Dust-Scattered X-rays in the *XMM* Era

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ABSTRACT

I give a brief overview on some selected ideas about possible future science with dust-scattered X-ray halos around cosmic X-ray sources.

1. Introduction

In the mid 1960s it was predicted that dust-scattered X-ray halos could exist around cosmic X-ray sources (Overbeck 1965; Fig. 1). It took more than 15 years until such halos were detected with the *Einstein* satellite (Catura 1983; Rolf 1983). Since then such halos have been investigated with *EXOSAT, Ginga, Tenma, ASCA,* and in a large number observed with *ROSAT* (Predehl & Schmitt 1995). Currently, the detection of about 50 dust-scattered X-ray halos is reported in the literature. *XMM* can considerable increase our knowledge in this field since it will become a very potential observational tool for the study of dust-scattered X-ray halos.

The main application of X-ray halos is to get information on the physical properties of the scattering grains (cf. Hayakawa 1970; Martin 1970; Mauche & Gorenstein 1986; Mathis et al. 1995; Predehl & Klose 1996). In certain cases dust scattering of soft X-rays can also provide informations about the physical nature of the X-ray source under consideration. In the following some of these ideas are presented (for a review, Klose 1998a).

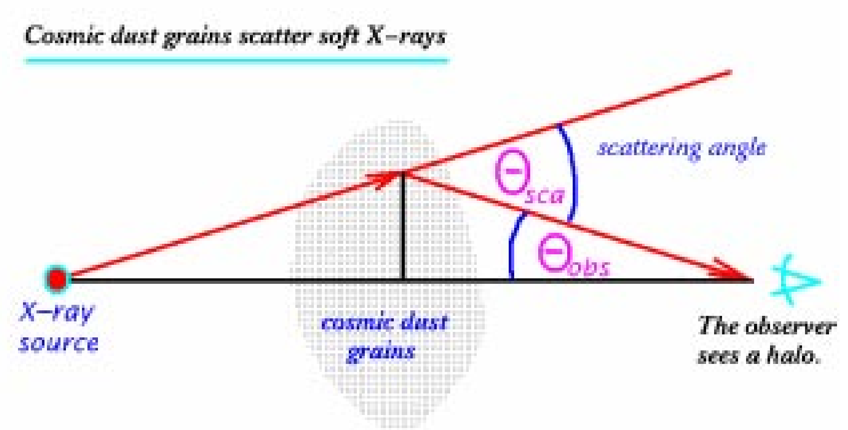

Fig. 1.— The basic model to calculate X-ray halos is the single scattering approximation (cf. Mauche & Gorenstein 1986; Mathis & Lee 1991; Smith & Dwek 1998).

2. X-ray Halo Spectroscopy

In general, the efficiency of X-ray scattering by dust grains is a smooth function of energy. At the energies of the K-edges of the chemical elements, however, the scattering cross section of the dust grains can vary considerable (Martin 1970; Martin & Sciama 1970). At the given high energy resolution of *XMM,* this anomalous behaviour of the index of refraction of the chemical elements in the cosmic dust grains could become detectable when fitting a model to an observed X-ray halo. This effect could result in a notable reduced halo intensity at certain energies (Fig. 2). The strength of this effect would be a measure of the mean atomic composition of the scattering interstellar grains. This can make X-ray halo spectroscopy to a novel observational tool for cosmic dust research.

3. X-ray Halos and Extragalactic Dust

Dust-scattered X-ray halos can be used to set constraints on an intergalactic dust component (Evans, Norwell, & Bode 1985; Fig. 3). The basic idea is relatively simple: The halo flux is a function of the total amount of dust and its spatial distribution between the X-ray source and the observer. Archived *ROSAT* data have already been used to set an upper limit on an extinction by intergalactic dust towards the quasar PKS 2155–304 ($z = 0.116$): $A_V \leq 10^{-4}$ mag Mpc^{-1} (Predehl & Klose 1996). Stronger constraints could be set in the future by using archived *XMM* data.

