# IRON ABUNDANCE DISCREPANCY IN ELLIPTICALS AFTER ASCA

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## 1. Introduction

The chemical composition of the ISM is expected to reflect the average composition of the stellar component as established at the time of its formation, then further enriched by SN's of Type Ia that are known to currently explode in elliptical galaxies. Renzini et al. (1993) estimate the expected iron abundance in the hot ISM of elliptical galaxies to range from a minimum of $\sim 2$ times solar, to perhaps as much as $\sim 5$ times solar or more, depending on the adopted SNIa's rate.

## 2. The Iron Abundance in the Hot ISM

We have analysed the *ASCA* data for nine elliptical galaxies NGC 499, NGC 507, NGC 720, NGC 1399, NGC 1404, NGC 4374, NGC 4406, NGC 4472, and NGC 4636. We have integrated the SIS spectral data within a radius of 5' centered on each galaxy and have fitted the spectra with $\chi^2$ method with the XSPEC spectral fitting package. Thin thermal plasma model (Raymond & Smith 1977) modified by interstellar absorption is fitted to each galaxy. The iron abundances are determined from the iron-L blends around 1keV.

Figures 1 shows the resulting temperature and iron abundances. Arimoto et al. (1995) have estimated the mean stellar iron abundances of about 50 ellipticals by precisely taking into account the observed metallicity gradients, among which four galaxies NGC 4374, NGC 4406, NGC 4472, and NGC 4636 are common with our *ASCA* analysis; the iron abundances of hot gas in these galaxies are 0.1, 0.2, 0.3, and 0.3 (in solar units), respectively. In contrast, the mean stellar iron abundances of these galaxies are 0.9, 0.7, 1.4, and 0.7 (in solar units), respectively. *There is clearly a macro-*



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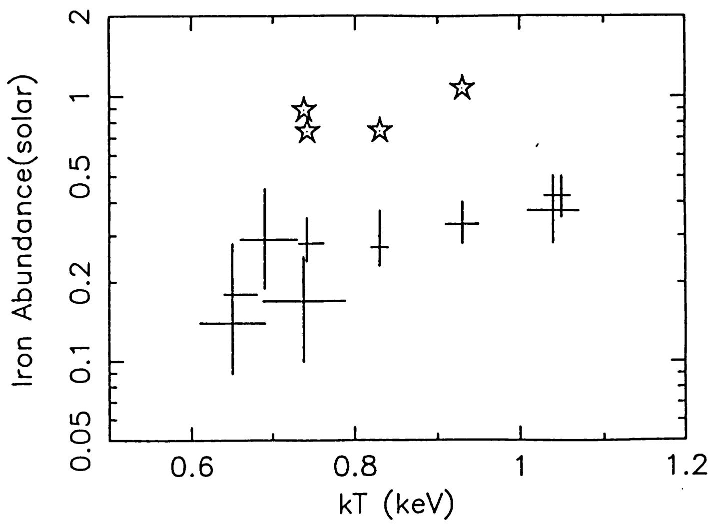


*Figure 1.* Iron abundance of hot ISM of elliptical galaxies. Stars indicate the mean stellar iron abundances derived by Arimoto et al. (1995).

*scopic discrepancy between the expected abundance and what is indicated by the X-ray observation of elliptical galaxies with ASCA.*

## 3. Astrophysical Implications of A Low Iron in The Hot ISM

We believe that the *optical* and the X-ray abundances cannot be easily reconciled, and therefore the existence of this macroscopic discrepancy opens three main options: 1) the optical abundances are seriously in error, 2) both optical and X-ray abundances are correct, but the ISM iron is somehow hidden to X-ray observations, and 3) there is a problem with the interpretation of the Iron-L lines.

The low iron abundances reported require the SNIa's iron enrichment at the present time to be vanishingly small, and the average iron abundances of the stellar component to be in error by a large factor.

