Scattering Line Polarization from Illuminated Disk-like Objects

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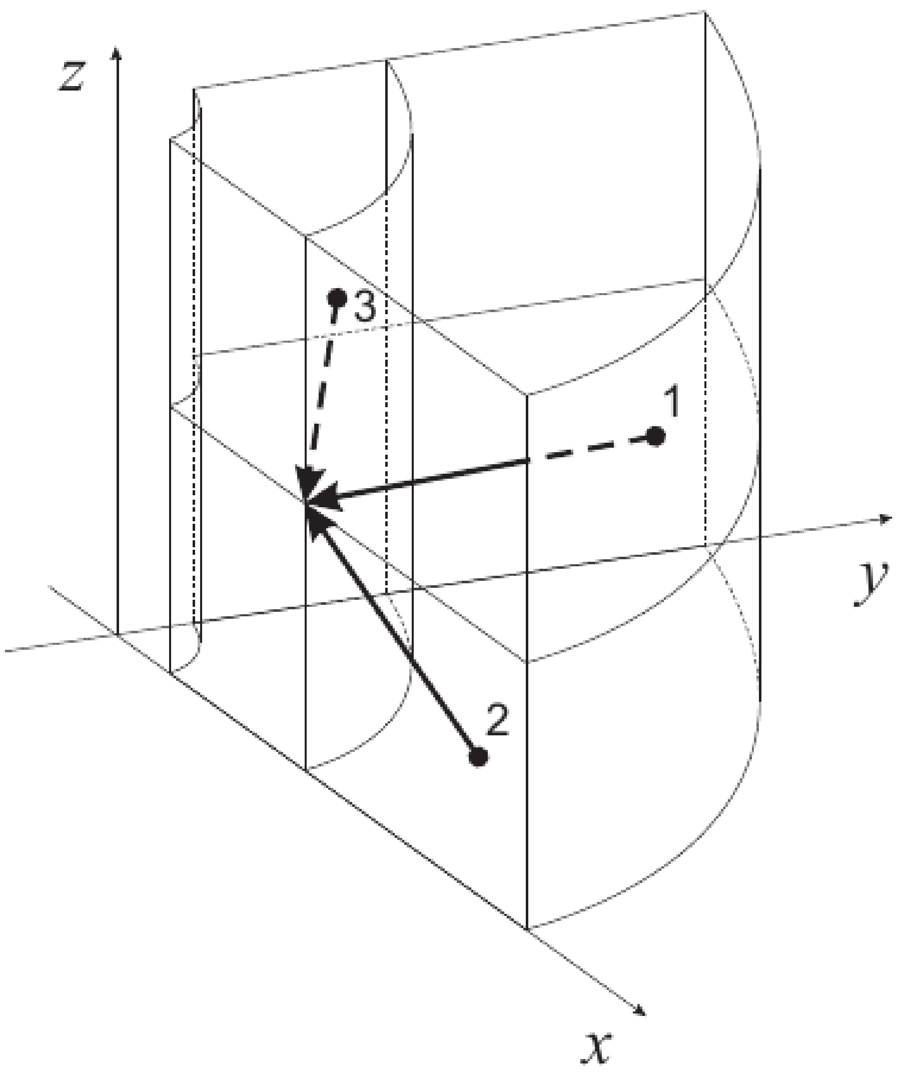
Transfer of radiation through various disks

- **AGNs** (usually MC approaches)
- **Other accretion disks** (self-emitting gas, e.g. Papkalla 1995, Elitzur et al. 2012)
- **Circumstellar disks** (scattering gas, e.g. Poeckert & Marlborough 1978, Halonen et al. 2013)
- **Solar prominences and loops** (also scattering gas, but different illumination, see series of papers by Gouttebroze, 2005+)
- **Polarization computed rarely, mostly in continuum** (although see Poeckert & Marlborough 1978, for a detailed treatment of Hydrogen Balmer series)
- **In detailed computations, to fully account for NLTE radiative transfer effects, 3D Cartesian grids are used**
- **Idea of this work: Exploit the axial symmetry and use 2D cylindrical coordinates**

2D Cylindrical Geometry

- **Short Characteristics method** (state-of-the-art formal solution method in “analytical” radiative transfer) **is very awkward to set-up in curved geometries**
- **Causality problems, curved characteristics** (see van Noort et al. 2002)
- **However, if geometry can be exploited a factor of 100 in Grid size can be saved** (Milić 2013)
- **Not so ideal as it seems:** angular interpolation, dynamic intensity allocation/deallocation problems, both especially hurt line polarization computations!



