

Color-Magnitude and Luminosity Function in Galaxy Clusters



Physics

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ABSTRACT

We present a study of the color-magnitude diagram of H_I Parks All Sky Survey HIPASS of faint H_I selected galaxies contain faint gas-rich, and a scatter plot of HIPASS of faint galaxies. The HIPASS of faint galaxies that contains gas fraction at absolute V-band magnitudes is shown. Also the surface brightness of HIPASS of faint galaxies brighter than $M_v = -12.55$ and the scale length which determine the morphological structure of galaxies are shown. Some of the galaxy clusters detected at $15\mu\text{m}$, and some others detected at $6.75\mu\text{m}$ which are brighter and more luminous. The size of the galaxy clusters depends on the energy radiated by the galaxies detected at $15\mu\text{m}$ and the energy radiated by the galaxies detected at $6.75\mu\text{m}$, and some of the clusters are active to star formation.

The luminosity function of the clusters is proved to be old, more luminous and have the reddest galaxies. The color distribution of the clusters are shown which contain larger number of galaxies at $b-v=0.4$ and $r-i=0.6$.

INTRODUCTION

The color-magnitude relation (CMR), first observed by Baum 1959 is the tight relation between colors and luminosities of the early type of elliptical and lenticular galaxies Faber 1973; Visvanathan & Sandage 1977; Bower Larson, Tinsley & Caldwell 1980; Stanford et al. 1997; Baldry et al. 2004; and Gallazzi et al. 2006. CMR is an important tool for studying the components of galaxies (gas and star), the evolution and formation of the both types of galaxies Sandage & Visvanathan 1978; Scodreggio & Gavazzi 1993; Van Dokkum 2005. By the Color-Magnitude Diagram the evolution of galaxies is well understood Bower et al. 1992a, 1992b.

In addition of surveying the sky Hogg et al 2004; Koribalski 2012 the luminosity functions of galaxies were studied theoretically Kauffmann, White, & Guiderdoni 1993; Benson et al. 2000; De Lucia, G., et al. 2006.

In theoretical models its established that in very high density regions galaxies are redder than the normal density region Di-ferio et al. 2001.

The HI Parkes All-Sky Survey (HIPASS) is the largest and most prominent of the Parkes HI surveys.

Different studies showed that CMR holds for all galaxies clusters of different masses from dwarf galaxies to the giant galaxies Janz & Lisker 2009.

Brightest cluster galaxies and most luminous early type galaxies brighter than $M_V \approx -21$ have cores in their central starlight distributions Cores are marked by a distinct physical radius interior to which the projected starlight surface-brightness increases only slowly as $r \rightarrow 0$, in marked contrast to the surrounding envelope, Postman et al. 2012.

THEORY

The HIPASS of faint galaxies used in the present work are given in two passbands, V and H contains faint-gas rich galaxies where no interaction occur among them. The absolute V-band magnitude brighter than $M_v = -12.5$. Because all galaxies are active for star formation, the formation considered to be obtaining with different time scaling between 0.1 and 14 Gyr. The age of galaxies was chosen between 8 and 13.75 Gyr at which produces galaxies of V-H color, therefore (ESO 383-G092) does not produce galaxy color because its age is less than 8 Gyr.

The position of HIPASS of galaxies cannot be detected precisely, therefore all galaxies in this sources were made by H α spectroscopy with the ANU Dual Beam Spectrograph on the 2.3 m telescope using two different detectors. The photometric data measured from Gurovich et al. 2010.

The mass of HIPASS of faint galaxies are virial mass M_{vir} , which refers to the mass within virial radius r_{vir} , within which the average density of baryon mass is 200 time the critical density ρ_c of the universe.

$$\rho = 200 \rho_c$$

$$r_{vir} \sim r_{200} = r \quad (1)$$

From the Friedmann equation,

$$\rho_c = \frac{3H^2}{8\pi G} \quad (2)$$

Where H is the Hubble parameter and G is the gravitational constant.

$$M_{vir} \sim M_{200} = \frac{4}{3} \pi r_{200}^3 \cdot 200 \rho_c$$

$$= 100 \frac{H^2}{G} r_{200}^3 \quad (3)$$

Where ρ is the mean density in a sphere of radius, r_{200} , and M_{200} is the mass within the sphere of radius, r_{200} .

