Influence of a polarised primary source on the X-ray polarisation resulting from disc reflection in AGN

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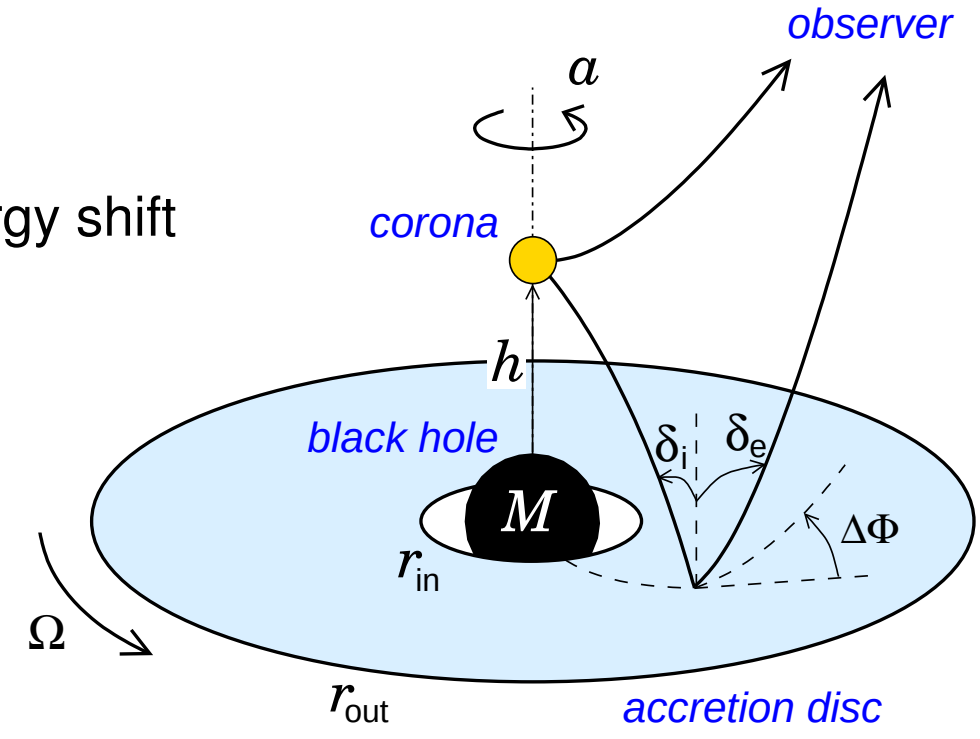
Scheme of the lamp-post geometry

- central black hole → mass, spin
- accretion disc
  → Keplerian, geometrically thin, optically thick and neutral
- compact corona
  → isotropic power-law emission
  → static (or slow motion)
  → height, photon index
- relativistic effects:
  → Doppler and gravitational energy shift
  → light bending (lensing)
  → aberration (beaming)
- references:
  → Matt (1993)
  → Dovčiak, Muleri, Goosmann, Karas & Matt (2011)

Corona: P_{p}, χ_{p}

Disc: P_{loc}, χ_{loc}
→ Chandrasekhar (1960)

Relativistic effects: χ_{o}, χ_{d}, χ_{do}



Stokes parameters at infinity

$$S(P_\mathrm{p},\chi_\mathrm{p}) = S(0,-) + P_\mathrm{p}\left\{[S(1,0)-S(0,-)]\cos 2\chi_\mathrm{p} + [S(1,\pi/4)-S(0,-)]\sin 2\chi_\mathrm{p}\right\}$$

$$I(E) = G_\mathrm{p}\, I_\mathrm{p}(E/g_\mathrm{p}) + \int_\Sigma \mathrm{d}S\, G\, I_\mathrm{loc}(E/g)$$

