Brief History of the Cosmic Ray Anisotropy Workshop

(a very biased account)

Paolo Desiati

Juan Carlos Díaz Vélez

May 15, 2026

Cosmic Ray Anisotropy Workshops

2011 - Madison



2013 - Madison



2015 - Bad Honnef

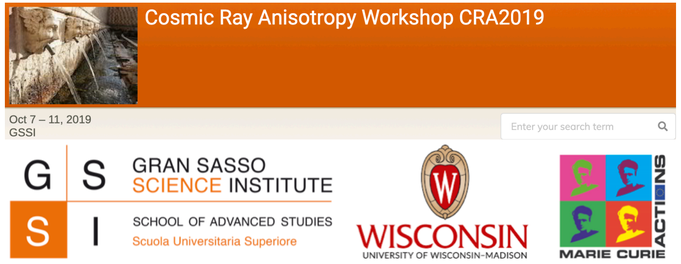
"Cosmic Ray Anisotropies"

26 - 30 Januar 2015, Physik Zentrum Bad Honnef, Bad Honnef, Germany

2017 - Guadalajara

CRA2017
4th Cosmic Ray Anisotropy Workshop
10 - 13 October, 2017
Guadalajara, Jalisco, México

2019 - GSSI



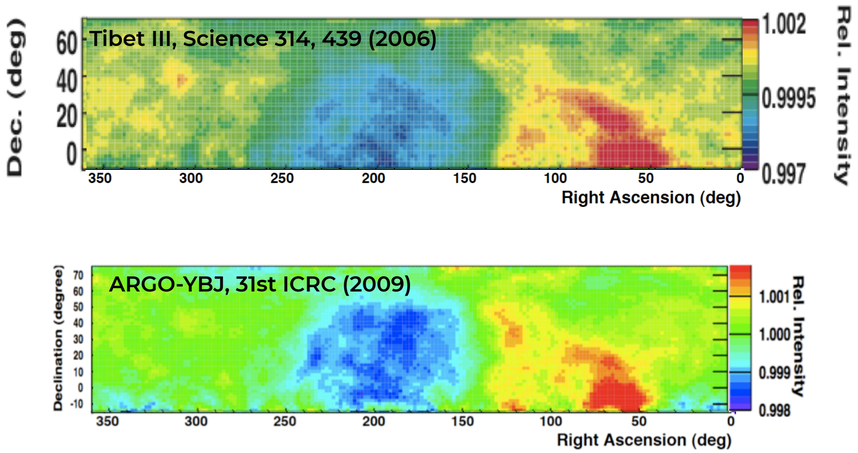
2023 - Loyola Chocago

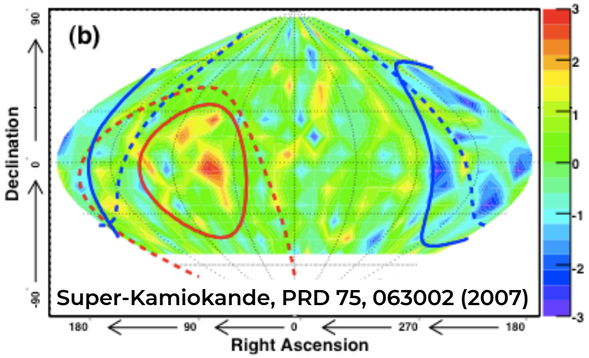
CRA 2023
sixth Cosmic Ray Anisotropy Workshop
May 16-19, 2023
Loyola University - Chicago

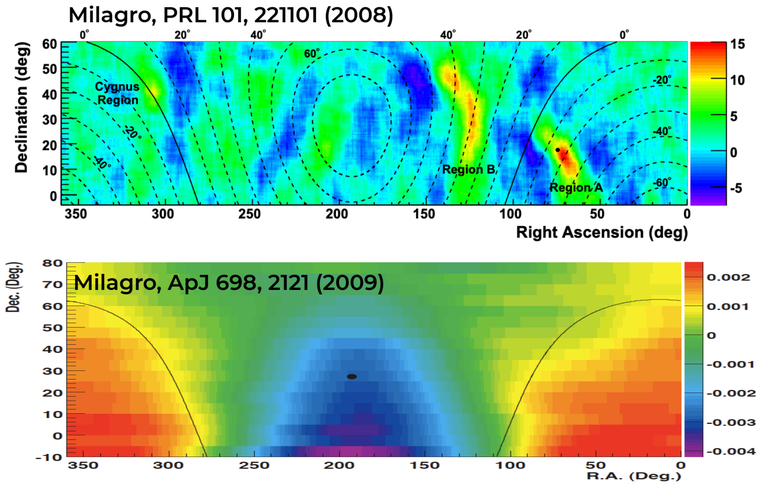
2026 - Monterrey

CRA2026
7th Cosmic Ray Anisotropy Workshop
3 - 6 November, 2026
Monterrey, Nuevo León, México

