Total derivative of I with respect to T

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Abstract

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As the issue from Monday kept me thinking two full days I think it deserves to be put on paper, simply to clear up confusion. So, given h and T grids (arrays), which do not depend on each other, and come very complicated mapping $I(T, h)$ (which is actually complete NLTE solution) we are able to compute dI/dT_i. However, we have the following issue: for the purpose of inversion, we can to use τ as our independent grid. If τ and T grids are given as the input to the problem, we have:

$$h = h(T, \tau) \tag{1}$$

$$I = I\left(T, h(T, \tau)\right) \tag{2}$$

In this case, we have:

$$\frac{dI}{dT_i} = \frac{\partial I}{\partial T_i} + \sum_j \frac{\partial I}{\partial h_j}\frac{\partial h_j}{\partial T_i}. \tag{3}$$

While the derivative of height to the temperature can be found relatively straightforwardly, the derivative of intensity with respect to height grid is pretty non-trivial especially in the NLTE case, as height grid influences both the formal solution (directly) and level populations (indirectly).

A question I immediately asked myself was: should things not be simpler if I just set τ (actually, this is τ_{500}), as the independent variable?

$$\frac{dI}{dT_i} = \frac{\partial I}{\partial T_i} + \sum_j \frac{\partial I}{\partial \tau_j}\frac{\partial \tau_j}{\partial T_i} = \tag{4}$$

$$\frac{\partial I}{\partial T_i} + \sum_j \sum_k \frac{\partial I}{\partial \tau_j}\frac{\partial \tau_j}{\partial \chi_k}\frac{\partial \chi_k}{\partial T_i} \tag{5}$$

While derivatives of τ with respect to opacity are easy, and the derivative of opacity with respect to temperature we already have, the derivative of intensity with respect to τ is equally non-trivial as before as τ, again, influences both the formal solution and the level populations.

I come back, again, to the convergence problems in SPINOR, is it possible that this second term here has not been taken into account? I did not see any discussion of this kind in any of the papers, nor in the book of Jose Carlos. I discussed a bit with Anusha and I will discuss with Rafa, but is seems to me that in the completely consistent approach, computing the derivative of I with respect to either h or *tau* grid is totally unavoidable. Or am I missing something completely?