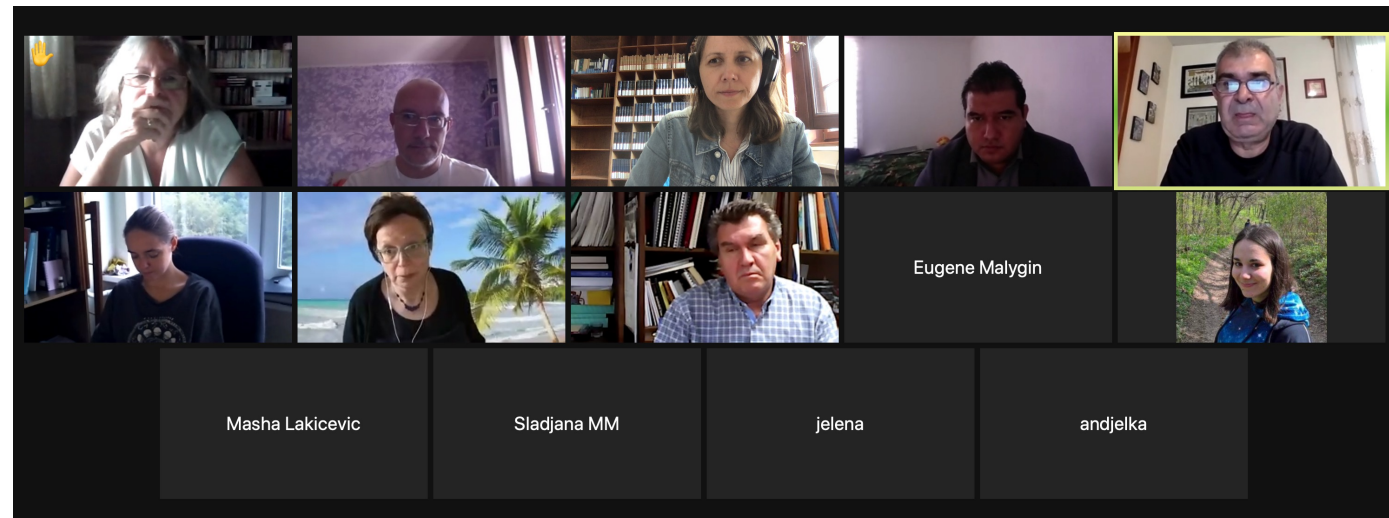




# Long-term (LoTerm) monitoring of AGN

**LoTerm Collaboration:** D. Ilic, L. C. Popovic, A. B. Kovacevic, A. Burenkov, E. Shablovinskaya, E. Malygin, R. Uklein, D. Oparin, A.V. Moisev. A. Smirnova, V. M. Patino Alvarez, V. Chavushyan, N. Rakic, S. Marceta Mandic, S. Ciroi, A. Vietri, L. Crepaldi, P. Marziani, B. W. Jiang, A. del Olmo



# AGN long-term campaign: from 1990s

- PIs: **Alla Shapovalova (Russia)**  
Vahram Chavushyan (Mexico)
- 6m + 1m telescopes - SAO RAS (Russia)
- 2.1m telescope - Guillermo Haro Observatory (Mexico)
- 2.1m telescope - Observatorio Astronómico Nacional, San Pedro Martir (Mexico)
- Later added: 3.5m + 2.2m telescopes – Calar Alto Observatory (Spain) – archival data of W.Kollatschny



Alla Shapovalova (1941 – 2019)



SCSLSA, 2023



D.Ilić et al: LoTERM



\*long=decades

# The sample: different type 1 AGNs

- **Seyfert 1s:**

**NGC 5548** – 9 yrs

**NGC 4151** – 11 yrs

**NGC 7469** – 20 yrs

**NGC 3516** – 21 yrs

- **Narrow Line Seyfert 1:**

**Ark 564** – 11 yrs

- **Double Peaked Line AGNs (DPLs):**

**3C 390.3** – 13 yrs

**Arp 102B** – 12 yrs

- **High luminosity quasar:**

**E1821+643** – 25 yrs

**Main papers:**

(Shapovalova+ 2004, Ilić 2007, Popović+ 2008)