Computing NLTE Scattering Line Polarization

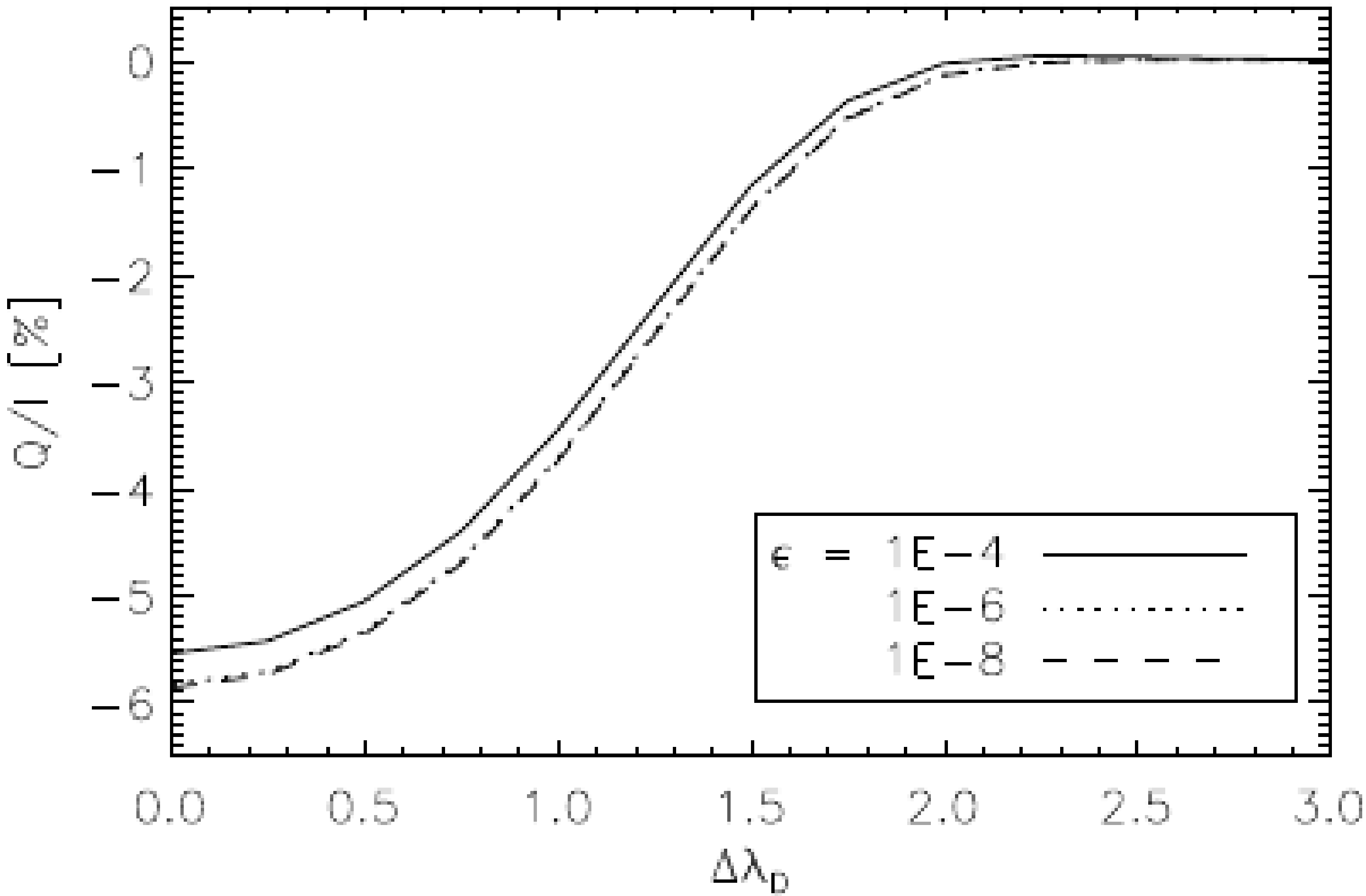
- **Consequence of the anisotropy of the radiation field**
- **Further affected by:** i) ellastic collisions; ii) magnetic fields (Hanle effect)
- **In a two-level atom, with no ground level polarization, all three Stokes parameters (I, Q, U) share same optical depth scale**
- **Two approaches:** **density matrix formalism** (Landi Degl'Innocenti & Landolfi, 2004) and **scattering matrix formalism** (Bommier 1997, Anusha et. al. 2011+)
- Scattering matrix formalism in **reduced intensity basis** preserves straightforward approach from scalar case and avoids dependence of the source function on angle.

