Some new projects in Russian Ground-Based Astronomy

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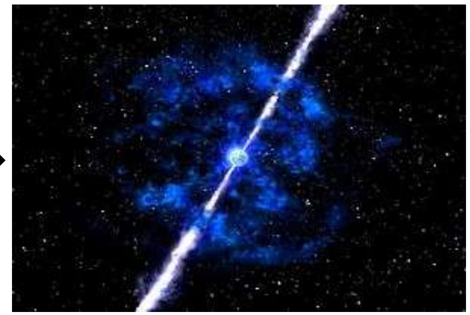
III BRICS Workshop on Astronomy Infrastructure and Instrumentation, Pune, 21-22 Sep 2017

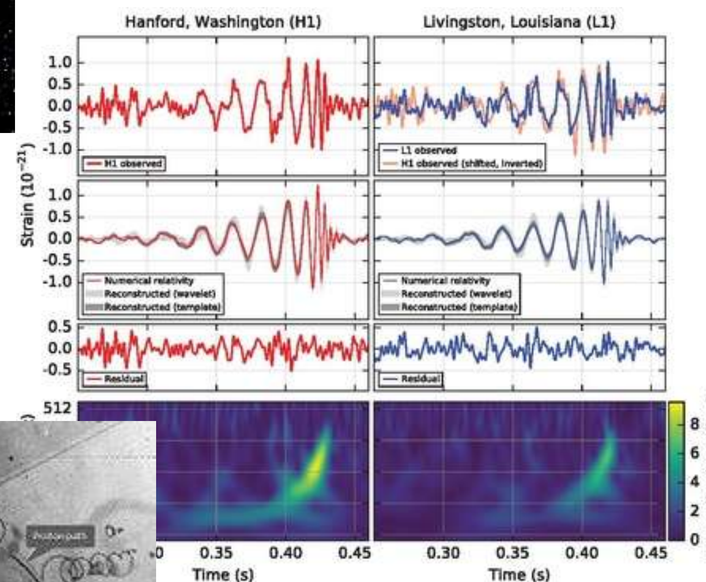
New challenges for the ground-based astronomy in the early 21st century

- Gamma-Ray Bursts:1978-1997-→

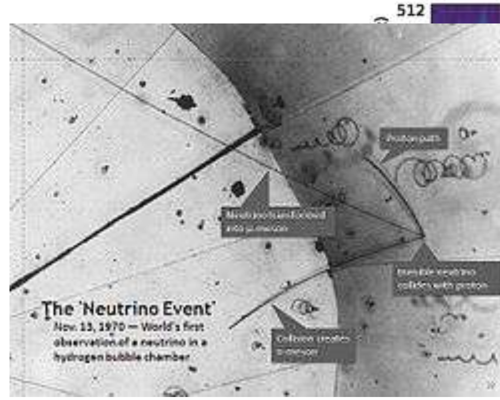


- Gravitational wave signals :

Signal GW150914 was detected
14.09.2015 at 9:51 UTC by two detectors LIGO in Hansford and Livingston (USA)
by 7 msec (LIGO & VIRGO collaboration).
Interpretation: mostly speculative. Signal form agreed well with GTR predictions for
Coupling of two BH with 36 & 29 solar masses;
New one BH should have mass about 62 solar.
Distance to event source is about 1.3 Giga light years,
Emitted within coupling process energy equivalent to
3 solar masses. Errror box – about 1000 sq.degrees,
No identification now.
GW170104 – close parameters.



- Neutrino events: SN1987A is the only reliable event so far, BUT the international projects ICECUBE, ANTARES , etc. are going on…



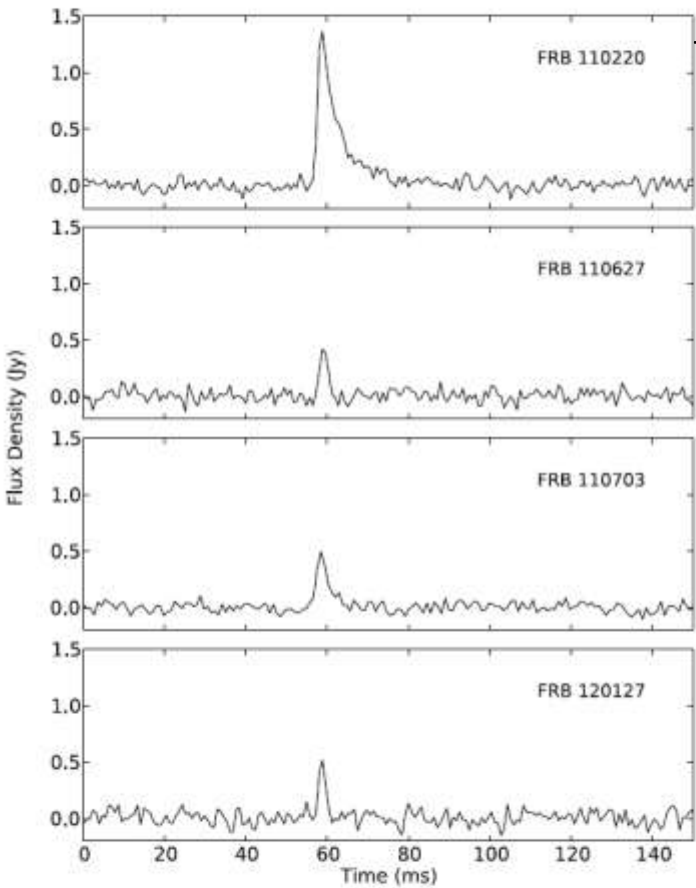
- FRB – Fast Radio Bursts (64-m Parks 13-beam):2001-2013-2016 (the first identification with a radio galaxy at z=0.5)

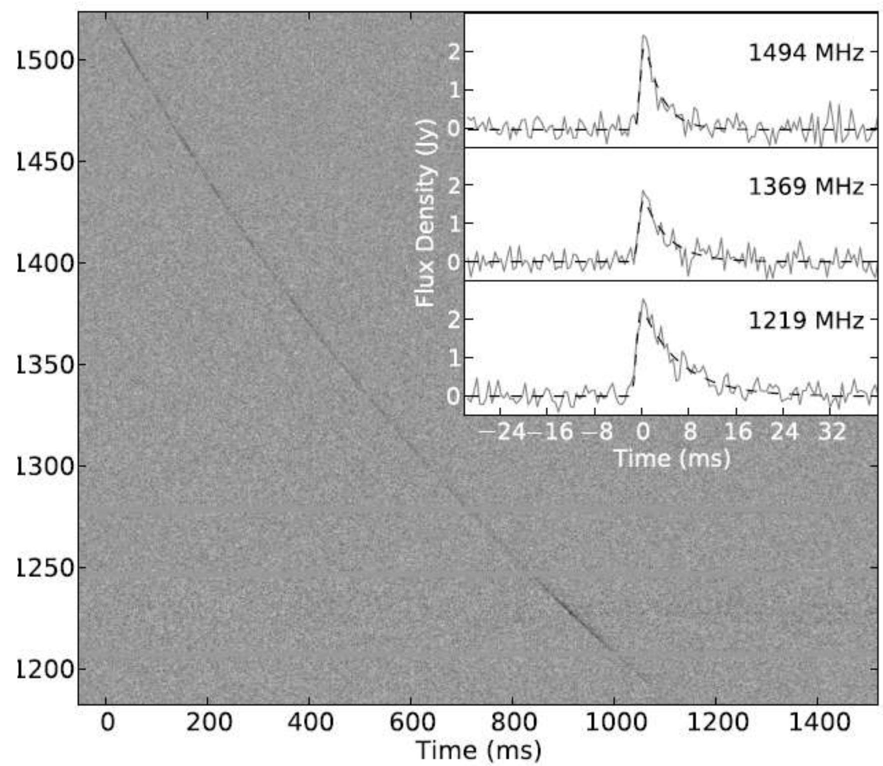
FRB – Fast Radio Bursts

Discovered in 2007, confirmed in 2013 (Thornton et al, 2013, Nature)

Dispersion measure (DM) – from 500 to 1100 pc/cm^3
Distances – 1.7-3.2 Gpc at DM = 100 pc/cm^3

The amount – about 1000 in the whole sky per day or
10^{-3} per a galaxy per year, which is close to the rate of core-collapse SN (10^{-2})





Observations

Reliable identification demands optical identification…

The rate of expected events

1. Gamma-Ray Bursts – 2-3 per week
2. Gravitational events (3 or 4 during the recent 1.5 years)
3. Neutrino events (several ones per year)
4. Fast Radio Bursts – less than 10 so far.

