Variability of massive stars in IC342 galaxy

Antoniya Valcheva[1]

Co-authors: Nikolay Tikhonov[2], Olga Galazutdinova[2], Olga Sholukhova[2] and Petko Nedialkov[1]

[1] Department of Astronomy, Sofia University, Bulgaria
[2] Special astrophysical observatory, Northern Caucasus, Russia

Main Goals

Program for searching of high luminosity stars beyond the Local Group

- Find massive and luminous star candidates in galaxies beyond the Local group;

- Spectral observation to reveal the true nature;

- Photometric optical monitoring to study optical properties and variability;

- Obtain astrophysical properties – SED, luminosity, effective temperature, mass, size, etc. (to be done).

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- Find massive and luminous star candidates in galaxies beyond the Local group;

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 - Target: IC 342 (d=3.3 Mpc)

    RA(J2000) = 03 46 49.7   DEC(J2000) = +68 05 45

  - Near the equator of the Milky Way's disc => large amount of material - glowing gas and obscuring dust, bright stars.

> 80 luminous and massive stars candidates selected in IC342 on the base of our B+Hα images obtained with the 2m RCC telescope at NAO Rozhen, Bulgaria.

Massive stars candidates

NE part

71

73 74

var73, var74

The slit
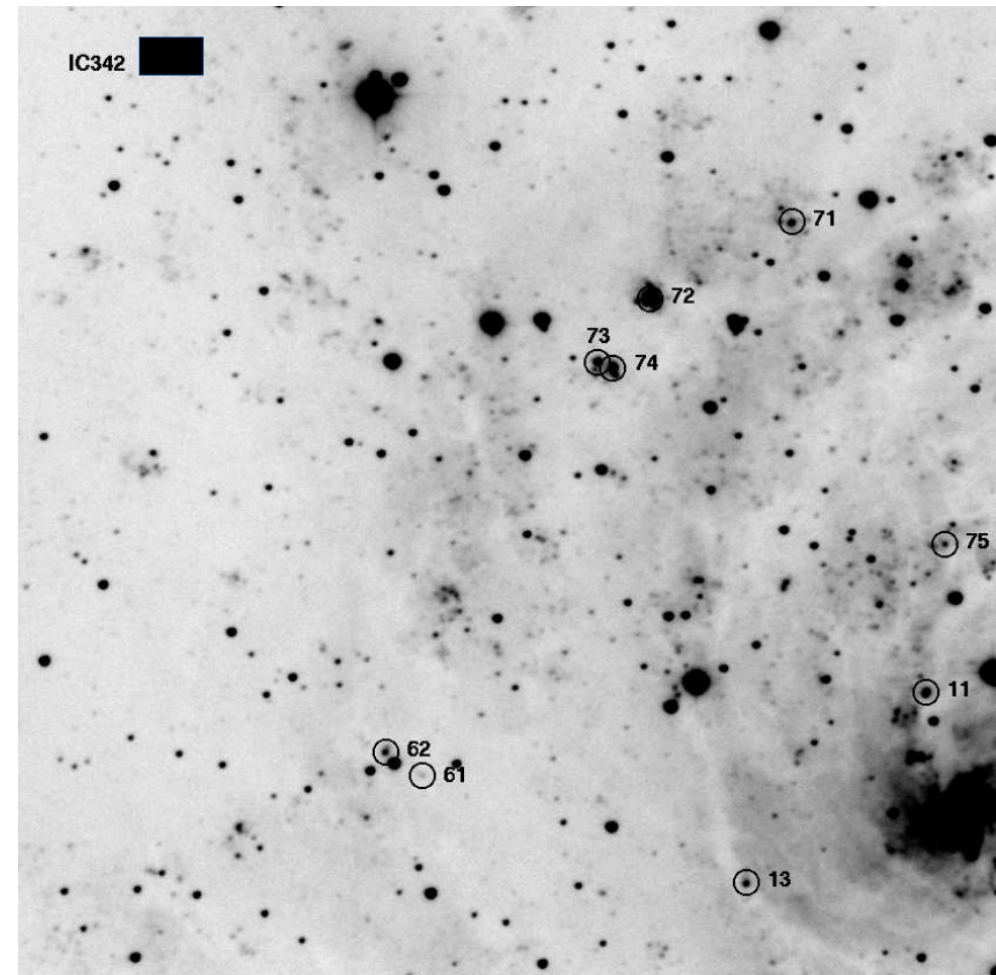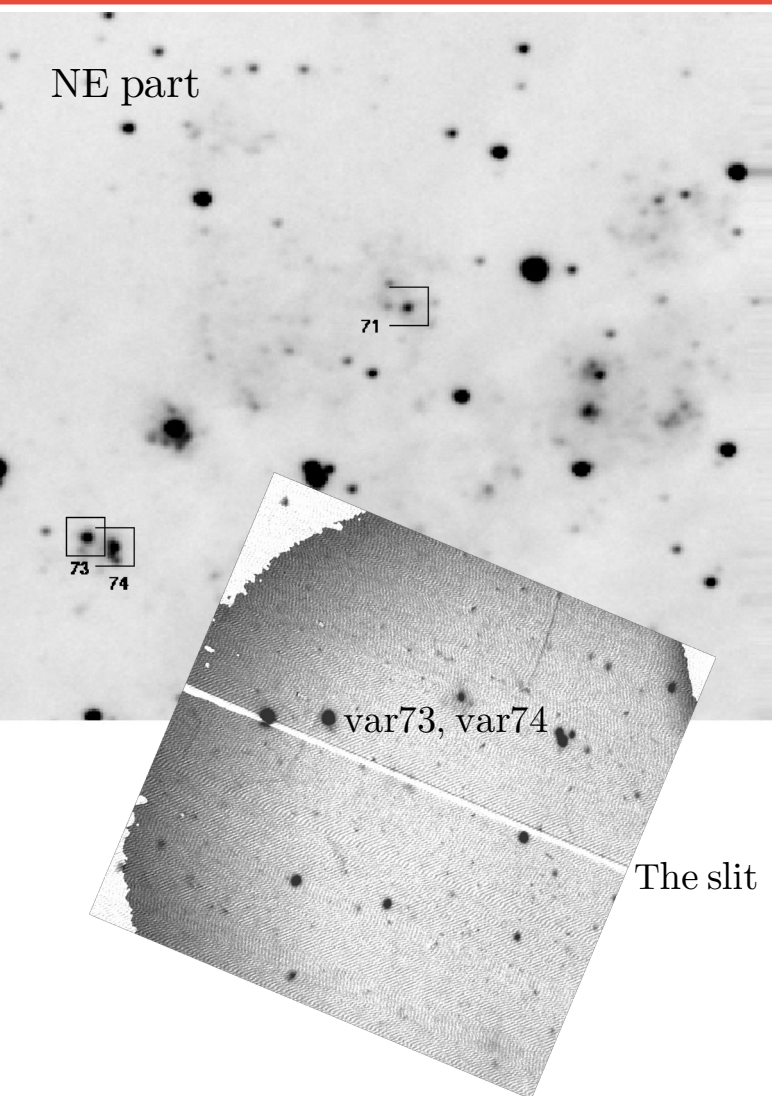
7 massive star candidates selected in a 10′x10′ field in north-east part of IC342 on the base of our B+Hα images obtained with the 2m RCC telescope at NAO Rozhen, Bulgaria.

