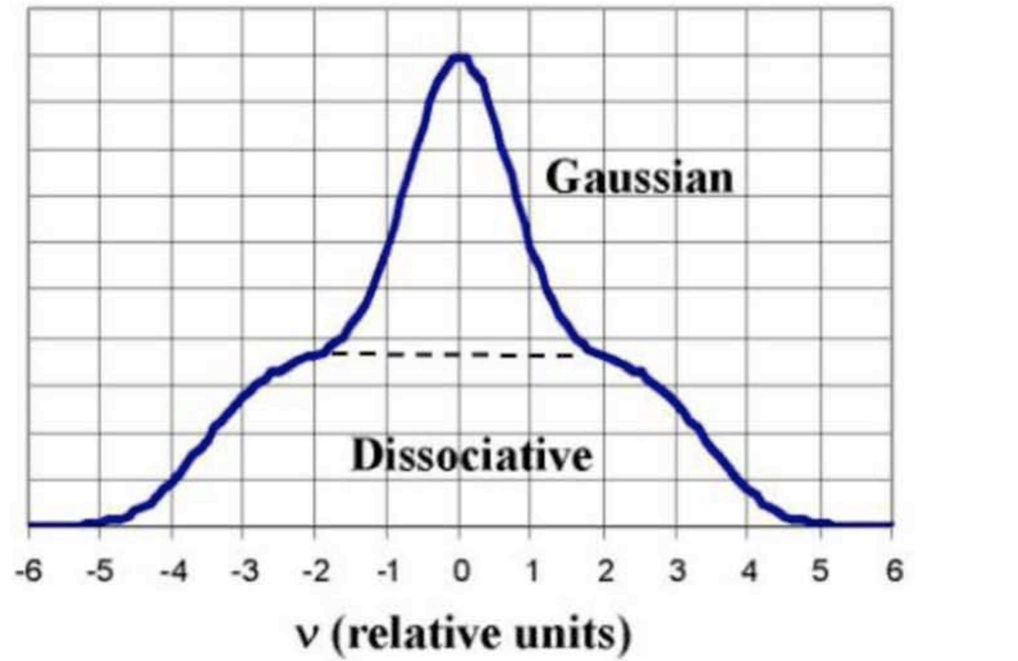
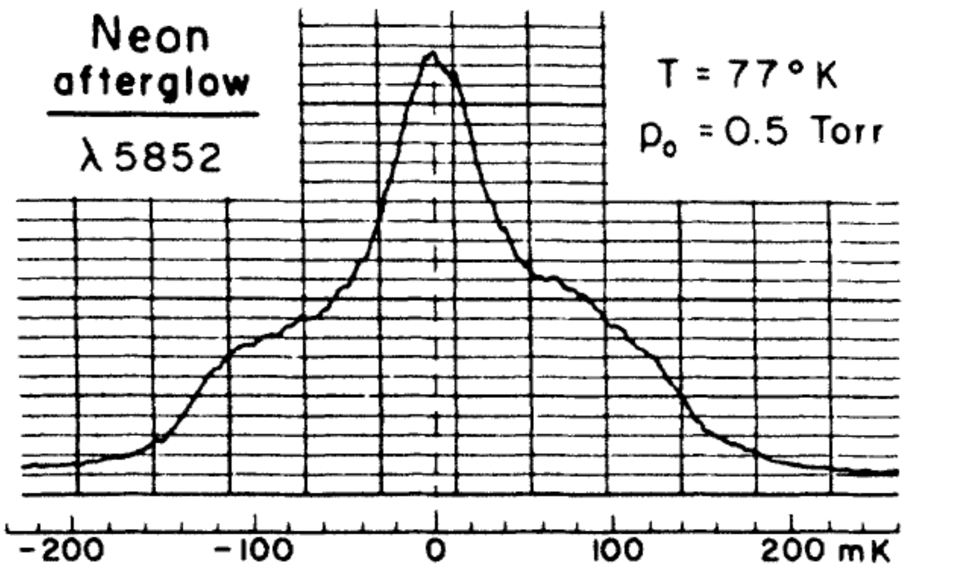


