Astrophysics in Kazakhstan

Chingis Omarov
Denis Yurin, Maxim Makukov

Joint Meeting with China-Kazakhstan collaboration
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Fesenkov Astrophysical Institute

photo: main building of Fessenkov Astrophysical Institute

Our Structure

Department for Observational Astrophysics (Physics of Stars and Interstellar Medium, Planets and Earth's Satellite Observations)

Department for Theoretical Astrophysics (Cosmology, Stellar Dynamics, Computational Astrophysics)

Staff : **112, where:**

Doctor of Phys & Math Sciences – 6
Candidate of Phys & Math Sciences – 24
Postdoc (PhD) - 9
PhD students – 9
Professors – 4
Docent – 8
Master degree - 6

Elliptical galaxies: Structure, dynamics and sources for gravitational waves

grant for 2021-2023 funded by Ministry of Education & Science

Research group: Chingis Omarov, Denis Yurin, Maxim Makukov, Pau Amaro-Seoane, Mukhagali Kalambai & Dana Kuvatova

Elliptical Galaxy (Messier 86)
http://www.cfht.hawaii.edu/HawaiianStarlight/HawaiianStarlight-Photos.html

What do we want to do?

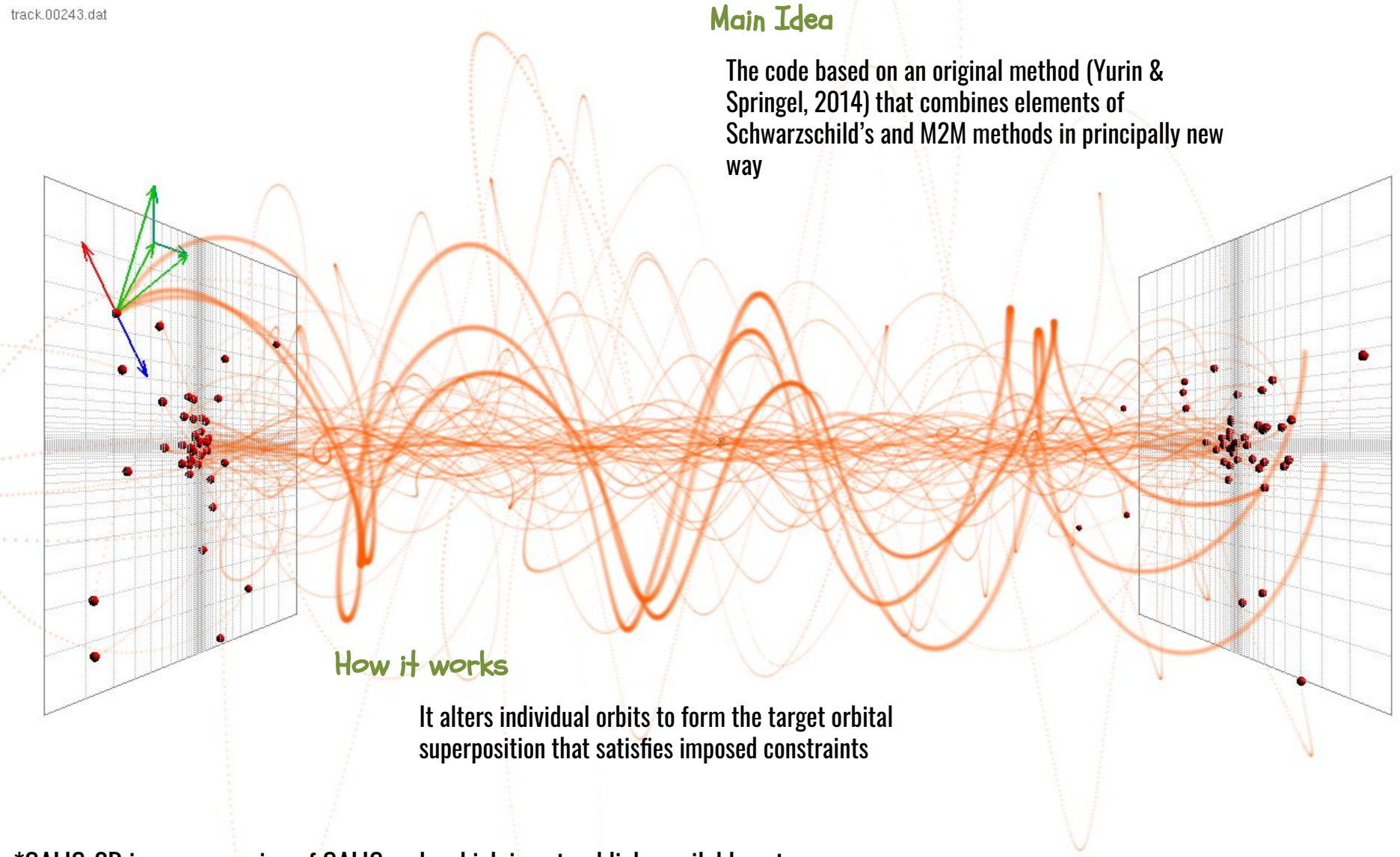
Understanding the effect of a SMBH and external perturbations on the stability of orbits in elliptical galaxies; studying the destruction of periodic orbits under the influence of perturbations, their stochastization and role in maintaining and changing an ellipsoidal shape; estimation of the event-rate of gravitational wave sources involving intermediate-mass black holes