(Shapovalova+ 2008, 2010a, Bon+ 2012, Ilić+ 2010)

(Shapovalova+ 2017)

(Shapovalova+2019, Ilić+ 2020, Popovic+2023)

(Shapovalova+ 2011, Shapovalova+ 2012)

(Shapovalova+ 2001, 2010b, Popović+ 2011)

(Shapovalova+2013, Popović+ 2014)

(Shapovalova+2016, Kovačević+2017)

...and many other papers based on these data sets: Jovanović+ 2010, Kovačević+ 2014, Ilić+2015, Kovačević+ 2015, Rakić+ 2017, Ilić+2017, Bon+ 2016, Kovačević+2018 ...

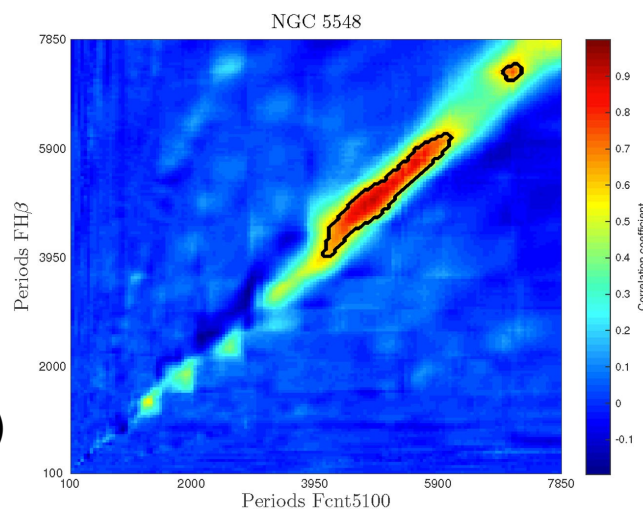
## Objects of the SAO's monitoring programme (1996-2016)

IAU Name Objects	Coordinates	m(b) M(b)	z	Sy
<b>0645+744 Mkn 6</b>	06 45 43.3 +74 29 07	14.29 -20.4	0.0185	1.5
1103+728 NGC 3516	11 03 22.8 +72 50 20	12.45 -20.4	0.0088	1.0
1208+396 NGC 4151	12 08 01.1 +39 41	11.13 -19.3	0.0033	1.5
1415+253 NGC 5548	14 15 43.5 +25 22 01	13.21 -20.9	0.0168	1.0
1717+490 ARP 102-B	17 17 56.3 +49 01 56	14.70 -20.4	0.0256	1.0
1821+643 E1821+643	18 21 41.9 +64 19 18	14.24 -27.1	0.297	QSO
1845+797 3C390.3	18 45 37.6 +79 43 00	15.28 -21.6	0.0556	1.0
2240+294 Akn 564	22 40 18.3 +29 27 47	14.4 -20.9	0.0253	1.0
2300+086 NGC 7469	23 00 44.4 +08 36 16	12.60 -21.6	0.0167	1.0
<b>2316-000 NGC 7603</b>	23 16 22.9 -00 01 47	13.99 -21.5	0.0295	1.0 ← work in progress

