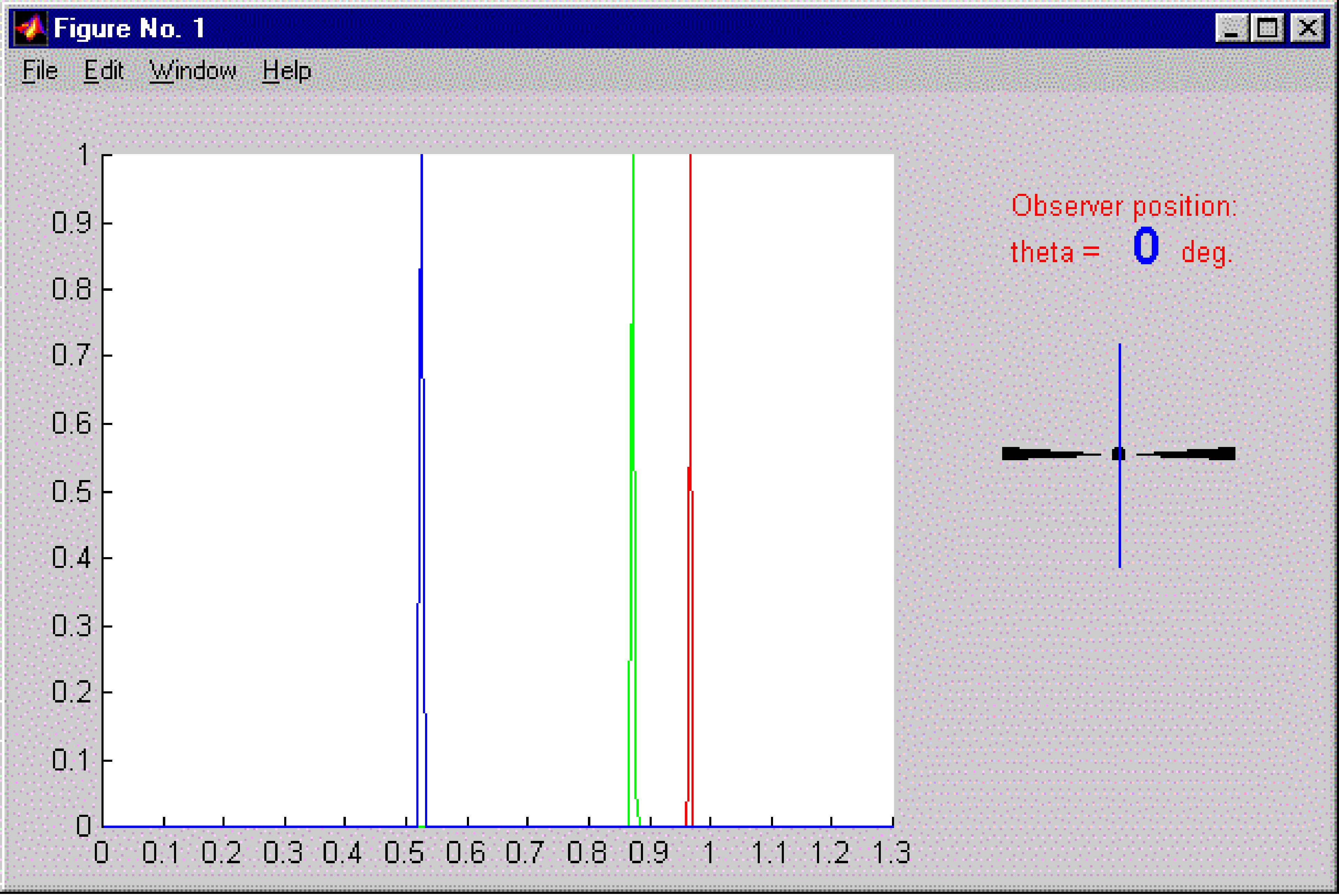
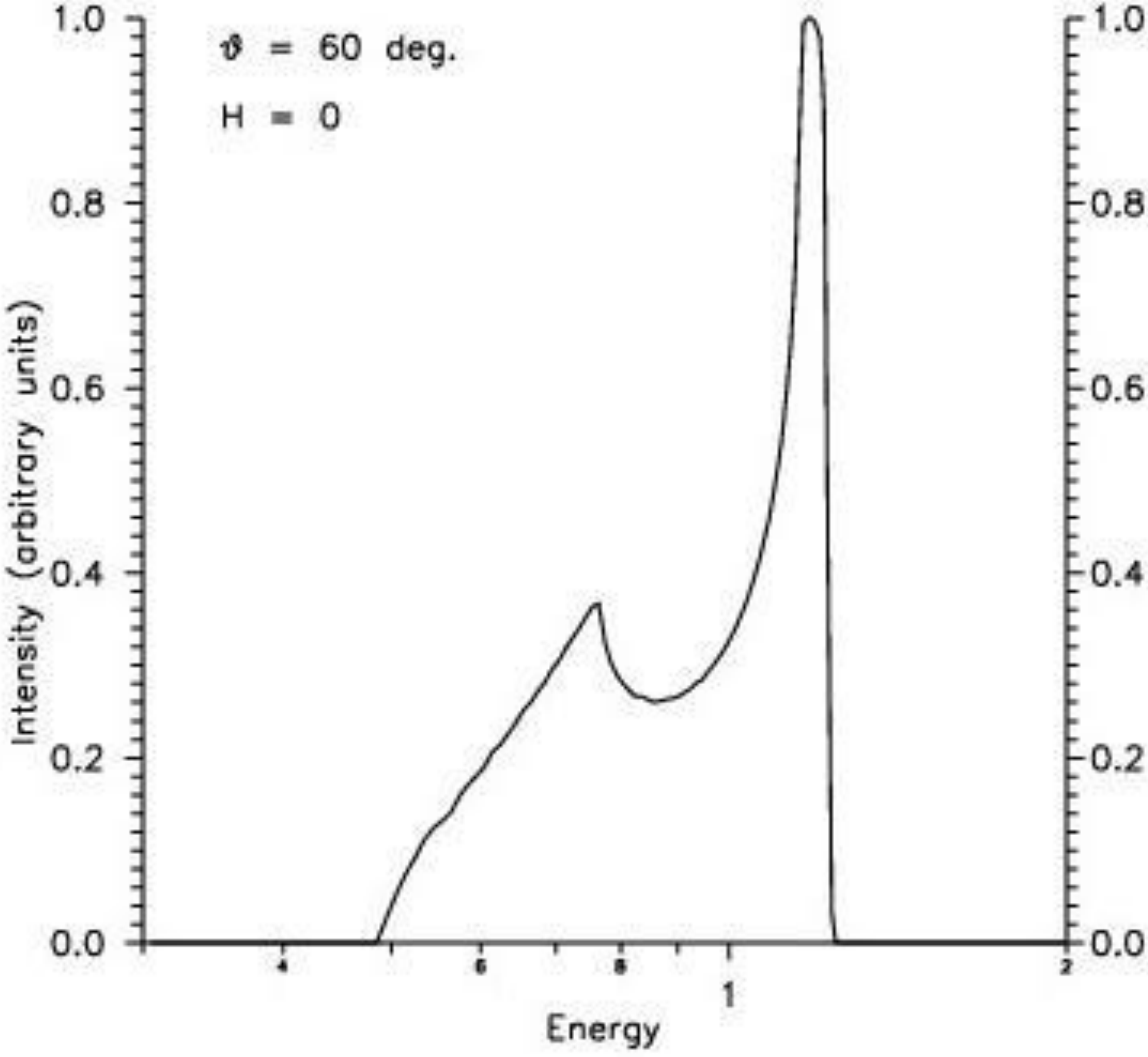