Spectral confirmation: 05/06 Jan 2021 UW05

DIS B400/R300 4900/6300A slit 0.9″ at 3.5m telescope of Apache point observatory, USA

IC342_71, 3x1200s, sg. 1.4″ clear sky
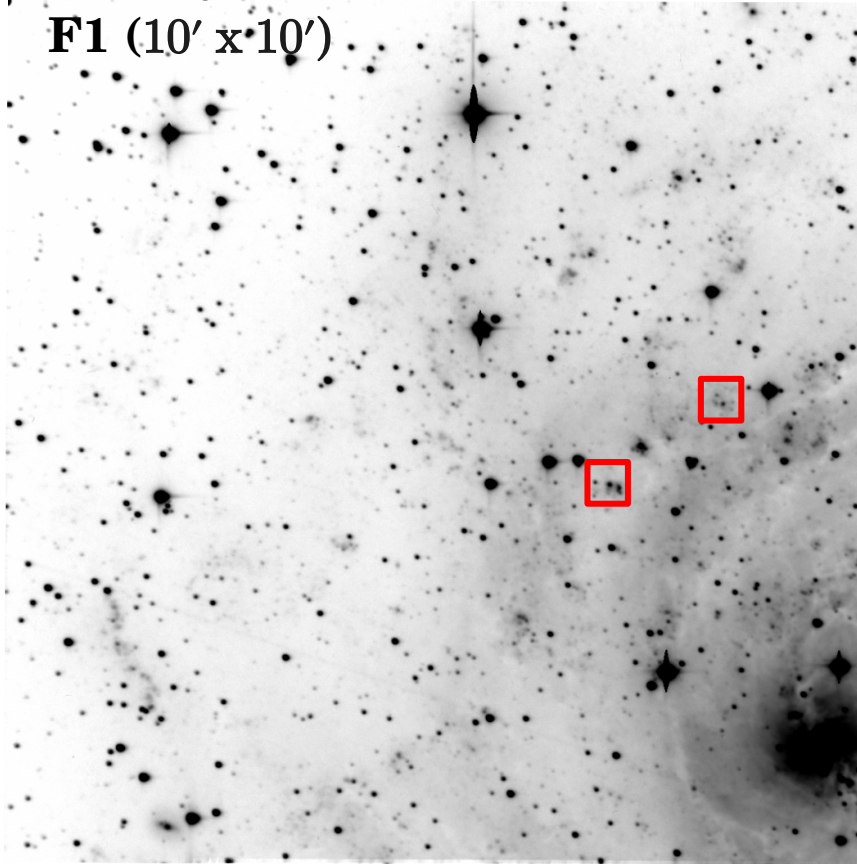IC342_73-74, 3x1200s, sg. 1.4″ clear sky

#71 and #73 spectra contain bright emissions of the surrounding nebula - broad H-alpha line, visible H-beta, neutral helium HeI [6678] with a possible PCyg profile, nitrogen [NII] and Fe lines.

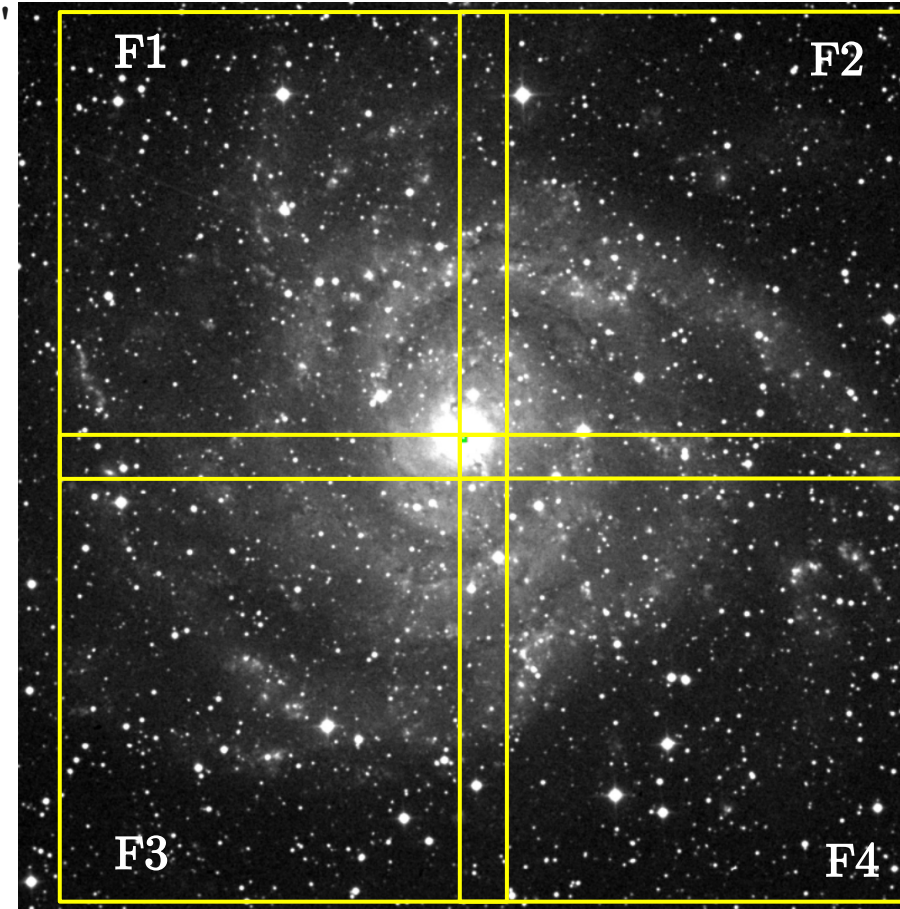* The analysis of the spectral observations will be discussed in different study.

IC 342 with the 2m NAO Rozhen

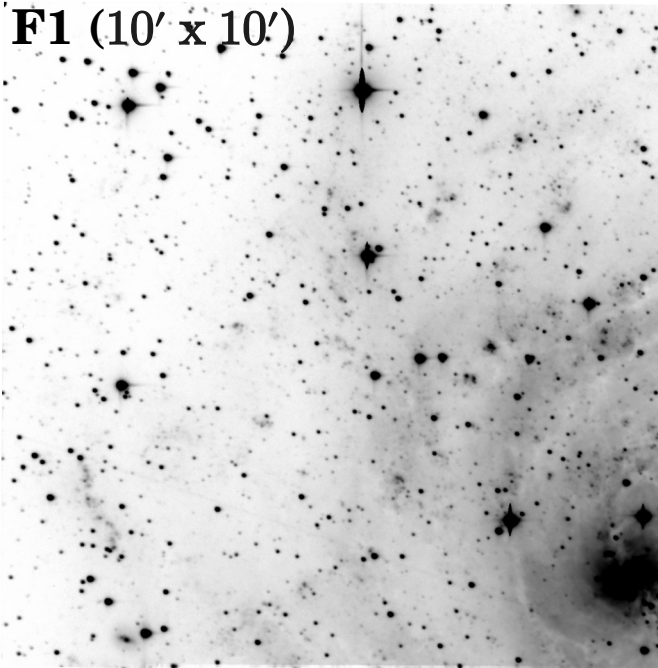Through B-filter
F1 (10′ x 10′)

FoV 21.2'x19.1'

- IC 342 is covered by 4 fields of 10′ x 10′ with the FoReRo2 – a two-channel focal reducer at the 2m telescope at NAO Rozhen, Bulgaria.

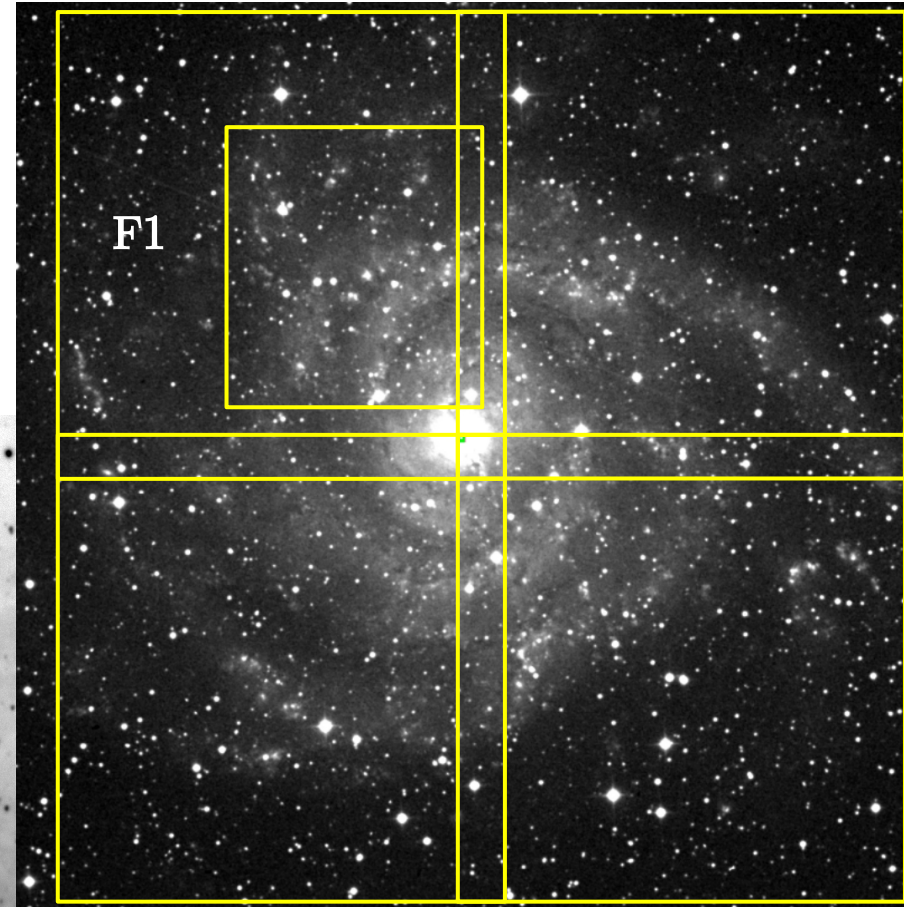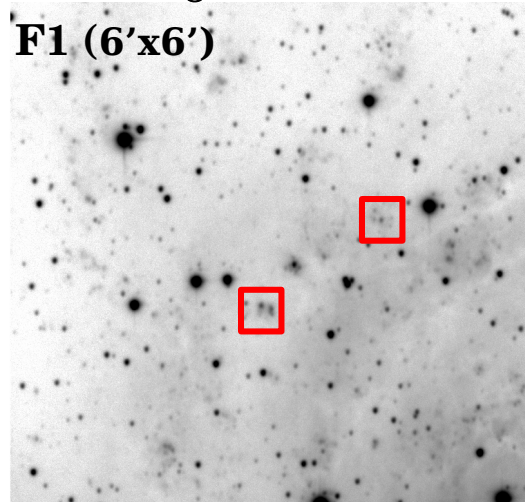# IC 342 with the 2m NAO Rozhen

