Обзор ArXiv/astro-ph, 12-16 апреля 2021 года

От Сильченко О.К.

ArXiv: 2104.07133

Gaseous nebulae and massive stars in the giant H I ring in Leo

Edvige Corbelli[1], Filippo Mannucci[1], David Thilker[2], Giovanni Cresci[1], and Giacomo Venturi[3,1]

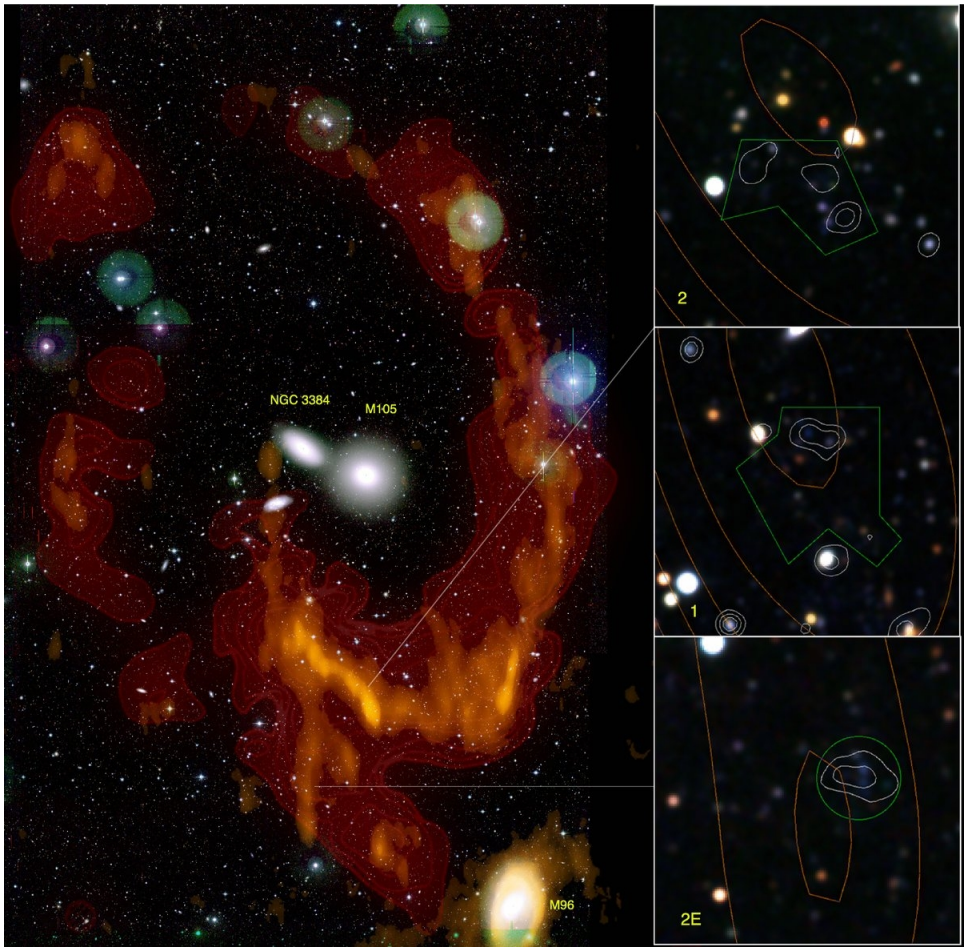
[1] INAF-Osservatorio di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy
e-mail: edvige.corbelli@inaf.it
[2] Department of Physics and Astronomy, The Johns Hopkins University, Baltimore, MD, USA
[3] Instituto de Astrofísica, Facultad de Física, Pontificia Universidad Católica de Chile, Casilla 306, Santiago 22, Chile

Received ....; accepted .....

