DIFFUSE X-RAY EMISSION FROM ABELL CLUSTERS

Dr. Melvin Ulmer
Northwestern University

Thank you. I must say it is my first visit to Huntsville after nearly 13 years of X-ray astronomy. I may have set a record for not coming here and I really appreciate the opportunity to take part in the guest observer program. It has given me an opportunity to continue in X-ray astronomy without having my own multimillion dollar satellite program. What I am going to talk about today are basically the Abell clusters of galaxies: Abell 401 and Abell 399. I will then talk about the follow-up work that can be related to the study of these objects.

Figure 1 is the map of the Abell 401, Abell 399 region. We actually had two sets of observations: one was the lunar occultation pointed observation in which we had two orbits in which to look at this region while the moon scanned over it and the other was a scanning observation through the area. The disc shows the size of the moon, the sloping line shows the apparent path of the moon in front of the region for the second set of data and the horizontal line shows the path of the moon for the first orbit. For reference this (dot, $\alpha \sim 44.0$, $\delta \sim 13.4$) is the optical center determined by Neta Bahcall. This (open dot, $\alpha \sim 44.0$, $\delta \sim 13.47$) is the cD galaxy which Abell had originally assigned as the optical center and this position down here is the optical center of Abell 399 as determined by the cD galaxy which is there also.

Figure 2 shows the data from the satellite. The background has been subtracted and the aspect corrected by determining the position which also minimizes χ^2. The solid lines show the best fit to a single diffuse model for the X-ray emission, the upper curve shows the apparent distance of the moon from the center of the emission region, so you can see in the first path (a), the moon was actually moving away from the center of the emission region, and in the next portion (b) it was coming down to the center of the emission region and then starting to move away.

We actually had more data but these were the data that we felt had the least contamination, the least problems with variation of the background. We varied the length of the data we selected and put in all kinds of fancy models for the background, and showed that the X-ray emission was insensitive to any kind of arbitrary variation so I am fairly confident of these results. In the lower portion of the figure (c), we show the scanning data. You can see indeed there is a signal. This is the center of the emission region which does come out in between Abell 401 and Abell 399.

Refer again to Figure 1. Here is the position that we determine from the lunar occultation data (solid elipse), this position (lower left rectangle) is determined from the scanning data, 4U error box here and the Ariel 5 error box. Taking both of these, I do not know how democratic you want to be but anyway by taking a weighted vote if you will, I like to think the center of the emission region is somewhere in here (α = 43.95, δ = 13.15). Notice it seems to be fairly well centered in between Abell 401 and Abell 399. Now as far as the models go for the emission, there are 2 basic kinds of models that work; one is a large diffuse emission region that covers both of these (one uniform disc), and the other is a double source model, a diffuse model in which one diffuse component is here and maybe another down here is equally as good as a diffuse model plus a point source somewhere else in the field. However, a 2 point source model does not fit the data well at all. We showed this by determining the lower limits to the size of the diffuse emitting region around here at 10 min of arc even assuming a point source somewhere else in the field of arbitrary strength and position.

Refer to Figure 3. At the bottom is Abell 399. There is a cD galaxy there. At the top is Abell 401, and its cD galaxy. The white circles demonstrate the two most interesting choices that were interpretations of our data: a huge diffuse gas cloud centered on here; or two separate gas clouds. Either of these interpretations will suggest that perhaps clusters like to form binary systems, if you will, just as stars like to form binary systems in our galaxy. I do not know whether that kind of formation law scales up; I'll leave that to theoreticians. But I believe that is an interesting suggestion. Now if you take the large single gas model, it is possible assuming it to be fairly diffuse and not too clumped to get quite a large amount of gas, in fact, 10^{15} - 10^{16} solar masses depending on how far out you want to run your model. Now if that interpretation is correct and if such phenomena are common, it opens up the possibility that we can close the universe, which is always nice to do because we do not want our errors to propagate forever. I do not know whether it is really opened or closed, but in any event, it is certainly an exciting interpretation of the results. Now we also did a survey of clusters of galaxies that Kent Wood alluded to this morning and in that survey of some 70 clusters of galaxies we found 2 in which there is certainly evidence for extended emission (see Figure 4). This is the point source response and the diffuse source response. You see the point source just does not work well at all. These are distance class 6 clusters and if indeed they are at the distance implied by that inferred red shift (to my knowledge there's no real measurement of the red shift of these clusters), then the linear extent of these things is even larger than the Abell 401, Abell 399 region. This one corresponds to about 10 Mpc and this about 5 in radius. So they are pretty large regions. I must admit they are awfully weak, which introduces the possibility of source confusion, which is why I used the words "evidence for" even though the data looked okay. In this survey, we also found

3 binary cluster systems, in which at least one member was an X-ray source. They are Abell 508, 509, 2177, 2178, 2204, and 2210. In conclusion then these binary cluster systems and/or large extended regions seem fairly common and I believe these kinds of studies (we've only looked at 1/9 the sky so far) should lead to much better understanding or a better model for the formation and evolution of clusters of galaxies and at most they will even be able to close the universe.

