

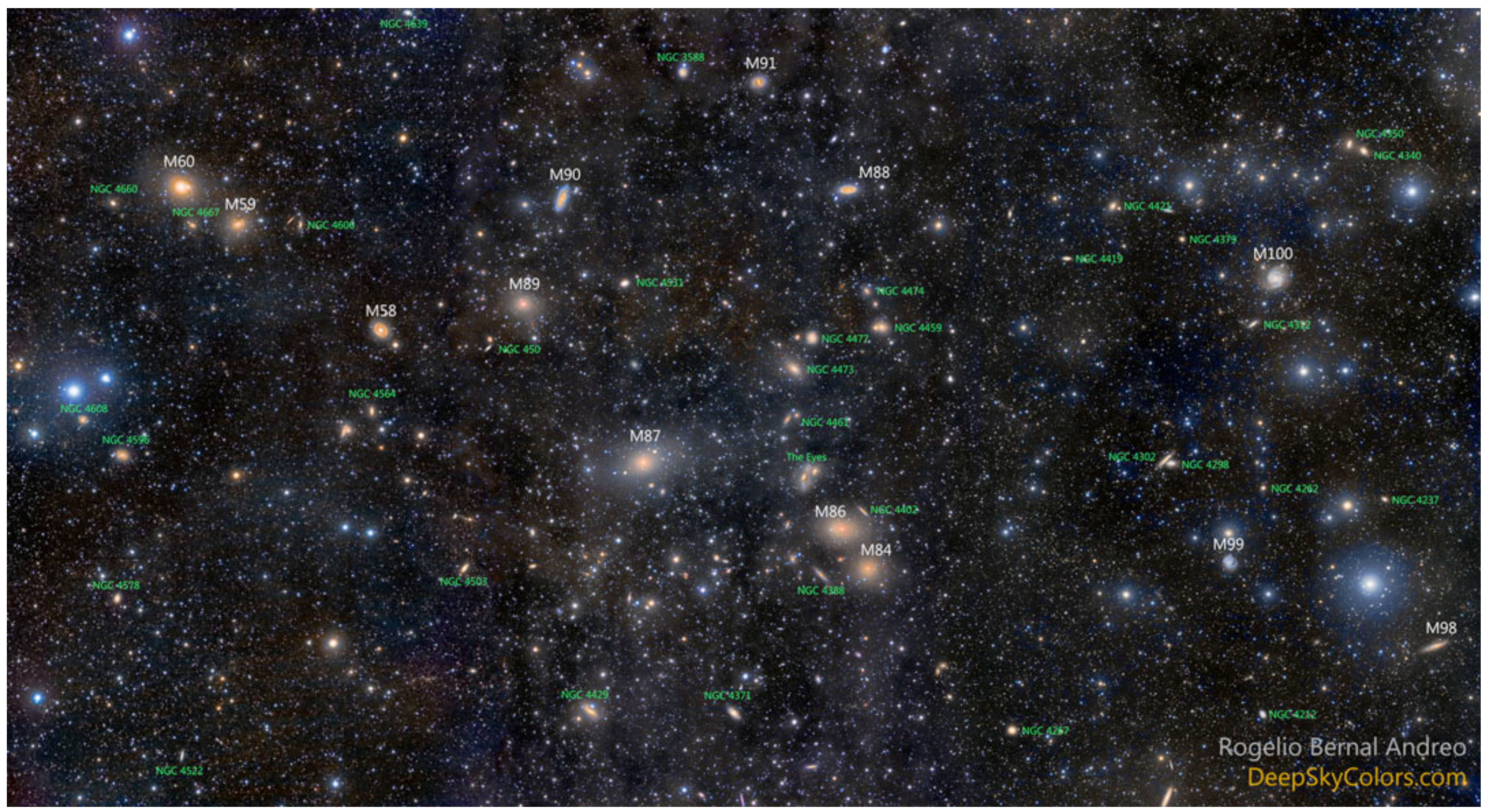
Virgo Intergalactic Globulars

from the
Sloan Survey

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