ABSTRACT

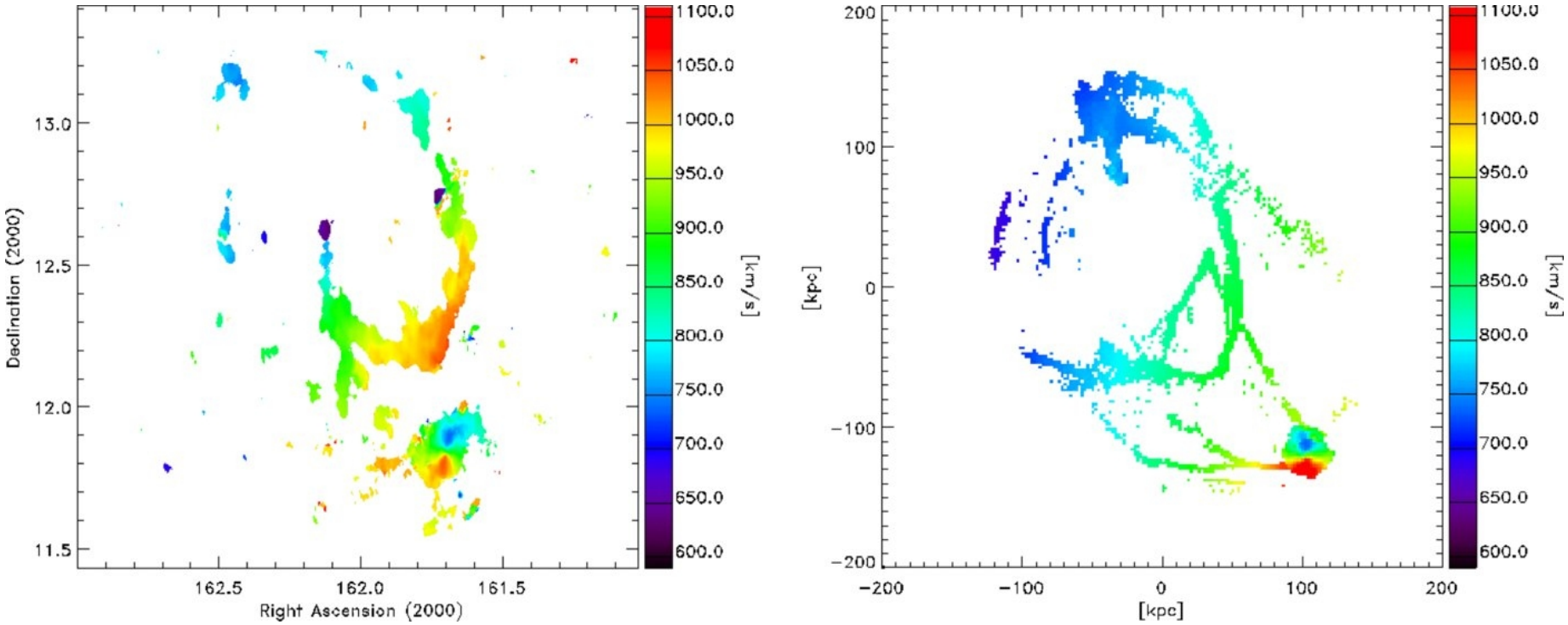
Context. Chemical abundances in the Leo ring, the largest H I cloud in the local Universe, have recently been determined to be close or above solar (Corbelli et al. 2021), incompatible with a previously claimed primordial origin of the ring. The gas, pre-enriched in a galactic disk and tidally stripped, did not manage to form stars very efficiently in intergalactic space.
Aims. Using Hα emission and a multi wavelengths analysis of its extremely faint optical counterpart we investigate the process of star formation and the slow building up of a stellar population.
Methods. We map nebular lines in 3 dense H I clumps of the Leo ring and complement these data with archival stellar continuum observations and population synthesis models.
Results. A sparse population of stars is detected in the main body of the ring, with individual young stars as massive as O7-types powering some H II region. The average star formation rate density in the ring is of order of 10^{-5} $M_\odot$ yr^{-1} kpc^{-2} and proceeds with local bursts a few hundred parsecs in size, where loose stellar associations of 500 – 1000 $M_\odot$ occasionally host massive outliers. The far ultraviolet -to-Hα emission ratio in nebular regions implies recent stellar bursts, from 2 to 7 Myr ago. The relation between the local H I gas density and the star formation rate in the ring is similar to what is found in dwarfs and outer disks with gas depletion times as long as 100 Gyrs. We find a candidate planetary nebula in a compact and faint Hα region with [OIII]/Hα line enhancement

Michel-Dansac+ 2010: глубокие снимки в оптике+ HI 21 см



Газовое кольцо радиусом 100 кпк в Leo I

2 миллиарда солнечных масс газа, регулярное круговое вращение



Michel-Dansac+ 2010

Старых звезд нет, а ультрафиолет есть!