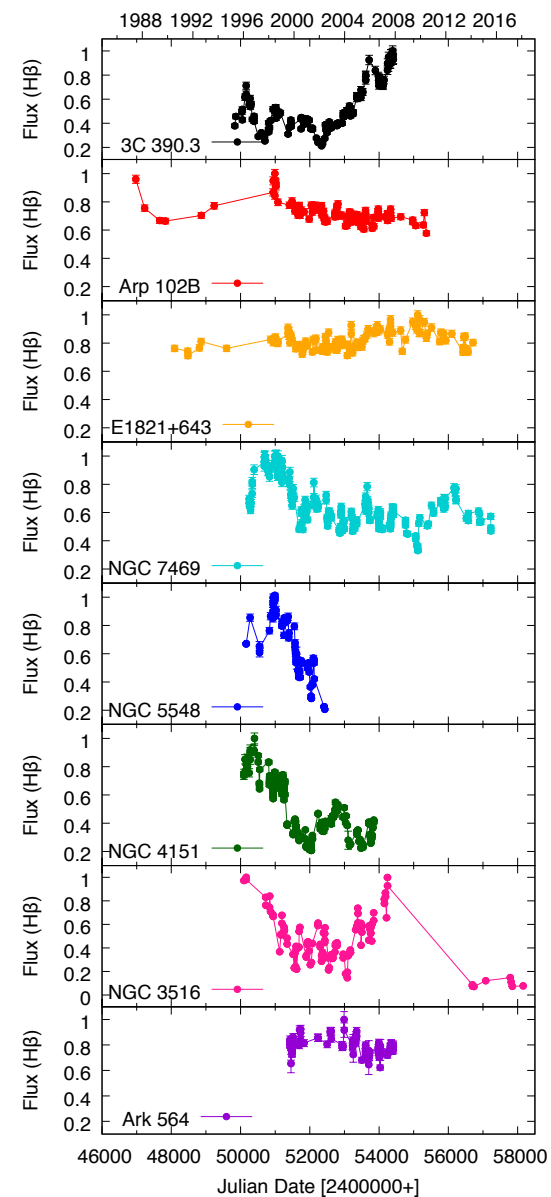
# Summary of the results

- determined the BLR size and the SMBH mass of 8 AGN
- periodicities for 2 candidates of SMBH binaries
- (re)discovery of changing-look AGN NGC 3516

- developed spectral fitting tools, light-curve analysis, physical models
  - novel hybrid method to search for periodic oscillatory behavior (Kovacevic+ 2018, 2019)
  - model of SMBH binary (Popovic & Simic, 2019, Popovic+ 2021)
  - Fantasy code (Rakic 2022, Ilic+2023)



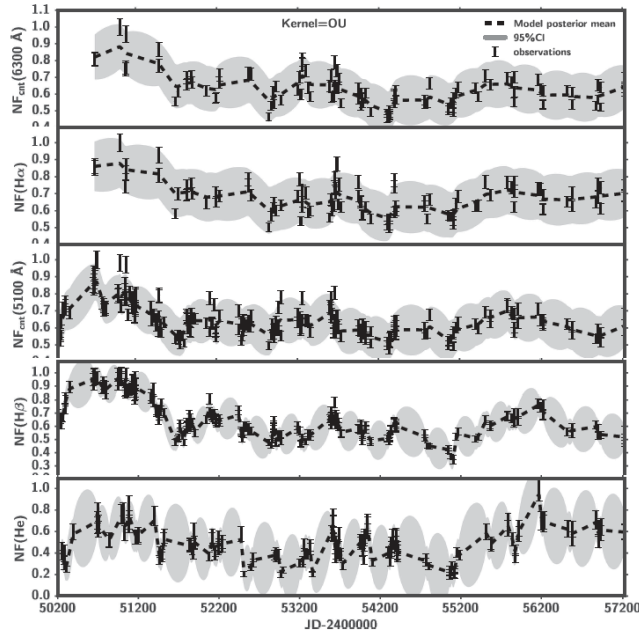
2D correlation maps of periodicities in H $\beta$  and continuum of NGC 5548



# Reverberation mapping results for H $\beta$ line

- apply Gaussian processes to address poor cadence and get simulated light curves needed for the Cross Correlation (CCF) analysis

Results included in the AGN Black Hole Mass Database!  
<http://www.astro.gsu.edu/AGNmass/>



