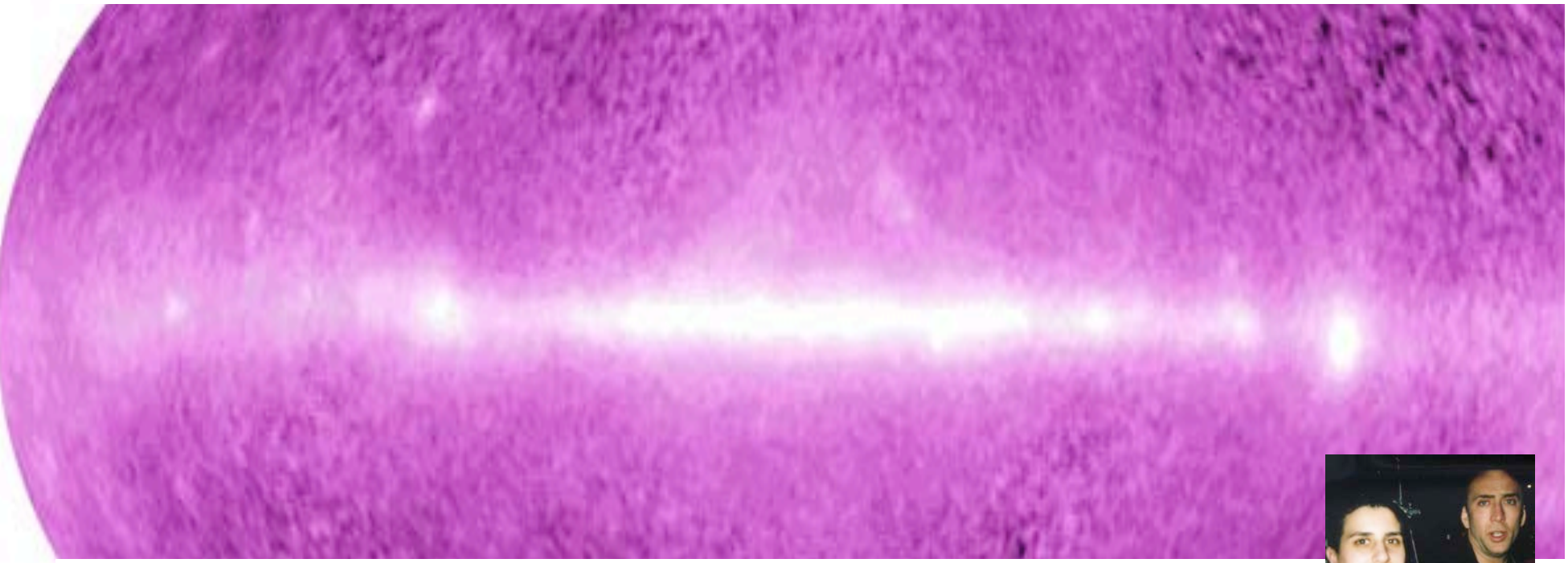
THE HISTORY OF COSMIC RAYS IN NORMAL GALAXIES

GAMMA-RAY AND LITHIUM FOSSILS



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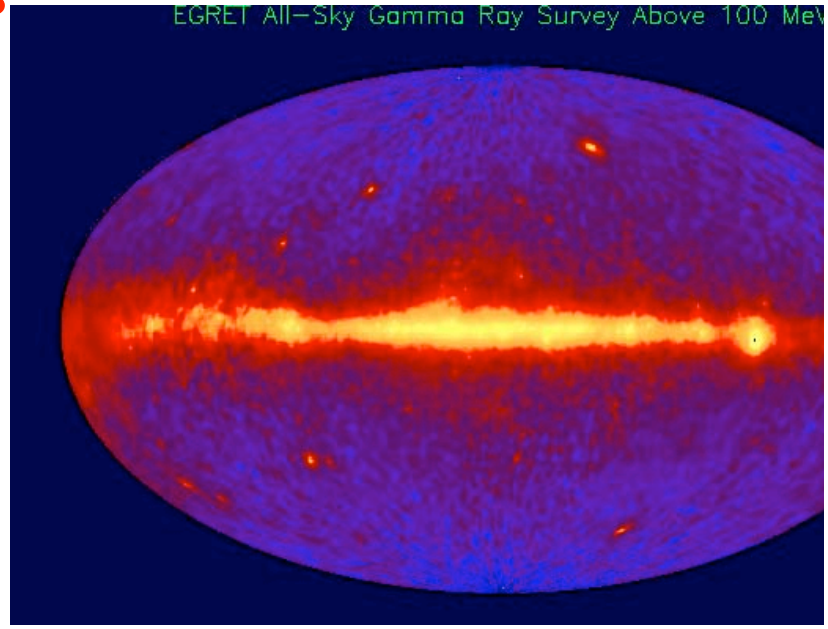
Guaranteed Gamma-Ray Backgrour from Cosmic Rays

Guaranteed extragalactic backgrounds

unresolved high-*z* counterparts to confirmed low-*z* sources

- ✓ AGN Stecker & Salamon, Mukherjeee & Chaing, Pohl
- ✓ Normal Galaxies Pavlidou & BDF



Normal Galaxies

- ✦ Milky Way resolved
  spatially & spectrally
- ✦ Gamma emission from cosmic rays
- ✦ both hadronic and leptonic
  relative contributions unclear
  no pion bump