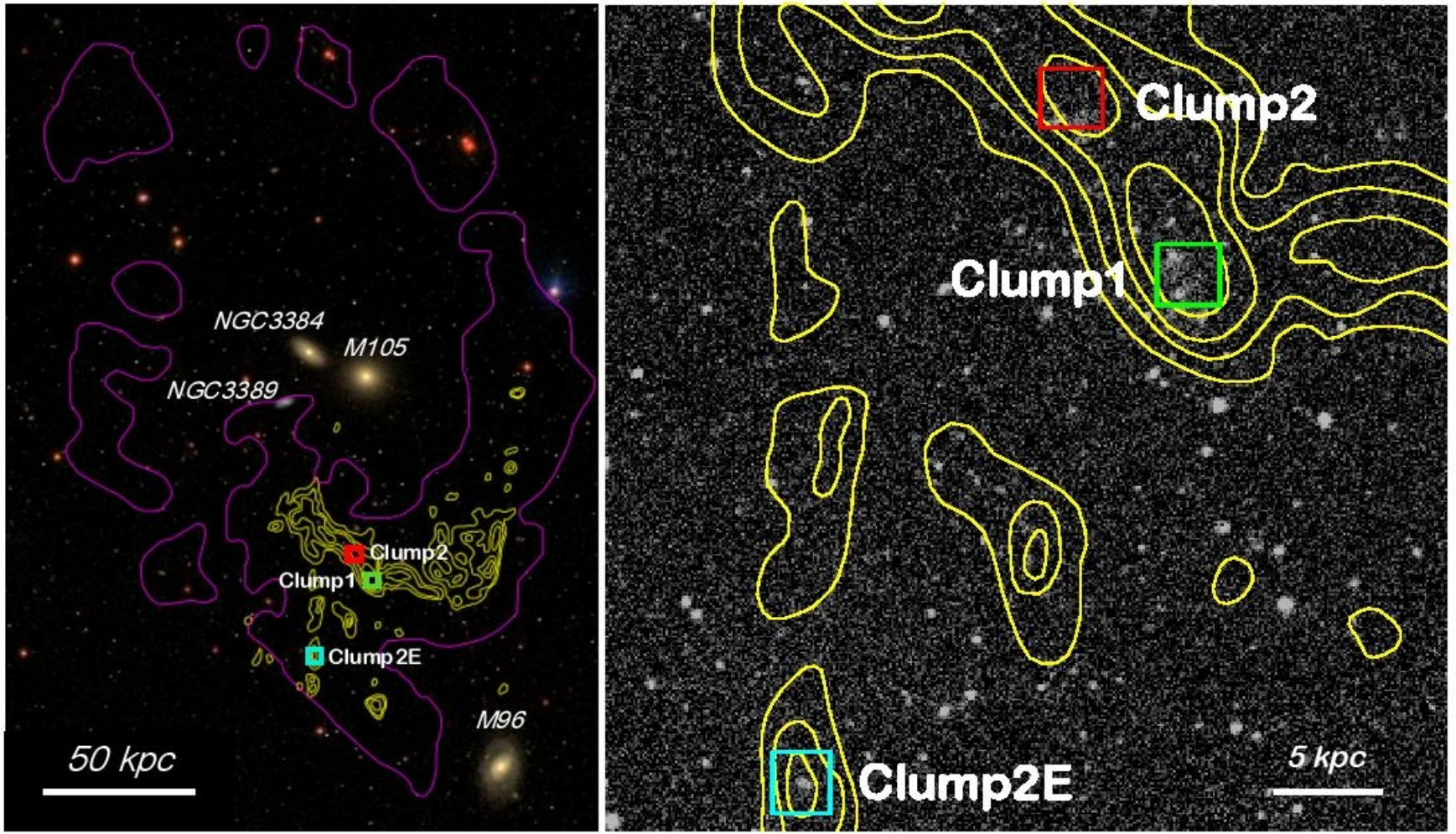


Fig. 1. The optical image of the M96 group in the background (SDSS color image) is shown in the left panel with H I contours of the Leo ring. In magenta the Arecibo contour at $N_{HI} = 2 \times 10^{18}$ cm^{-2}, in yellow the VLA H I contours of the southern part of the ring as described by Schneider et al. (1986). Square symbols indicate the positions of the 3 H I clumps observed with MUSE: Clump1, Clump2 and Clump2E. In the right panel an enlargement of the 3 H I clumps shows the coverage of the 8.5 kpc^2 MUSE fields overlaied on the far UV-GALEX image.