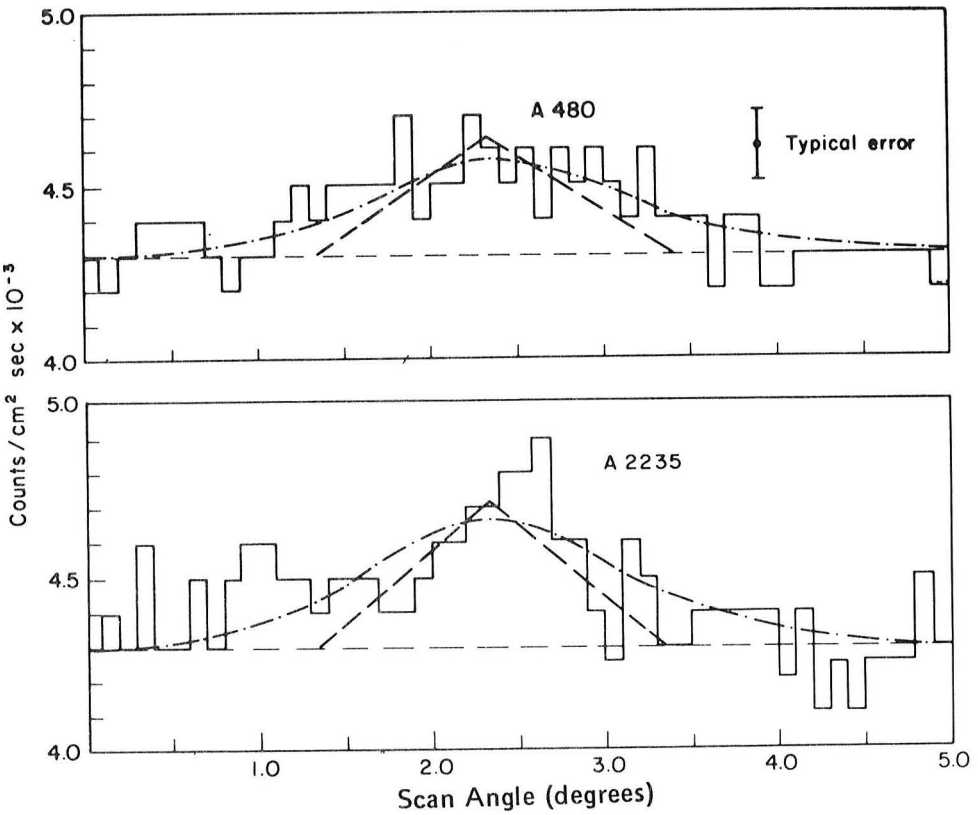

Figure 1

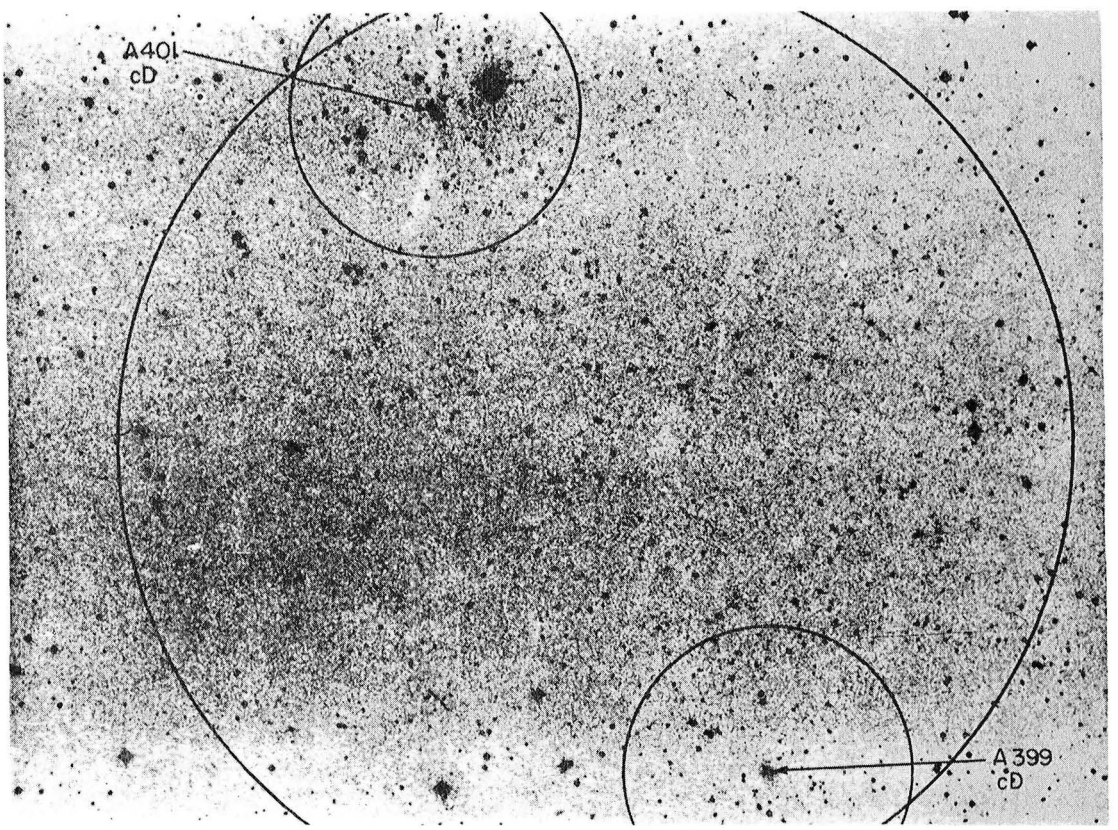

Figure 2

