The following sections have been generated by the PI. The total page limit for these sections is 4 × A4 pages (6 × A4 pages for Partnership Proposals). Font size should not be less than 10 points.

15. SCIENTIFIC RATIONALE

This section needs to discuss the scientific background and aims of the proposal and why you want to make these observations. This section should not exceed 1000 words (2000 words for Partnership Proposals). Figures and graphics can be included, or appended in Section 21.

According to the present paradigm acting within the LCDM cosmological model, galaxies form hierarchically, from dwarfs to giants, by consequent mergers. Morphological differences between spheroidal (elliptical, following Hubble's classification scheme) and disk (spiral and lenticular) galaxies are explained in the frame of this paradigm by episodes of smooth pristine gas accretion from their own galactic halos, occuring between the merging events; disk galaxies are those which are caught during these quiescent periods of their lifes. However, in the frame of this classical scenario the giant elliptical galaxies must be the youngest, and dwarf galaxies must be the oldest. In reality, observations demonstrate the opposite trend: the giant early-type galaxies have the oldest stellar populations and have been completely shaped at the epoch before $z = 1$, while the low-luminosity galaxies continues their star formation to the present epoch.

There is common opinion that lenticular galaxies have formed from spirals by quenching star formation in their disks under the environmental influence. The so called Butcher-Oemler (1978) effect – an appearance of blue disk galaxies at the redshift of 0.4 in rich clusters which lack such blue galaxies at $z = 0$ – is treated now as an observational evidence of a rather recent epoch of S0 formation. Since blue (spiral?) disk galaxies are replaced in clusters by red (S0) disk galaxies at $z = 0.4$ (Fasano et al. 2000), or only 4 Gyr ago according to the cosmological timescale in the frame of the LCDM model, then the stellar population of large-scale disks of S0s in present-day clusters must be of intermediate age. Also in the frame of this paradigm we would expect solar magnesium-to-iron ratio in stars of the disks because during 10 Gyr before the transformation continuous star formation in the disks would produce just the solar chemical composition, if we refer to the disks of nearby spiral galaxies.

Dating of morphological transformations of S0s. One possible way to trace the evolution of galaxies is to study in detail the properties of stellar populations in nearby galaxies which can be observed with a very high accuracy. Concerning the problem under consideration, we can determine the present ages of the large-scale stellar disks in nearby S0s and so to date the epoch of star formation quenching, if any took place. We have undertaken deep long-slit spectroscopy of a small sample of nearby S0s over diverse types of environments at the Russian 6m telescope. We have found that 60%±13% of the sample S0s have very old outer disks (see left panel of Fig.1), with the quenching epoch of at least 10 Gyr ago and in addition to that are magnesium-overabundant and were therefore formed over a short period of time (Sil'chenko et al. 2012). Though the sample was very small, only 20 galaxies, we have had a hint on an environmental tendecy in our results: field S0s may have rather young stellar disks, $T_{SSP} \approx 8$ Gyr, while all the galaxies in dense environments, in Virgo cluster and in rich groups, have very old large-scale stellar disks. Similar results were obtained in the frame of multi-band photometry approach by Prochaska Chamberlain et al. (2011) and Roediger et al. (2011). The recent study of the Virgo-cluster S0s by Johnston et al. (2014) has shown that all the S0 galaxies for which they have found the parameters of the disk stellar populations, have old (older than 10 Gyr) and magnesium-overabundant large-scale stellar disks. This fact is in contradiction with the scenario according to which S0s were born in clusters at $z = 0.4$. Following these results, the epoch of S0 formation must be put at $z > 2$, and had therefore to be very short. Keeping it in mind, we would rather prefer to accept the following sequence of evolutionary stages for massive disk galaxies which is indeed observed at high redshifts: brief effective star formation in gas-rich clumpy disks at $z \approx 2$ (Bournaud et al. 2007) and more quiescent secular evolution including bar effects and gas redistribution between the disk and the bulge area at $z < 1$ (Kraljic et al. 2012). By accepting the described evolutionary scenario for disk galaxies, we would expect a dominance of S0-galaxies among disk galaxies between $z = 2$ and $z = 1$, after finishing the epoch of star-forming clumpy disks, and their subsequent morphological evolution completely depending on the external gas accretion regime. If this accretion is smooth and persistent, we would obtain a spiral galaxy with the cold, thin stellar disk and a continuous star formation. If, due to some obstacles, the accretion is absent or sporadic, we would obtain a lenticular galaxy with a smooth, old stellar disk and without regular star formation. Obviously, clusters of galaxies, with their tidal perturbances and hot intracluster medium, are the worst place to sustain smooth accretion of the outer cold gas, which would cause the S0 galaxies, with old stellar disks, to dominate in the clusters at the present epoch.

