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ABELL 521: MULTIWAVELENGTH ANALYSIS OF A CURRENTLY FORMING CLUSTER

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We present new results of a combined optical /X-Ray analysis of the galaxy cluster Abell 521. New data both in X-Ray (Chandra observation) , and in optical (multi-object spectroscopy) are well explained by the scenario of Arnaud et.al (2000) which suggests A521 has endeavored two phases of merging and is currently forming at the crossing of two filaments.

1 Summary of previous work

Abell 521 is a very particular cluster, which has been the object of an intensive X-Ray/optical analysis, through imaging (ROSAT/HRI and CFHT, Arnaud et.al 2000) and multi-object spectroscopy (Maurogordato et.al 2000). The optical distribution has been shown to be very irregular and anisotropic. The main features evidenced are two "ridges" S1 and S2 intersecting in a cross-like structure. The ROSAT/HRI image shows an irregular structure with two X-Ray maxima distant of 2.2' (Fig.1, Arnaud et.al 2000). From the analysis of the X-Ray surface brightness profiles, it was shown that A521 is clearly made of two components, a Northern one with an X-Ray emission typical of a group, A521N, and a Southern one typical of a rich cluster, A521S (Arnaud et al. 2000). Several campaigns of multi-object spectroscopy have been performed (Maurogordato et.al 2000). It was there shown that Abell 521 is a moderately distant cluster, with location $C_{BI} = 74132^{+202}_{-250}$ km/s. Its very high velocity dispersion: $S_{BI} = 1380^{+206}_{-132}$ km/s, taken with its very irregular morphology suggests that this cluster is undergoing strong dynamical evolution. Comparing optical and X-Ray imaging, the galaxy distribution appears much more irregular than the gas one. There is no one-to-one coincidence between gas and galaxy high density regions. Several uncommon features are shown: there is no strong optical over density in the region of A521N as would be expected. The BCG galaxy is clearly angularly offset of both X-Ray maxima. Its velocity is however, within the errors, comparable to the mean velocity of the cluster. The BCG itself exhibits multiple nuclei, and a puzzling configuration of several knots superposed on a diffuse arc-like structure, probably resulting from previous collisions and interactions between the knots. However, strong alignments do exist along the two axes defined by the optical ridges: A521S with S1, and X_N/X_S with S2, and with the orientation of the BCG and of the brightest galaxies. Significant alignment of the bright galaxies of this cluster along preferential axes has been shown to exist (Plionis et al. 2000). The direction towards several clusters in the periphery of A521 seems too to follow these privileged axes.

These results have been interpreted at the light of some characteristic features of merging events in clusters well evidenced in numerical simulations. The fact that A521N is a clearly distinct in X-Ray, the shape of its X-Ray profile, and the clear alignment between the axis X_N/X_S, the BCG and the S2 ridge, strongly suggests that it is a group in a pre-merger phase along S2. The absence of velocity offset implies it occurs roughly in the plane of the sky. In this case, the X-Ray emission centered on X_N would be associated to a group of galaxies probably bound to the BCG, and angularly offset. There are multiple evidences that the BCG region is still undergoing interaction processes. The elongation of A521S along the ridge axis S1, the extremely large X-Ray core radius, the very high velocity dispersion within the ridge S1, suggest that it corresponds to the main cluster which has endeavored an older merger along the S1 direction. The previous alignments along the two privileged axes can be understood in the framework of formation of galaxy clusters at the crossing of large-scale galaxy filaments by infall of matter and successive merging of small-scale structures. However, puzzling questions are still open, in particular, why the emission of the X-Ray group, A521N is clearly offset from the BCG, and centered on a region nearly devoid of galaxies.

