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Կարապետյան Արփինե Գրիգորի

Գերնորերի և դրանց մայր գալակտիկաների դինամիկական հատկությունների ուսումնասիրություն

Ա.03.02 - « Աստղաֆիզիկա, ռադիոաստղագիտություն » մասնագիտությամբ ֆիզիկամաթեմատիկական գիտությունների թեկնածուի գիտական աստիճանի հայցման ատենախոսության

ՍԵՂՄԱԳԻՐ

ԵՐԵՎԱՆ – 2023

A. I. ALIKHANYAN NATIONAL SCIENCE LABORATORY

(YEREVAN PHYSICS INSTITUTE)

Arpine Karapetyan

Study of supernovae and their host galaxy dynamical features

SYNOPSIS

of Dissertation in 01.03.02 – Astrophysics, radio astronomy presented for the degree of candidate in physical and mathematical sciences

YEREVAN – 2023

Ատենախոսության թեման հաստատվել է Ա. Ի. Ալիխանյանի անվան Ազգային Գիտական Լաբորատորիայի (ԵրՖԻ) գիտական խորհրդում:

Գիտական ղեկավար՝
Ֆիզ.մաթ. գիտ. թեկնածու Արթուր Աշոտի Հակոբյան (ԱԱԳԼ)

Պաշտոնական ընդդիմախոսներ՝
Ֆիզ.մաթ. գիտ. դոկտոր Վահագն Գրիգորի Գուրզադյան (ԱԱԳԼ)
Ֆիզ.մաթ. գիտ. թեկնածու Սերգեյ Սամվելի Միրզոյան (ԱԱԳԼ)

Առաջատար կազմակերպություն՝
Փարիզի աստղաֆիզիկայի ինստիտուտ, Ֆրանսիա
Ատենախոսության պաշտպանությունը կայանալու է 2023 թ. դեկտեմբերի 5-ին ժամը 11:00-ին, ԱԱԳԼ-ում գործող ԲՈԿ-ի 024 «Ֆիզիկայի» մասնագիտական խորհրդում (Երևան, 0036, Ալիխանյան Եղբայրների փ. 2):
Ատենախոսությանը կարելի է ծանոթանալ ԱԱԳԼ-ի գրադարանում:
Սեղմագիրն առաքված է 2023 թ. հոկտեմբերի 25-ին:

Մասնագիտական խորհրդի գիտական քարտուղար՝
Ֆիզ.մաթ. գիտ. դոկտոր Հրաչյա Մարուքյան

The subject of the dissertation is approved by the scientific council of the A. I. Alikhanyan National Science Laboratory (YerPhI).

Scientific supervisor:
Candidate of ph-math. sciences Artur Hakobyan (AANL)

Official opponents:
Doctor of ph-math. sciences Vahagn Gurzadyan (AANL)
Candidate of ph-math. sciences Sergey Mirzoyan (AANL)

Leading organization: Institut d'Astrophysique de Paris, France

The defence will take place on the 5th of December 2023 at 11:00 during the “Physics” professional council’s session of SCC 024 acting within AANL (2 Alikhanyan Brothers str., 0036, Yerevan).

The dissertation is available at the AANL library.
The synopsis is sent out on the 25th of October, 2023.

Scientific secretary of the special council:
Doctor of ph-math. sciences Hrachya Marukyan

Abstract

The thesis is devoted to study supernovae (SNe) and their host galaxy dynamical features. To constraint the nature of the SNe progenitors the spectral and photometric properties of Type Ia and core-collapse (CC) SNe are investigated and connections with the properties of their host stellar populations are established, specifically focusing on dynamical ages within galaxies.

Particularly, the impact of bars and bulges on the radial distributions of the different types of SNe in the stellar discs of host galaxies with various morphologies has been analysed by using a well-defined sample of 500 nearby SNe and their S0-Sm host galaxies. Furthermore, based on the UV/Hα images of the discs of galaxies hosting 185 SNe Ia, a simple visual classification method is presented to perform a comparative analysis of the locations and light-curve (LC) decline rates Δm_{15} of both normal and peculiar SNe Ia in the star formation deserts (SFDs) and beyond.

On the other hand, constraints on SN progenitors have been also approached from a dynamical perspective, such as by studying the spiral structure of host galaxies. The impact of spiral density waves (DWs) on the radial and surface density distributions of 333 SNe hosted in relatively nearby, low-inclined, morphologically non-disturbed and unbarred 269 galaxies with different arm classes has been analysed. Moreover, the distribution of 77 SNe Ia relative to spiral arms of their host galaxies have been analysed by using our original measurements of the SN distances from the nearby arms. The LC decline rates (Δm_{15}) of the SNe have been studied as well.

With the implementation of the WOLFRAM MATHEMATICA software and Monte Carlo simulations, the well-known statistical tests (Kolmogorov-Smirnov [KS] and Anderson-Darling [AD] tests) are used to perform various comparisons between the properties/numbers of the different subsamples. Moreover, to analyse the possible correlations between the physical properties of SNe and their host galaxies the Spearman's rank correlation test are used.