Our main approaches

- to find the initial phase space distributions of stellar density with anisotropy of the velocity dispersion in equilibrium (GalIC code);
- to simulate the perturbed motion of stars based on the GADGET and phi-GPU codes. To apply nonlinear phase-space analysis, will enable us to obtain a detailed qualitative and quantitative view of the dynamical evolution of elliptical galaxies and;
- As for the sources of gravitational waves, from the numerical simulations we will derive an estimate of the event rate of mergers by post-processing the data

GALIC-3D Code*

allows to construct triaxial N-body galaxy models in collisionless equilibrium with prescribed density and velocity structures



Main Idea

The code based on an original method (Yurin & Springel, 2014) that combines elements of Schwarzschild's and M2M methods in principally new way

How it works

It alters individual orbits to form the target orbital superposition that satisfies imposed constraints

*GALIC-3D is a new version of GALIC code which is not publicly available yet

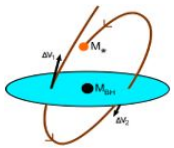

t = 1.076 Gyr
Velocities set by GALIC 2D
Y

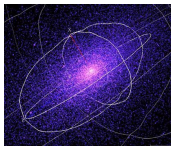
Petaflop-scale Computing Cluster at FAI

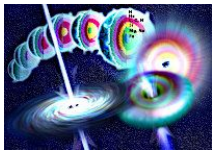
Drivers

It is developing in framework of various projects and programs carrying out in FAI

Past and current projects and programs that are using the FAI cluster and contributing to its growth







STARDISK, GALIC-3D, Origin of Spiral Arms, Numerical investigation of galactic nuclei with direct N-body integration, Elliptical Galaxies, Gamma-ray bursts associated with supernovae, National Virtual Observatory and more

Specs

528C / 1056T with 400G link

252 TB RAID6 with 400G link

2626 GB distributed RAM with 400G link

~35 TFlops CPU (float, accounting AVX512)

~420 TFlops GPU (float), opt. +560 Tflops

27.3 kW protected backup power

18 kW max power consumption

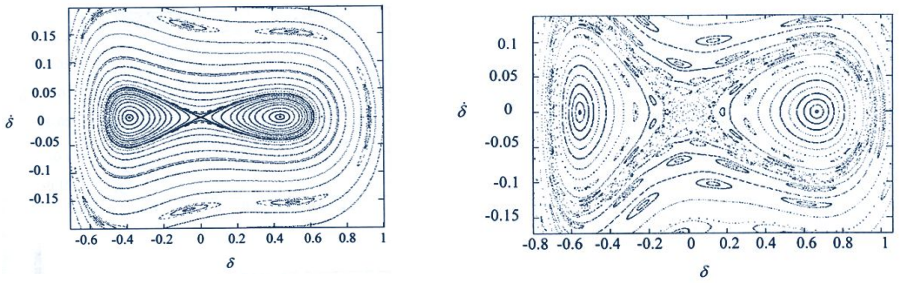
17.3 kW of precision cooling (inc. free-cooling)