$$\frac{d\hat{I}^r(r,z,\theta\,\varphi,x)}{d\tau} = \phi(\nu)(\hat{I}^r(r,z,\theta,\varphi,x) - \hat{S}^r(r,z))$$

$$\hat{J}^r = \frac{1}{4\pi}\int_{-\infty}^{\infty}\phi(x)dx\int_0^{2\pi}\int_0^{\pi}\hat{\Psi}^r(\theta',\theta,\varphi',\varphi) \times \hat{I}^r(\theta',\varphi',x)\sin\theta d\theta d\varphi.$$

Results for the test cases

- **The method successfully reproduces the well-known results from 1D cases.** Here we mimic the 1D atmosphere with a very large cylinder.
- **“Edge” effects are quite prominent!**



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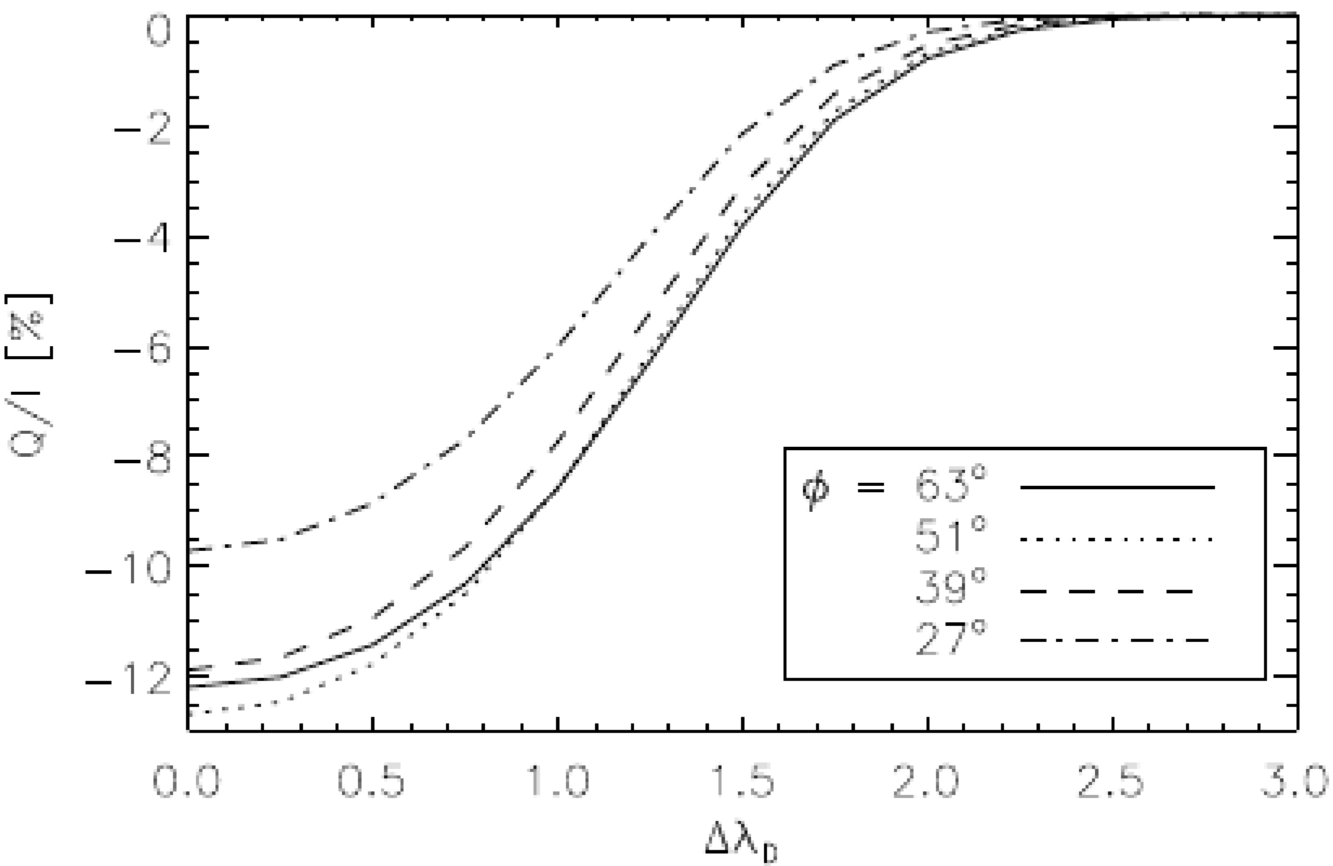

