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`GridChoque`: A grid environment to experiment on Spherically Symmetric General Relativistic Radiation Hydrodynamics

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Abstract

This paper presents a Grid application, `GridChoque`: a distributed, and a grid based, environment devised to explore the general relativistic spherically radiative stellar collapse using several tools of calculus and visualization.

`GridChoque` calculation engine uses a general method to solve the Einstein Equations for Spherically Radiant spacetimes proposed by L. Herrera, and Collaborators. Besides regularity conditions, models are only restricted by a heuristic assumption relating hydrodynamics and radiation physical variables such as density, pressure, energy flux and radial matter velocity. This *ansatz*, guided by very solid physical intuition, reduces the problem of solving the partial and nonlinear Einstein Equations to a numerical integration of a system of ordinary differential equations for quantities evaluated at the surfaces (shocks and/or boundaries).

These portlets were developed following the JSR-168 standard and using GridSphere as a container, in order to achieve a faster and dynamic development as it provides its own libraries for developing portlet. The portlets work using the Model-View-Controller (MVC) model to achieve a robust programming style.

`GridChoque` allows to study the evolution of the radiant shock wave front within the context of a suitable definition of the post-quasistatic approximation introducing the flux factor, the variable Eddington factor and a closure relation between them to describe a more realistic radiation transport mechanism. As a grid based tool, `GridChoque` offers the possibility to use all the processing and memory resources of the grid in a transparent and intuitive way. The

user can provide all the relevant initial values for the physical variables, send the job, monitor the status of the job and visualize the results obtained. It is also possible to follow the evolution of the physical variables (i.e. hydro & radiation pressures, energy & energy flux densities, shell velocities) through animated variable vs time and variable vs radius graphs. This is why `GridChoque` can become an useful analysis and educational tool for the relativistic astrophysics community

1. Introduction

Gravitational core collapses of compact are triggered by the implosion of the inner nucleus of a massive star (M~8-20M) when its mass is in the limit of Chandrashekar (M_{core}~1.4M). During the implosion nearly all of an enormous gravitational binding energy ($(GM^2)/R \sim 5\times10^{53}$ ergs ~0.2Mc^2) gained is stored as internal energy of a newly born proto-neutron star (PNS) and it is driven by neutrino diffusion which cools this new born compact object. Temporal and spectral characteristics of the neutrino emission depend on the rate at which they diffuse through the imploded PNS which, at this early stage, would have a mean density several times the standard nuclear density, $\bar{\rho}$~$3M/\left(4\pi R^3\right) \approx 7\times10^{14}\,gcm^{-3}$, with $\rho_0 2.\times10^{14}\,gcm^{-3}$. [**1**].

Roughly speaking, there is a consensus that this collapsing scenario requires, three main "ingredients" (see Figure **1**) [**2**]:

1. a copious emission of radiation, been a consequence of the microphysics of the system, tends to abandon the system, but the absorption and the scattering in the medium hinder it to escape freely.
2. phase transitions that can induce local anisotropic pressures (i.e. $P_r \neq P_\perp$). An increasing amount of theoretical evidence strongly suggests that, for certain density ranges, a variety of very interesting physical phenomena may take place giving rise to local anisotropy (see [**3**, **4**])
3. the formation and propagation of a surface of discontinuity: a shock wave, a detonation or combustion front (deflagration or slow combustion) having width very small compared to the size of the system.

Although now exist several independent numerical codes which provide accurate modeling of gravitational collapse in full General Relativity (see [**5**] for a good review on this subject and/or visit some these links concerning codes for simulations `http://wugrav.wustl.edu/Codes/GR3D` also see CACTUS `http://www.cactuscode.org`), none of these codes provide all the above mentioned "ingredients".

Conscious of the difficulties to cope with dissipation due to the emission of photons and/or neutrinos and, aware of the uncertainties of the microphysics when considering the interaction between radiation and ultradense matter, the approach we follow to solve the Einstein Equations starts from heuristic assumptions relating density, pressure, radial matter velocity and choosing a known interior (analytical) static spherically symmetric (considered as "seed") solution to the Tolman-Oppenheimer-Volkov equation. This scheme transforms the Einstein partial differential equations into a system of ordinary differential equations for quantities evaluated at surfaces whose numerical solution, allows the modelling of the dynamics of the configuration. This method is an extension of the so called HJR [6], which has been successfully applied to a variety of astrophysical scenarios (see [7] and [8] and references therein) and which has been recently revisited [9, 10] in order to appreciate its intrinsic worth.