TeV anisotropies - early 2000's



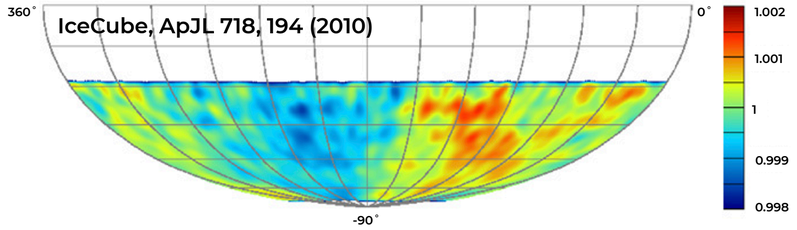




Ground-based experiments collecting a **large number** of TeV-scale cosmic-ray events

Early **sky maps** of cosmic-ray arrival direction distributions

Due to the **small size** of the anisotropies (10^{-4} - 10^{-3}), quantitative studies require careful separation of detector effects from the observations



2011

First workshop in Madison

- The notion that CRs are isotropically scrambled is only approximate
- The first CR map in the Southern Hemisphere
- What does anisotropy tell us about cosmic rays?

"Anisotropy in the TeV Cosmic Rays: A Challenge for Interpretation"

Segev BenZvi

Focus on understanding the measurements and their **systematic uncertainties** and biases

"Trying to Understand the Interstellar Transport and Resulting Anisotropies "

J. R. (Randy) Jokipii

Small-scale features: heliospheric or interstellar turbulence origin?

Large-scale features: QLT diffusion processes predict too high an anisotropy at the TeV- PeV scale

Turbulence affecting both spectrum and directions

2011

Comparing observations & ideas

- The notion that CRs are isotropically scrambled is only approximate
- The first CR map in the Southern Hemisphere
- What does anisotropy tell us about cosmic rays?

Discuss several cosmic-ray measurements:

Milagro · **ARGO-YBJ** · **Tibet** · **AMANDA** · **IceCube** · **PAMELA**

The first **IBEX** results that would lead to measuring the local B-field

Priscilla Frisch on the **local interstellar magnetic field**

2013

Establish a new community



- We established the workshop's interdisciplinary structure

cosmic-ray observations	**astrophysics**	**interstellar medium**	**plasma physics**	**heliosphere**

Discuss several cosmic-ray measurements:

HAWC · **KASCADE-Grande** · **Telescope Array** · the first **AMS-02** results

Not only anisotropy but also spectrum & composition

2015

Full immersion into heliophysics

- Hosted by the **heliophysics** group at Ruhr-Universität Bochum
- Focused on heliophysics

Discussions on

Heliospheric structure · **particle transport** · **pitch-angle scattering** · **perpendicular diffusion** · **the heliotail**

Diffusion processes in the inner heliosphere → astrophysical media

2017

First all-sky map in Guadalajara

- Limited reach from individual ground-based observatories
- No single detector can provide clean anisotropy observations

IceCube and HAWC, combined

Each observatory sees only part of the sky, and a partial sky distorts the measurement: the start of an initiative that we are expanding

Now extending to **GRAPES-3**, **LHAASO**, **KASKADE**, **TALE**,...

Results from direct CR experiments: **CALET, DAMPE**

What these years built

Magnetic field models

Cosmic rays are deflected by magnetic fields

A map of the sky needs a map of the field

Joint analyses

Combining detectors with complementary sky coverage to drasticaly reduce observational biases

Quantitative transport

Provide observational results to test diffusion models

2019

Voyager's ISM at GSSI

- By 2019, both Voyagers had crossed the heliopause
- Voyager 1 on 25 August 2012 - Voyager 2 on 5 November 2018
- Strong astrophysics community participation: origin of cosmic rays

Alan Cummings

Reported that the two Voyagers were measuring nearly identical spectra.

