Relevance of High Energy Astrophysical Sources for Space Weather

Mauro Messerotti[1,2,3,4]

[1]***INAF, National Institute for Astrophysics, Italy***

[2]*Dept. of Physics, University of Trieste, Italy*

[3]*INFN, National Institute for Nuclear Physics, Trieste Division*

[4]*NATO Science and Technology Organisation, Paris, France*

Scheme of the Presentation

- Introduction
- From Solar to Extragalactic Weather Sources
- High Energy Galactic Sources and Impacts
- Summary and Conclusions

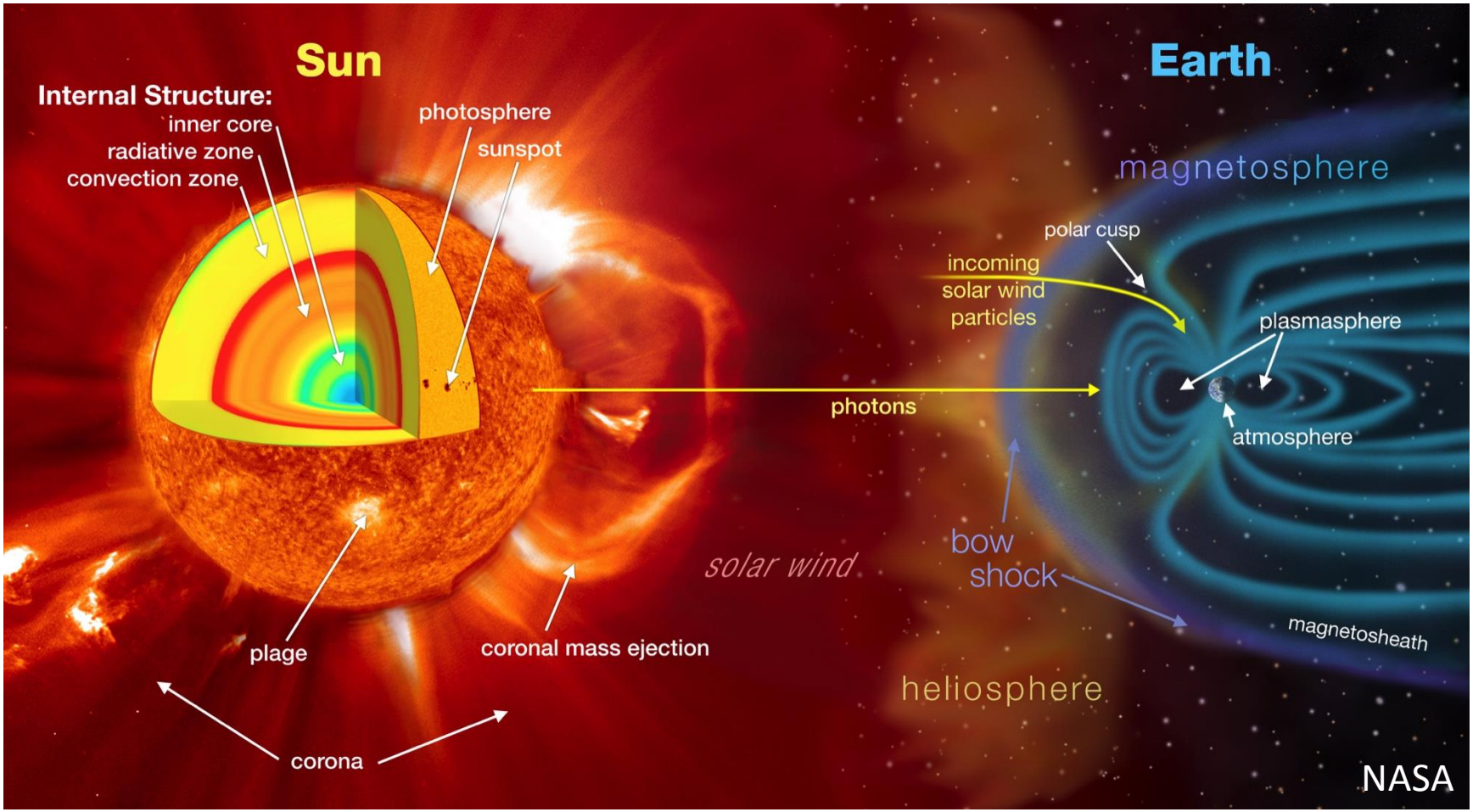
INTRODUCTION

Key Aspects Relevant to Space Weather and Space Climate

- The ensamble of impacts originated by SWx is very varied
- It is due to a system of astrophysical systems, that are complex and nonlinearly coupled, and exhibit a chaotic behaviour at multiple space, time, and energy scales
- A comprehensive approach to SWx cannot be provided by monitoring and modelling only the Sun-Earth/Planets environments
- Extragalactic, Galactic, Heliospheric, and Solar Weather must be studied to provide a comprehensive space climatology
- This aspect has not been considered by specialists both in civilian and in military applications
- Civilian and military customers are typically unaware of it
- It certainly represents a significant challenge, but it has a great potentiality e.g. in identifying unexpected effects and making them incorporated in the SWx workflow schemes

