# Cosmic rays & their interstellar medium environment CRISM-2011

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# Book of Abstracts

# Contents

**Cosmic Ray propagation / 33**

## A Markov Chain Monte Carlo technique to sample transport and source parameters of Galactic cosmic rays

We implemented a Markov Chain Monte Carlo (MCMC) technique within the USINE propagation package to estimate the probability-density functions for cosmic-ray transport and source parameters within an 1D diffusion model. From the measurement of the B/C ratio and radioactive cosmic-ray clocks, we calculate their probability density functions, with a special emphasis on the halo size L of the Galaxy and the local underdense bubble of size r_h. We also derive the mean, best-fit model parameters and 68% confidence intervals for the various parameters, as well as the envelopes of several elemental ratios. Additionally, we verify the compatibility of the primary fluxes with the transport parameters derived from the B/C analysis before deriving the source parameters (slope, abundance, and low-energy shape). Finally, we investigate the impact of the input ingredients of the propagation model on the best-fitting values of the transport parameters (e.g., the fragmentation cross sections) in order to estimate the importance of the systematic uncertainties. We conclude that the size of the diffusive halo depends on the presence/absence of the local underdensity damping effect on radioactive nuclei. Moreover, we find that models based on fitting B/C are compatible with primary fluxes. The different spectral indices obtained for the propagated primary fluxes up to a few TeV/n can be naturally ascribed to transport effects only, implying universality of elemental source spectra. Finally, we emphasise that the systematic uncertainties found for the transport parameters are larger than the statistical ones, rendering a phenomenological interpretation of the current data difficult.

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## A new nearby PWN overlapping the VelaJr SNR

PSR J0855−4644 is an energetic pulsar (Edot = 1.1 × 10^36 erg/s) with a period of 65 ms recently discovered near the South-East rim of the supernova remnant RX J0852.0-4622 (aka VelaJr) by the Parkes Multibeam Survey.The position of the pulsar is in spatial coincidence with an enhancement in X-rays and TeV gamma-rays, which could represent its pulsar wind nebula (PWN).
We have revealed with recent XMM-Newton observation the X-ray counterpart of the pulsar together with an extended emission thus confirming the suggestion of a PWN. Interestingly, the core of the PWN (r < 1 arcmin) exhibits some knots of X-ray emission separated by 180° suggesting a jet-like structure.
The comparison of the absorption column density derived in X-rays from the pulsar and with 12CO and HI observations is used to derive a distance and to discuss a possible association of the pulsar with the VelaJr SNR.

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## AGILE observations of middle-aged SNRs

The gamma-ray imager on-board the AGILE satellite detected several
middle-aged Supernova Remnants.
Unlike young SNRs, these objects are bright also for energies greater than some tens of MeV.
Here we present an overview of the AGILE observations of middle-aged SNRs in the "low energy" band (50-400 MeV)
and the spectral and morphological studies performed for some of them (IC443, W28, W44. W51C).
These data, combined with the results from instruments operating at higher energy (Fermi, HESS,

MAGIC, Veritas)
can constrain the theoretical models for the gamma ray production in SNRs.

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## Alfven Wave Amplification and Self-Containment of Cosmic-Rays Escaping from a Supernova Remnant

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We study the escape of cosmic-ray (CR) protons accelerated at a supernova remnant (SNR) by numerically solving a diffusion-convection equation from the vicinity of the shock front to the region far away from the front. We consider the amplifications of Alfven waves generated by the escaping CR particles and their effects on CR escape into interstellar medium (ISM). We find that the amplification of the waves significantly delays the escape of the particles even far away from the shock front (on a scale of the SNR). This means that the energy spectrum of CR particles measured through gamma-ray observations at molecular clouds around SNRs is seriously affected by the particle scattering by the waves.

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## An Integral View of Shocks: VIMOS-IFU Observations of SN1006

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Supernova remnants are laboratories for studying optical shocks. Shocks with velocities of a few hundred km/s (or more) produce two-component Hα lines: a narrow spike atop a broad base. The widths of these lines serve as thermometers for the pre- and post-shock ambient interstellar medium, the ratio of the line strengths is a diagnostic for plasma conditions in the shock, and the offset between the centroids of the lines indicate the geometry of the shocks away from edge-on viewing. Moreover, investigating in detail the shape of the Hα-line has the potential to provide observational constrains on cosmic ray (CR) acceleration.
Observing the north-eastern rim in the supernova remnant of SN1006 with the VIMOS-IFU spectrograph on the VLT, we show that such spectroscopic imaging techniques allow us to trace and distinguish multiple, projected shocks, and at the same time provide us in detail the Hα line profile at each position. By fitting these profiles, we extract maps of the broad and narrow line width, the broad-to-narrow line ratio, as well as velocity offsets between broad and narrow line centroids. We find that all four quantities vary as function of position along and perpendicular to the shock fronts, indicating changing geometry and plasma conditions, as well as presence of CRs. The detection of significant deviations from a (double) Gaussian Hα line profile further supports the presence and acceleration of CRs in SN1006.

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## CR escape from Supernova remnants and their radiative signatures

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## Cosmic Ray Transport in the Heliosphere and its Connection to the Local Interstellar Spectra

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In recent years one could witness tremendous progress regarding the physics of the transport of cosmic rays in the heliosphere. This progress derives from both theoretical advances and new measurements from the outer boundary region of the heliosphere. At the same time theory and observations give new constraints on the local interstellar cosmic ray spectra. The talk

will address the new data, ideas and corresponding developments.

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## Cosmic Ray production of Beryllium and Boron at high redshift

Observations of 6Li in Pop~II stars of the galactic halo have shown in some cases a surprisingly high abundance of this isotope, about a thousand times higher than its predicted primordial value. Using a cosmological model for the cosmic ray-induced production of this isotope in the IGM allows us to explain the observed abundance at low metallicity. Given this constraint on the 6Li, we also calculate the non-thermal evolution with redshift of D, Be, and B in the IGM. In addition to cosmological cosmic ray interactions in the IGM, we include additional processes driven by SN explosions: neutrino spallation and a low energy component in the structures ejected by outflows to the IGM. We take into account CNO CRs impinging on the intergalactic gas. Although subdominant in the galactic disk, this process is shown to produce the bulk of Be and B in the IGM, due to the differential metal enrichment between structures (where CRs originate) and the IGM. We also consider the resulting extragalactic gamma-ray background which we find to be well below existing data. The computation is performed in the framework of hierarchical structure formation considering several star formation histories including Pop~III stars. We find that D production is negligible and that a potentially detectable Be and B plateau is produced by these processes at the time of the formation of the Galaxy (z~3).

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## Cosmic ray driven galactic magnetic field dynamo

I am going to review recent developments of local and global, galactic-scale numerical models, of the Cosmic-Ray-driven dynamo, which was originally proposed by Parker (1992). The concept of Cosmic-Ray driven MHD dynamo relies on buoyancy forces induced by the presence of cosmic rays in the interstellar medium. The CR-driven dynamo models are realized by means of direct CR-MHD numerical simulations of the dynamics of interstellar medium, composed of gas, magnetic-field, and Cosmic Rays. It is assumed that Cosmic Rays are accelerated in randomly distributed supernova remnants, and that supernovae deposit small-scale, randomly oriented, dipolar magnetic-fields into the ISM. Numerical experiments show that galactic magnetic fields are amplified to the equipartition values on timescales comparable to the rotation period of the galaxy. The amplification process is associated with efficient conversion of small-scale magnetic fields of SN-remnants into the galactic-scale magnetic fields. The resulting magnetic field reveals a spiral structure in face-on views, and it resembles the observed X-shaped magnetic fields in edge-on galaxies.