The results obtained in this thesis, give an excellent possibility to constrain the nature of SNe Ia progenitors by assuming that these events can be interpreted in the framework of sub-$M_{\rm Ch}$ mass white dwarf (WD) explosion scenario. In this context, the SN Ia LC decline rate serves as an effective gauge of the age of the progenitor population. On the other hand, it is demonstrated how the mentioned dynamical features of host galaxies affect the distributions of CC SNe.

Relevance and motivation

The spatial distribution of SNe within host galaxies offers significant constraints on the characteristics of their progenitor stars. Much work has been done to determine the nature of SNe progenitors by studying the relations between the properties of SNe and characteristics of galaxies in which they are discovered. However, specific and much detailed investigations regarding the influence of spiral DWs and stellar bars on the distribution of star formation from the perspective of SNe have not been conducted. Furthermore, the dynamical ages of these structural features have not been clearly explored within the context of the diverse nature of SN progenitors. Here, we intend to fill this gap and perform relevant studies in the field.

Aim of the thesis

The central aim of this thesis is to scrutinize the spectral and photometric properties of Type Ia and CC SNe and establish connections with the properties of their host stellar populations, specifically focusing on dynamical ages of the different structural components within galaxies. This exploration seeks to provide additional important constraints on the nature of the SNe progenitors.

Novelty of the work

For the first time

- We present an analysis of the impact of bars and bulges on the radial distributions of the different types of SNe in the stellar discs of host galaxies with various morphologies.
- We perform a comparative analysis of the locations and LC decline rates of normal and peculiar SNe Ia in the SFDs and beyond.
- We present an analysis of the impact of spiral DWs on the radial and surface density distributions of SNe in host galaxies with different arm classes.
- We analyse the distribution of SNe Ia relative to spiral arms of their host galaxies and study their LC decline rates.

Main points of defence

- The impact of bars and bulges on the radial distribution of SNe in disc galaxies are studied.
- The radial distributions of SNe in different morphological types of host galaxies are studied.
- In grand design (GD) galaxies the impact of spiral DWs on the distribution of SNe are obtained.
- SN Ia progenitors are constrained by their locations relative to spiral arms.
- Different correlations between SN Ia distances from the spiral arms, their galactocentric radii, and SN LC decline rates are demonstrated.

Structure of the thesis

The dissertation consists of

- Introduction
- Chapter 1 “The impact of bars and bulges on the radial distribution of supernovae in disc galaxies”
- Chapter 2 “Type Ia supernovae in the star formation deserts of spiral host galaxies”
- Chapter 3 “The impact of spiral density waves on the distribution of supernovae”
- Chapter 3 “Constraining Type Ia supernovae via their distances from spiral arms”
- Conclusions
- Bibliography

The thesis contains 114 pages, including 23 figures and 21 tables.

Content of the thesis

In the Introduction, the scheme of SN classification, their spectral and photometric properties, explosion models of SNe progenitors are discussed. The nature of SNe progenitors by studying the relations between the properties of SNe and the impact of dynamical features of galaxies in which they are discovered are analysed. The chapters of the thesis are outlined below, detailing their content.

Chapter 1

In the first chapter, we study the possible influence of bars and bulges on the SNe distributions through an analysis of the radial distributions of different types of SNe in discs of host galaxies with various morphological types. We use a well-defined sample of 500 nearby (≤ 100 Mpc) SNe and their low-inclined ($i \leq 60^{\circ}$) and morphologically non-disturbed S0–Sm host galaxies from the Sloan Digital Sky Survey (SDSS).

The results obtained in this chapter are explained by the distinct distributions of massive stars in the discs of early- and late-type spirals and summarized below. We found that in Sa–Sm galaxies, all CC and the vast majority of Type Ia SNe belong to the disc, rather than the bulge component. The result suggests that the rate of SNe Ia in spiral galaxies is dominated by a relatively young/intermediate progenitor population. This observational fact makes the deprojection of galactocentric radii of both types of SNe a key point in the statistical studies of their distributions. We performed two-sample KS and AD tests to compare the radial distribution of SNe Ia in S0–S0/a galaxies with their distribution in Sa–Sm hosts. *P*-values of KS and AD tests show that they are significantly different, which is probably due to the contribution of the outer bulge SNe Ia in S0–S0/a galaxies (see left panel of Fig. 1). These results confirm that the old bulges of Sa–Sm galaxies are not significant producers of Type Ia SNe, while the bulge populations are significant for SNe Ia only in S0–S0/a galaxies.