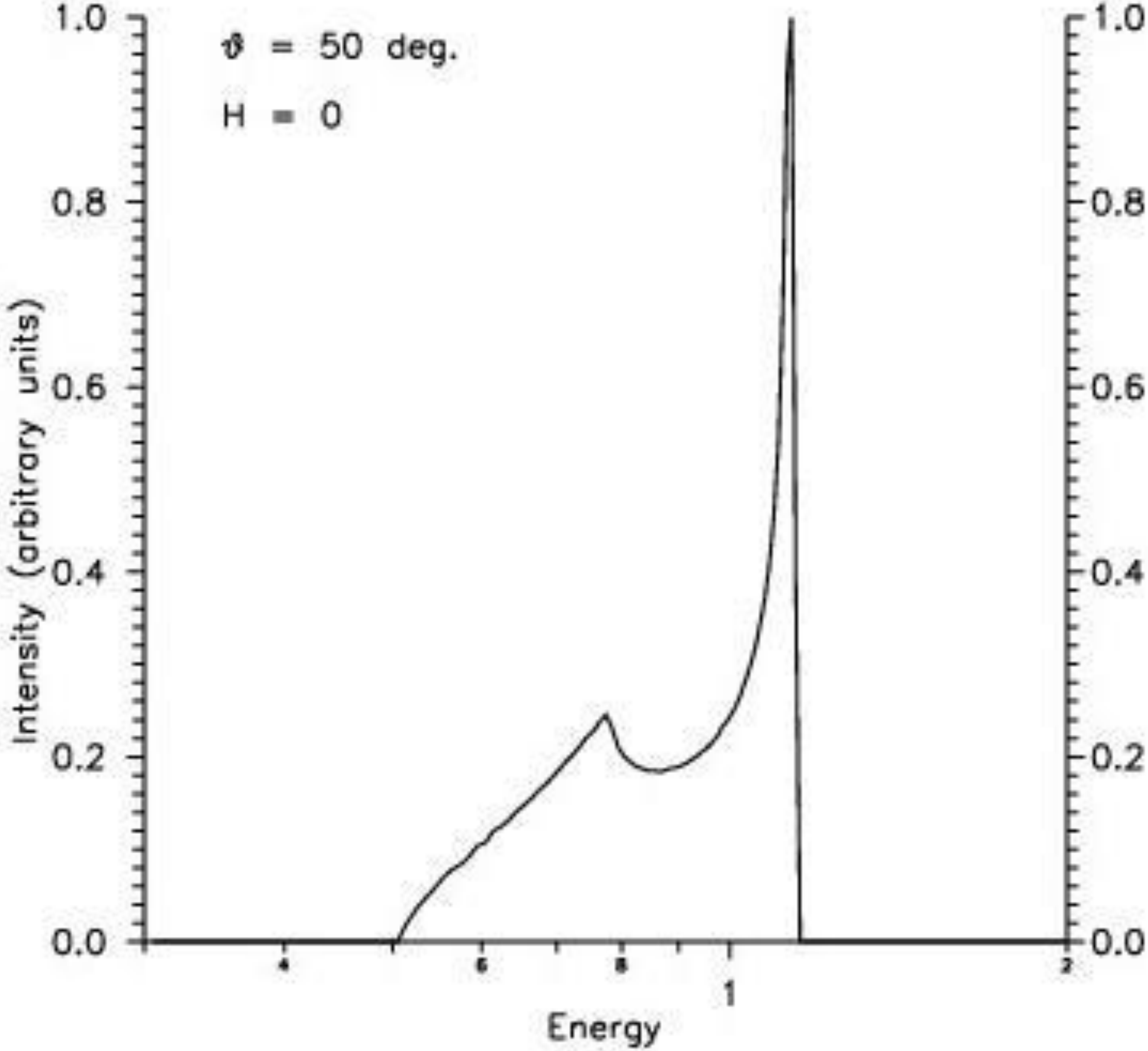
Figure No. 1
File Edit Window Help
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3
Observer position:
theta = 0 deg.

Magnetic field estimations near BH horizon in AGNs and GBHCs
(Zakharov, Kardashev, Lukash, Repin, MNRAS, 342,1325, (2003))

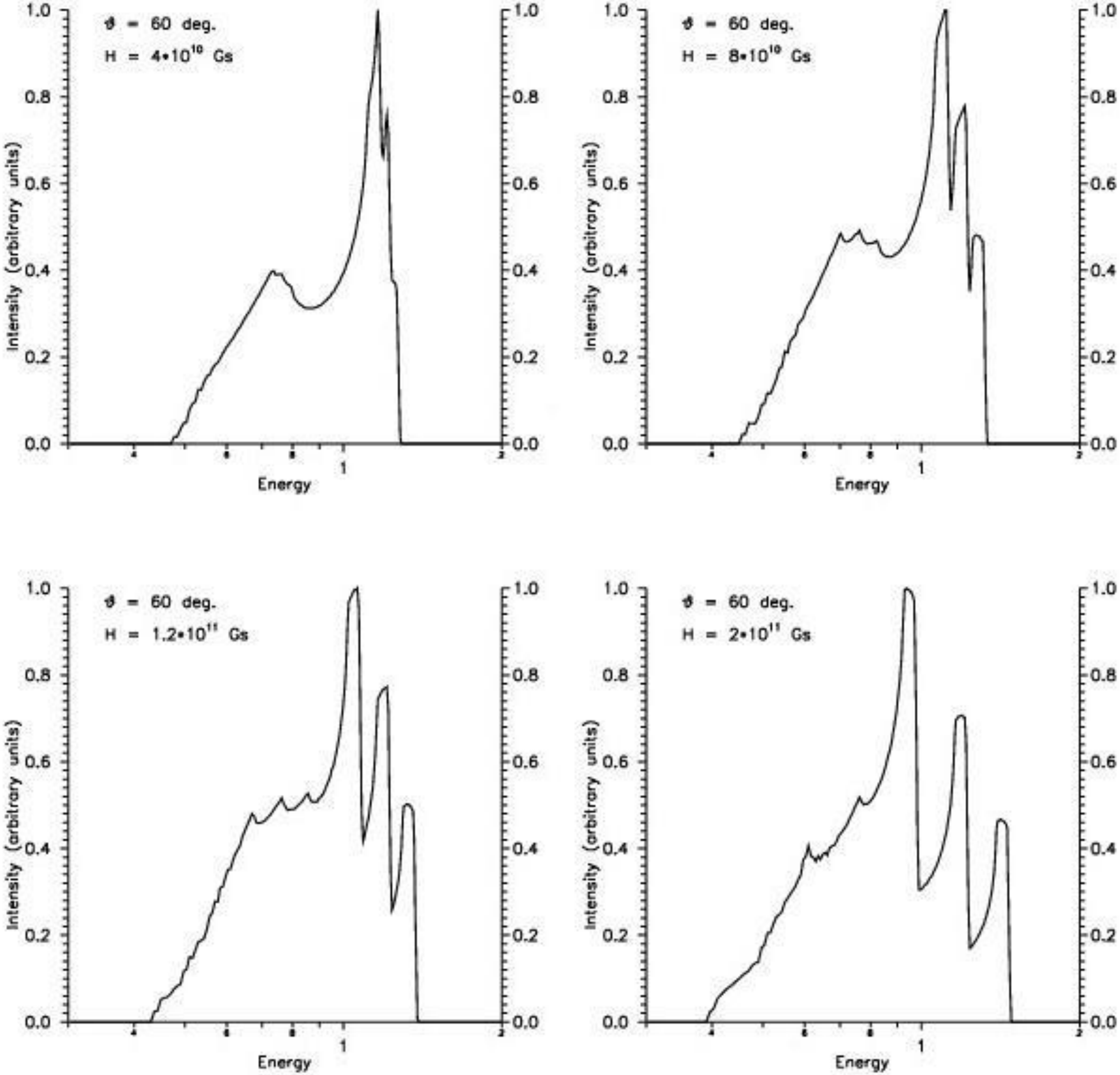
- Zeeman splitting $E_1=E_0-\mu_B H$, $E_2=E_0+\mu_B H$, $\mu_B=e\hbar/(2m_e c)$, $\mu_B=9.3*10^{-21}$ erg/G
- Figure1
- Figure2
- Figure3
- Figure4
- Figure5
- Figure6
- ASCAdata