The images of color-color plot used in the present work are given in three passbands, B, V and R. The photometric data measured by P. A. Duc et al. 2002 with the SExtractor (SE) software used, for source extraction Bertin & Arnouts 1996. The software (SE) gives more information about the detection and photometry.

We performed our detection using a 6×6 (corresponding to 0.95×0.95 Mpc) detection filter with a pixel size of 6×6 . The galaxy clusters are in all the mid-infrared source emitter which detected at $6.75\mu\text{m}$ and $15\mu\text{m}$.

In the present work also the luminosity function and the color distribution are studied for galaxy clusters of redshift $z=0$, the galaxy cluster have been imaged in b, v, r, and i, are the reddest and brightest galaxies which are active to star formation. The photometric data calculated by Gabriella De Lucia 2006.

RESULTS AND DISCUSSIONS

Figure 1 shows the absolute V-band magnitude and V-H color of the HIPASS of faint gas-rich galaxies. These galaxies have absolute V-band magnitude brighter than $M_v = -12.5$.

The majority of the faintest gas-rich galaxies in the absolute V-band magnitude are in a range between -12.5 and -14.5.

The galaxies of absolute V-band magnitude in the range of -18 and -19.3 are brighter than other HIPASS of galaxies in which the interaction do not occur between galaxies.

For HIPASS of galaxies, stars that are formed produce galaxy color as indicated by the amount of detected gas. These galaxies

can continue to form stars, except the (ESO 383-G092) galaxy which cannot produce galaxy color because its age is less than 8 Gyr.

The (HIPASS J1934-67) is a bright galaxy that has a central region to recent star formation and it has a luminous blue nucleus that has a large effect on galaxy's integrated color of (V-H=1.99). The analysis is shown in the below figure with dust extinction in detail. The (ESO 321-G014) is the bluest faintest galaxy which has $M_v = -12.55$ lies on the color magnitude diagram, which is ongoing to form stars.

The bright population in the V-band have M_v brighter than -17 mag is dominated by star burst galaxies.

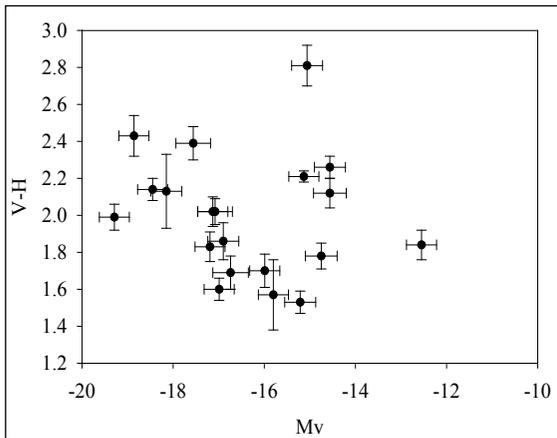


Fig. 1: The color-magnitude diagram for the HIPASS of faint galaxies. These galaxies have absolute V-band magnitude brighter than $M_v = -12.5$

Figure 2 shows the B-V and R-B color-color plot of the galaxy clusters. The galaxies that have $B-V = 1.13, 1.09, 1.34, 1.55, 1.73, 1.94, 1.27, 1.74, 1.89, 1.24, 1.32, 1.1, 1.35,$ and 0.74 were detected at $15\mu m$ by the ISOCAM camera onboard the ISO satellite, while other galaxies were detected at $15\mu m$ in the color-color plot. The infrared radiation are emitted by the galaxy clusters, and the galaxies that detected at $6.75\mu m$ are more luminous and reddest galaxies. The majority of the galaxies were detected at $6.75\mu m$, are spiral galaxies, while the others which were detected at $6.75\mu m$, are elliptical and lenticular galaxies.

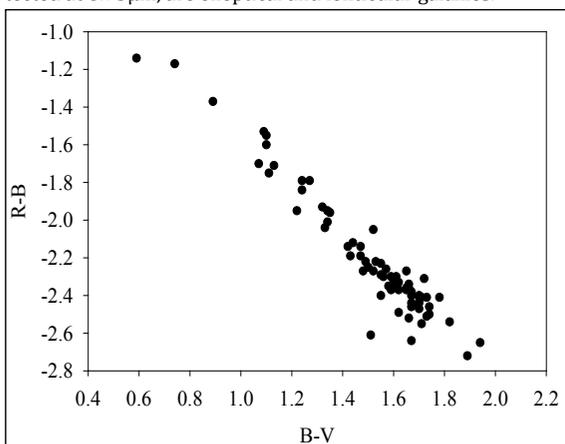


Fig. 2: The B-V versus R-B color-color plot. The galaxies were detected at $15\mu m$ and $6.75\mu m$ by the ISOCAM camera onboard the ISO satellite.