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## Cosmic ray driven galactic winds

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## Cosmic ray production and gamma-ray emission from Tycho's supernova remnant

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We calculate the flux of non-thermal radiation from the Tycho's supernova remnant in the context of the non-linear theory of particle acceleration at shocks, which allows us to take into account self-consistently the dynamical reaction of the accelerated particles, the generation of magnetic fields in the shock proximity and the dynamical reaction of the magnetic field on the plasma.
Assuming a modest acceleration efficiency we find that the strength of the magnetic field obtained as a result of streaming instability induced by cosmic rays is compatible with the interpretation of the X-ray emitting filaments being produced by strong synchrotron losses in ~300 μG magnetic fields.
In such a strong magnetic field the magnetic turbulence in the upstream region of the shock can move with a speed which is a non negligible fraction of the shock speed. As a consequence the accelerated particles feel an effective compression factor less than 4 and their energy spectrum is steeper than the standard prediction, $n(E) \propto E^{-2}$.
Taking into account the speed of magnetic turbulence, we consistently predict the observed gamma-ray spectrum, from the GeV band observed by FermiLAT up to the TeV band observed by VERITAS, as due to pion decay produced in hadronic collisions of a population of accelerated ions with a slope ~2.2.
Remarkably the same model predict a relativistic electron population whose synchrotron emission well explain both the radio spectral index of 0.65, as well as the non-thermal X-ray emission.

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## Cosmic ray propagation in the interstellar medium

The problems of cosmic ray transport in the Galaxy are discussed. The discussion covers the diffusion model of cosmic ray propagation in the Galaxy, the fluctuations of cosmic ray intensity due to random nature of sources, the collective effects of relativistic particles in the interstellar medium, the nature of "hardening" and "knee" in cosmic ray spectrum and the transition to extragalactic component.

**Cosmic ray acceleration processes / 107**

## Cosmic ray streaming instabilities in the long-wavelength limit

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Diffusive shock acceleration is the prime candidate for efficient acceleration of cosmic rays. Galactic cosmic rays are believed to originate predominantly from this process in supernova remnant shock waves. Confinement of the cosmic rays in the shock region is key in making the mechanism effective.

It has been known that on small scales (smaller than the typical gyroradius) high-amplitude non-resonant instabilities arise due to cosmic ray streaming ahead of the shock. For the efficiency of scattering of the highest energy cosmic rays it is of interest to determine the type of instabilities that act on longer length scales, i.e. larger than the cosmic ray gyroradius. I will present the results of our analysis of an instability that acts in this regime and will discuss its driving mechanism.

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## Cosmic ray-induced carbon isotope fractionation of molecules in dense dark gas.

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Cosmic rays induce a low level of ionization of helium in dense dark gas where the main sink of He+ is He+ + CO -> C+ + O + He, at least until CO depletes onto grains. So C+ is introduced into the gas relatively quickly, but the carbon exchange reaction of C+ and CO selectively returns 13C+ to CO (because it is more tightly bound than 12CO, by 35K), depleting the C+ pool in 13C+. This leads to substantial carbon isotope fractionation in molecules that from or exchange carbon with C+. However there is also a pool of neutral atomic carbon in the gas, perhaps a few percent of CO, whose origin is less clear but probably arises from photodissociation of CO and is not fractionated. So the pools of free neutral and ionized carbon may have different isotope ratios, leading to a variety of complex chemical effects that provide particular signatures of the chemistry but greatly complicate the interpretation of molecular isotopomeric abundance ratios. I will demonstrate various of these effects and discuss why CO itself should not be strongly fractionated.

**Impact of cosmic rays over chemistry and climate / 43**

## Cosmic rays and climate forcing

An important factor affecting the terrestrial environment is the flux of cosmic rays permanently impinging on Earth. Energetic cosmic rays initiate a nucleonic-electromagnetic cascade in the atmosphere, affecting its physical-chemical properties. In particular, cosmic rays form the dominant source of ionization in the lower and middle atmosphere. Therefore, a detailed knowledge of processes leading to the cosmic ray induced ionization makes a solid basis for a quantitative study of the outer space influence upon Earth. Via the variable heliospheric modulation of cosmic rays, this provides an indirect solar-terrestrial link.
Because of the additional shielding effect of the geomagnetic field, regional ionization is greatly affected by the geomagnetic dipole migration, making it possible to disentangle direct (radiance) and indirect (cosmic ray) effects on the Earth's climate.

We present here a review of atmospheric effects of cosmic rays, including ionization, aerosol particle formation, and production of traceable radioactive nuclides. Both physical modeling and phenomenological relations are considered on different time scales.

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## Cosmic rays and the thermal instability

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In the absence of magnetic fields and cosmic rays, radiative cooling laws with a range of dependences on
temperature affect the stability of interstellar gas. For about four and a half decades, astrophysicists have
recognised the importance of the thermal instability for the formation of clouds in the interstellar medium.
Even in the past several years, many papers have concerned the role of the thermal instability in the production of molecular
clouds. About three and a half decades ago, astrophysicists investigating radiative shocks noticed that for many
cooling laws such shocks are unstable. Attempts to address the effects of cosmic rays on the stability of radiative media that are initially uniform or that are shocked have been made. The simplest approach to such studies
involves the assumption that the cosmic rays behave as a fluid. Work based on such an approach is described.

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## Cosmic-ray ionisation of molecular clouds

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We explore the possibility that a low-energy component of cosmic rays, not directly measurable from the Earth, can account for the discrepancy between the ionisation rate measured in diffuse and dense interstellar clouds. Starting from different extrapolations at low energies of the demodulated cosmic-ray proton and electron spectra, we computed the propagated spectra in molecular clouds in the continuous slowing-down approximation taking all the relevant energy loss processes into account. Available data combined with simple propagation models support the existence of a low-energy component (below about 100 MeV) of cosmic-ray electrons or protons responsible for the ionisation of molecular cloud cores and dense protostellar envelopes.
We also computed the attenuation of the cosmic-ray flux rate in a cloud core taking into account magnetic focusing and magnetic mirroring, adopting a standard cloud model characterised by a mass-to-flux ratio supercritical by a factor of about 2 to describe the density and magnetic field distribution of a low-mass starless core, following the propagation of cosmic rays through the core along flux tubes enclosing different amount of mass.