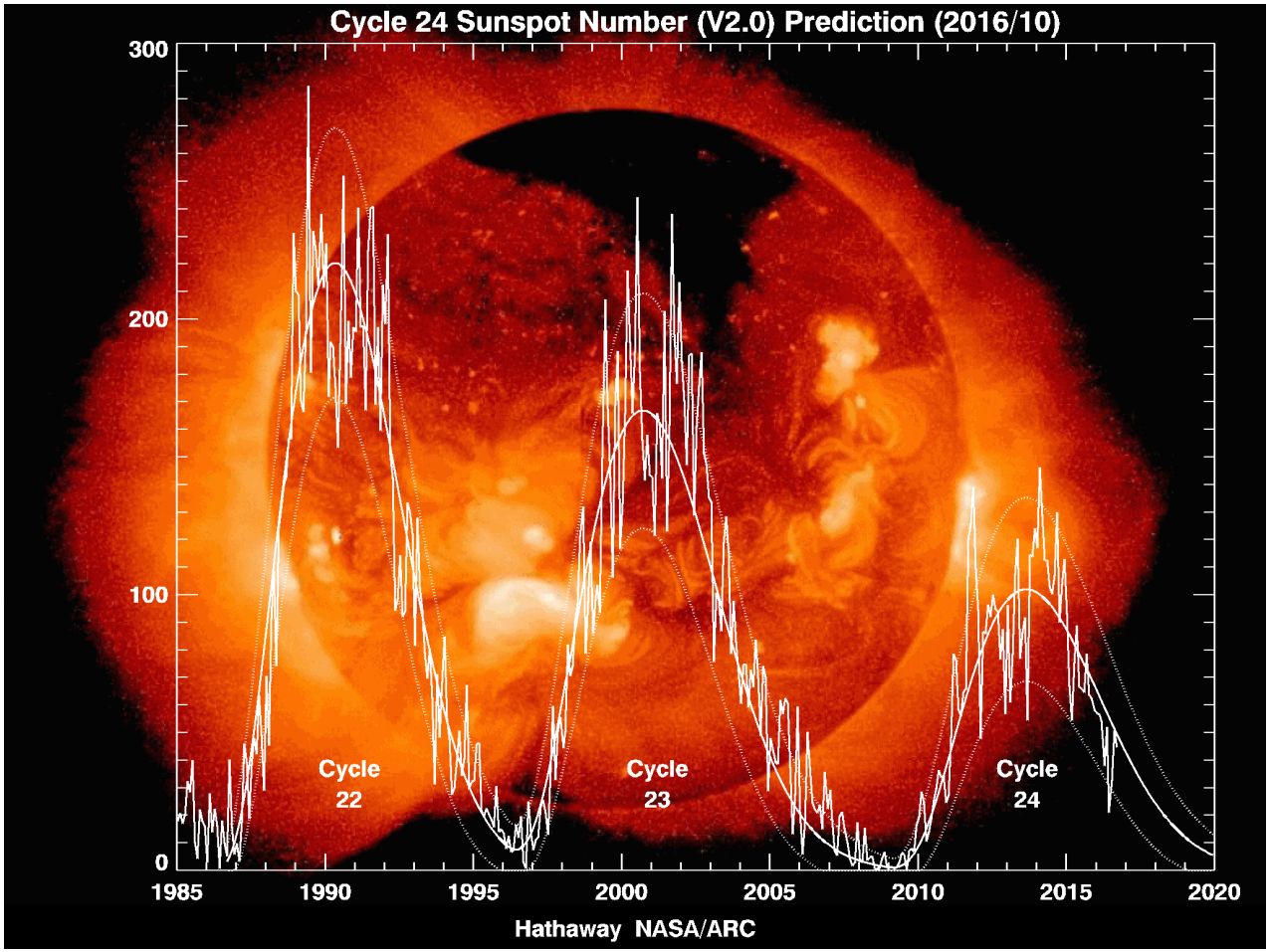
FROM SOLAR TO EXTRAGALACTIC WEATHER SOURCES

Solar Weather as SWx Primary Source in the Solar-Terrestrial Environment



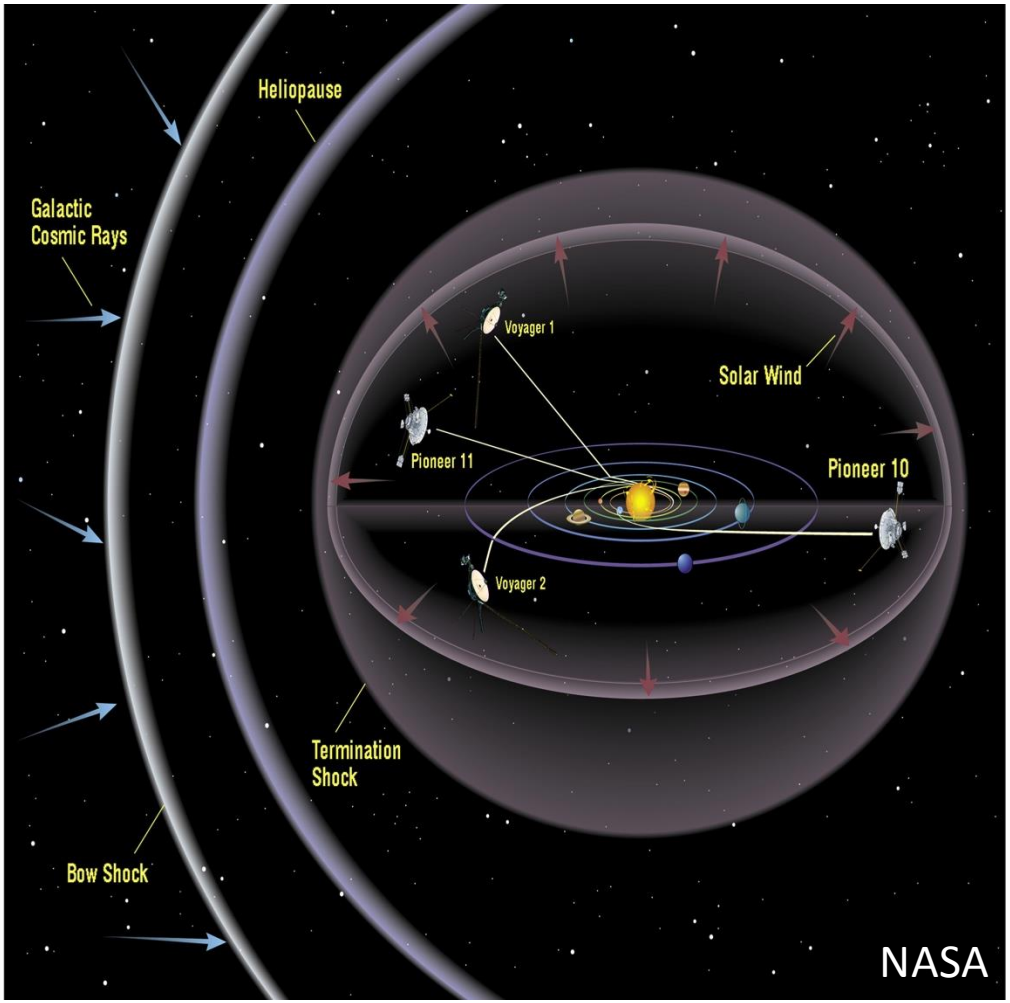
SUNSPOTS, FLARES, PROMINENCES, CHs => EM OUTBURSTS, CMEs, SEPs, FAST SW, CIRs