**Current and planned state of the cluster (as it will be at the end of 2021)*

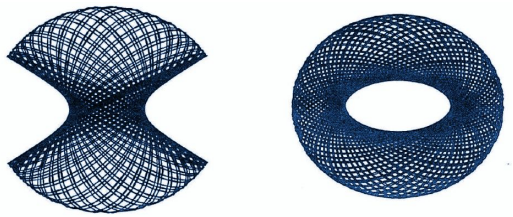
Elliptical galaxies: Structure, dynamics and sources for gravitational waves

Expected Results

- better understanding the shape and stability of elliptical galaxies;
- it will provide us with the initial phase density- and mass distributions corresponding to equilibrium states;
- the numerical analysis will deliver a detailed analysis of stability vs. instability of the initial system as a function of external perturbations;
- to shed light on the mechanism of transition from oblate to elongated configurations. By processing the data, we will be in the position of performing a nonlinear analysis of stellar orbits (including box-and loop-orbits), which is of utmost importance to comprehend the processes of parametric resonance and destruction of periodic orbits as well as their stochasticity;



Poincare section



Box and loop orbits

- to derive the event rate of relativistic mergers of binaries of IMBHes and also of stellar-mass compact objects with intermediate-mass black holes, of big interest in view of the recent detections of the ground-based detectors LIGO/Virgo.

Development of the national Virtual Observatory (VO) based on robotic telescopes, Big-Data technologies, and high-performance computing

Targeted program funding 2021-2023 by Ministry of Education & Science (government order)

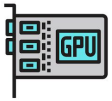
What is our aim?

Development of the digital virtual environment to enhance the capabilities of astronomical research and provide services to external users. Development of the methods to process, store and analyze Big Data in astronomy for the investigation of near-Earth and deep space objects

Our main approaches

- experimental development — development of software for automated control system for optical telescopes and their remote access, compatible with international open standards;

- optimization works — evaluating the efficiency of the GPU cluster;

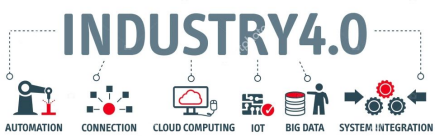


- works on data analysis — development of methods, algorithms and tools to analyze Big Data in various astronomical contexts;

- development of methods for integrating astronomical data obtained from ground-based telescopes into a single environment, with the access to that data provided;

- design of an information space — the development of user interface that provides an interactive service for accessing the large volumes of astronomical data.

Conceptual scheme for a virtual observatory



VO

Web-interface

Data Storage

Simulations & Data Processing

Observation Service
- Online Observation Ordering
- Automatic Observation Order Execution
- Online Results Delivery