2 New results

2.1 Chandra observation

A521 has been observed with Chandra/ACIS-I in December 1999 for 40 ks. Fig.2 shows a superposition of the X-Ray isocontours computed from the Chandra image to the previous CFHT image. One finds again the double structure with two X-Ray maxima, but now the Northern maximum is perfectly centered on the BCG. Thanks to the high spatial resolution of Chandra, another peak of X-Ray emission appears at the Northern side of A521N. This emission, taken together with the emission of the BCG, was responsible in the lower resolution map provided by ROSAT/HRI, of the *apparent* offset of A521N. The hardness ratio map (Fig.3a) shows that there is a cool component centered on the BCG galaxy. There might be too a hot spot lagging behind the BCG.

2.2 Velocity distribution

New data have been obtained at ESO on the 3.6m telescope with EFOSC2, in October 1999. Combining them to the first campaign, we obtain 85 galaxies (towards 44 in Maurogordato et.al 2000) in the range 70000-80000 km/s, suspected to be cluster members. The new values of location and velocity dispersion calculated with the ROSTAT package are $C_{BI} = 74028^{+248}_{-124}$ km/s, and $S_{BI} = 1161^{+132}_{-125}$ km/s. The velocity dispersion stabilize to a slightly lower value than in Maurogordato et.al 2000, but remains substantially high. This confirm that A521 is clearly undergoing strong dynamical evolution. Thanks to the largest number of velocities, we have re-analyzed the velocity distribution in particular regions of interest, mainly X-Ray or optical over densities. The velocity distribution within the optical ridge S1 is particularly interesting. We confirm a very high value for the velocity dispersion $S_{BI} = 1820^{+285}_{-163}$ km/s (25 objects). It does not result from a superposition of several clumps at different mean velocities, as the high and low velocity objects are distributed all over the ridge. This large velocity dispersion could be the remnant of the older process of merging along S1, and would imply for the merging axis