Observations are possible only in the ToO (Target of Opportunity) mode.

How can Russian ground-based astronomy meet the challenge today?

1. 6-meter BTA + complexes of spectroscopy, photometry, and fast photopolarimetry
2. 1-meter Zeiss-1000 + a CCD photometer (FOW~ 7’) and the low-resolution spectrograph
3. MiniMegaTORTORA – a multi-channel wide-angle complex of subsecond temporal resolution (FOW~ 900 sq°)
4. 2-meter Zeiss-2000 of Terskol Branch of INASAN + a CCD photometer (FOW~ 11’) + a moderate-resolution spectrograph
5. Crymean 2.6-meter Shayn + CCD photometers (the fields of 9’ and 20’)

Now some Russian astronomical institution prepared some projects,
which should be useful in a future studies,
like as a complex of small telescopes with the fields of 2° or wide-field 1-m aperture telescope.

Anyway, we need large-aperture telescopes with large field and gigapixel CCD mosaic detectors as well.

Project 1. A high-resolution optical spectrograph

Main task: high-precision RV-spectroscopy (search for exoplanets), classical spectroscopy, spectropolarimetry.

Developed in SAO RAS by G.Valyavin's team for 6-m telescope with Support od Russian science foundation since 2015.

Several new state-of-the-art optical spectrographs have been launched to operate at giant European, Japanese and American telescopes.

The project is aimed to construct a high-resolution, fiber-fed spectrograph equipped with laser-based calibration system and adaptive optics in order to be installed at the 6-m Russian telescope (BTA, North Caucasus).

This instrument will make it possible to carry out a number of unique studies in fundamental science such as search for exoplanets, organic molecules in the Universe, and even serch for extraterrestrial life.

Requirements to accuracies in the RV-measurements

Hot jupiters — 20-30 m/sec

Jupiterian/neptunian mass planets — 1-10 m/sec

Planetary systems — a few m/sec

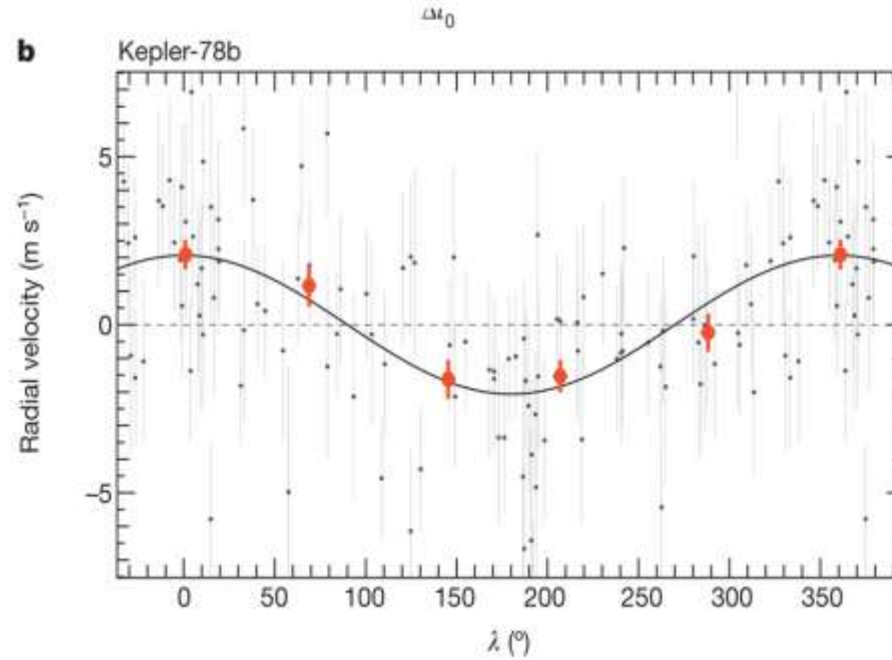
Earth type planets — 0.03-0.5 m/sec (!)

Is it possible?

YES IT IS!

First detection of the earth-type planet

The HARPS spectrograph at ESO



Requirements to the spectrograph

- 1. High resolving power (R ~100000)
- 2. Wide spectral range (from 400 to 750 nm)
- 3. High optical, termal and mechanical stability to provide the RV measurements on the order of about one meters per second
- 4. Spectropolarimetric mode for all 4 Stokes parameters.

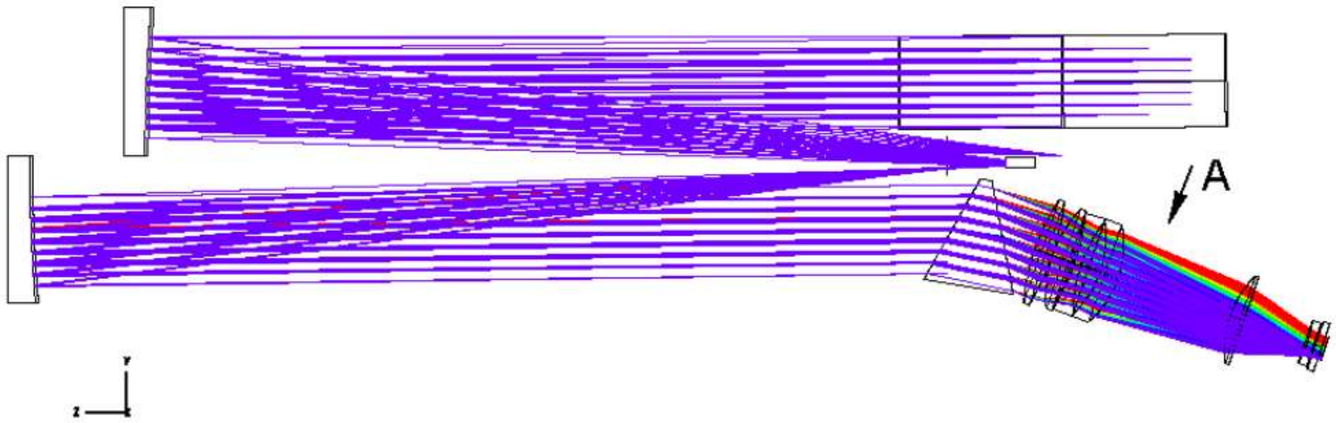
Calibration systems

- 1. Thorium-Argonium lamps + halogen lamps: provide about 10 m/sec accuracy
- 2. Iodine cells (absorption lamps with iodine vapor) + halogen lamps: provide ~1 m/sec accuracy
- 3. (FUTURE) Femtosecond laser: provides up to 3 sm/sec (!) internal accuracy and 10-20 sm/sec real accuracy.

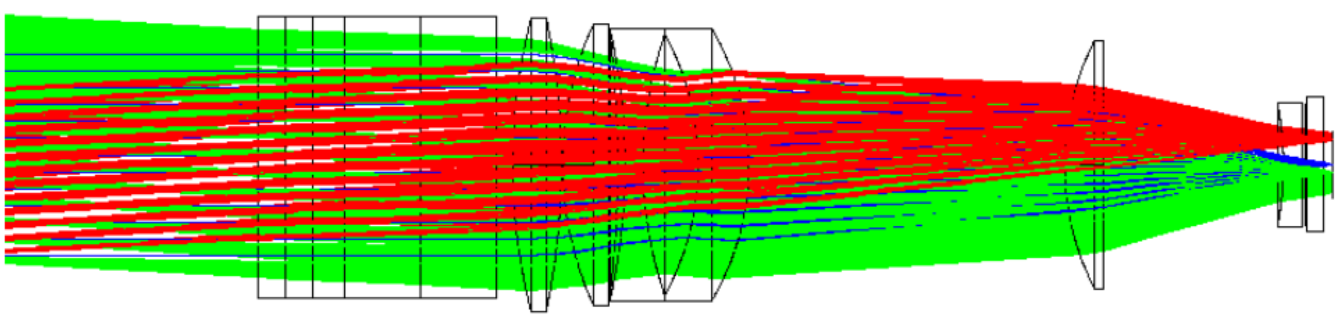
Resolution

- $R = 2*d*tg\ f / (D*tg\ S)$
- S=1''; d=200mm; D=6000 mm; tg f=4
- R = 55000 (ordinary slit)
- R ~ 75000 (fiber output)
- S=0.75'' → R ~ 100000