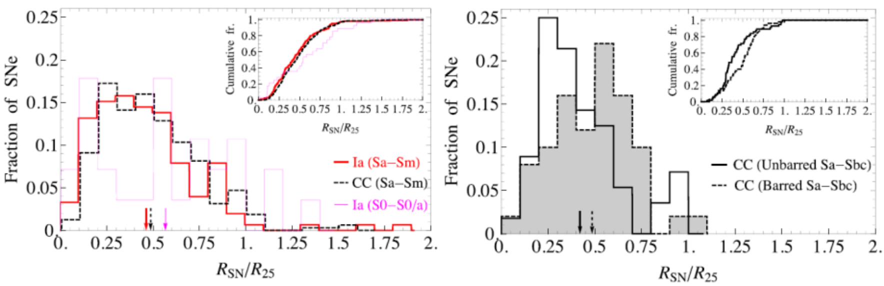

Figure 1. Left panel: *Distributions of deprojected and normalized galactocentric radii (R_{SN}/R_{25}) of Type Ia SNe in S0–S0/a and Sa–Sm hosts, as well as CC SNe in Sa–Sm galaxies.* Right panel: *The distributions of CC SNe in unbarred Sa–Sbc and Sc–Sm galaxies.The insets present the cumulative distributions of SNe. The mean values of the distributions are* shown by arrows.

We found, that the radial distribution of CC SNe in barred Sa–Sbc galaxies is not consistent with that of unbarred Sa–Sbc hosts. (see right panel of Fig. 1). We propose that the additional mechanism shaping the distributions of Type Ia and CC SNe can be explained within the framework of substantial suppression of massive star formation in the radial range swept by strong bars, particularly in early-type spirals. On the other hand, the radial distribution of CC SNe in unbarred Sa–Sbc galaxies is more centrally peaked and inconsistent with that in unbarred Sc–Sm hosts. The result can be well explained by the distinct distributions of massive stars in the discs of early- and late-type spirals.

Chapter 2

In the second chapter, with the aim of linking the Δm_{15} of SN Ia with the progenitor age, the SN decline rates that exploded in SFDs and other regions of hosts are studied. In addition, the SN galactocentric distances between the spectroscopic subclasses is compared, and the possible correlations between the Δm_{15} and galactocentric distances are checked. To accomplish this, a simple visual classification approach based on the UV/Hα images of the discs of host galaxies are presented. The SFDs are observed in some barred Sa–Scd galaxies, therefore the morphologies of SNe hosts are restricted to the mentioned types, with barred and unbarred counterparts. Host galaxies with strong morphological disturbances are also ignored, which may add undesirable projection effects, and complicate the assignment of an SN Ia to the SFD. It should be noted that, because of the absorption and projection effects in the discs, the SFDs are observed in some spiral galaxies only with low/moderate inclinations. Therefore, host galaxy sample in this Chapter is also limited to inclinations $i < 70^{\circ}$.

Table 1 . Comparison of the B-band Δm_{15} distributions between normal SNe Ia in different locations

Subsample 1: SN in	$N_{\rm SN}$	$\langle\Delta m_{15}\rangle$	Versus	Subsample 2: SN in	$N_{\rm SN}$	$\langle\Delta m_{15}\rangle$	$P_{\rm KS}^{\rm MC}$	$P_{\rm AD}^{\rm MC}$
SFD	12	1.32 ± 0.08	Versus	bar/SF	12	1.07 ± 0.05	**0.005**	**0.020**
SFD	12	1.32 ± 0.08	Versus	outer disc	52	1.13 ± 0.03	**0.009**	**0.029**
bar/SF	12	1.07 ± 0.05	Versus	outer disc	52	1.13 ± 0.03	0.660	0.682
SFD+bar/SF	24	1.20 ± 0.05	Versus	outer disc	52	1.13 ± 0.03	0.445	0.477
Inner class i disc	17	1.19 ± 0.05	Versus	outer class i disc	58	1.11 ± 0.02	0.517	0.253

Notes. Since, the $\langle\tilde{r}_{\rm dem}\rangle = 0.30$ for class *ii–iv* discs, we define inner and outer class *i* discs when $\tilde{r}_{\rm SN} < 0.30$ and ≥ 0.30, respectively.

To link the LC properties of SN Ia with the progenitor age from the perspective of the dynamical age constrain of SFD the Δm_{15} distribution of normal SNe Ia in the SFD with that in the bar/SF is compared. The KS and AD tests show that these distributions are significantly different (see Table 1). Fig. 2 and Table 1 show that the Δm_{15} distribution of normal SNe Ia that are in the outer disc population is consistent with that in the bar/SF and inconsistent with that in the SFD. Normal SNe Ia that are in the SFD, dominated by the old population (>2Gyr) have, on average, faster declining LCs compared to those located in the bar/SF, where UV/Hα fluxes are observed (i.e. age ≲ a few 100 Myr).

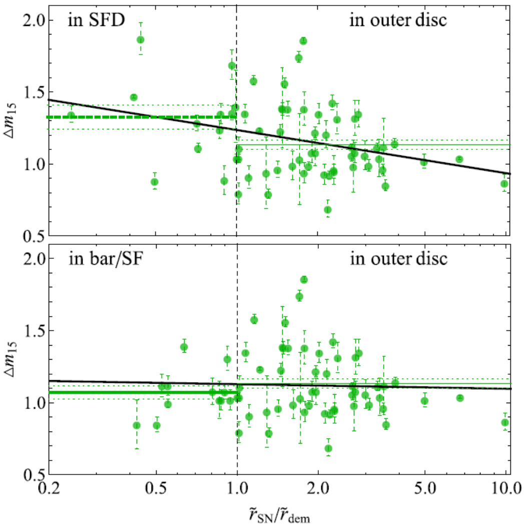

Figure 2. *Variation of the Δm_{15} as a function of r_{dem}-normalized galactocentric distance, split between different SN locations. The best fits are shown by thick (black) solid lines. The vertical dashed line indicates the location of radial demarcation (see the text for details). Themean values (with standard errors) of the distributions are shown by arrows (with error bars) in the upper panel, and by horizontal lines in the bottom panel.*

The SFD phenomenon gives an excellent possibility to separate a subpopulation of SN Ia progenitors with ages older than a few Gyr. We show, for the first time, that the SFDs contain mostly faster declining SNe Ia (Δm_{15} > 1.25). For the galaxies without SFDs, the region within the bar radius, and outer disc contain mostly slower declining SNe Ia.