Могучая MUSE: эмиссионный спектр газовых сгустков

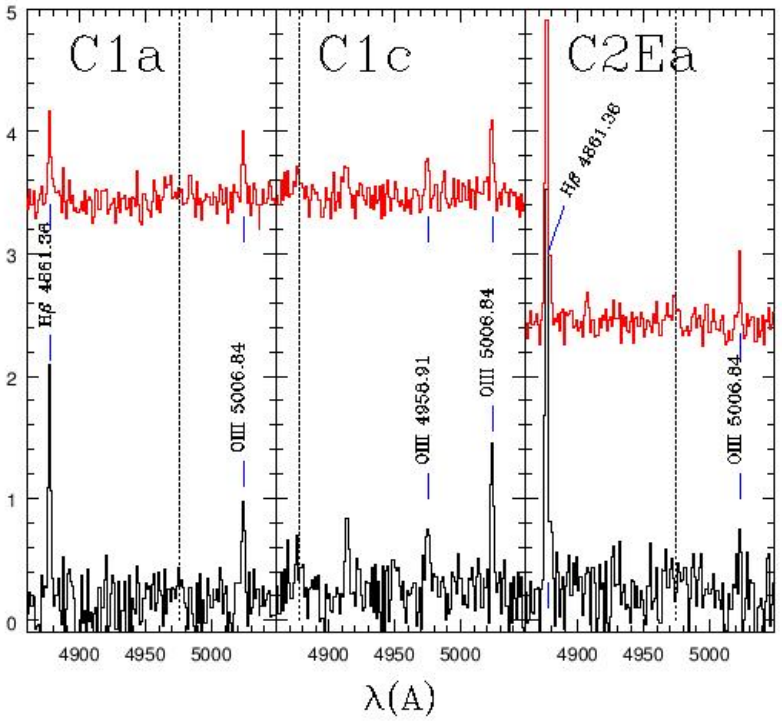


Fig. 2. Detected and undetected nebular line emission in the blue portions of the spectra for 3 regions of the Leo ring. Apertures have radii of 2.4″(black lines) and of 1.2″(red lines). Emission lines detected at least in one aperture are labeled with the rest frame wavelengths and blue tick marks. Dotted lines for undetected lines are placed at the expected wavelengths. Line intensity units along the y-axis are 10^{-17} erg s^{-1} cm^{-2} A^{-1}. Spectra have been arbitrarily shifted along the y-axes for display purposes.

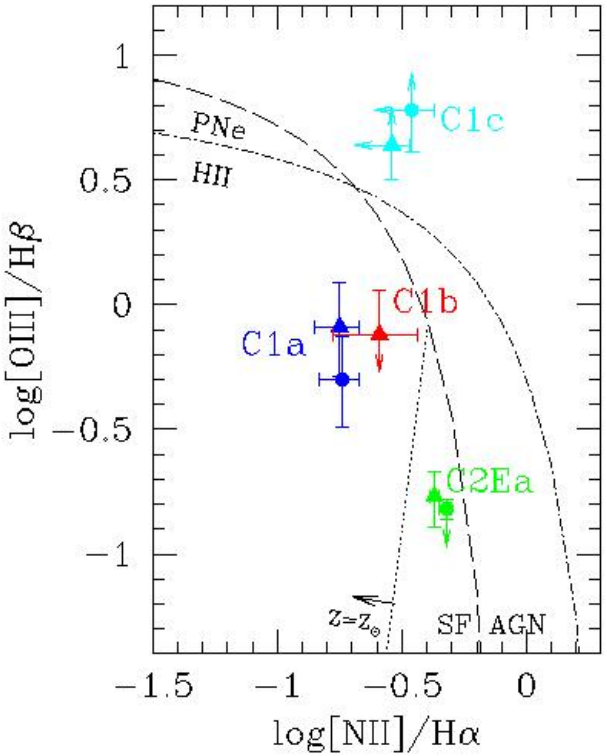
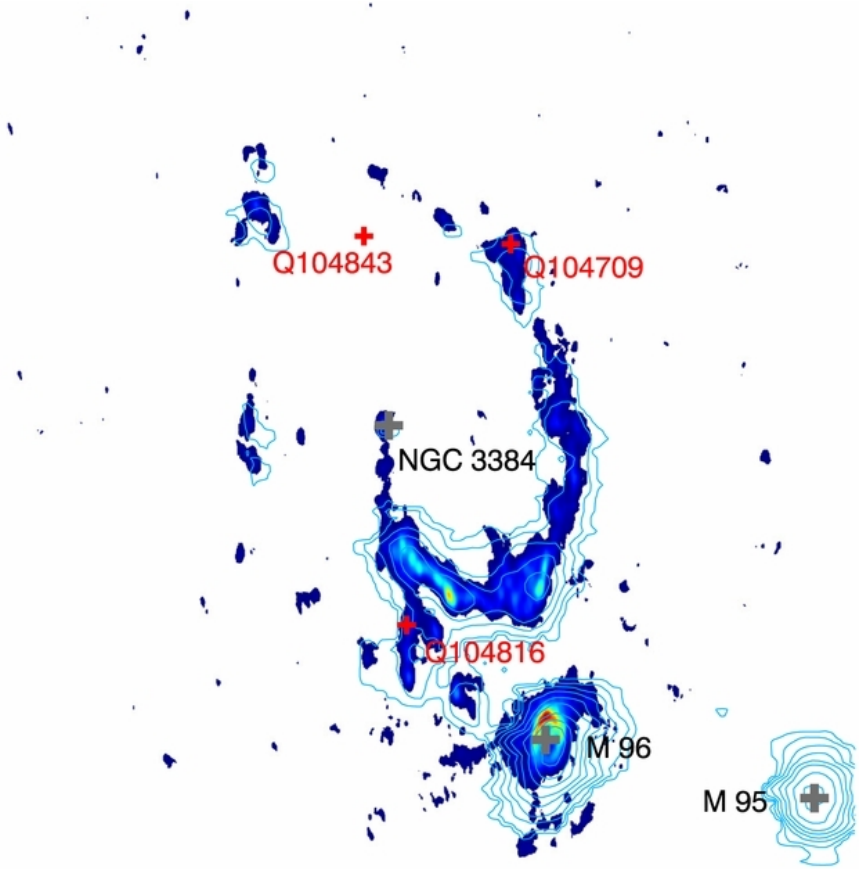
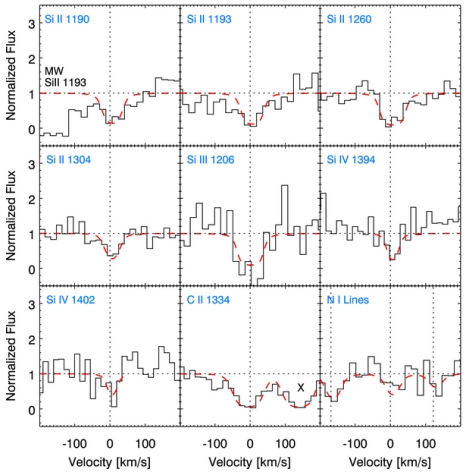
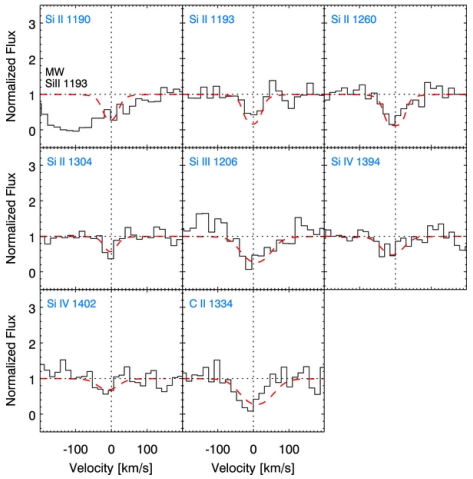