Current optical design



Spectral camera design



CCD

4к x 4к

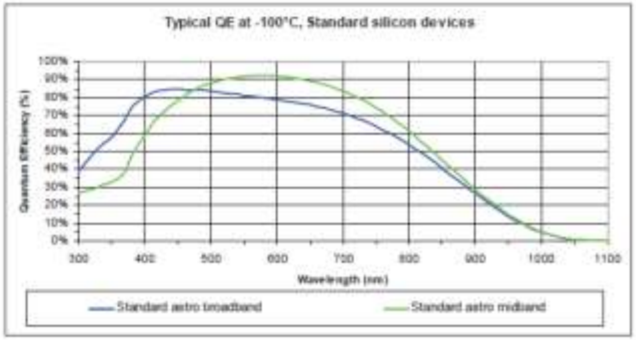
(CCD231-84)

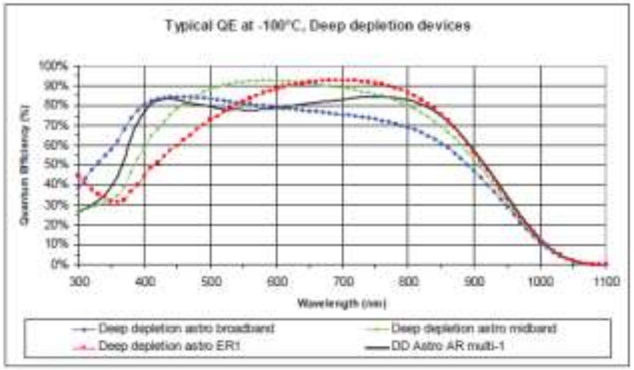
www.e2v.com

CCD231-84 Back Illuminated Scientific CCD Sensor
4096 x 4096 Pixels, Four Outputs
Non-inverted Mode Operation

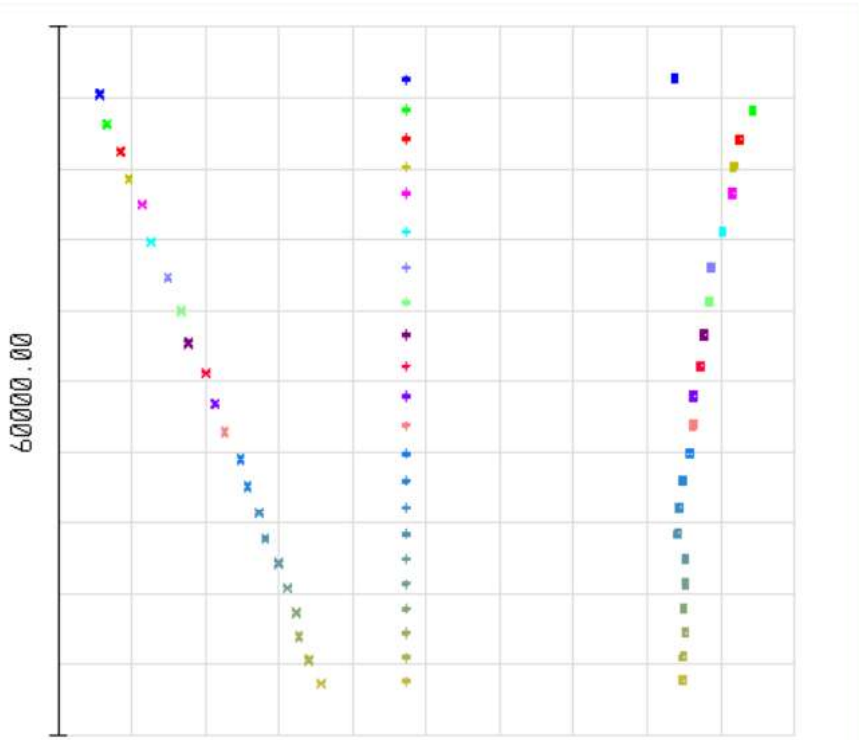
SUMMARY PERFORMANCE (Typical)

Number of pixels	4096(H) x 4112(V)
Pixel size	15 µm square
Image area	61.4 mm x 61.4 mm
Outputs	4
Package size	63.0 x 69.0 mm
Package format	Silicon carbide with two flexi connectors
Focal plane height, above base	15.0 mm
Height tolerance	±10 µm
Connectors	Two 37-way micro-D
Flatness	<20 µm (peak to valley)
Amplifier sensitivity	7 µV/e⁻
Readout noise	5 e⁻ at 1 MHz 2 e⁻ at 50 kHz
Maximum pixel data rate	3 MHz
Charge storage (pixel full well)	350,000 e⁻
Dark signal	3 e⁻/pixel/hour (at –100 °C)

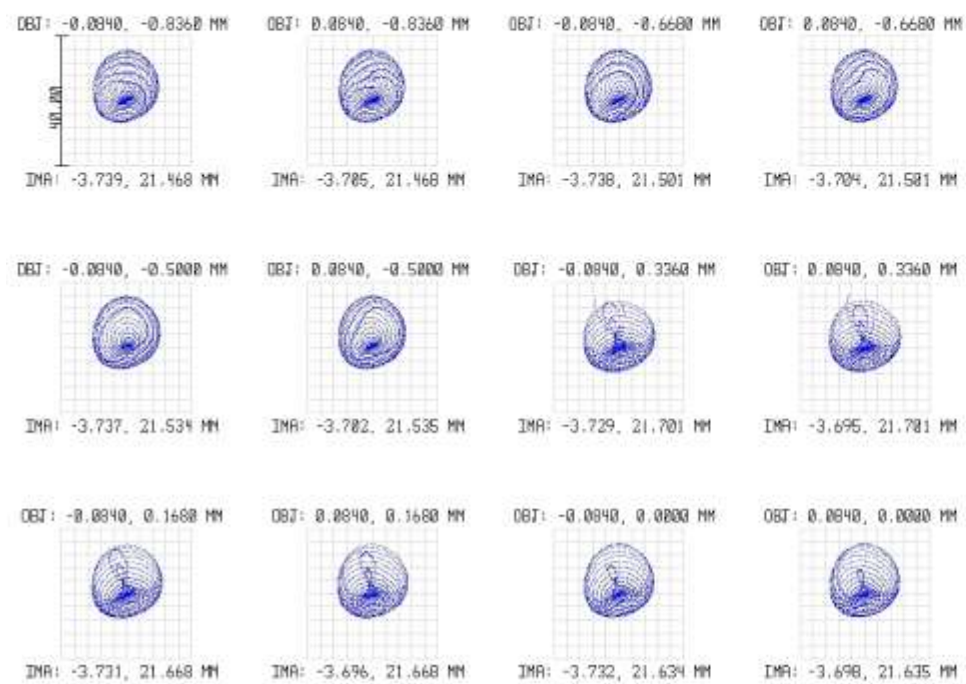




Echelle image in 400-760 nm over CCD frame



Optical quality over focal plane



Project’s current status

1. Optical design completed and checked
2. Pre-slit and calibration units are ready
3. Fabrication of camera and CCD are under process

4. Expected first light – end of 2018.

Project 2. Project of complex of 0.5-m telescopes (SAO of RAS + RusSciFoundation)

Aerial view of future complex (model)

Prototype of first telescope in SAO Lab.

System’s parameters

1. Up to 6 telescopes with D=0.5 m by “AstroSib” company (Novosibirsk, Russia) with Ritchie-Cretien system

FOW in primary focus with corrector (F/2.7) will be about 2°× 2°
FOW in secondary focus (F/8) will be 40’× 40’

2. Fast mounts from 10 Micron (Austria) (model GM 4000 HPS)
Pointing speed - 5°/сек
Tracking accuracy - < 1” for 2 hour exposure

3. Low-noise wide-field CCD cameras with Peltier cooling
Size: 4К × 4К (4096 × 4096)
Readout noise 10 e-
Pixel size: 9 мкм

4. Wideband filters SDSS (ugri) and Johnson-Cousins (UBVRcIc) systems, analyzers of circular and linear polarization

Current status

1. The 2 telescopes with CCD cameras were bought in 2016 (by RusSciFoundation supports)
2. First dome now is under construction and should be completed in 2-3 months
3. Second dome should be completed in 2018
4. Some agreements with Russian foundations and leading universities about next telescopes are in progress

Project 3. 1-meter Wide-Field Telescope with FOW= 3º

Project by Institute of Astronomy of RAS (Moscow)
Model - ASA AZ100WF:

Manufacturer - ASA Astrosysteme GmbH (Австрия).