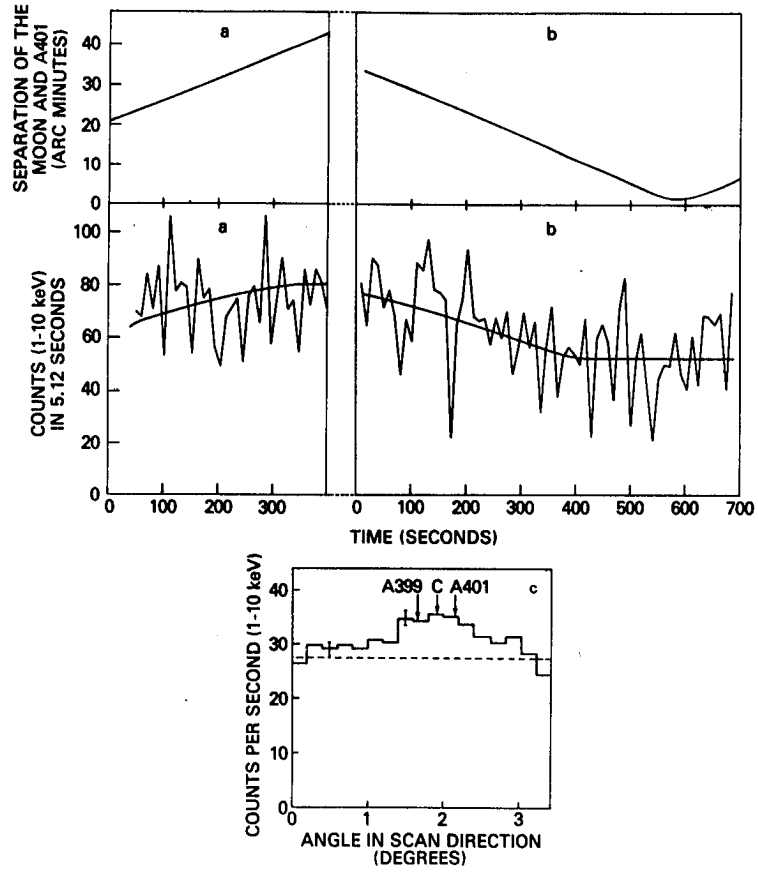

Figure 3

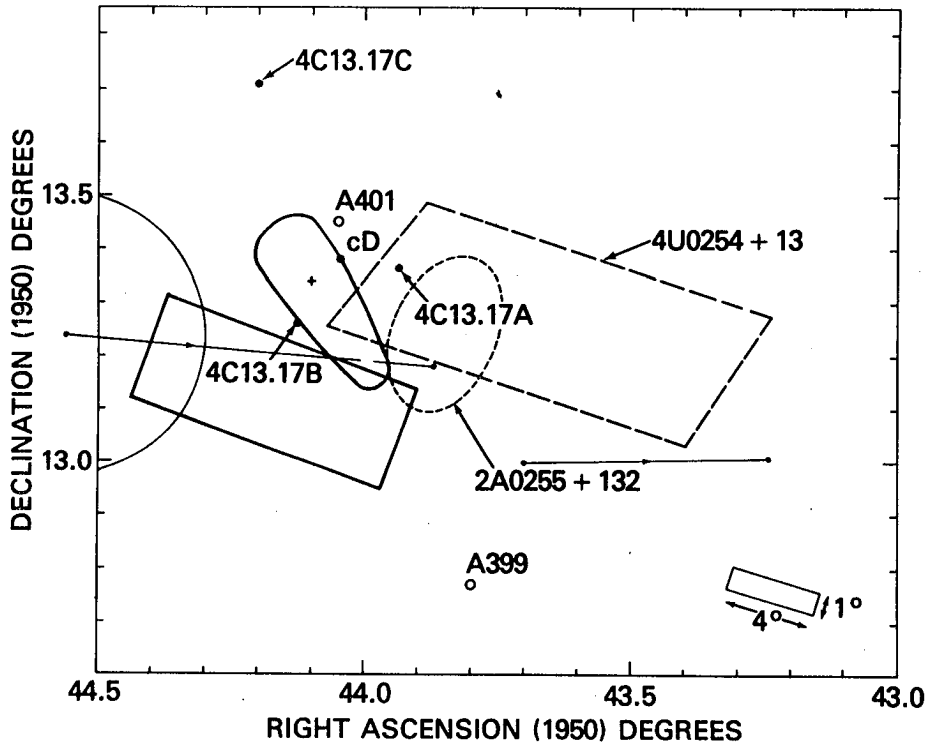

Figure 4