Fig. 3. The line ratios [OIII]5007/Hβ and [NII]6586/Hα are plotted for all nebular regions in Table 1 for which these ratios have been measured or limiting values can be inferred. Different colors indicate different regions. Data for the largest aperture (radius 2.4″) has been plotted with a filled circle and are listed in Table 2, filled triangles refer to 1.2″ apertures. For reference we also indicate the criteria proposed by Kauffmann et al. (2003) for distinguishing between star forming galaxies and AGN (dashed line) and by Sanders et al. (2012) to separate H II regions and

Противоречие по химсоставу газа: эмиссия vs на просвет







Rosenberg+ 2014: [m/H]=-1

Основной предмет статьи: молодые звезды в кольце

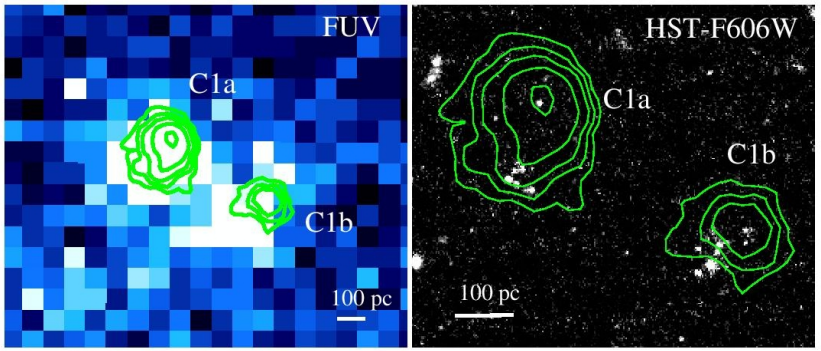
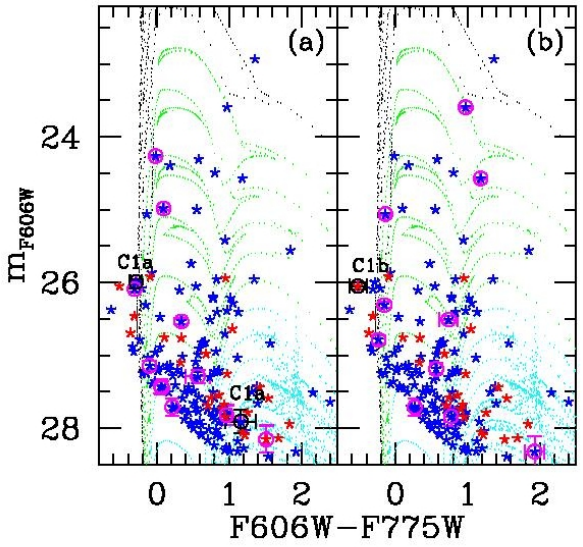


Fig. 6. Contours of the Hα emission of the two brightest HII regions in Clump1, C1a and C1b, are overplotted in green to the GALEX-FUV continuum image in the left panel and to the HST-ACS-F606W optical image in the right panel. Contour levels are: 2.5,4,6,10,20×10^{-20} erg per pixel (0.2″). The radius of the 10×10^{-20} erg s^{-1} cm^{-2} contour level is about 70 and 50 pc for C1a and C1b respectively. The HST ima that only part of the stellar population in the cloud is emitting ionizing photons powering the Strömgren spheres.