Through B-filter

F1 (10′ x 10′)

FoV 21.2'x19.1'

Through R-filter

F1 (6′x6′)

F1

- IC 342 is covered by 4 fields of 10′ x 10′ with the FoReRo2 – a two-channel focal reducer at the 2m telescope at NAO Rozhen, Bulgaria.
- Additional observations of the massive stars in the direct focus of the 2m telescope at NAO Rozhen, Bulgaria. The field is covering and aria of 6′ x 6′.

IC 342 with the 2m NAO Rozhen

Observing log

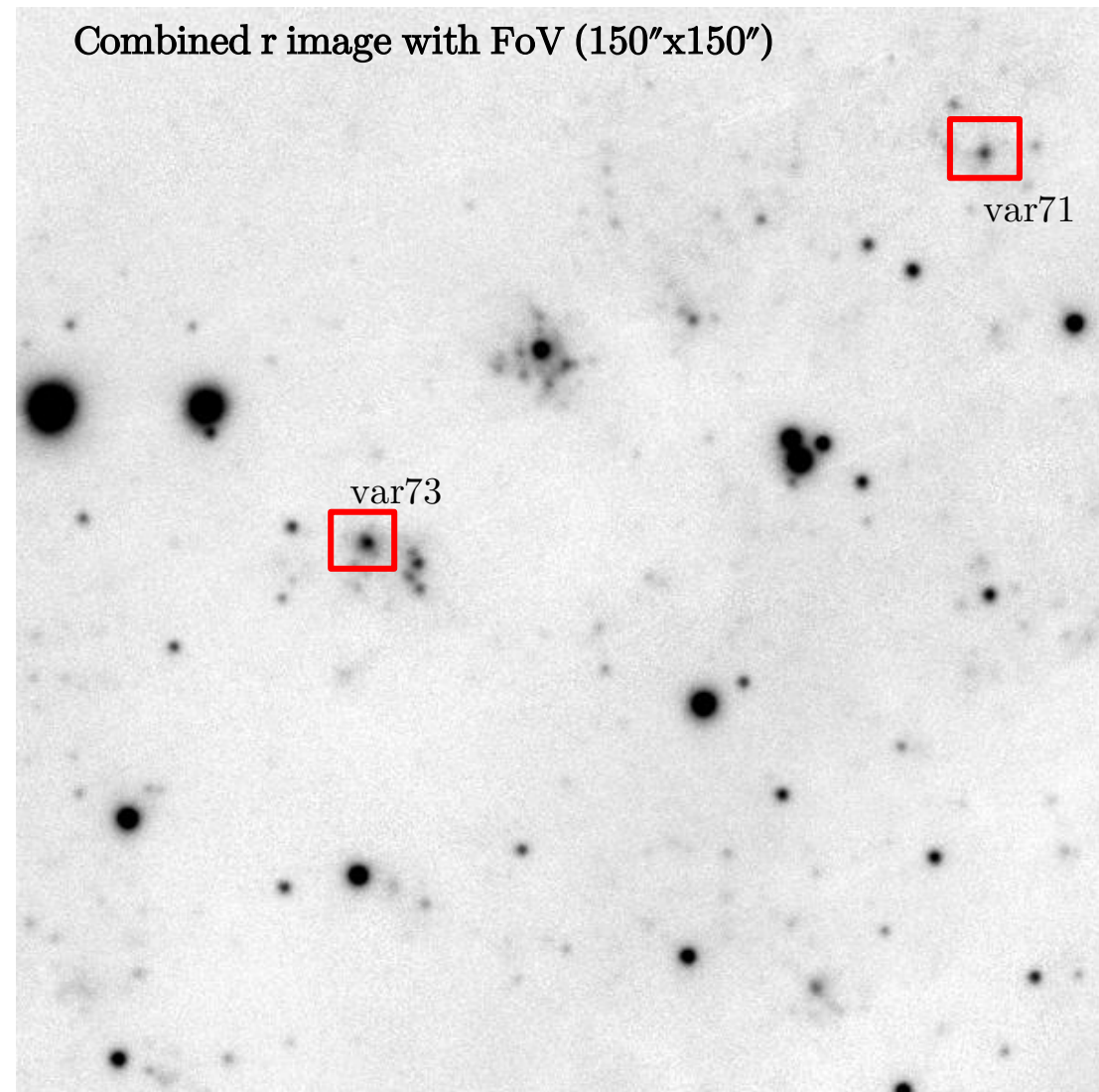| Date	Instrument	FoV	Filter	Exposure	Seeing
28/10/2019	2m/FoReRo2	10′x10′	B	9x300 sec	~1.8″
22/11/2020	2m/FoReRo2	10′x10′	R	5x300 sec	~2.0″
07/08/2021	2m/FoReRo2	10′x10′	B,R	5x300 sec	~ 2.4″
11/09/2021	2m/FoReRo2	10′x10′	B,R	5x300 sec	~ 2.0″
04/01/2022	2m/FoReRo2	10′x10′	B,R	5x300 sec	~3.0″
06/01/2022	2m/FoReRo2	10′x10′	B,R	5x300 sec	~2.5″
27/02/2022	2m/FoReRo2	10′x10′	B,R	5x300 sec	~2.4″
29/06/2022	2m/FoReRo2	10′x10′	B,R	5x300 sec	~2.2″
03/07/2022	2m/Direct	6′x6′	R	5x300 sec	~2.4″
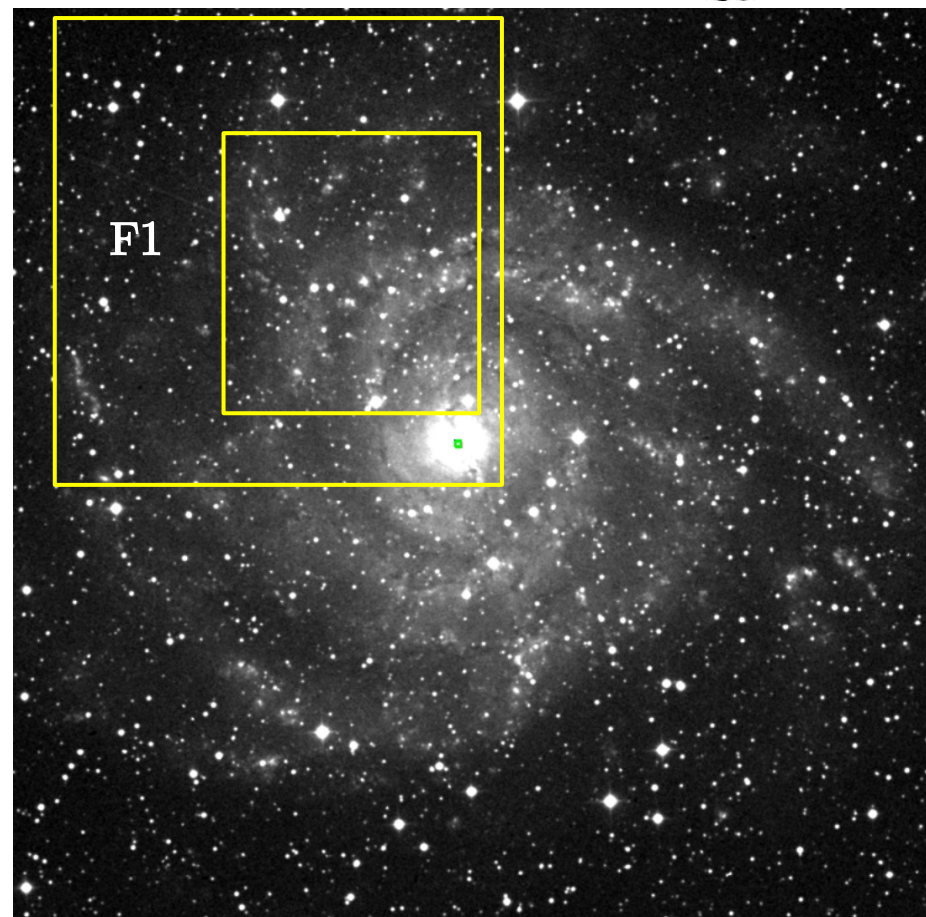
- Time coverage: ~32 months → 9 epochs;
- Initial reduction; alignment; combination = sum;
- PSF photometry of all stars in the field
- Calculated standard magnitudes in gr Pan-STARRS filters using stable stars around the LBVs in PS1.
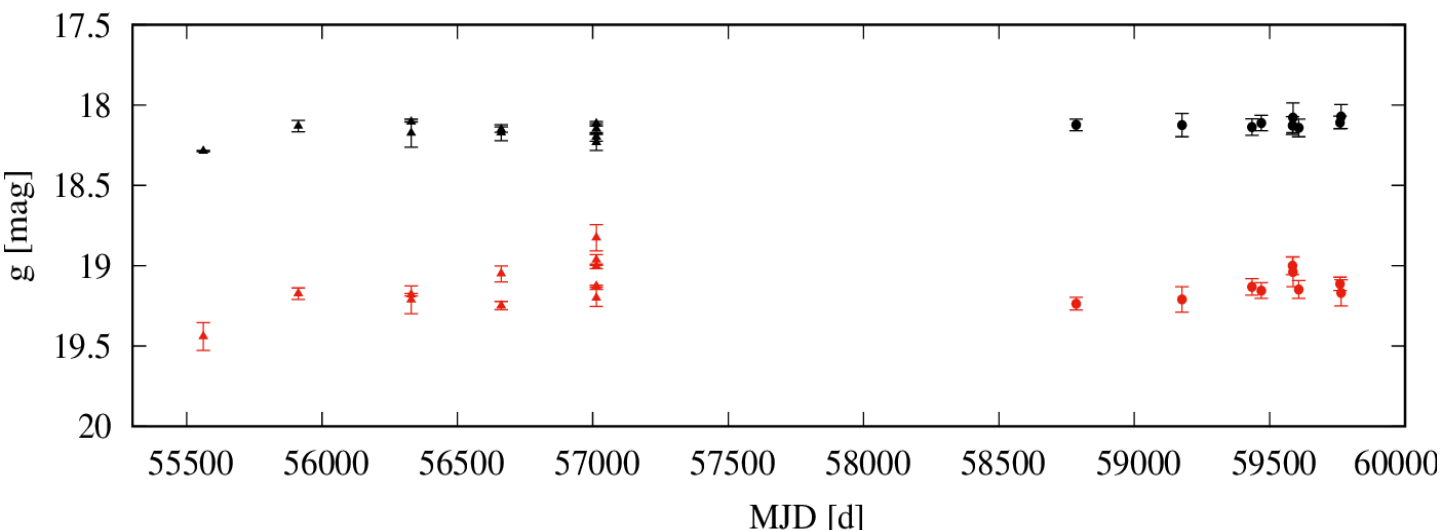
IC 342 in Pan-STARRS