FIG. 3. Hypothetical line shape arising from superposition of several dissociation kinetic energies and a thermal Doppler core. The contributions, $\alpha, \beta, \gamma, \Delta_i$, might arise from energy states and curve crossings of the type indicated by the corresponding letters in Fig. 1.



al spectral line profile for the dissociative recomb

The line shapes are non Gaussian



Fromholde and Biondi, 1969

Planet. Space Sci. 1971, Vol. 19. pp. 467 to 476. Pergamon Press. Printed in Northern Ireland

THE SIGNATURE PROFILES OF $O(^1S)$ IN THE AIRGLOW

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Abstract—The spectral line shapes, or signature profiles, of $O(^1S)$ proceeding from the dissociative recombination of $O_2^+(^2\pi_g)$ in the upper atmosphere have been optically observed in the nightglow at the geomagnetic equator with a Fabry–Perot spectrometer. The results indicate that the recombination leading to $O(^1S)$, $O(^3P)$ and 2·79 eV excess energy is favored relative to that leading to $O(^1S)$, $O(^1D)$ and 0·83 eV. excess energy by at least a factor of 5 to 1. Partial thermalization of the profile was observed indicating energy exchange with the medium. From this, a relaxation time of about 3 sec, or a collision cross section of about 6×10^{-16} cm^2 can be derived depending on the mechanism invoked for thermalization.

This paper looked at the question of the importance of "hot O atoms" in connection with the emission from the $O(^1D)$ airglow generated by DR.