Solar Activity Trend Impact on SWx



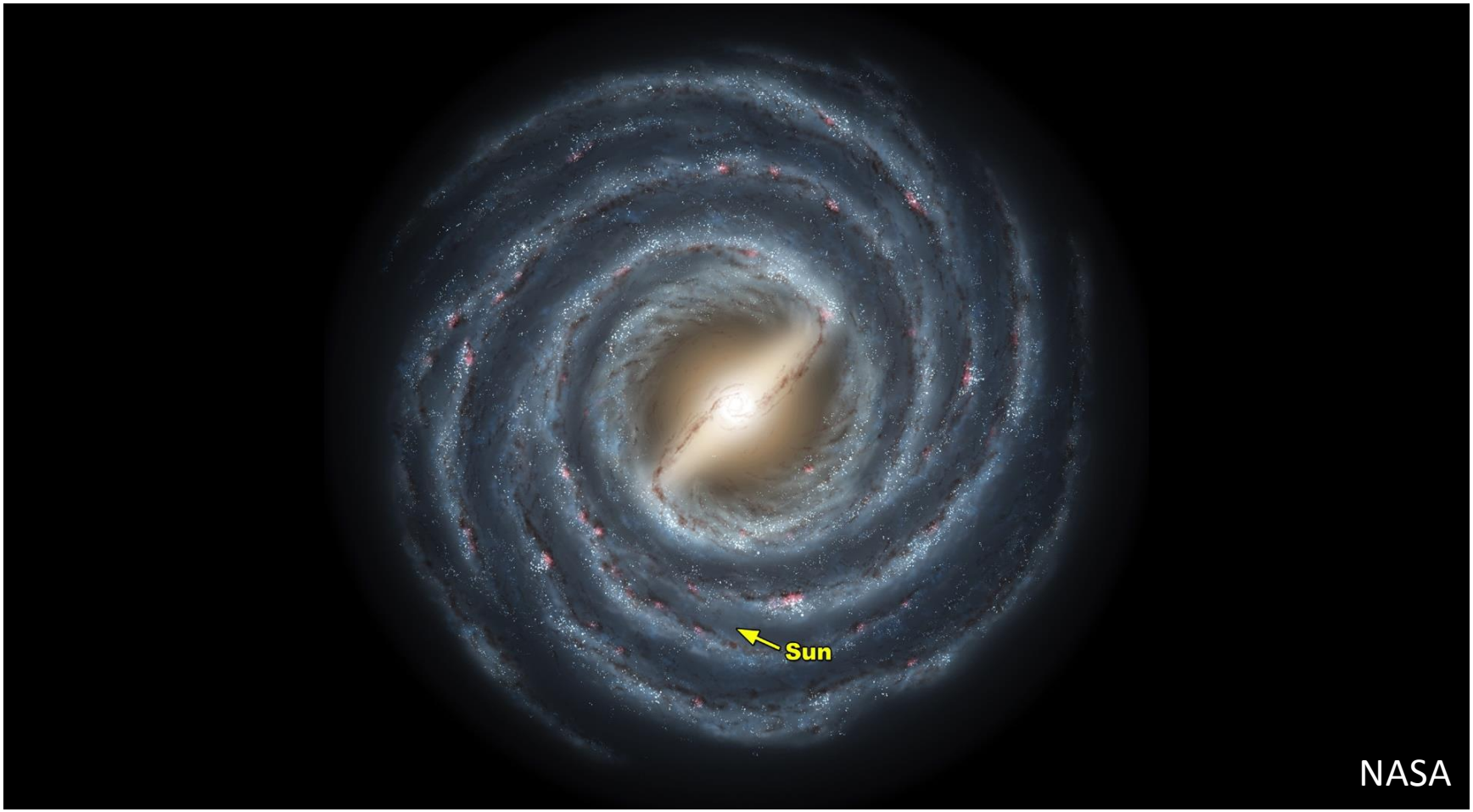
MODEST ACTIVITY CYCLE => SLOW DILUTED SOLAR WIND => HIGHER CR FLUENCE IN HELIOSPHERE

Heliospheric Weather



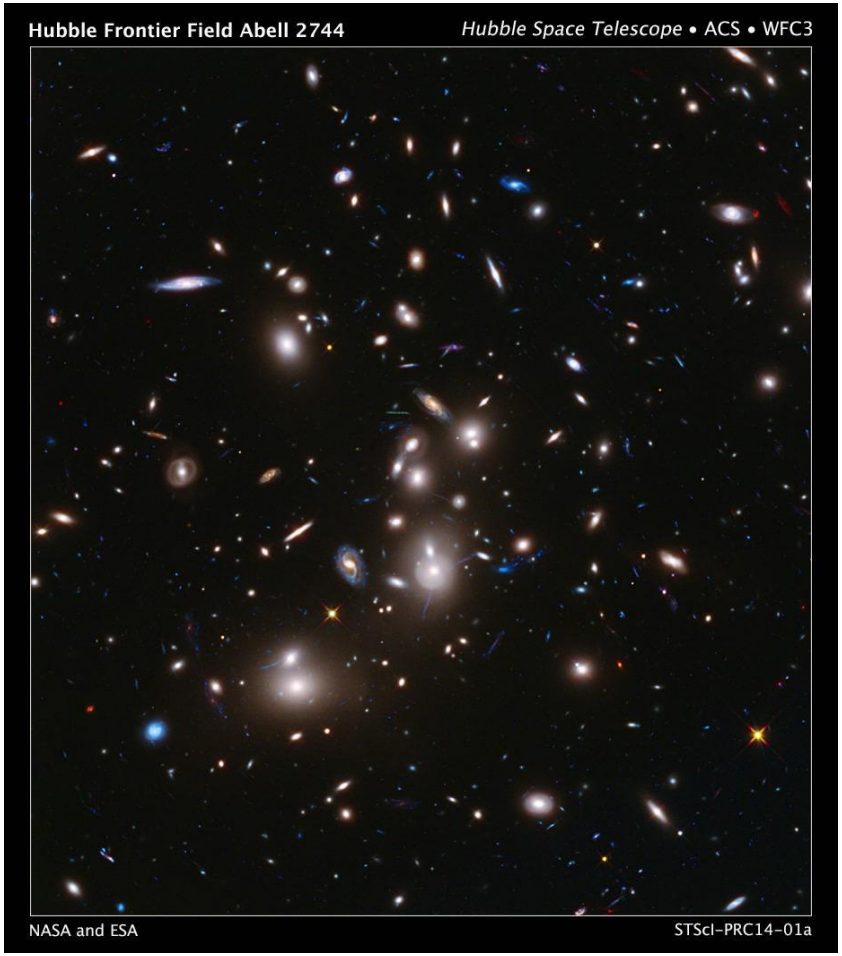
SLOW AND FAST SW, CIRs, ICMEs, SEPs (keV-GeV), CRs (GeV-EeV), INeutrals