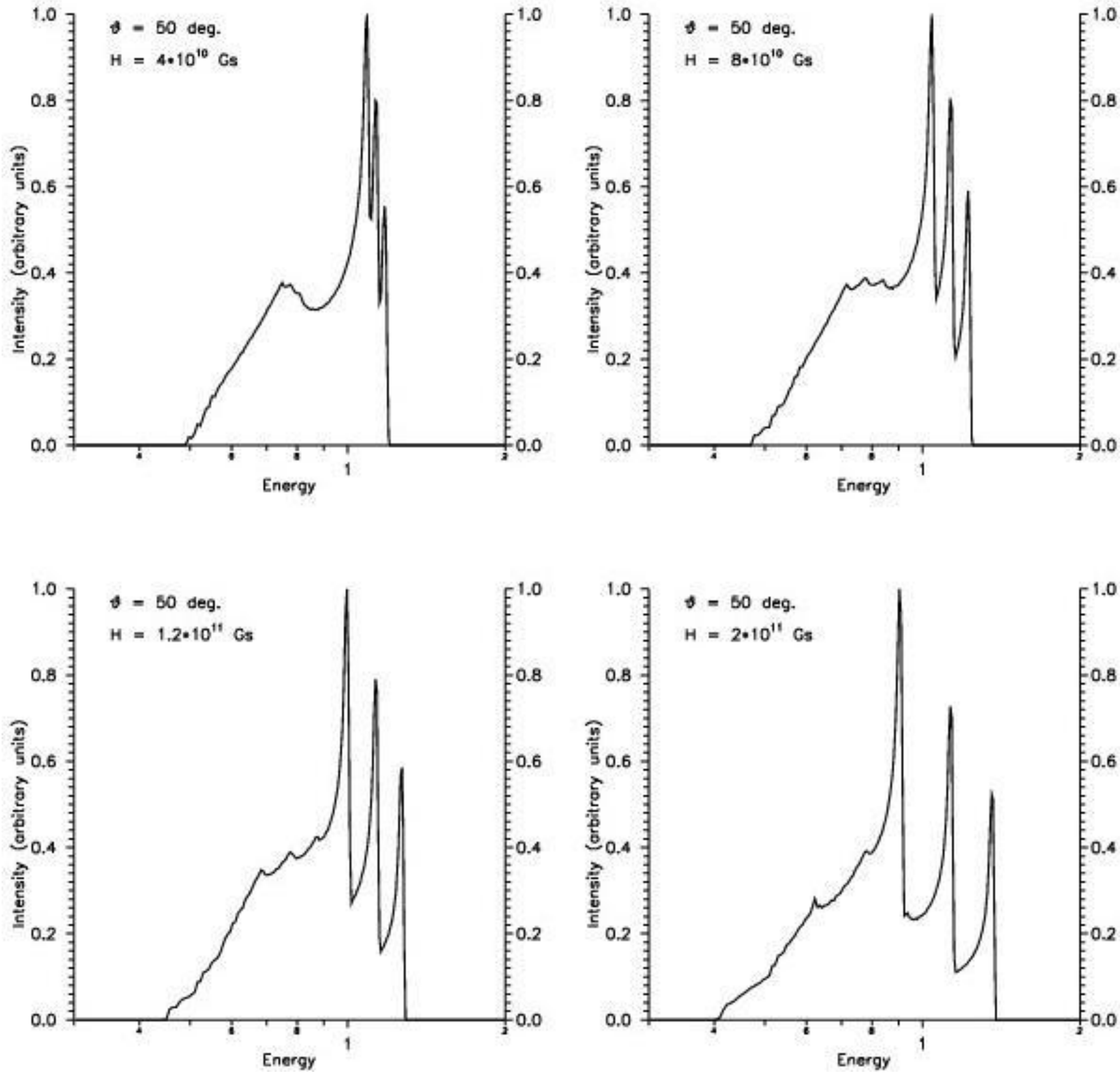
ϑ = 60 deg.
H = 0
Intensity (arbitrary units)
1.0
0.8
0.6
0.4
0.2
0.0
4
6
8
1
2
Energy



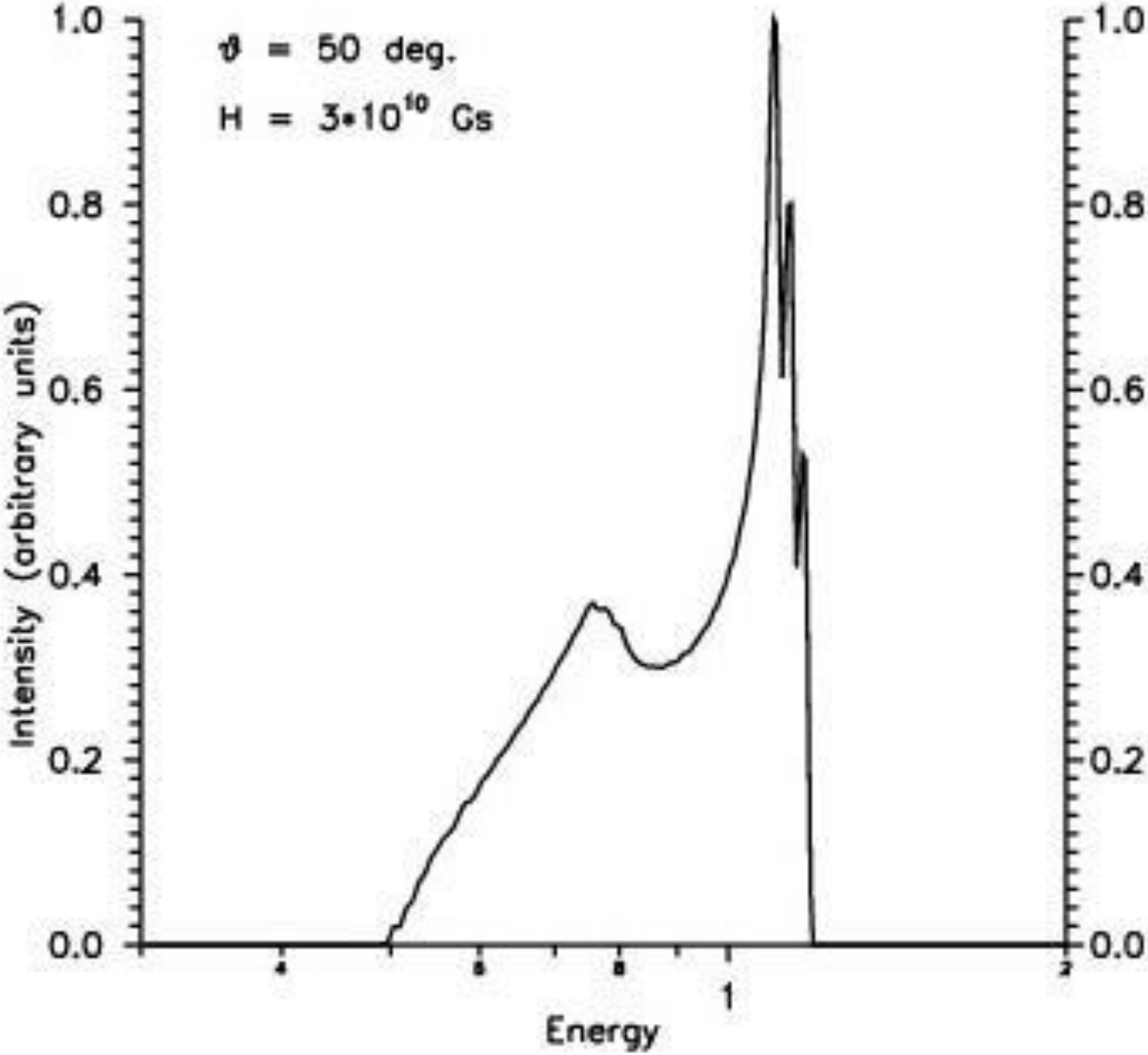
ϑ = 50 deg.
H = 0
Intensity (arbitrary units)
1.0
0.8
0.6
0.4
0.2
0.0
4
6
8
1
2
Energy