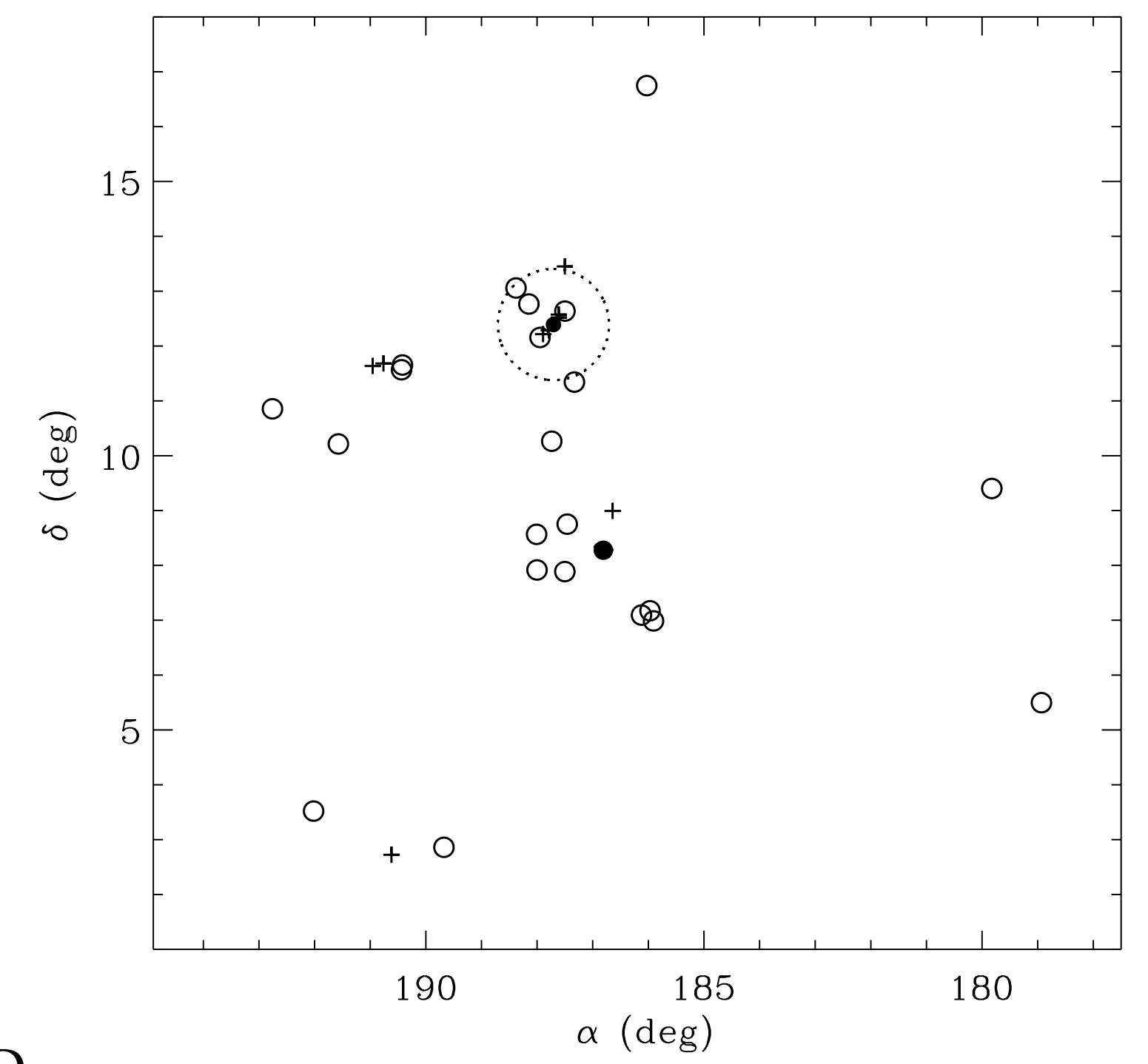
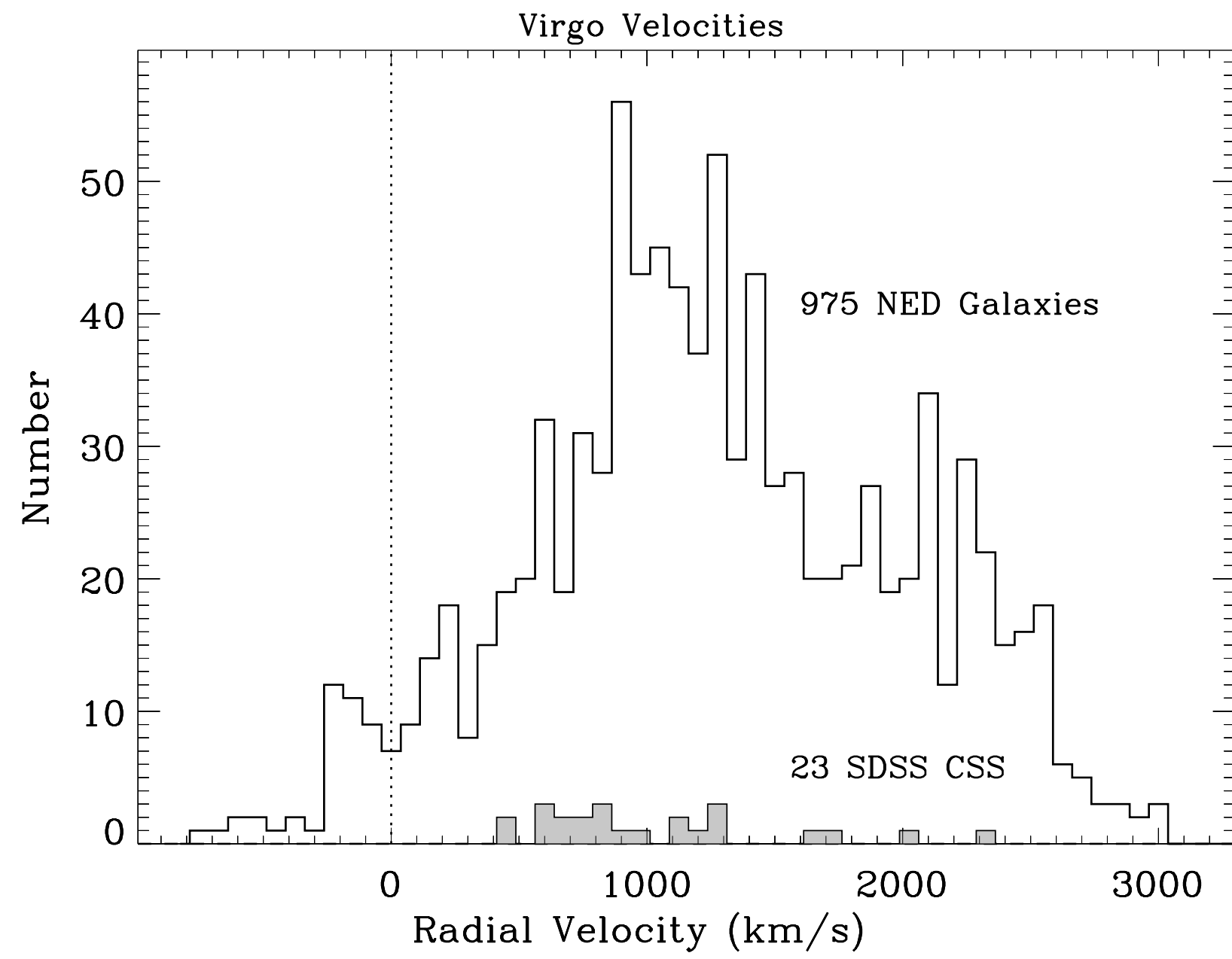
Wide field image of the Virgo Cluster (from APOD)