The drastic reduction in the rate of SNIa's has major implications for the interpretation of the X-ray properties and evolution of elliptical galaxies. With $\vartheta_{\rm SN} \ll 1/4$ the SN heating of the ISM becomes virtually negligible for the dynamics of the gas flows in these galaxies at the present time. In absence of alternative internal sources of heat, the ISM of virtually all elliptical galaxies would now be in a cooling flow regime. *Correspondingly, all elliptical galaxies would be very bright in X-rays, at variance with the observations that indicate a large disperion in X-ray luminosity for given optical luminosity* (Canizares, Fabbiano, & Trinchieri 1987; Donnelly, Faber, &

O'Connell 1990; Ciotti et al. 1991; Fabbiano, Kim, & Trinchieri 1992).

We have implicitly assumed that all the iron ejected by stars and SNIa's is now in the gas phase of the ISM. While there is little doubt that at least a fraction of the iron is injected in the form of solid particles, the question is as to whether iron remains in a solid phase for a long enough period of time so to account for the iron discrepancy. The time required to evaporate 90% of iron particles in a $10^7$ K plasma is $\sim 10^5/n_e$ yr cm$^{-3}$ (Itoh 1989). Electron densities in the ISM of ellipticals range from $\sim 10^{-1}$ near to center to $\sim 10^{-3}$ several effective radii away, and therefore evaporation times range from $10^6$ to $10^8$ yr. This compares to a flow time of a few Gyr, and *we conclude that only a tiny fraction of iron could be hidden in dust particles.*

Local thermal instabilities causing a fraction of the gas to drop out of the flow locally have often been invoked as the ultimate depository for both cluster and galaxy inflows (e.g., Fabian et al. 1986). Together with this hypothesis comes the additional conjecture that such instabilities would lead to the formation of low mass, safely unobservable objects such as lower main sequence stars, brown dwarfs, or jupiters. This scenario has one testable prediction. Local thermal instabilities – if they exist – should be more efficient in dropping SNIa products out of the flow near the center where the cooling time is short, compared to the outer regions. Thus, iron should be preferentially depleted near the center, and a positive abundance gradient should develop. Actual observations seem in case to indicate the opposite gradient, with iron being more enhanced near the center (Mushotzky et al. 1994). *We conclude that neither hiding iron into jupiters appears to be a viable solution to the discrepancy.*

At the temperature that are typical of the hot ISM of elliptical galaxies ($\lesssim$1 keV), the iron abundance is derived from the strength of a few hundreds lines originated by electron transitions down to the L shell in incompletely ionized iron ions, typically Fe XVIII-XXI, hence called Iron-L.

Spectra of ellipticals are dominated by the iron-L blends, by which both temperature and iron abundance are determined. However, is the interpretation of the iron-L lines correct? Atomic data such as ionization, recombination, and excitation rate coefficients are still controversial. New calculation of spectra of plasma (Liedahl et al 1994), using new Fe data, show that the total power of the iron-L lines is several tens of % different from Meka model (Mewe, Gronenshild & van den Oord 1985; Kaastra & Mewe 1993). Ambiguity of the iron-L blend is very large for the total power and line ratios, thus ambiguity of the resulting abundance is of no doubt significant. *We conclude that the reliability of iron-L line diagnostic tools that are currently used in conjunction with X-ray observations is in question.*

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## Discussion

*S.M.Faber:*

We have not tried to estimate real [Fe/H] abundances for giant ellipticals because our models are clearly wrong due to non-solar Mg/Fe ratios. But if we ignore that problem, we would get *significantly* reduced [Fe/H], maybe down by a factor of 3 below solar for the whole galaxy. This would not surprise me.

*N.Arimoto:*

I am not sure if giant ellipticals do really have non-slar Mg/Fe ratios, although it is suggested by analyses of metallic absorption lines.

*L. Vigroux:*

If the wind takes place during the very early phase of galaxy formation, a dilution might take place with the remnant of the primordial gas which have been with the origin of the galaxies. This has already been used to explain the low metal abundance ($\sim 0.5[Fe/H]_{\odot}$) in clusters of galaxies. A clue to this problem is to use mass instead of abundance ratio. Dr.Renzini, in the previous talk, has shown that the mass of iron normalized to galaxy luminosity is constant from group to clusters of galaxies. How the elliptical galaxies of your sample compare with clusters in this ratio?

*N.Arimoto:*

Although it would be of great interest to derive the mass of iron normalized to galaxy luminosity, it is not yet possible to do, because total masses of hot X-ray gas cannot be accurately estimated by *ASCA*.