First Results from a Combined Weak-Lensing/X-ray Search for Clusters

Jörg Dietrich, Thomas Erben, Peter Schneider
IAEF, University of Bonn, Germany

Axel Schwope
Astrophysikalisches Institut Potsdam, Germany

Abstract

We present first results from a combined weak lensing, X-ray, and optical search for galaxy with the Wide Field Imager (WFI) at the ESO/MPG-2.2 m telescope and XMM-Newton archival data. Our survey will eventually cover an area of 6 sq. deg. on deep XMM-Newton serendipitous fields, allowing the immediate comparison of lensing detected cluster candidates to X-ray data. The combination of X-ray and weak lensing data will allow us to dig deeper into the mass function than any method by itself.

1. Introduction

The detection of galaxy clusters using the weak gravitational lensing technique provides an interesting alternative to the selection of clusters from optical or X-ray searches. Specifically, weak lensing can detect halos with little or no gas and weak lensing mass estimates make no simplifying assumptions like virial or hydrodynamical equilibrium. This method was proven to be effective by small number of weak lensing detected clusters (e.g. Wittman et al. 2003; Dahle et al. 2003). A systematic search for clusters via weak lensing allows to generate a shear selected sample of cluster candidates. This sample can be directly compared to model predictions from N-body simulations of the number density of halos of a given mass at a given redshift, which depends on the cosmological model.

2. Survey Overview

We present first results from such a weak lensing survey with WFI@ESO/MPG-2.2 which eventually will cover 6 sq. deg.. The survey is carried out on fields for which deep publicly available XMM-Newton exposures exist. The almost perfectly matched FOVs of the XMM-Newton satellite and the WFI will allow us to look for X-ray counter-parts for weak lensing detections and vice versa.

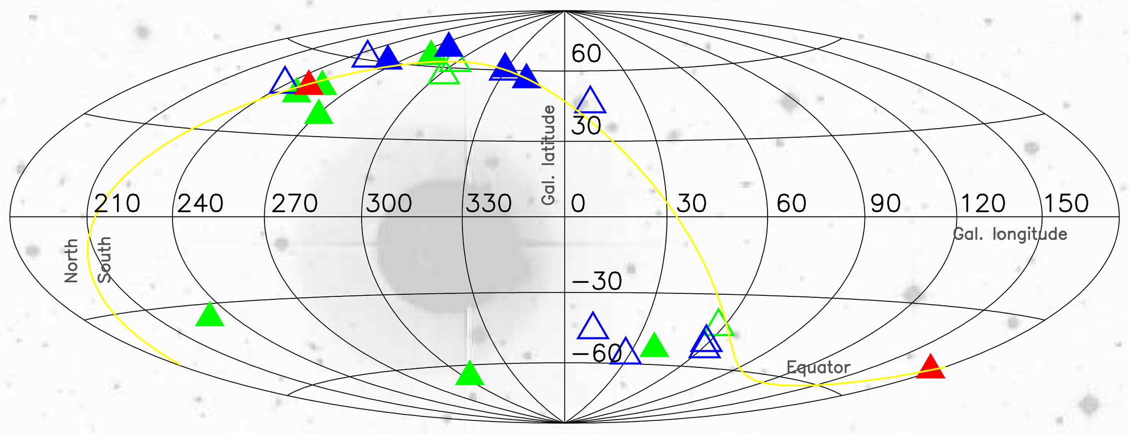

Figure 1. Field distribution of our survey in Galactic coordinates. Filled triangle mark completed fields, open triangles mark fields in which part of the planned observations is not yet completed. The colors indicate the passband coverage. Red triangles represent fields observed only in R-band, blue triangles denote the fields observed in B- and R-band, green triangles mark the fields with B-, V-, R-, and I-band observations.

The survey is carried out in coordination with the XMM-Newton follow-up survey of the ESO Imaging Survey that contributes V- and I-band observations for some of the fields in which we supply the B- and R-band observations. R-band is primary science band for the lensing analysis. Fig. 1 shows the distribution of our fields in Galactic coordinates. The table below gives typical exposure times for the observations.