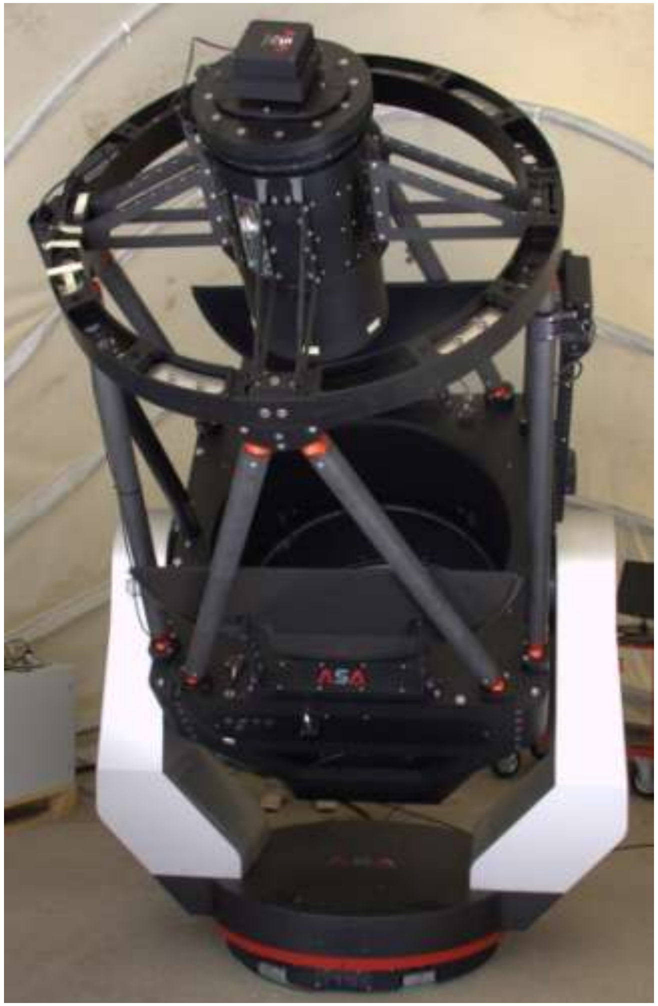
Main parameters of ASA AZ1000WF

Aperture	1000 мм
Focal Ratio	f/2.5
FOW angular	3 º
FOW linear	130 мм
D80, center-to-edge	8-15 мкм

- Field rotator and focuser are presented
- Alt-azimuthal mountind
- Pointing speed: >6°/s (on both axes)
- Pointing acceleration: 1°/s² (both axes)