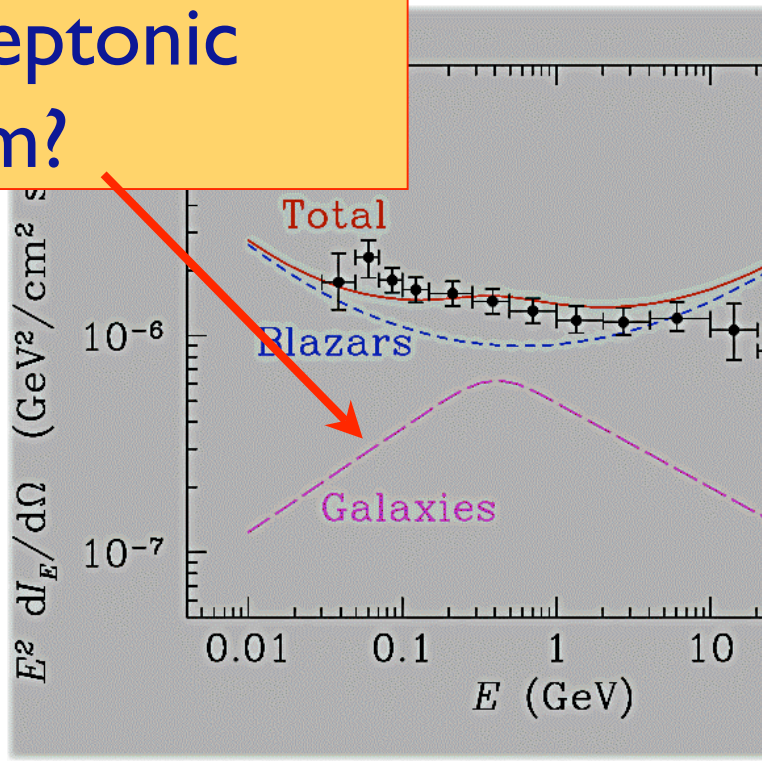
Cosmic-Ray Sources Across the Universe

Pavlidou & BDF

Modeling the cosmic history of

cosmic-ray signal sums hadronic+leptonic
but can we separate them?

- ★ interstellar medium as targets
- ★ both fixed by cosmic star formation rate
- ★ normalize to Milky Way CR/SN efficiency



Results

Pavlidou & BDF

- galaxies' contribution peaks ~0.5 GeV
  - offset from MW peak: distinguishable
- near peak, ~30% of EGRET background (AGN)
- GLAST: more AGN resolved
  - galaxy peak emerges

Paleolithography:
Lithium Probes of Cosmic-Ray History

Prodanovic & BDF

Hadronic gamma production $pp \rightarrow \pi^0 \rightarrow \gamma\gamma$

inevitably means ***lithium synthesis*** $\alpha\alpha \rightarrow {}^6\mathrm{Li} + \cdots$

Observables

★ gammas: measure mean CR fluence across universe

★ lithium abundance: measures local CR fluence

$$\frac{\mathrm{Li}}{\gamma} \sim \frac{\int \Phi_{\mathrm{CR}}(\mathrm{local})\ dt}{\int \Phi_{\mathrm{CR}}(\gamma\mathrm{path})\ dt}$$

Complementary:

use one to probe the other

Milky Way Cosmic-Ray Anomaly

Lithium as Milky-Way Dosimeter

★ ^{6}Li: cosmic rays are *only* conventional nucleosynthesis source

alternative: dark matter decays in early universe

★ Li/γ link demands pionic production

$$I_{\pi^0\to\gamma\gamma}(^6\mathrm{Li}_\odot) > I_{\mathrm{bgnd,total}} > 2I_{\mathrm{bgnd,hadron}}$$

★ ***Local cosmic-ray exposure > avg galaxy***

➡ Milky Way anomalously high hadronic CR actvity?

★ Turn the problem around

if Milky Way not greatly anomalous expect large normal galaxy gamma signal

GLAST Impact

★ Extragalactic diffuse background

- sensitivity, angular resolution: better foreground separation
- intensity, spectrum probes normal galaxies

★ AGN

- resolved foreground lowers AGB background contribution, galaxies stand

★ Local Galaxies

- Multiple Local Group galaxy detections
- tests cosmic-ray dependence on local environment (star formation) and universality of cosmic-ray confinement

★ Milky Way

- better diffuse/point source separation
- identification of pion bump?

The History of Cosmic Rays in Normal Galaxies
Conclusions

★ Extragalactic cosmic rays at cusp of revolution

★ Smoking Gun: cosmic-ray/ISM interactions

$pp \rightarrow \pi^0 \rightarrow \gamma\gamma$ extragalactic background ⇨ global CR history

$\alpha\alpha \rightarrow {}^6\mathrm{Li} + \ldots$ abundances ⇨ local CR history

★ GLAST will provide crucial new information

✓ pionic component reveals hadrons & encodes history with ^{6}Li probes Milky Way anomaly

✓ all other survey data (diffuse and point sources) will contribute new insight

Extrasolar Hadronic Cosmic Rays Still Undetected in Gamma Rays

- ★ Unambiguous hadronic signature: pion bump $pp \rightarrow \pi^0 \rightarrow \gamma\gamma$
- ★ But pion bump unseen anywhere
- ★ Milagro Galactic TeV signal inconsistent with local cosmic-rays
- ★ Unresolved point sources?