Filter	T_{exp}
B/123_ESO879	1800
V/89_ESO843	4400
Rc/162_ESO844	11500
I/203_ESO879	9000

3. Aperture Mass M_{ap}

The aperture mass statistics M_{ap} (Schneider 1996) is particularly suited for weak lensing searches for clusters of galaxies. M_{ap} is defined as a weighted integral over the surface mass density κ in a (circular) aperture

$$M_{ap} = \int d^2\theta \; U(|\vec{\theta}|)\kappa(\vec{\theta}) \; . \tag{1}$$

The weight function $U(|\vec{\theta}|)$ is compensated,

$$\int d\theta \; \theta \, U(|\vec{\theta}|) = 0 \; , \tag{2}$$

so that the mass-sheet degeneracy has no influence on the value of M_{ap}. It is possible to express M_{ap} in terms of the tangential shear γ_t

$$M_{ap} = \int d^2\theta \; Q(|\vec{\theta}|) \, \gamma_t(\vec{\theta}) \tag{3}$$

with a weight function $Q(|\vec{\theta}|)$ that is related to $U(|\vec{\theta}|)$. $Q(|\vec{\theta}|)$ can be optimized to follow the expected shear profile (see the poster by M. Hetterscheid et al.).

M_{ap} allows for an easy computation of the the signal-to-noise ratio of a peak detection, either analytically

$$S/N = \frac{M_{ap}}{\sigma} = \sqrt{\frac{n}{\pi\sigma_\varepsilon}} \, \frac{\int d^2\theta \; Q(|\vec{\theta}|)\gamma_t(\vec{\theta})}{\int d^2\theta \; Q(|\vec{\theta}|)} \; , \tag{4}$$

or by randomizing the orientation of the background galaxies and performing the computation of the M_{ap} statistics on the randomized catalogs to see how often the true signal exceeds the signal from the randomized catalog.
As weight function Q we choose the function proposed by Schirmer (2004):

$$Q(x) = \frac{1}{1 + e^{a-bx} + e^{-c+dx}} Q_{\tanh} \; , \quad Q_{\tanh}(x) = \frac{\tanh x/x_c}{x/x_c} \; , \tag{5}$$

with $a = 6$, $b = 150$, $c = 47$ and $d = 50$, where we have set $x = \theta/\theta_0$, θ_0 being the scale radius of the filter function. The function $Q_{\tanh}(x)$ closely follows the shear profile expected from an NFW halo with an exponential cut-off at small radii and near to 1. The paramter x_c allows one to change the width of the filter over the $[0, 1]$ interval. The smaller x_c, the more weight is given to the shear at smaller radii.

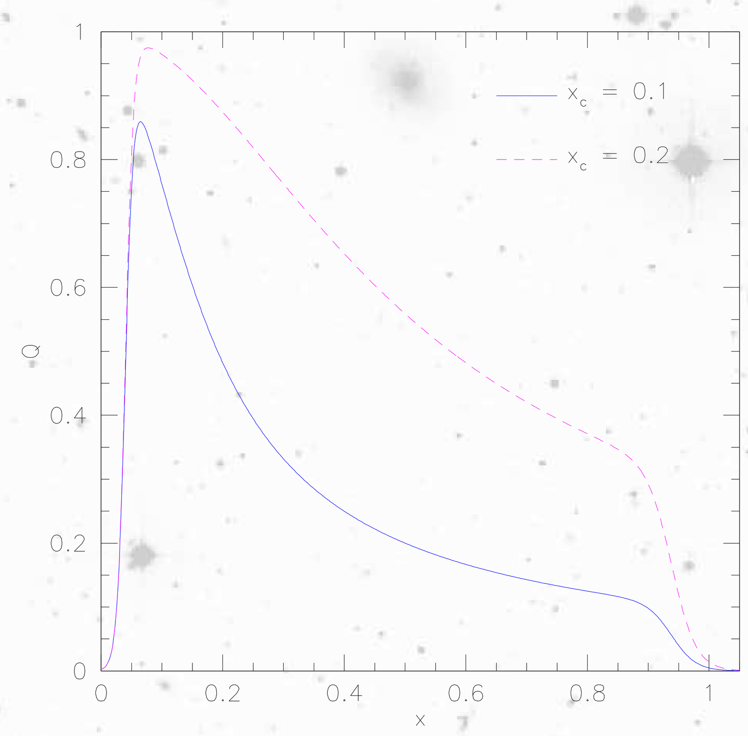

Figure 2. Example of the weight function $Q(x)$ we employed for two different values of the parameter x_c.

4. Cluster Candidates

Currently 3.25 sq. deg. are already observed; observations should be complete by the end of the year. A preliminary lensing analysis was started for some of the fields. The survey contains a few previously known clusters like MS 1054.3−0321, which is at a redshift $z = 0.83$. A lensing map of this field is shown in Fig. 3. MS 1054.3−0321 is detected at the 4.4σ level.

