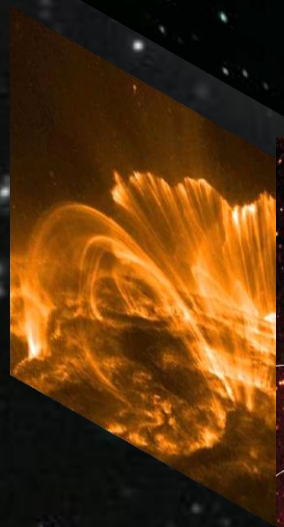
MAGNETISMO CÓSMICO

ElisaBete de Gouveia Dal Pino

IAG-USP



Astronomia ao Meio Dia, 6 de Abril 2017

magnetismo e um fenomeno muito conhecido por nos

Por exemplo, os imas tem a propriedade de atrair os metais

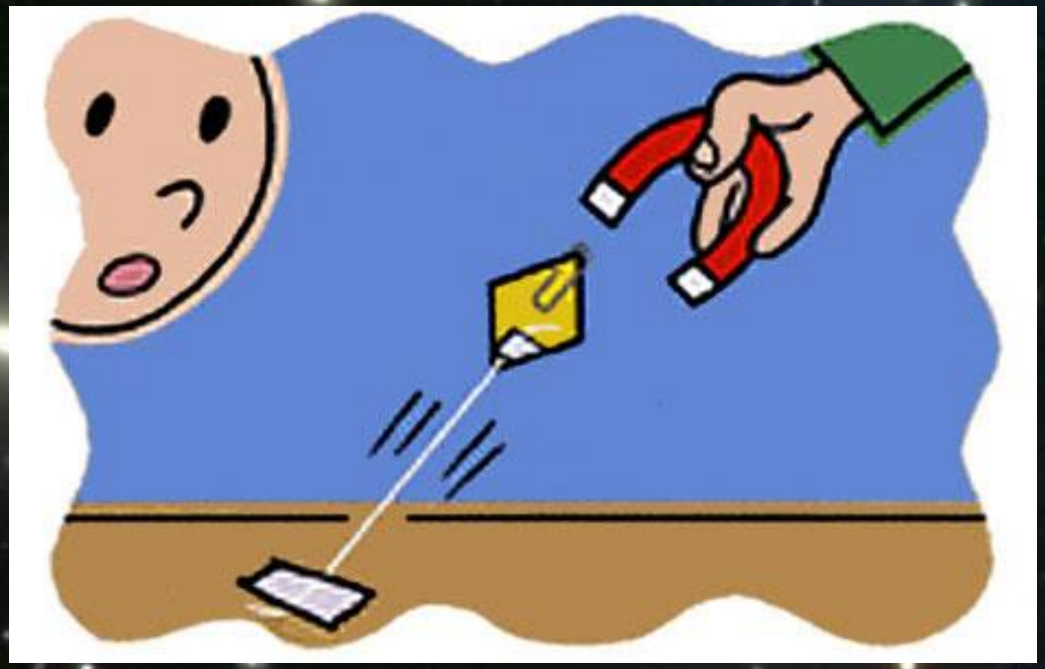
Bussola: agulha imantada que aponta sempre para o Norte!

Magnetismo conhecido desde a Grecia antiga

pedra magnetita

IMA Natural

O Que e o Magnetismo ?



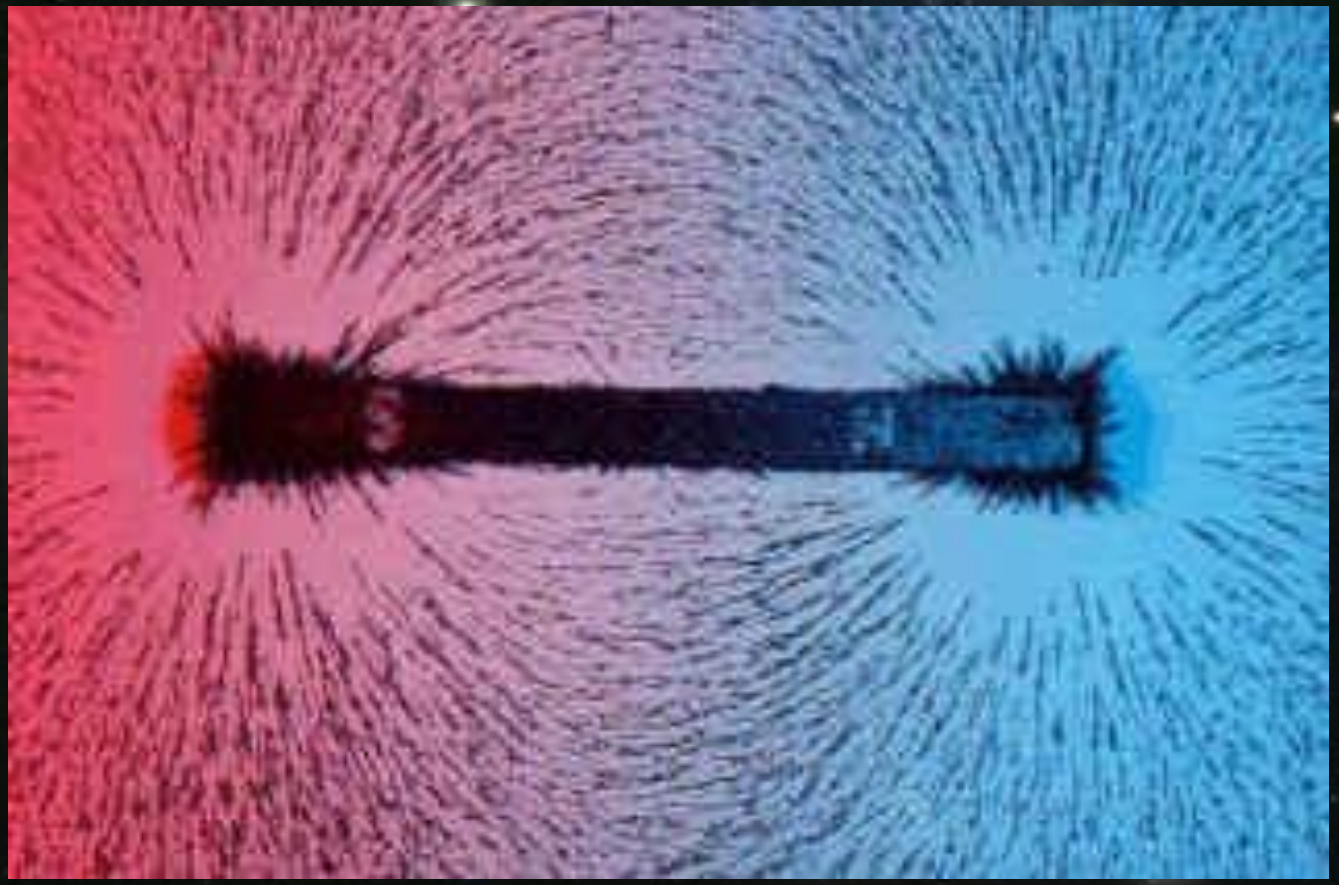
E um fenomeno fisico produzido pelo **movimento de cargas eléctricas**, que resulta em forcas atrativas e repulsivas entre os objetos: **Forcas Magneticas!**

O que e Magnetismo ?

Campo magnético gerado por um imã em forma de barra e em forma de ferradura.

