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BG GRID FOR SCIENTIFIC APPLICATIONS. INSTITUTE OF ASTRONOMY APPLICATIONS

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Abstract. The development of the Bulgarian GRID for scientific applications and some basic astronomical GRID applications in the Institute of astronomy are presented. Among the applications are N_body simulations of binary open clusters, baryon-antibaryon universe simulations, modeling of comet dust structures, expressing of weak structures in galaxies, active processes on the Sun, etc.

1. INTRODUCTION

The Institute of Astronomy of the Bulgarian Academy of Sciences is included in the national initiative to exploit the opportunities of the Bulgarian GRID for scientific applications. The astronomical community will work with GRID in the following tasks:

Task 1: N-body simulation of diffuse star cluster system of two Cup.
Task 2: numerical simulation of non-homogeneous bariogenesis models.
Task 3: Monte Carlo modeling of comet dust structures.
Task 4: PIXON method for expression of weak structures in galaxies.
Task 5: Modeling of active phenomena on the Sun.

TASK 1: MODELLING OF N-BODY SYSTEM

1. Open star cluster
2. A system of two open star clusters

Method: The Particle-Particle method

* Accumulate forces by finding the force *F(i,j)* of particle *j* on particle *i*,
* Integrate the equations of motion (which includes the accumulated forces)
* Update the time counter.
* Repeat for the next time step.

For example, in a gravitational N-body simulation, a particle of mass M attracts another particle of mass m with a force: $-(GMm/r^3)*r$. You have N particles, which you are computing the force (N-1) times. Then you separate the equation into two first-order differential equations involving acceleration and involving velocity. Finally, use an integration scheme like Euler or Runge-Kutta to get the positions and velocities.

While the particle-particle method is the most straight-forward method of the N-body methods, the computational physicist must still think carefully about the numerical details of formulating the theoretical physics of the problem into a digital form, in order to derive results that are physically plausible. For example, as the particles approach each other, the forces between them, and hence the accelerations, become much larger. If one uses a constant time-step in the integration scheme in order to calculate the velocities and positions, then you're likely to encounter computer overflow errors giving nonsense numbers. To avoid this situation, you may want to consider a numerical integration scheme that uses variable time-steps, instead of constant time-steps. Such a scheme should automatically cut down the time-step when the particles are near each other, and increase the time-step when the particles are far away from each other.

Figure 1. Binary open cluster *h* and χ Persei.

The Particle-Particle direct integration approach is flexible but has a high computational cost: O(N^2) operations are required to evaluate the forces on all N particles. If you have less than about N=1000 particles, and are interested in the close-range dynamics of the particles, (or if you have more particles but special hardware) then this method is the most straight-forward.

The evolution of the binary open clusters were studied in Portegies Zwart and Rusli (2007) and the problems of existence of binary/multiplicity of open clusters – in de La Fuente Marcos and de La Fuente Marcos (2009).

In the Fig. 1 the well-known binary open cluster *h* and χ Persei is shown.

TASK 2: GENERATION AND EVOLUTION OF BARYONS-ANTIBARION ASYMMETRY OF THE UNIVERSE

The question of the occurrence of observable baryons-antibarion asymmetry of the Universe (BAU) is one of the most interesting and studied questions in modern cosmology and physics particles. Still specify the exact model of bariogenesis based on a comparison of the parameters of models with observable characteristics of the universe.

Investigated our model is based on bariogenesis Affleck-Dine (AD) mechanism for the generation of baryon excess. In order publications it was shown that the analytical estimates baryon asymmetry by several orders of magnitude may differ of numerical estimates used the exact equations describing the generation and evolution of baryons. This requires the use of numerical modeling in the study of this type bariogenesis models.

Age of baryon excess generation is significantly earlier than the epoch of cosmological nucleosinthesis therefore follow the evolution of BAU since the creation until today requires serious computing power with great performance.

Even more serious is the problem of numerical modeling of non-homogeneous bariogenesis models, except where the long evolution of BAU is necessary to trace and its spatial variations.

Successful completion of the numerical analysis of the issue of model would help us to specify the parameters of model allows generation of locally observable BAU.

Observation of cosmological data would also be possible derive cosmological constraints on the range values of the parameters of supersymmetric theories in which realize the mechanism of AD-bariogenesis. The details of the problem are discussed in Kumar (2009) and using of AD - mechanism is demonstrated in Sasuya et al. (2008).

TASK 3: MONTE CARLO MODELING OF COMET DUST STRUCTURES

Use model based on the theory of Finson and Probstein (1968) on the dynamics of particulate matter. Unknown parameters are the amount of active area coordinates on the surface of the comet nucleus and range of particulate sizes. For rotation period and inclination of the axis of rotation are fixed values used in literature (Schleicher, 2001). By trial and error we found that when the axis of rotation coincides with the z axis then the model best reproduces the observations. If the surface of the comet nucleus has a small active pool area with coordinates and particulate matter leaves then their radial position after time t is given by the following equations:

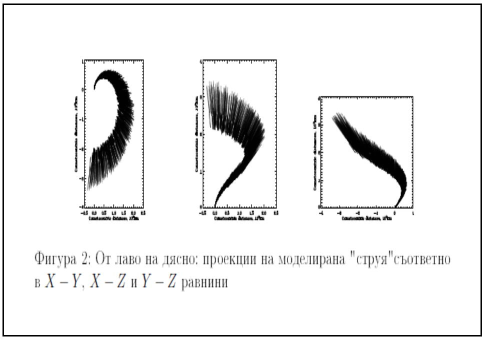
$$x = V_d t \sin\varphi \cos\theta - \frac{1}{2} a t^2$$
$$y = V_d t \sin\varphi \sin\theta$$
$$z = V_d t \cos\varphi,$$

where a is the acceleration of the particles. Our model works with constant acceleration in the inertial coordinate system. This model is valid because they assume that these structures are short-. Dust particles must be evenly distributed in this area. Initial coordinates are described as follows:

$$\varphi = \varphi_0 - \frac{d\varphi}{2} + R_i d\varphi$$
$$\cos\theta = \cos\left(\theta_0 - 2\pi\frac{t}{P} - \frac{d\varphi}{2}\right) + R_i d\cos\theta,$$

where Ri is a series of uniformly distributed random numbers in the range (R € [0,1]).