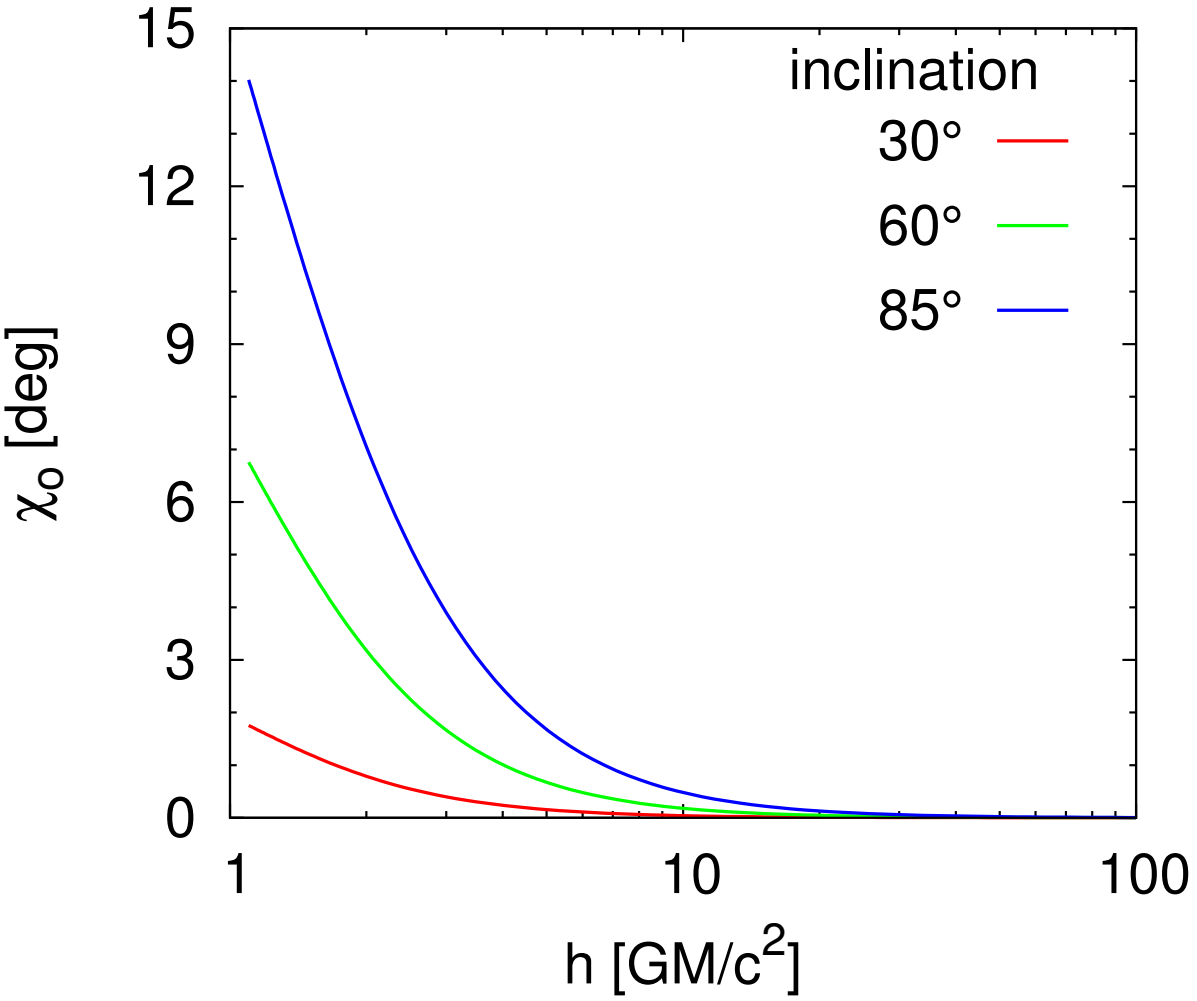
$$Q(E) = G_\mathrm{p}\, P_\mathrm{p}(E/g_\mathrm{p})\, I_\mathrm{p}(E/g_\mathrm{p})\, \cos 2[\chi_\mathrm{p}(E/g_\mathrm{p}) + \chi_\mathrm{o}] + \int_\Sigma \mathrm{d}S\, G\, P_\mathrm{loc}(E/g)\, I_\mathrm{loc}(E/g)\, \cos 2[\chi_\mathrm{loc}(E/g) + \chi_\mathrm{do}]$$

$$U(E) = G_\mathrm{p}\, P_\mathrm{p}(E/g_\mathrm{p})\, I_\mathrm{p}(E/g_\mathrm{p})\, \sin 2[\chi_\mathrm{p}(E/g_\mathrm{p}) + \chi_\mathrm{o}] + \int_\Sigma \mathrm{d}S\, G\, P_\mathrm{loc}(E/g)\, I_\mathrm{loc}(E/g)\, \sin 2[\chi_\mathrm{loc}(E/g) + \chi_\mathrm{do}]$$