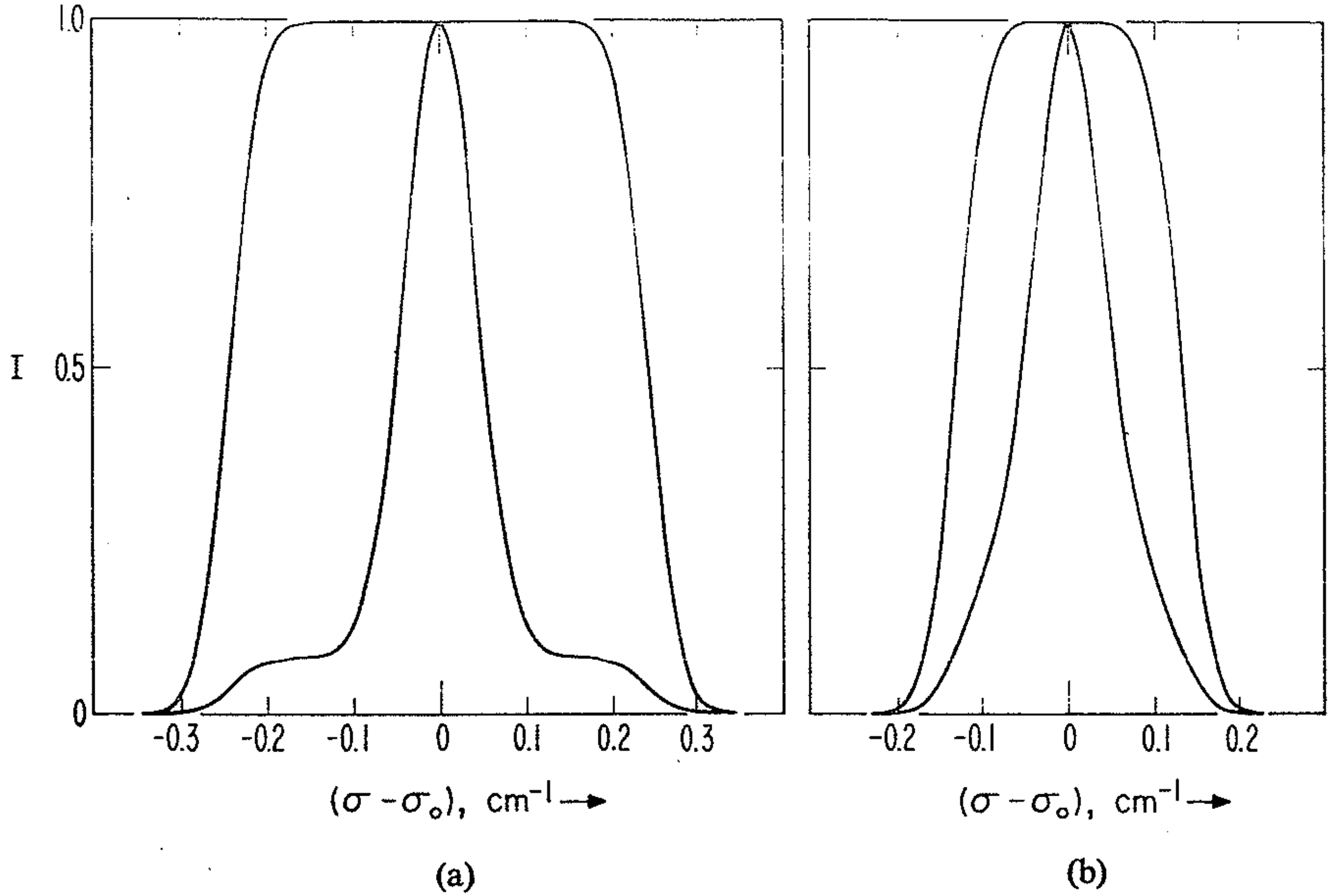

FIG. 1. COMPUTED SIGNATURE PROFILES FOR THE EXCITATION EXCHANGE SCHEME (a) 2·79 eV EXCESS ENERGY FOR NO COLLISIONS (FLAT TOP) AND 3 COLLISIONS sec^{-1}; (b) 0·83 eV EXCESS ENERGY FOR NO COLLISIONS AND ~2 COLLISIONS sec^{-1}.

Collisions change the lineshape from its original broad profile toward that of a thermalized distribution

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Observation of anomalous temperatures in the daytime $O(^1D)$ 6300 Å thermospheric emission: A possible signature of nonthermal atoms

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Abstract. A study of the effect of a thermospheric population of nonthermal $O(^1D)$ atoms on the 6300 Å emission is undertaken based on a comparison between daytime observations from space and theoretical simulations. Vertical temperature profiles deduced from 6300 Å airglow emission measurements using the Fabry-Perot interferometer (FPI) instrument onboard the Dynamics Explorer 2 (DE 2) satellite are compared to the MSIS-90 model. Metastable $O(^1D)$ temperatures about 150 K larger than the MSIS neutral kinetic temperature are deduced from the 6300 Å line profiles observed during daytime, when the satellite altitude is higher than 400 km. We propose a theoretical explanation for this difference, based on the presence of a nonthermal $O(^1D)$ population in the line-of-sight of the instrument. Monte Carlo simulations of the nonthermal $O(^1D)$ energy distribution function are used to calculate the red line emission and to simulate the FPI behavior, including the line-of-sight integration. The comparison between the simulated data and the FPI ones as well as sensitivity tests allow us to conclude that the presence of nonthermal atoms in the instrument field of view is the most likely explanation of the observed discrepancy.

Detailed calculations show there is a non-thermal population that varies with height