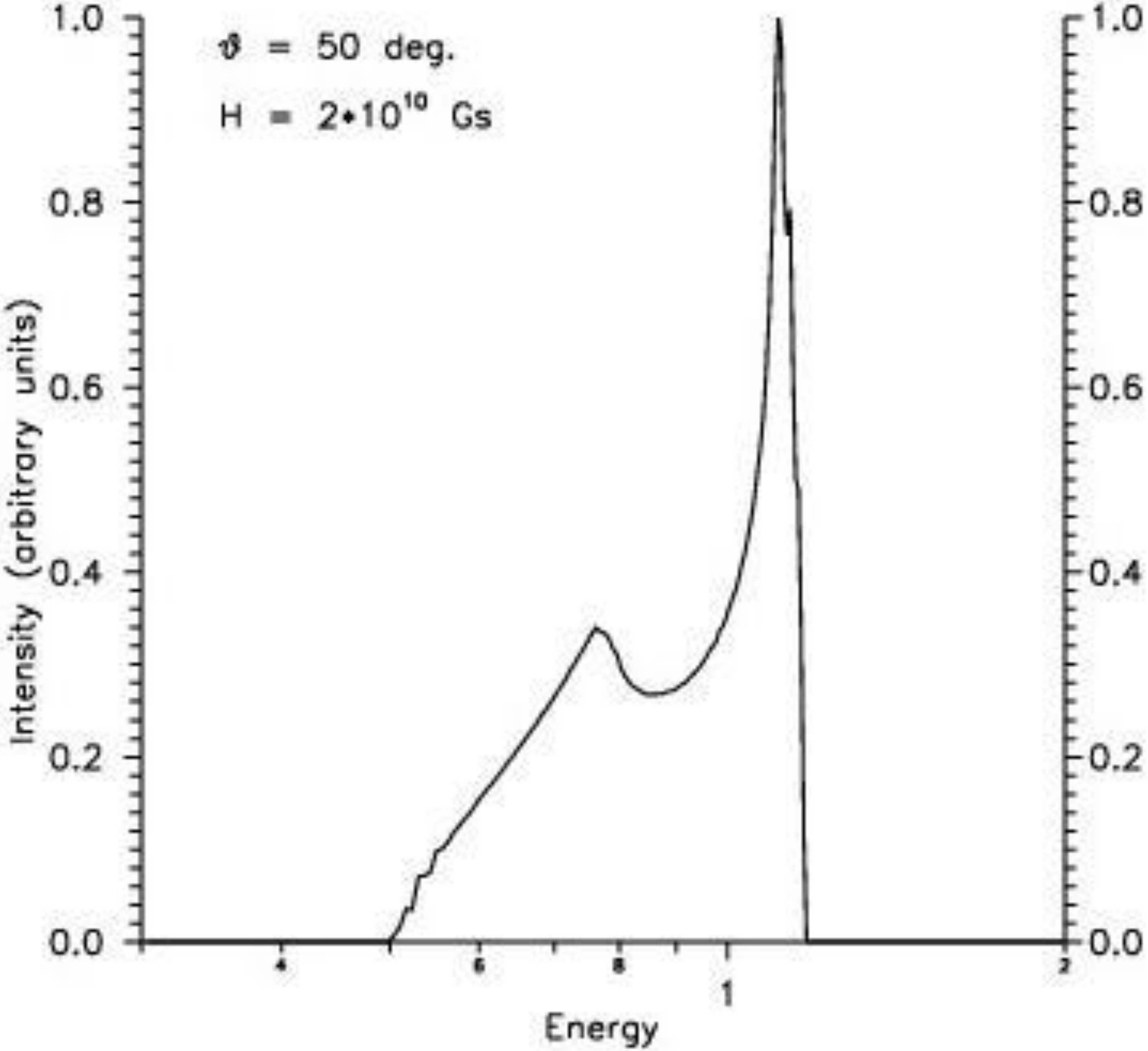
ϑ = 60 deg.
H = 4•10^10 Gs
Intensity (arbitrary units)
Energy
ϑ = 60 deg.
H = 8•10^10 Gs
Intensity (arbitrary units)
Energy
ϑ = 60 deg.
H = 1.2•10^11 Gs
Intensity (arbitrary units)
Energy
ϑ = 60 deg.
H = 2•10^11 Gs
Intensity (arbitrary units)
Energy



