COSMIC RAYS IN SUPER BUBBLES

DESCRIPTION ET PROBLEMATIQUE

A century-long standing problem in astrophysics is to explain how cosmic rays are accelerated to relativistic energies and how they diffuse in their host galaxy. Notable progress has been made on their production in supernova remnants, but the recent discovery in gamma rays, with the Fermi satellite, of a cocoon of fresh and energetic cosmic rays in the Cygnus X superbubble has disclosed an important new facet of the problem: what is the impact on particle (re-)acceleration and diffusion of the large level of turbulence generated in the superbubble medium by the activity of its numerous massive stars? Can this turbulent phase significantly modify our current views on cosmic-ray transport in the Galaxy because most cosmic-ray sources are to be found in active, turbulent star-forming regions?

http://www.nasa.gov/mission_pages/GLAST/news/cygnus-cocoon.html

In this project, we propose to compare two superbubbles: the extreme case of the few-million-year old, bursting Cygnus X bubble, which hosts several stellar clusters and the Cygnus OB2 supercluster; and the older, more frequent, but less energetic case of the Orion-Eridanus superbubble near the Sun. We propose to combine expertise on cosmic-ray transport/acceleration, on gamma-ray observations of cosmic rays, and on multi-wavelength observations of the interstellar medium in these bubbles, in order to test a new acceleration mechanism and to revisit the impact of the turbulent bubble medium on different observational cosmic-ray diagnostics, Galactic-wide and locally in the Superbubble where the Sun lies.

The comparison of the two superbubbles will serve for future statistical studies of the impact of starburst regions on the cosmic-ray content of a galaxy, therefore on the importance of cosmic rays in the early development of galaxies.

DESCRIPTION GROUPE/LABO/ENCADREMENT

This project builds on the complementary expertise and long experience of two teams: on multi-wavelength interstellar tracers and the discovery of the gamma-ray signal from superbubbles at Saclay/Irfu/AIM (I. Grenier, J. M. Casandjian, D. Marshall); and on advanced cosmic-ray acceleration theory at the Bochum University in Germany (R. Schlickeiser, A. Stockem)

The thesis advisor, I. Grenier, has successfully led or co-led 15 PhD thesis in high-energy astrophysics.

Figure 1 : « composite radio and infrared map of the Cygnus X superbubble with the overlaid contour of the excess of gamma-ray emission detected by Fermi LAT, signing the presence of freshly accelerated cosmic rays »

TRAVAIL PROPOSE

The project aims at a quantitative theoretical modelling of cosmic-ray acceleration and transport in two relatively well-known superbubbles of different age and energy density. The modelling includes complementary tasks in order to

characterise the particle environment and to compare the models with gamma-ray observations: (i) a detailed account of the interstellar conditions and particle losses in the bubbles; (ii) an assessment of the stellar wind and supernova activity in these young starburst regions; (iii) the derivation of average cosmic-ray spectra for random electric and velocity fields in the bubbles, for two injection sources (in-situ injection and injection of outer Galactic cosmic rays); (iv) comparisons with the available gamma-ray data. Task (iii) will be developed in close collaboration with R. Schlickeiser.

FORMATION ET COMPETENCES REQUISES

Master in physics and/or astrophysics

COMPETENCES ACQUISES

The student will benefit from exposure to advanced theoretical calculations as well as to state-of-the-art multi-wavelength observations. This is a clear strength for future research with the future CTA TeV observatory, which will devote guaranteed time to observations of starburst regions. The focus on low cosmic-ray energies will also serve them as the high-energy community looks forward to a soft \g-ray observatory (e.g. Astrogam, Pangu, ComPair proposals) in the next decade.

COLLABORATIONS/PARTENARIATS

This project has been proposed as an International France-Germany Collaborative Research Project (ANR – DFG)

CONTACTS

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