Introduction

The existence of large numbers of intergalactic globular clusters and ultra-compact dwarfs in rich environments offers a new window into the history of clusters of galaxies. UCDs and the brightest IGCs may be the remnant nuclei of larger, now tidally stripped, objects. The ages, abundances, luminosities, and stellar populations of these compact stellar systems provide constraints on the original galaxies in dense environs where clusters of galaxies arose, with the potential to reveal the extent and history of galaxy interactions, mergers, and destruction in building cD galaxies as well as the intracluster population which can account for 20-40% of a cluster's total light.

We have identified a sample of Virgo CSSs from DR12 SDSS spectra of point sources with $500 < v < 3000$ km/s. Removing previously known objects and those in the halos of bright galaxies leaves 23 new, intergalactic CSSs, spread over an area with a 10 degree radius from the center of Virgo. There are a further ~25 objects with less secure redshifts, at least some of which will turn out to be Virgo CSSs. We are pursuing higher S/N spectra to better characterize this wide field Virgo sample of intergalactic CSS. The serendipitous nature of this sample implies a much larger population of CSS awaiting discovery across the wider Virgo cluster.



Left: Velocity distribution of the 23 SDSS CSS (shaded) compared to 975 Virgo members from NED.

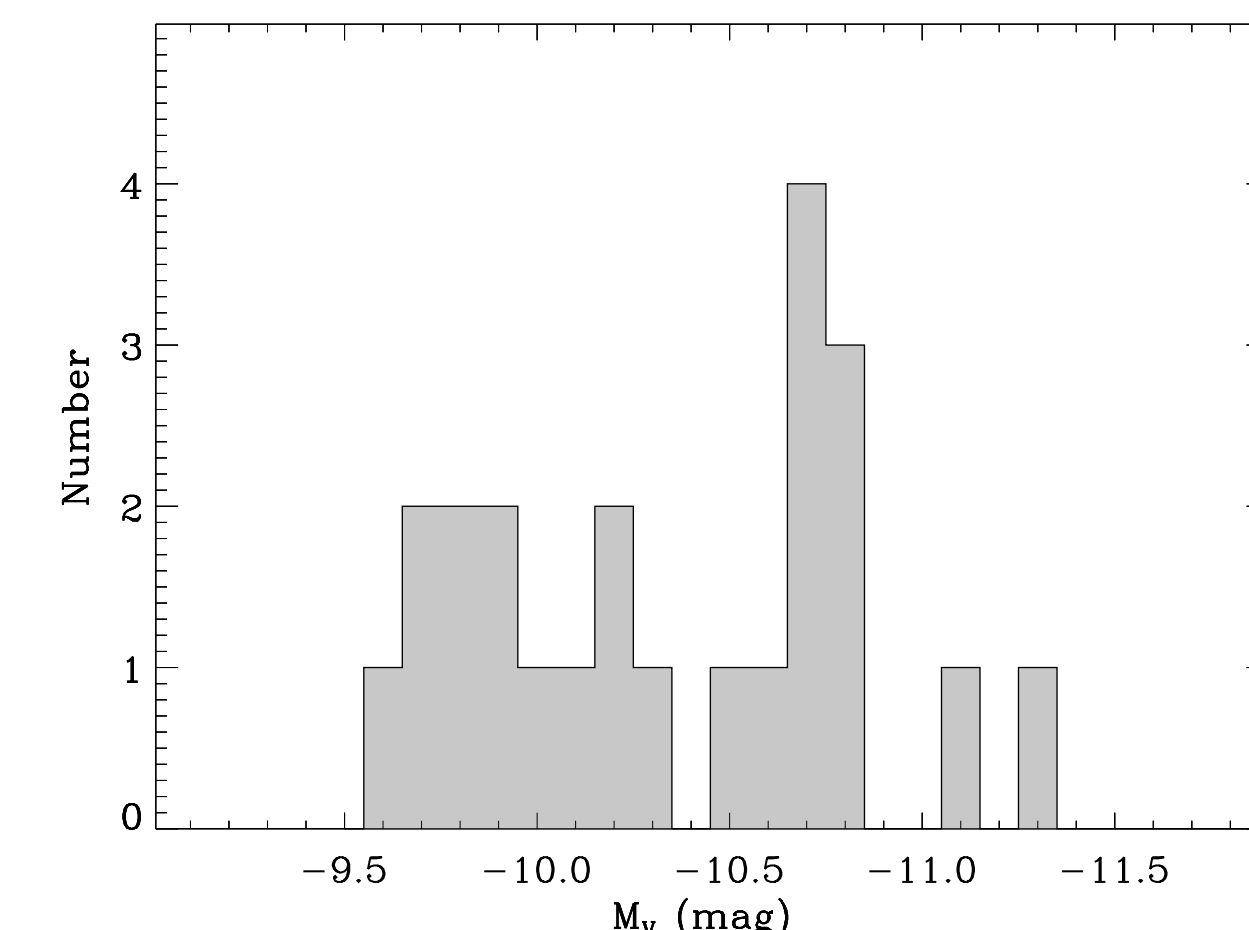
Right: Locations of the 23 new SDSS CSS on the sky in Virgo (open circles), and positions of the few previously known objects (+). The locations of M87 and NGC4472 are shown as black dots; the area most explored with 2dF/AAOmega is indicated with a dashed circle. These new objects extend the known CSS in Virgo over a much wider area.