Environmental effect. It is very important to verify whether the age of S0 disks correlates with the environmental density. The present-day paradigm relates S0 formation by SF quenching in spiral disks to environment effects which are effective only in clusters and rich groups: ram pressure by X-ray gas, gravitational tides from neighbouring galaxies and from the cluster/group potential which are thought to be main agents of gas removal and SF quenching, all act only in dense environments. According to the hierarchical paradigm of the modern cosmology, the clusters and massive groups are the last to assemble their content, so the disks of S0s in clusters must be **the youngest**. If the relation is opposite, as our and other recent results imply, the scenario must be revisited. Presently, we have two S0 samples studied: (1) a sample of ∼20 nearby S0s mostly in loose groups, where two thirds of the disks are older than 10 Gyr, and (2) a sample of 18 completely isolated S0s partly observed with the SALT during three semesters (Katkov, Kniazev, Sil'chenko 2014; KKS2014 thereafter), where the ages of the disks cover homogeneously the range of 1–15 Gyr (see right panel of Fig.1). Now is **the time** to probe another extremity of the environment – southern S0s in clusters.

16. IMMEDIATE OBJECTIVES

This section needs to present the plan of how you will use the data you will gather to achieve the science goals set out above. There is a 250 word limit.

By using **the same method as for the sample of completely isolated SOs**, we plan to obtain long-slit spectra for a sample of nearby S0 galaxies in clusters: in the full spectral range (3700–6900 Å) with medium spectral resolution ($R \sim 1000$). The spectra will be used to derive stellar population ages, metallicities, and magnesium-to-iron ratios by (1) calculating Lick indices along the slit – the method for the RSS with this grating and slit was calibrated by Kniazev & Sil'chenko (2012) and (2) to perform full spectral fitting of the observed spectra, using IDL-based package NBursts from Chilingarian et al. (2007); this method is accurate, it is the only posiible one when strong emission lines contaminate the Balmer absorption lines, but it is inapplicable to the magnesium-overabundant stellar populations. The exposures must be deep enough to reach the outermost disk regions. The proposed sample of the galaxies includes members of 8 southern rich clusters. We have selected 4–7 S0 (according to NED and HyperLEDA) galaxies in every cluster, taking them from the range of absolute magnitudes of $M_B = -18 - -20.5$, therewith making sure that they are not dwarfs, while at the same time not relating to very luminous S0s which may have quite particular origin beyond the common evolutionary paths of disk galaxies (Van den Bergh 1990, Barway et al. 2009).

17. DATA REQUIREMENTS FOR PROPOSAL COMPLETION

This section should explain what (if any) other observations are needed to complete the science objectives. If time is requested for more than one semester, the justification should be here. There is a 100 word limit.

As it was written above, (1) a sample of nearby S0s mostly in loose groups consists of 20 galaxies (Sil'chenko et al. 2012, Sil'chenko 2013); (2) a sample of completely isolated S0s consists of 18 galaxies (KKS2014). For that reason, we would finally like to have the same level of statistic and plan to have deep long-slit data for ∼20 S0s in clusters from our total sample of 48 galaxies in the submitted list.