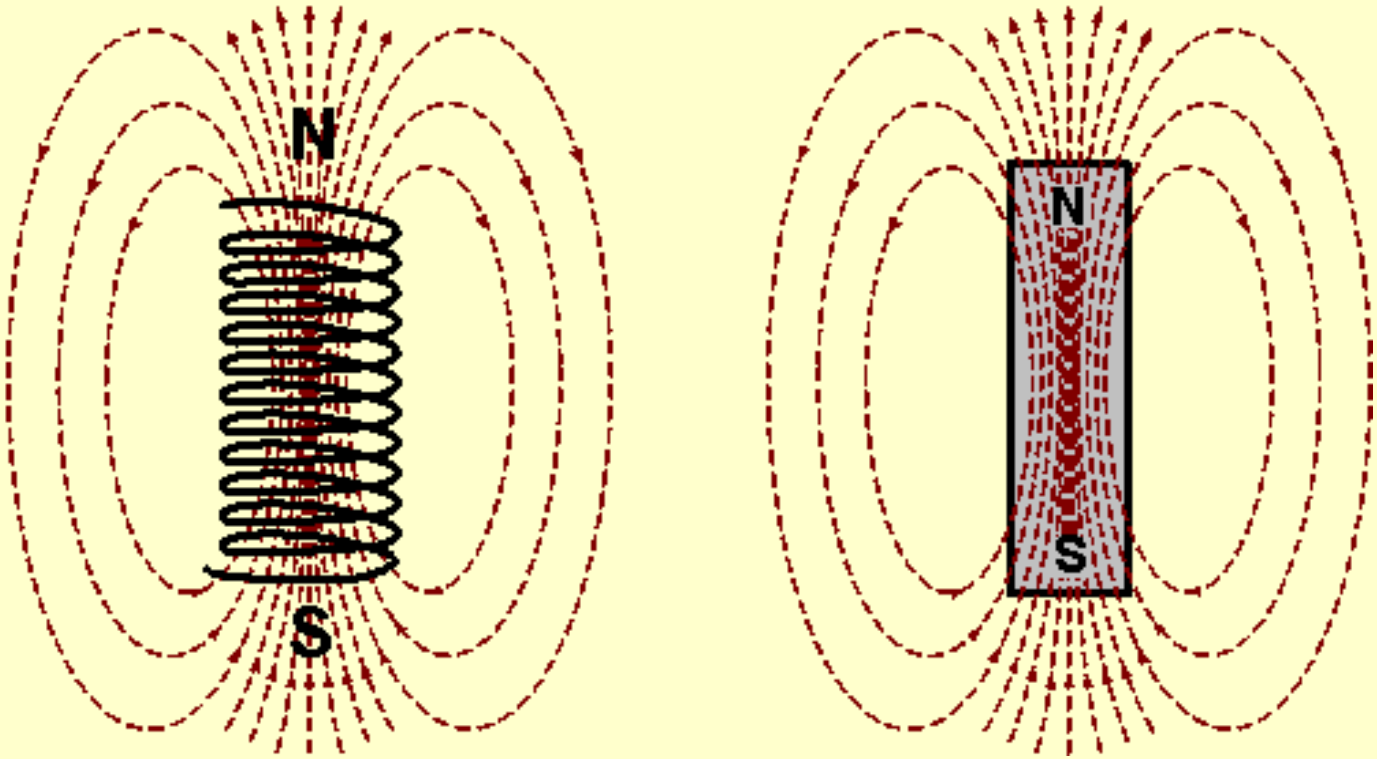
o fenomeno do magnetismo e "mediado" pelo campo magnético.

O que e Magnetismo ?



O fenomeno do magnetismo e "mediado" pelo campo magnético.

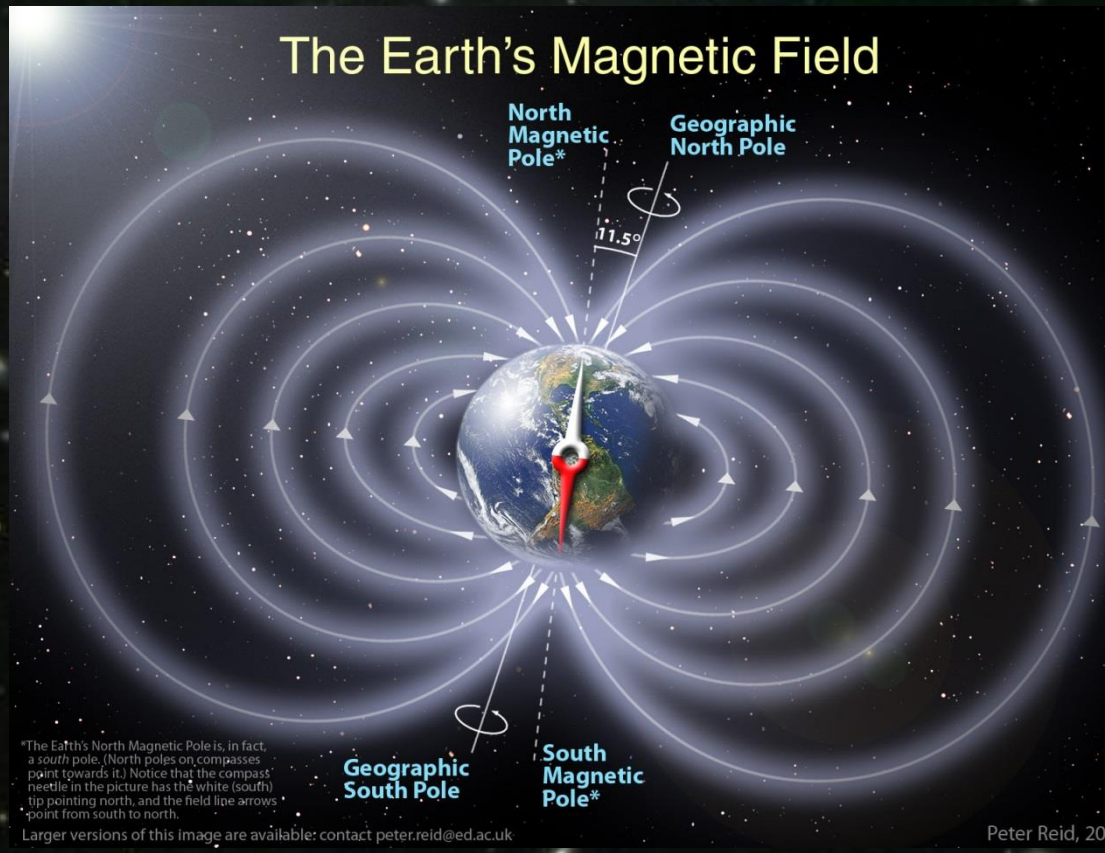
O que e Magnetismo ?



corrente elétrica através do fio metálico produz campo magnético igual ao ima

Terra: Ima gigante

1600: William Gilbert, médico da rainha Elisabete I, estudou a inclinacao da agulha magnética da bussola e chegou `a conclusao que "a Tierra e' um ima gigante"

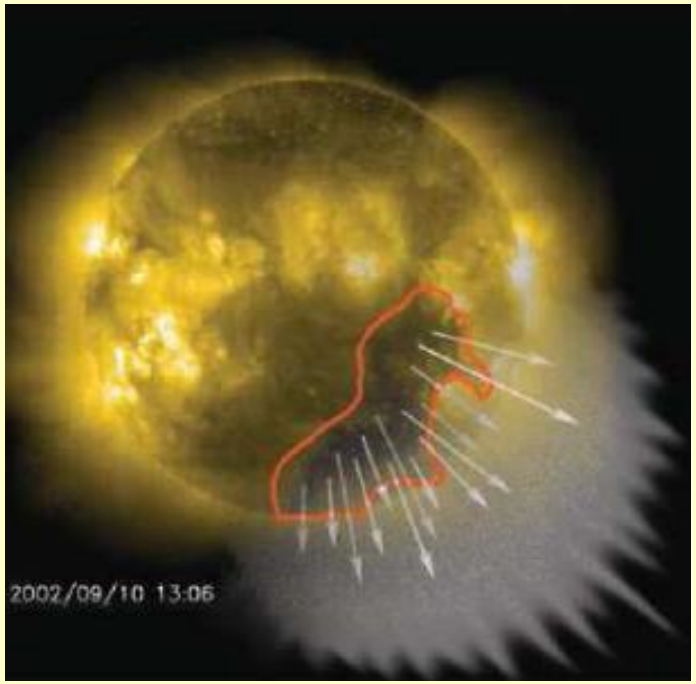


Mais de 90% da materia visivel no Universo:

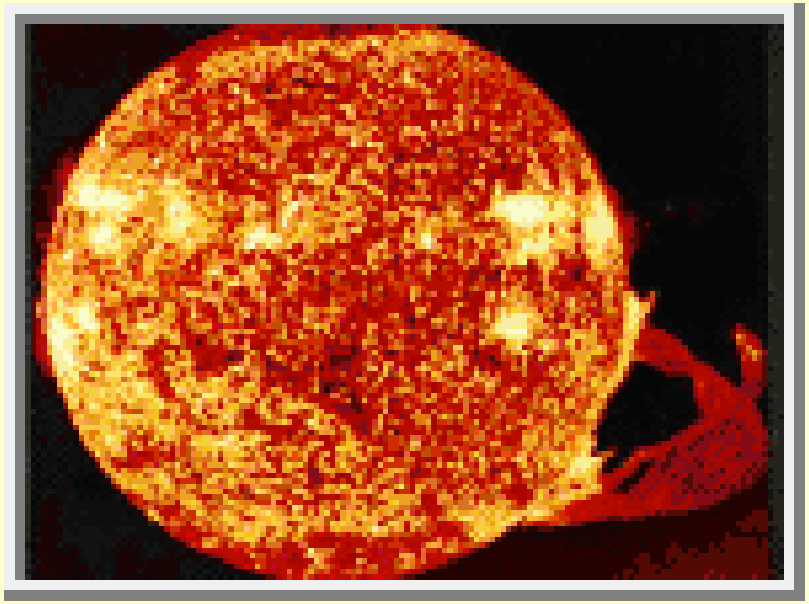
fluido de cargas em movimento com campos magneticos

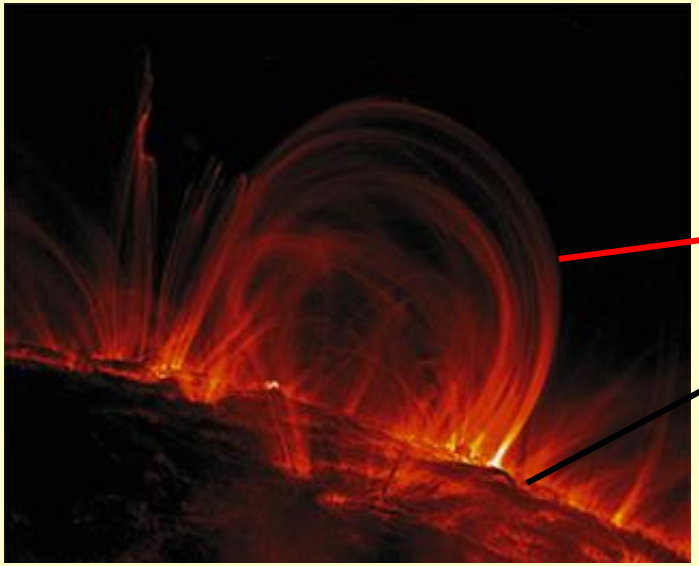
=

PLASMA



CAMPOS MAGNÉTICOS NO SOL





Sol: fluido condutor (PLASMA)

Na coroa (2 x 10^6 graus Celcius):

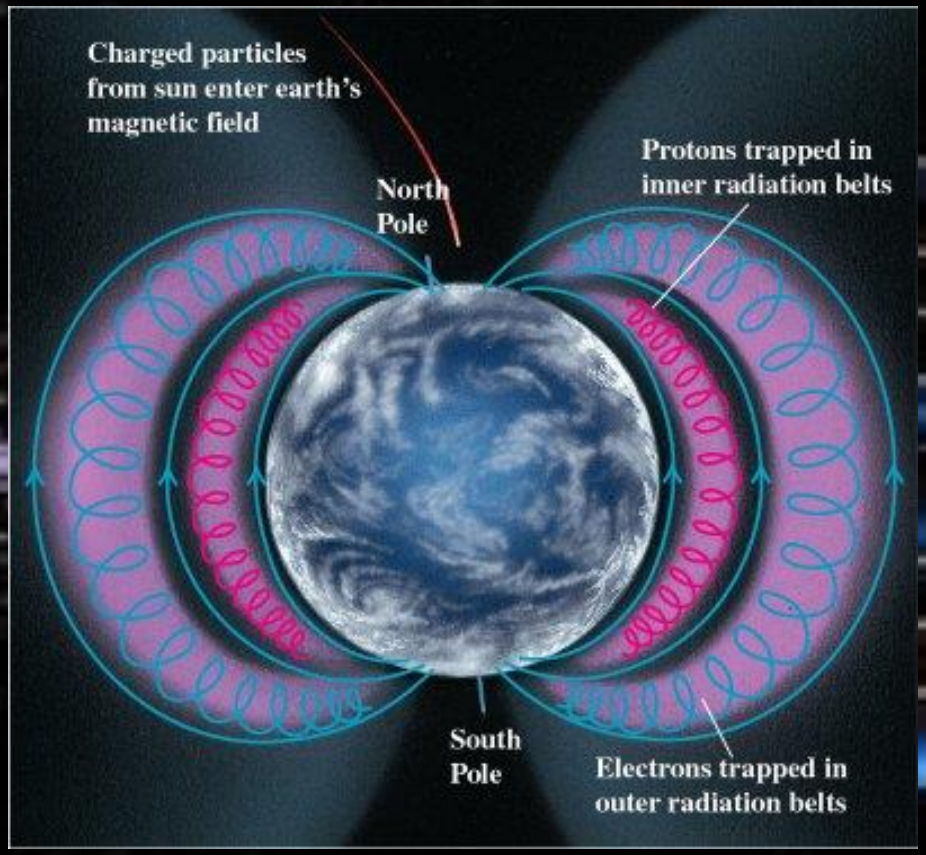
arcos magnéticos **(30.000-100.000 km)**

Manchas Solares:

B = 500-4000 vezes B_{Terra}

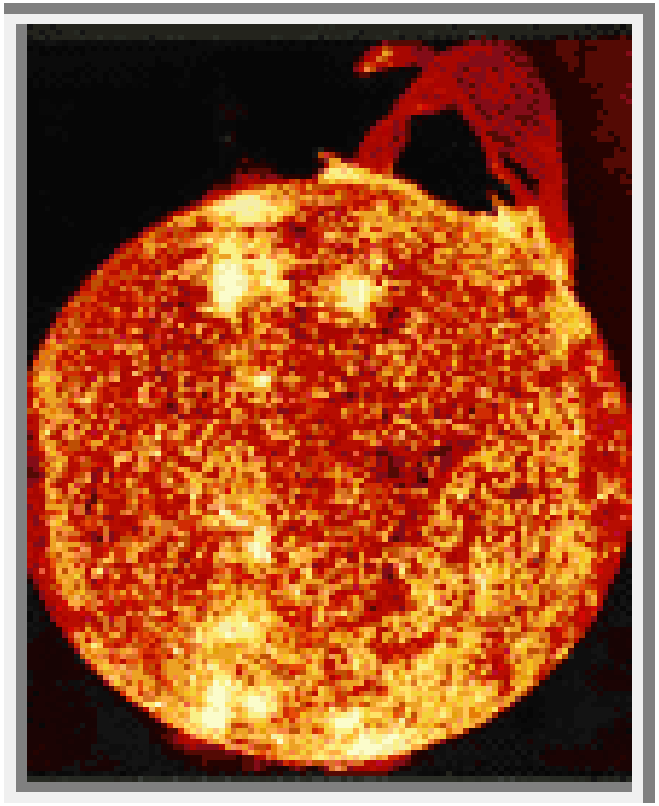
Sol eTerra

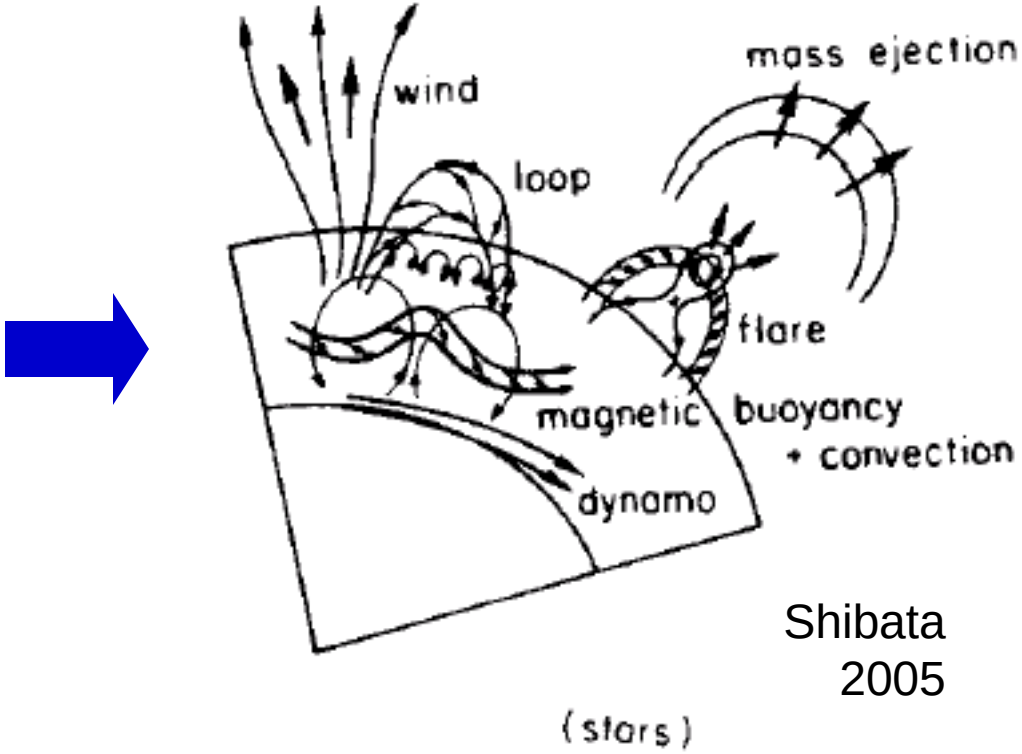
Sol e Terra


Charged particles
from sun enter earth's
magnetic field
North
Pole
Protons trapped in
inner radiation belts
South
Pole
Electrons trapped in
outer radiation belts

Qual a origem do campo magnetico no Sol ?
Dínamo

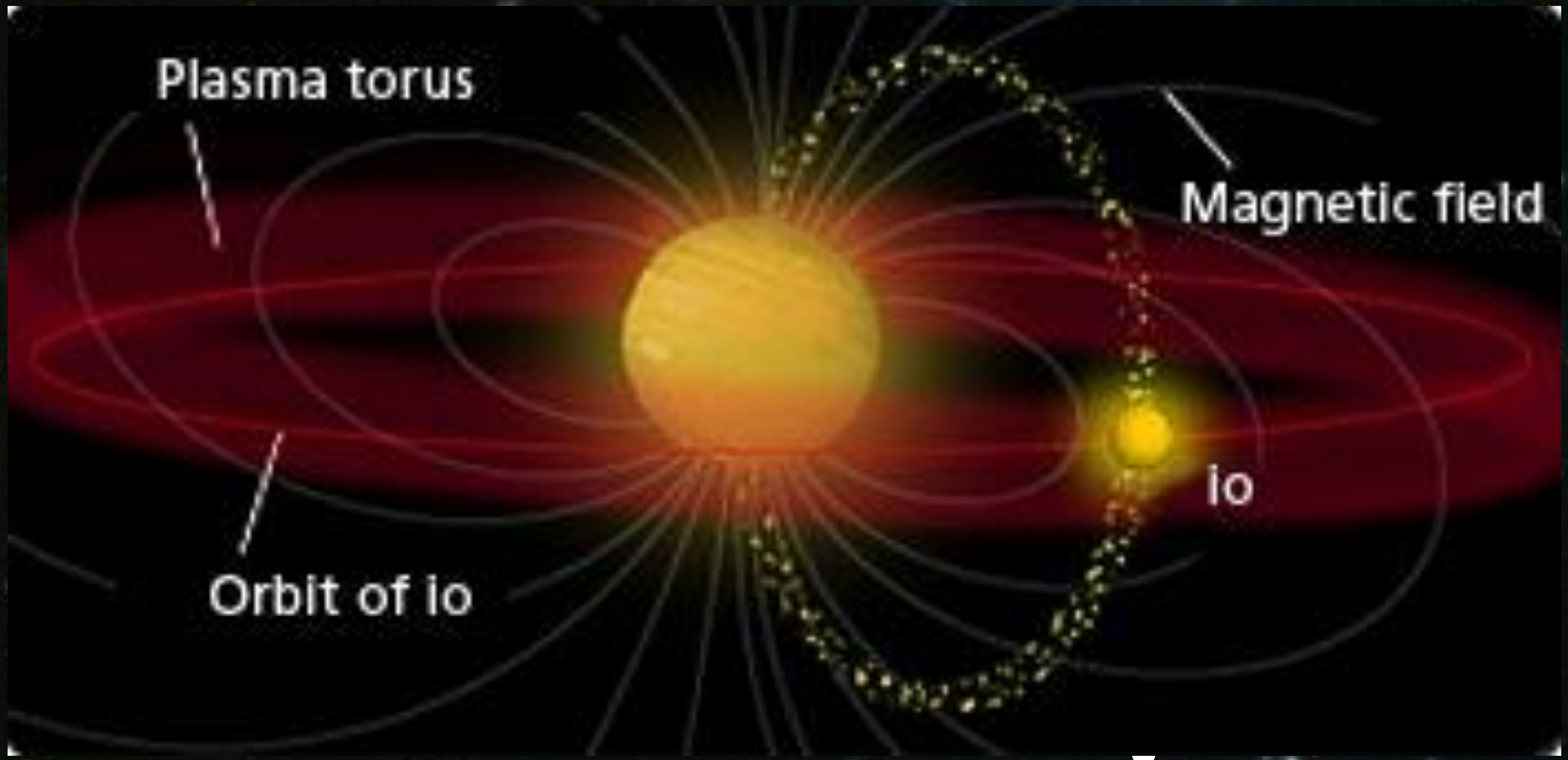
Dinamo: Rotacao + Conveccao do fluido carregado