For the first time, we had cosmic rays measured outside the Sun's influence: something everything else could be calibrated against

2023

New additions at Loyola Chicago



- New members of the community joined the proceedings

LHAASO results

The newest and largest air-shower array presents its anisotropy for the first time

Three flagship datasets now cover both hemispheres: IceCube, HAWC, LHAASO

The Gaia era

A new block of local interstellar astronomy:

Linsky on the local clouds
Maconi on the Local Bubble
Benjamin on the local gas and spiral structure

Gaia measured positions and distances for about two billion stars, enabling 3D maps of the nearby interstellar medium possible for the first time

2026

New instruments to change the field

IMAP

Launched in September 2025

First science data released in August 2026

What do we expect from it?

Gaia Data Release 4

Due 2 December 2026: four weeks after the workshop

Which makes this the moment to say what we need from it

A unique opportunity to understand our very very local environment and how our local ISM is connected to the galactic medium

Remaining questions

Heliosphere or ISM?

How much of the anisotropy is shaped by the heliosphere, and how much is already there?

Can we read the turbulence off the sky?

Gwenael Giacinti has asked a version of this at every single edition.
Yes, no, or still not yet?

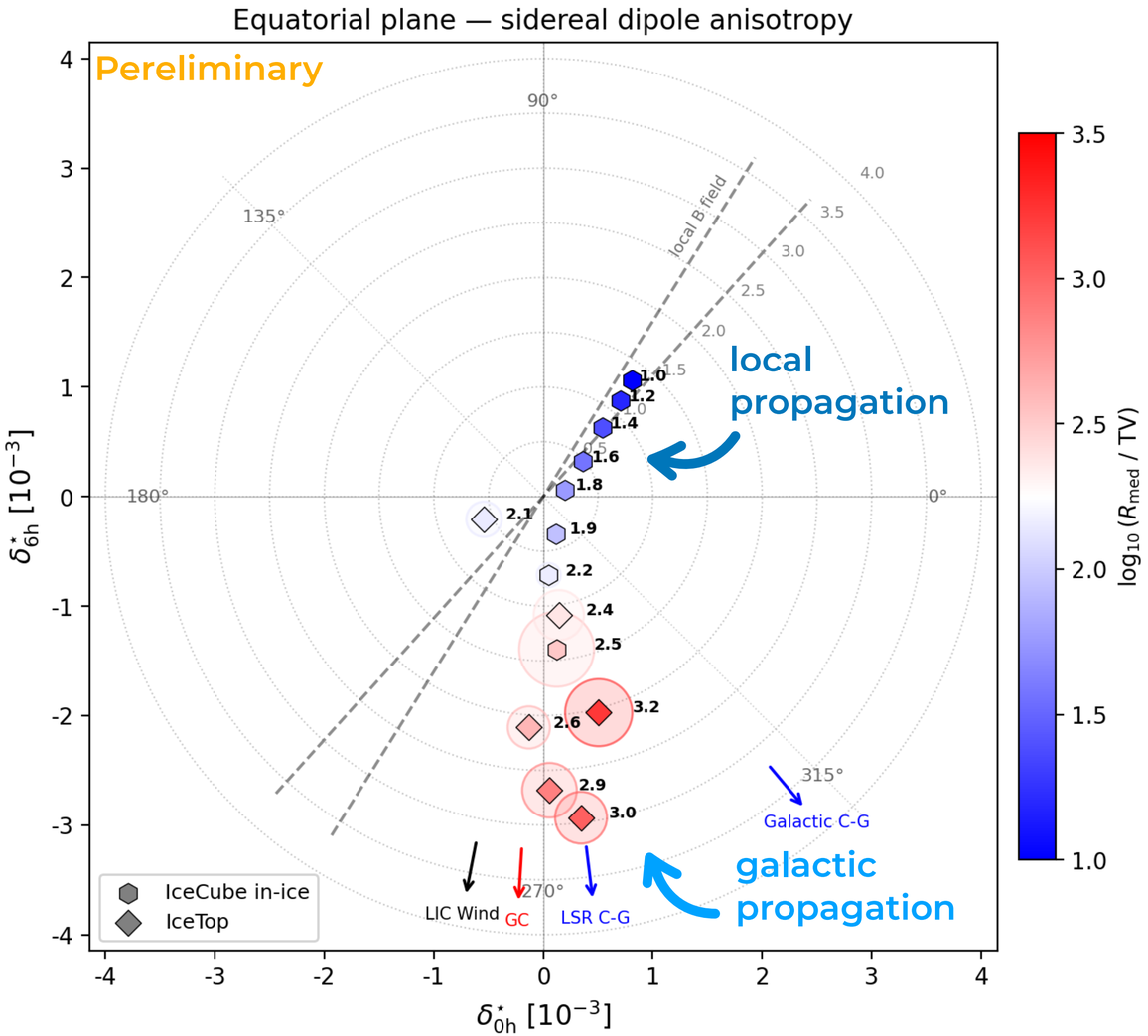
What replaces quasi-linear theory?