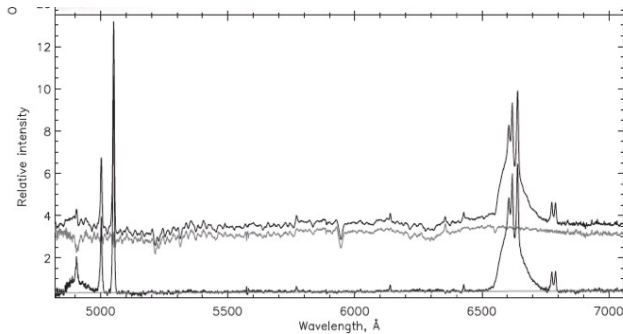
NGC 7469, Shapovalova et al. 2017

object	period [years]	tau [days]	method	mass [Msun]
NGC 3516	1996-2007	$17^{+5}_{-0}$	GP+ZDCF	$4.7 \times 10^7$
NGC 7469	1996-2015	$21^{+7}_{-0}$	GP+ZDCF	$1.1 \times 10^7$
NGC 4151	1996-2003	$5^{+28}_{-5}$	ZDCF	$1.6 \times 10^8$
NGC 5548	1996-2002	$49^{+19}_{-8}$	ZDCF	$2.1 \times 10^9$
Arp102B	1987-2010	$15^{+20}_{-15}$	ZDCF	$1.1 \times 10^8$
3c390.3	1995-2007	$96^{+28}_{-47}$	ZDCF	$2.1 \times 10^9$
Ark564	1999-2010	$4^{+27}_{-4}$	ZDCF	$1.0 \times 10^6$
E1821+643	1990-2014	$118^{+0.1}_{-0}$	GP+ZDCF	$2.6 \times 10^9$

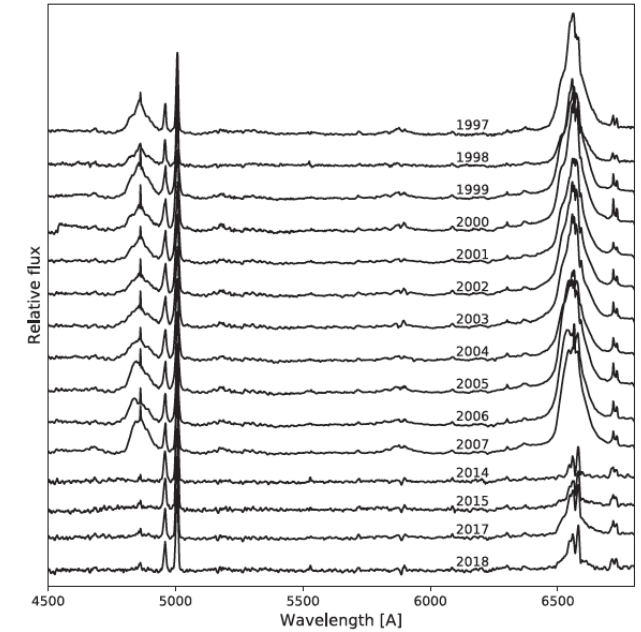
Shapovalova+2012,2013,2016,2017,2019  
Kovačević+2014, Ilić+2017

# Changing Look AGN: NGC 3516

- collected 22 years of data
- **captured a disappearance of broad lines in 2014**



in 2017: still in low state,  
but broad lines start to appear

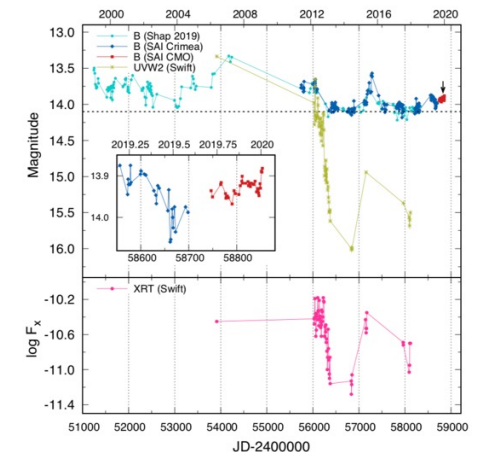
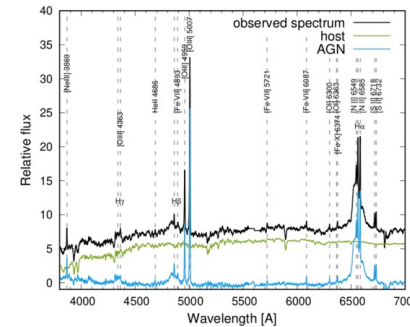


Shapovalova et al. 2019, MNRAS

- Recent (end 2019) observations, indicate that NGC3516 is maybe awakening (increase of coronal emission lines)