Chapter 3

The third chapter is devoted to analyse the impact of spiral DWs on the radial and surface density distributions of SNe in host galaxies with different arm classes (AC). All barred galaxies are excluded from this sample to eliminate the effect of substantial suppression of massive star formation in the radial range swept by strong bars, i.e. the observed suppression of CC SN numbers inside the bar radius, and study only the expected impact of the DWs on the distribution of SNe. ACs according to the flocculence, regularity, and shapes of the spiral arms are assigned. The SDSS three-colour images representing examples of SN host galaxies with different ACs can be found in fig. 1 of Chapter 3 of the thesis. Host galaxies with strong morphological disturbances are also removed which may add significant distortion into the SN distribution in discs of galaxies. A well-defined sample of 269 relatively nearby, low-inclination, morphologically non-disturbed and unbarred Sa–Sc galaxies from the SDSS, hosting 333 SNe is used for this study.

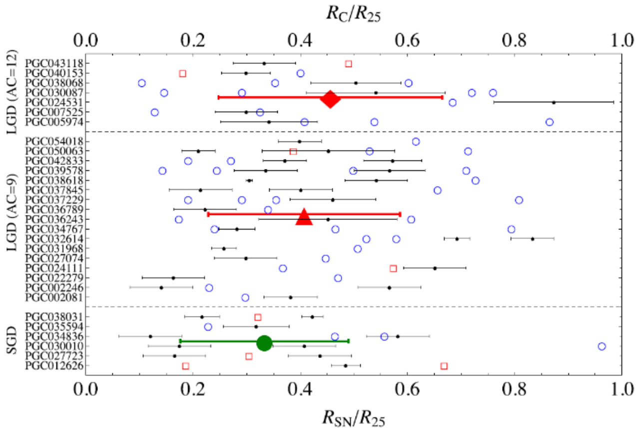

Figure 3. *Galactocentric positions of normalized corotation radii (black points) and their errors for host galaxies. SGD, LGD, and LGD galaxies are separated by horizontal dashed lines. The filled diamond, triangle, and circle are the corresponding mean values of the corotation radii (with their standard deviations). For each host galaxy, galactocentric positions of Type Ia (red empty squares) and CC (blue empty circles) SNe are also presented.*

To study the distribution of SNe relative to corotation radii (R_C) of hosts, an extensive literature search for corotation radii of short-armed grand-design (SGD) and long-armed grand-design (LGD) galaxies are carried out. Only 30 nearby host galaxies ($\lesssim$ 80 Mpc) with 8 Type Ia and 48 CC SNe have available corotation radii (see Fig. 3). The mean value of normalized corotation radii and the standard deviation for the united LGD (AC = 9 and 12) subsample is 0.42 ± 0.18.

Only for CC SNe, a significant difference appears when comparing their R_{25}-normalized radial distributions in LGD versus non-GD (NGD) hosts, with that in LGD galaxies being marginally inconsistent with an exponential profile, while SNe Ia exhibit exponential surface density profiles regardless of the arm class.

To check the possible impact of DWs on the distribution of SNe we now normalize the SN radii to the corresponding corotation radii of host galaxies. When a host galaxy has two corotation radii we use a proximity criterion, selecting only the value of R_C that is closest to the value of R_{SN}. Although not statistically significant, the high CC SNe surface density just inside and outside corotation may be the sign of triggered massive star formation by the DWs (see Fig. 4).

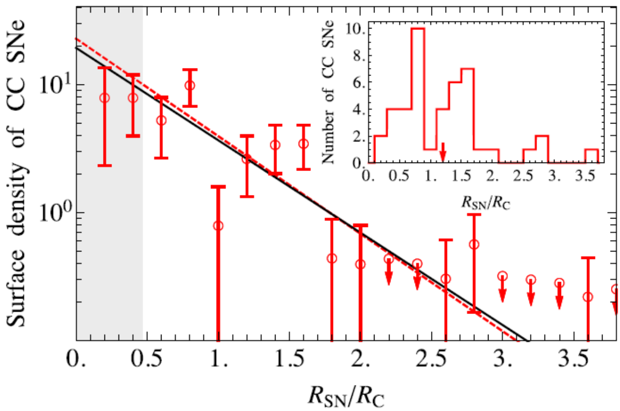

Figure 4. *Surface density profile of CC SNe (with arbitrary normalization) in LGD host galaxies. The error bars assume a Poisson distribution. The upper limits of surface density (with +1 SN if none is found) are represented by down arrows. The black solid and red dashed lines are the best maximumlikelihood fits of global and inner-truncated (from 0.48 corotation radii outwards to avoid the obscured inner region [grey shaded]) exponential surface density models, respectively. The inset presents the histogram of SN radii (the mean value is shown by arrow).*

Results, which obtained in this chapter, may, if confirmed with larger samples, support the large-scale shock scenario induced by spiral DWs in GD galaxies, which predicts a higher star formation efficiency around the shock fronts, avoiding the corotation region.