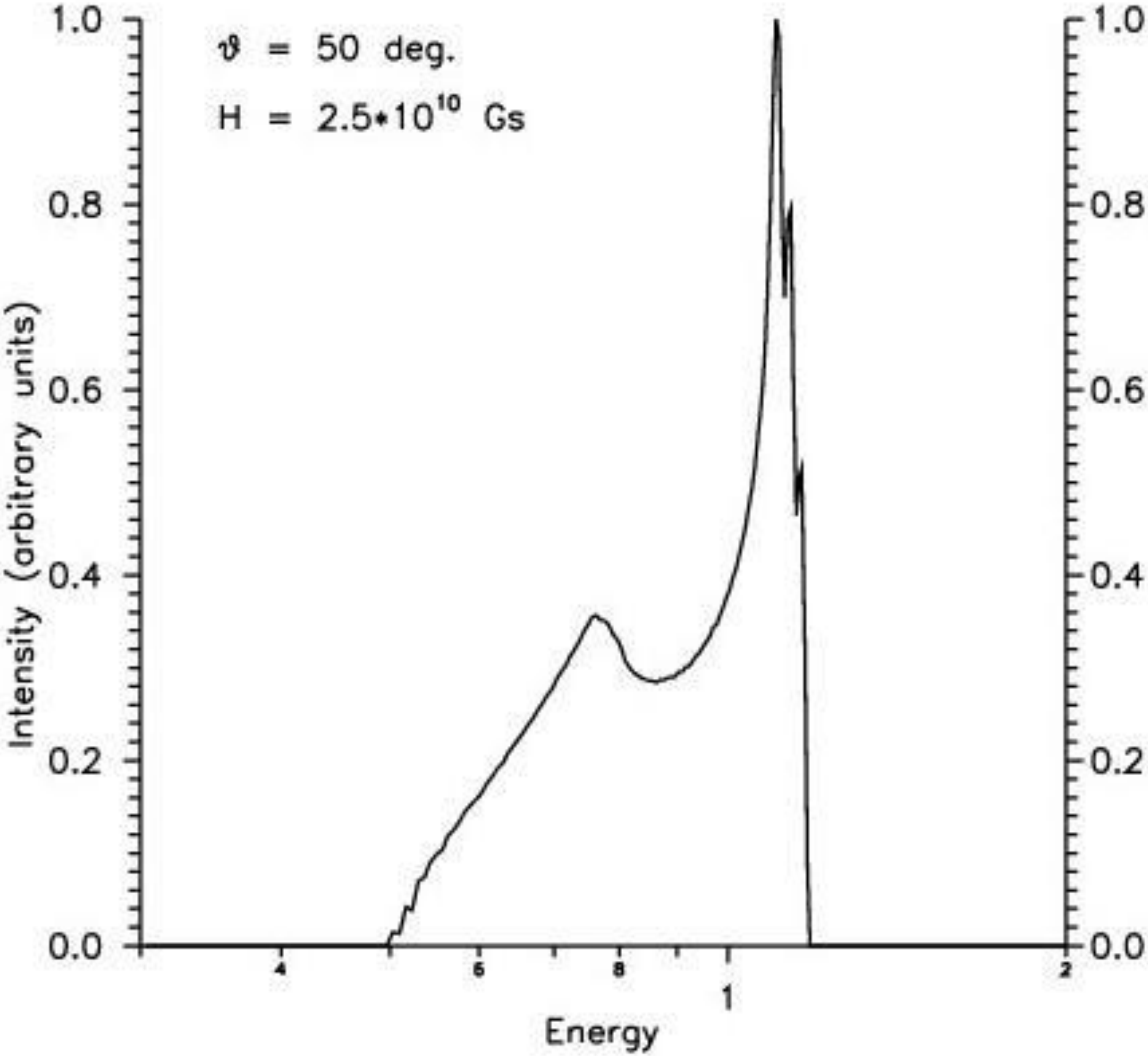
ϑ = 50 deg.
H = 4•10¹⁰ Gs
ϑ = 50 deg.
H = 8•10¹⁰ Gs
ϑ = 50 deg.
H = 1.2•10¹¹ Gs
ϑ = 50 deg.
H = 2•10¹¹ Gs
Intensity (arbitrary units)
Energy
0.0
0.2
0.4
0.6
0.8
1.0
1



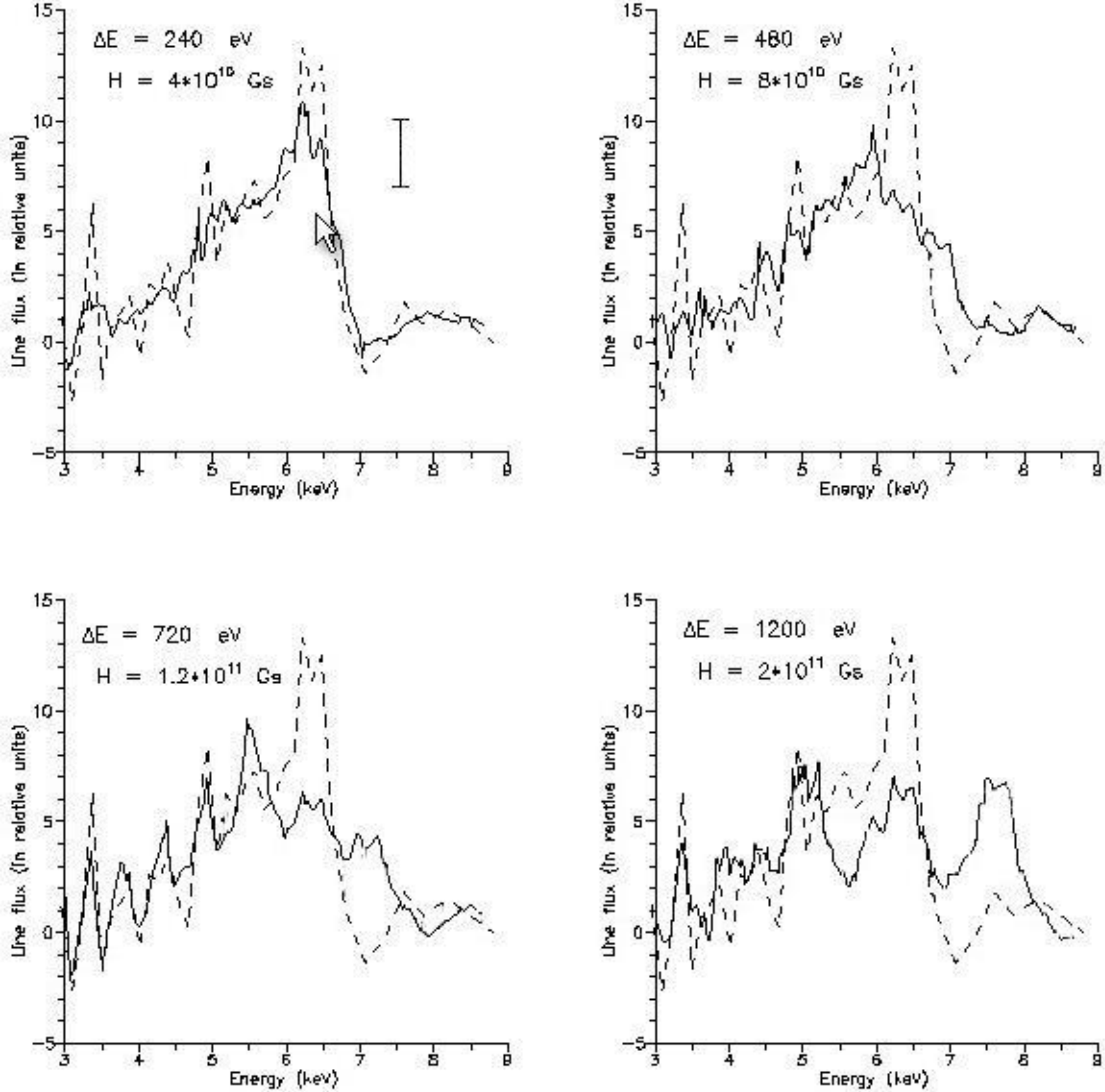
ϑ = 50 deg.
H = 3•10^10 Gs
Intensity (arbitrary units)
1.0
0.8
0.6
0.4
0.2
0.0
1
Energy



ϑ = 50 deg.
H = 2•10^10 Gs
Intensity (arbitrary units)
1.0
0.8
0.6
0.4
0.2
0.0
4
6
8
1
2
Energy



ϑ = 50 deg.
H = 2.5*10^10 Gs
Intensity (arbitrary units)
Energy
0.0
0.2
0.4
0.6
0.8
1.0
4
6
8
1
2


ΔE = 240 eV
H = 4*10^10 Gs
ΔE = 480 eV
H = 8*10^10 Gs
ΔE = 720 eV
H = 1.2*10^11 Gs
ΔE = 1200 eV
H = 2*10^11 Gs
Line flux (in relative units)
Energy (keV)

Mirages around Kerr black holes and retro-gravitational lenses

- Let us consider an illumination of black holes. Then retro-photons form caustics around black holes or mirages around black holes or boundaries around shadows.
- (Zakharov, Nucita, DePaolis, Ingrosso,
- New Astronomy 10 (2005) (479-489); astro-ph/0411511)

RETRO-MACHOS: π IN THE SKY?