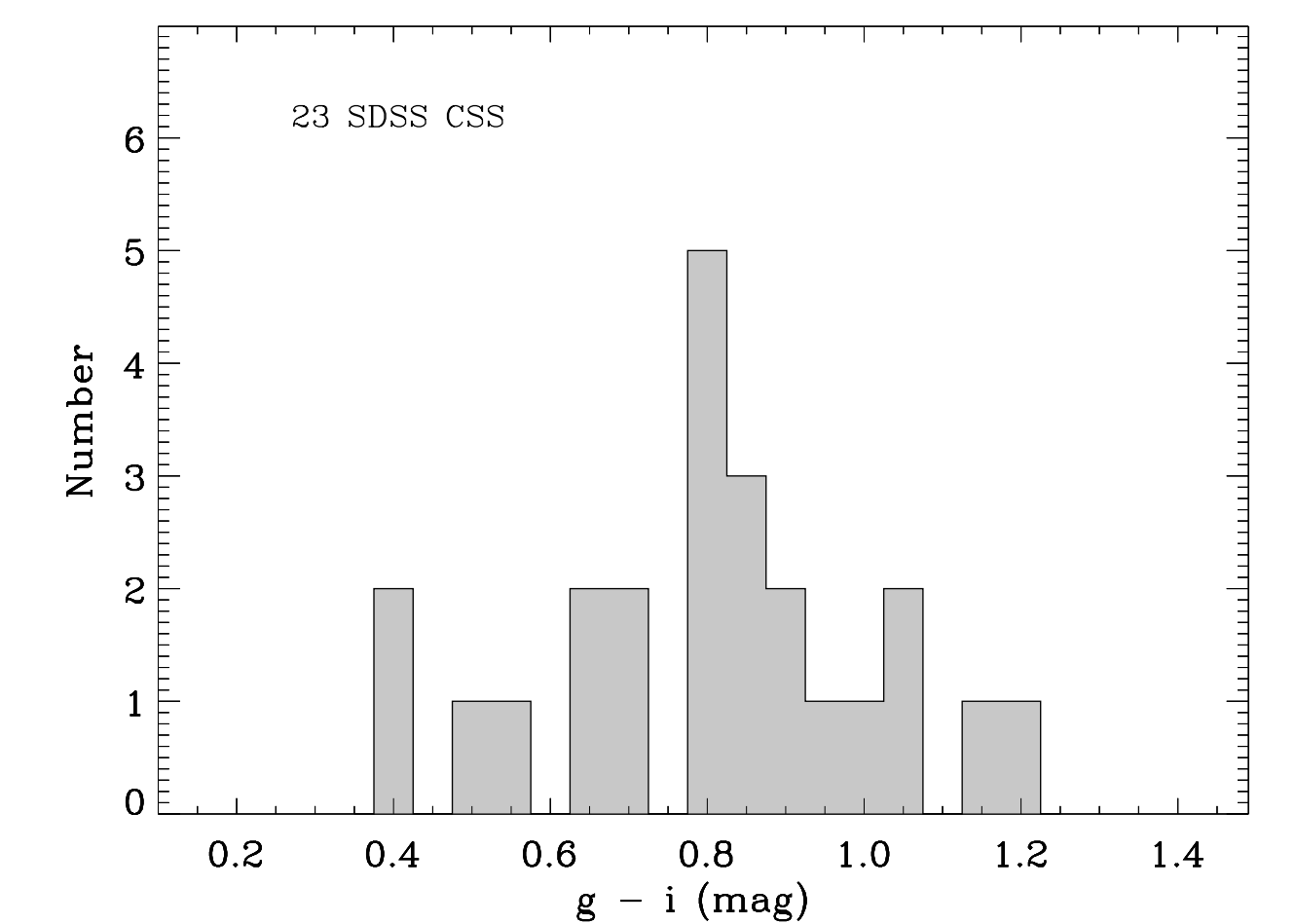
Above: SDSS postage stamps (25'') of some of the new CSS, showing that they are point sources.