The standard scattering picture cannot make the small-scale structure we see. Said in 2019, said again in 2023

2026

Remaining questions

Espinosa Castro, Evoli & Blasi (2026)



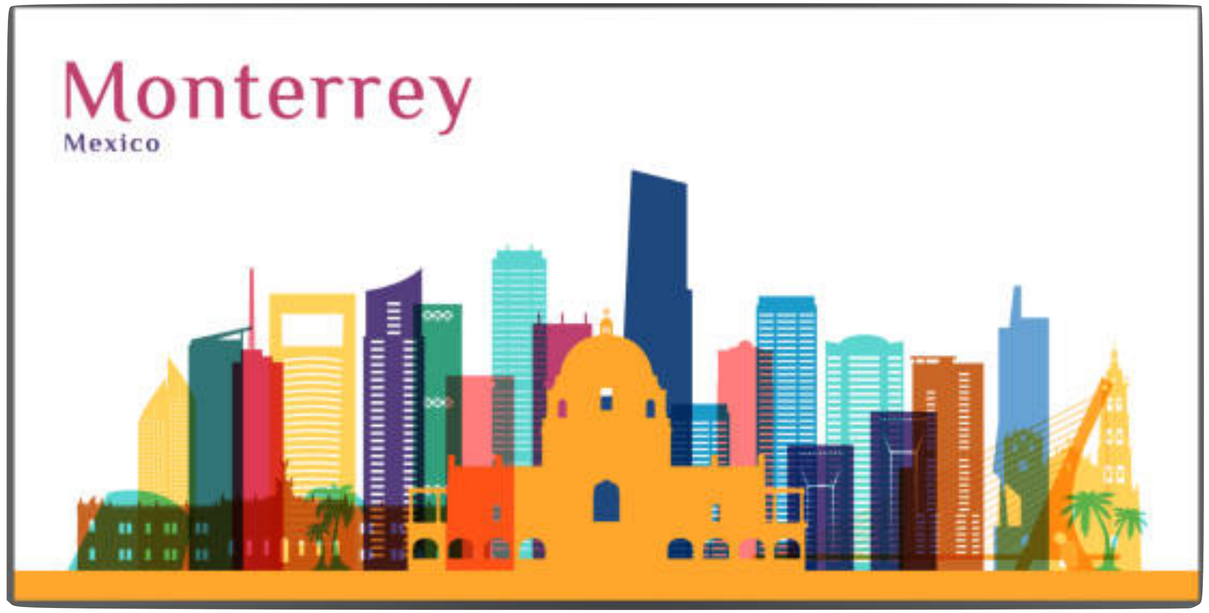
- **Drift as the origin of the CR knee:** requirements on B-field geometry and turbulence
- **<knee:** $D_{\parallel} \gg D_{\perp}, D_A$ streaming along $\vec{B}$
- **>knee:** drift streaming $\perp \vec{B} \propto$ Rigidity where most of the sources are located
- **Changes should track rigidity:** amplitude and phase vs. rigidity at 1–30 PeV (IceTop, LHAASO)

Outlook

Heliospheric, interstellar, Galactic and extragalactic magnetic fields may be studied as **separate subjects**, but charged particles **obey the same scattering and transport physics across** them: from MeV particles in the solar wind to cosmic rays at 10^{20} eV, a span of fourteen orders of magnitude.

The heliosphere is the only environment we can measure from within, making it our **best-calibrated laboratory** for understanding particle transport throughout the Universe.

Thank you for been here



- **Mind that this event hosts scientists from different fields**
- Make sure you don't use technical language that it too specific
- Take the time to explain and connect with the other communities
- Participate in the discussions and propose what you want to see next

Extra Slides

extracting the dipole component