→ **important to continue monitoring of AGN in multi-wavelength**

Ilić et al. 2020, A&A



# LoTerm Aims

1. search for long-term changes in type 1 AGN with peculiar broad line profiles and extreme variability (CL AGN)
2. analysis of broad line profiles in order to understand the BLR physics and structure
3. build a LEGACY of LoTerm spectra and preliminary notification service



# LoTerm: Facilities

- SAO - 1m (+6m), Special astrophysical observatory (Russia)
- AsV - 1.4m, Astronomical station Vidojevica (Serbia) - for now only photometry
- GHO - 2.1m, Guillermo Haro Observatory at Cananea, Sonora, (Mexico)
- AsO - 1.8m, 1.2m Asiago observatory (Italy)
- OSN - 1.5m Observatory Sierra Nevada, Granada (Spain) – in progress

Vidojevica 1.4m



Asiago 1.2m



SAO 1m Zeiss



GHO 2.1m



Asiago 2m



OSN 1.5m



# LoTerm Future Strategy

- Build LoTerm consortium (SAO, ASV, Asiago, GHO, OSN)
- **Continue spectral observation and build the LEGACY of spectra of bright and well-known type 1 AGN**
- Proposed observing strategy: cadence is not crucial; possibility of filling the gaps in allocated time
- Make a database of publicly available spectra (calibrated data) → LoTerm LEGACY website
- Organize telegram-like operation



# LoTerm Action Items - Future

- Monitor/organize the observing sessions
- Retrieve the information of the successful observation (log file, comments, etc.) but also note if the allocated observation was not successful --> Master LOG file with all info
- Collect/store the observed data --> have one repository (**we have astro-cloud**)
- Organize preliminary data reduction
- **Put the preview info on the LoTerm LEGACY webpage**
- Initiate ToO observations with higher cadence at one of the consortium members
- Final data reduction
- Organize data analysis and publication

A dark-themed login form for 'astro-cloud'. It features a title 'astro-cloud' at the top. Below it are two input fields: 'Username' with a person icon and 'Password' with a lock icon. There are two checkboxes: 'Remember me' (unchecked) and 'Secure login' (checked). A 'Login' button is at the bottom.