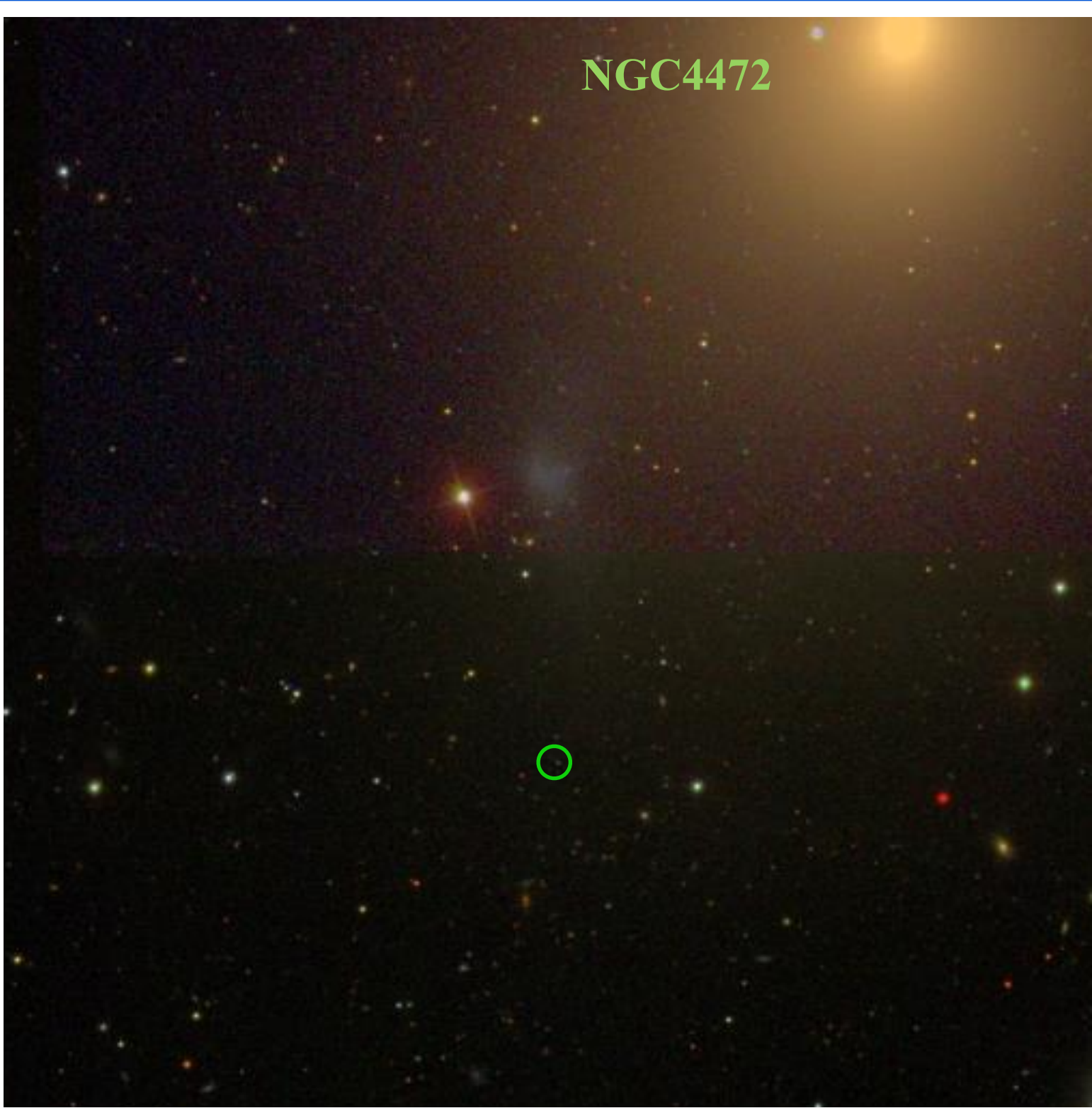
Right: Wider field views of the new CSS, about 100 kpc square at the distance of Virgo. Most of the objects are isolated and truly intergalactic. The ones near bright objects are far enough away to be subject to escape easily from their hosts in the cluster environment.