18. TECHNICAL JUSTIFICATION

This section should be limited to 500 words (1000 words for Partnership Proposals) and needs to clearly demonstrate that you have used the SALT instrument simulation tools to find a configuration which makes sense and matches your science goals, including the S/N required. It needs to verbalize the overall observing strategy and to demonstrate that you understand the overheads involved in the observations and hence a justification of the total time requested.

For the accurate derivation of stellar population ages and metallicities we need **(1)** to cover a spectral

range 4700–5600 Å with a high signal-to-noise (S/N) ratio; **(2)** to have the highest medium spectral resolution ($R > 1000$) to estimate velocity dispersion; and **(3)** to reach a reasonable S/N ratio during a reasonable amount of integration time. All these requirements can be met with the RSS spectrograph at the SALT, using grating GR900 and slit 1.25 arcsec width.
For the accurate derivation of gas kinematics, metallicities, and densities, and also to derive the corrections for the emission-line contamination of the Lick index H-beta by using the H-alpha emission-line equivalent width, we need to cover a spectral range 4300–6750 Å with a moderate signal-to-noise ratio. The RSS simulator allows us to estimate the final S/N$\sim$15 at λ5500 Å for the level $\mu(V) \sim$ 22.0 mag/sq.arcsec (some outer part of the disk) with dark moon conditions, seeing about 2.0–3.0 arcsec, slit width of 1.25 arcsec and exposure times 6×1400sec. We also require observations of spectrophotometric standards, as minimum once per observational set, and a reference spectrum together with flat-fields once per track.
All our previously taken SALT data proves that our selected spectral region and spectral resolution are enough to study the kinematics of stars and gas separately. To derive a statistically significant result we plan to collect data for the sample consisting of 20 galaxies from the nearest clusters. All our clusters with the exception of Abell S0805 have coordinates where the REAL track length is ABOUT 3600s. With one hour track ($\sim$3600s) we can observe each galaxy for about 2×1400sec and therefore we need 3 tracks to reach the requested S/N. For that reason we apply for a total of 216000sec of dark time for this project. All clusters are located in the range of RA = 01h–19h leading to our application for this program as **a long-term program**, where we plan to split the total requested time into two semesters with 108000sec each.

Special notes regarding the TAC remarks:

1. Our requested study is proposed to use **BOTH** methods for the analysis of the obtained data: Lick indices and NBursts analysis in the same style as it **HAS BEEN DONE** before with our previous samples of S0 in other environments. We explain it everywhere in our proposal, and for that reason we do not see ANY room for ANY systematic differences to compare the results for our different samples.
2. Our work with Lick indices does not request any additional long-time calibrations, since this method was **CALIBRATED** for SALT during RSS comissionnig time (Kniazev & Sil'chenko 2012).
3. Our comparison of the results obtained earlier by both methods (Lick indices and NBursts) shows that they produce totally **COMPARABLE** results for S0 galaxies (for example, right panel of Fig.2), and we check it every time for each studied galaxy.
4. Even taking into account the advent of modern methods like NBursts, which used "high-resolution, well calibrated stellar libraries", we need to note here that the **ONLY** Lick indices method gives a possibility to define Mg/Fe ratio.
5. We do not accept the disbelief of the referees expressed concerning the morphological classification of galaxies in NED and HyperLEDA. In any case, every target image is inspected BY EYE to assure ourselves that it is a regular disk galaxy lacking spiral arms, in other words, S0. As for the galaxy mass as a discriminator of its evolution path, we have selected our sample in the absolute-magnitude range of −18 to −20.5 (in B) **TO MATCH THE CORRESPONDING ABSOLUTE-MAGNITUDE RANGES** taken for the samples studied before, namely, for the sample of group S0s and for the sample of isolated S0s, to make the comparison physically motivated. This point has been **already** noted in our previous 2014-1 proposal.

19. ROLE OF THE PI

This section, which is only required if you request time from the South African TAC, should describe the role the PI will have in the project other than proposing and being a co-author on the proposal and the published paper.