Price: 0.5 M Euro

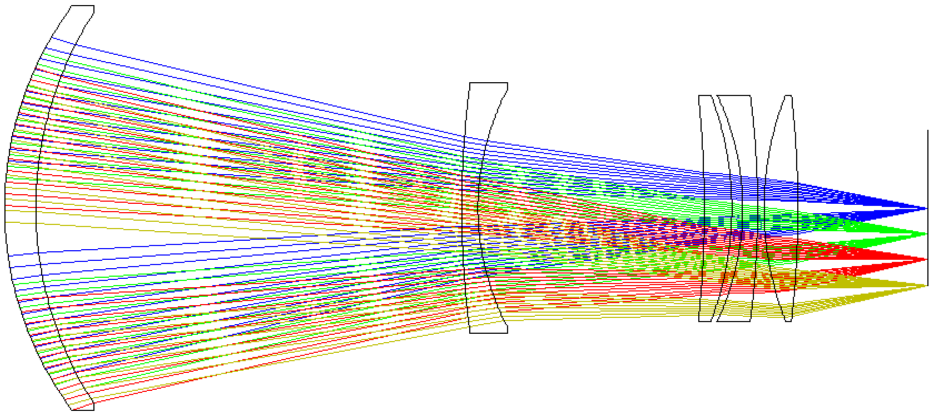
Delivery time: 18 months



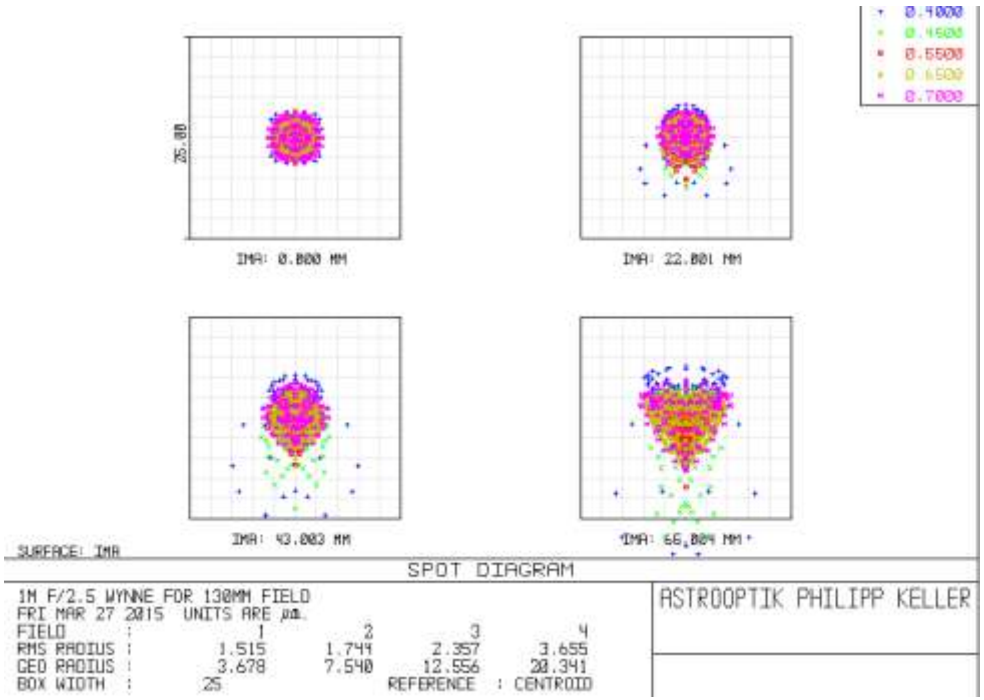
ASA AZ1000WF June 2017, Austriaя

1-meter Wide-Field Telescope with FOW= 3°

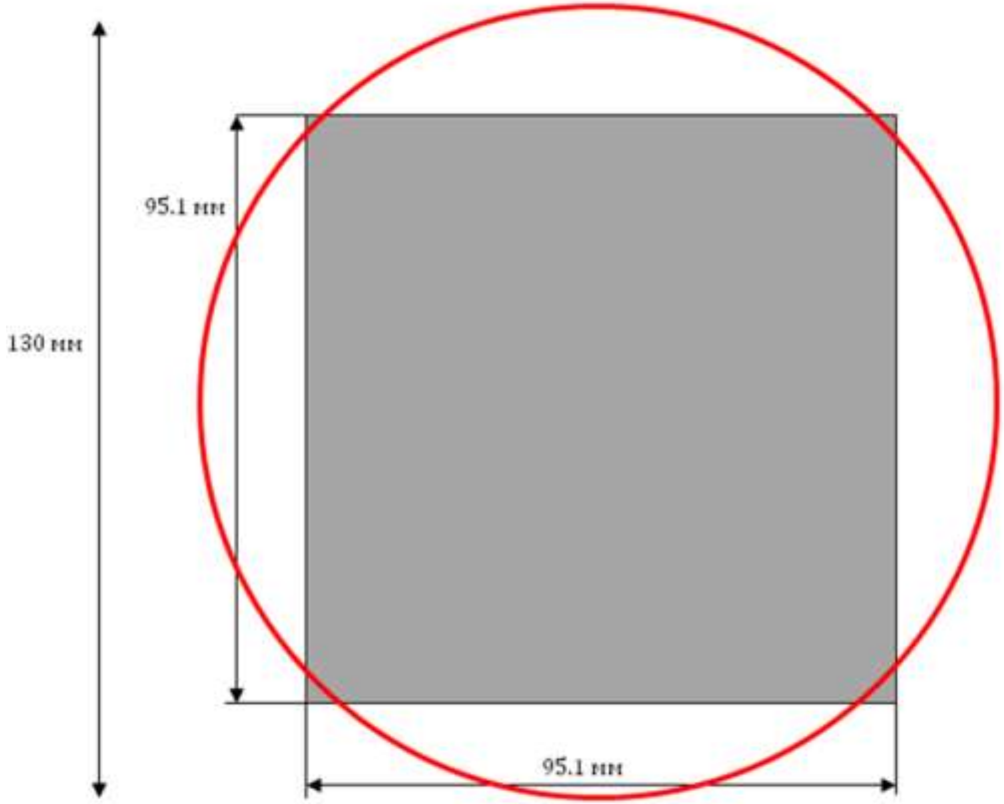
Optical design of lens corrector

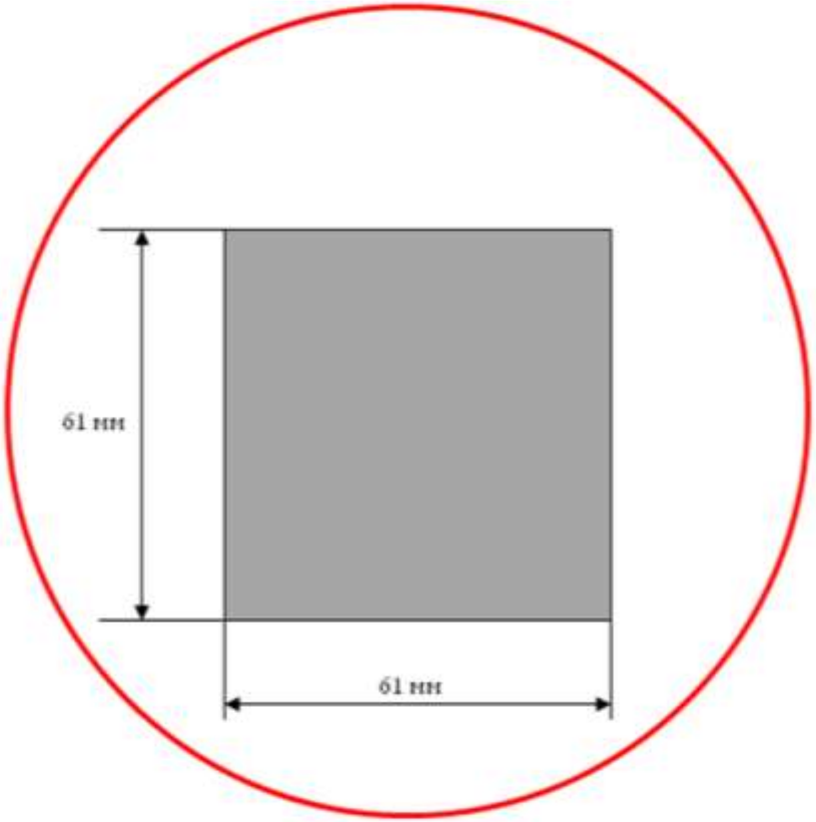


Optics quality



CCD fields for Telescope: 2 types



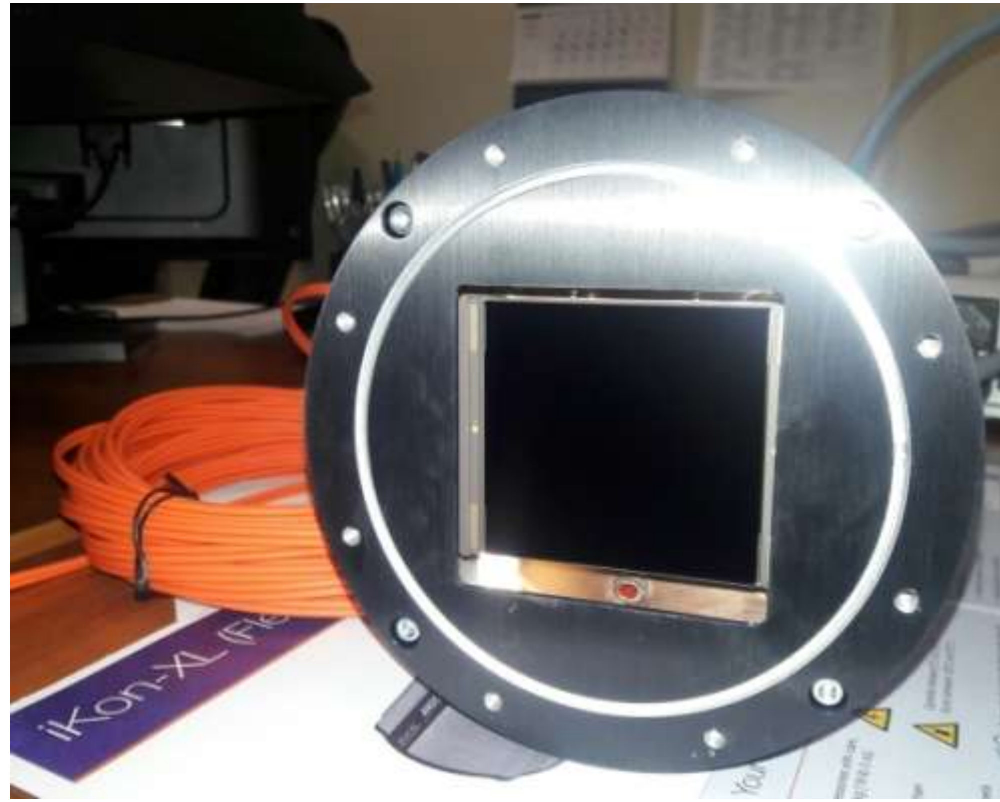


Spectral Instruments 1110S (USA)
STA 1600
95x95 mm
10к x 10к 9 mkm pixel

ANDOR iKon-XL 230 (UK)
CCD230-84
61.4 x 61.4 mm
4096 x 4112 15 mkm pixel

CCD for the Telescope:

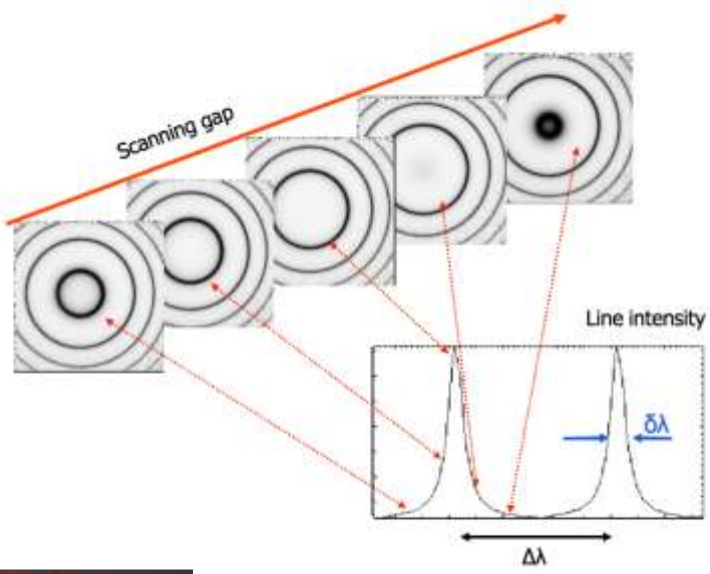
ANDOR iKon-XL in Institute of Astronomy Lab



Project 4. 3D spectroscopy with scanning Fabry-Perot interferometer

Scanning FPI at the Russian 6-m telescope: 35 years history, progress in technique:
- Boulesteix et al. (1982): “Two dimensional interferometric photon counting observations with the 6m telescope”
- FPI+SCORPIO focal reducer: Afanasiev et al (2005), Moiseev & Egorov (2008)
- modern SCORPIO-2 focal reducer: Afanasiev & Moiseev (2011), Moiseev (2015)

large field of view: 6 arcmin
high spectral resolution: δλ= 0.5…2Å
small spectral range: Δλ=λ/n=8…30 Å



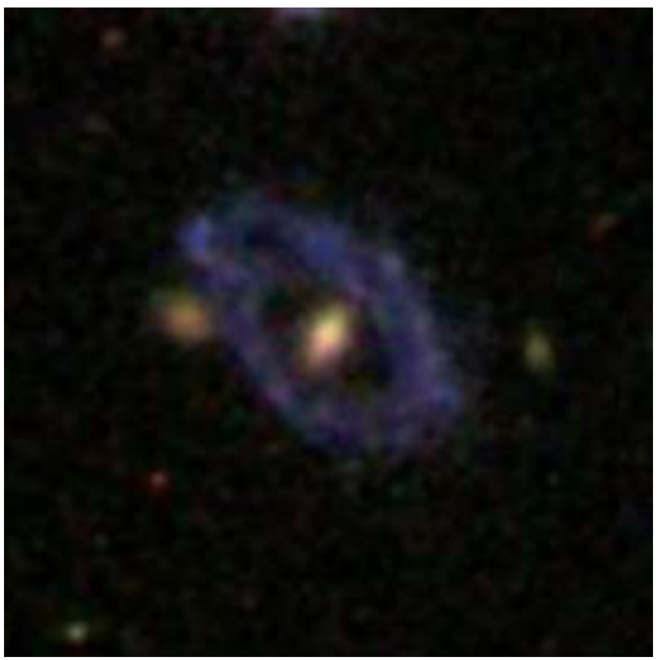
SAO (Russia) – SAAO (South Africa) collaboration: ring galaxies in 3D