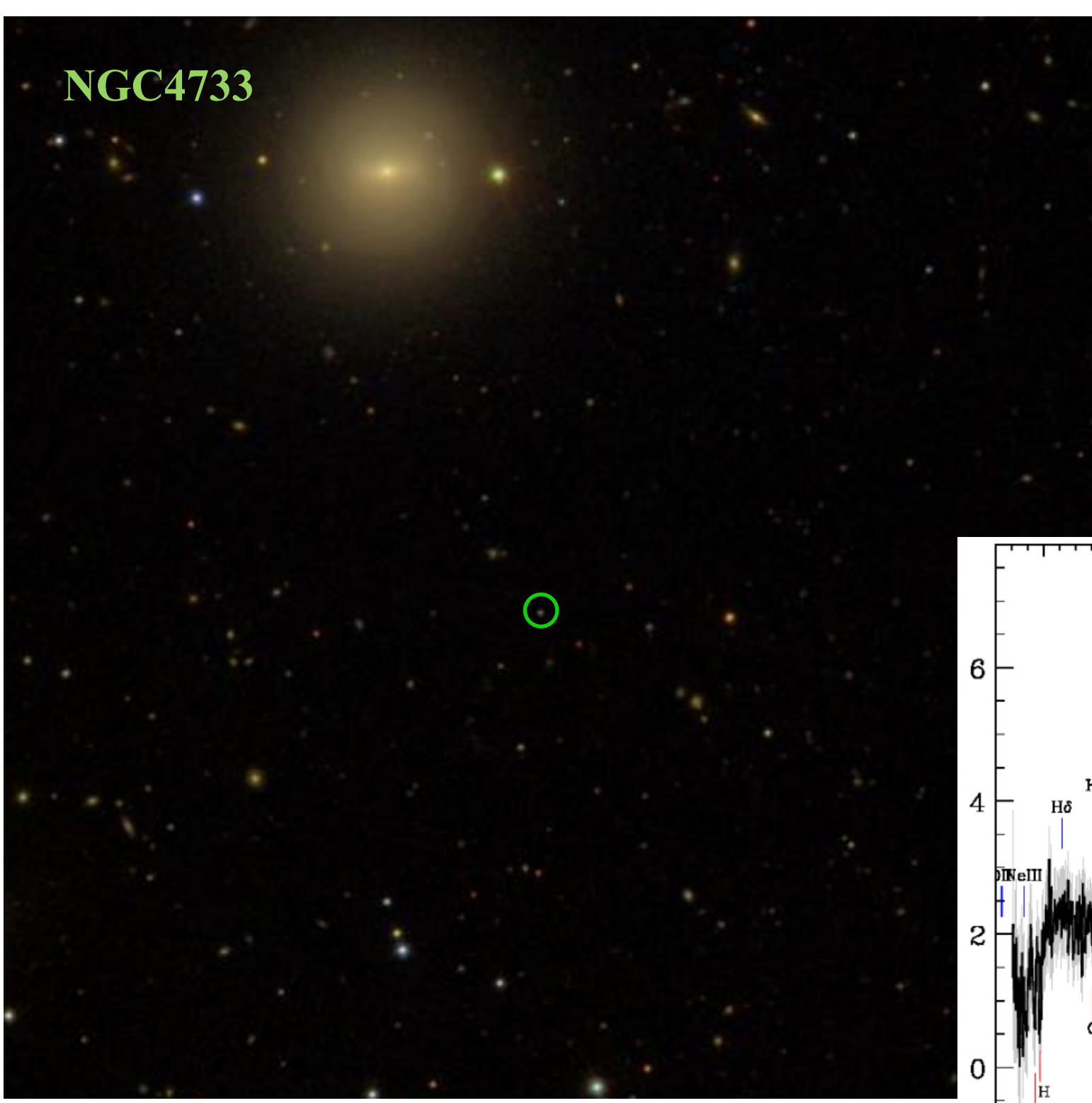
Left: histogram of absolute V magnitudes of the 23 objects in the SDSS sample. These are similar in luminosity to Omega Cen and are typical of UCDs in the Virgo and Fornax clusters.