Контуры H-alpha

Clump 1



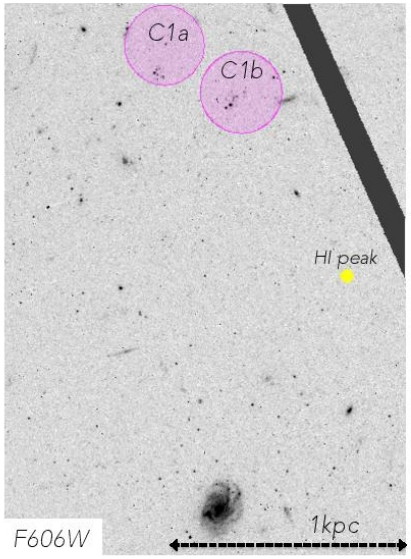


Fig. 7. Point-like sources within 1 kpc of the center of the area hosting the two brightest nebulae in Clump1 are shown with asterisk symbols in the CMD (in VEGAMAGS) of panel (a) and (b). The open magenta circles mark sources within 3.8″ from the center of C1a in panel (a) and of C1b in panel (b), with black color and labels used for sources at the center of the nebulae. Blue asterisks are for objects of type=1 (good stars). The dotted lines are the predicted evolutionary tracks for PADOVA isochrones for Z=0.0142, with black color for ages ≤ 10 Myr, green color for ages between 10 and 100 Myr and cyan color for ages ≥ 100 Myr. No extinction corrections have been applied. To the right the HST-F606W image shows the sparse population of stars in a region of Clump1. Magenta circles of 3.8″ radii have been placed at the location of C1a and C1b, a filled yellow dot indicates the HI peak of Clump1. For reference the dashed line is 1 kpc in length.

Clump C2E

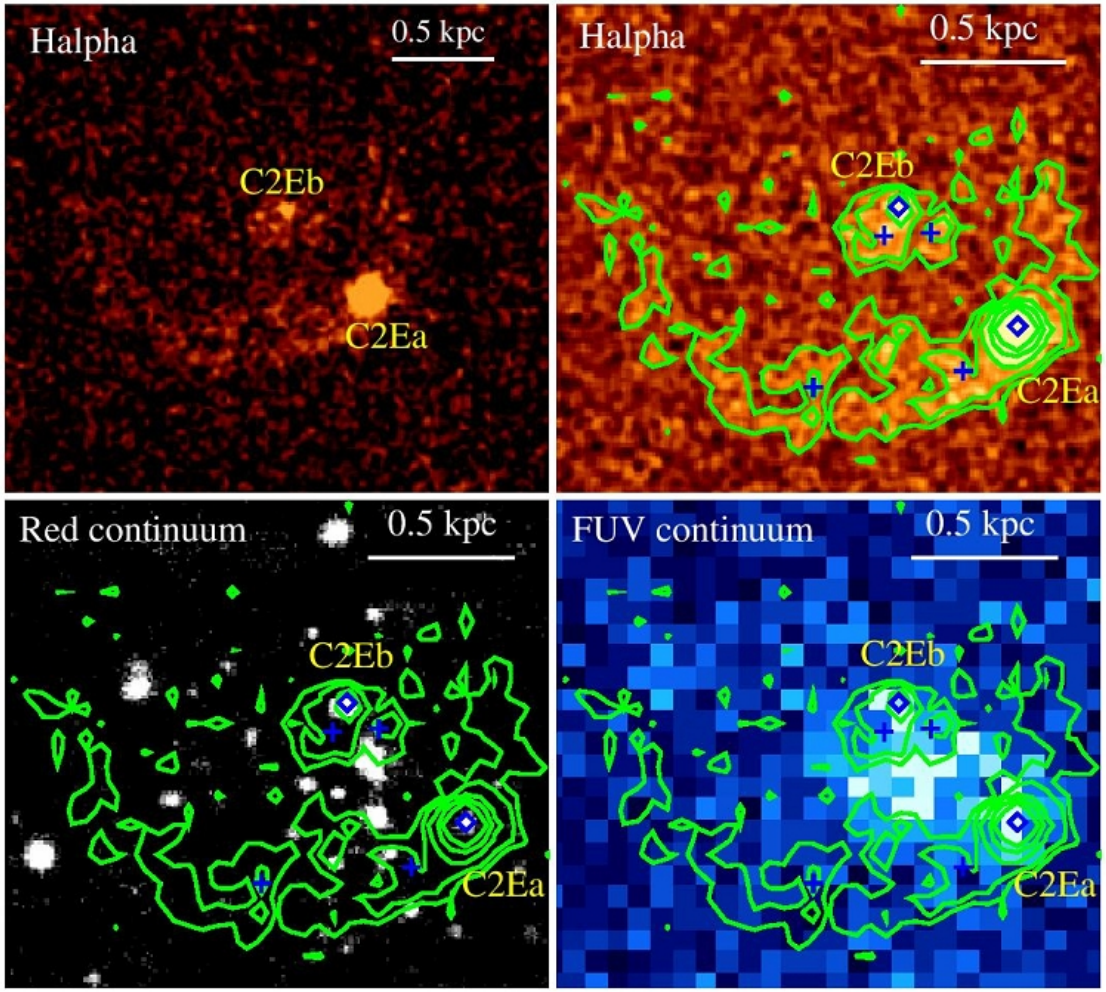
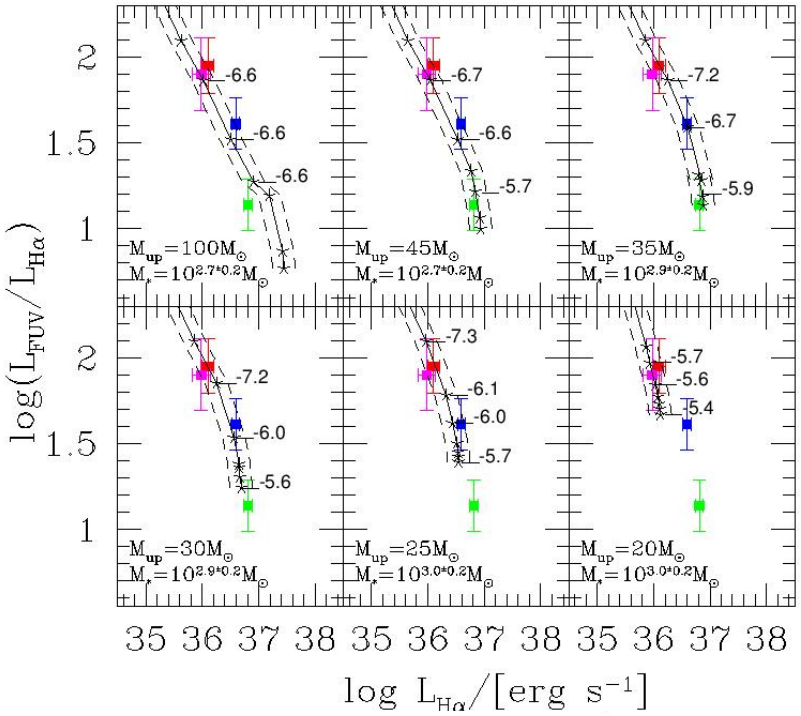