This project is a result of long-term collaboration between PI and Prof. Olga Sil'chenko. All spectral data reduction will be done by PI. Lick index measurements and analysis will be done by Prof. Sil'chenko and NBursts analysis will be done with help of her team. The PI is involved in the subsequent data analysis and discussions.

20. REFERENCES

A list of all relevant references.

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H. Butcher, A. Oemler Jr., 1978, ApJ, 219, 18

L.C. Prochaska Chamberlain, et al., 2011, MNRAS, 412, 423

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Chilingarian et al. 2007, IAU Symposium, V.241, 175-176

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K. Kraljic, F. Bournaud, M. Martig, 2012, ApJ, 757, Aid60

S. van den Bergh, 1990, ApJ, 348, 57

H. Butcher, A. Oemler Jr., 1978, ApJ, 226, 559

J.C. Roediger, S. Courteau, L.A. MacArthur, M. McDonald, 2011, MNRAS, 416, 1996

O.K. Sil'chenko, et al., 2012, MNRAS, 427, 790

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Katkov, Kniazev, Sil'chenko 2014, (**KKS2014**) in preparation

Kniazev & Sil'chenko, 2012, SALT report 2202AA0001

Johnston E.J., et al., 2014, MNRAS, 441, 333

21. ADDITIONAL RELEVANT FIGURES AND GRAPHICS

Any additional figures or graphics not already inserted in the text boxes can be placed here, provided the 4 page limit (or 6 page limit for Partnership Proposals) is maintained.

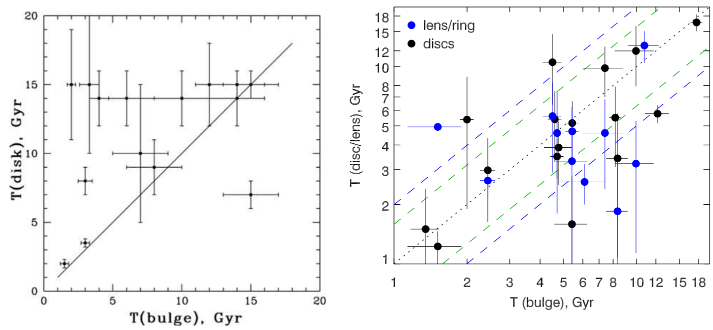

Fig 1: The comparison of the obtained SSP-equivalent ages of the discs and bulges of S0s. The equality straight line is plotted for the reference. *Left panel:* For a sample of nearby S0s in loose groups (Sil'chenko et al. 2012); *Right panel:* For a sample of completely isolated S0s (KKS2014).

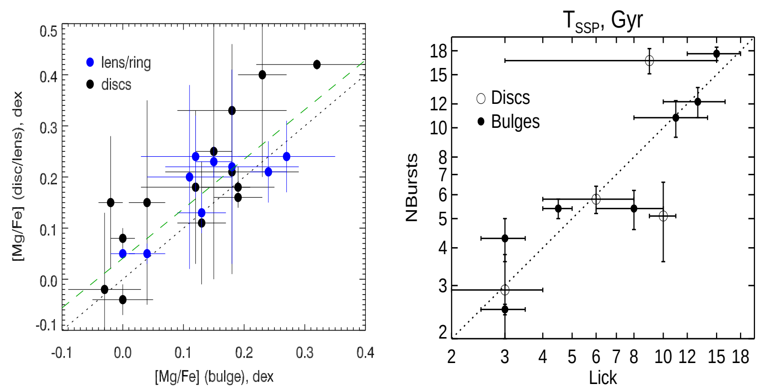

Fig 2: *Left panel:* The comparison of Mg/Fe ratio in the bulges and in the disc structures (could be found **ONLY** with Lick indices method) for S0 galaxies (KKS2014). *Right panel:* The comparison of bulges/disks ages defined with both methods: Lick indices and NBursts package.