Galactic Weather in the Milky Way



SUPERNOVAE, HYPERNOVAE, MAGNETARS => GALACTIC CRs, GRBs

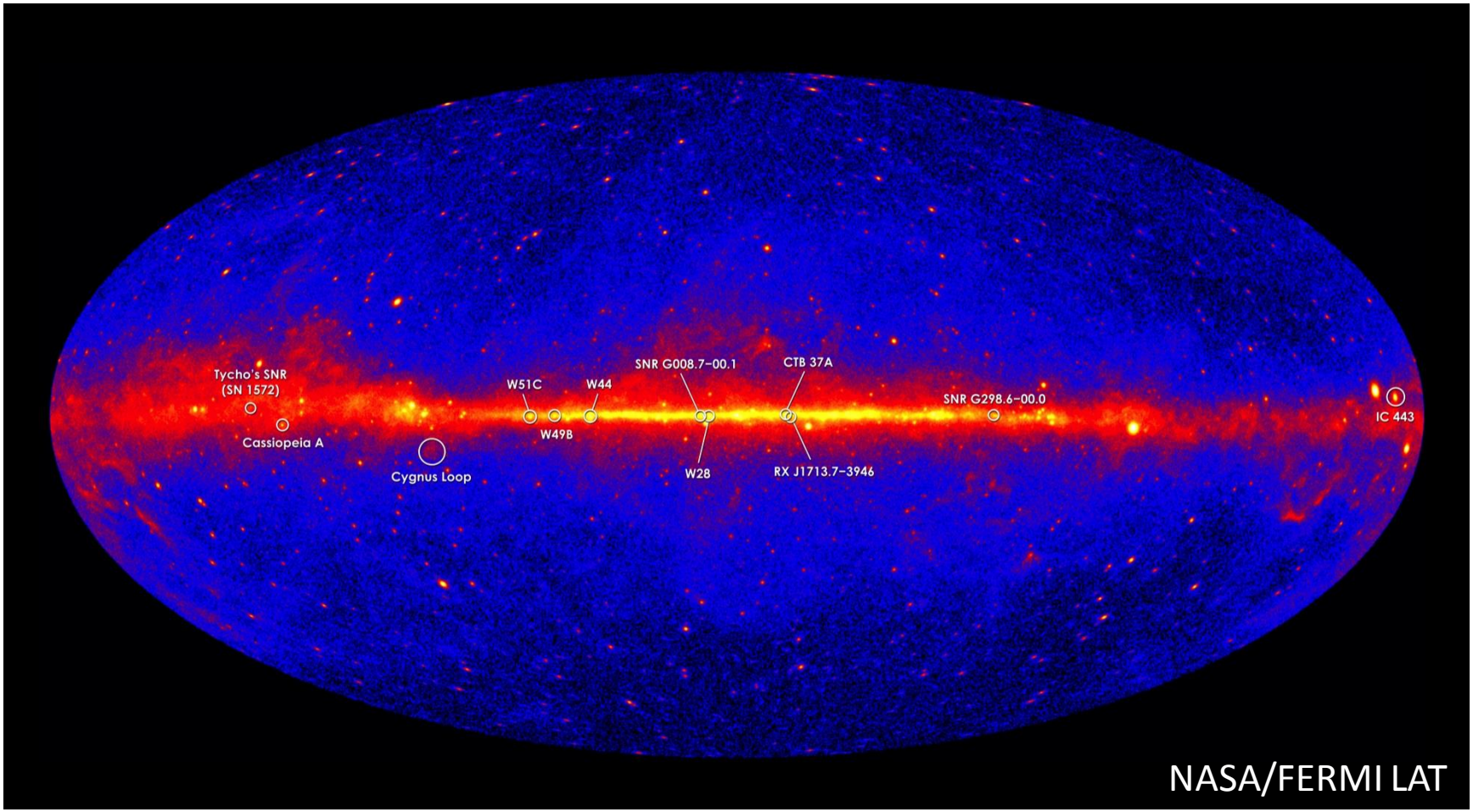
Extragalactic Weather from Outer Galaxies