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## Cosmic-ray ionization and chemistry: observations

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## Cosmic-ray ionization and chemistry: theory

The gas-phase chemistry of interstellar clouds is powered by ionization caused by

primary cosmic rays, mainly protons, and secondary electrons. The cosmic ray ionization rate throughout a cloud, ζH, can be estimated based on the initial energy spectrum entering a cloud. However, there are a number of uncertainties, including poor knowledge of the flux of the lowest energy cosmic rays, which are the most critical for ionization. So, to most astrochemists, ζH is still regarded as a parameter with no dependence on depth into a cloud. For dense interstellar clouds in most regions of the galaxy, the best value of ζH lies in the range 10-17 – 10-16 s-1. This value, determined by comparison between molecular observations and the results of chemical simulations, has had a varied history. Recent studies of selected interstellar ions; namely H3
+, detected in
the infrared, and OH+ and H2O+, detected in the far-infrared, indicate through chemical simulations that there are regions, including diffuse clouds in the galactic spiral arms, outflows from objects such as Orion KL, and much of the galactic center, where the cosmic ray ionization rate can be 1-3 orders of magnitude greater than the standard value. In my talk, I will discuss the role of cosmic rays in interstellar chemistry, and emphasize the apparent need for a large range of values for ζH in diverse sources.

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## Diffuse Galactic Gamma Rays at intermediate and high Latitudes, Constraints on ISM properties and DM

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Recently published $\gamma$-ray spectral data from the Fermi Collaboration
have provided the possibility to study the diffuse $\gamma$-ray sky at medium and
high latitudes ($\mid b \mid > 10°$) and energies of 1-100 GeV with unprecedented accuracy.
This provides us the chance of probing and constraining models of annihilating
and decaying Dark Matter, as well as studying and confirming conventional assumptions
made on Interstellar Medium properties including gasses distributions, diffusion and
propagation of cosmic rays.
Implementing the publicly available DRAGON code,
that has been shown to reproduce local measurements of cosmic rays, we can study
assumptions made in the literature on galactic gas models, and on diffusion properties of cosmic rays,
in order to confirm or exclude those that can (cannot) fit the observed $\gamma$-ray spectra.
Also constraints are placed on a garden variety of Dark Matter models recently
proposed to explain the local spectra of electrons, positrons and antiprotons,
and $\gamma$-rays at the center of the Galaxy.

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## Diffuse galactic gamma-ray emission

The Galactic gamma-ray diffuse emission is currently observed in the GeV-TeV energy range with unprecedented accuracy by the Fermi satellite. Understanding this component is crucial as it provides a background to many different signals such as extragalactic sources or annihilating dark matter. It is timely to reinvestigate how it is calculated and to assess the various uncertainties which are likely to affect the accuracy of the predictions. The Galactic gamma-ray diffuse emission is mostly produced above a few GeV by the interactions of cosmic ray primaries impinging on the interstellar material. The theoretical error on that component is derived by exploring various potential sources of uncertainty. Particular attention is paid to cosmic ray propagation. Nuclear cross sections, the proton and helium fluxes at the Earth, the Galactic radial profile of supernova remnants and the hydrogen distribution can also severely affect the signal. The propagation of cosmic ray species throughout the Galaxy is described in the framework of a semi-analytic two-zone diffusion/convection model. This allows to convert the constraints set by the boron-to-carbon data into a theoretical uncertainty on the diffuse emission. New deconvolutions of the HI and CO sky maps are also used to get the hydrogen distribution within the Galaxy. The thickness of the cosmic ray diffusive halo is found to have a significant effect on the Galactic gamma-ray diffuse emission while the interplay between diffusion and convection has little influence on the signal. The uncertainties related to nuclear cross sections and to the primary cosmic ray fluxes at the Earth are significant. The radial distribution of supernova remnants along the Galactic plane turns out to be a key ingredient. As expected, the predictions are extremely sensitive to the spatial distribution of hydrogen within the Milky Way. Most of the above mentioned sources of uncertainty are likely to be reduced in the near future. The stress should be put (i) on a better determination of the thickness of the cosmic ray diusive halo and (ii) on refined observations of the radial profile of supernova remnants.

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## Direct detection of cosmic rays

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## Electron-molecule collisions in harsh astronomical environments

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In the most energetic regions of space (shocks, photodissociation regions, comets, etc.), the electron fraction, xe, can increase by several orders of magnitude. When xe exceeds about 10-5, free electrons can compete or even dominate over neutrals in the collisional excitation of molecules. Recent theoretical studies, based on the UK molecular R-matrix method, have revisited the electron-impact excitation of many interstellar molecules. The accuracy of the calculations has been checked against storage ring experiments. We compare in this talk theoretical and experimental cross sections for the two benchmark species HD+ and H2O. We also discuss the importance of electrons as a possible source of rotational (de)excitation in dissociative recombination. Finally, we will present the first observational results suggesting an electron density enhancement within the magnetic precursor of C-shocks.

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## Equipartition calculation for supernova remnants

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Equipartition or the minimum-energy calculation is a widespread method for estimating magnetic field strength and energy in the magnetic field and cosmic rays particles by using only the radio synchrotron emission. Despite of its approximate character, it remains a useful tool in situations when no other data about the source are available. We give a modified calculation which we think is more appropriate for estimating magnetic fields and energetics of supernova remnants.

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## Fe Ka line emission as a tracer of high energy processes in the Galactic Centre region - evidence against a past AGN activity of Sgr A*?

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The X-ray reflection nebulae (XRN) in the Galactic Centre (GC) region have been proposed to be the smoking gun of a past low AGN activity of Sgr A*, which is suspected to have undergone a flare about 10^4 times brighter than the brightest flare ever measured, this high state happening some hundred years ago. This enhanced X-ray activity must have left a trace in the diffuse emission permeating the GC region, especially in the ionization of molecular clouds (MCs) in the central molecular zone (CMZ) seen through the Fe fluorescent line at 6.4 keV, and the Thomson scattering of hard X-rays into the line of sight by the MCs. The picture is however still unclear and confusing, since other high energetic phenomena can account for the 6.4 keV emission from MCs in the CMZ. In my talk I will review the history and the main discoveries related to this topic, and will show that the XRN/Sgr A* scenario alone has strong difficulties in accounting for the observed fluorescence; indeed, a strong component induced by particle (subrelativistic electrons and/or protons) interaction with the MCs is needed in order to account for all the spectral/temporal properties of the observed MCs. I will also show the results of my studies on the Fe Ka emission from the MCs in the Arches cluster region, which state that Sgr A*cannot be the source of ionization for every 6.4 keV bright cloud; these MCs are to be considered the prototype for particle bombardment induced Fe Ka line emission. I will also present the recent discovery of the MC showing the fastest variability in the 6.4 keV line flux, clearly related to an X-ray transient source other than Sgr A*.

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## Fermi gamma-ray 'bubbles' from stochastic acceleration of electrons

Gamma-ray data from Fermi-LAT reveal a bi-lobular structure extending up to 50 degrees above and below the galactic centre, which presumably originated in some form of energy release there less than a few million years ago. It has been argued that the gamma-rays arise from hadronic interactions of high energy cosmic rays which are advected out by a strong wind, or from inverse-Compton scattering of relativistic electrons accelerated at plasma shocks present in the bubbles. We explore the alternative possibility that the relativistic electrons are undergoing stochastic 2nd-order Fermi acceleration by plasma wave turbulence through the entire volume of the bubbles. The observed gamma-ray spectral shape is then explained naturally by the resulting hard electron spectrum and inverse Compton losses. Rather than a constant volume emissivity as in other models, we predict a nearly constant surface brightness, and reproduce the observed sharp edges of the bubbles.