Figure 3 shows the B-V and V-R color-color plot of the galaxy clusters. In Fig. 3 the galaxies have color $V-R = 0.58, 0.44, 0.61, 0.85, 0.78, 0.71, 0.52, 0.76, 0.83, 0.55, 0.5,$ and 0.43 were detected at $15\mu m$, while others were detected at $6.75\mu m$ are reddest and brightest galaxies. The size of the cluster of galaxy

depends on the ratio of the energy radiated by the galaxies detected at $6.75\mu m$ to the energy radiated by the galaxies detected at $15\mu m$. If the ratio is small, it means that the galaxy clusters are bigger in size and contain more luminous galaxies. In the color-color plot some galaxies are active to star formation, but in most galaxies star formation continue but cannot be detected due to galactic extinction, an some galaxies detected at $15\mu m$ are not active to star formation.

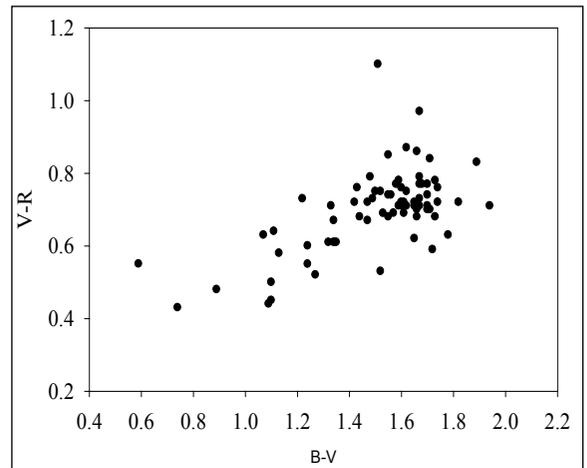


Fig. 3: The B-V versus V-R color-color plot. The galaxies were detected at $15\mu m$ and $6.75\mu m$ by the ISOCAM camera onboard the ISO satellite.

Figure 4 displays the V-H color as a function of gas mass for HIPASS of faint galaxies. The galaxy population in the figure contains faint gas-rich galaxies (with dust extinction). The faintest and bluest galaxy in the V-H color diagram ($V-H = 1.84$) is (ESO 321-G014) that dominated by starburst with its gas mass $1.78 \times 10^7 M_{sun}$. Although gas particles in the HIPASS of galaxies continue to cool and to convert to stars but in (ESO 383-G092) galaxy, stars has a negligible effect on the galaxies color due to the age of this galaxy which is younger than 8 Gyr.

When the gas particles convert to stars, it returns to the interstellar medium. The fraction of hydrogen in low mass galaxies is ionized by the blue light which form new stars.

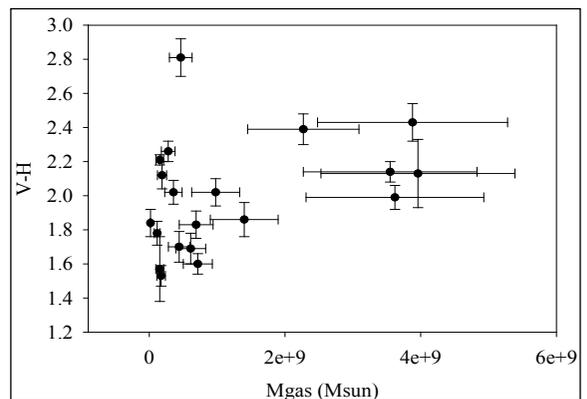


Fig. 4: The V-H color as a function of the gas mass for HIPASS of galaxies. The gas particles continue to cool and it convert to stars but in some time some stars not appear due to dust extinction.

Figure 5 presents a scatter plot of HIPASS of galaxies V-H color against stellar mass. The faint gas-rich galaxies in the V-H color diagram in which most of the cold gas has turned into stars. The current star formation in (ESO 321-G014) is at a low level in the $V-H = 1.84$, but highest star formation appear in (HIPASS J1801-72), which is $V-H = 2.43$. Each galaxy contains a wide range of possible star formation. Star formation began in galaxies in the

age between 0.1 and 14 Gyr, but we choose the age between 8 and 13.75 Gyr produce observed galaxy color. These galaxies have newly formed stellar population but in (ESO 383-G092) galaxy, stars do not produce galaxy color because their ages younger than 8 Gyr. The intrinsic color of the faintest galaxy (ESO 318-G013) are very blue in the color diagram which have $V-H=1.53$.