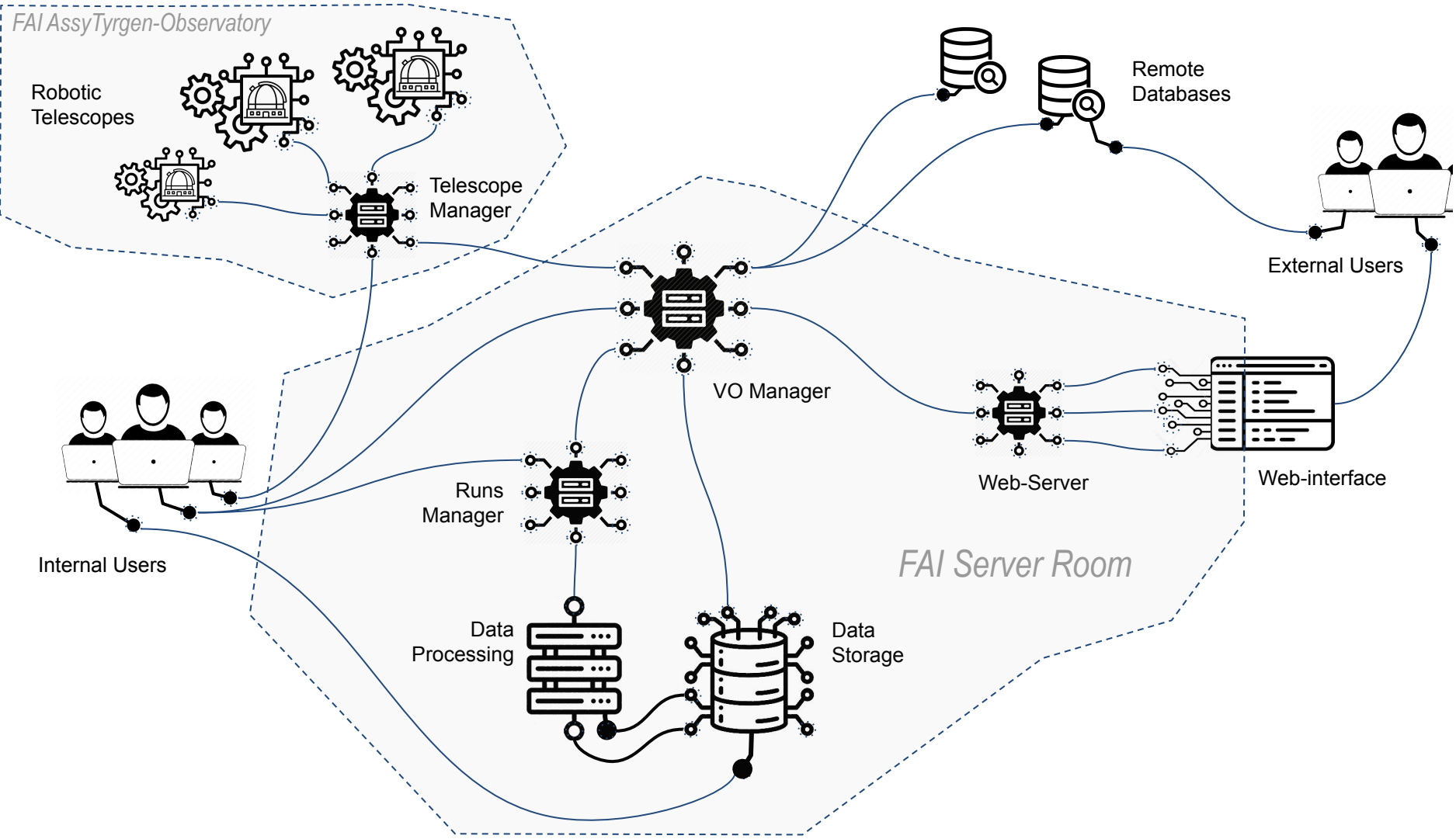
Data Service
- Online Access to *Observation* Datasets
- Protocol Access to *Observation* Datasets
- Online Access to *Simulations* Datasets

Current DataSets

Astroplate Library

Computational Service
- Online Simulation Ordering
- Automatic Simulation Order Proceeding
- Online Results Delivery

Virtual Observatory System Interconnections Concept



Development of the National System for Space Situational Awareness: Monitoring of Near-Earth and Deep Space and Space and Deep Space and Space Weather

Targeted program funding 2021-2023 by Kazcosmos (government order)

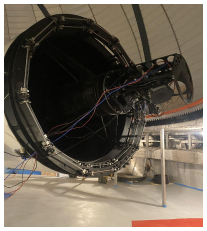
What is our aim?

Development of the Space Situational Awareness (SSA) system to monitor the situation in the near-Earth space (NES) and beyond, identify and predict situations that pose a threat to the operation of spacecraft.

The program is mainly aimed at solving the problems of NES safe usage, orbital objects near-miss events (primarily, for Kazakhstani satellites), asteroid hazard, space weather monitoring, and tracking of space debris fragments.