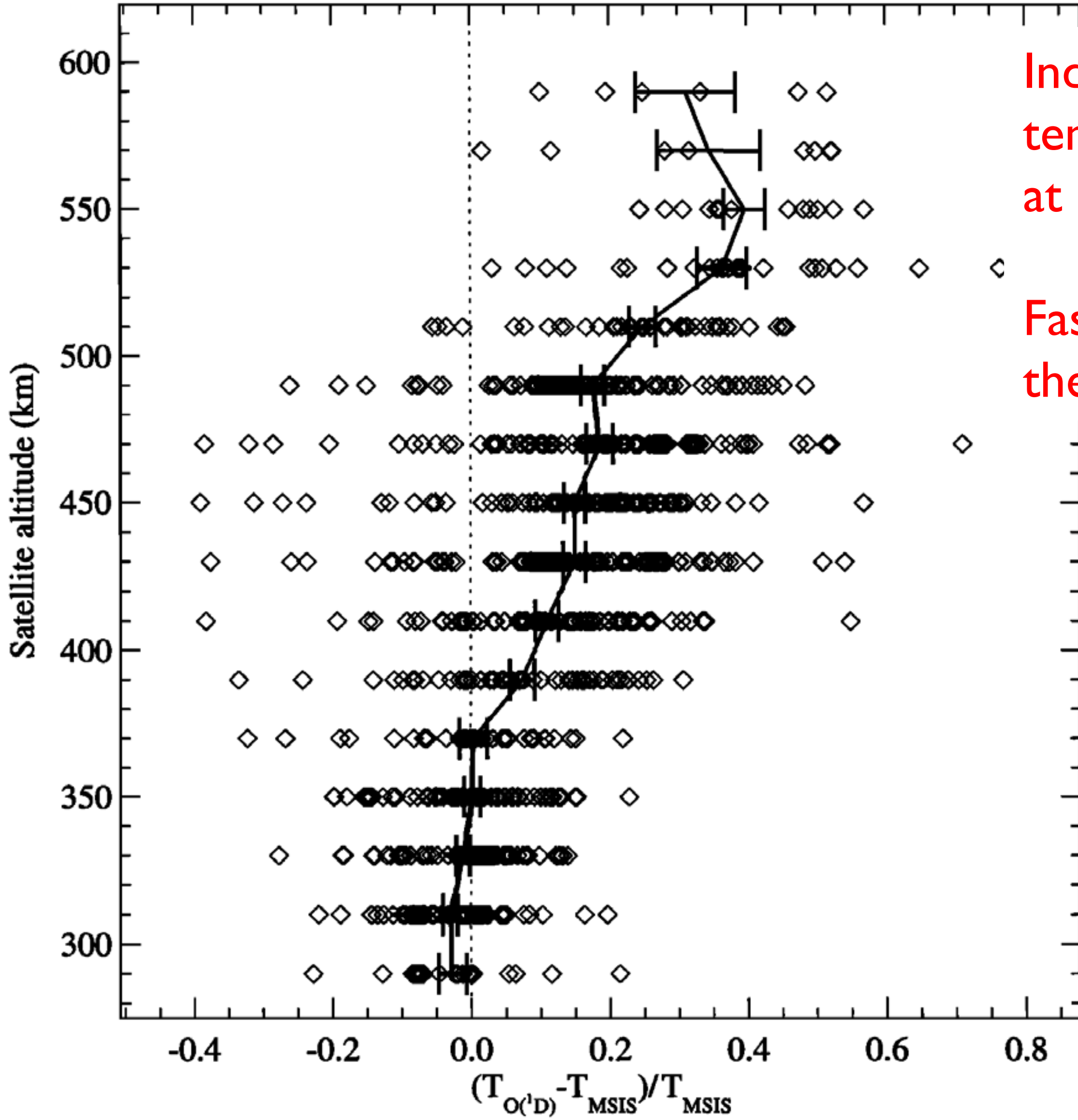
Points to consider

Excitation transfer to ambient atoms and momentum transfer elastic collisions help to remove excess energy in DR reactions, but this is height-dependent.

Most excited atoms have the temperature of the ambient atmosphere, while a small fraction (generally < 10%) retain some of the initial dissociation energy when they radiate. This group may be said to have a very high "temperature."

Both the fraction of fast atoms and their energies are functions of altitude since the collisional frequency removing the excess energy decreases with increasing altitude.