I_loc, P_loc and χ_loc depend on:

- local geometry of scattering (μ_i, μ_e, $\Delta\varphi$)
- incident polarisation properties (P_p, χ_p, χ_d)

Relativistic effects – lamp to observer

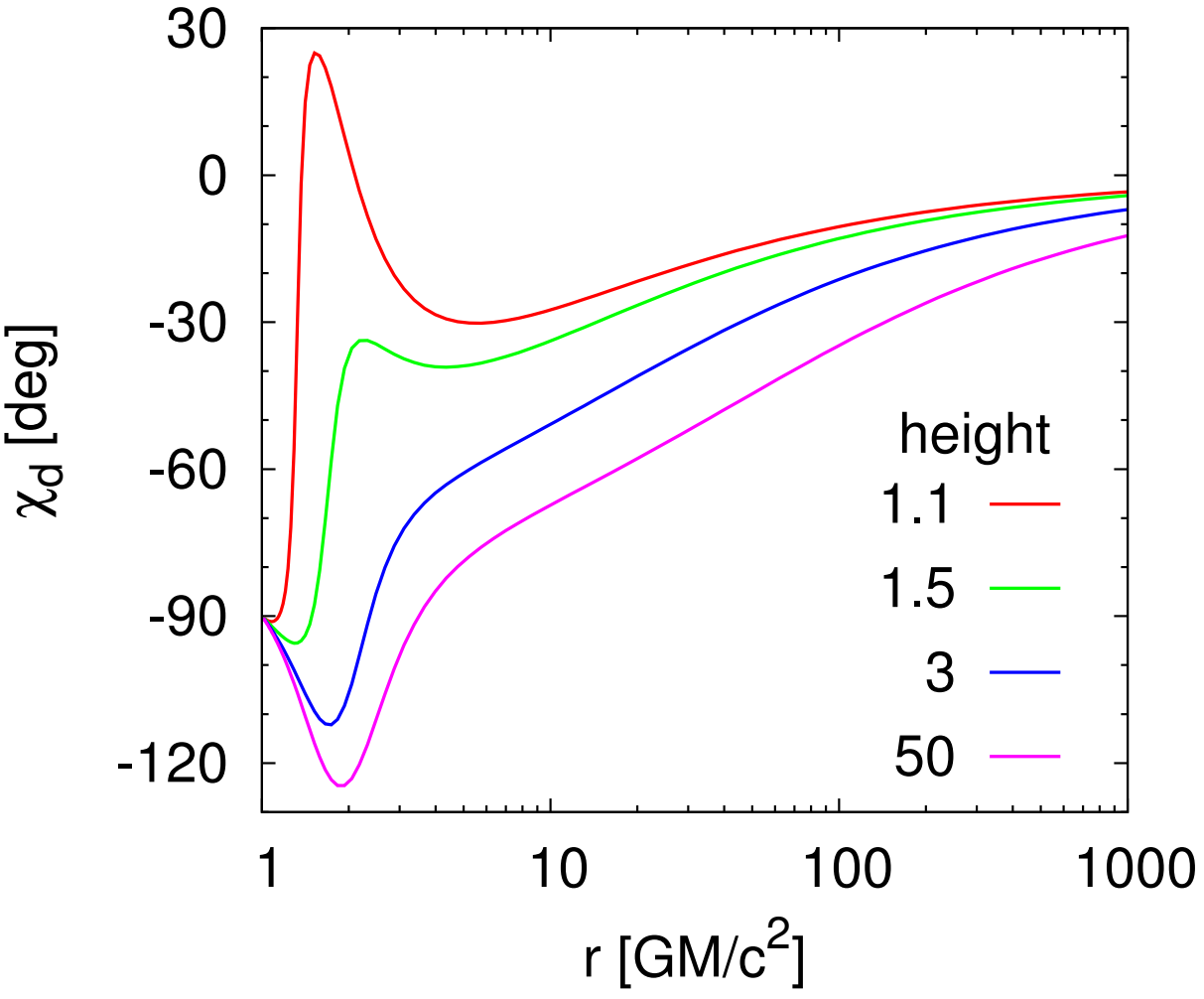


$$\tan\chi_o = a\,\frac{\beta - h\sin\theta_o}{a^2\sin\theta_o + \beta h}$$

relativistic change of polarisation angle χ_o:

- is relatively small (and zero for non-rotating BH)
- has counter-clockwise direction
- increases with
  - → *inclination*
  - → *BH spin*
  - → *lower height*

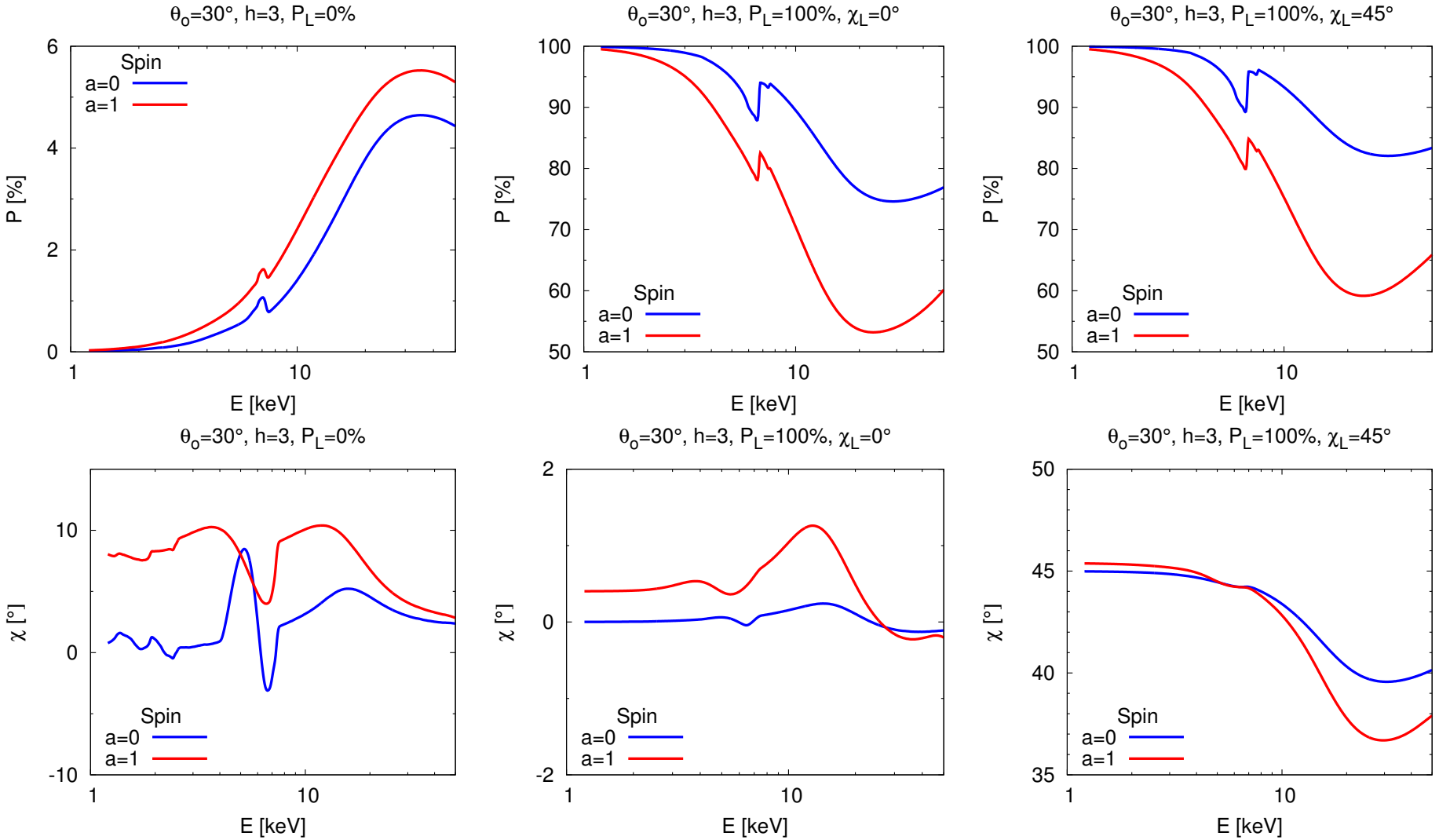
Relativistic effects – lamp to disc



Relativistic change of polarisation angle χ_d:

- is quite large (especially close to the BH)
- has mostly clockwise direction
- special relativistic effects important (aberration)
- for highly spinning BH and very low heights, gravitational dragging causes rotation in counter-clockwise direction

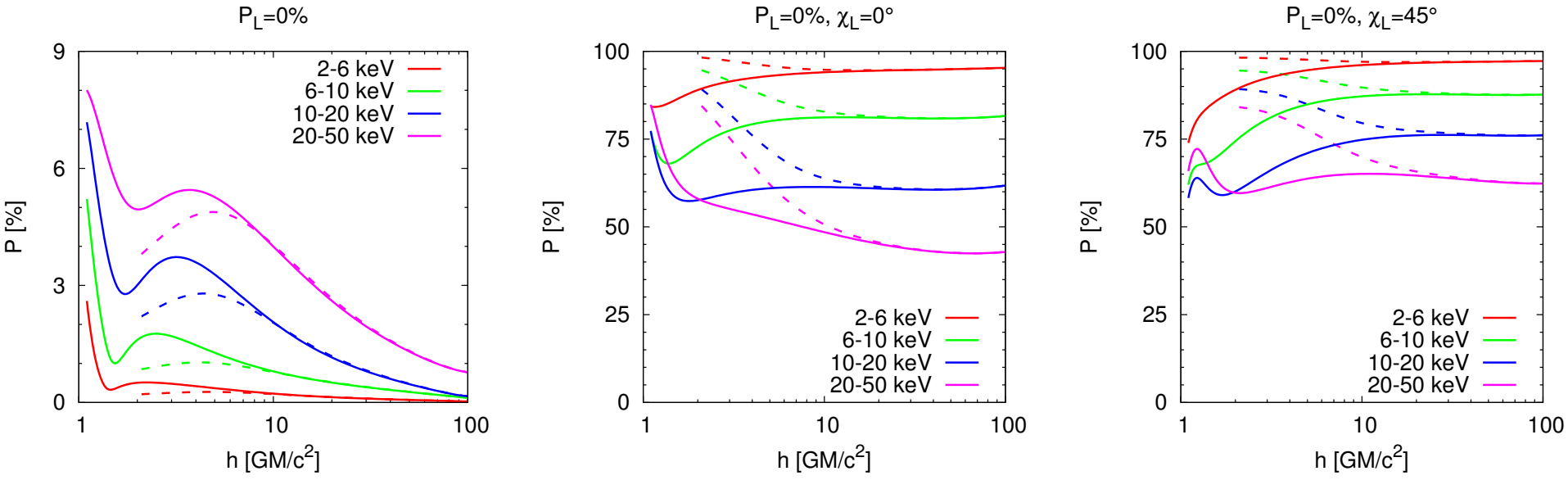
Energy dependence



- polarisation changes with energy
  $\rightarrow$ primary power-law decrease and reflection Compton hump
- features at the energies of spectral lines and edges