Fig. 8. The image of Clump2E in Hα (log scale) is shown in the *upper-left* panel.The two brightest H II regions, with more than one nebular line detected, are marked with blue diamonds in a zoom in image of the Hα emission in the *upper-right* panel (linear scale). The Hα smoothed contour levels at 1.2,2,4,10,20$\times 10^{-20}$ erg s^{-1} cm^{-2} per pixel shape a partial ring of radius $\sim$ 0.6 kpc. They are marked also on the VLT red continuum image (*bottom-left* panel) and on the FUV-GALEX image (*bottom-right* panel). The blue crosses, at the location of the Hα sources listed in Table 3, are

Их эволюционные модели и параметры



Starburst99: 1 --> 7 Myr

Table 4. Massive stars and star formation rates in the Leo ring

Source	log $L_{H\alpha}$ erg s^{-1} total	central stellar type	$L_{\nu,FUV}/L_{H\alpha}$ $\frac{[\text{erg s}^{-1}\ \text{Å}^{-1}]}{[\text{erg s}^{-1}]}$ R_{ap}=184 pc	age Myr burst	$L_{\nu,FUV}/L_{H\alpha}$ $\frac{[\text{erg s}^{-1}\ \text{Å}^{-1}]}{[\text{erg s}^{-1}]}$ R_{ap}=364 pc	M_{up} $M_\odot$ cont.	log Σ_{SFR} $M_\odot$ yr^{-1} kpc^{-2} R_{ap}=364 pc	log Σ_{SFR} $M_\odot$ yr^{-1} kpc^{-2} R_{ap}=2.2 kpc
C1a	36.58	O7	1.6	5	1.8	30	-3.4	-4.3
C1b	36.06	O8.5	1.9	7	2.3	20	-3.5	-4.3
C2Ea	36.79	O6.5	1.2	3	1.5	45	-3.5	-4.5
C2Eb	35.97	O9	1.9	7	2.3	20	-3.5	-4.5