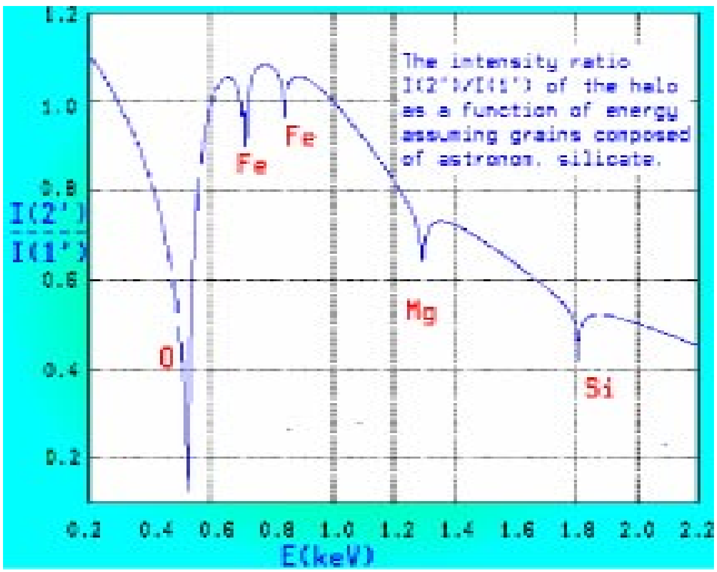

Fig. 2.— Results of a model calculation which shall demonstrate how the halo intensity could vary as a function of energy (see Predehl & Klose 1996).

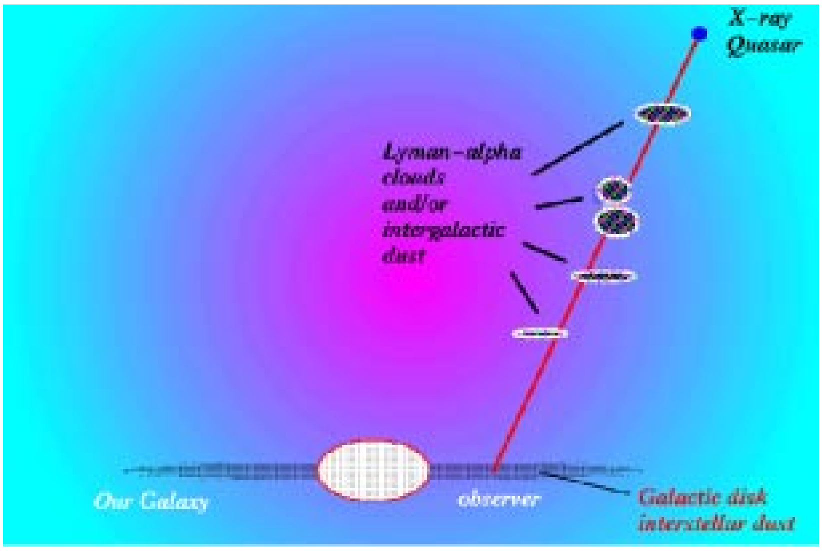

Fig. 3.— X-ray halos can provide constraints on the occurrance of dust between the X-ray source and the observer. This holds also in the case of an extragalactic X-ray source.

4. Quasars seen through Nearby Dusty Galaxies

There is convincing evidence that quasars are at cosmological distances (cf. Dar 1991). This can be further demonstrated by X-ray observations.

Consider an X-ray bright quasar which is seen through an X-ray faint, nearby spiral (Fig. 4). Such a galaxy represents a dusty plane between the quasar and the observer, where X-ray scattering can occur. However, after correcting for the influence of Galactic dust, no dust-scattered halo is expected to exist around such a quasar if the distance ratio quasar - galaxy / quasar - observer is close to one and no intergalactic dust exists (Sect. 3).

The galaxy-quasar association NGC 4319 - Mrk 205 would be an interesting target for such observations (Klose 1996, and references therein).