astro-cloud

Username

Password

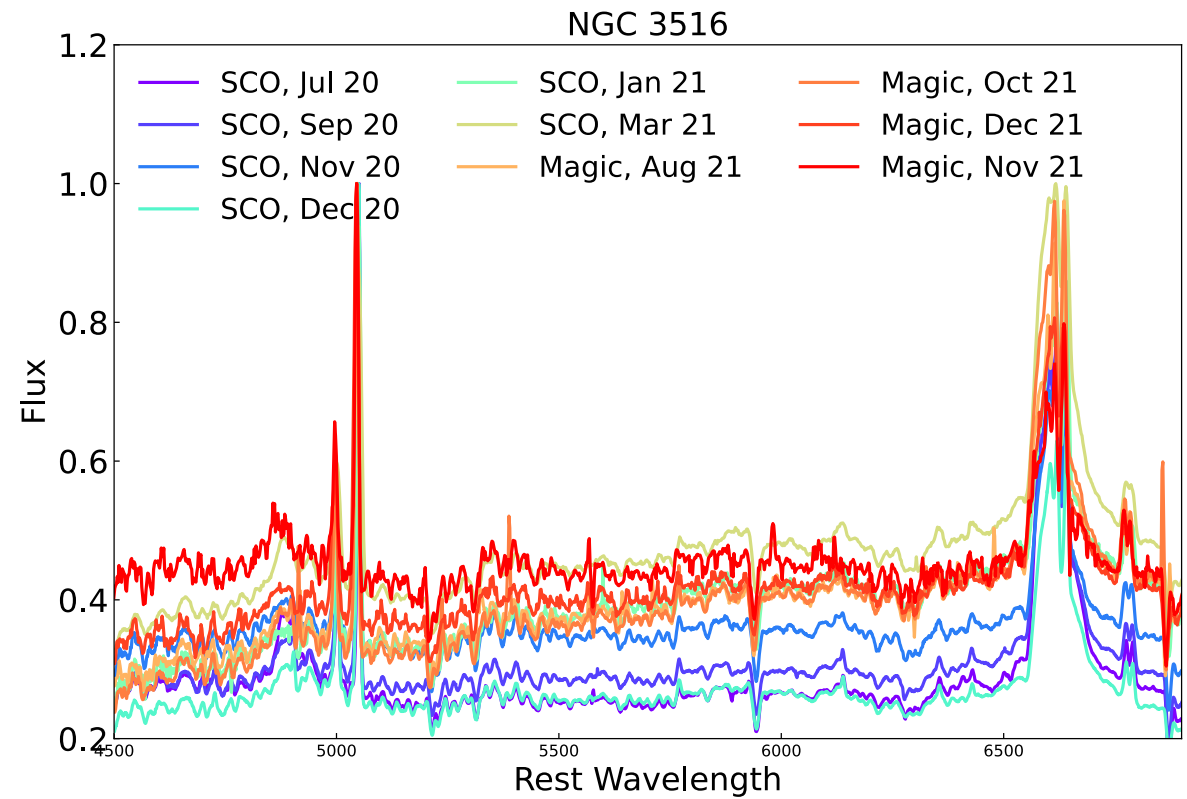
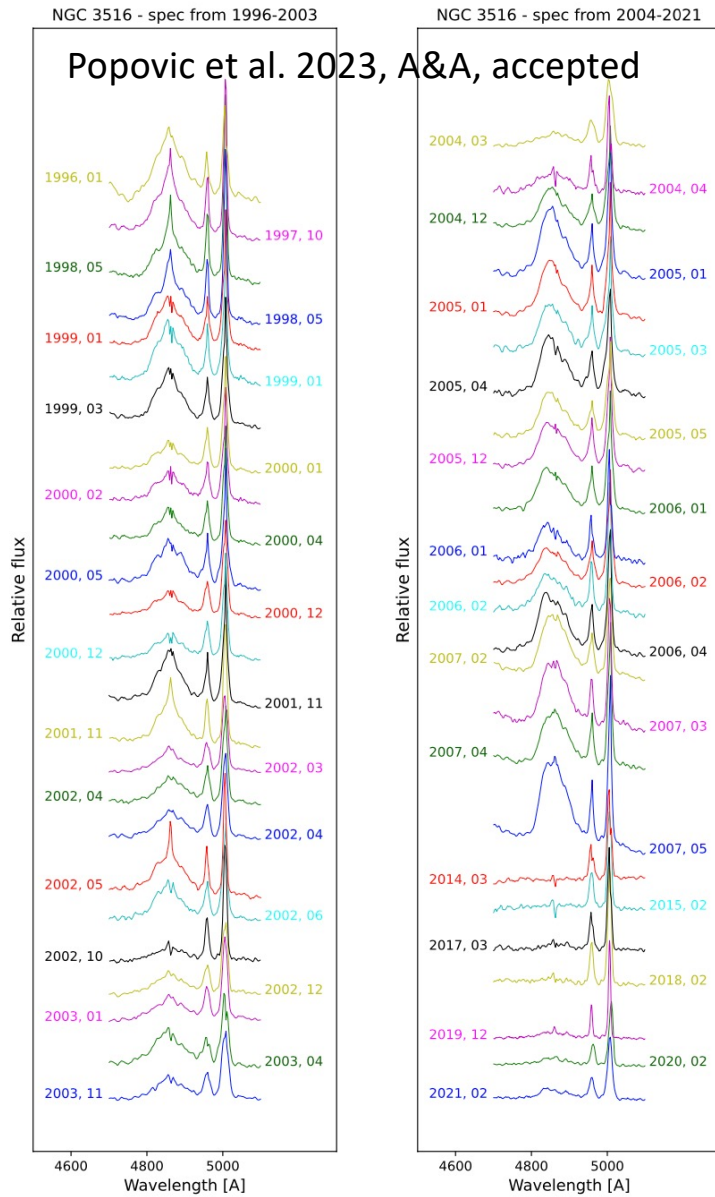
Remember me

Secure login

Login

# NGC 3516

## Changing-look AGN



Thank you!