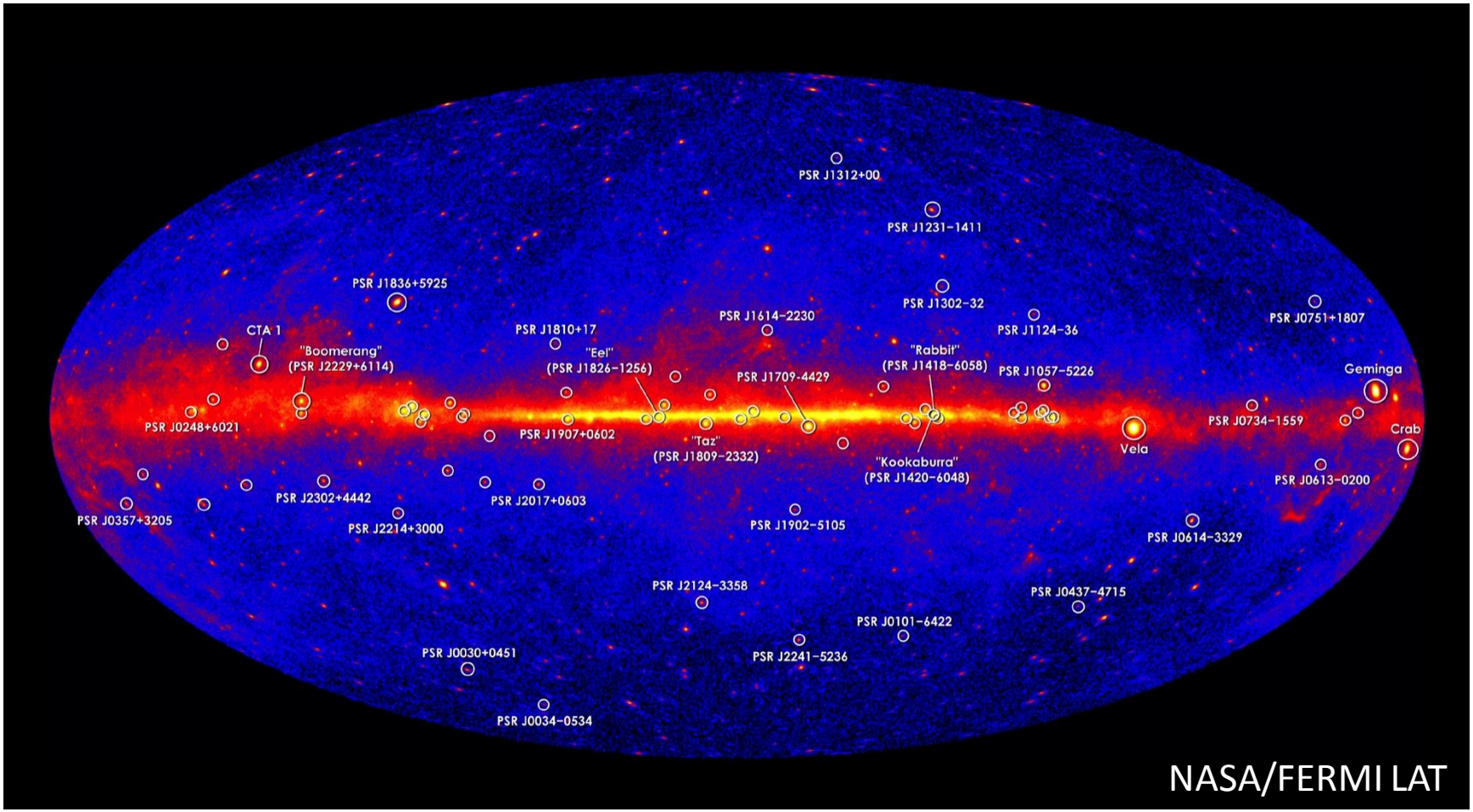
DISTANT (Mly-Gly) ACTIVE GALAXIES => GRBs (10^{44} J), UHECRs (> 1 EeV), EHECRs (>50 EeV)