5. Transient Halos from Gamma-Ray Bursts

Cosmic Gamma-Ray Bursts (GRBs) are not only very intense transient sources in gamma-rays, but also in the soft X-ray band (cf. Piro et al. 1998). Their soft X-ray tails can make them to very bright, transient X-ray sources on the sky. Therefore, at certain Galactic latitudes GRBs could produce relatively long-lived (some hours), faint, transient dust-scattered X-ray halos caused by the dust in our Galaxy (Paczyński 1991; Klose 1994; Fig. 5). Although the detection of such halos would not tell us news about the physical nature of GRBs, it could make these halos useful

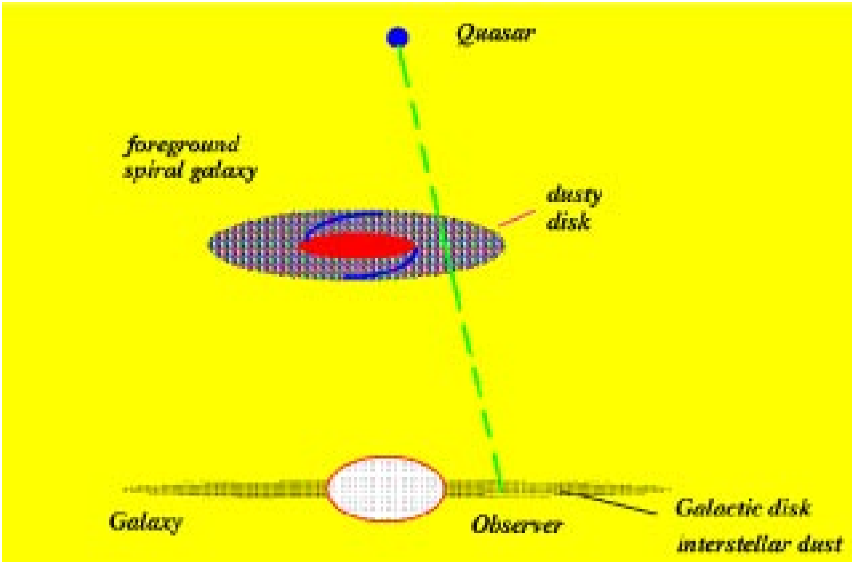

Fig. 4.— An X-ray bright, remote quasar seen through an X-ray faint, dusty, nearby spiral. A halo is not expected to exist, provided that there is no intergalactic dust.

for Galactic dust studies. *XMM* with its large collecting area could detect and monitor such faint, transient halos.

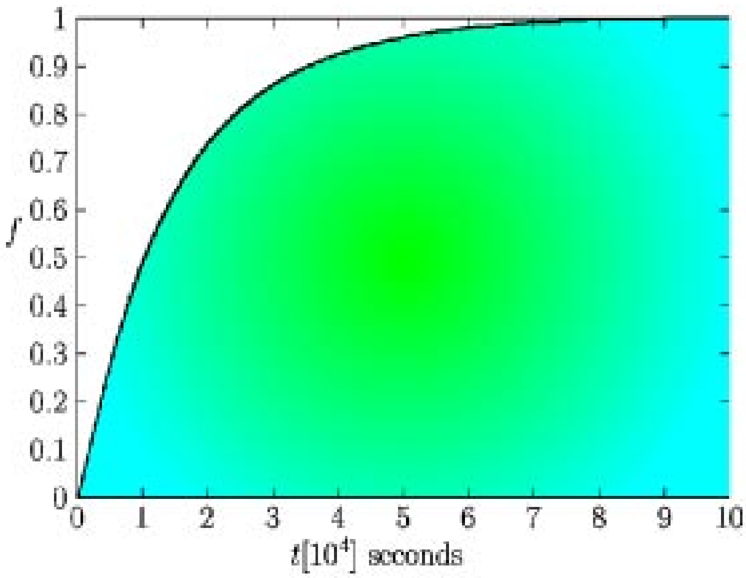

Fig. 5.— The time evolution of the flux from the inner 6 arcmin of a modeled dust-scattered X-ray halo caused by the soft X-ray tail of a GRB (see Klose 1994). f is the fraction of halo flux which has arrived at the observer at the time t after the occurrence of the burst.

6. Dust Scattering in GRB Host Galaxies

What are the sources of Gamma-Ray Bursts? According to the hypernova model of GRBs (Paczyński 1998), the gravitational collaps of a massive star does not lead to an ordinary supernova, but to a giant explosion resulting in a GRB. One of the main points of the hypernova model is that the GRB sources should be located in or close to star-forming regions, since massive stars are rapidly developing objects. Consequently, at the time of their explosion these stars are still located close to their birthplaces. X-ray observations could be used to check the validity of this model, since star-forming regions might be very rich on dust.