Observations: 6-m telescope BTA (Russia)

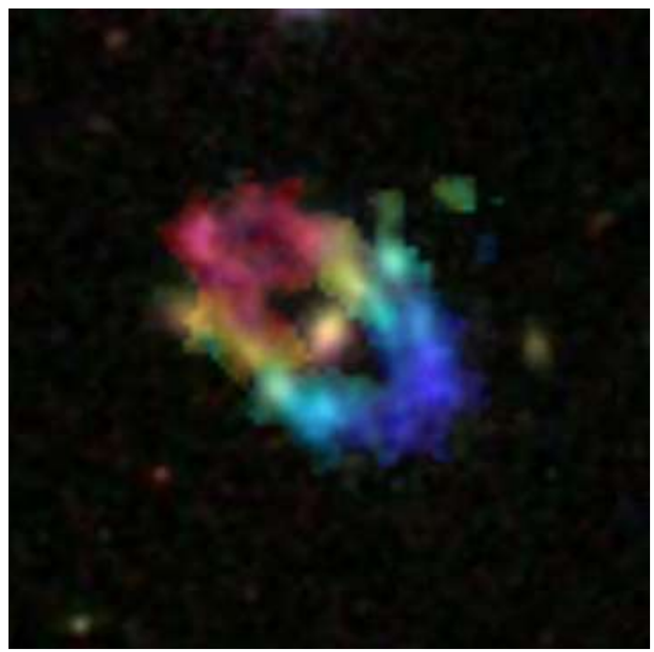
New distant polar ring galaxy SDSS J075...
Brosch et (2010)

A gigant (D=50 kpc) stellar-gaseous disk inclined on
Δi= 73±12º relative central S0-like host. M/L=20

SDSS-image



FPI mapped velocities of the ionized gas:



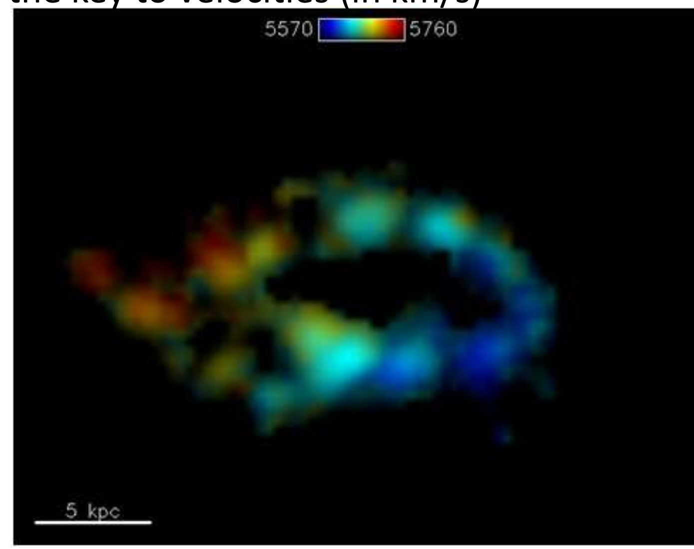
SAO (Russia) – SAAO (South Africa) collaboration: ring galaxies in 3D

Observations: 11-m The Southern African Large Telescope

ESO474-G040: Not “the Eye of Sauron”, but still a fascinating galaxy

https://www.salt.ac.za/news/not-the-eye-of-sauron/

The velocities of gas in the galaxy, resulting from the Fabry-Pérot observations, are colour-coded, with the key to velocities (in km/s)



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS 451, 4114–4125 (2015) doi:10.1093/mnras/stv1245

The empty ring galaxy ESO 474-G040

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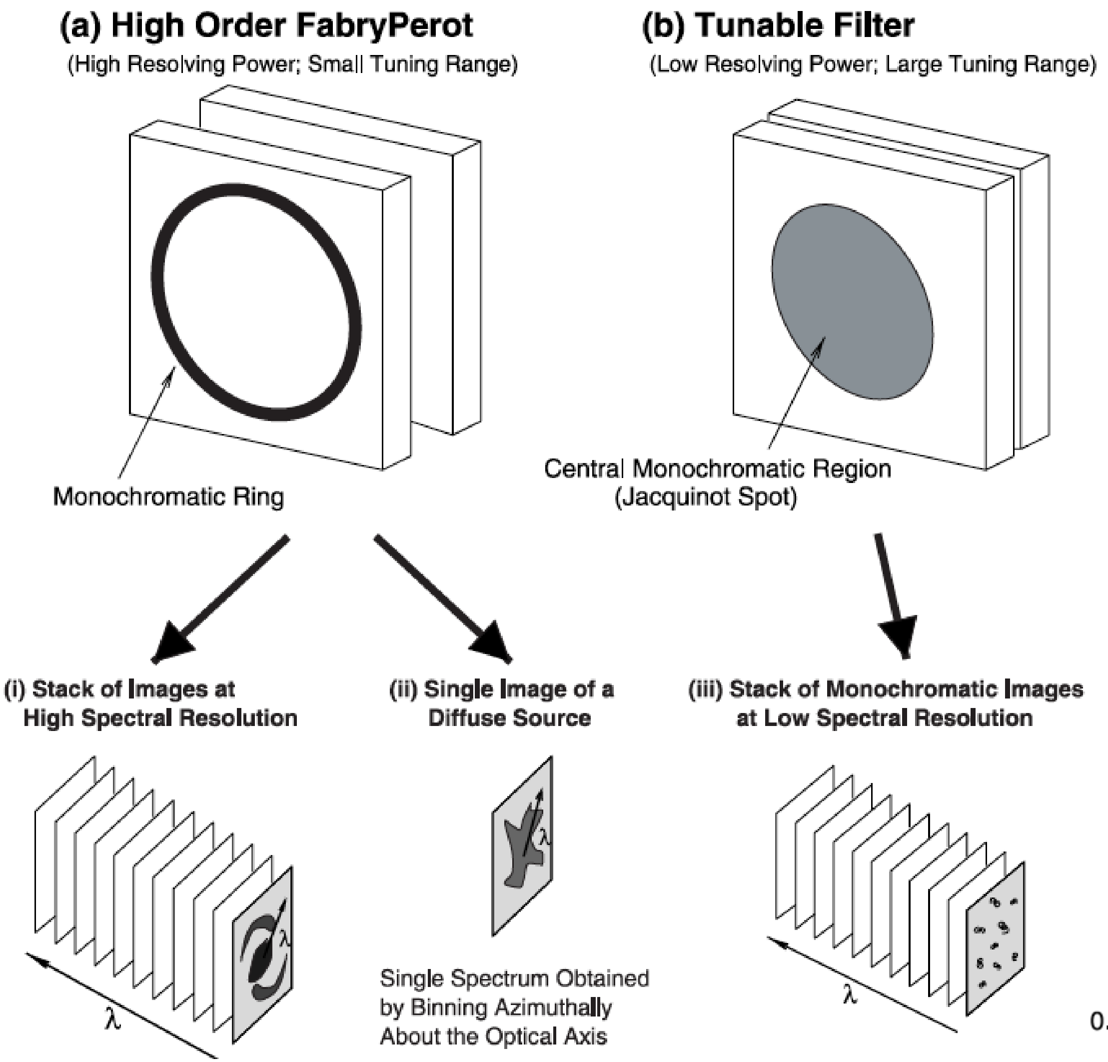
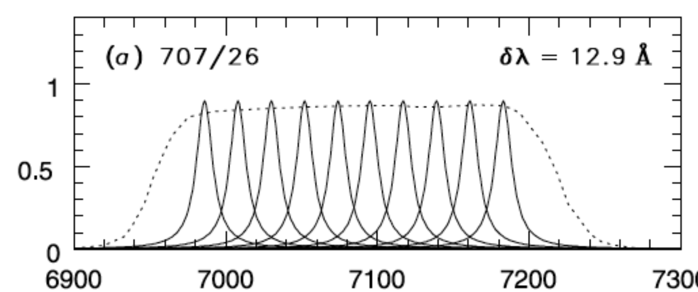
[2]*South African Astronomical Observatory, PO Box 9, Observatory 7935, Cape Town, South Africa*