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## Fermi-LAT detection of gamma-ray emission in the vicinity of the star forming regions W43 and Westerlund 2

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Particle acceleration in massive star forming regions can proceed via a large variety of possible emission scenarios, including high-energy gamma-ray production in the colliding wind zone of the massive Wolf-Rayet binary (here WR 20a and WR121a), collective wind scenarios, diffusive shock

acceleration at the boundaries of wind-blown bubbles in the stellar cluster, and outbreak phenomena from hot stellar winds into the interstellar medium.
In view of the recent Fermi-LAT detection of HESS J1023-575 (in the vicinity of Westerlund 2), we examine another very high energy (VHE) gamma-ray source, HESS J1848-0145 (in the vicinity of W43), possibly associated with a massive star cluster. Considering data from other wavelengths, in particular X-rays and TeV gamma-rays, we examine the available evidence that the gamma-ray emission from Westerlund 2 and W43 could originate in particles accelerated by the above-mentioned mechanisms in massive star clusters.

**Massive stars and cosmic-ray sources / 17**

# Fermi/LAT view of eta Carinae

One of the most outstanding stellar object in our Galaxy, eta Carinae, a colliding wind binary with the largest mass loss rate observed, presents a hard X-ray emission and is therefore a primary candidate to search for particle acceleration by probing its gamma-ray emission.
The detection of eta Carinae at high energy through analysis of Fermi/LAT data between 0.2 to 100 GeV was reported in Farnier et al., 2011. A modeling of multi-wavelength observations in which the non-thermal emission due to inverse Compton scattering of UV photons by electrons and pi0 decay of accelerated hadrons arising from the colliding wind region was proposed.
I will present the latest results derived from eta Carinae high energy observations.

**Cosmic Ray direct detection / 28**

# Few-degree anisotropies in the cosmic-ray flux observed by the ARGO-YBJ experiment

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The ARGO-YBJ experiment is a full coverage EAS array sensitive to cosmic rays with energy threshold few hundreds GeV.
Looking at all data collected since November 2007 several few-degree anisotropies in the arrival directions of cosmic rays have been found. The observation is highly significant (more than 17 s.d.) and the relative intensity with respect to the isotropic background flux reaches 10^{3}. Each region seems to have its own energy spectrum, mostly harder than VHE cosmic rays and peaked at 10 TeV (protons). The presence of such regions challenges the standard model of cosmic rays, suggesting the presence of unknown features of the magnetic fields the charged cosmic rays propagate through, as well as potential contributions of nearby sources to the total flux of cosmic rays.

**Cosmic ray sources: Multiwavelength observations / 101**

# Gamma-ray SNRs and the interacting neutral clouds

I present recent results on comparison between gamma ray SNRs and the interacting neutral clouds. I shall discuss on SNRs including RX J1713.7-3946, W28, W44 and RX J0852.0-4622 with an emphasis on the role of dense atomic and molecular gas in the interaction. In RX J1713.7-3946, I shall present highly clumped distribution of dense gas which exhibits good correlation with gamma rays and X rays on a pc scale and argue that cosmic ray acceleration is enhanced around dense gas, leading to production of these high energy radiations. I interpret that such enhanced CRs are due to the highly turbulent state caused by the shock interaction with the dense clumps as suggested by recent MHD numerical simulations (Inoue, Yamazaki, & Inutsuka 2009)

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## Gamma-ray emission from CR-ISM interactions in star-forming galaxies

Cosmic-rays with energies up to the PeV are very likely related to stellar phenomena. As they propagate away from their sources, cosmic rays illuminate the various components of the interstellar medium and give rise to emissions in the radio and gamma-ray bands. The resulting galaxy-wide radiation can provide insights into the physics of cosmic-ray acceleration and transport. The recent observations of gamma-ray emission at GeV and TeV energies from several nearby star-forming galaxies has opened the way for population studies, allowing to compare the diffuse gamma-ray emission from different systems. The dependence of the gamma-ray luminosity of these objects on some of their large-scale properties can provide constraints on the processes that rule cosmic-ray populations at galactic scales. After a review of the detections achieved so far for several Local Group objects and two nearby starbursts, we present the outcome of a systematic search for GeV emission from a large sample of star-forming galaxies using Fermi/LAT. These results are then discussed in the context of a simple model for the gamma-ray emission of star-forming galaxies.

**Cosmic ray sources: Multiwavelength observations / 7**

## Gamma-ray emission from Supernova remnants

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**Diffuse emission and cosmic ray interaction with interstellar matter / 39**

## How does the cosmic rays influence the gas and grain chemistry in star-forming regions?

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The presence of cosmic rays in regions where stars are forming actually dramatically changes the gas and grain chemistry as compared to environments where photons less energetic such as FUV and UV photons usually dominate. In my talk, I will review first the main differences existing between these two illumination mechanisms of the interstellar matter. I will then present their respective influence on the star-forming gas chemical and physical properties. I will show the key species to observe if one want to disentangle these mechanisms or identify the cosmic rays presence in a specific star forming source. These results are of prime interest since they increase our understanding of the star formation processes occurring especially on galaxy scales where usually photons with different energy are well mixed. I will focus also on the potential contaminating influence of X-ray photons on the chemistry driven by cosmic ray.

**Poster session / 120**

## Ion irradiation experiments relevant to the astrophysics ices

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Methane ($CH_4$) and methanol ($CH_3OH$) ices are present in various astrophysical environments, from dense molecular clouds to several small objects in the outer solar system, in particular on Saturn satellite Triton and to be a constituent of the icy mantle on interstellar grain [1]. There is a clear lack of information about the phenomena induced by the heavy-ion component of cosmic-rays in the electronic-energy-loss regime.

In this work, the chemical and physical effects induced by fast heavy ions irradiation on frozen pure methane and methanol at 15 K are studied. Measurements were performed at the medium energy beam-line of the heavy ion accelerator GANIL (Grand Acc\'el\'erateur National d'Ions Lourds), Caen-France [2]. The analysis was done by infrared spectroscopy (FTIR) during irradiation by 220 MeV $^{16}O^{7+}$ ion beam. For the case of methane, the principal molecular species identified as a product after irradiation are: $CH_3$, $C_2H_2$, $C_2H_4$, $C_2H_6$ and $C_3H_8$. For methanol ices are: $H_2CO$, $CH_2OH$, $CH_4$, CO, $CO_2$, HCO and $HCOOCH_3$ other products are identified with ambiguity. Their formation and dissociation cross sections are determined. The cross section of $CH_4$ and $CH_3OH$ and its daughters species follows a power law as a function of the electronic stopping power. It is found that, some daughters species cross sections increase with the electronic stopping power roughly as $\sigma \propto S_e^{3/2}$. As astrophysical implication, the $S_e^n$ power law, where $n \approx 3/2$ should be very helpful for predicting the $CH_4$ and $CH_3OH$ formation and the dissociation cross sections for other ion beam projectiles and energies in the ISM rich in hydrocarbons that are continuously bombarded by cosmic rays.