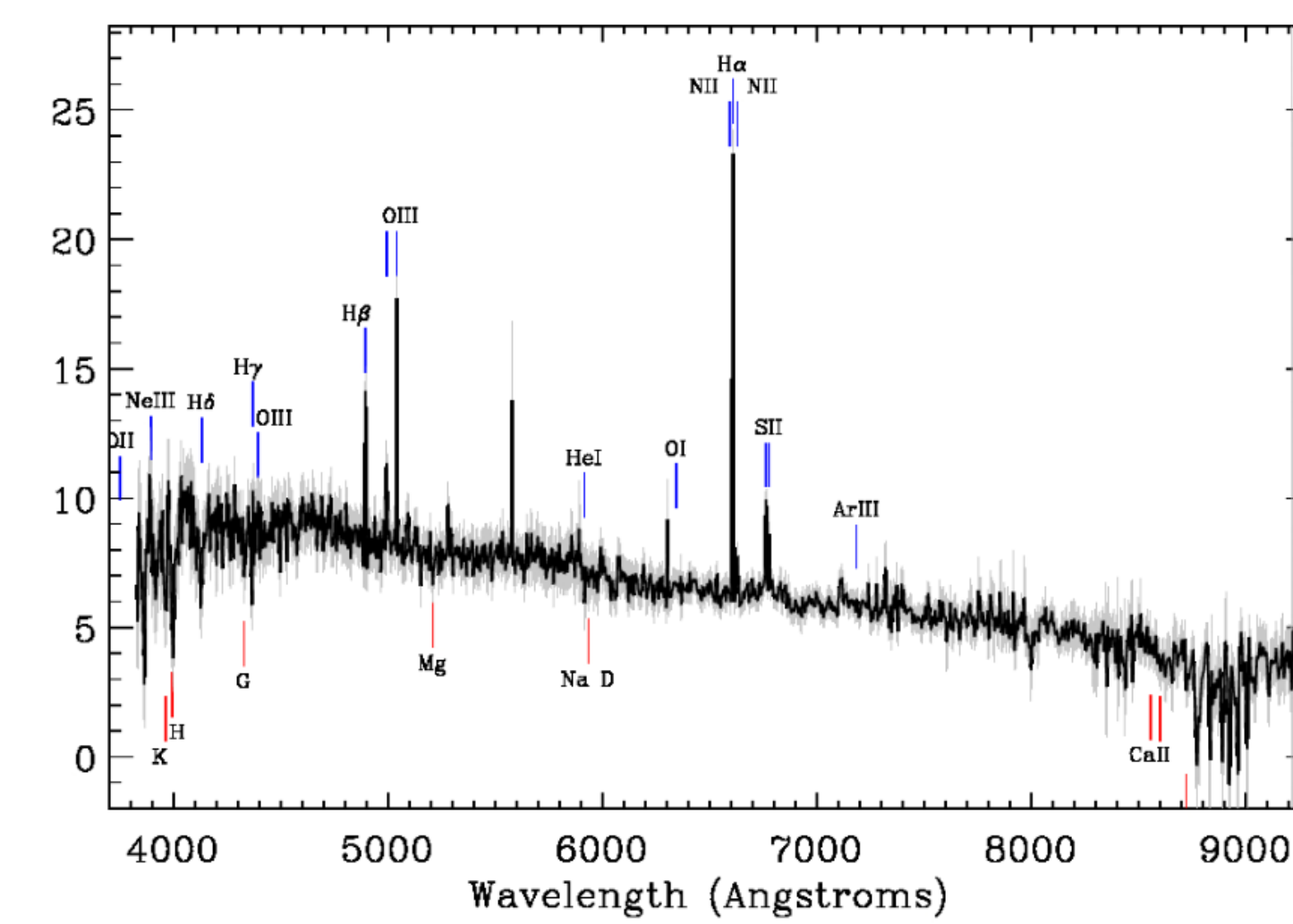
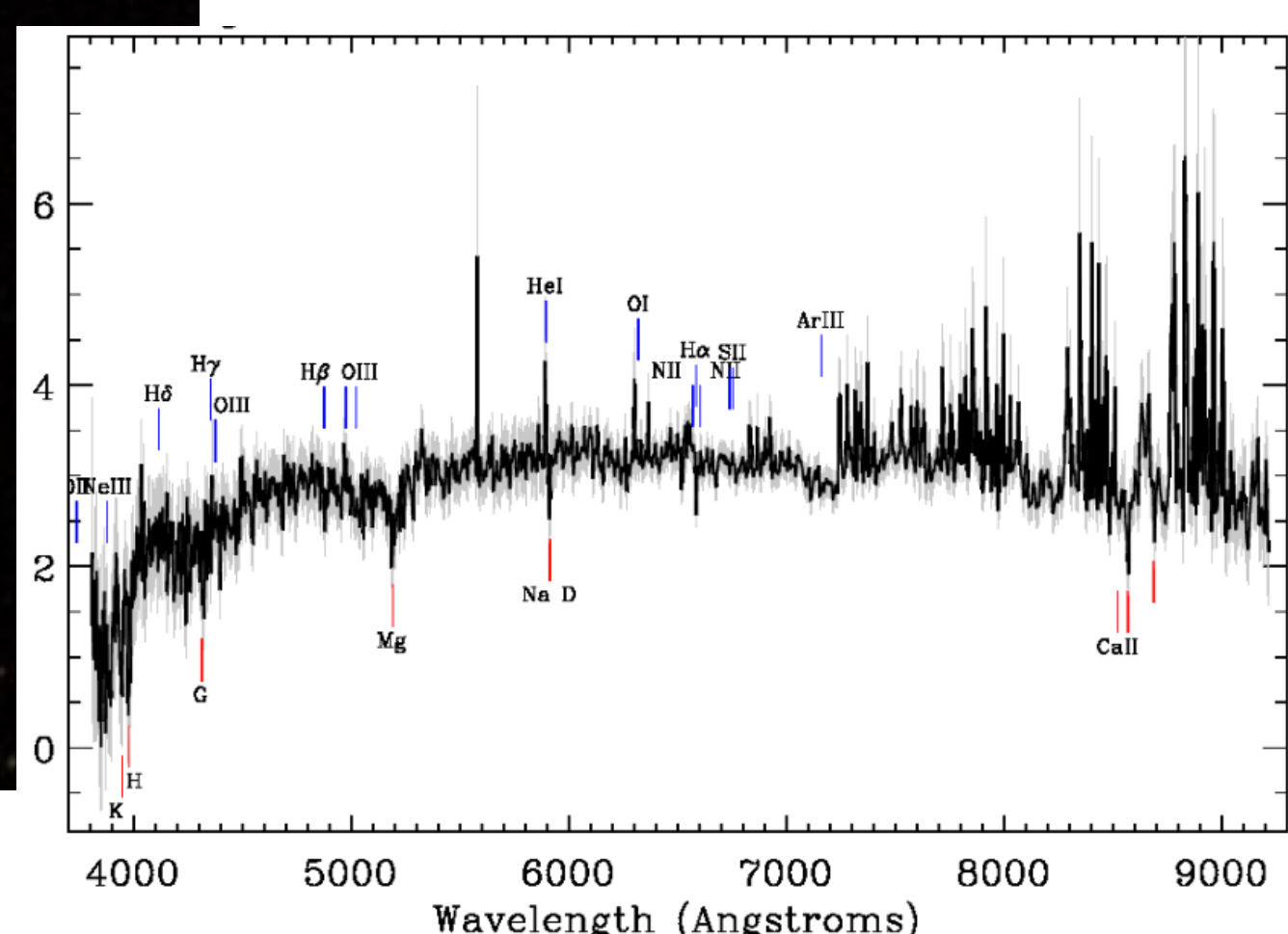
Right: histogram of SDSS colors of the 23 objects. Statistics are too poor to see if these objects have a bimodal distribution, or if they differ significantly from the larger population of objects known around M87 (Jones et al. 2006; Firth et al. 2008; Hasegan et al. 2005; Powalka et al. 2016).