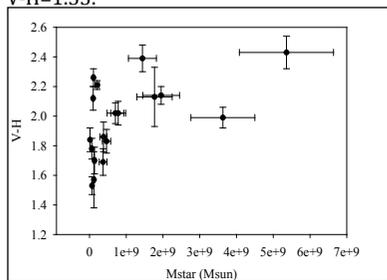


Fig. 5: The V-H color as a function of stellar mass for HIPASS of galaxies. The galaxies produces V-H color have an age more than 8 Gyr.

Figure 6 shows the cold gas fraction as a function of galaxy luminosity. The cold gas fraction is defined as M_{gas}/M_{star} , and this fraction depends on the star formation efficiency in galaxies. From the figure it is clear that the lower gas fraction appear in (ESO 085-G088) at absolute V-band magnitude, $M_v=-17.08$, but the larger gas fraction appear in (IC 5028) at $M_v=-16.9$, because star formation efficiency in (ESO 085-G088) is larger than in IC 5028, and also (IC 5028) is fainter than (ESO 085-G088). In (ESO 383-G092) galaxy, gas fraction are not calculated because in this type of galaxy, stars have negligible effect on V-H color diagram since the age has not reached to 8 Gyr. yet.

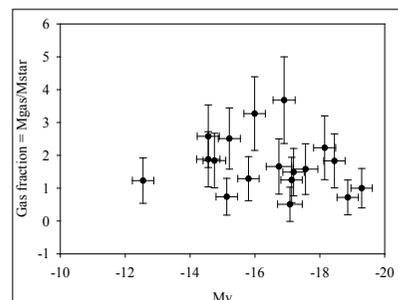


Fig. 6: The V-H color as a function of gas fraction for HIPASS of galaxies. The gas fraction defined as M_{gas}/M_{star} , and this fraction depends on the star formation efficiency.

Figure 7 demonstrates the absolute V-band magnitude of HIPASS of galaxies versus their V-band disk central surface brightness. The bright galaxy (HIPASS J1934-67) which, $M_v=-19.29$ have lower surface brightness than the galaxy (ESO 321-G014) have, $M_v=-12.55$.

The absolute V-band magnitude of galaxies brighter than $M_v=-12.5$ has low surface brightness, therefore the bright galaxies which obtained have lower surface brightness than the faint galaxies.

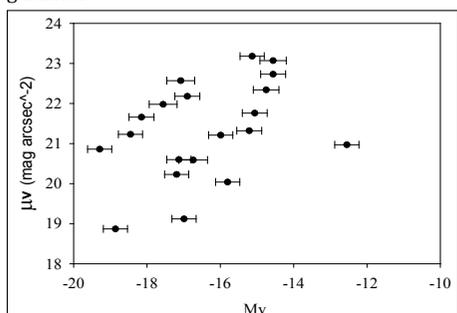


Fig. 7: The absolute V-band magnitude M_v of HIPASS of galaxies versus their V-band disk central surface brightness. These galaxies have absolute V-band magnitude brighter than $M_v=-12.5$, have lower surface brightness.

Figure 8 shows morphology of the galaxy as a function of V-band disk central surface brightness and V-band scale length.

To further display the range in size and morphology, fig. 8 displays the galaxies with respect to their disk scale length. Irregular morphology is most common at small scale lengths, and spiral morphology have larger scale length. The scale lengths for disk galaxies are not expected to depend on Hubble morphological type. Therefore the exponential scale length of galaxy disk is one of the most fundamental parameter to determine its morphological structure, and also the scale length determines how the stars are distributed throughout a disk.