Downloaded individual images of 150″ x 150″ area in gr filters from Pan-STARRS-1:

- Time coverage:
from 11-17-2010 to 12-22-2014.

- 11 epochs in g (seeing 1.4″ – 2.5″)

- 11 epochs in r (seeing 1.4″ – 1.8″)

- Aperture photometry of the individual images.

- Calibration using stable stars in the field and PS1 magnitudes.

Combined r image with FoV (150″x150″)

var71

var73

gr light curves of var71

g light curve: 11 PS1 epochs (triangles)+9 Rozhen epochs (filled circles)

- Var 71 in red
- Comparison field star in black
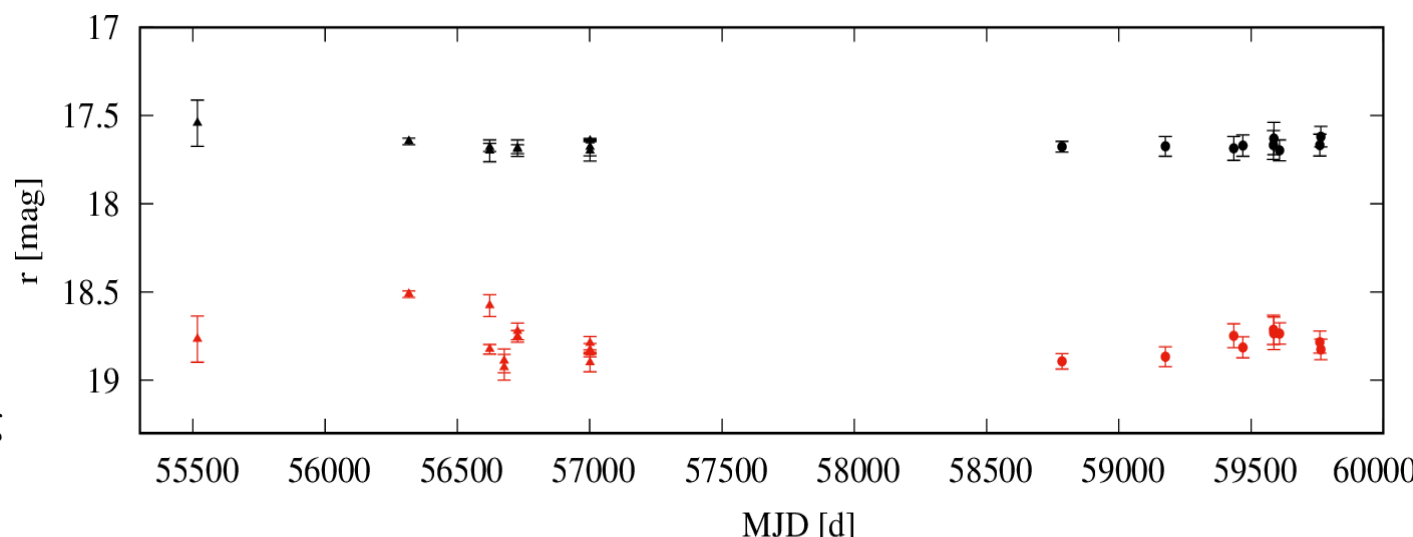
- Max g amplitude for 6.6 yrs is Δg=0.62mag.
- Rozhen g amplitude is Δg=0.24 mag (2.6 yrs).

r light curve: 11 PS1 epochs (triangles)+9 Rozhen epochs (filled circles)

- Var 71 in red
- Comparison field star in black

- Max r amplitude for 6.6 yrs is Δr=0.42 mag.
- Rozhen r amplitude is Δr=0.18 mag (2.6 yrs).