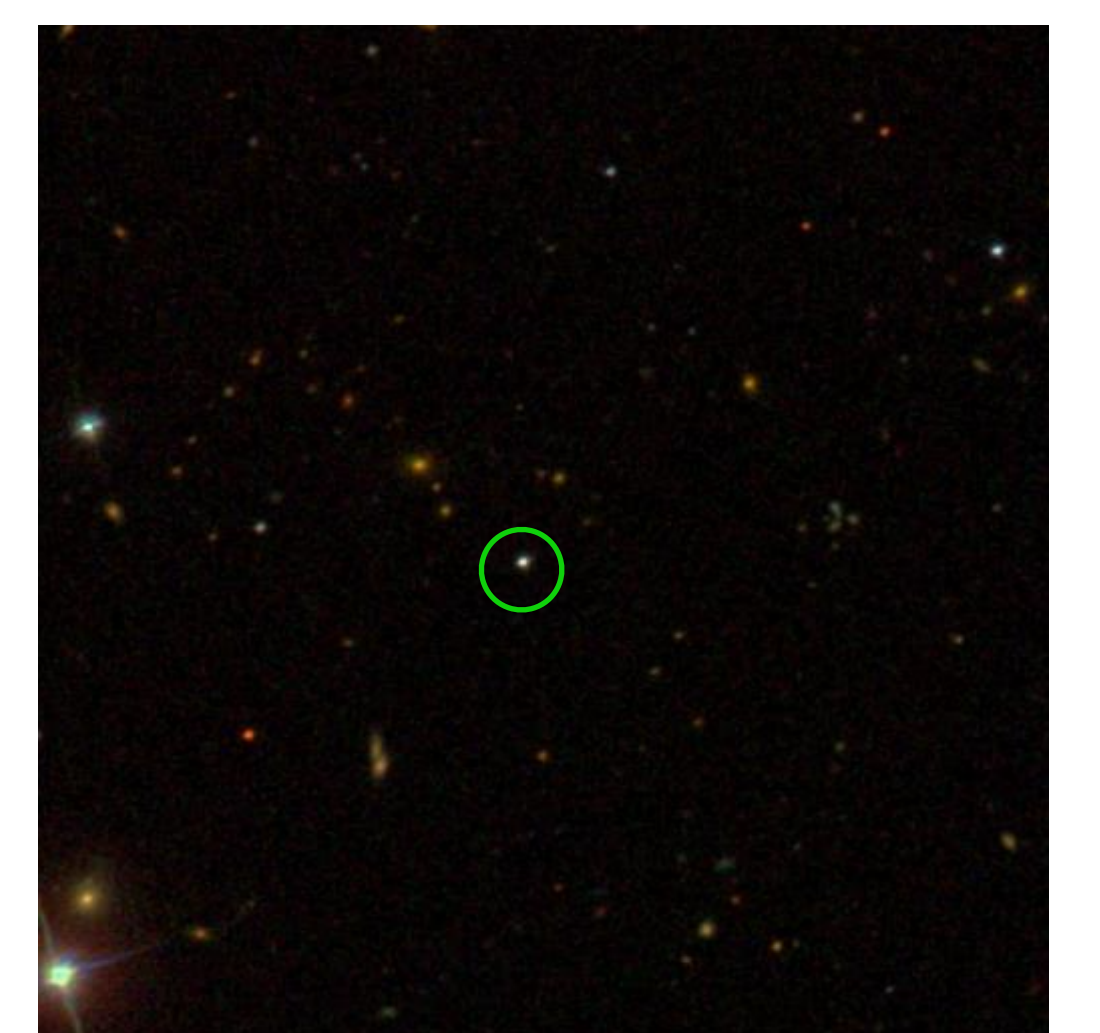
A handful of the new CSSs are near bright galaxies, such as this one near NGC4472 (=M49, the brightest galaxy in Virgo). We have retained them in our list for various reasons; this CSS (in the green circle) is rather blue, $g-i=0.7$, and may be associated with the dwarf galaxy (VCC1249, red arrow) at the same velocity, now undergoing tidal disruption and merger with NGC4472 (Battaia et al. 2012).



This CSS is in the very outer halo of NGC4733, ~18-20 kpc away, projected distance. This object is interesting because of its very high Mg absorption, indicating a high abundance, plus it is well out on the eastern edge of Virgo.



The prevailing view is that CSSs are early type populations, formed from stripping of dE and small galaxies in the early days of cluster formation. Yet there are some objects which suggest that at least some CSS may form ab initio. This unresolved SDSS object (not one of our 23) has emission lines and relatively blue continuum ($g-i = 0.7$), indicative of a burst of star formation. Now on the very northern outskirts of Virgo, it is perhaps infalling for the first time, and is 2-3 magnitudes brighter than the typical UCD, $M_v \sim -13.5$. As this object ages over the next several Gyr, it will fade and join the general population of Virgo intergalactic CSS.



Summary

Using SDSS DR12 spectra, we have documented a population of at least 23 new intergalactic compact stellar systems in the Virgo cluster. These objects have luminosities typical of ultra compact dwarfs and the brightest globular clusters. These objects are distributed over a very large area, out to the farthest reaches of the Virgo cluster, and their serendipitous discovery implies a much larger population waiting to be unearthed. These 23 appear to have a wide range of line strength and color. It is an open question whether these CSS are part of the same large population around M87 or are perhaps have a distinct origin. Higher S/N spectra of these far-flung objects can characterize their stellar populations in more detail, and perhaps offer clues to their origin and evolution, and comparison with the central CSS population may provide insight into the formation and evolution of the sprawling Virgo cluster.