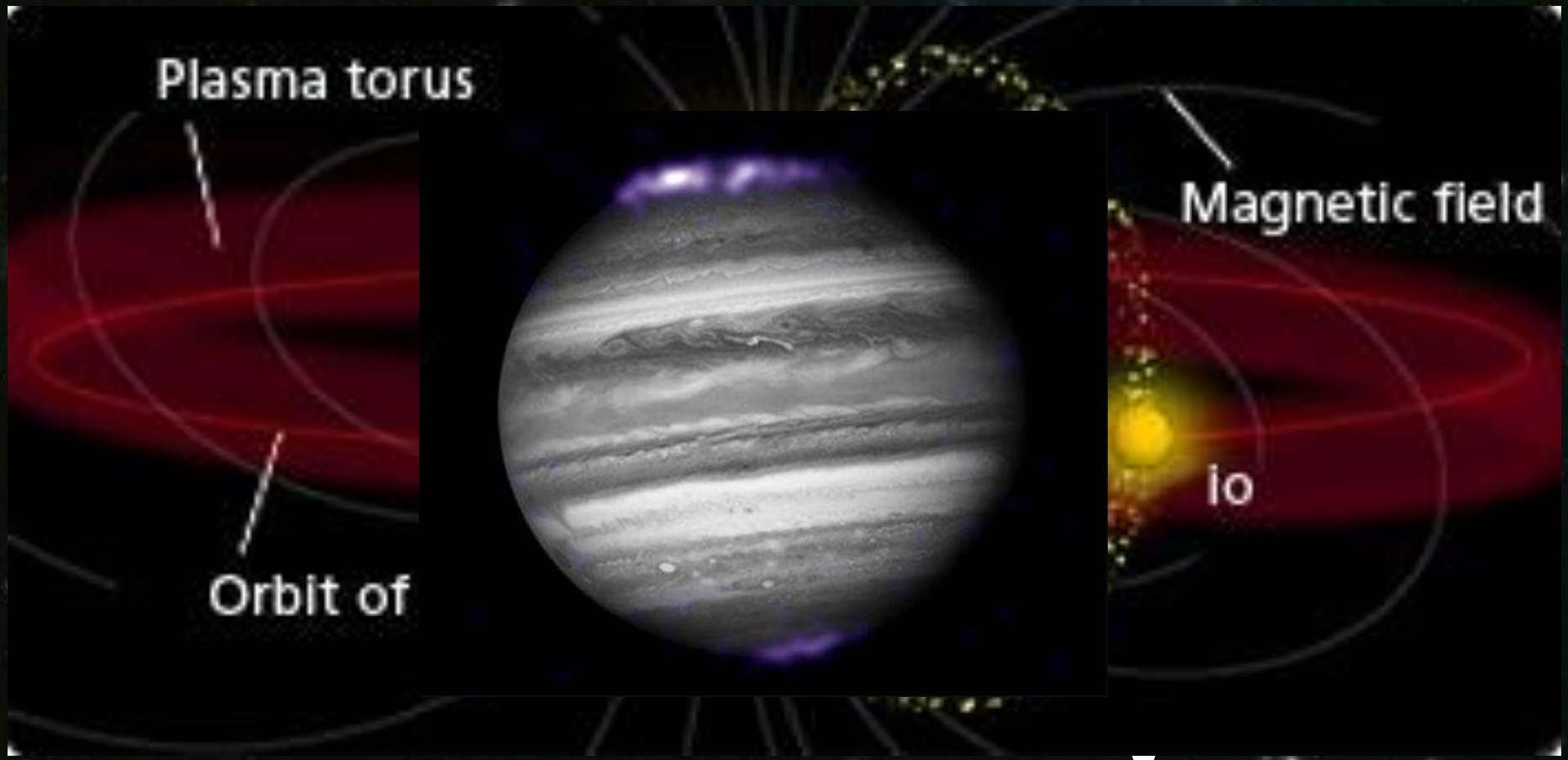


Shibata
2005

Campos magnéticos em outros planetas



Campos magnéticos em outros planetas



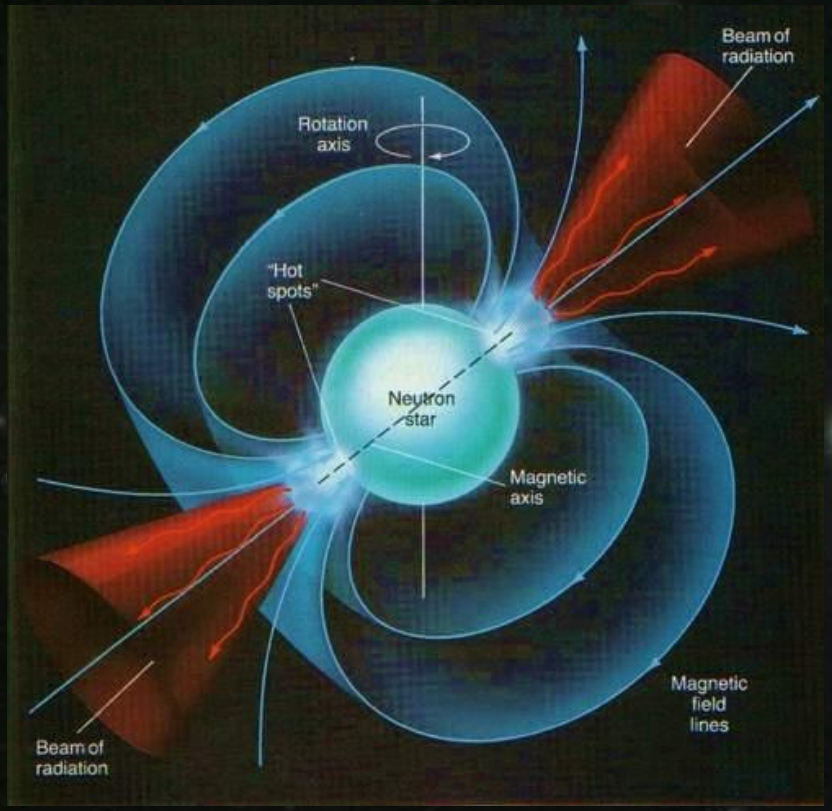
JUPITER

Campos magnéticos em estrelas moribundas

Pulsar

Ana Branca: o Sol de amanha

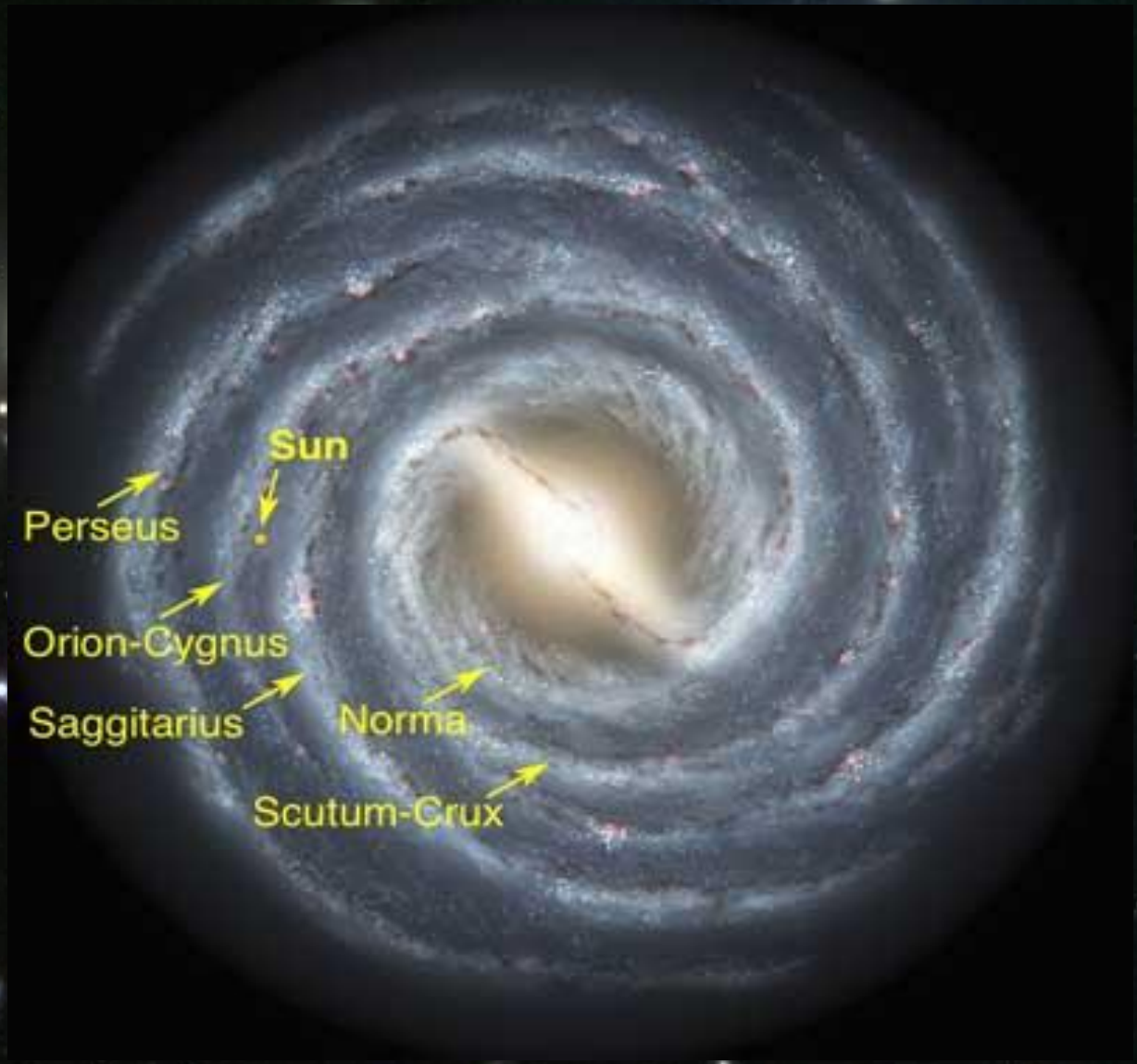
Campos magnéticos em estrelas moribundas