g light curve: 11 PS1 epochs (triangles)+9 Rozhen epochs (filled circles)
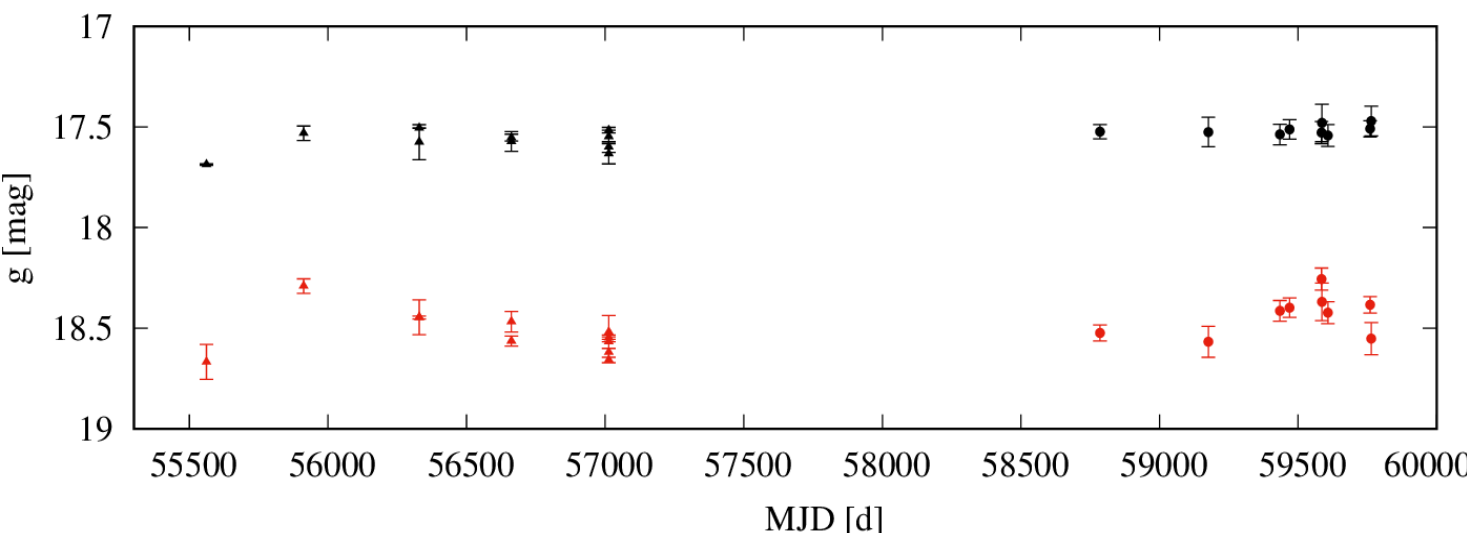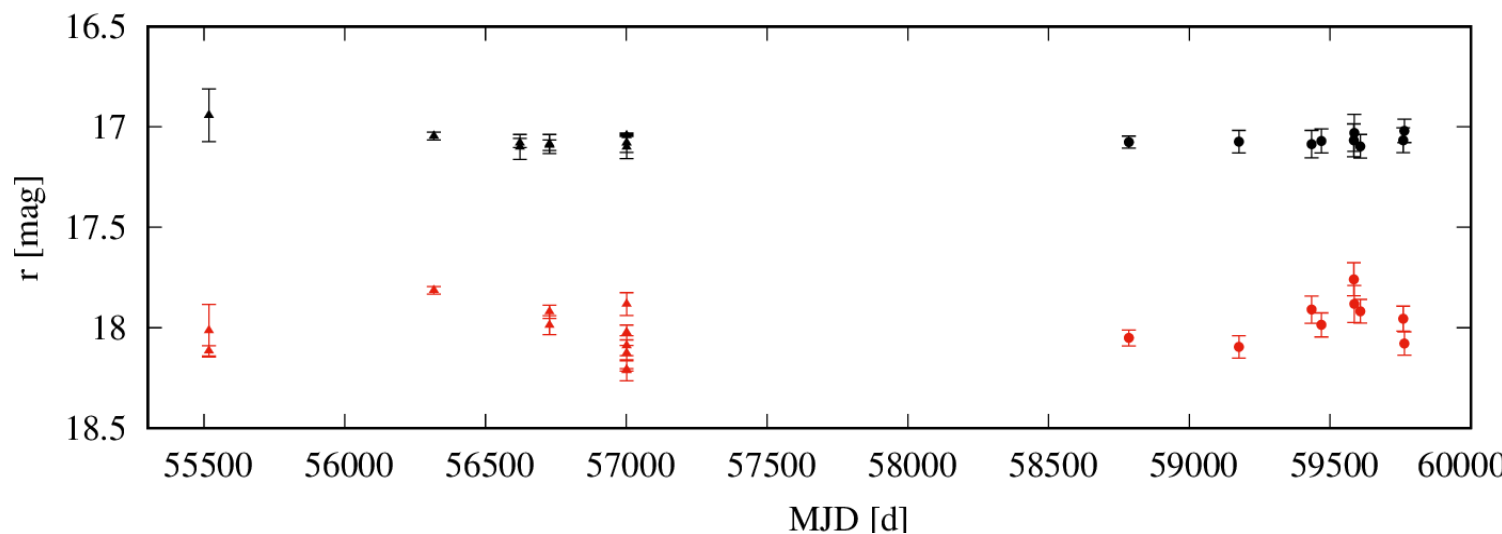
- var71 in red
- Comparison field star in black

- Max g amplitude for 6.6 yrs is Δg=0.41 mag.
- Rozhen g amplitude is Δg=0.31 mag (2.6 yrs).

r light curve: 11 PS1 epochs (triangles)+9 Rozhen epochs (filled circles)

- var71 in red
- Comparison field star in black

- Max r amplitude for 6.6 yrs is Δr=0.40 mag.
- Rozhen r amplitude is Δr=0.18 mag (2.6 yrs).

IC 342 with HST

The Giant Hiding in Our Backyard: The Nearby Spiral Starburst Galaxy IC 342
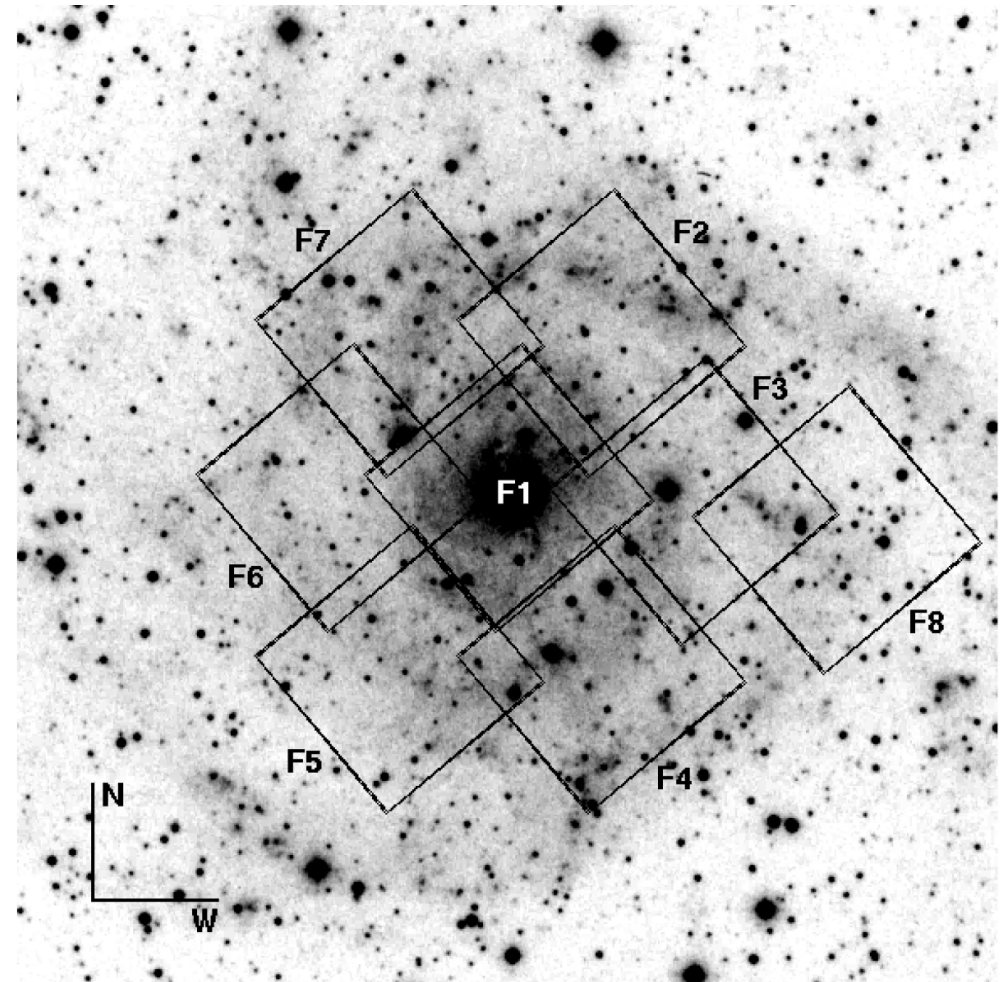
HST Proposal 16002