Consider the case that part of the dust located many parsecs away from a GRB source survives the explosion for some time and affects the propagation of the soft X-rays of the burst and its afterglow to the observer by scattering (Fig. 6). Scattered X-rays travel an extra way to the observer. Hence, they arrive at the observer with a time delay (Trümper & Schönfelder 1973). Therefore, a dusty GRB environment in a remote galaxy could manifest itself in a characteristic hard-to-soft spectral evolution of a GRB afterglow in the soft X-ray band some hours after the explosion (Klose 1998b). *XMM* carries the potential instrumental equipment to search for this effect.

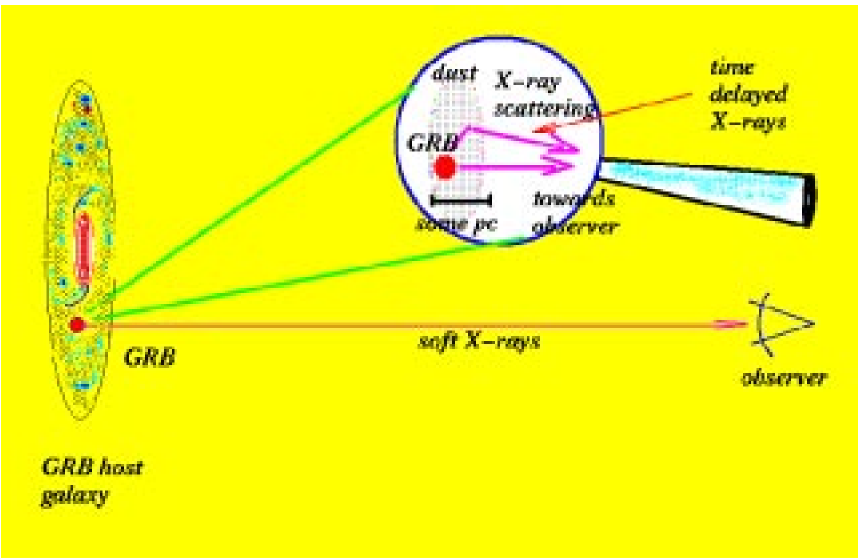

Fig. 6.— Dust scattering in a GRB environment can result in a time-delayed arrival of soft X-rays at the observer some hours after the original burst.

REFERENCES

Catura, R. C., 1983, ApJ, 275, 645

Dar, A., 1991, ApJ, 382, L1

Evans, A., Norwell, G. A., & Bode, M. F., 1985, MNRAS, 213, 1P

Hayakawa, S., 1970, Progr. Theor. Phys., 43, 1224

Klose, S., 1994, A&A, 289, L1

Klose, S., 1996, ApJ, 473, 806

Klose, S., 1998a. In: B. Aschenbach, & M. Freyberg (eds.), Highlights in X-ray Astronomy. A symposium in honour of Joachim Trümper's 65th birthday. MPE Report, in press; also available via anonymous ftp from ftp.tls-tautenburg.de in the directory pub/klose

Klose, S., 1998b, ApJ, 507, in press

Martin, P. G., 1970, MNRAS, 149, 221

Martin, P. G., & Sciama, D. W., 1970, Astroph. Lett. Comm., 5, 193

Mathis, J. S., et al., 1995, ApJ, 449, 320

Mathis, J. S., & Lee, C. W., 1991, ApJ, 376, 490

Mauche, C. W., & Gorenstein, P., 1986, ApJ, 302, 371

Overbeck, J. W., 1965, ApJ, 141, 864

Paczyński, B., 1991, Acta Astron., 41, 257

Paczyński, B., 1998, ApJ, 494, L45

Piro, L., et al., 1998, A&A, 331, L41

Predehl, P., & Klose, S., 1996, A&A, 306, 283

Predehl, P., & Schmitt, J. H. M. M., 1995, A&A, 293, 889

Rolf, D. P., 1983, Nature, 302, 46

Smith, R. K., & Dwek, E., 1998, ApJ, 503, 831

Trümper, J., & Schönfelder, V., 1973, A&A, 25, 445

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