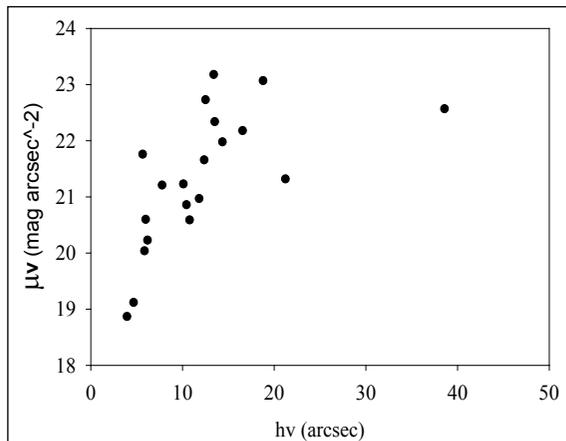


Fig. 8: The V-band scale length as a function of V-band disk central surface brightness. The scale length of disk galaxy is one of the most fundamental parameter determine its morphological structure.

Figure 9 shows the number of galaxies as a function of absolute v-band magnitudes which are in the range between -20 and -15 for the galaxy clusters at redshift $z=0$.

For $M_v < -17$, the luminosity function of the cluster of galaxy contain a small number of galaxies, while for $M_v > -17$, the cluster of galaxy contain a larger number of galaxies. The red sequence galaxies populated at absolute v-band magnitude brighter than $M_v=-17$ more luminous and reddest galaxies but the galaxies fainter than $M_v=-17$ are the faint red galaxies. The red sequence galaxies in these clusters can be described as an old and more luminous galaxies after a large fraction of the faint red galaxies in current clusters moved on to the red sequence.

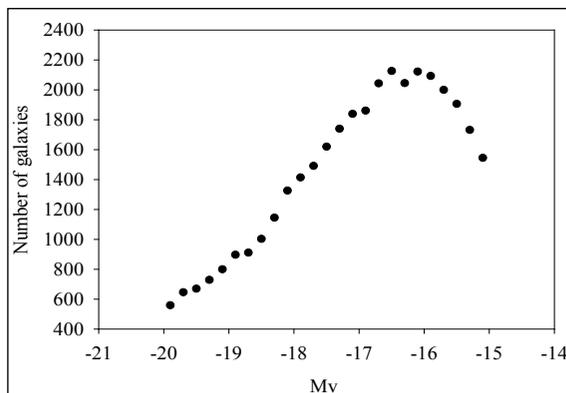


Fig. 9: The luminosity functions of the red galaxies at the absolute v-band magnitude are in the range between -20 and -15, at redshift $z=0$. The luminosity function of the cluster of galaxies

at absolute v-band magnitude brighter than $M_v = -17$ contain a smaller number of galaxies.

Figure 10 presents the color distribution of galaxy clusters at redshift $z=0$, in the b-v color, when the absolute b-band magnitude, M_b between -20 and -19 most of the galaxy clusters are shown in the histogram are the brightest and reddest galaxies. From the figure obtained 30 % of the cluster of galaxies at $b-v=0.6$, and 40 % of the cluster of galaxies at $b-v=0.4$. The luminous and reddest of the cluster of galaxies are active to star formation, and the b-v color distribution of the cluster of galaxies that exhibit IR emission, the gas and dust surrounding the stars absorb blue light and emit infrared light.

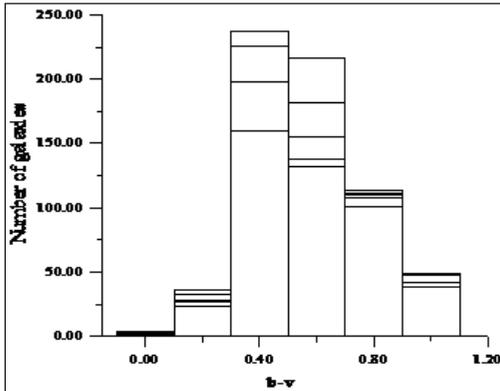


Fig. 10: The histogram of b-v color distribution for the absolute b-band magnitudes, M_b are in the range between -20 and -19, at redshift $z=0$. The larger number of galaxies are observed at the color $b-v=0.4$.

Figure 11 shows the color distribution of the cluster of galaxies in the r-i color at redshift $z=0$, when the absolute r-band magnitude, M_r is between -20 and -19. The largest cluster of galaxies are distributed in the color $r-i=0.6$ are around 50 % of the galaxy cluster. And the smallest cluster of galaxies are distributed in the color $r-i=0.8$ are around 1 % of the galaxy cluster as shown with histogram. The cluster of galaxies are distributed in the r-i color between 0.2 and 0.8 are brightest and reddest galaxies. And the cluster of galaxies are in all value of r-i color are very sensitive to any recent or ongoing star formation.