PI: Paul Sell / University of Florida

Cycle: 27

Status: completed April 2019
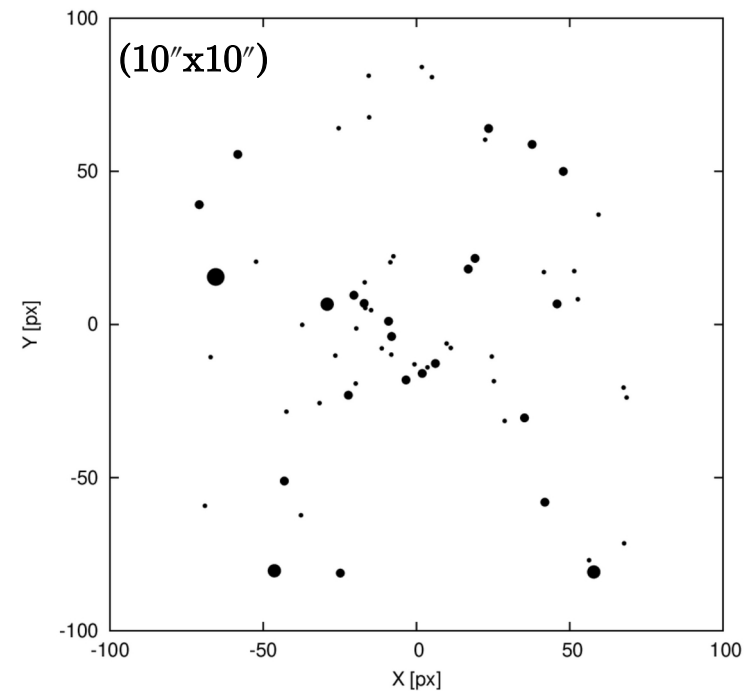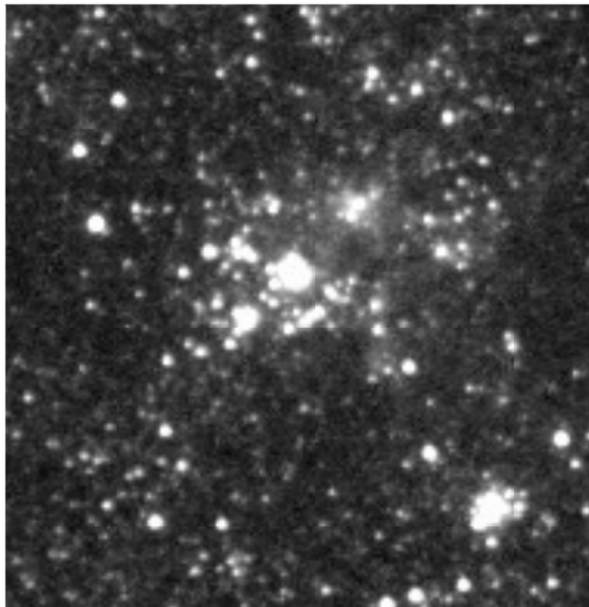
No published paper yet (ADS)

In BV (F450&F555) filters
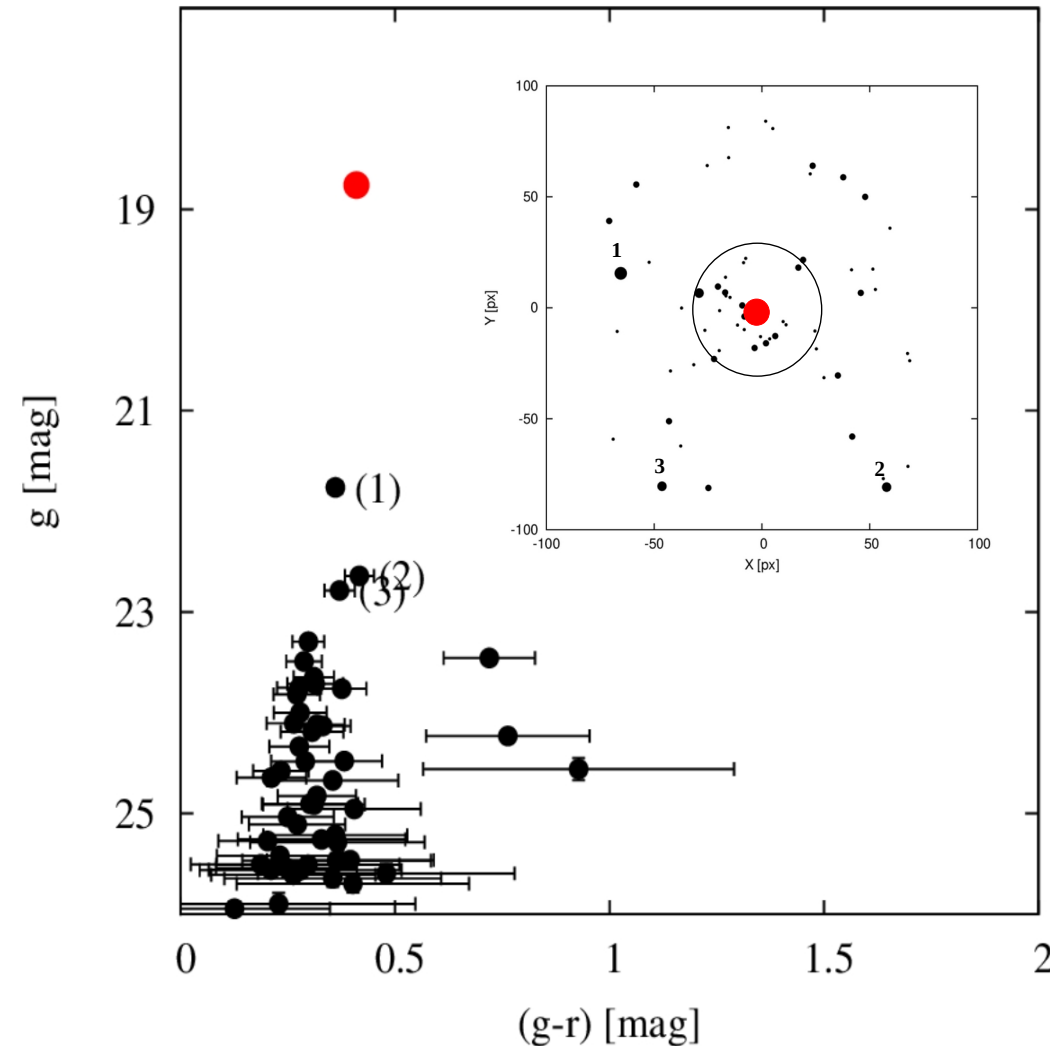
Left: HST image (10″ x 10″);

Right: position of stellar-like objects with m < 24 mag in the field 10″ x 10″

Our PSF photometry (DOLPHOT–2 package), performed by N. Tikhonov (SAO), shows that var71 is a non-stellar object (the blob in the center of the image).

The circle of radius 1.4″ is shown in the inner panel to visualize the stars that lie very near to var71 (this size is nearly equal to the seeing of Rozhen and PS1 images).

- Color-magnitude diagram of stellar-like objects around var71 in the circle of radius 1.4″.

- All the star in the circle have magnitudes > 23 mag and their contribution to var71 is negligible.