Our main approaches

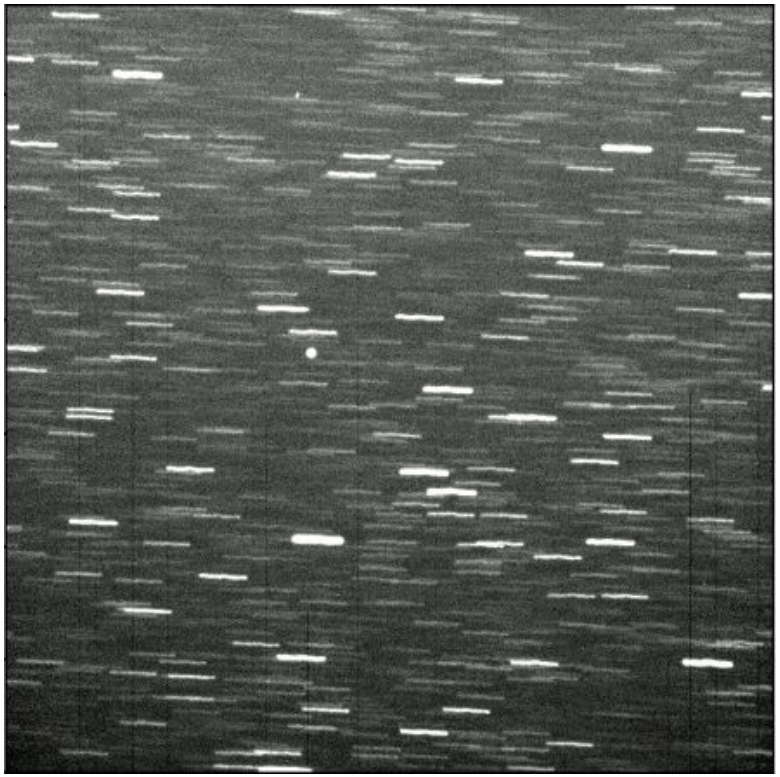
- a wide-angle optical system with the field of view of 3.8°×2.5° will be developed for monitoring and survey observations of the NES;
- for spectral observations of extremely weak objects exhibiting fast spectral variability, a prototype spectrograph based on volume phase holographic gratings (VPHG) equipped with a CCD-camera with signal amplification (EMCCD) will be created. This spectrograph will be used at the 1.5-m telescope of the Assy-Turgen Observatory (FAI) for follow-up observations and studies of deep and near-Earth space objects;



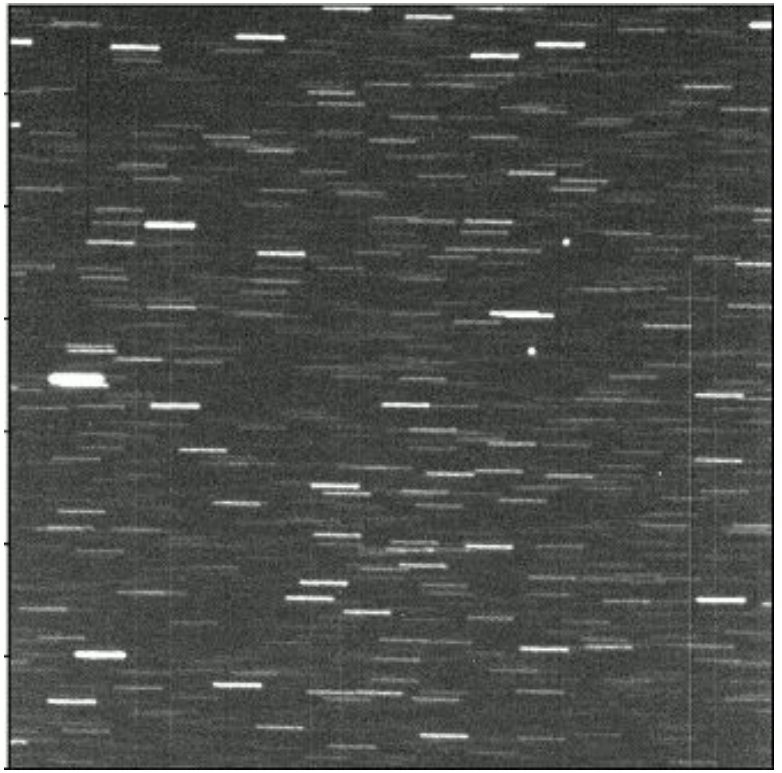
VPHG in testing

- for the development of Kazakhstani segment of space weather monitoring and forecasting, a prototype system of alert signaling about dangerous radiation in spacecraft orbits will be developed;
- a digital environment will be developed to provide centralized and coordinated
- control and interaction of all devices included in the space situational awareness system.

Earth's Satelite Observations



STTW-2 1546 & EXPRESS 2
on May 25, 2020
Forecast: UT=20:27:39, ang.dist. = 3.20 km
Observ. : UT=20:27:35, ang.dist. = 1.71 km



RADUGA 32 & RADUGA 30
on June 13, 2020
Forecast: UT=20:10:23, ang.dist. = 10.10 km
Observ. : UT=20:10:22, ang.dist. = 10.71 km

Development of the National System for Space Situational Awareness: Monitoring of Near-Earth and Deep Space and Space Weather

Assy-Turgen Observatory Plan (~3000m)

New construction started

Thank You!