`GridCHOQUE` is based in a numerical code that solves the evolution of a radiant shock wave in relativistic autogravitant spheres in the context of a post-quasistatic approximation. The central code for `GridCHOQUE` have been taken form Rueda and Nuñez [11], whose model provides all the necessary ingredients to study the gravitational collapse: first, a copious emission of radiation, been a consequence of the microphysics of the system, tends to abandon the system, but the absorption and the scattering in the medium hinder it to escape freely. Second, phase transitions that can induce local anisotropic pressures (i.e. $P_r = P_\perp$). Third, the formation and propagation of a surface of discontinuity: a shock wave, a detonation or combustion front (deflagration or slow combustion) having width very small compared to the size of the system.

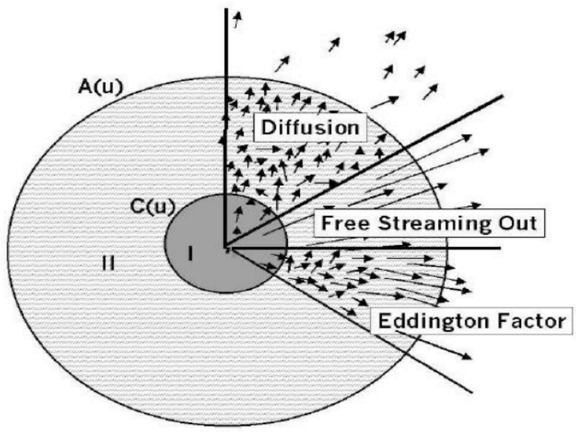

Figure 1: Regions of the matter distribution. The nucleus (I) is the more compact region, the mantle (II) is located in the middle and at last the outer space-time (III)

2. `GridCHOQUE`

`GridCHOQUE` is a integrated environment devised by web interfaces and grid technologies, portable, easy to use and well documented that let the user simulate and visualize, in an easy and systematic way, the gravitational collapse and the propagation of hydrodynamic discontinuities in radiant spheres. In addiction, `GridCHOQUE` offers a userfriendly interface, making use of the security, computing and storage capacity of grid technology. The structure of `GridCHOQUE` is composed by three main modules: pre-processing, processing and post-processing.

Pre-processing:

This module allow the user to introduce the parameters to model the matter configurations . These paramenter are related to the initial state of the selfgravitanting sphere, the characteristics of the shock wave and the interaction between matter and radiation. They are: $A(0)$ (inicial radius of the configuration), $\dot{A}(0)$ and $\dot{C}(0)$ (inicial velocity of the border or shock wave, which separate the core and mantle of the sphere), C(0) (inicial position on the shock wave), N (shock strength), ξ_I (anisotropy of the nucleus), ξ_{II} (anisotropy of the mantle), f_I (Eddington variable factor of the nucleus), f_{II} (Eddington variable factor of the mantle), $M(0)$ (initial mass of the configuration), M_f (final mass of the configuration), s (width of the Gaussian luminosity pulse), t_0 (starting time of the evolution) y t_f (ending time of the evolution). Also in this module the `JDL` file is created. The `JDL` (**J**ob **D**escription **L**anguaje), is a fully extensible language for distributed frameworks, allowing to use whatever attribute for the description of a job that is going to be sent to the grid (see `http://egee.cesnet.cz/en/voce/JDL_Info.pdf`).

Processing:

Given the initial conditions, the fortran subroutines integrate numerically the system of ordinary differential equations at the surfaces and evaluate the expressions for the metric functions to determinate and validate the value of the physical variables (hydrodynamic and radiation contributions to the radial pressure, tangential pressure, radiation flux, density and radial velocity of the material). The execution of the program is made on the grid of the Universidad de Los Andes (ULA) using its storage and processing resources.

Post-processing:

This module allow to visualize and analyze the results obtained using two different types of applets. The first one shows the evolution of the physical variable versus the radius of the spherical configuration through the time and enable the communication between the user and the program by using the a serie of control buttons in the working area of the applet. The second one, makes an association between a color array and the distribution of the physical variable inside the material configuration, this allow seeing its time evolution. Also it is possible to obtain the result files in a compressed file.