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## Magnetic fields in the interstellar medium

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I will review the observational properties of interstellar magnetic fields in the disk and halo of our Galaxy. These properties are inferred from a variety of observational methods, primarily based on polarization of starlight, polarization of dust infrared emission, Zeeman splitting, Faraday rotation, and synchrotron emission. I will discuss each of these methods in some detail and explain what it tells us about the strength, direction, and spatial structure of interstellar magnetic fields. I will then compare the observational properties to theoretical predictions from dynamo theory.

**Cosmic rays at multiple galactic scales. / 116**

## Magnetic turbulence in the shock precursor and CR acceleration

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We overview recent progress on small-scale dynamo and apply the results to the the problem of nonlinear shock acceleration in which particle mean free paths in front of the shock are greatly reduced due to magnetic fields in the shock precursor which are generated through small-scale dynamo in the density gradient's-induced turbulence. Previous DSA models considered magnetic fields amplified through cosmic ray streaming instabilities either by way of individual particles scattering in the magnetic fields, or by macroscopic electric currents associated with large-scale cosmic ray streaming. The small-scale dynamo mechanism provides fast growth and is very generic. For supernovae shocks this mechanism is estimated to generate upstream magnetic fields that are sufficient for accelerating cosmic rays up to around 10^16 eV.

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# Magnetohydrodynamic simulations of the interstellar medium

**Cosmic ray sources: Multiwavelength observations / 12**

# Massive stars clusters at high energies

In massive star-forming regions, the evolution of massive stars (M > 20 Msol) forming "OB associations" is so rapid that they explode as supernovae close to their birthplaces, the molecular clouds. Before reaching this final stage, they lose a significant fraction of their mass via dense stellar winds. The result is a feedback effect, in the form of vast hot plasma bubbles filling the star-forming region. When supernovae collide with molecular clouds, there is observational evidence that they are powerful cosmic-ray accelerators : at high energies, they induce GeV-TeV gamma-ray emission; at low energies, they induce enhanced ionization and peculiar meV chemistry. But they can also explode in the pre-existing wind cavities, in which case cosmic rays are inefficiently accelerated or convected away by the hot gas. As a result, the high-energy life of an OB associations is made up of successive phases of long (Myr) quiescent, wind-dominated phases, interrupted by temporary (< 0.1 Myr) episodes of supernova-dominated phases, possibly characterized by an intense, localized acceleration of cosmic rays.

**Massive stars and cosmic-ray sources / 104**

# Modeling supernova remnants: effects of diffusive cosmic-ray acceleration on the evolution, application to observations.

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We present numerical models for supernova remnant evolution, using a new version of the hydrodynamical code SUPREMNA. We added cosmic ray diffusion equation to the code scheme, employing two-fluid approximation. We investigate the dynamics of the simulated supernova remnants with different values of cosmic ray acceleration efficiency and diffusion coefficient. We compare the numerical models with observational data of Tycho's and SN1006 supernova remnants. We find models which reproduce the observed locations of the blast wave, contact discontinuity, and reverse shock for the both remnants, thus

allowing us to estimate the contribution of cosmic ray particles into total pressure and cosmic-ray energy losses in these supernova remnants. We derive that the energy losses due to cosmic rays escape in Tycho's supernova remnant are 10-20% of the kinetic energy flux and 20-50% in SN1006.

**Cosmic Ray propagation / 54**

## Models of GeV-TeV Galactic cosmic ray electrons

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**Impact of cosmic rays over chemistry and climate / 58**

## Models of interstellar chemistry - The influence of cosmic rays.

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Cosmic rays have a strong impact on interstellar chemistry. By ionizing some species, they initiate fast ion-neutral reactions that lead to the formation of complex molecules. So, the measurement of the cosmic ionization rate in different media is crucial to understand the chemical mechanism leading to the composition of interstellar clouds.
In diffuse interstellar gas, the abundances of molecules as OH and HD are directly proportional to the cosmic rays flux. These species can be considered as probes of this flux. On another hand, the measurement of the elemental abundances of O and D from OH and HD observations can only be done if the flux of cosmic rays is precisely known. In parallel, from several years, H3+, as been detected on several diffuse lines of sights. It has been shown that its abundance can only be explained by a cosmic rays flux higher by a factor 5 to 10 than what was thought previously. Herschel observations seem to confirm this highest cosmic ionization rate.
In dense gas, cosmic rays initiate the formation of H3+ (and its isotopologue H2D+) that leads to the formation of more complex molecules. Dense clouds are open and non-thermal equilibrium systems. Our team showed that such properties can lead to chemical bistability in which the flux of cosmic rays, that controls the ionization degree, is a critical parameter. Between the two possible chemical phases, abundances of some species can be different by one order of magnitude. In particular the abundance of deuterated species can be strongly affected.

Our team is developing the Meudon PDR code that computes the chemical and thermal structure of interstellar clouds. It solves in a consistent way the radiative transfer, the chemistry of several hundreds species as well as the thermal processes. In this talk, I will show, thanks to this code, the influence of cosmic rays on the interstellar chemistry and why it is important to constrain as much as possible the flux of cosmic rays to interpret observations in the interstellar medium.

**Cosmic ray acceleration processes / 110**

## Molecular Clouds as Cosmic Ray Laboratories

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The advent of high sensitivity, high resolution gamma-ray detectors, together with a knowledge of the distribution of the atomic hydrogen and

especially of the molecular hydrogen in the Galaxy on sub-degree scales creates a unique opportunity to explore the flux of cosmic rays in the Galaxy. We here present a methodology which aims to provide a test bed for current and future gamma-ray observatories to explore the cosmic ray flux at various positions in our Galaxy. Also, using model predictions for cosmic rays escaping supernova remnants we present the GeV to TeV gamma-ray emission produced by the collisions of runaway cosmic rays with the gas in the environment surrounding the shell-type supernova remnant RX~J1713.7-3946.

**Interstellar medium / 115**

## Non-thermal emission from molecular clouds in the Galactic centre: Illumination vs cosmic rays.

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The molecular clouds at the Galactic centre (GC), Sgr B2 among others, emit strong Fe Kalpha photons as well as hard X-rays up to 100 keV. The origin of this emission has been the subject of a controversy. Irradiation by subrelativistic cosmic rays, electrons or protons, might account for the observed spectra, but it can also be the result of the illumination of the clouds by a past high luminosity period of X-ray sources in the GC (e.g. the supermassive black hole Sgr A*). We present here the results of monitoring observations of molecular clouds in the GC in X-rays and hard X-rays (XMM, Chandra, Integral) which show large variation of the emission over 10 years. This variation can not be accounted for by cosmic ray interpretations and supports the idea that Sgr A** was more active in the past. We discuss the possible level of emission due to cosmic ray irradiation in these regions.

**Cosmic ray sources: Multiwavelength observations / 11**

## Observation of Supernova remnants by HESS

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**Massive stars and cosmic-ray sources / 105**

## On the origin and composition of Galactic cosmic rays

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I explore the implications of a model in which cosmic rays are accelerated by the forward shocks of supernovae exploding within massive star winds, by using realistic stellar models with mass loss and rotation. Using the same models, I also show that the idea that the bulk of Galactic cosmic rays are accelerated in superbubbles fails to reproduce the key observable of GCR composition, namely the Ne22/Ne20 ratio.