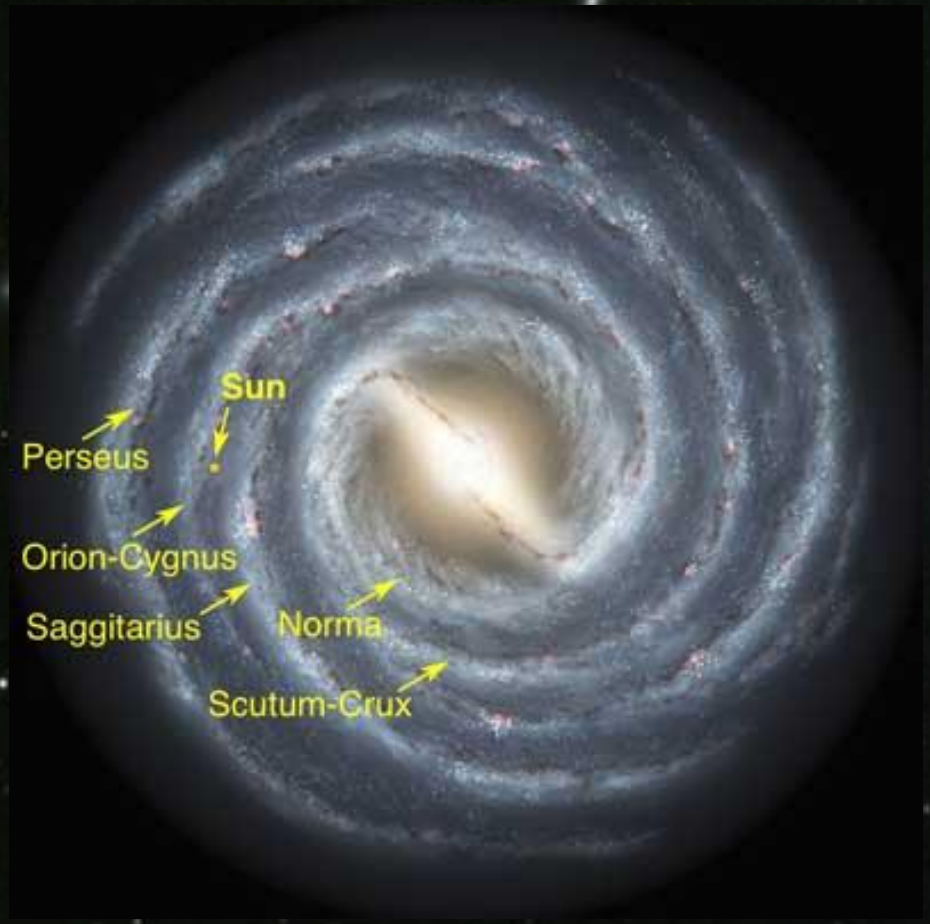
Pulsar

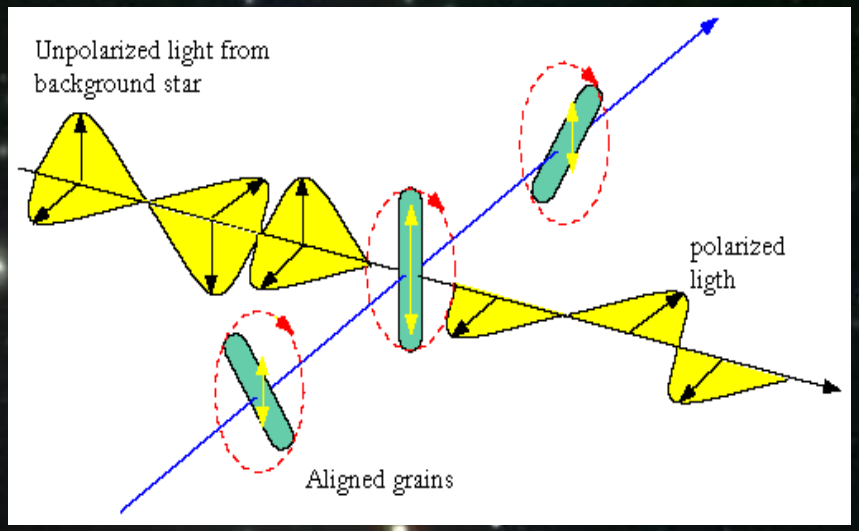
Ana Branca: o Sol de amanha

Nossa Galaxia: a Vía Láctea



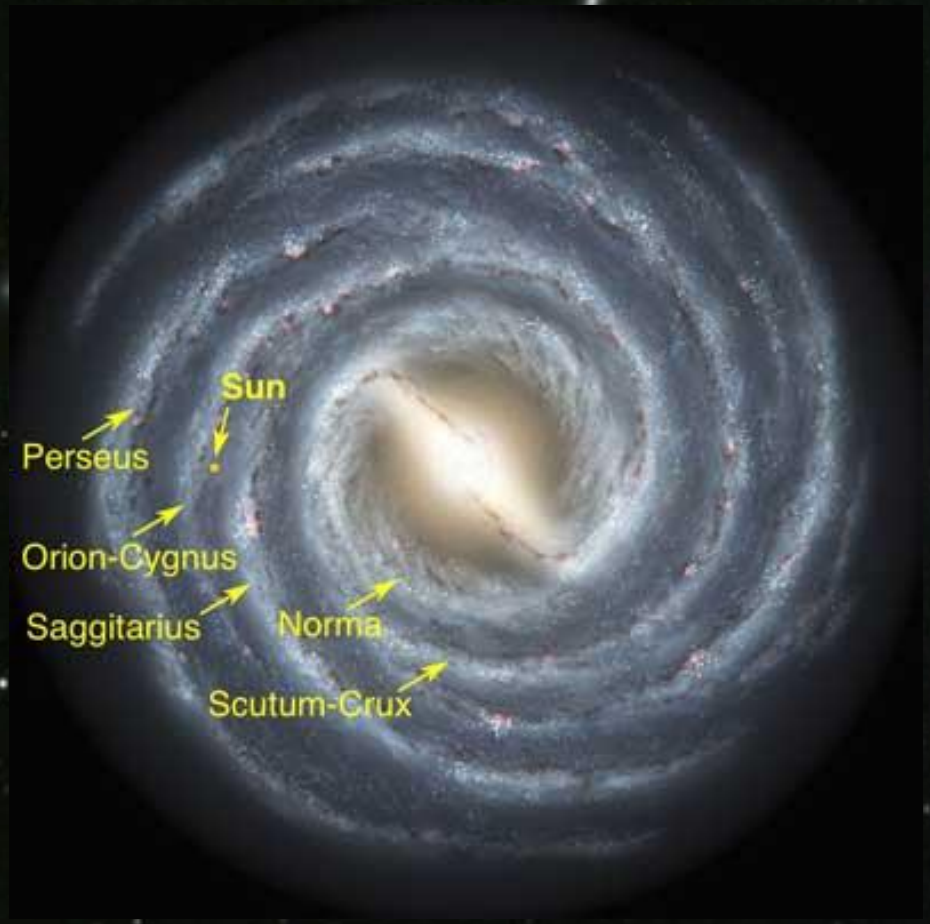
Campos magnéticos na Vía Láctea

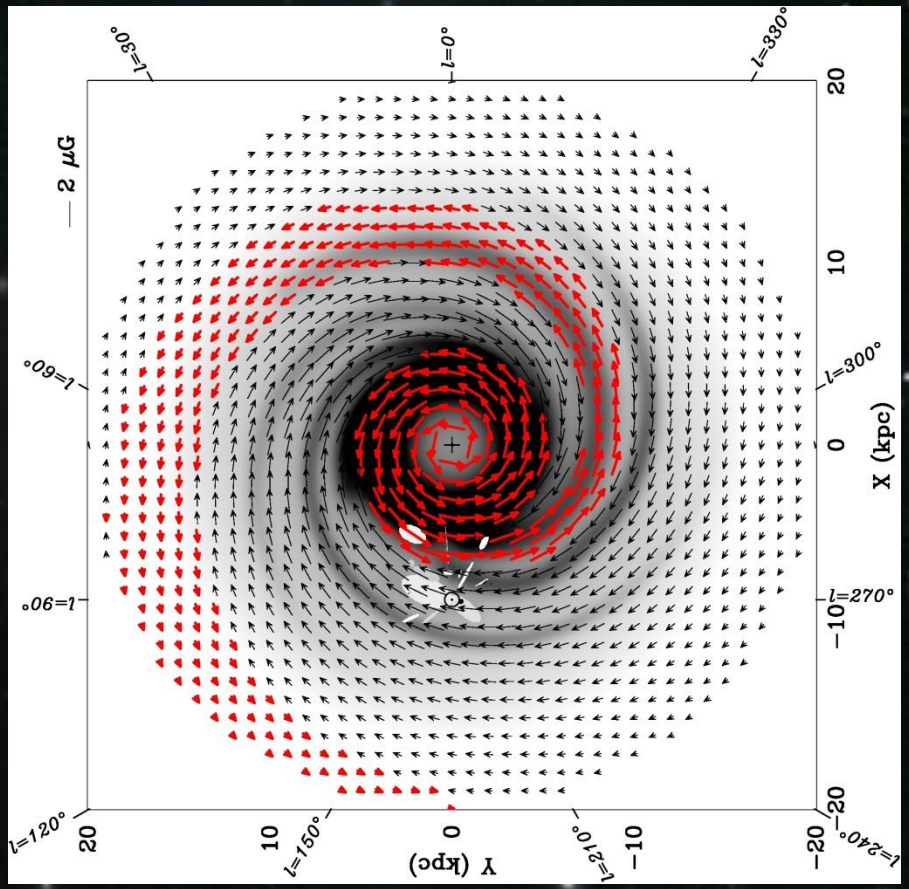




Campo magnético da galaxia:
1 Milhao de vezes menor que o da Terra!