DANIEL E. HOLZ
Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106

AND

JOHN A. WHEELER
Department of Physics, Princeton University, Princeton, NJ 08544

Draft version September 20, 2004

ABSTRACT

Shine a flashlight on a black hole, and one is greeted with the return of a series of concentric rings of light. For a point source of light, and for perfect alignment of the lens, source, and observer, the rings are of infinite brightness (in the limit of geometric optics). In this manner, distant black holes can be revealed through their reflection of light from the Sun. Such retro-MACHO events involve photons leaving the Sun, making a π rotation about the black hole, and then returning to be detected at the Earth. Our calculations show that, although the light return is quite small, it may nonetheless be detectable for stellar-mass black holes at the edge of our solar system. For example, all (unobscured) black holes of mass M or greater will be observable to a limiting magnitude $\bar{m}$, at a distance given by: $0.02\,\mathrm{pc} \times \sqrt[3]{10^{(\bar{m}-30)/2.5}\,(M/10\,M_{\odot})^2}$. Discovery of a Retro-MACHO offers a way to *directly* image the presence of a black hole, and would be a stunning confirmation of strong-field general relativity.

Subject headings: gravitational lensing—black hole physics—relativity

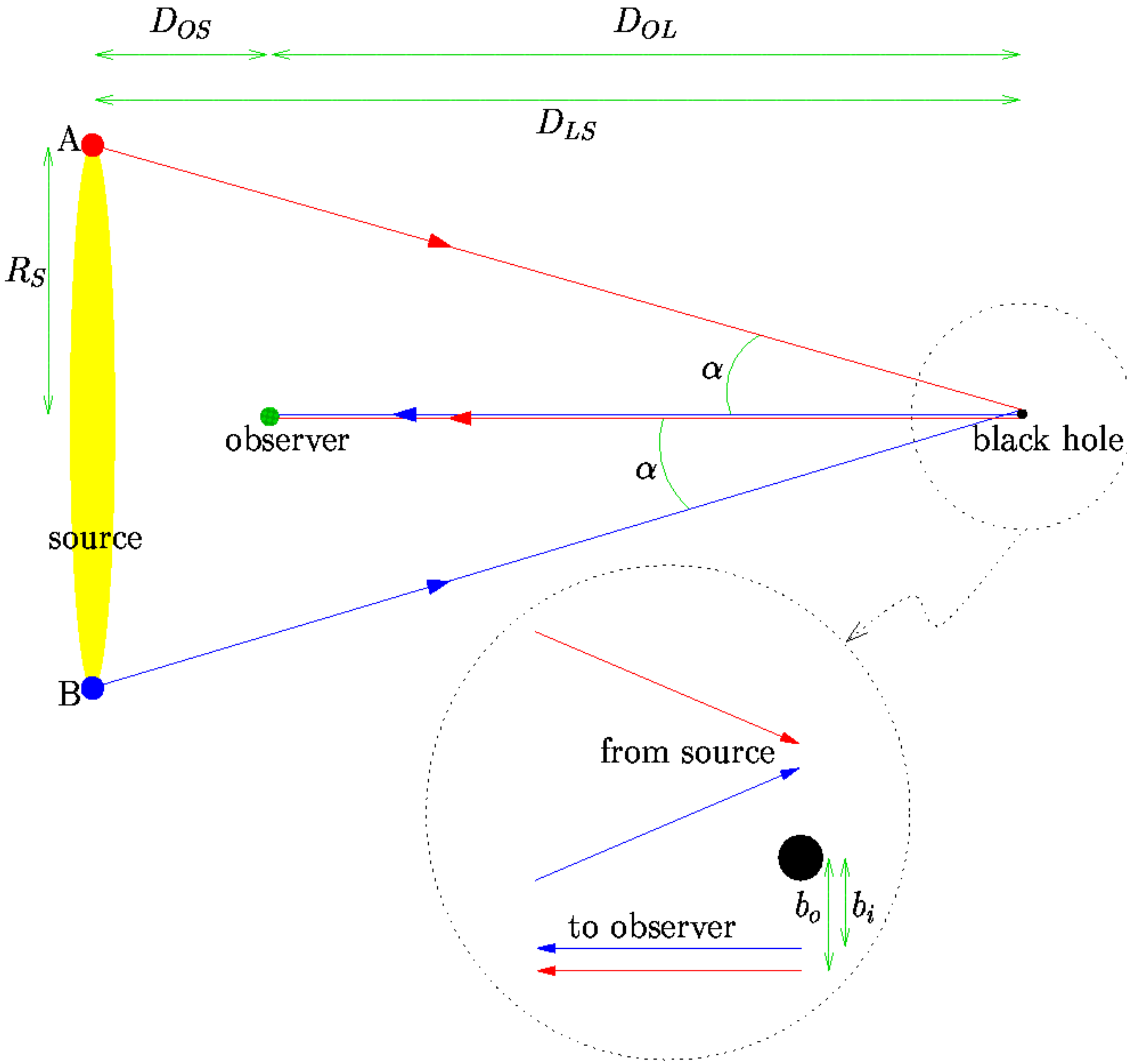


FIG. 1.— Perfect alignment: the (extended) source, observer, and lens are colinear. The resulting image of the source, as lensed by the black hole, is a ring. (The angles in this figure are greatly exaggerated.)