Chapter 4

Chapter four is devoted to analysis of the distribution of SNe Ia relative to spiral arms of their host galaxies, using our original measurements of the SN distances from the nearby arms, and study their LC decline rates. The database of this Chapter consists of nearby SNe Ia with known spectroscopicaly normal, 91T-, and 91bg-like SN Ia subclasses and Δm_{15} values. Host galaxies are restricted to Sab–Scd morphologies since we are interested in studying SNe Ia in galaxies with well-developed arms, where spiral DWs play an important role. The hosts with interacting and merging attributes were excluded from the sample since we are interested in studying SNe Ia in non-disturbed spiral galaxies. In addition, to avoid projection and absorption effects in the discs due to high inclinations, as well as to accurately investigate the immediate vicinity of SNe in terms of the existence of host spiral arms, the sample is limited to galaxies with $i < 60^{\circ}$. Only 142 SNe Ia in 137 host galaxies met the applied restrictions.

In the bulge + disc subtracted (residual) images of the host galaxies arm and interarm SNe Ia that are discovered inside the host arm edges or in the interarm region are defined, respectively. For each SNe Ia in the subtracted images, the distance from the g-band surface brightness peak of the nearest spiral arm through the galactocentric direction is measured and normalized to the corresponding semi-width of the spiral arm ($\tilde{d}$). Moreover, for each SNe Ia, the distance (D) from the shock front of spiral arm through the galactocentric direction is also measured and normalized to the width of the spiral arm ($\widetilde{D}$).

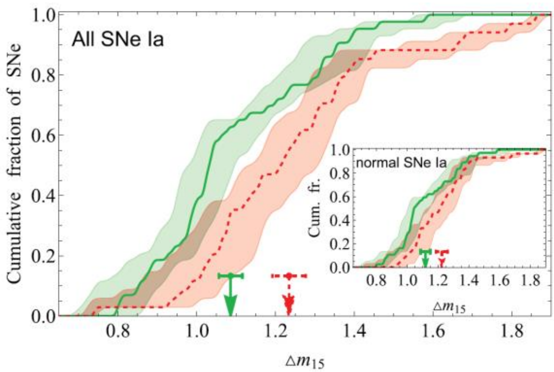

Figure 5. *Cumulative Δm_{15} distributions of all arm (green solid) and interarm SNe Ia (red dashed). The associated spreads for each cumulative curve are shown by coloured regions, taking into account the uncertainty in Δm_{15} values. Arrows show the mean values (with their standard errors) of the distributions. The inset is the same but only for normal SNe Ia.*

P-values of KS (0.006) and AD (0.005) tests indicate that the Δm_{15} distributions of SNe Ia in arm and inter arm regions are significantly different. The same result was obtained for normal SNe Ia (with only barely AD test 0.075 significance): the Δm_{15} values of arm SNe Ia are, on average, smaller (slower declining LCs) in comparison with those of interarm SNe Ia (faster declining LCs).

Then, we analyse continuous parameter distributions, such as the galactocentric radii of SNe and their distances from the host spiral arm, and relate them with SN LC decline rates. The relation between the normalized distances ($\tilde{d}$) of SNe Ia from the arm peak and their deprojected and normalized galactocentric distances r_{SN} are shown in the left panel of Fig. 5.

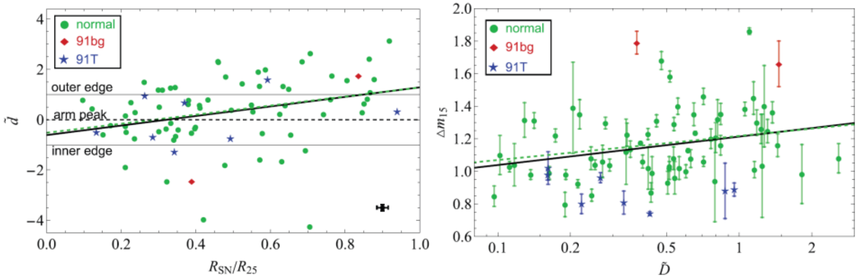

Figure 5. Left panel:*Distribution of the distances of SNe Ia relative to the peaks of spiral arms versus the deprojected and normalized galactocentric distance. The inner and outer edges (solid lines), as well the peak of spiral arm (dashed line) are shown by parallel lines. The best fits for all and normal SN subclass are presented by the solid- and dashed-thick lines, respectively. The error bars in the bottom-right corner display the typical measurement errors.* Right panel: Distributions of Δm_{15} values of SNe Ia versus $\widetilde{D}$ distances from the shock fronts of host spiral arms. The best fits for all and normal SN subclass are presented by the solid- and dashed-thick lines, respectively.