Campos magnéticos na Vía Láctea



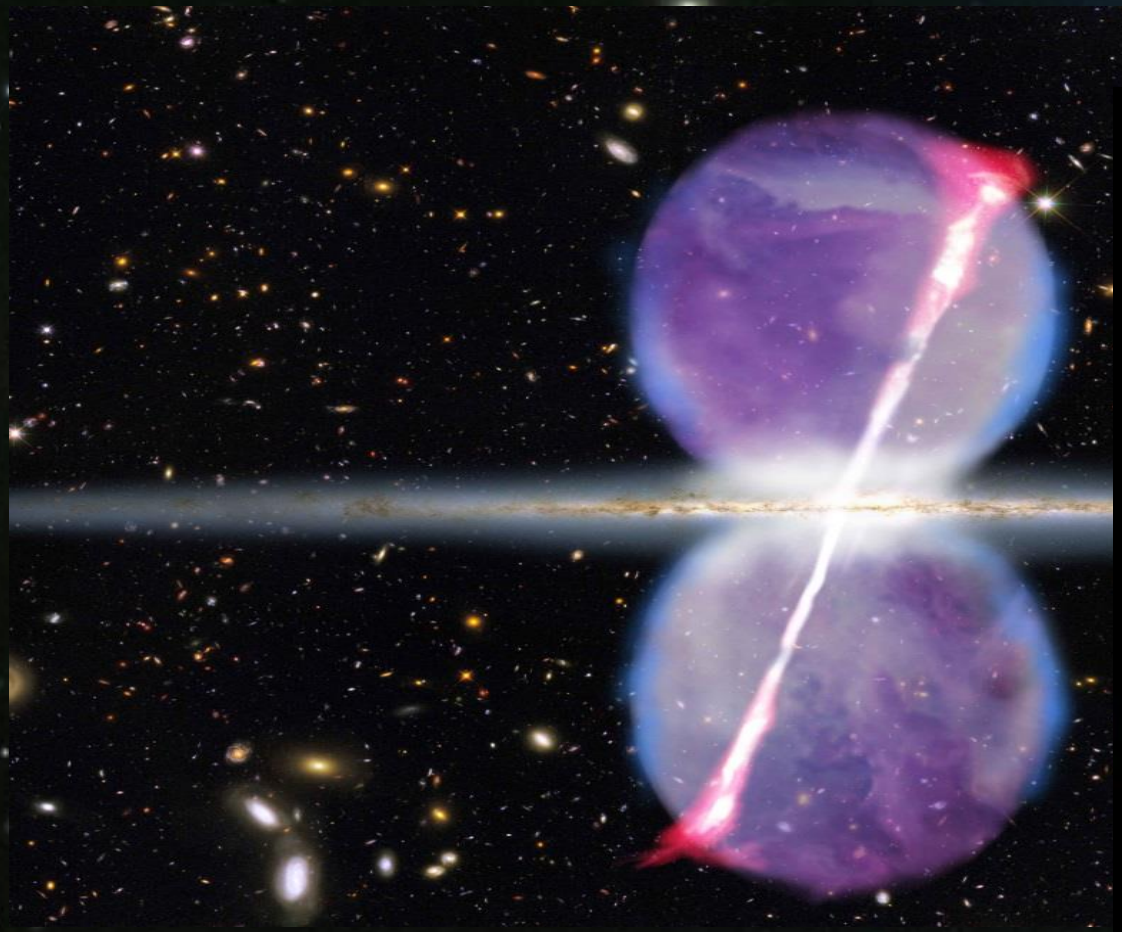


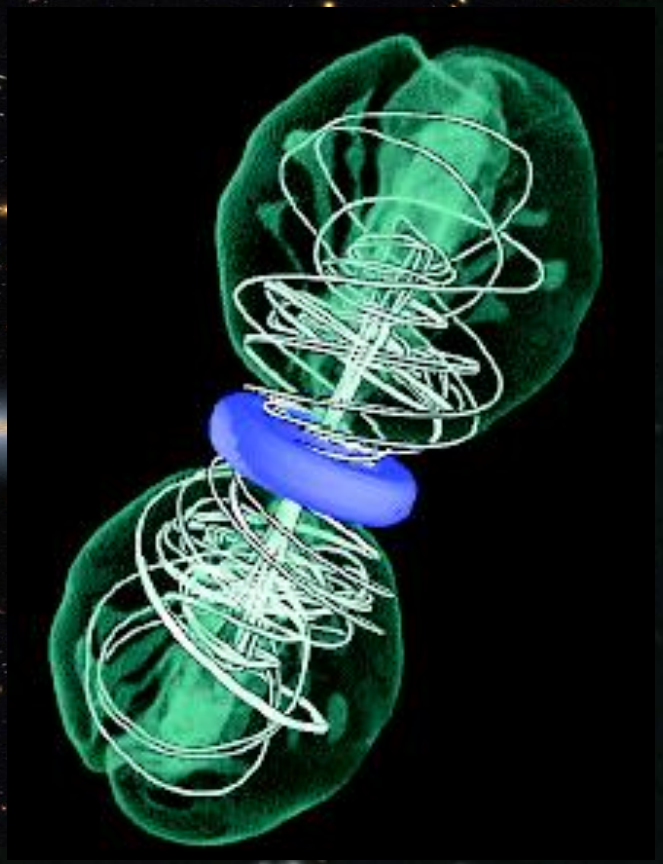
Campo magnético da galaxia:
1 Milhao de vezes menor que o da Terra!

Origen dos campos magnéticos da Vía Láctea

Sementes de campos magnéticos das explosoes de supernovas: amplificados pela rotacao gerando campos espirais