Fig. 2 shows an example simulation of the "stream" derived from the active area on the comet nucleus coordinates latitude - 45 °. The structure is shown by the production release of particulate matter in comet half day.



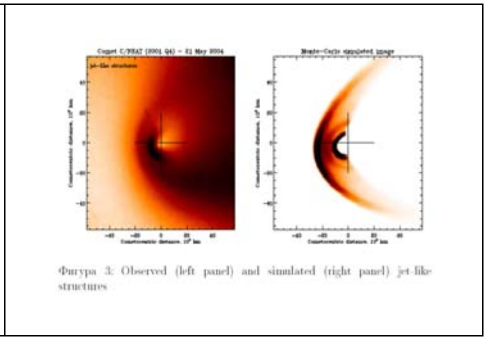


Figure 2a. From left to right: modeled projections of the "stream" respectively in the X - Y, X - Z and Y - Z planes.

Figure 2b. Observed (left panel) and simulated (right panel) jet-like structures.

The simulation at this stage is carried out for 10 comet days used were 101 particles with sizes from 10 to 100 mm with a time step 12 seconds. Provides simulation is several orders of magnitude more particles and much larger period.

TASK 4: PIXON METHOD FOR EXPRESSION OF WEAK STRUCTURES IN GALAXIES

Astronomers constantly want to detect fainter objects and discern finer details. The Pixon digital image processing technology offers the best improvements possible in image quality:

According to WEB_page of the PIXON team (see http://www.pixon.com) - *„The Sky is the Limit, not Diffraction or Seeing“* **.**

PIXON method, described by Pina and Puetter (1993) allows the users to:

- Deblur images to undo the blur caused by diffraction or atmospheric seeing.
- Denoise images without losing any of the resolution improvement achieved by deblurring.
- No introduction of spurious artifacts during image processing.
- Multiframe analysis to further improve the signal-to-noise ratio and resolution, including subpixel resolution.
- Multispectral/hyperspectral analysis to optimize image processing by taking advantage of information obtained at different wavelengths.
- Statistical flux conservation (nobias introduced).
- User control of the tradeoff between noise suppression and resolution improvement.
- Typical, artifact-free improvements in image quality are:

- Reduction of the full-width at half maximum (FWHM) of the blur by a factor of a few.
- Noise reduction by an order of magnitude or more.

In Fig. 3 from the Internet the reconstruction of the FIR image of well-known M51 galaxy (optical DSS image on the left) is shown.

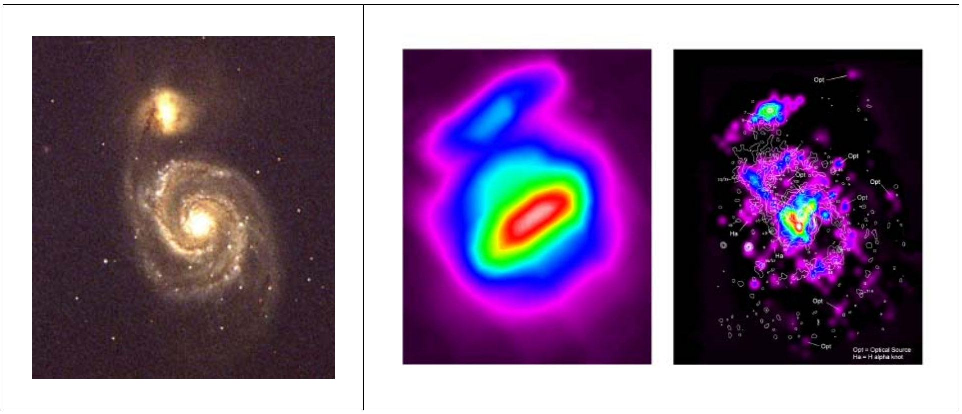


Figure 3. The reconstruction of the FIR image of M 51 galaxy.

A lot of frames, taken with the 2-m telescope at medium quality conditions will be reconstructed. A series of plates from the 2-m telescope, covering a dozen of known voids were scanned. The 15K x 15K sqr.px images were splitted on 256 sub-frames 1000 x 1000 sqr.px. each. These are ideal for parallel processing.

TASK 5: MODELING OF ACTIVE PHENOMENA ON THE SUN

The main goal of this task is modeling of prominence plasma behavior blasted by an external wave.

For this purpose we use a two-dimensional model of the protuberance in the form of an arch-shaped structure. We take standard plasma parameters values. For each step of model height we calculate conditions for generation of longitudinal currents. Also, we estimate the maximal height, where these currents close through the photosphere and the damping rate of the MHD wave.

Using GRID we hope to construct a 3D model, also to take into account fine structure of the prominence arch and to explore the nonlinear effects in the amplification of longitudinal currents.

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