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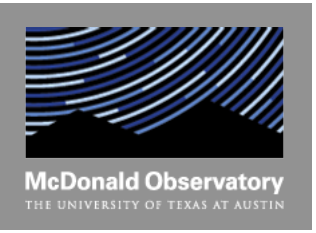

Modeling Hydrogen Line Profiles with *Xenomorph*: Remaining Uncertainties

M. H. Montgomery, P. B. Cho, T. Gomez, B. H. Dunlap

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U.S. DEPARTMENT OF ENERGY | Office of Science

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Xenomorph

Simulation of Stark Broadened Hydrogen Balmer Line Shapes for DA White Dwarf Synthetic Spectra

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Submitted to ApJ

ABSTRACT

White Dwarfs (WD) are useful across a wide range of astrophysical contexts. For example, their cooling can be leveraged in cosmochronology, they are the progenitors of type Ia supernovae, their pulsations tell us about their interior structure and prior stages of stellar evolution, and they are used as spectrophotometric standards for many major astronomical observatories. In all of these contexts, the fidelity of the information we can extract relies on the accuracy of WD atmosphere models. One essential ingredient of atmosphere models is the theory used to calculated broadened spectral lines for bound-bound transitions, known as line shape calculations.

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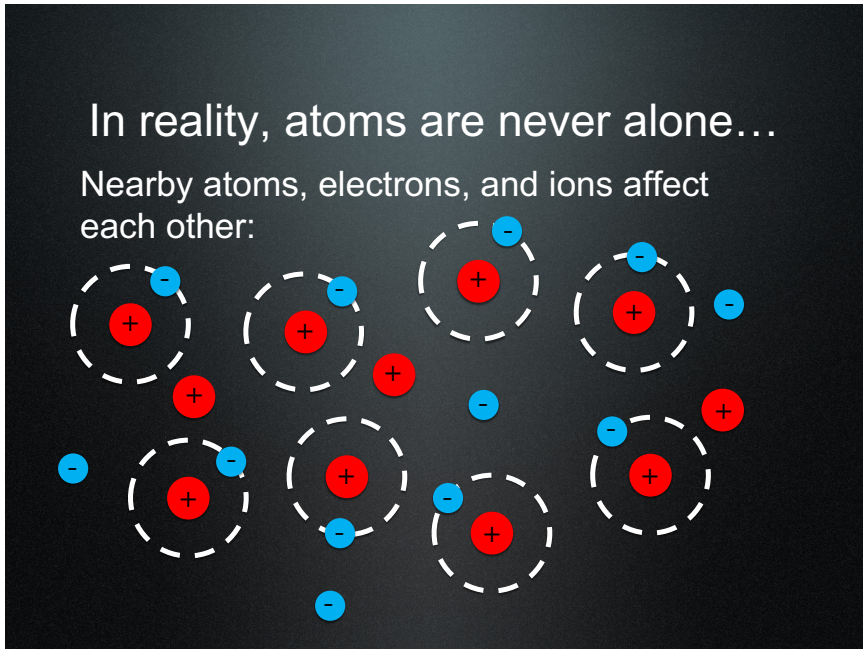
from higher principle quantum numbers will be explored in future work. We find that screening effects and occupation probability have the largest effects on the line shapes and the way they are calculated will likely have important consequences in stellar synthetic spectra. This paper presents a detailed description of these

Xenomorph physics improvements

- ion dynamics
  - electrons *and* protons can move
- an expanded basis set
  - more atomic states are included in the calculation
- higher-order multipole expansion
  - gradients in the electric field are taken into account
- "time ordering" is implicitly included
- increased randomness in the simulations
  - particle re-injection now allows for a change in both the velocity and impact parameter of particle



But, for the things that matter most:

- For the first time, an occupation probability/continuum lowering formalism was incorporated in simulation-based line profile calculations
- The "usual" screening prescription was used:
  - Debye screening with protons screened only by electrons:

If protons are included in the calculation of λ_D (as they *should be*), then λ_D decreases by a factor of $\sqrt{2}$

$$V(r) = \frac{q\, e^{-\lambda_D r}}{r} \qquad \lambda_D = \left(\frac{k_B T}{4\pi n_e e^2} \right)^{1/2}$$