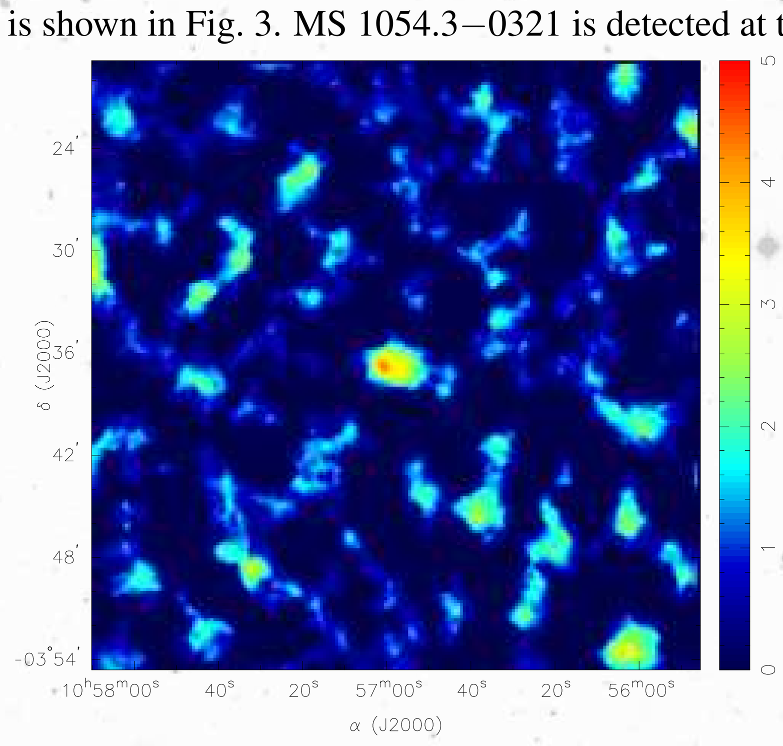

Figure 3. Significance map for the M_{ap} statistics. The cluster in the center, MS 1054.4-0321, is detected at the 4.4σ level. This is of course not a serendipitous detection as this cluster was the primary target of the XMM-Newton observations. It serves, however, to prove the method and that weak lensing observations can detect clusters at higher redshifts if they are massive enough.

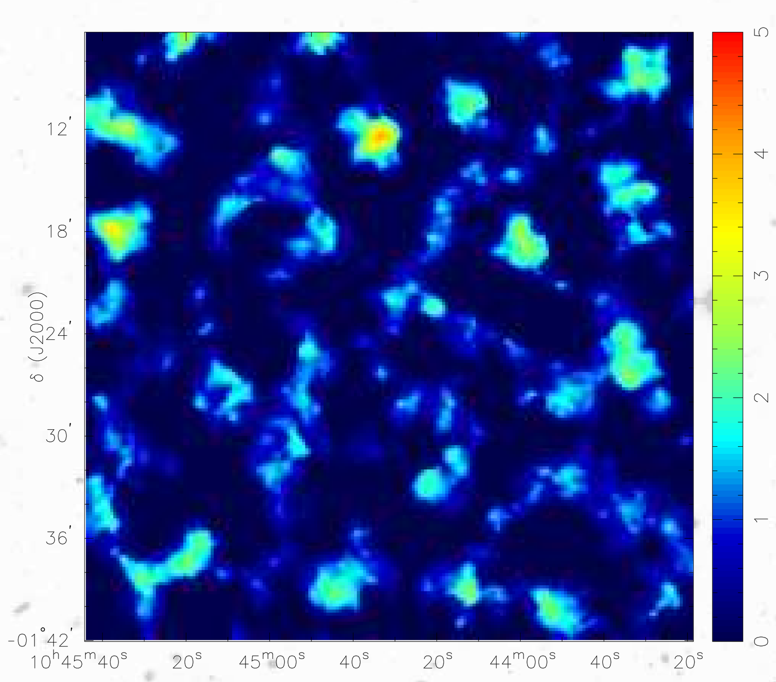

Figure 4. Significance map for the M_{ap} statistics in the field of the high redshift ($z = 5.74$) quasar SDSS J104433.04-012502.2. The WFI image of this field is the background of this poster. The 4σ peak in the North is a new candidate cluster.

Fig. 4 shows a M_{ap} significance map for the field around the quasar SDSS J104433.04-012502.2. A cluster candidate at the 4σ level associated with a small overdensity of galaxies is visible in the North of the field.
It is known that weak lensing searches for galaxy clusters produce a number of peaks which are caused by the superposition of large scale structures (e.g. Hamana et al. 2004; Hennawi & Spergel 2004). The reality of this cluster therefore needs to be confirmed by further observations.

5. The RX J0505.3−2849 Field

RX J0505.3−284 is cluster at redshift $z = 0.509$ detected in the Southern SHARC survey (Burke et al. 2003). Fig. 5 shows a weak lensing reconstruction, smoothed X-ray contours, and luminosity density distribution in this field.