HIGH ENERGY GALACTIC SOURCES AND IMPACTS

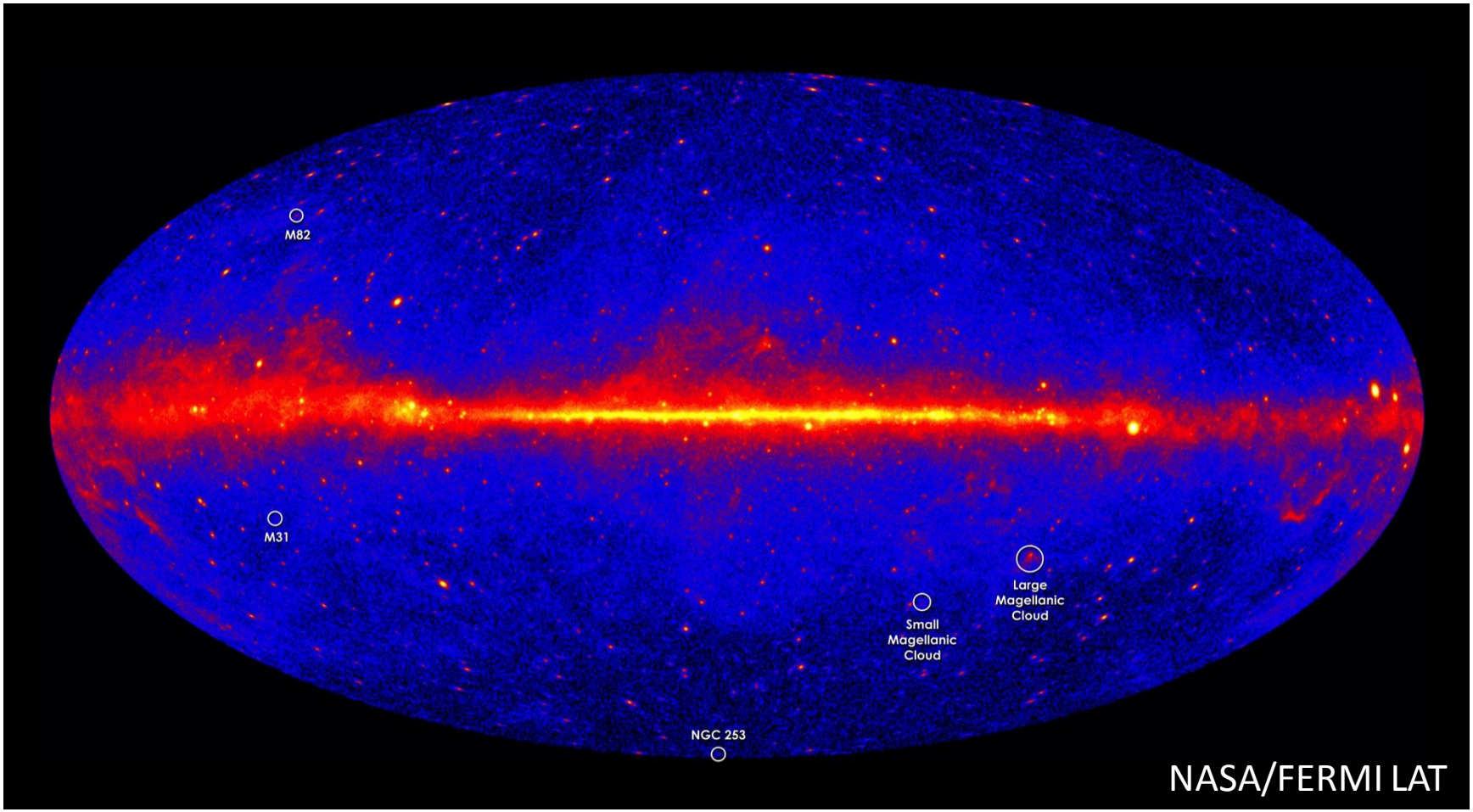
GRBs and SNRs in Milky Way



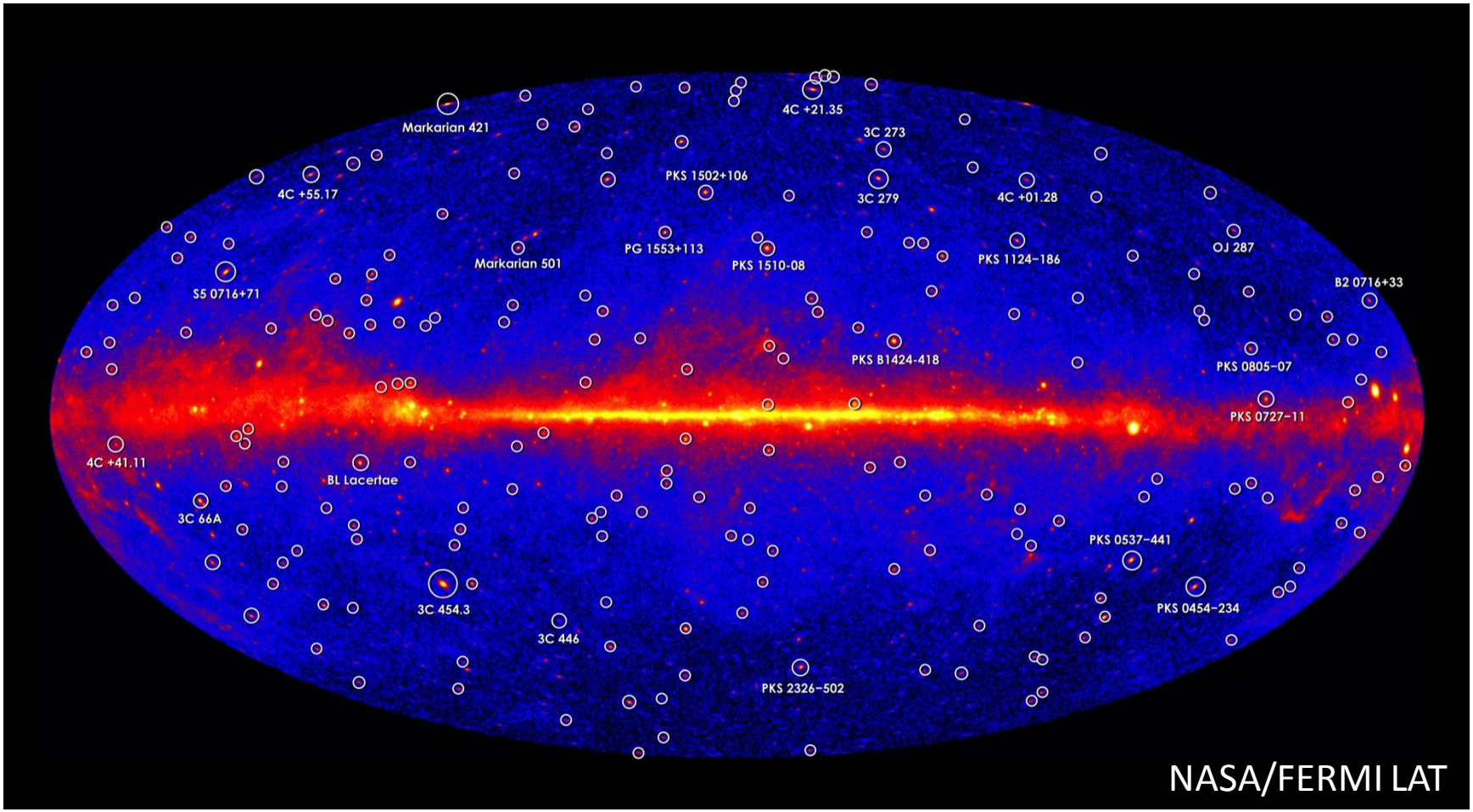
GRBs and Pulsars



GRBs and Normal Galaxies



GRBs and Blazars (Blazing QSO)