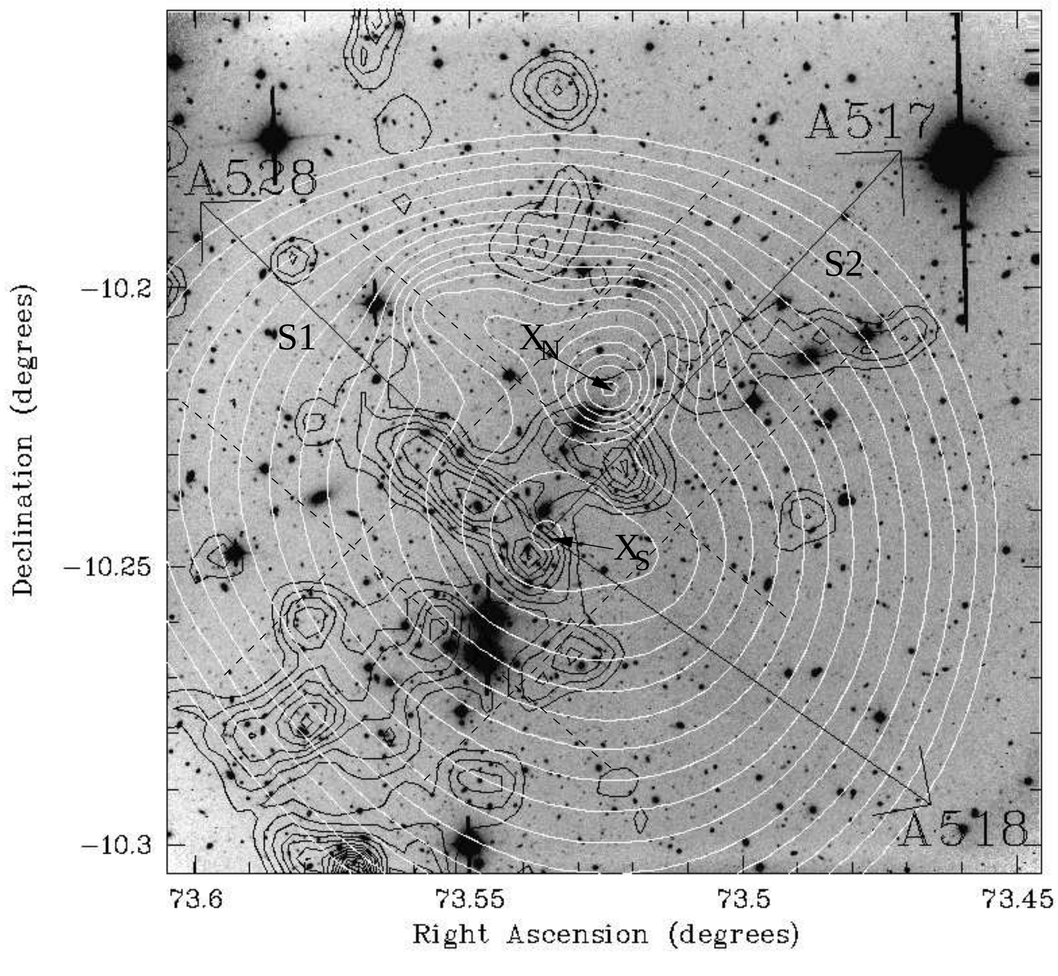

Figure 1: Galaxy iso-density contours up to $V < 23$ (black) and ROSAT-HRI isocontours (white) are superimposed to the MOS optical image in V-band obtained at CFHT. For the galaxy isodensity map, the lowest contour corresponds to 1σ level above the mean density in the field, the contours are spaced by 0.5σ. The X-Ray isocontours of the cluster are logarithmically spaced by 0.15 digits, the lowest contour corresponds to 2.2 10^{-2} ct/pixel. The direction towards the clusters A517, A528 and A518 are also indicated (from Arnaud et.al 2000)

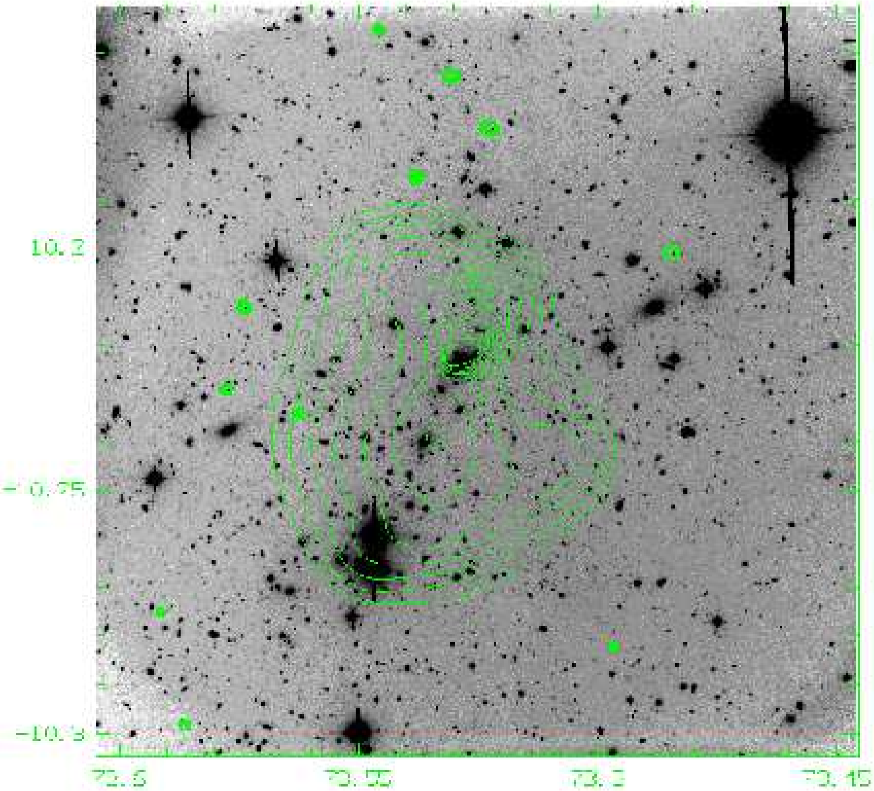

Figure 2: X-Ray isodensity contours from the Chandra image superimposed to the CFHT V-band image