Thus, the "vertical winds" observed for Brazil twilight are perhaps an indication of the lack of incomplete thermalization of O atoms



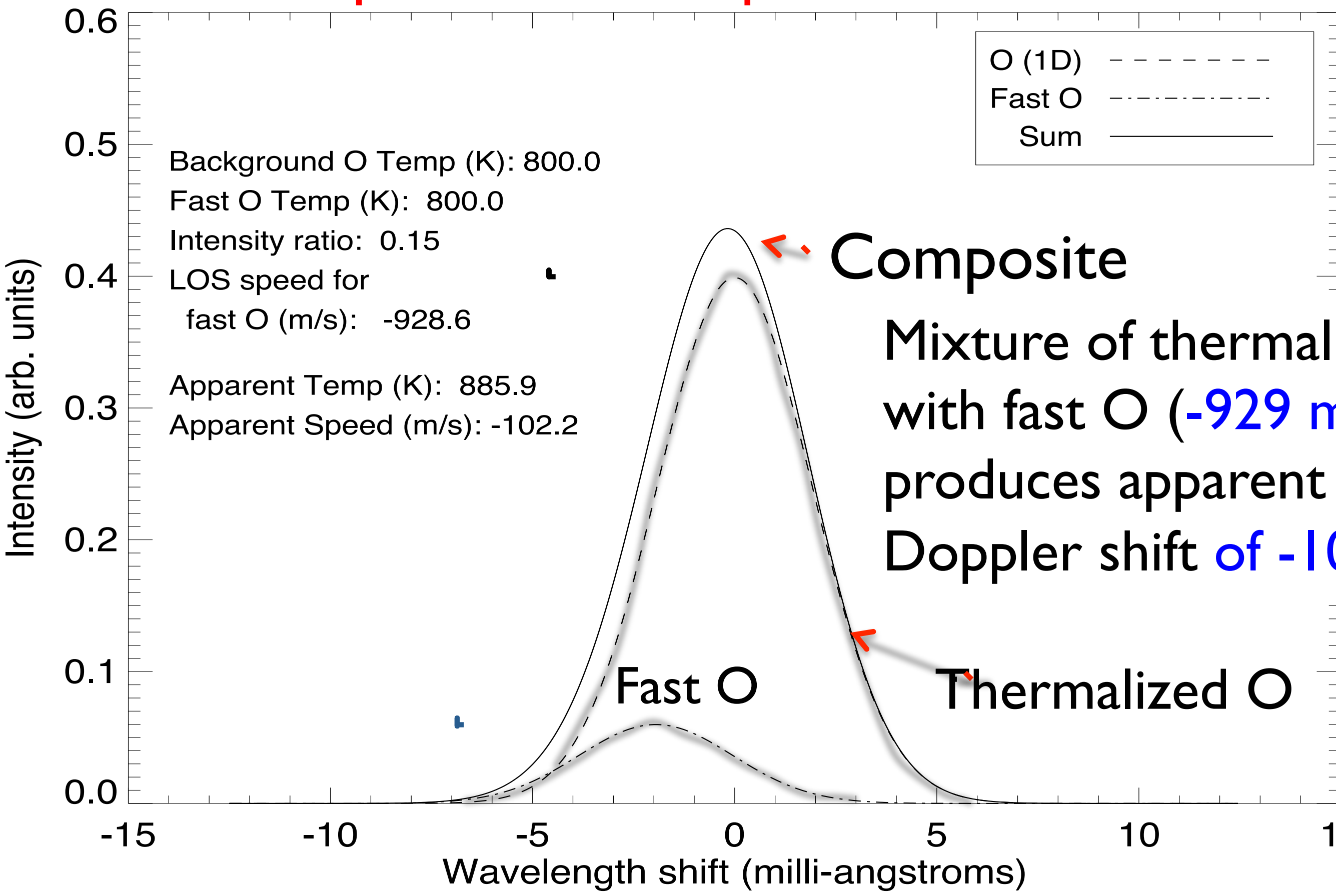
Indication of excess temperature relative to T at 325 km