Hypernovae as GRBs & CRs Sources

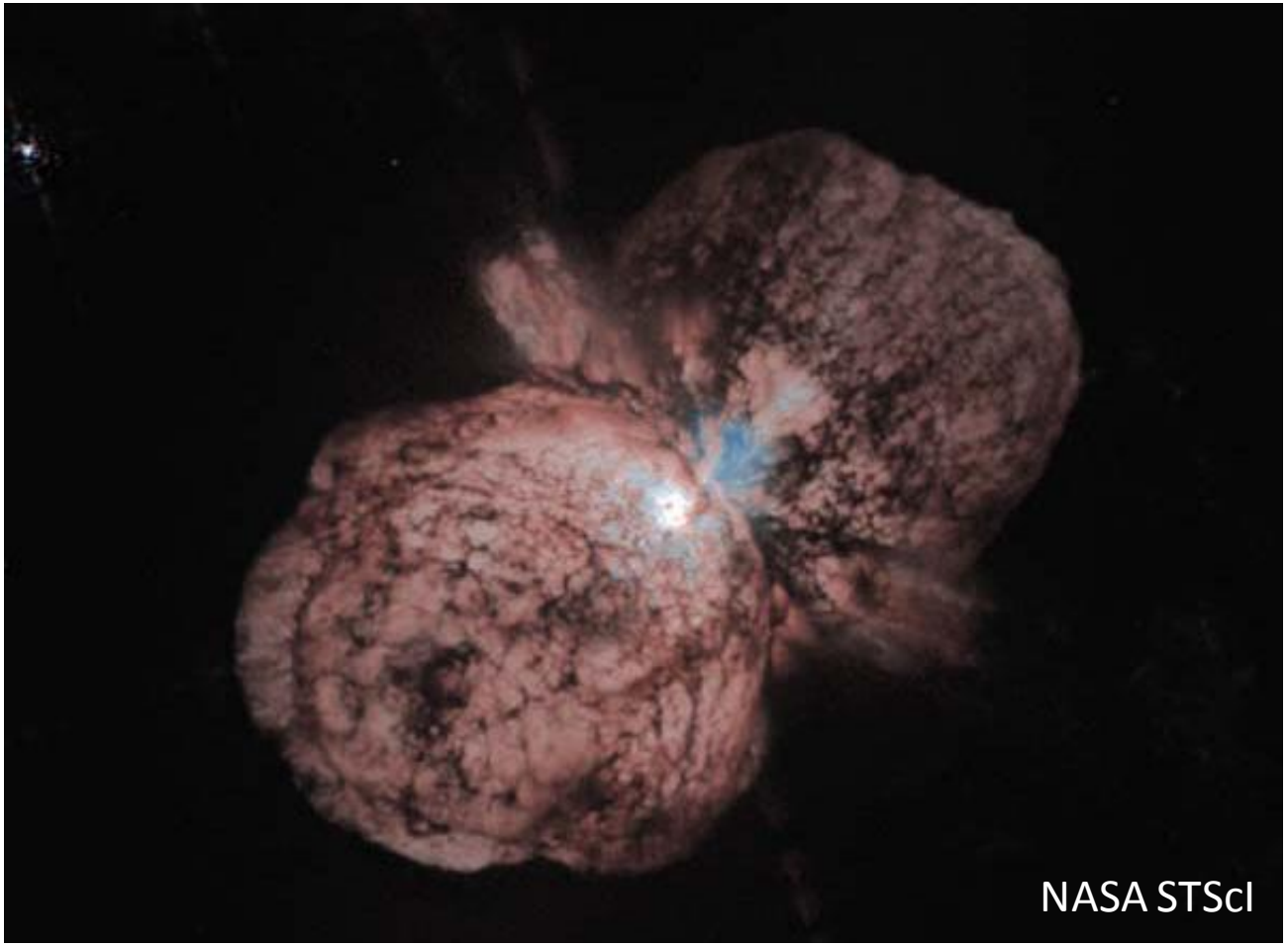
- Are very massive stars (50-100 $M_{\odot}$)
- Originate a huge explosion
- Can produce very intense GRBs

Example of Galactic Hypernova

Eta Carinae

- Luminosity: brightest object in our Galaxy
- Distance: less than 8,000 ly
- Mass: 100 $M_\odot$
- Luminosity: 5 x 10^6 $L_\odot$
- 150 years ago the luminosity had a dramatic increase, then it has become lower, it has increased in 1940 and doubled in 1998-99

η Carinae



Expected Impacts at the Earth

Dependent on object's distance:

- Flash of light in the Earth's atmosphere (superaurora) that can burn almost everything and significantly change the climate
- Destruction of the ozone layer and penetration of the shorter wavelength UV radiation that is harmful for living organisms
- Generation of particles (muons) in the Earth's atmosphere upon interaction with Cosmic Rays and showers of muons in lethal doses up to depths of tens of meters in water and rocks

Magnetars as GRBs and CRs Sources

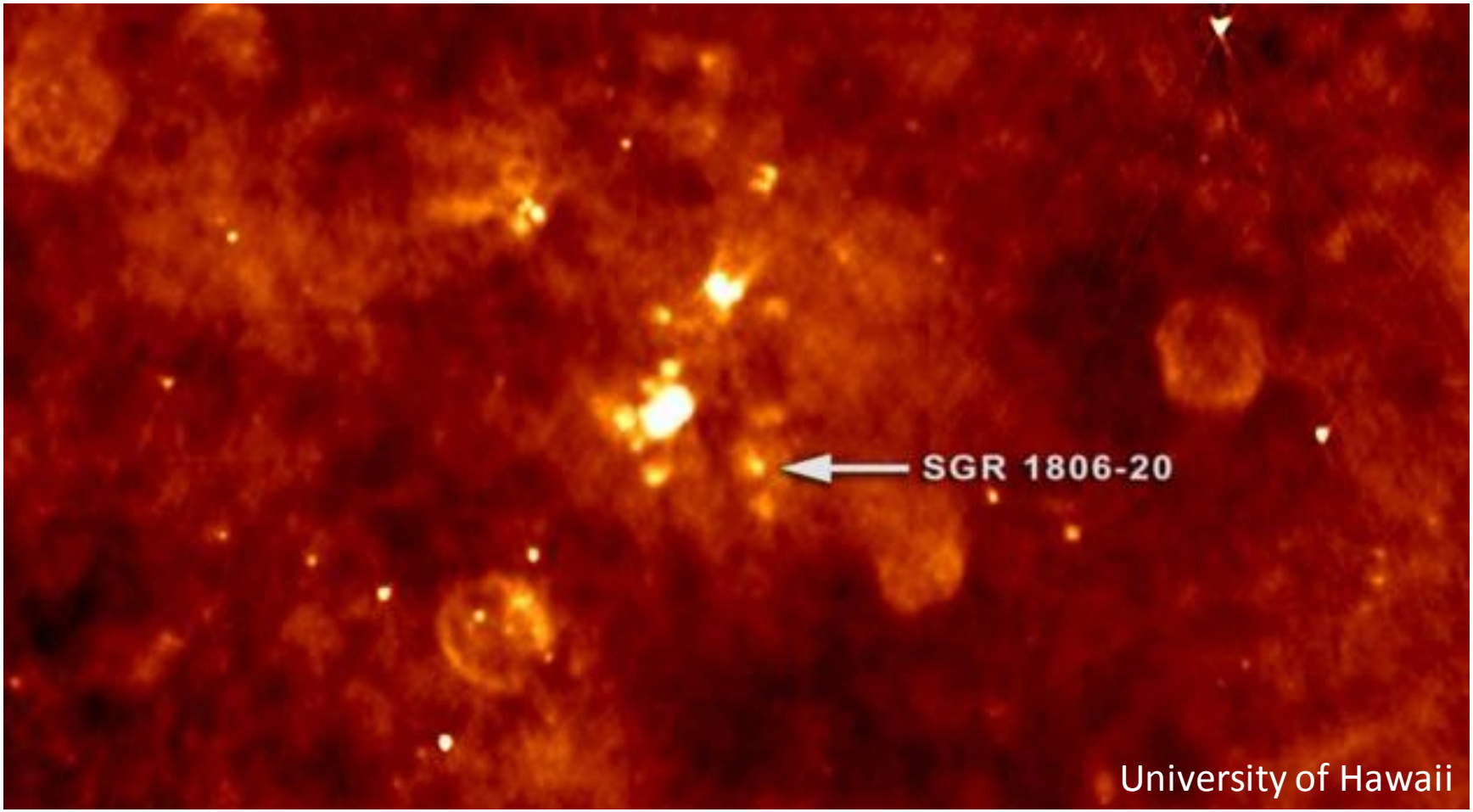
- Ultra-magnetic neutron stars
- Very small objects (a few tens km), very dense and made of neutrons
- With fast rotation
- Mass of the order of a few $M_{\odot}$
- Originate very strong magnetic fields (1,000 TG= 1 PG = 10^{15} G = 100 GT) that produce explosions
- Exceptionally intense Gamma Ray Bursts are produced
- More than 10 are known in our Galaxy
- None of them is nearer than 4,000-5,000 ly