Tunable Filter based on Fabry-Perot interferometer



Tuning with 1-2 nm resolution on individual emission lines and continuum



Jones + 2002

Tunable Filter: a solution for 1-2 m class telescopes

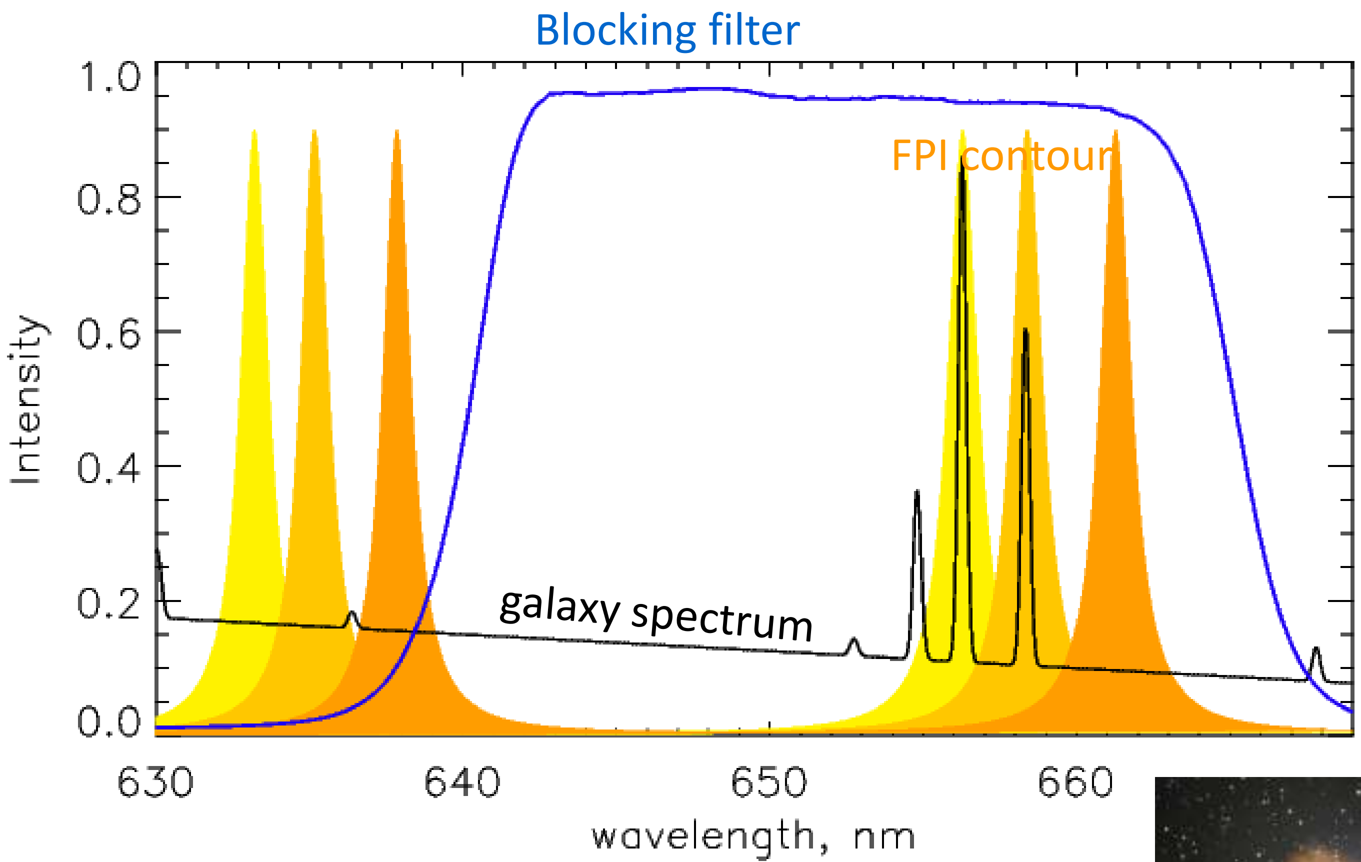
1-m SAO RAS telescope:
(the first light was taken in Sep 5th, 2017)

Focal reducer (1:2) with FPI tunable filter:
FOV: 9'
Resolution: 1 nm
Detector: iKon M-934, Andor

Instrument at the Z-1000 Cassegrain focus

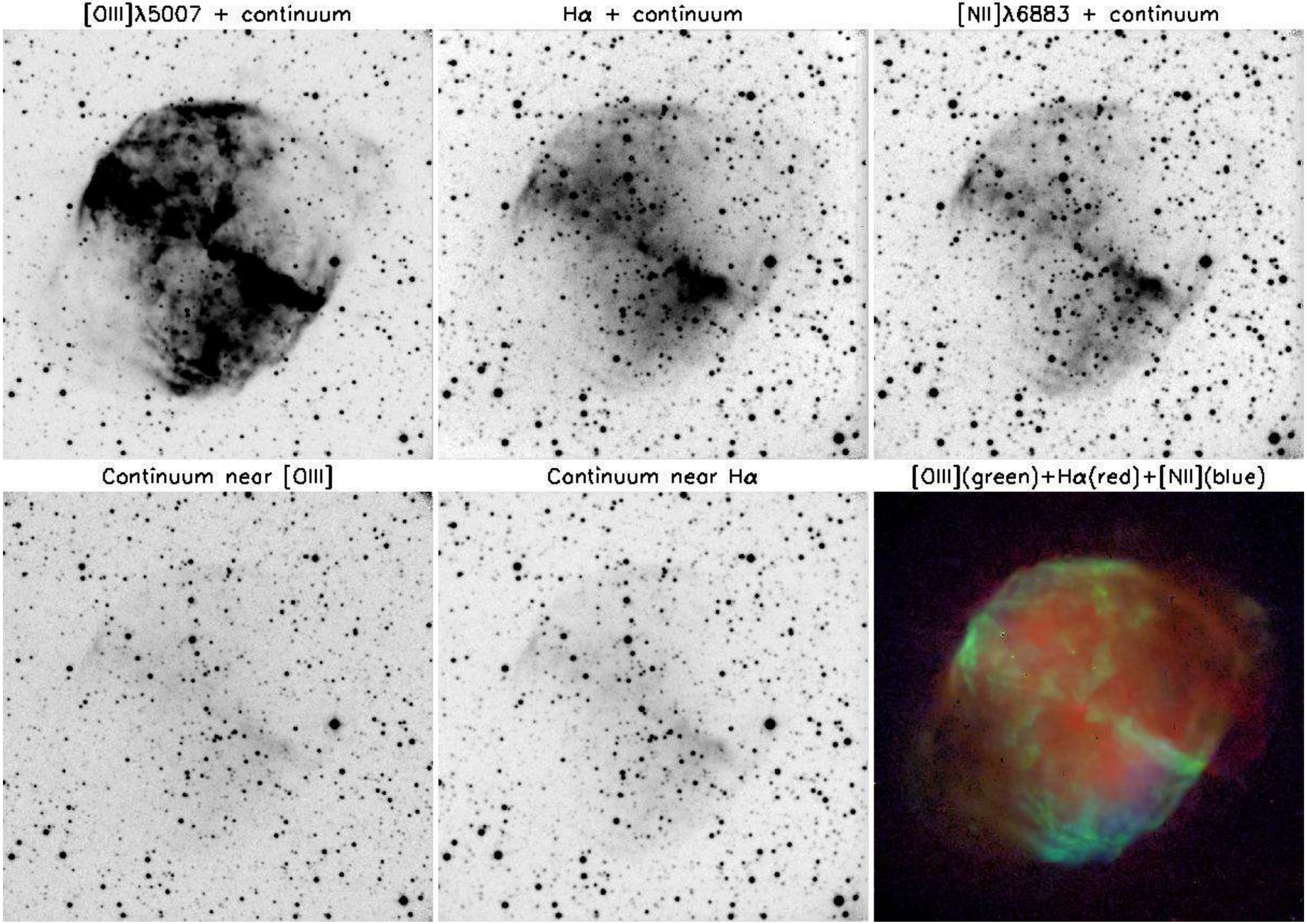
2.5-m SAI Moscow State University telescope
(October 2017?)