UV-звездообразование: → 100 Myr

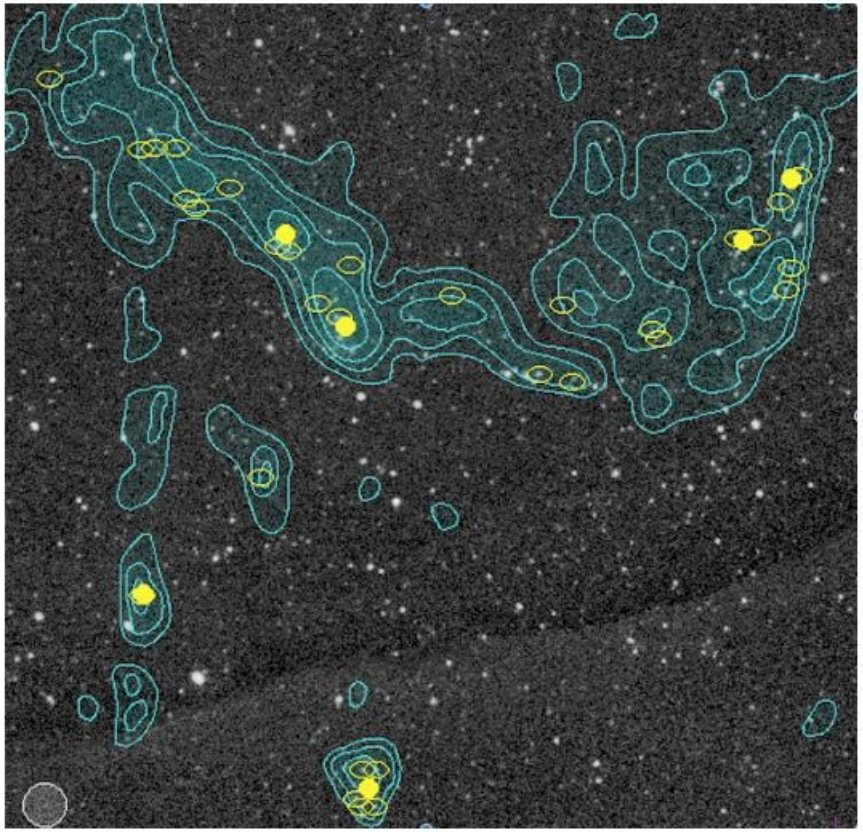


Fig. 10. Location of possible star forming sites (yellow ovals) identified in the FUV-GALEX map of the Leo ring (background image). Green contours are relative to 21-cm H I emission mapped by Schneider et al. (1986). Filled yellow circles indicate the location of H I peaks with associated FUV emission estimated using a circular aperture of 45″ in radius, indicated by a gray circle at the bottom left corner.

Закон Кенниката-Шмидта: как во внешних дисках спиральных галактик

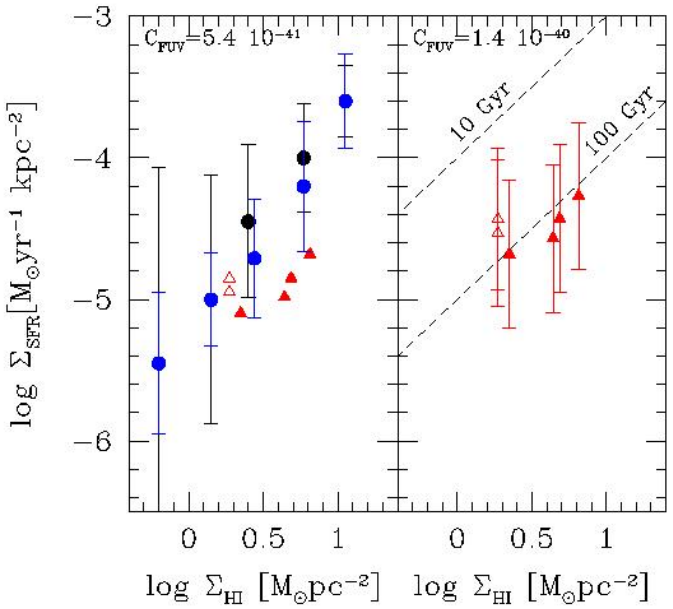


Fig. 11. In the left panel FUV based estimates of the star formation rate densities Σ_{SFR} and H I gas mass surface densities Σ_{HI} are shown with red triangles for the 6 H I peaks in the Leo ring with non negligible FUV emission. The open triangles indicate H I peak data not listed by Schneider et al. (1986) relative to cloudlets towards M96. Filled dots trace the relation for the median values of the large database on outer disks of spiral galaxies (black color) and on dwarf galaxies (blue color) obtained by Bigiel et al. (2010) and their dispersion. For this panel we use the same star formation rate coefficient as in Bigiel et al. (2010). In the right panel we show the star formation rate densities for the same 6 H I peaks in the ring but computed with the conversion coefficient relative to Starburst99 continuous star formation models with M_{up}=35 $M_\odot$

Вопросы остаются:

- Все-таки, кольцо – первичное или столкновительное?
- Если столкновительное, почему такое устойчивое (минимальные темпы звездообразования, 3 10^{-4} масс Солнца на квадратный килопарсек)?