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## Pause

**5**

## Pause

**Impact of cosmic rays over chemistry and climate / 42**

## Phase lags between 11-yr cycles of Sunspot Number, Cosmic Ray Flux and Length of Day time series.

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We analyzed phase lags between the 11-year cycles of solar activity (sunspot numbers, SSN), cosmic ray flux (CRF) and 0.5-year oscillations of the length of day (LOD). The analysis is performed for the solar cycles number 20-23 (1965-2010). Phase lags are calculated by using different methods: time lag between maxima of corresponding cycles, according to maximal coefficient of cross-correlation, maximal amplitude of wavelet cross coherence, and as time lag between equivalent momentary phases calculated following the method of 2D-diagrams in phase space. For SSN and CRF time series, these methods allow to document a clear phase difference between odd and even cycles as shown by previous authors (e.g. Nymmik & Suslov 1995 Adv. Space Res. 9, 217; Usoskin et al. 2001 Adv. Space Res. 27, 571). By contrast, the phase lags between SSN and LOD do not show such a clear-cut systematic pattern. We will tentatively discuss the implications of these results for the plausibility of physical mechanisms proposed to link SSN, CRF and LOD.

**Cosmic ray sources: Multiwavelength observations / 8**

## Probing proton acceleration in W51C with MAGIC

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Located in a dense complex environment, W51C provides an excellent scenario to probe accelerated protons in SNRs and their interaction with surrounding target material. Here we report the observation of extended Very High Energy (VHE) gamma-ray emission from the W51C supernova remnant (SNR) with MAGIC. Detections of extended gamma-ray emission in the same region have already been reported by the Fermi and HESS collaborations. Fermi measured the source spectrum in the energy range between 0.1 and 50 GeV, which was found to be well fit by a hadronic (neutral-pion decay) model . The VHE observations presented here, obtained with the improved MAGIC stereo system, allow us to

pinpoint the VHE gamma-ray emission in the dense shocked molecular cloud surrounding the remnant shell. The MAGIC data also allow us to measure, for the first time, the VHE emission spectrum of W51C from the highest Fermi energies up to several TeV. The spatial distribution and spectral properties of the VHE emission suggest a main contribution of hadronic origin of the observed gamma-rays.

**Impact of cosmic rays over chemistry and climate / 57**

# Propagation of Low-Energy Cosmic Rays in Molecular Clouds: Calculations in Two Dimensions

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MOTIVATION: Low energy ($< 1$ GeV) cosmic rays drive interstellar chemistry and may cause specific spectral features recently measured, such as the 6.7 keV emission line. Yet the origin and flux of low energy cosmic rays is currently unknown because the Sun's magnetic field deflects these particles, so that they cannot be directly observed. A robust model of cosmic ray transport in molecular clouds is important in order to better understand interstellar chemistry and to explore possible line emissions caused by these cosmic rays.

METHOD: We calculate cosmic ray transport with a collisional Boltzmann Transport Equation, treating both elastic and inelastic collisions, including external electromagnetic forces. We apply the Crank-Nicholson Method to solve the Boltzmann Transport Equation. At each time step, the spatial distribution of cosmic rays is applied to the ZEUS 2D magnetohydrodynamics model. The ZEUS model is then utilized to calculate the resulting electromagnetic field. Finally, the field is applied to the Boltzmann Transport Equation. This sequence is repeated over many time steps until a steady state is reached.

RESULTS: We consider results from $t = 0$ until steady state for an isotropic low energy cosmic ray flux, and also for an enhanced cosmic ray flux impinging on one side of a molecular cloud. The calculated flux is related to the distance into the cloud, and fit by analytic functions.

IMPLICATIONS: This cosmic ray flux is used to determine an ionization rate of interstellar hydrogen by cosmic rays, $\zeta$. Astrochemical implications and possible spectral features are briefly mentioned.

**Massive stars and cosmic-ray sources / 15**

# Propagation of supernova blastwaves in the circum- and interstellar medium

I will review the evolution of SN shock waves in the surrounding medium, using analytic solutions and numerical simulations. I will discuss both white-dwarf and core-collapse SNe, the medium surrounding these SNe, and their evolution through various phases.

**Cosmic ray sources: Multiwavelength observations / 3**

# Radio observations of supernova remnants and the surrounding molecular gas

Supernova remnants (SNRs) are believed to be the main source of Galactic cosmic rays with energies up to 10^15 eV. Strong SNR shocks provide ideal acceleration sites for electrons and maybe ions.
In fact, among the identified Galactic gamma-ray sources the majority are associated with the violent, late phases of the stellar life.
Good radio continuum observations at different frequencies can provide information about three main aspects the SNRs: morphology, polarization and spectrum. In principle, from this information it is possible to locate the sites of particle acceleration and investigate the energy spectrum of the accelerated particles. It is also possible to estimate the intensity, orientation and degree of order of the magnetic fields. Also middle-aged SNRs interacting with molecular clouds can emit hadronic

gamma-rays arising from neutral pions produced in inelastic collisions of the cosmic ray protons with molecular material. Therefore, a complete radio study of SNRs and the surrounding matter constitute an invaluable tool to advance in the comprehension of the physics underlying the very-high energy emission.
In this talk I will present some recent radio studies of SNRs and the interstellar gas, paying particular attention in discussing the caveats for a proper use of radio data.

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## Review on interstellar medium propoerties

**Massive stars and cosmic-ray sources / 49**

## Role of ejecta clumping and back-reaction of accelerated cosmic rays in the evolution of supernova remnants

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The thermal structure of the post-shock region of a young supernova remnant (SNR) is heavily affected by two main physical effects, namely the back-reaction of accelerated cosmic rays and the Rayleigh-Taylor instabilities developing at the contact discontinuity between the ejecta and the shocked interstellar medium (ISM). In this contribution, we investigate the role played by both physical mechanisms in the evolution of SNRs through detailed MHD modeling. In particular, we explore the role of the initial ejecta clumpiness in developing strong instabilities at the contact discontinuity which may extend upstream to the main shock and beyond. Here we present a three-dimensional MHD model which describes the expansion of the remnant through a magnetized ISM, including consistently the initial ejecta clumping and the effects on shock dynamics due to back-reaction of accelerated cosmic rays.

**Cosmic ray sources: Multiwavelength observations / 47**

## SNR interacting with molecular clouds as seen by HESS

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Supernova from massive stars are exploding in giant molecular cloud (MC). Thus it is possible to see supernova remnants (SNR) expending in dense material. The physical interaction between SNR and MC can produce OH maser (1720 MHz) emission tracing the shocked surrounding medium.
High and very-high energy (HE and VHE) gamma rays have been detected in coincidence with OH maser, SNR and shocked MC. Neutral pions decay is the best model to explain the origin of the gamma-ray emission.
I will present some joined results of HE and VHE gamma-ray experiments of known cases as IC443, W44, W28 and W51C as seen by H.E.S.S. and Fermi-LAT to study in an easier way the morphology and the spectra.
The very good angular resolution of H.E.S.S. analysis reconstruction methods is usefull to model the morphology in the GeV range, and the HE spectra is helpful to constrain the gamma-ray origin.