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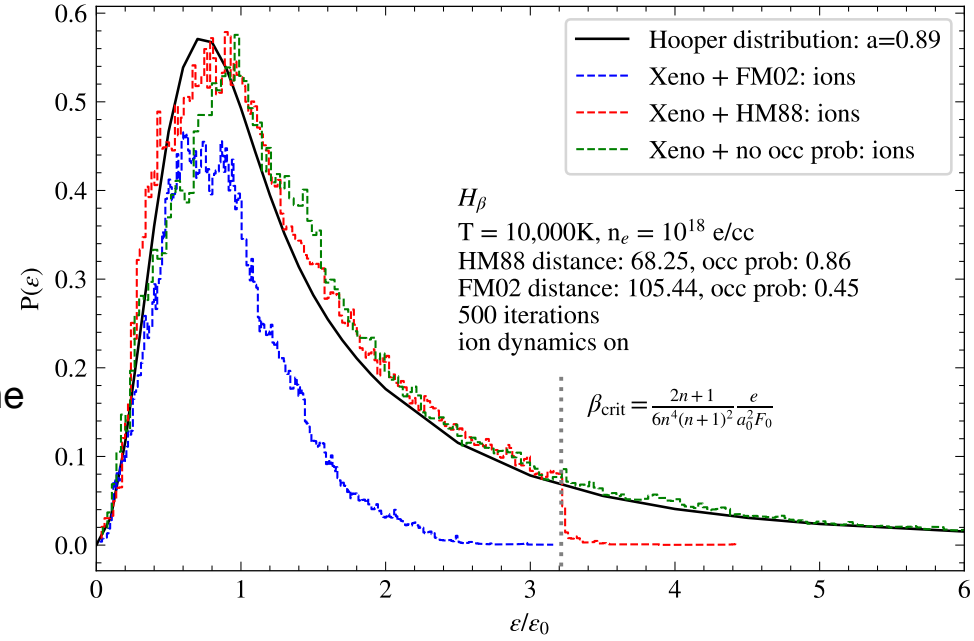

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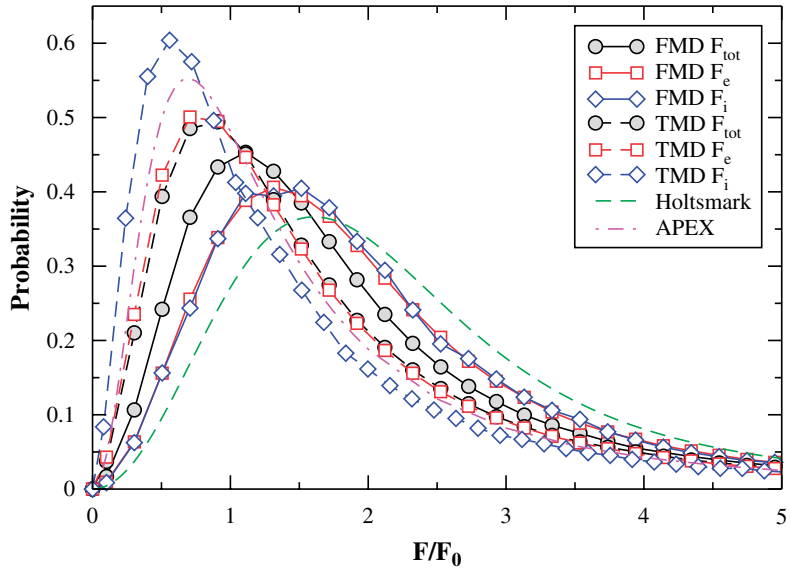
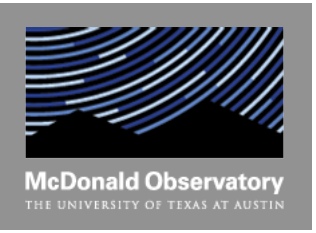
The Electric Field Calculation

- A line profile calculation is an “ensemble average” over electric field configurations of the electrons + protons
- We need thousands of time series of the electric field, and each time series contains thousands of time steps
  - much too expensive to compute with straightforward N-body codes
- The standard approach is to use non-interacting electrons and protons on straight-line trajectories, which is much less expensive computationally
- The particle interactions are “taken into account” by using screened potentials for the electrons and protons
- Could we somehow use APEX?
  - We need ions + electrons, not just ions, so I worry about this option…



Stambulchik et al., 2007, HEDP, 3, 272



Summary

- While a theoretically solved problem, a practical way of generating 1000s of E-field time series is still out of reach
- What is the best way of correcting the “trivial” N-body simulations so that the E-field distributions match the full simulations?

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