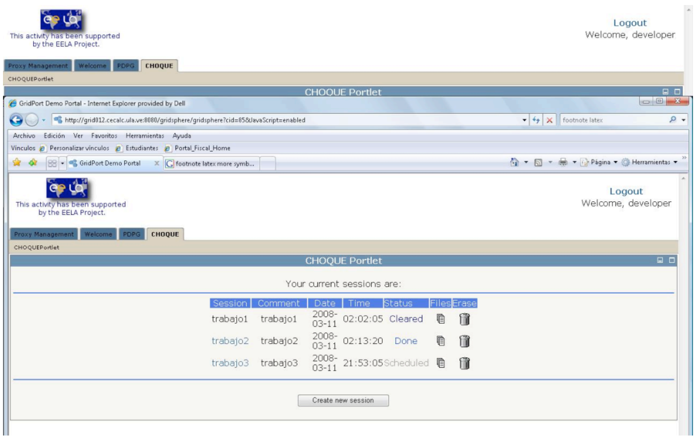

Figure 2: Initial screen of `GridCHOQUE` where is possible to see the name of the jobs sent to the grid, the date and time when they were sent and their status,

3. Portlet Choque

A portlet is web component made in Java, portable, based on standards and managed through a portlet container which process all the client petitions and produce dynamic content. There are different tools used in the portlet development.

3.1. Portlet Choque Architecture

To create CHOQUE portlet we used `GridSphere` version 3.1. The `GridSphere` portal framework provides an open-source portlet based Web portal (http://www.gridsphere.org/gridsphere/gridsphere). `GridSphere` enables developers to quickly develop and package third-party portlet web applications under the JSR.168 specification that can be run and administered within the portlet container. The Java Portlet Specification (JSR) defines a contract between the portlet container and portlets. It provides a convenient programming model for Java portlet developers (http://developers.sun.com/portalserver/reference/techart/jsr168/pb whitepaper.pdf). The middleware used is gLite 3.0.1 (shttp://www.eu-egee.org/glite) [12]. The middleware is defined as the software lawyer located between the operating system and the applications in each host. This software consists of a set of services that allows multiple processes running on one or more machines to interact [13].

The web container used in Apache Tomcat 5.5.25 (http://tomcat.apache.org/). The resource used include the hardware described in the last section and we have used the fortran compiler G95. `GridChoque` use the arquitecture Model-View-Controller (MVC) (http://www.phpwact.org/pattern/model view controller). The heart of the portlet is a servlet application and a group of dynamic java pages, Java Server Page (JSP).

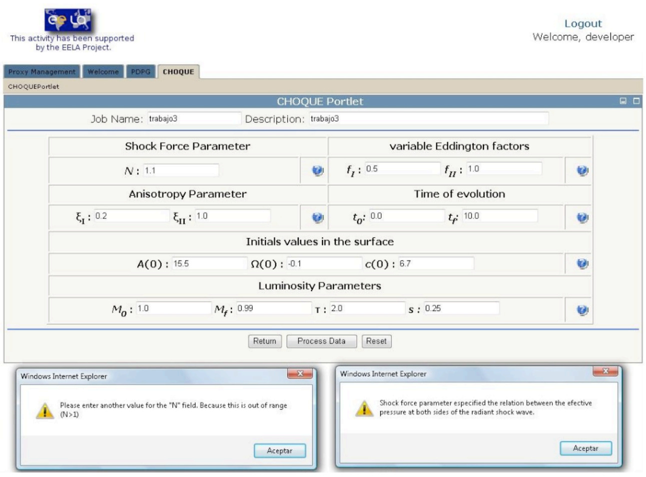

Figure 3: Screen of data capture in `GridCHOQUE`

All the portlets have a life cycle, which is managed by the `GridSphere` container. The life cycle of portlet CHOQUE is defined using three different methods: `init()`, `processAction()` and `doView()`. When the portlet is initiated for the first time, the `init()` method is invocated and provides to the portlet with all the initializations and information of configuration necessaries to manage the requests made to the portlet by the user. At this time the database used by `GridCHOQUE` is also created. In general the portlet separate the graphic presentation (`JSP` files displayed) from the logic part (operations in response to an occurred action like the user click a button or send a form) of the portlet in different methods. In case of `GridCHOQUE` the presentation is manage by the `doView()`, it is responsible to decide which `JSP` are going to be displayed and what information is given to those pages. The logic part is managed by the `processAction()` method and it captures all the data entered by the user and process them.

3.2 User interface

When the user enter in `GridCHOQUE` the `doView()` method display a JSP file where he can see the name of the jobs sent to the grid, the date and time when they were sent, their status. There is a button to erase them, a button to visualize them and/or to obtain the results files and another one to create a new job (see Figure 2)

If the user decides to send a new job a jsp file template will be displayed. In this template the user can introduce initial parameters of the system, the name of the job and a brief description of it. The validation of the data is made using some functions written in JavaScript (see Figure **3**). Then the `processAction()` will create the jdl file and will send the job to the grid. The portlet send the initial files and the executable of `GridCHOQUE` to the grid. In this way the nodes on the grid only need the g95 compiler to run the job.