**Cosmic ray sources: Multiwavelength observations / 4**

## Shock-Molecular cloud interactions: CO data and OH masers

I will review the class of galactic supernova remnants which show strong interactions with molecular clouds, revealed either through shock-excited masers or dense gas tracers. These remnants are preferentially found among the known GeV and TeV detections of supernova remnants. It has been argued that the masers and dense gas trace out the sites of hadronic particle acceleration. I will review what we know about the physical conditions of these shocked regions and I will introduce a potential new tracer for identifying the sites of cosmic ray acceleration.

**Diffuse emission and cosmic ray interaction with interstellar matter / 35**

## Spallation modelling - What's new on nuclei production with INCL4.5-Abla07?

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Spallation reactions play a role in the production of stable and radioactive isotopes in meteorites by galactic cosmic ray (GCR) particles. For several decades cosmogenic nuclide production rates have been measured in different types of meteorites and calculation models have been improved. The main microscopic ingredients of these models are: i) the particle fluxes responsible of the nuclide production (primary and secondary particles) and ii) the production cross-section of nuclides from a given particle (in the whole energy range). Up to now the best choice seems to compute the particle fluxes with Monte-Carlo codes (ex: LAHET code system - LCS) and use experimental measurement for the production cross section, if available.
Meanwhile spallation models have also been improved the last ten years, and especially the combination INCL4-Abla. INCL4 (Intra-Nuclear Cascade Liège) is the intra-nuclear part and Abla deals with the deexcitation phase. These two models have been recently benchmarked with about ten other models within the "Benchmark of spallation models" carried out by IAEA and it comes out that INCL4-Abla is one of the best combinations to describe spallation reactions.
Then we will show, with microscopic excitation functions, the great improvement done in the estimates of nuclides of interest in stony and iron meteorites (3He, 10Be, 21Ne, 26Al, 36Cl, …). Moreover INCL4-Abla can emit nucleons, d, t, 3He, $\alpha$ and heavy ions, and computes reactions with nucleons, d, t, 3He and $\alpha$ as projectiles. Then we can study p+Fe, n+Fe and $\alpha$+Fe as well where experimental excitation functions exist. It has to be mentioned that these new versions of INCL4 and Abla have been implemented in a transport code, MCNPX, and thus macroscopic calculations with inter-nuclear cascades can be done.

**Diffuse emission and cosmic ray interaction with interstellar matter / 34**

## Spallation reaction and cosmic rays

**Cosmic ray sources: Multiwavelength observations / 9**

## Supernova remnants and Pulsar Wind Nebulae in the CTA era

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The Cherenkov Telescope Array (CTA) project, currently under its Preparatory Phase, is an initiative to build the next generation of ground-based very high energy gamma-ray instruments. It will serve as an open observatory to a wide astrophysics community and will provide a deep insight into the non-thermal high-energy universe. It foresees a factor of ~10 improvement in sensitivity above 100 GeV, with a better angular resolution in comparison with currently operational IACTs.
The CTA consortium is investigating the different physics cases for different proposed array configurations and subsets. Pulsar Wind Nebulae (PWNe), the most numerous VHE Galactic sources, and Supernova Remnants (SNRs), believed to be the acceleration sites of the bulk of cosmic rays, will certainly be two of the main observation targets for CTA. We will discuss the main scientific goals to be achieved concerning PWNe and SNRs and discuss quantitative examples of the capability of CTA to achieve these objectives based on Monte Carlo simulations.

**Interstellar medium / 113**

## The CO-H2 conversion factor of diffuse ISM: Bright 12CO emission also traces diffuse gas

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Summarizing 20 years of efforts, we will quantify the CO luminosity and CO-H2 conversion factor applicable to diffuse but partially molecular ISM when H2 and CO are present but C+ is the dominant form of gas-phase carbon. To do this, we will discuss galactic lines of sight observed in HI, HCO+ and CO where CO emission is present but the intervening clouds are diffuse (locally Av ~ 1 mag) with relatively small CO column densities N(CO) ~ 2.10^16 cm-2. We will separate the atomic and molecular fractions statistically using Ebv as a gauge of the total gas column density and compare N(H2) to the observed CO brightness.

Although there are H2-bearing regions where CO emission is too faint to be detected, we will show that the mean ratio of integrated CO brightness to N(H2) for diffuse ISM does not differ from the usual value of 1 K.km/s of integrated CO brightness per 2.10^20 H2.cm-2. Moreover, the luminosity of diffuse CO viewed perpendicular to the galactic plane is 2/3 that seen at the Solar galactic radius in surveys of CO emission near the galactic plane.

Commonality of the CO-H2 conversion factors in diffuse and dark clouds
can be understood from considerations of radiative transfer and CO
chemistry. There is unavoidable confusion between CO emission from diffuse and dark gas and misattribution of CO emission from diffuse to dark or giant molecular clouds. The character of the ISM is different from what has been believed if CO and H2 that have been attributed to molecular clouds on the verge of star formation are actually in more tenuous, gravitationally-unbound diffuse gas.

**Cosmic ray sources: Multiwavelength observations / 13**

## The Fermi Large Area Telescope unveils a cocoon of freshly-accelerated cosmic rays in the Cygnus X region

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Supernova remnants are generally considered as the accelerators of the Galactic cosmic rays. The majority of supernovae have massive star progenitors and explode in a highly turbulent medium

sustained by stellar winds and intense ionizing radiation in and around the parent stellar clusters. The early evolution of cosmic rays after their injection in the turbulent medium and the potential trapping and reacceleration of the particles in this environment have escaped observations so far. CRs can be traced in gamma rays as they interact with ambient interstellar gas and radiation. We present an analysis of the Fermi Large Area Telescope (LAT) observations of the Cygnus X region: gamma-ray emission above 1 GeV reveals a 50-pc wide cocoon of freshly-accelerated cosmic rays following the cavities carved by Cyg OB2 and other young stellar clusters. We will discuss the cocoon properties and its relationship with the nearby gamma-ray bright supernova remnant gamma Cygni.

**Cosmic ray acceleration processes / 109**

## The Impact of the Reverse Shock on Cosmic-Ray Spectra in Supernova Remnants

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It is known that two shocks co-exist in young Supernova Remnants (SNRs) during their free expansion into the circumstellar/interstellar medium. It is widely accepted that the forward shock is responsible for the bulk of accelerated particles and the creation of a non-thermal power-law distribution of cosmic-rays. Under a test-particle approach the index of the power-law spectrum at high energies is s=2, and s<2 if non-linear theory with particle back reaction is employed. However, the observations of cosmic rays (CRs) and SNRs show that the index is typically softer, s>2. We study possible reasons for that and investigate the impact of the reverse shock on particle spectra and subsequent particle emission in young SNRs. For this purpose we use a test-particle approach to the solution of CR-transport equation and 1-D hydrodynamical simulations of SNR evolution. We found that the reverse shock significantly affects the overall distribution of
high-energy particles and their emission in young SNR. Generally, the reverse shock can produce spectral features that may be mistaken as signatures of non-linear cosmic-ray feedback, and it may also be responsible for the observed softening of the high-energy emission coming from SNRs.

