NUMERICAL STUDY ON THE FRAGMENTATION CONDITION IN A PRIMORDIAL ACCRETION DISK

Allocation: Illinois/1,000 Knh
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EXECUTIVE SUMMARY

This project uses Blue Waters to study the accretion flow that surrounds the first luminous objects known as Population III stars. These early-stage protostars are believed to be surrounded by massive accretion disks where competition between gravity and turbulence leads to the formation of multiple stellar objects. The goals of the project are to understand the multiplicity of the first stellar systems as well as to find the limits on the final mass of individual Population III stars. The research team also aims to uncover the unique roles of both turbulence and gravity on the resulting variability of the accreted mass that governs the final mass of Population III stars.

RESEARCH CHALLENGE

The simulation will provide a numerical model that furthers our understanding of the formation of Population III stars and their possible observable quantities.

METHODS & CODES

This work uses GAMER-2 [1] in conjunction with GRACKLE [2]. The numerical scheme allows the team to explore the accretion flow instability while self-consistently evolving the primordial chemistry.

RESULTS & IMPACT

The simulation suggests that the primordial accretion disks are highly turbulent and, thus, the formation of companion stars could be delayed. Using Blue Waters, the team aims to deepen the understanding of the conditions under which companion protostars may form and how it may impact the initial mass function of primordial stars.

WHY BLUE WATERS

Blue Waters provides the environment that ensures high performance and scalability. GAMER-2 has been optimized and tested to run efficiently on Blue Waters.

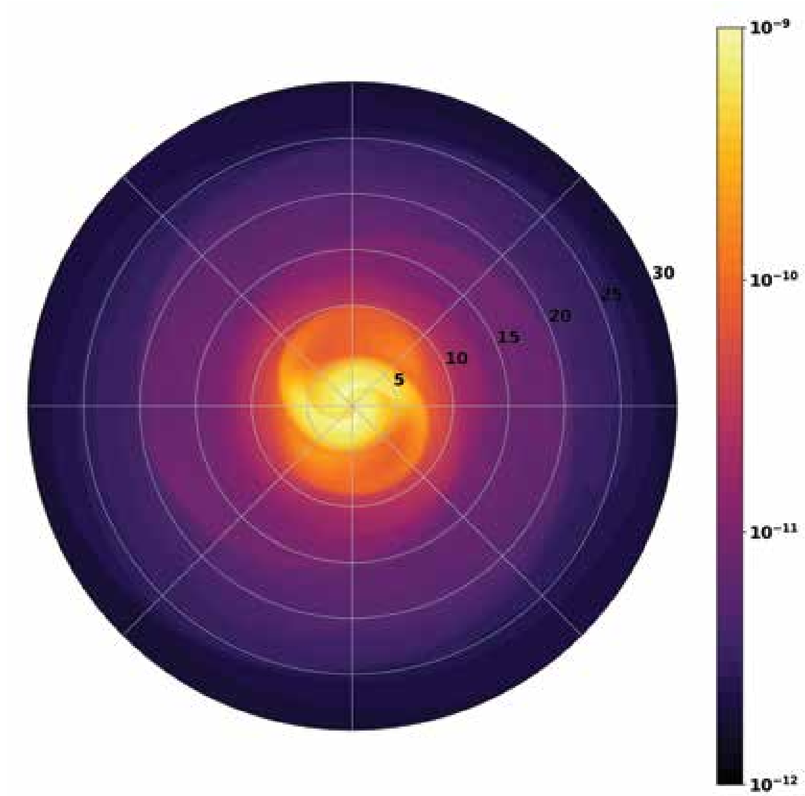

Figure 1: A map of density within a primordial accretion disk at an early evolutionary stage. Two overdense spiral arms have built up, are gravitationally unstable, and are the most likely region for emergence of a companion protostellar object.

MERGING BLACK HOLES AND NEUTRON STARS

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EXECUTIVE SUMMARY

The primary purpose of the project is the numerical solution of Einstein's equations of general relativity. The goal is to track the coalescence and merger of binary black hole systems and to calculate the emitted gravitational waves (GWs). Another goal is to carry out a similar project for binary systems containing a black hole and one or two neutron stars. The work is aimed at providing theoretical predictions that can be compared with the signals measured by the National Science Foundation's LIGO (Laser Interferometer Gravitational-Wave Observatory) GW detector.

RESEARCH CHALLENGE

The primary scientific objective of this project is to theoretically underpin and improve the ability of LIGO to extract the rich information that the observed GWs carry. Gravitational waves provide a new window on the universe that will enable scientists to test their understanding of fundamental physics as well as learn about the most extreme events in the cosmos.

METHODS & CODES

Most of the computations are done with the SpEC code (spectral Einstein code) developed by the collaboration. The numerical methods that are used make it the fastest and most accurate code for treating black holes. The research team is also developing a new code, SpECTRE, that will include innovative methods to treat neutron star systems.

RESULTS & IMPACT

The researchers have released a new version of their public catalog of gravitational waveforms for use by all scientists, largely through simulations on Blue Waters. The new version increased the size of the catalog from 174 waveforms to 2,018. These waveforms have already been employed to produce a very accurate waveform model that LIGO can use in its data analysis, and will meet most of LIGO's needs for the next two to three years.

WHY BLUE WATERS

The research team's numerical code runs most efficiently on 50 to 70 processors for each waveform. Blue Waters' nodes are perfectly sized for using one or two nodes per waveform and exploring hundreds of different parameter values to develop the team's catalog.

PUBLICATIONS & DATA SETS

M. Boyle *et al.*, "The SXS Collaboration catalog of binary black hole simulations," *Class. Quant. Grav.*, vol. 36, p. 195006, 2019.