Dependence on height

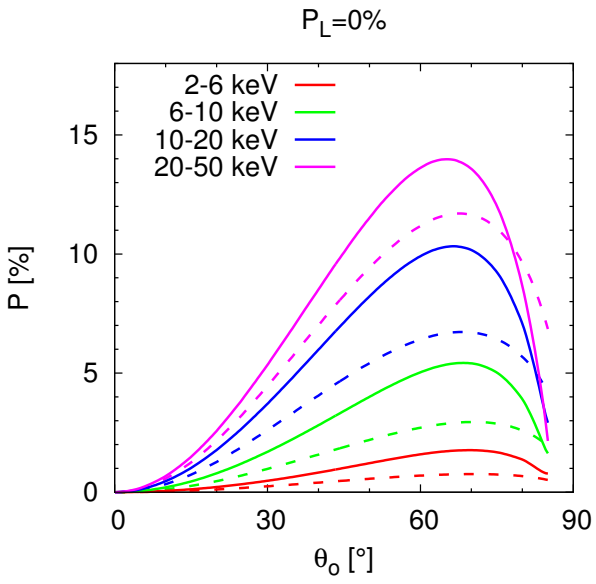
$\theta_o = 30^\circ$

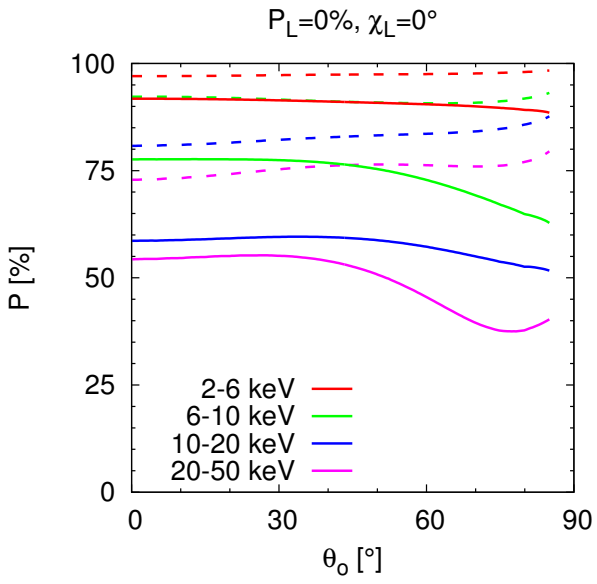


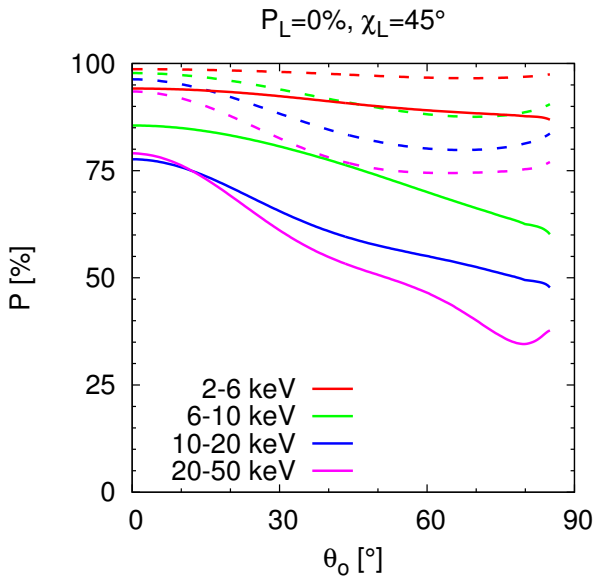
- larger changes in polarisation and de-polarisation for higher energies
- larger effect for higher spin
- largest polarisation for small heights ($h \lesssim 10$)
- significant de-polarisation for all heights