There is a positive trend between the parameters, as shown by the fit line to the data. The *Spearman's* (ρ) *rank* test indicates that this trend is statistically significant for all (P_s^{MC}=0.003) and normal (P_s^{MC}=0.002) SNe Ia samples. The fit line to the distances of SNe Ia relative to the arm peak intersects with the arm roughly at a value of 0.35 in units of isophotal radii, which is consistent with the averaged value of R_c for seven host galaxies of SNe Ia from our earlier study.

We study the correlations between Δm_{15} values and $\widetilde{D}$ distances from the shock fronts of host spiral arms. The corresponding P_s values (0.011 for all SN Ia, 0.022 for normal type SN Ia) show that there are significant correlations between these parameters. The result enables us to draw the conclusion that, on average, the progenitors of SNe Ia with smaller Δm_{15} values have shorter lifetimes and thus travelled shorter distances from the shock fronts, i.e. birthplace, in contrast to progenitors with larger values, which have longer lifetimes and thus travelled farther away from the shock fronts.

The results obtained in Chapter 4 can be interpreted within the frameworks of DW theory, where SN progenitors were born around shock fronts of spiral arms and migrate crossing the spiral pattern to the explosion sites, and WD explosion models with sub-M_{Ch}, where SN LC decline rate is an indicator of progenitor age.

Conclusions

The most significant conclusions are listed:

1. In Sa–Sm galaxies, all CC and the vast majority of Type Ia SNe belong to the disc, rather than the bulge component. The result suggests that the rate of SNe Ia in spiral galaxies is dominated by a relatively young/intermediate progenitor population. This observational fact makes the deprojection of galactocentric radii of both types of SNe a key point in the statistical studies of their distributions.
2. The radial distribution of Type Ia SNe in S0–S0/a galaxies is inconsistent with that in Sa-Sm hosts. This inconsistency is mostly attributed to the contribution by SNe Ia in the outer bulges of S0–S0/a galaxies. In these hosts, the relative fraction of bulge to disc SNe Ia is probably changed in comparison with that in Sa–Sm hosts, because the progenitor population from the discs of S0–S0/a galaxies should be much lower due to the lower number of young/intermediate stellar populations.
3. The radial distribution of CC SNe in barred Sa–Sbc galaxies is not consistent with that of unbarred Sa–Sbc hosts, while for Type Ia SNe the distributions are not significantly different. At the same time, the radial distributions of both Type Ia and CC SNe in Sc–Sm galaxies are not affected by bars. These results are explained by a substantial suppression of massive star formation in the radial range swept by strong bars of early-type barred galaxies.
4. The radial distribution of CC SNe in unbarred Sa–Sbc galaxies is more centrally peaked and inconsistent with that in unbarred Sc–Sm hosts. On the other hand, the radial distribution of Type Ia SNe in unbarred galaxies is not affected by host morphology. These results can be well explained by the distinct distributions of massive stars in the discs of early- and late-type spirals. In unbarred Sa–Sbc galaxies, star formation is more concentrated to the inner regions (Hα emission outside the nucleus) and should thus be responsible for the observed radial distribution of CC SNe.
5. The radial distribution of CC SNe, in contrast to Type Ia SNe, is inconsistent with the exponential surface density profile, because of the central ($\tilde{r} \lesssim 0.2$) deficit of SNe. However, in the $\tilde{r} \in [0.2;\infty)$ range, the inconsistency vanishes for CC SNe in most of the subsamples of spiral galaxies. In the inner-truncated disc, only the radial distribution of CC SNe in barred early-type spirals is inconsistent with an exponential surface density profile, which appears to be caused by the impact of bars on the radial distribution of CC SNe.