- The brightest stars in the field (denoted with 1,2 and 3) are also show in the diagram for comparison).
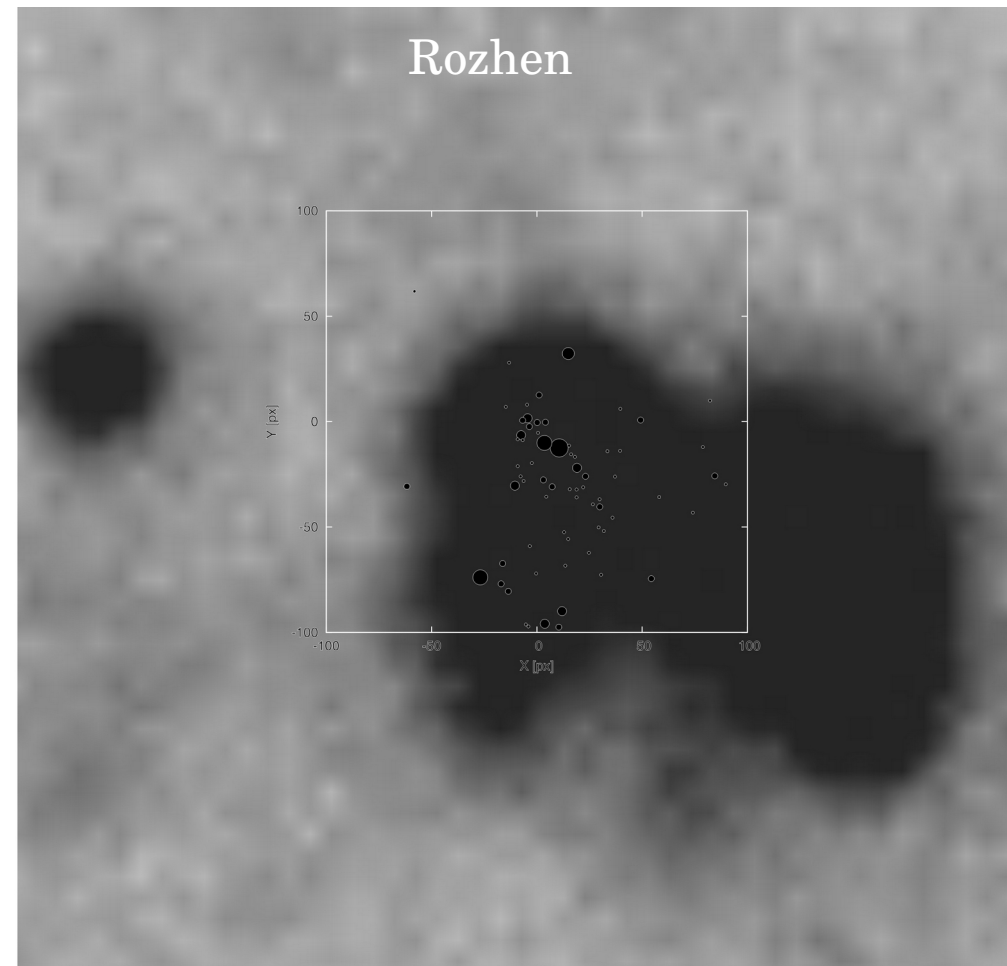
* HST magnitudes are converted in gr PS1 magnitudes using the transformations from Kostov & Bonev 2018, BlgAJ, 28, 3.

- The red dot gives the integral magnitude of var71 in Pan-STARRS-1.

Left: HST image (10″ x 10″);
Right: Rozhen image with 10″x10″ superimposed HST field with stellar-like objects

Positions of the nearest stars around var73

- Two bright stars at the position of var73 are resolved at distance of 0.4″.

Color-magnitude diagram of **68 stars with PSF photometry** around var73 in the circle of radius 1.4″ (shown in the inner panel).

- The position of the brightest stars in the circle is denoted in the CMD.

- **Mainly stars #1 and #2 contribute to the integral brightness of var73.**
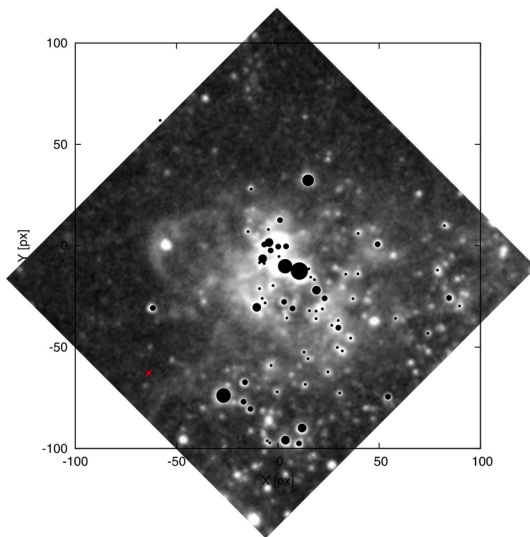
- **The red dot gives the integral magnitude of var73 in Pan-STARRS-1.**

*HST magnitudes are converted in gr PS1 magnitudes using the transformations from Kostov & Bonev 2018, BlgAJ, 28, 3.
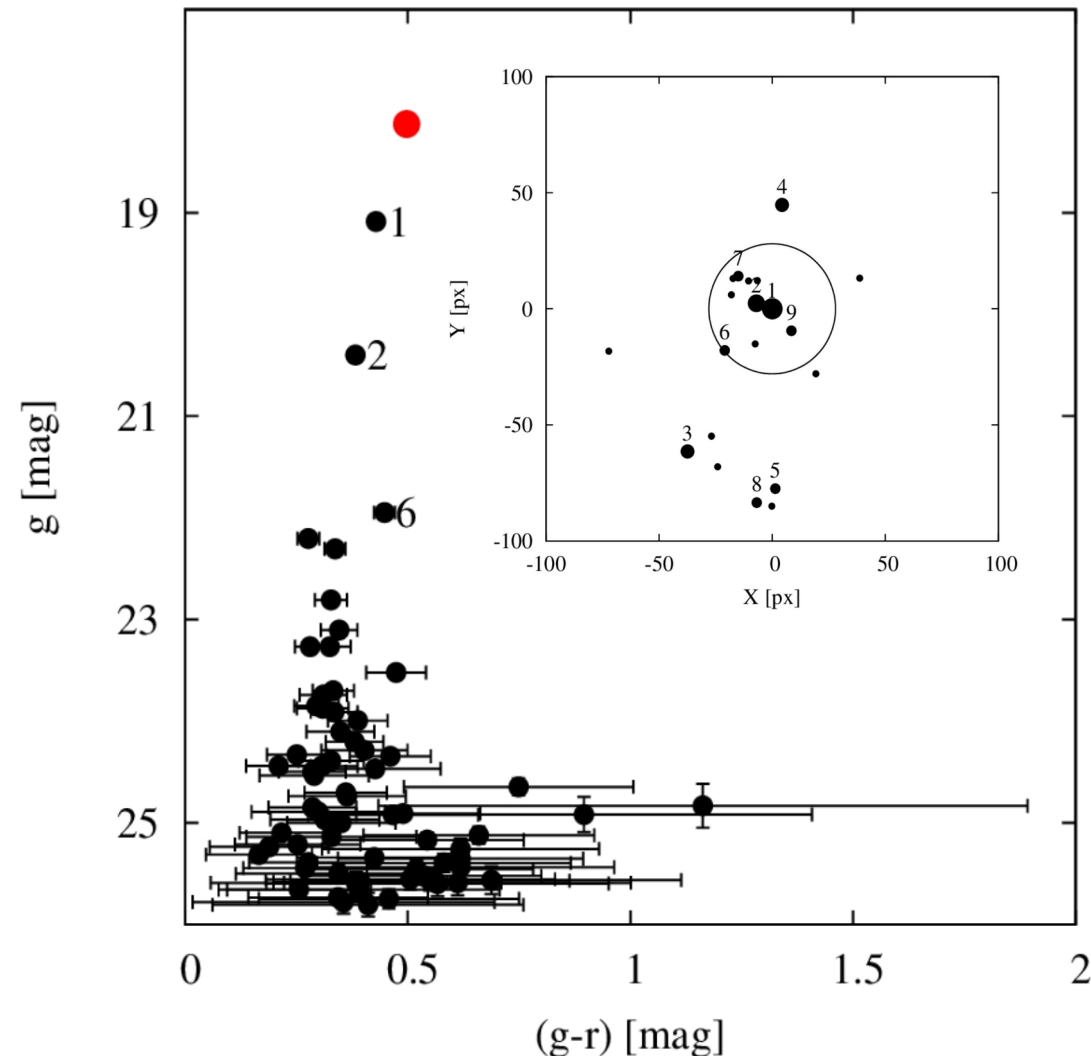
Var 73 light budget

- Rozhen observations (MJD=**58785.38)** and HST observations (MJD=**58769.26**) are taken close in time.

- We can use HST resolution to decompose the obtained magnitudes (Rozhen anda PS1) into components and to make deeper analysis.