Dependence on inclination

$h = 3\,\mathrm{GM}/\mathrm{c}^2$

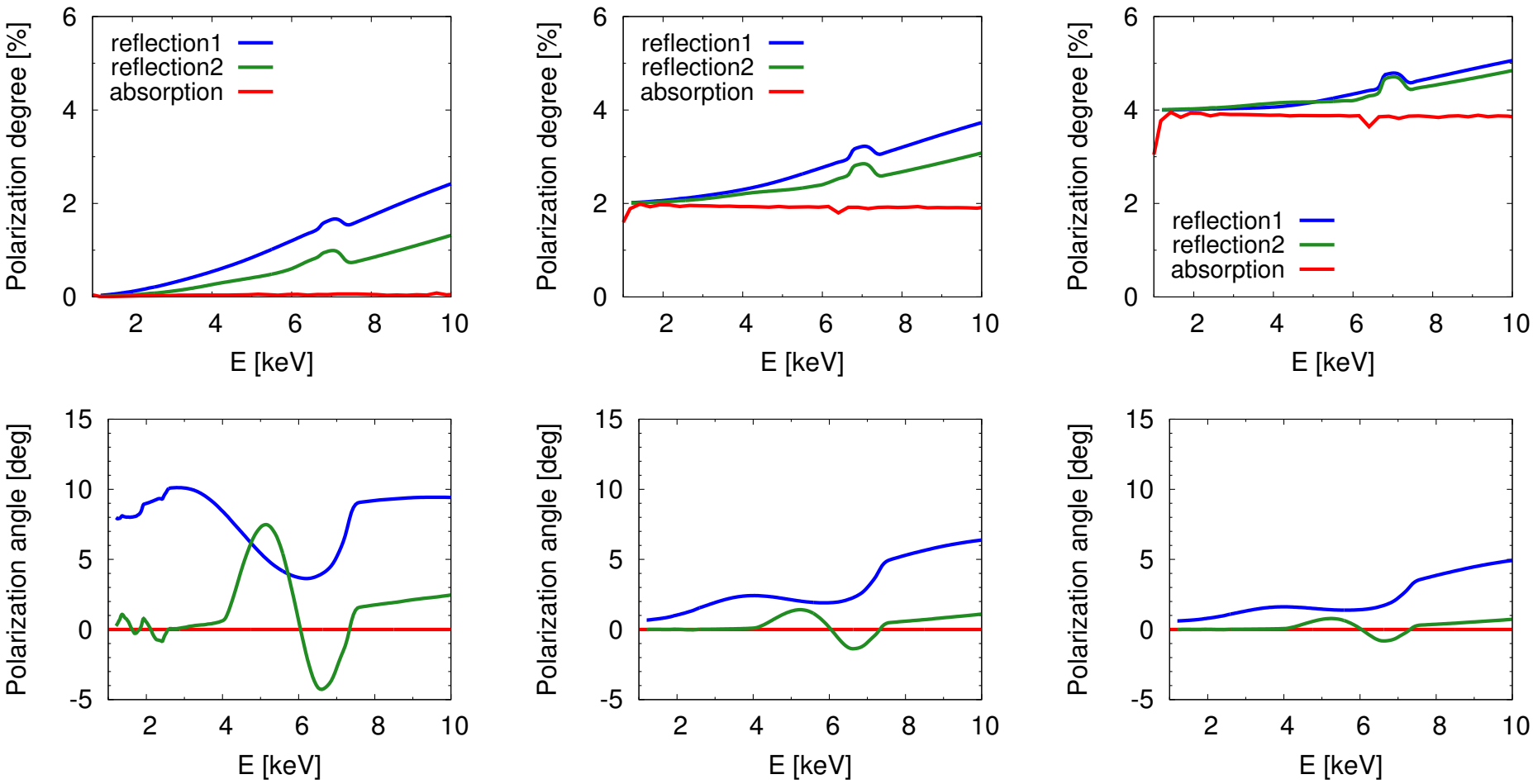






- larger changes in polarisation and de-polarisation for higher energies
- larger effect for higher spin
- largest polarisation for inclinations $55^\circ \lesssim \theta_o \lesssim 75^\circ$
- usually significant de-polarisation for all inclinations