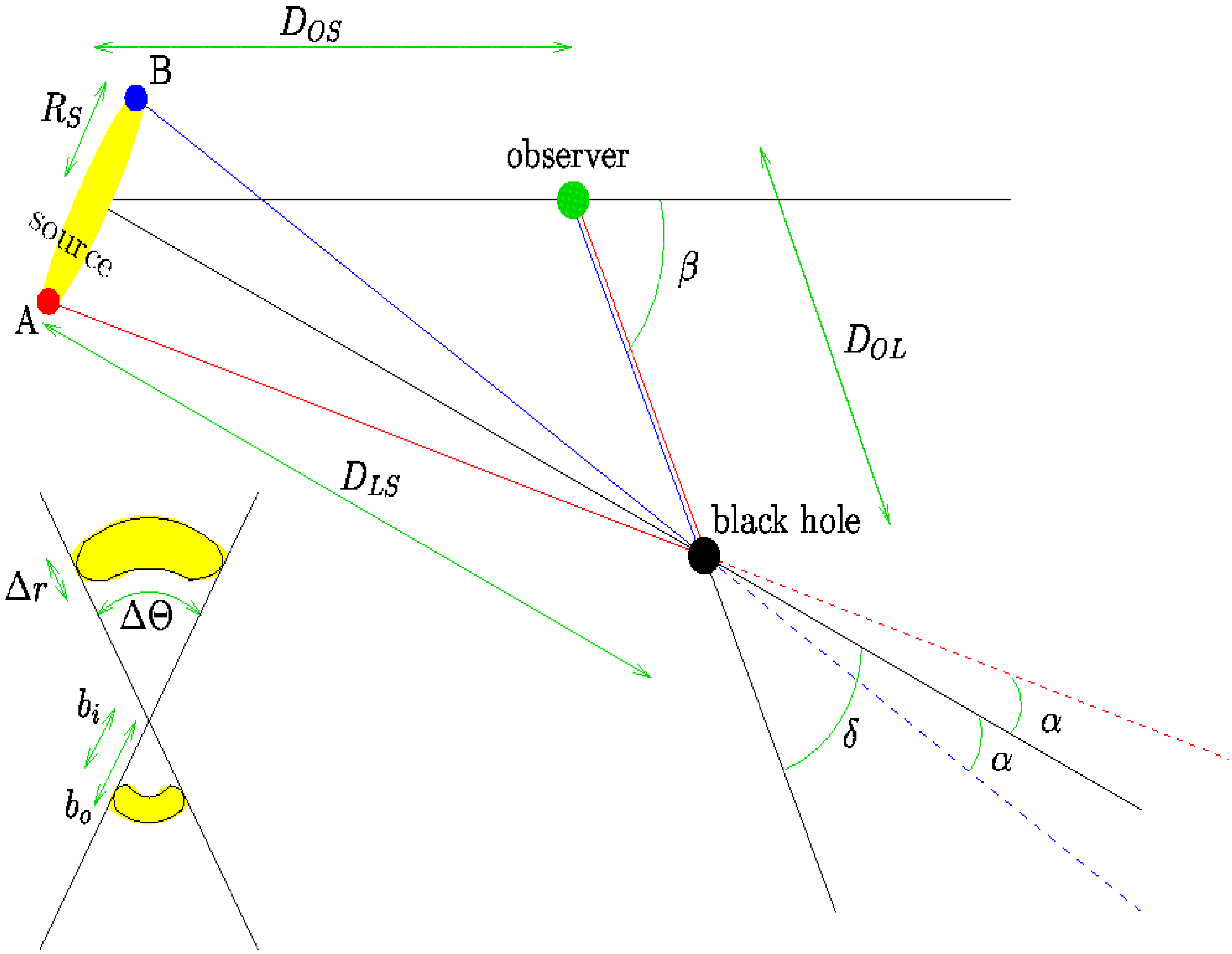


FIG. 2.— Imperfect alignment: the source, observer, and lens are not colinear. Pairs of images are produced, centered on the source–observer–lens plane, on opposite sides of the lens (see inset).

OXFORD SCIENCE PUBLICATIONS

INTERNATIONAL SERIES OF MONOGRAPHS ON PHYSICS 69

The Mathematical Theory of Black Holes

S. Chandrasekhar

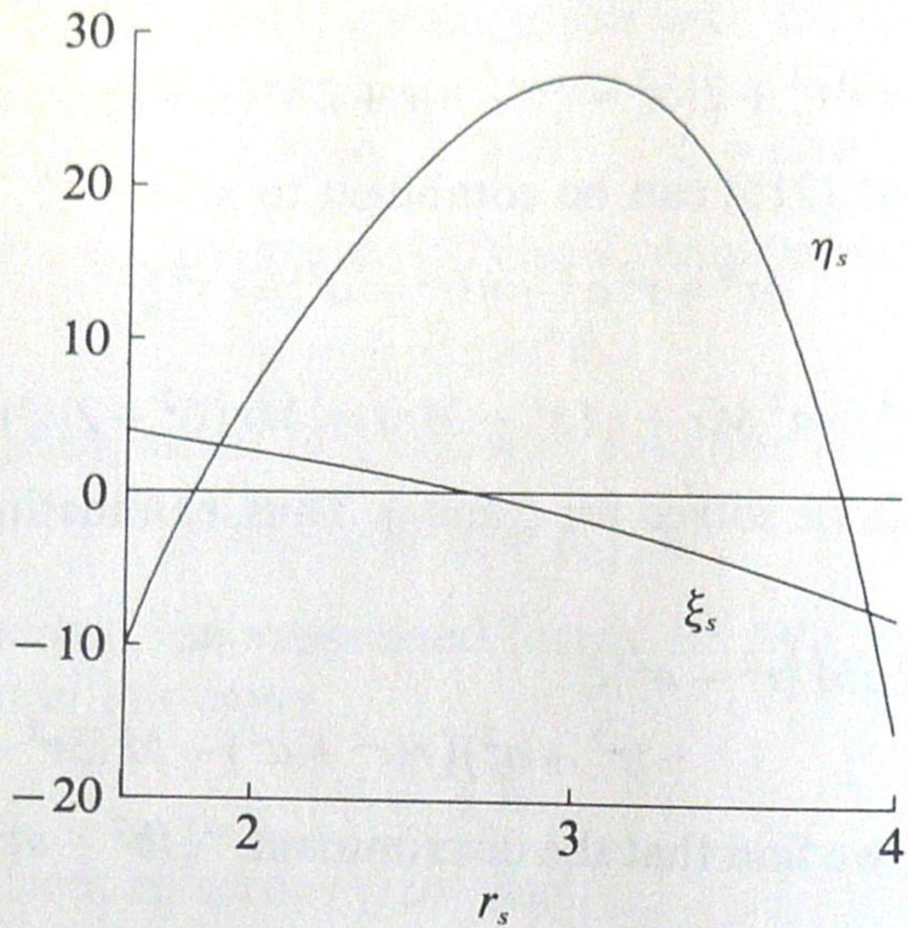


FIG. 34. The locus (ξ_s, η_s) determining the constants of the motion for three-dimensional orbits of constant radius described around a Kerr black-hole with $a = 0.8$. The unit of length along the abscissa is M.

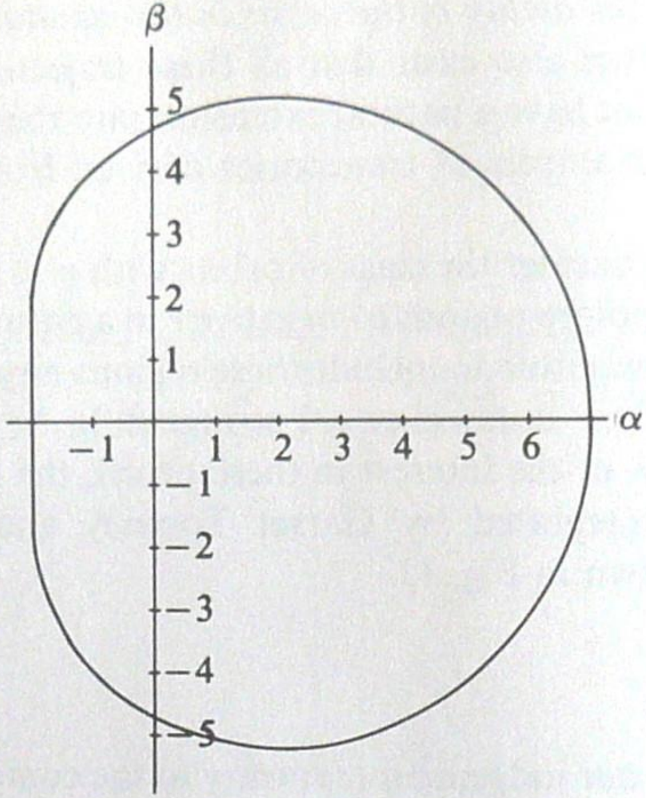


FIG. 38. The apparent shape of an extreme ($a = M$) Kerr black-hole as seen by a distant observer in the equatorial plane, if the black hole is in front of a source of illumination with an angular size larger than that of the black hole. The unit of length along the coordinate axes α and β (defined in equation (241) is M.