Under the assumption that only star #1 varies and the other contribution is constant, we can solve new light curve for var 73.

$$flux(\#1)=flux(Rozhen/PS1) - flux(Resolved\ stars) - flux(Unresolved)$$

Results: The amplitudes increase:
$\Delta g=0.41$ —>0.97 mag
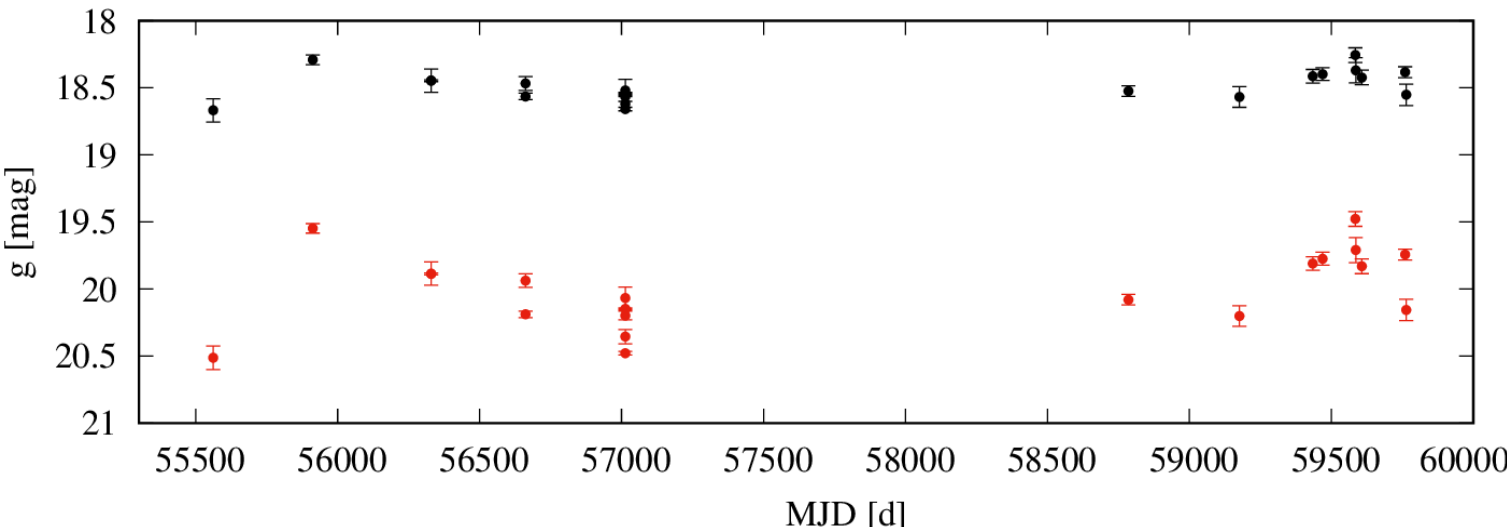$\Delta r=0.4$ —> 1.1 mag

*If #2 is the one that varies, the amplitudes could be even much larger.

| Name	Instrument	g [mag]	r [mag]	(g-r) [mag]
Var 73	Rozhen MJD=58785.38	**18.52**	**18.05**	**0.47**
=======	======	====	===	======
#1 star	HST MJD=58769.26	19.52	19.09	0.43
Resolved stars in 1.4″ radius (without #1)	HST MJD=58769.26	19.58	19.21	0.37
Unresolved stars	HST MJD=58769.26	20.06	19.47	0.58! redder, due to H-alpha
Total HST		**18.52**	**18.05**	

Recalculated g light curve in red has amplitude Δg=0.97 mag.
Ampl. change 0.41 —>0.97 mag.

*Recalculated light curve is shifted with 0.5 mag for better visualization.

Recalculated r light curve in red has amplitude Δr=1.1 mag.
Ampl. change 0.4 —> 1.1 mag.
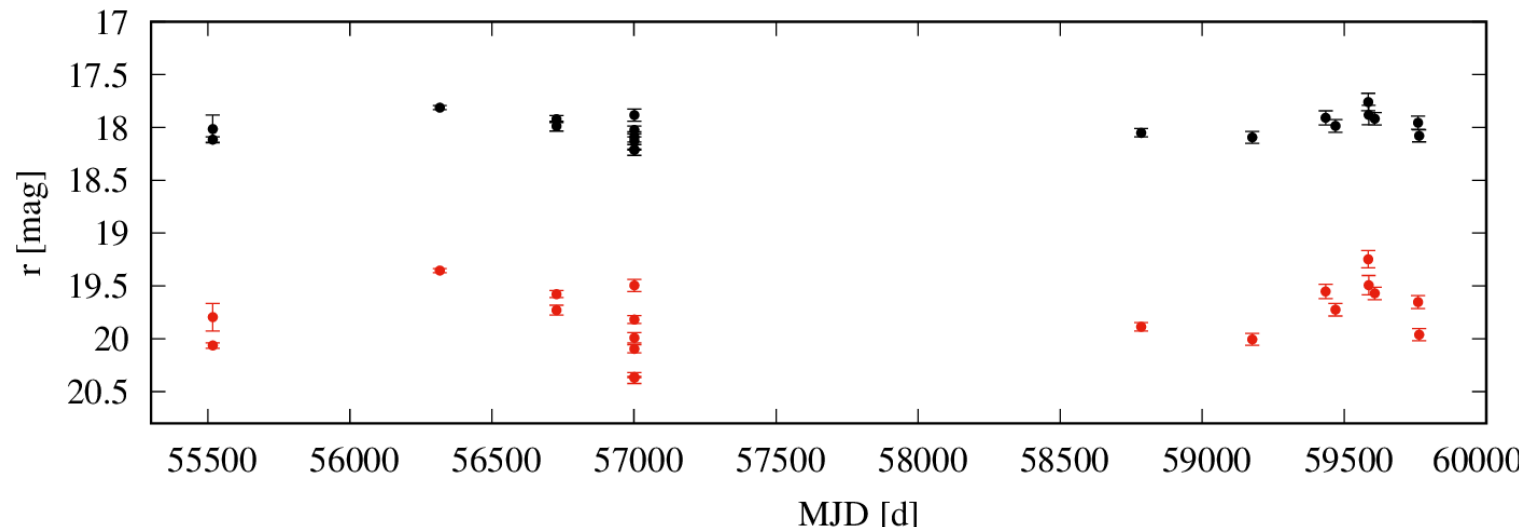
*Recalculated light curve is shifted with 0.8 mag for better visualization.

Monte Carlo simulations

- **We generate a set of 20 points (light curve) from a constant source with the measured mean magnitude of var71, var73 and var73_recalc.**
  - Each of these points was generated according to a Gaussian distribution with the observational error of the corresponding measurement.
- **For each object we performed 1 000 000 simulations for:**
  - 2 bands (g & r); 2 modes of error estimations (median errors; individual observational errors)
- **We check whether the rms of the generated light curves exceeds the rms of the observed light curves.**
- **We obtain the percentage of the cases the data are inconsistent with a constant source in all 12 cases:**

Name	g-filter		r-filter	
	med_err	ind_err	med_err	ind_err
Var 71	99.9999	100	99.50	100
Var 73	99.994	100	99.98	100
Var 73 recalc	100	100	100	100

- **We applied the same procedure also to the light curves of the comparison stable star and the percentage of the cases in which the data are inconsistent with a constant source are: 2.5 % in r-filter; 64.5 % in g-filter.**

Summary

- We report BR-bands monitoring of 2 spectroscopically confirmed massive young star in the north-east quarter of the IC342 galaxy obtained with the 2m RCC telescope at NAO Rozhen, Bulgaria.

- We analyzed 2.6 yr gr-light curves of the objects and detected photometric variations smaller than 0.3 mag and no overall brightness changes.

- We supplemented our photometry with gr photometry from Pan-STARRS-1 and expanded the light curve time coverage to 6.6 yrs. The obtained amplitudes are: for var71 - $\Delta g=0.62$mag and $\Delta r=0.42$mag; for var73 - $\Delta g=0.41$ mag and $\Delta r=0.40$ mag.

- To check for a blending effect of neighboring stars on our photometry we use BV HST magnitudes, obtained by us using the DOLPHOT 2 package.

- Accounting for the blending effect, we recalculate the gr light curves of var73 and larger amplitudes were obtained: $\Delta g=0.97$ mag and $\Delta r=1.1$ mag $\rightarrow$ consistent with the time variations of LBV stars.

Acknowledgments

Thank you for your attention!