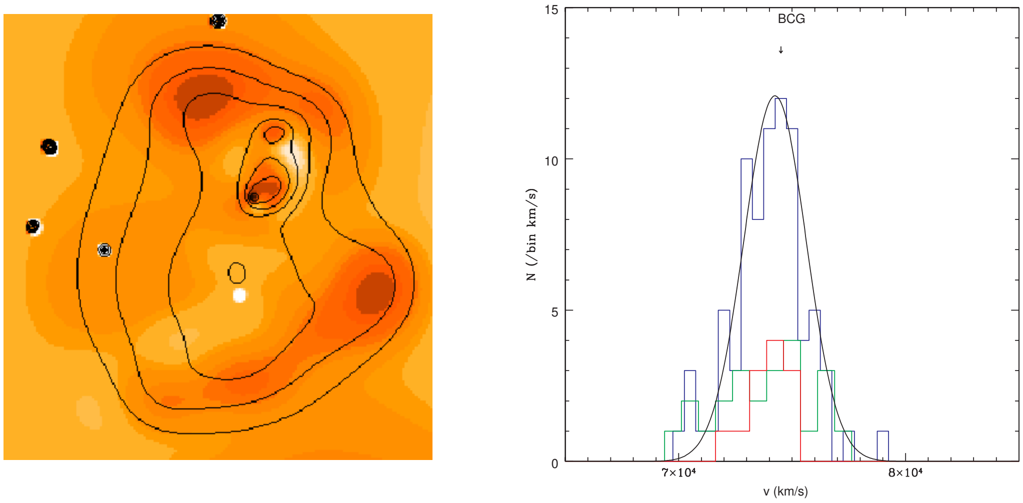

Figure 3: Left (3a): Hardness ratio map from Chandra in the cluster central region defined as the flux ratio between 0.5-2 keV and 2-10 keV. Images in both bands have been first reconstructed by the wavelet technique. White corresponds to hot regions, whence black to cool ones. Isodensity contours in the soft band are shown. Right(3b): Histogram of the velocity distribution within the cluster, respectively in blue (whole cluster: 85 objects), green (ridge S1: 25 objects), and red (group around the BCG: 12 objects). A larger binning (750 km/s) in velocity has been used for the ridge S1 and for the BCG group, instead of 500 km/s in the case of the whole cluster. Note the lower velocity dispersion of the BCG group and the large spread in velocity of S1

a non negligible component parallel to the line of sight.

At variance, the region around the BCG galaxy (12 objects) is composed essentially of galaxies of velocities comparable to that of the BCG, with a location of $C_{mean} = 74247^{+116}_{-225}$ km/s . Its velocity dispersion $\sigma = 521^{+109}_{-109}$ km/s is well compatible with that of a group. The histograms of the velocity distribution of the whole cluster, within the ridge and in the region of the X-Ray group A521N, are shown in Fig.3b.

3 Conclusion

The analysis of these new data confirms that A521 is a cluster in a very particular dynamical state. It might be a very young cluster still forming at the intersection of two filaments. The high resolution of Chandra has allowed to show that there is no offset of the BCG towards the center of the X-Ray Northern emission A521N, as suggested by ROSAT/HRI imaging. The velocity distribution in this region agrees well with that of a group. Taken together with the respective mean velocities, this supports the scenario of a group infalling on the main cluster in the plane of the sky as suggested by Arnaud et.al 2000.

Observations are on-going on this cluster, including a full velocity mapping up to $m_V = 21.5$ in order to test the dynamics of the high density X-Ray and optical regions, and wide-field imaging to investigate the large scale environment of the cluster and its connection with the central filamentary structure.

4 References

Arnaud, M., Maurogordato, S., Slezak, E., Rho, J.,2000,A&A, 355, 461

Maurogordato, S., Proust, D., Beers, T.C., Arnaud, M., Pello, R., Cappi, A., Slezak, E., Kriessler, J.R., 2000, A&A, 355, 848

Plionis,M., et al.,2000, in preparation