Example of a Magnetar

SGR 1806-20

- Rotation period: 7.5 s
- Diameter: 20 km
- Distance: 50,000 ly

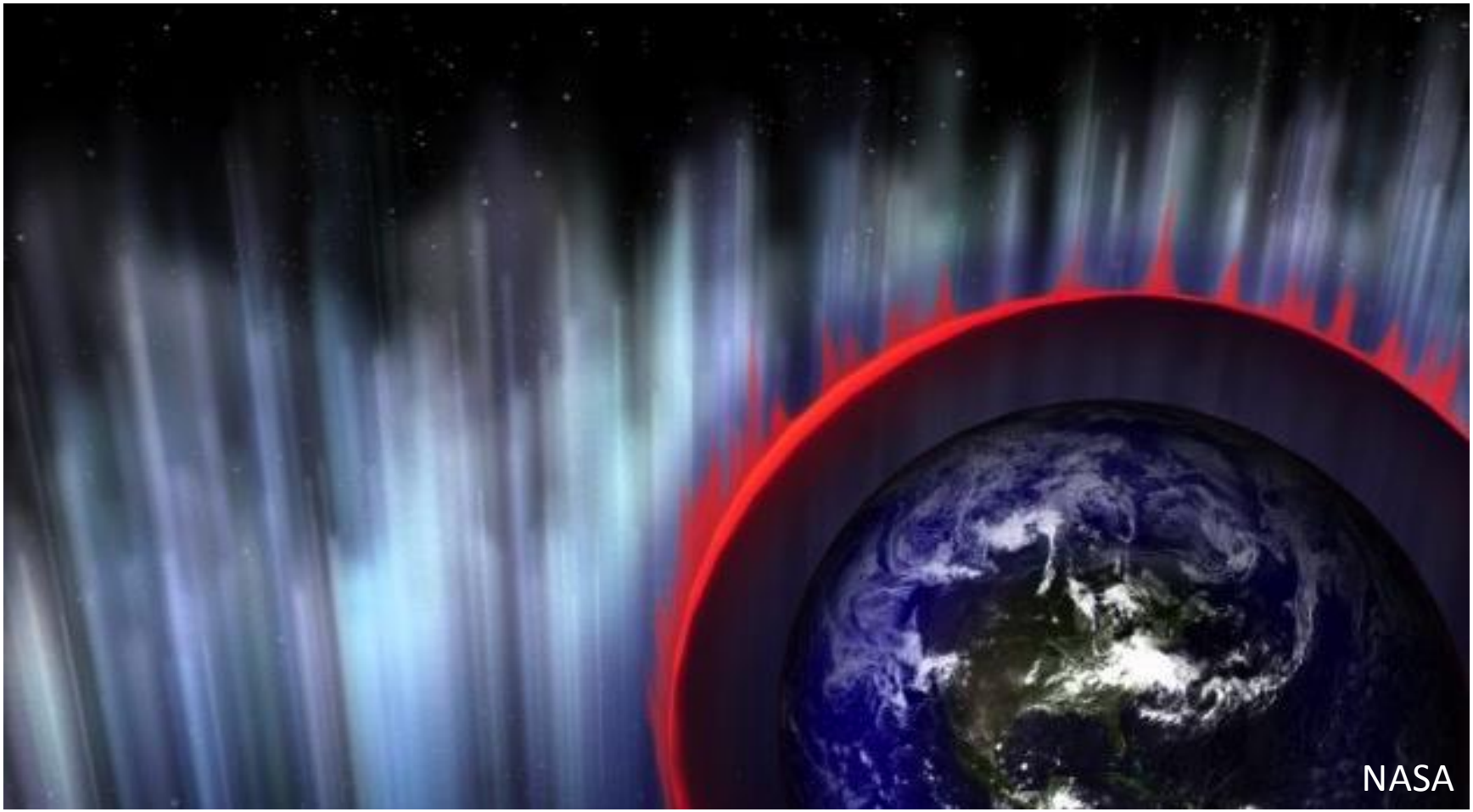
Radio Emission from SGR 1806-20



The Great GRB on 27 Dec. 2004

- In 0.1 s the emission of energy was higher that that emitted by the Sun in 100,000 years
- 10,000 trillions of trillions of trillions of watts = 10^{40} W
- The Earth's ionosphere has experienced an ionisation increase
- If the magnetar were nearer to the Earth (e.g. 10 ly), the ozone layer would have been destroyed causing the penetration of shorter wavelength UV radiation harmful for living species

Artistic View of Ionisation Increase



SUMMARY AND CONCLUSIONS

Summary and Conclusions

- SWx is not limited either to the Sun-Earth or to the Heliosphere environments
- High-energy astrophysical sources can significantly impact planetary environments by global SWx effects
- The latter ones are Low-Probability-High-Risk events
- Coping with such occurrences requires an adequate multi-level training for awareness raising and diachronic monitoring and alerting facilities coordinated in a worldwide framework
- Cosmoclimatology is to be pursued on a systematic basis
- Meteorology of Space requires a multi-disciplinary approach in monitoring, modelling and prediction, which involves particle and plasma physics, solar and planetary physics, stellar and exoplanetary physics, physics of galaxies, and cosmology, via theory, ground- and space-based observations

THANK YOU FOR YOUR ATTENTION!