6. In the inner regions of non-disturbed spiral hosts, we do not detect a relative deficiency of Type Ia SNe with respect to CC, contrary to what was found by other authors, who had explained this by possibly stronger dust extinction for Type Ia than for CC SNe. Instead, the radial distributions of both types of SNe are similar in all the subsamples of Sa–Sbc and Sc–Sm galaxies, which supports the idea that the relative increase of CC SNe in the inner regions of spirals found by the other authors is most probably due to the central excess of CC SNe in disturbed galaxies.
7. As was found in earlier studies, the physical explanation for the more concentrated distribution of SNe Ibc with respect to SNe II in non-disturbed and unbarred spiral galaxies is that SNe Ibc arise from more metal-rich environments. The radial distributions of Types Ib and Ic SNe are sufficiently similar that the KS and AD tests fail to distinguish them with statistical significance.
8. As in earlier studies, we confirm that in the stacked spiral disc, the Δm_{15} of SNe Ia do not correlate with their galactocentric radii, and such disc is outnumbered by slower declining/prompt events.
9. For the first time, we demonstrate that from the perspective of the dynamical timescale of the SFD, its old stellar population ($\gtrsim$2 Gyr) hosts mostly faster declining SNe Ia (Δm_{15} > 1.25). By linking the LC decline rate and progenitor age, we show that the SFD phenomenon gives an excellent possibility to constrain the nature of SNe Ia.
10. We find no statistical differences between the pairs of the R_{25}-normalized radial distributions of Type Ia and CC SNe in discs of host galaxies with different spiral ACs, with only one significant exception: CC SNe in LGD and NGD galaxies have significantly different radius distributions. The radial distribution of CC SNe in NGDs is concentrated to the centre of galaxies with relatively narrow peak and fast exponential decline at the outer region, while the distribution of CC SNe in LGD galaxies has a broader peak, shifted to the outer region of the discs.
11. The surface density distributions of Type Ia and CC SNe in most of the subsamples are consistent with the exponential profiles. Only the distribution of CC SNe in LGD galaxies appears to be inconsistent with an exponential profile for the AD statistic but only very marginally so for the KS statistic), being marginally higher at $0.4 \lesssim R_{SN}/R_{25} \lesssim 0.7$. The inconsistency becomes more evident when comparing the same distribution with the scaled exponential profile of CC SNe in NGD galaxies.
12. Using a smaller sample of LGD galaxies with estimated corotation radii, we show, for the first time, that the surface density distribution of CC SNe shows a dip at corotation, and enhancements $^{+0.5}_{-0.2}$ corotation radii around it. The CC SNe enhancements around

corotation may, if confirmed with larger samples, indicate that massive star formation is triggered by the DWs in LGD host galaxies. Considering that the different LGD host galaxies have various corotation radii distributed around the mean value of $\langle R_C/R_{25} \rangle$ = 0.42 ± 0.18, the radii of triggered star formation by DWs are most probably blurred within a radial region including $\sim$ 0.4 to $\sim$ 0.7 range in units of R_{25}, without a prominent drop in the mean corotation region.

13. In Sab–Scd galaxies, the Δm_{15} values of arm SNe Ia are typically smaller (slower declining) than those of interarm SNe Ia (faster declining).

14. The SN distances from the spiral arms and their galactocentric radii are correlated: before and after the average corotation radius, SNe Ia are located near the inner and outer edges (shock fronts) of spiral arms.

15. For the first time, we find a correlation between Δm_{15} values and the SN distances from the shock fronts of the arms. The results can be interpreted within the frameworks of DW theory, where SN progenitors were born around shock fronts of spiral arms and migrate crossing the spiral pattern to the explosion sites, and WD explosion models with sub-M_{Ch}, where SN LC decline rate is an indicator of progenitor age. On average, the progenitors of SNe Ia with smaller Δm_{15} values have shorter lifetimes and thus traveled shorter distances from the shock fronts, i.e. birthplace, in contrast to progenitors with larger Δm_{15} values, which have longer lifetimes and thus traveled farther away from the shock fronts.

Publications list

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- Hakobyan A.A., **Karapetyan A.G.**, Barkhudaryan L.V., Gevorgyan M.H., Adibekyan V., *“Type Ia supernovae in the star formation deserts of spiral host galaxies”*, Monthly Notices of the Royal Astronomical Society: Letters, 2021, Volume 505, Issue 1, pp. L52-L57.
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Կարապետյան Արփինե Գրիգորի

Գերնորերի և դրանց մայր գալակտիկաների դինամիկական հատկությունների ուսումնասիրություն

Ամփոփագիր

Ատենախոսությունը նվիրված է Գերնոր աստղերի (ԳԱ) և դրանց մայր գալակտիկաների դինամիկական հատկությունների ուսումնասիրությանը: Որպեսզի սահմանափակումներ դրվեն նախագերնոր աստղերի բնույթի վրա, ուսումնասիրվել են Ia դասի և միջուկի կոլապսով (ՄԿ) պայմանավորված ԳԱ-երի սպեկտրային/լուսաչափական հատկությունները և դրանց մայր գալակտիկաների աստղային բնակչության հատկությունների հետ կապերը՝ առանձնահատուկ կենտրոնանալով գալակտիկաներում դինամիկական տարիքների վրա:

Մասնավորապես ուսումնասիրվել է տարբեր ձևաբանություն ունեցող մայր գալակտիկաների սկավառակներում տարբեր ենթադասերի ԳԱ-երի շառավղային բաշխումների վրա բալջերի և ձողերի (bar) ազդեցությունը՝ օգտագործելով մոտ Տիեզերքում գտնվող 500 ԳԱ-երի և դրանց S0–Sm մայր գալակտիկաների լավ կազմված ընտրանք: Ավելին՝ հիմնվելով մայր գալակտիկաների UV/Hα պատկերների վրա, որոնցում հայտնաբերվել են 185 Ia դասի ԳԱ-եր, ներկայացված է վիզուալ դասակարգման մեթոդ, որպեսզի իրականացվի նորմալ և պեկուլյան ԳԱ-երի դիրքերի և պայծառության կորերի անկման տեմպերի (Δm_{15}) համեմատական ուսումնասիրություն, որոնք գտնվում են աստղառաջացման անապատներում (SFD) և դրանցից դուրս:

Մյուս կողմից, սահմանափակումներ են դրվել նախագերնոր աստղերի բնույթի վրա մայր գալակտիկաների դինամիկական հատկությունների տեսանկյունից՝ ուսումնասիրելով դրանց պարուրաձև կառուցվածքը:

Ուսումնասիրվել է պարուրաձև խտության ալիքների ազդեցությունը 333 ԳԱ-երի շառավղային և մակերևութային բաշխումների վրա, որոնք գտնվում են համեմատաբար մոտ, փոքր թեքվածությամբ, չձևախեղված և առանց ձող 269 գալակտիկաներում: Ավելին, օգտագործելով պարուրաթևի նկատմամբ 77 Ia դասի ԳԱ-երի հեռավորությունների մեր օրիգինալ չափումները, հետազոտվել են թևի նկատմամբ ԳԱ-երի բաշխումները: Ուսումնասիրվել է նաև Ia ԳԱ-երի պայծառության կորերի անկման տեմպերը (Δm_{15}):

WOLFRAM MATHEMATICA ծրագրի և Monte Carlo սիմուլյացիաների կիրառմամբ օգտագործվել են Kolmogorov-Smirnov և Anderson-Darling վիճակագրական թեստերը, որպեսզի իրականացվեն բազմաթիվ համեմատություններ տարբեր ենթաընտրանքների քանակների, պարամետրերի միջև: Ավելին, որպեսզի ուսումնասիրվի հնարավոր կորելյացիաները ԳԱ-երի ֆիզիկական հատկությունների և դրանց մայր գալակտիկաների միջև, օգտագործվել է Spearman’s rank թեստը:

Ատենախոսության մեջ ստացված արդյունքները տվել են հիանալի հնարավորություն սահմանափակումներ դնել Ia նախազերնոր աստղերի վրա այն ենթադրությամբ, որ այս օբյեկտները կարող են մեկնաբանվել մինչև 1.4 $M_{\text{Արեգակ}}$ զանգվածով սպիտակ թզուկ աստղի պայթելու մեխանիզմով: Այս համատեքստում Ia ԳԱ-երի պայծառության կորերի անկման տեմպերը հանդիսանում են ծնող աստղային բնակչության տարիքի էֆեկտիվ ցուցիչներ: Նաև, ցույց է տրվել թե ինչպես են մայր գալակտիկաների դինամիկական առանձնահատկությունները ազդում ՄԿ ԳԱ-երի բաշխումների վրա:

Карапетян Арпине Григорьевна

Исследование сверхновых и динамических характеристик их родительских галактик

Резюме

Диссертация посвящена изучению сверхновых звёзд и динамических характеристик их родительских галактик. Для ограничения природы предсверхновых звёзд исследовались спектральные и фотометрические свойства сверхновых типа Ia и с коллапсом ядра (КЯ), и устанавливаются связи с характеристиками их родительских звёздных популяций с особым акцентом на динамическом возрасте структур внутри галактик.

В частности, с использованием чётко определённой выборки из 500 близких сверхновых и их родительских галактик, относящихся к типам S0–Sm, было проанализировано влияние балджов и перемычек на радиальное распределение разных типов сверхновых в звёздных дисках галактик. Более того, на основе UV/Hα изображений дисков галактик, в которых были обнаружены 185 сверхновых типа Ia, представлен простой метод визуальной классификации, который позволяет провести сравнительный анализ местоположения и скорости падения кривых яркостей (Δm_{15}) как нормальных, так и пекулярных сверхновых типа Ia в пустынях звездообразования (SFD) и за их пределами.

С другой стороны, ограничения на свойствах предсверхновых были также рассмотрены с динамической точки зрения, например, при изучении спиральной структуры родительских галактик. Было проанализировано воздействие спиральных волн плотности на распределение радиальной и поверхностной плотности 333 сверхновых, расположенных в относительно близких, с малым

углом наклона плоскости к лучу зрения, морфологически ненарушенных 269 галактиках с различными классами спиральных рукавов и без перемычек. Кроме того, было проанализировано распределение 77 сверхновых Ia относительно спиральных рукавов с использованием наших оригинальных измерений расстояний сверхновых до ближайших рукавов. Изучались также скорости падения кривых яркостей (Δm_{15}) сверхновых.

С помощью программного обеспечения WOLFRAM MATHEMATICA и метода Монте-Карло, для выполнения различных сравнений между свойствами и количеством различных подвыборок использовались известные статистические тесты (Колмогорова-Смирнова и Андерсона-Дарлинга). Более того, для анализа возможных корреляций между физическими свойствами сверхновых и их родительских галактик использовался тест ранговой корреляции Спирмена.

Полученные в этой диссертации результаты предоставляют отличную возможность ограничить природу предсверхновых Ia, предполагая, что эти объекты могут быть интерпретированы в рамках сценария взрыва белого карлика массой ниже массы Чандрасекара (sub-$M_{\rm Ch}$). В этом контексте скорость падения кривой яркости сверхновой Ia служит эффективным индикатором возраста предсверхновой звезды. С другой стороны, показано, как упомянутые динамические характеристики родительских галактик влияют на распределение КЯ сверхновых.