Fast O atoms indicated in these results

Figure 5. Relative difference $(T_{O(^1D)} - T_{MSIS})/T_{MSIS}$ versus satellite altitude. The dotted line is the zero line. Daytime data from 57 DE2 orbits between days 262 and 300 (1982) matching 45° < latitude < 45° are used for all *Ap* values. Interferograms with tangent heights below 210 km are rejected. Each diamond represents the fitted temperature of the interferogram constructed by adding data of a single orbit by tangent height bins of 20 km and satellite altitude bins of 20 km. The solid line is the arithmetic average of the diamonds; the error bars represent the standard deviation of the arithmetic average σ_a ($2\sigma_a$ wide).

Simulation suggests fast O contamination of thermalized O line shape would shift linecenter toward the blue tail

Spectral line shape simulation



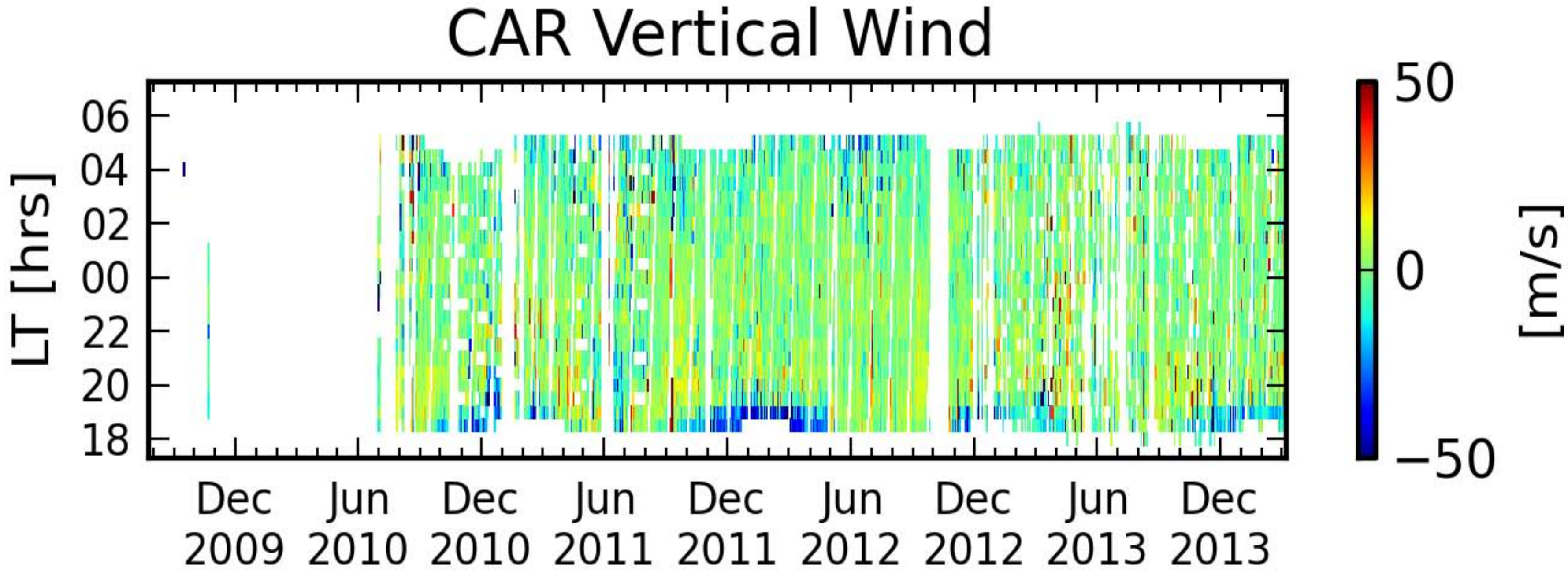
Composite

Mixture of thermalized [O] with fast O (-929 ms^{-1}) produces apparent Doppler shift of -102 ms^{-1}.