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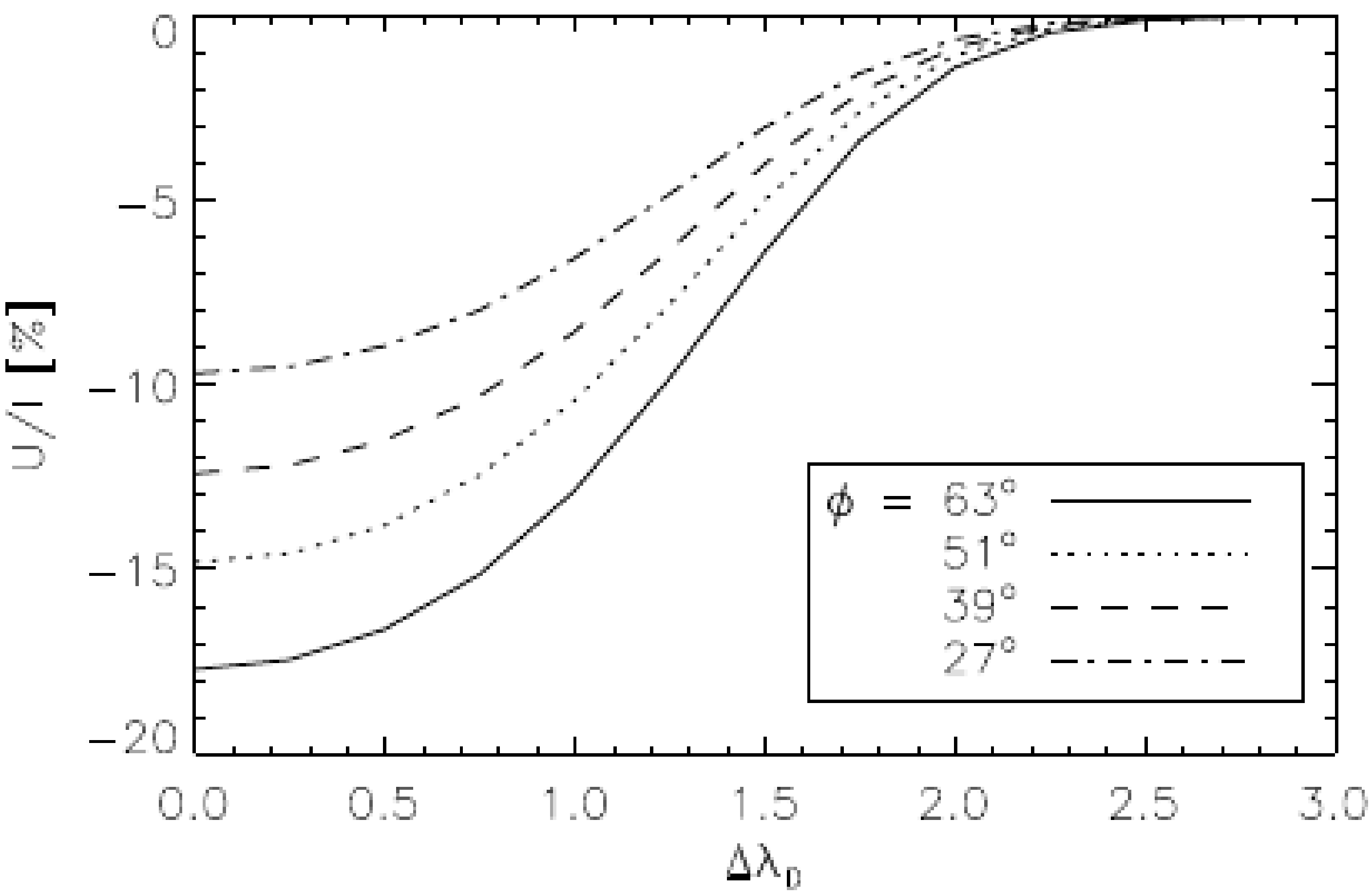
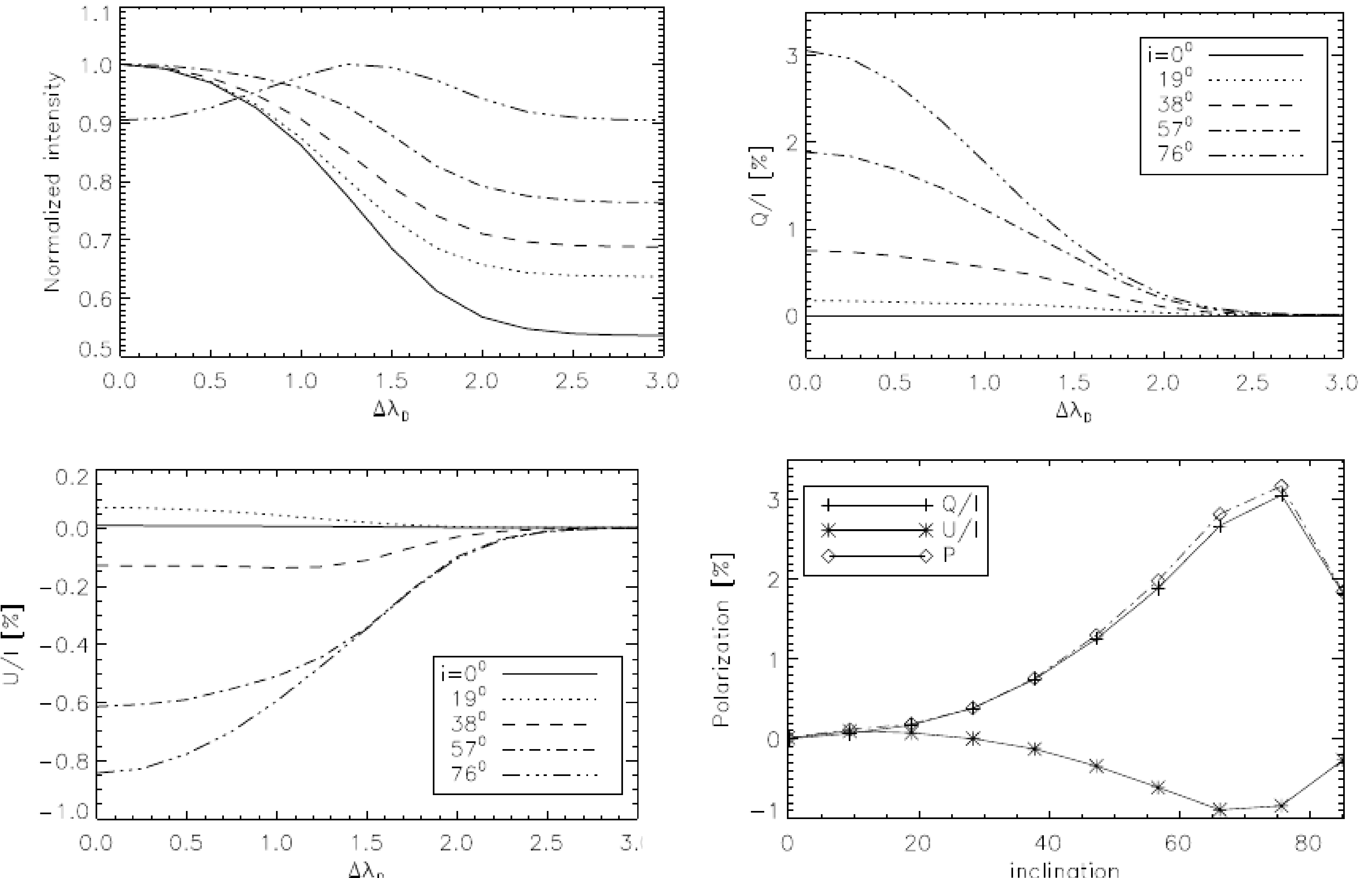


A simple circumstellar disk example:



Discussion

- **Presence of the disk influences polarization levels a lot!**
- **Our 2D approach reproduces other known results well and offers a significant time saving compared to 3D approaches**
- **Drawbacks:**

  i) Axial symmetry

  ii) Restrictive geometry of the magnetic field → bad for prominences

iii) Hard to deallocate unneeded intensity

  iv) Angular interpolation slows down computation a bit

- **However, there are also lots of advantages!**
- **Future implementation: Co-moving frame approach** in order to handle large velocities found in accretion disks