Reflection versus absorption – MCG-6-30-15



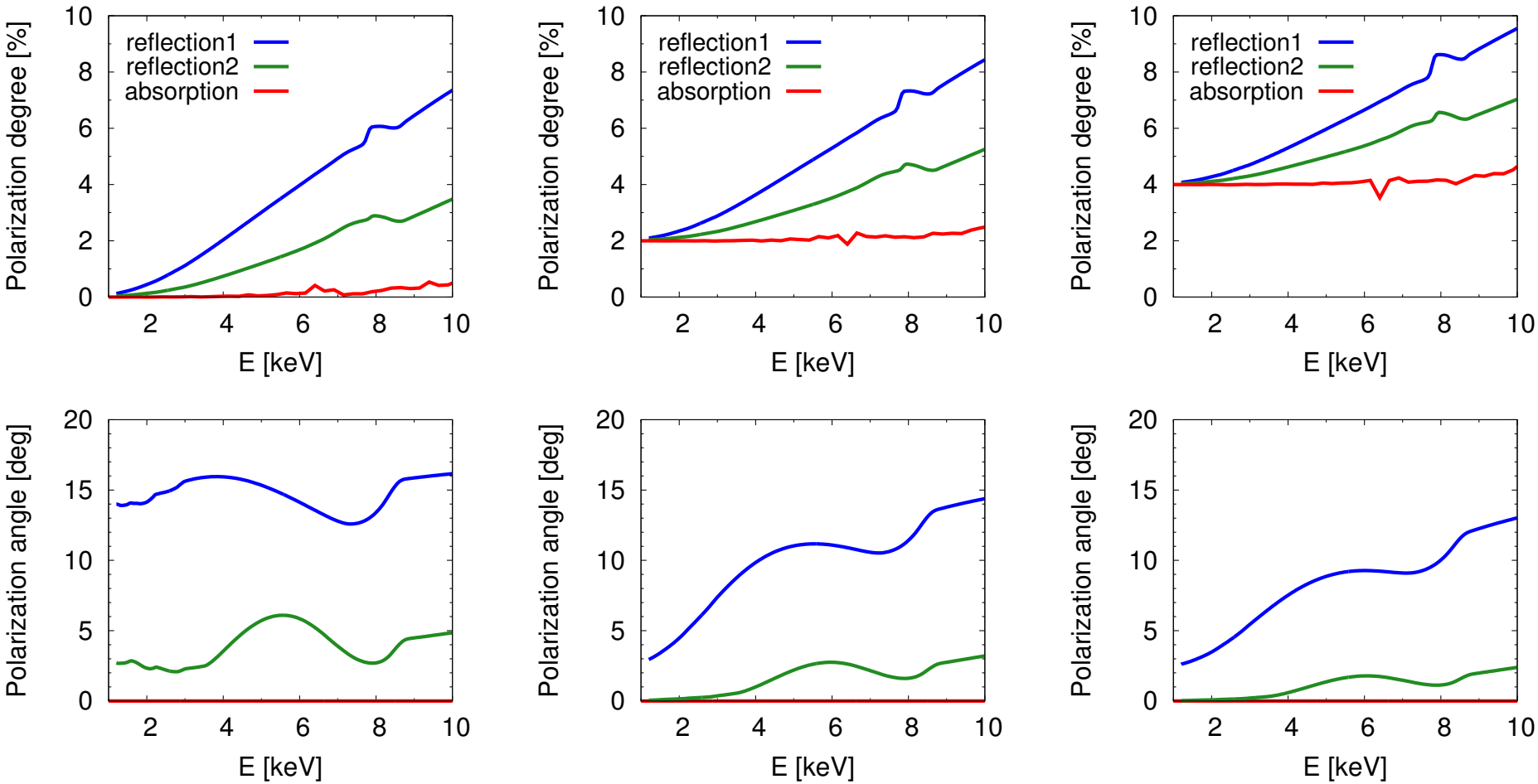
Inclination:	**30°**
Spin:	**a = 0**, **a = 1**
Photon index:	**Γ = 2**
Height:	**h = 2.5 GM/c²**
Primary pol. deg:	**P = 0, 2, 4%**
Primary pol. ang:	**χ = 0°**

Absorption scenario – *clumpy wind*:
→ constant polarisation degree and angle

Reflection scenario:
→energy dependent polarisation degree and angle

see Marin et al. (2012) MNRAS, 426, L101

Reflection versus absorption – NGC-1365



Inclination:	**60°**
Spin:	**a = 0**, **a = 1**
Photon index:	**Γ = 2**
Height:	**h = 2.5 GM/c²**
Primary pol. deg:	**P = 0, 2, 4%**
Primary pol. ang:	**χ = 0°**

Absorption scenario – *obscuring circumnuclear clouds*:
→ constant polarisation degree and angle

Reflection scenario:
→energy dependent polarisation degree and angle

see Marin et al. (2013) MNRAS, 436, 1615

Summary of results

- relativistic effects from the lamp to the observer are small
- relativistic effects from the lamp to the disc are large even for high heights and large radii
- largest polarisation degree for high spin, low heights, inclinations of $55^\circ - 75^\circ$ and high energy
- expected variation of polarisation angle with energy is $\Delta\chi \lesssim 10^\circ$