Tunable Filter: the main idea

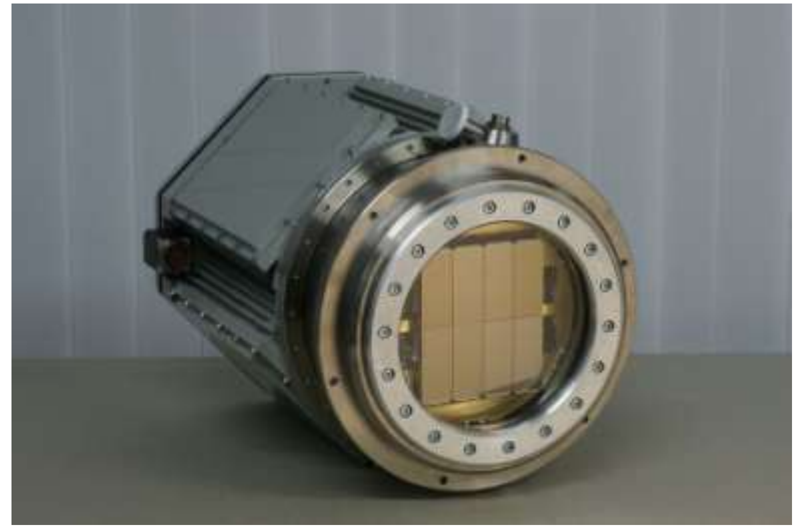
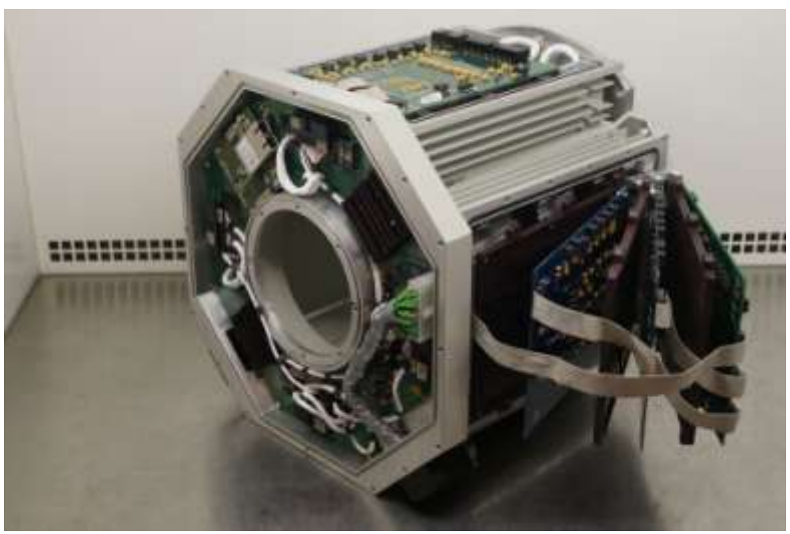
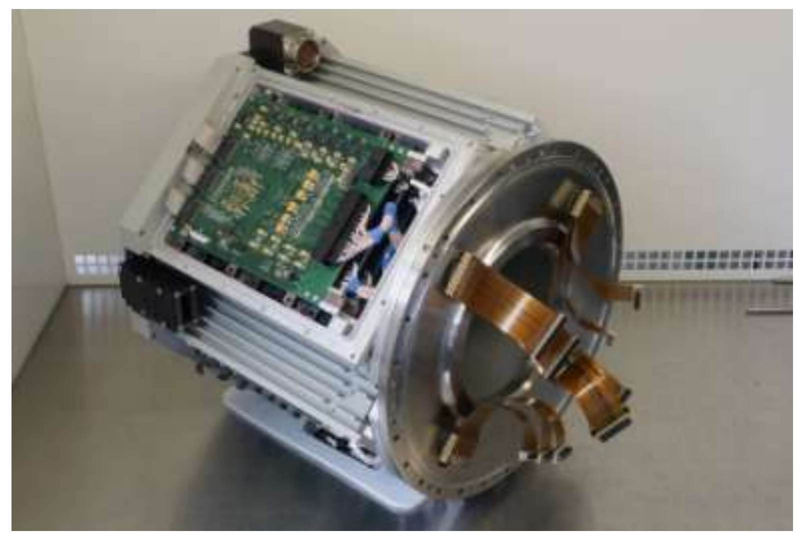


- planetary nebulae, HII regions, Supernova remnants
- extended ionized gas disks in galaxies
- emision filaments and jets around active galactic nuclei

MaNGaL at 1-m telescope: tunable filter mode. NGC 6853



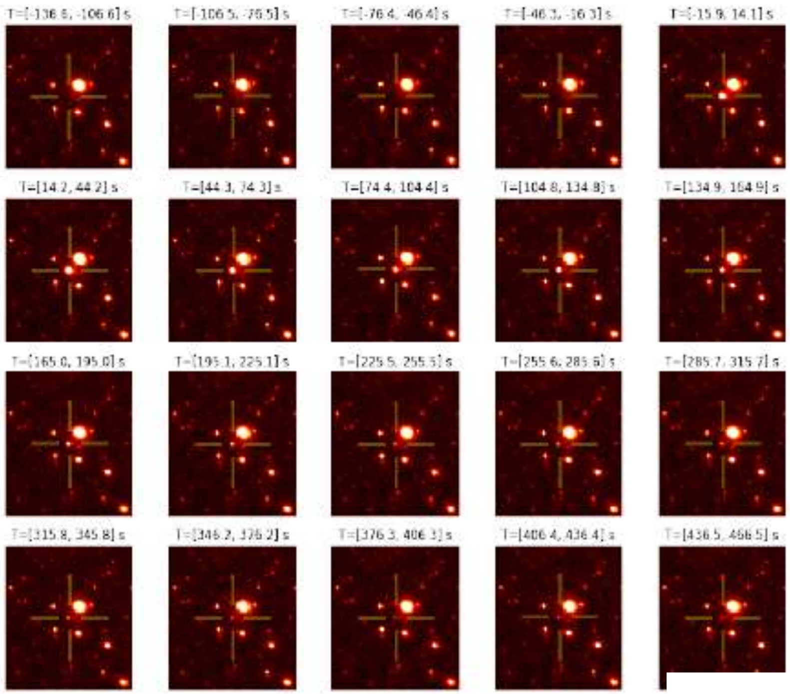
Project 5. Current projects of SAO RAS – large format cameras and mosaics

Project 6. The multi-channel wide-angle telescope of high temporal resolution Mini-MegaTORTORA – since 2014

Performance capabilities : 9 channels with the field of view of 100 sq.deg. each.
Threshold of magnitude – about 11.5 mag during 0.1s or 15 mag during 60s.
There is a project of extending the system.

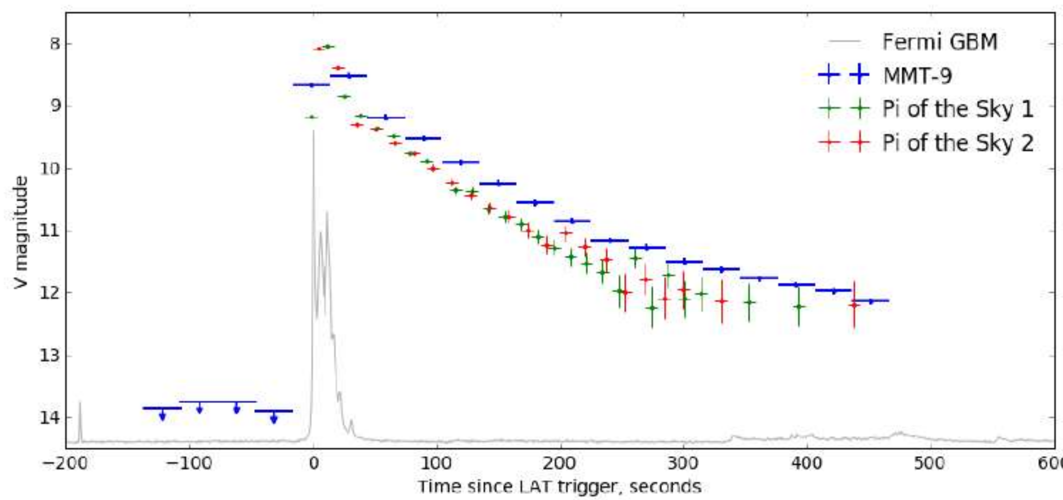
The MMT study of GRB160625B



Operation by a precursor at -180 sec

The study in the field of30x30 grad
T_{exp}=30sec

The lag of optics in comparison with gamma-rays is about 3 sec




Thank you for your attention!