black hole from infinity, the apparent shape will be determined by

$$(\alpha, \beta) = [\xi, \sqrt{\eta(\xi)}]. \tag{242}$$

The full classification of geodesic types for Kerr metric is given by Zakharov (1986). As it was shown in this paper, there are three photon geodesic types: capture, scattering and critical curve which separates the first two sets. This classification fully depends only on two parameters $\xi = L_z/E$ and $\eta = Q/E^2$, which are known as Chandrasekhar's constants (Chandrasekhar 1983). Here the Carter constant Q is given by Carter (1968)

$$Q = p_\theta^2 + \cos^2\theta \left[a^2\left(m^2 - E^2\right) + L_z^2/\sin^2\theta\right], \tag{1}$$

where $E = p_t$ is the particle energy at infinity, $L_z = p_\phi$ is z-component of its angular momentum, $m = p_i p^i$ is the particle mass. Therefore, since photons have $m = 0$

$$\eta = p_\theta^2/E^2 + \cos^2\theta \left[-a^2 + \xi^2/\sin^2\theta\right]. \tag{2}$$

The first integral for the equation of photon motion (isotropic geodesics) for a radial coordinate in the Kerr metric is described by the following equation (Carter 1968; Chandrasekhar 1983; Zakharov 1986, 1991a)

$$\rho^4 (dr/d\lambda)^2 = R(r),$$

where

$$R(r) = r^4 + (a^2 - \xi^2 - \eta)r^2 + 2[\eta + (\xi - a)^2]r - a^2\eta, \tag{3}$$

and $\rho^2 = r^2 + a^2\cos^2\theta, \Delta = r^2 - 2r + a^2, a = S/M^2$. The constants M and S are the black hole mass and angular momentum, respectively. Eq. (3) is written in dimensionless variables (all lengths are expressed in black hole mass units M).

If we fix a black hole spin parameter a and consider a plane (ξ, η) and different types of photon trajectories corresponding to (ξ, η), namely, a capture region, a scatter region and the critical curve $\eta_{\rm crit}(\xi)$ separating the scatter and capture regions. The critical curve is a set of (ξ, η) where the polynomial $R(r)$ has a multiple root (a double root for this case). Thus, the critical curve $\eta_{\rm crit}(\xi)$ could be determined from the system (Zakharov 1986, 1991a)

$$
\begin{aligned}
R(r) &= 0, \\
\frac{\partial R}{\partial r}(r) &= 0,
\end{aligned}
\tag{4}
$$

for $\eta \geq 0, r \geq r_+ = 1 + \sqrt{1-a^2}$, because by analysing of trajectories along the θ coordinate we know that for $\eta < 0$ we have $M = \{(\xi, \eta) | \eta \geq -a^2 + 2a|\xi| - \xi^2, -a \leq \xi \leq a\}$ and for each point $(\xi, \eta) \in M$ photons will be captured. If instead $\eta < 0$ and $(\xi, \eta) \bar{\in} M$, photons cannot have such constants of motion, corresponding to the forbidden region (see, (Chandrasekhar 1983; Zakharov 1986) for details).

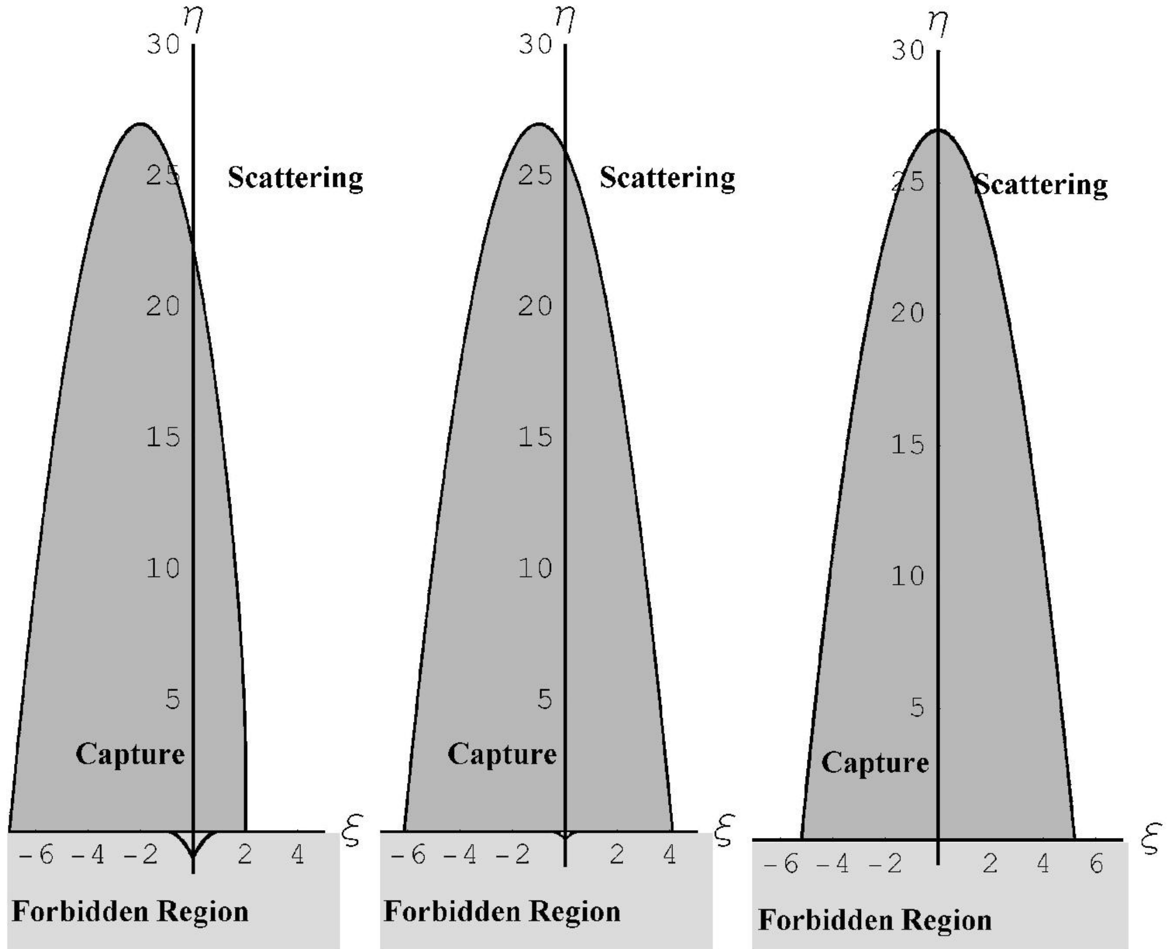


Fig. 1. Different types for photon trajectories and spin parameters ($a = 1., a = 0.5, a = 0.$). Critical curves separate capture and scatter regions. Here we show also the forbidden region corresponding to constants of motion $\eta < 0$ and $(\xi, \eta) \bar{\in} M$ as it was discussed in the text.