**Cosmic Ray propagation / 32**

## The Long-Term Azimuthal Structure of the Galactic Cosmic Ray Distribution due to Anisotropic Diffusion

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In the description of Cosmic Ray transport following the well-known Parker Transport Equation, the spatial diffusion of energetic particles, in general, has to be treated by employing a tensorial quantity for the diffusion, i.e. using different diffusion strengths along and perpendicular to the magnetic field, respectively. This leads to results for the distribution function of these particles which differ from those obtained with just a scalar diffusion coefficient. Since the sources of Cosmic Rays are mainly supernova remnants distributed along the spiral arms of the Galaxy, our Solar System experiences different levels of Cosmic Ray intensities along its way around the galactic center. The actual azimuthal structure of the distribution then depends critically on the diffusion model and the employed magnetic field model and may be of interest in the context of (very) long-term climatology.

**Massive stars and cosmic-ray sources / 16**

## The sources of galactic cosmic rays

Many of the core-collapsed supernovae are expected to explode within or in the vicinity of their parent clouds. The manifestation of the supernova remnants (SNRs) can differ substantially for different type of their progenitor stars. For the relatively low mass progenitor the stellar wind and photoionizing radiation are not sufficient to clear up substantially the surrounding cloud and already at a radius of about a few pc the remnant is entering a radiative phase with a shock directly interacting with the molecular cloud. In contrast, the winds of the most massive stars blow much larger caverns filled with structured wind resulting in different CR particle acceleration regimes. Observations of SNRs and galactic cosmic rays (CRs) suggest that there is a high efficiency of conversion of the kinetic power of supernova shocks into CRs. We discuss the specific mechanisms to convert a sizable fraction of the power released by SNRs into CRs and fluctuating magnetic fields of wide dynamical range of scales and the observational appearance for the different types of SNRs. Star forming activity with clustered supernova explosions in superbubbles observed in galaxies may affect the observed non-thermal spectra of the starburst galaxies.

**Cosmic ray acceleration processes / 106**

## The streaming instability

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Streaming instabilities are thought to play a fundamental role in both the processes of acceleration and propagation of Cosmic Rays in the Galaxy.
Resonant scattering on self-generated magnetic turbulence has long been recognized as the most plausible mechanism for the confinemet of energetic particles. The streaming of these particles along magnetic field lines at super-alfvenic speeds generates magnetic turbulence at a wavelength corresponding to the particles' gyroradius: such turbulence could then provide efficient scattering of the same particles so as to ensure a small diffusion coefficient and hence large confinement times in the Galaxy.
Particle streaming is even more important in the acceleration region, if galactic Cosmic rays up to the knee are indeed accelerated in Supernova Remnant shocks. Reaching energies in excess of 1 PeV requires very effective particle scattering, leading to infer a turbulent magnetic field in the shock region much in excess of the average field in the ISM. The field amplification is thought to be provided by the streamining CRs themselves, but sufficient levels of turbulence, such as to guarantee acceleration up to the knee, are still difficult to obtain, even after the resonant generation of Alfven waves is taken into account.

In more recent times, the streaming instability has been reconsidered to show that in addition to the well known and long studied resonant modes, there are also non-resonant modes in the dispersion relation, that might show in some situations very large growth rates, much larger than for the resonant ones. These non-resonant waves lead to magnetic field strengths that could ensure, in principle, acceleration of particles up to the knee. Problem with these modes, in terms of their efficacy for particle scattering (and hence acceleration) is that they are born as short wavelength modes and some inverse cascading is necessary before they can provide effective particle scattering.

I will give a brief overview of our understanding of streaming instabilities and their role in Cosmic Ray physics, following the historical development of studies in this field, from the pioneering works by Skilling and Wentzel in the '70s to the most recent works, both theoretical and numerical, on the non-resonant modes.

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## The thermal instability: effect of cosmic rays

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**Cosmic Ray propagation / 53**

## Three-dimensional anisotropic transport of solar energetic particles in the inner heliosphere

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The missions STEREO A/B with large separation distances, together with ACE, SOHO, and WIND near Earth, provide a unique opportunity to observe solar energetic particles (SEP) over a large range of solar longitudes and latitudes in the inner heliosphere. It is evident from these observations that temporal and directional characteristics of solar energetic particles strongly depend on the location of the spacecraft relative to the source at the Sun. Our three-dimensional model of SEP propagation incorporates anisotropic pitch-angle scattering by magnetic inhomogeneities in the solar wind, focusing, streaming along the large-scale magnetic field, adiabatic energy losses and pitch-angle-dependent diffusion perpendicular to the magnetic field. We report the results of a parameter study of SEP time profiles, anisotropy and pitch-angle distribution as a function of different propagation parameters, angular and radial distances from the source and the source size. A comparison of the simulation results with multi-spacecraft observations allows to diagnose the propagation conditions in interplanetary space. Possibilities to apply our model to the investigation of anisoptropic transport of high energy cosmic rays in the galaxy will be discussed.

**Cosmic ray sources: Multiwavelength observations / 46**

## Towards Fermi-LAT Detected Supernova Remnants as Cosmic Ray Accelerators

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With the detection of more than 7 Supernova Remnants (SNRs) by the Fermi-LAT telescope, we now have access to an energy range opening a window onto emission mechanisms not previously available for these objects. In particular in combination with multiwavelength observations, we are now better able to determine the probable particle populations accelerated by the SNRs as well as the environmental conditions, such as the magnetic field strength. The SNR CTB 37A is one example where we have determined that hadrons dominate the GeV emission, as for many ‘’middle-aged” Fermi-LAT SNRs, providing further evidence for this SNR as a probable galactic cosmic ray accelerator. Moreover we have bounded the magnetic field strength to better than an order of magnitude below its previous value, within the constraints of our model, and for first time for this source, we also determined the minimum magnetic field strength necessary to self-consistently produce the multiwavelength emission. We will explore the current understanding of Fermi-LAT SNRs as cosmic ray accelerators and anticipate future developments with the continued increase in SNR associations. By assembling such populations of SNRs, we will be able to more definitively define their contribution to the observed galactic cosmic rays, as well as better understand SNRs themselves, thereby illuminating the long-standing cosmic ray mysteries, shedding light on potential sources, acceleration mechanisms, and cosmic ray propagation.

**Interstellar medium / 114**

## Turbulence in the interstellar medium

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**Poster session / 123**

## Unraveling HESS J1745-303 with new results from the Fermi-LAT telescope

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HESS J1745-303 is an extended, unidentified VHE (very high energy) gamma-ray source located at the edge of the giant molecular ring surrounding the Galactic Center.
Unraveling the nature of this emission is not easy in this region densely populated by plausible VHE emission candidates, like supernova remnants, pulsar wind nebulae, and X-ray binaries.
Recently, an excess positionally consistent with the HESS source has been observed in the GeV energy range with the Fermi-LAT data.
A detailed and more specific analysis performed with the most updated knowledge of the Fermi-LAT instrument response, and as well of the gamma-ray sky model, leads to the discovery of important features that can strongly help in the understanding of this source.
The interpretation of the GeV/TeV connection is discussed, especially in the context of supernova remnant interacting with molecular clouds.

**Massive stars and cosmic-ray sources / 14**

## Winds of massive stars

**Cosmic ray sources: Multiwavelength observations / 6**

## X-ray observations of Supernova remnants

**Cosmic ray sources: Multiwavelength observations / 10**

# Young SNRs: a new family of HE gamma ray emitters

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