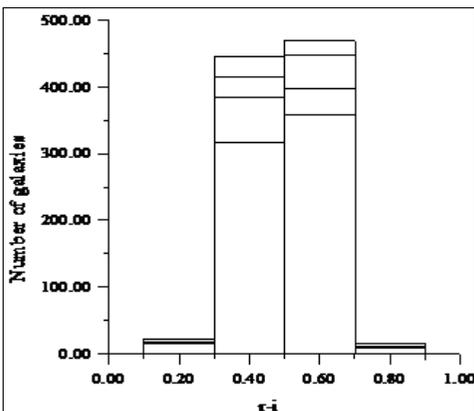


Fig. 11: The histogram of r-i color distribution for the absolute

r-band magnitudes, M_r are in the range between -20 and -19, at redshift $z=0$. The larger number of galaxies are observed at the color $r-i=0.6$.

CONCLUSION

In the present work, the conclusion can be shown as follows:

- 1- The HIPASS of faint galaxies contain faint gas-rich, and have absolute V-band magnitude brighter than and not interactions occur between them.
- 2- The HIPASS of faint galaxies are active to star formation and produce galaxy color except (ESO 383-G092) does not produce galaxy color because its age is younger than (8Gyr). For galaxy color to be produced, it is required that the age must be between 8 and 13.75 Gyr.
- 3- Gas particles in the HIPASS of faint galaxies continue to cool and it convert to stars but in some cases stars not appear due to dust extinction
- 4- The HIPASS of faint galaxies contain larger gas fraction at faint absolute V-band magnitude galaxies.
- 5- The absolute V-band magnitude of HIPASS of faint galaxies brighter than $M_v = -12.5$, has lower surface brightness.
- 6- The scale length of galaxy disk is one of the most important parameter to determine its morphological structure.
- 7- In the color-color plot, those galaxy clusters that were detected at, and those that were detected at are more luminous and reddest than those galaxy clusters detected at. The galaxy clusters are active to star formation but in most galaxies the radiation emitter from stars cannot be detected due to dust extinction, and also some galaxies detected at are not active to star formation.
- 8- The luminosity function of the red sequence galaxies populated at absolute V-band magnitude, $M_v < -17$ is described as an old and more luminous galaxies and reddest than the galaxies with $M_v > -17$.
- 9- The b-v and r-i color distribution of the cluster of galaxies which contain a larger number of galaxies at $b-v=0.4$ and $r-i=0.6$.

REFERENCE

- Baldry, I., et al. 2004, ApJ, 600, 681. | Baum, W. A. 1959, PASP, 71, 106. | Benson, A. J., Baugh, C. M., Cole, S., Frenk, C. S., & Lacey, C. G. 2000, MNRAS, 316, 107. | Bertin, E., Arnouts, S., 1996, A&AS 117, 393. | Bower, R. G., Lucey J. R., Ellis R. S., 1992a, MNRAS, 254, 601. | Bower, R. G., Lucey J. R., Ellis R. S., 1992b, MNRAS, 254, 589. | De Lucia, G., et al. 2006, MNRAS, 366, 499. | Diaferio, A., et al. 2001, MNRAS, 323, 999. | Duc P.A. et al., 2001, arXiv:astro-ph/0112249. | Faber, S. M. 1973, ApJ, 179, 731. | Gallazzi, A., Charlot, S., Brinchmann, J., & White, S. D. M. 2006. | Guiderdoni, B. 1993, MNRAS, 264, 201. | Gurovich et al., 2010, The Astronomical Journal, 140:663–676. | Hogg, D. W., et al. 2004, ApJ, 601, 29. | Janz1, J. and Lisler, T., 2009 The Astrophysical Journal, 696:L102–L105. | Kauffmann, G., White, S. D. M., Sandage, A., & Visvanathan, N. 1978a, ApJ, 225, 742. | Koribalski, B. S., 1206.6916v1 [astro-ph.CO] 29 Jun 2012. | Larson R. B., Tinsley B. M., Caldwell C. N., 1980, ApJ, 237, 692. | Postman, M., Accepted for publication in The Astrophysical Journal, 24 July 2012. | Van Dokkum, P. G. 2005, AJ, 130, 2647. | Visvanathan, N., & Sandage, A., 1977, ApJ, 216, 214, MNRAS, 370, 1106. |