It is important to mention, that the user can consult the status of the job: SUBMITTED, WAITING, READY, SCHEDULED, RUNNING o DONE. Once the status of the job is DONE, the user can visualize the results files, clicking on the Files icon. In this page the user can chose a line graphics (graphics option) or a color animation (animation option). The user can also download the initial files and the results files from the server to his own computer by clicking on the Get these file button (Figure **6**)

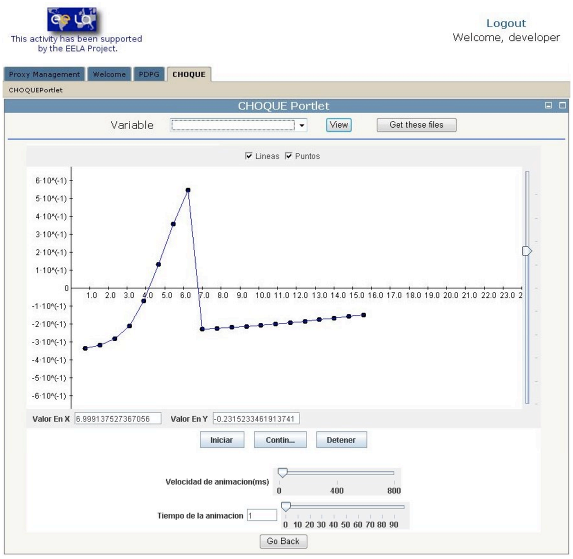

Figure 4: Visualization of the variable radiation flux using line graphics

If the user press the View button and the option chosen is Graphics, it will appear a page of data visualization by line graphics. There the user can select which physical variable he want to visualize (radial velocity, hydrodynamic radial pressure, radiation radial pressure, hydrodynamic tangential pressure, radiation tangential pressure, total pressure, radiation flux, hydrodynamic energy density, radiation energy density and/or total energy density) (see Figure 4). In case that the option chosen is animation, it will appear the animation of the selected physical variable (see Figure **5**)

The `sendind`, consult status and result recovery are operations that the user can do in a transparent way through a userfriendly interface.

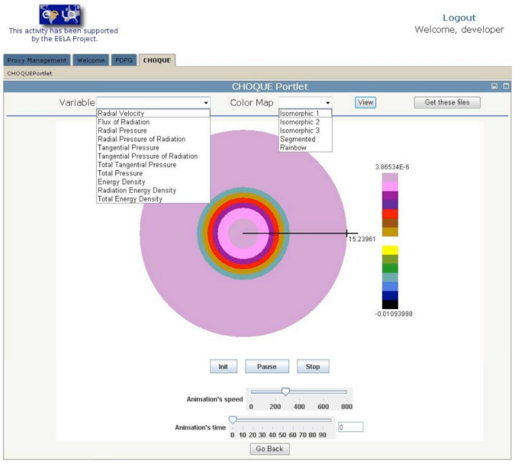

Figure 5: Visualization of the radial velocity of the system using map color animation

3. Conclusions

The use of grid technology have been increasing fast in the last years, because of the advantage to use a distributed computational and storage power. However, it's necessary that the users can be profited by the grid and its applications in a simple and transparent way. This can be achieved through the use of portals and portlets, which have a simple and attractive interface to the hardware and software resources in the grid.

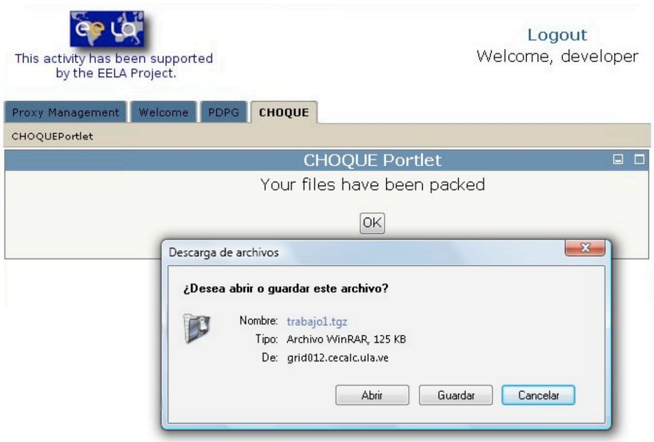

Figure 6: Screen to get a compressed file with the initial and results files in GridCHOQUE

In this case we hav developed `GridCHOQUE`, a web tool in Java, following the standard JSR168, which can be use to create the initial files necessary to run a serie of fortran subroutines in the grid in order to study the evolution of the radiant shock wave in a spherical matter configuration. Also it allow the user to visualize the results files using two different techniques: line graphics and color animation. All this characteristics makes `GridChoque` a suitable analysis and educational tool for the relativistic astrophysics community.

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