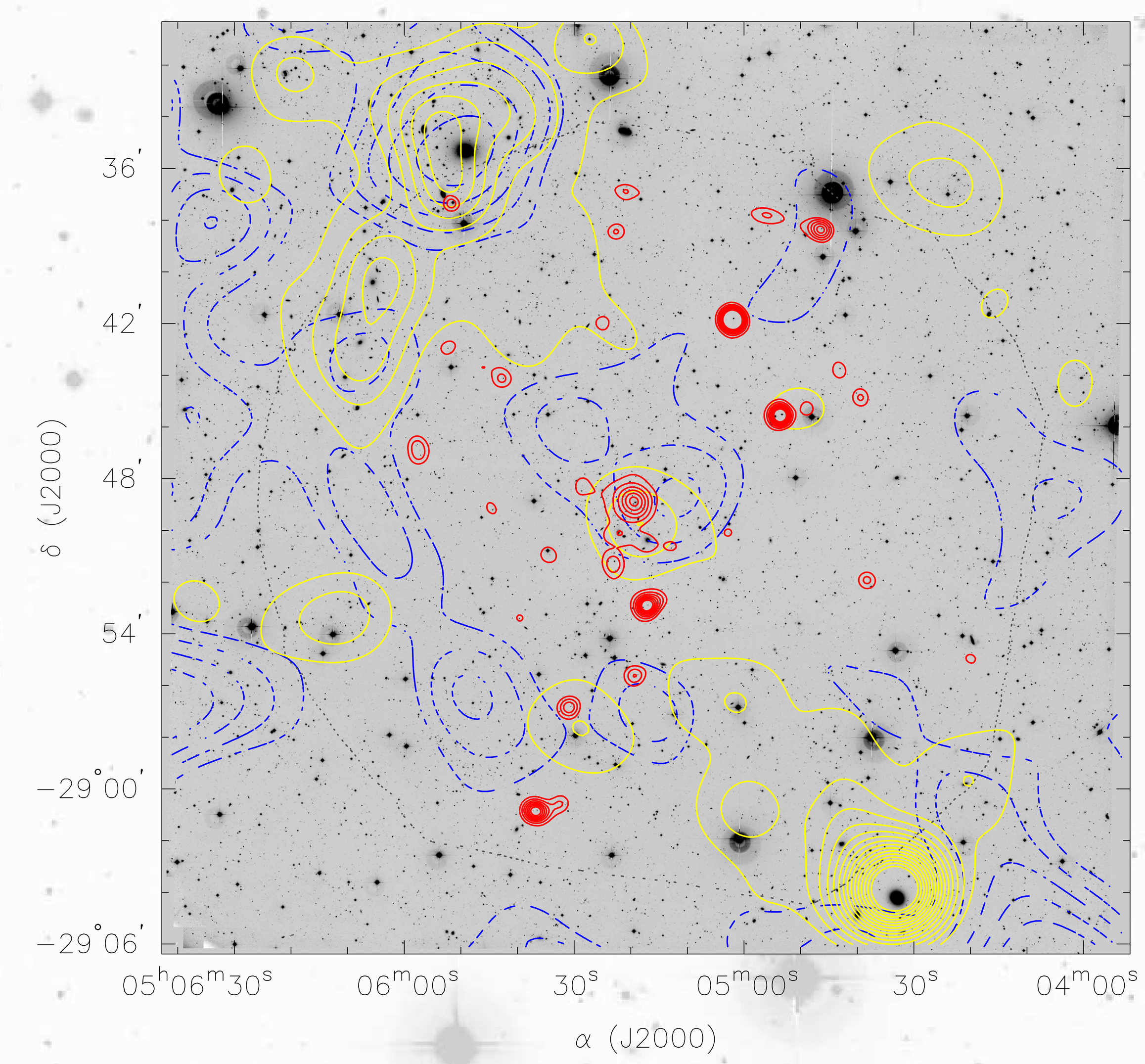

Figure 5. The RX J0505.3−2849 Field. The image in the background is our final WFI R-band image. The dashed blue lines are the mass reconstruction. Red contours are smoothed X-ray contours from XMM-Newton observations. The dotted gray line approximately marks the area covered by the X-ray image. Yellow lines are luminosity density contours of all galaxies in the field.

The known cluster in the center is marginally detected in the weak lensing reconstruction. Having the confirmation of the cluster detection from the X-ray data will allow us to dig deeper into the mass function than using the weak lensing method alone. The lensing reconstruction above is based on R-band data alone. Incorporating the redshift information available through the colors will allow us to boost the lensing signal and increase the number of significantly detected mass peaks (Hennawi & Spergel 2004). The mass and light peak seen in the top left corner is another new candidate cluster, unfortunately out of the FOV of the XMM-Newton exposure.

6. Acknowledgment

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