Black Holes from Stars to Galaxies – Across the Range of Masses
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AGN polarization modeling with STOKES

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Abstract. We introduce a new, publicly available Monte Carlo radiative transfer code, STOKES, which has been developed to model polarization induced by scattering of free electrons and dust grains. It can be used in a wide range of astrophysical applications. Here, we apply it to model the polarization produced by the equatorial obscuring and scattering tori assumed to exist in active galactic nuclei (AGNs). We present optical/UV modeling of dusty tori with a curved inner shape and for two different dust types. The polarization spectra enable us to clearly distinguish between the two dust compositions. The STOKES code and its documentation can be freely downloaded from http://www.stokes-program.info/.

Keywords. Polarization – radiative transfer – dust, extinction – galaxies: active

1. Introduction

Spectropolarimetric data in the optical/UV range put important constraints on the emission and scattering geometry of AGNs (see e.g. Antonucci 2002). For the interpretation of spectropolarimetric data detailed modeling tools are important. Here, we use a new, publicly available radiative transfer code, STOKES (Goosmann & Gaskell 2007), to model the obscuring torus of AGNs. The code is based on the Monte-Carlo method and allows the simulation of various emission and scattering geometries. Polarization due to Thomson and dust (Mie-)scattering is included. Moreover, the code computes wavelength-dependent time delays and can thus be used to study polarization reverberation (Shoji, Gaskell & Goosmann 2005).

2. Modeling an obscuring torus

We consider a torus with an elliptical cross-section and centered on a point source. The source isotropically emits a flat continuum spectrum between 1600 Å and 8000 Å. The torus half-opening angle is set to $\theta_0 = 30°$. The inner and outer radii of the torus are fixed at 0.25 pc and 100 pc respectively. The radial optical depth in the equatorial plane is 750 for the V-band. The dust models (table 1) assume a mixture of graphite and "astronomical silicate" and a grain radii distribution $n(a) \propto a_s^{\alpha}$ between $a_{\rm min}$ and $a_{\rm max}$.

The "Galactic dust" model reproduces the interstellar extinction for $R_{\rm V} = 3.1$ whilst the "AGN dust" parameterization is obtained from quasar extinction curves derived by Gaskell *et al.* 2004. This latter dust type favors larger grain sizes.

Table 1. Parameterization of the dust models

Type	Graphite	Silicate	$a_{\rm min}$	$a_{\rm max}$	α_s
Galactic	62.5%	37.5%	0.005 μm	0.250 μm	−3.5
AGN	85%	15%	0.005 μm	0.200 μm	−2.05

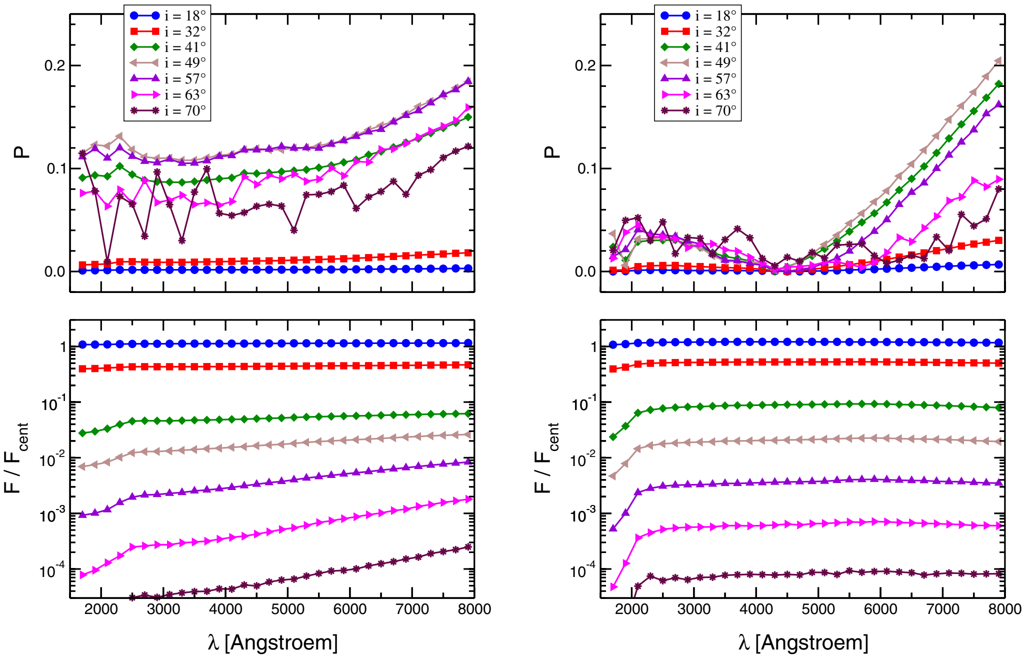

Figure 1. Polarization (top) and flux (bottom) spectra for a centrally-illuminated torus filled with "Galactic dust" (left) or "AGN dust" (right). The flux spectra are normalized to the illuminating flux and the inclination angle i is measured from the symmetry axis.

3. Results and discussion

The angular distributions of the polarization and flux spectra are shown in figure 1. In a face-on view, the central source is seen directly and the obtained polarization is low. At obscured inclinations $i > \theta_0$, the scattering properties of both dust types lead to different results. For "AGN dust", the polarization is lower in the UV but rises quickly toward longer wavelengths. Detailed spectropolarimetric observations of dust reflection thus effectively constrain the dust composition. For both dust types the polarization position angle is oriented perpendicularly to the projected symmetry axis of the object.

If the torus is filled with "AGN dust" then the total flux spectra are wavelength-independent above 2500 Å at all possible inclinations. For the "Galactic dust" model the scattered flux rises gradually toward longer wavelengths. The albedo of both dust compositions changes significantly below 2500 Å so that less radiation is scattered in the UV.

Spectropolarimetric data from AGNs contain not only information about the obscuring torus, but also include other scattering regions. To obtain a more detailed picture of AGN polarization it is therefore necessary to model several, radiatively coupled scattering regions self-consistently. While this is beyond the scope of this proceedings note, Stokes is capable of solving such problems.

References

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