Thermalized O

Blue-shifted O atoms

Red shifted O atoms



Hypothesis: These "anomalous" downward vertical winds are a result of "hot" O atoms contaminating the thermal profiles due to the lack of thermalization of O because the plasma is still quite high during the recovery phase of the pre-reversal enhancement

Questions?

Thermospheric distribution of fast $O(^1D)$ atoms

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[1] Detailed calculations are carried out of the sources of energetic metastable $O(^1D)$ atoms in the atmosphere at altitudes between 80 km and 200 km, and the corresponding energy distribution functions are derived, taking account of energy transfer and quenching in collisions of the metastable atoms with the ambient atmospheric gas constituents. The energy relaxation of metastable oxygen atoms produced by O_2 and O_3 photolysis and O_2^+ dissociative recombination is determined by solving the time-dependent Boltzmann equation. The $O(^1D)$ thermalization and quenching times are obtained as functions of the altitude. The steady state distributions of metastable $O(^1D)$ are computed and used for the determination of the parameters characterizing the nonthermal $O(^1D)$ atoms. The nonthermal atoms comprise 4–6% of the distribution, and their effective temperatures are larger by 25–46% than the local temperatures of the ambient gas. The role of hot metastable oxygen atoms in the production of vibrationally excited OH molecules is analyzed.

Citation: Kharchenko, V., A. Dalgarno, and J. L. Fox (2005), Thermospheric distribution of fast $O(^1D)$ atoms, *J. Geophys. Res.*, *110*, A12305, doi:10.1029/2005JA011232.

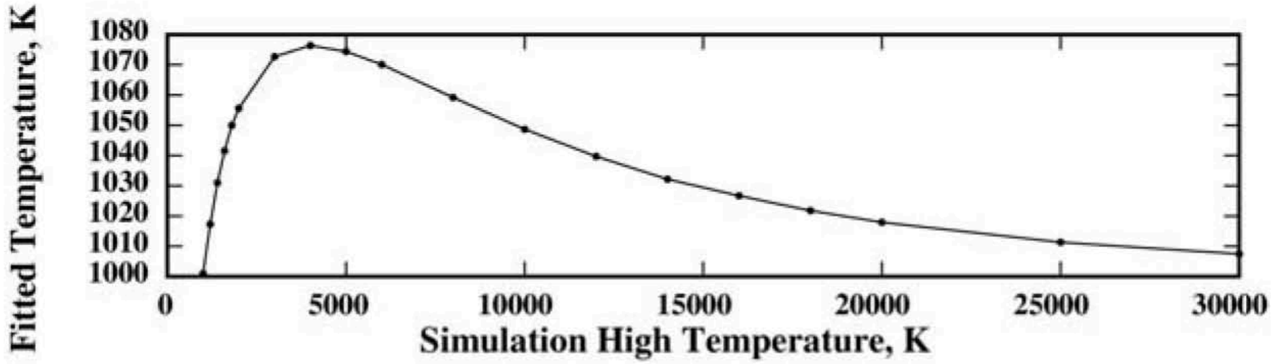

Figure 7. Deduced "temperature" from fitted FPI profiles as a function of the simulation high temperature T_h for a constant T_l = 1000 K in a gas with a 10:1 low/high temperature component ratio.

Table 1. Definition of the Regions Used to Simulate the Varying Temperature Over the 630.0 nm Emitting Region For Moderate Solar Activity[a]

Region	Altitude, km	Emission Fraction, %	Average MSIS Temperature, K	Fast Atom "Temperature," K	Fast Atom Fraction, %
1	<250	24.4	1012		0
2	250–275	28.2	1065	3000	2
3	275–350	40.8	1090	5180	3
4	350–450	6.4	1106	11,090	5
5	>450	0.2	1110	15,000	10

[a]Moderate solar activity $F_{10.7}$ = 133. The fraction of fast atoms and their "temperature" are the same for all values of solar activity used in this study.