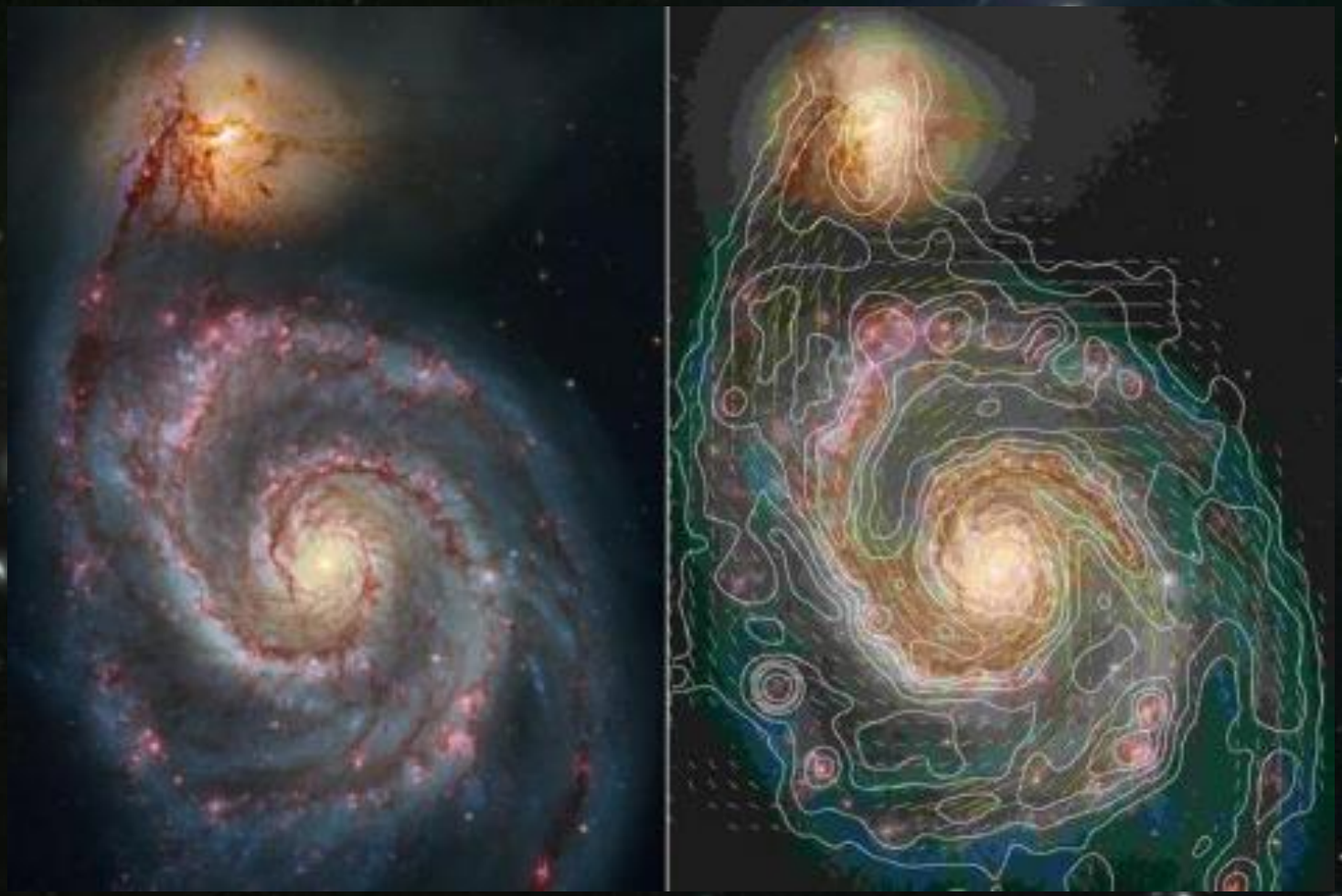
Campos magnéticos no nucleo da Via Láctea





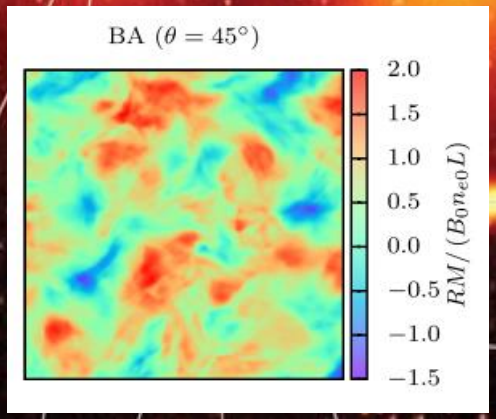
buraco negro no núcleo da nossa galaxia
Descoberta de um jato de raios gama: 27000 lyr

Campos magnéticos em outras galaxias




Magnetismo Intergaláctico

Origem do Magnetismo nos aglomerados de Galaxias ?

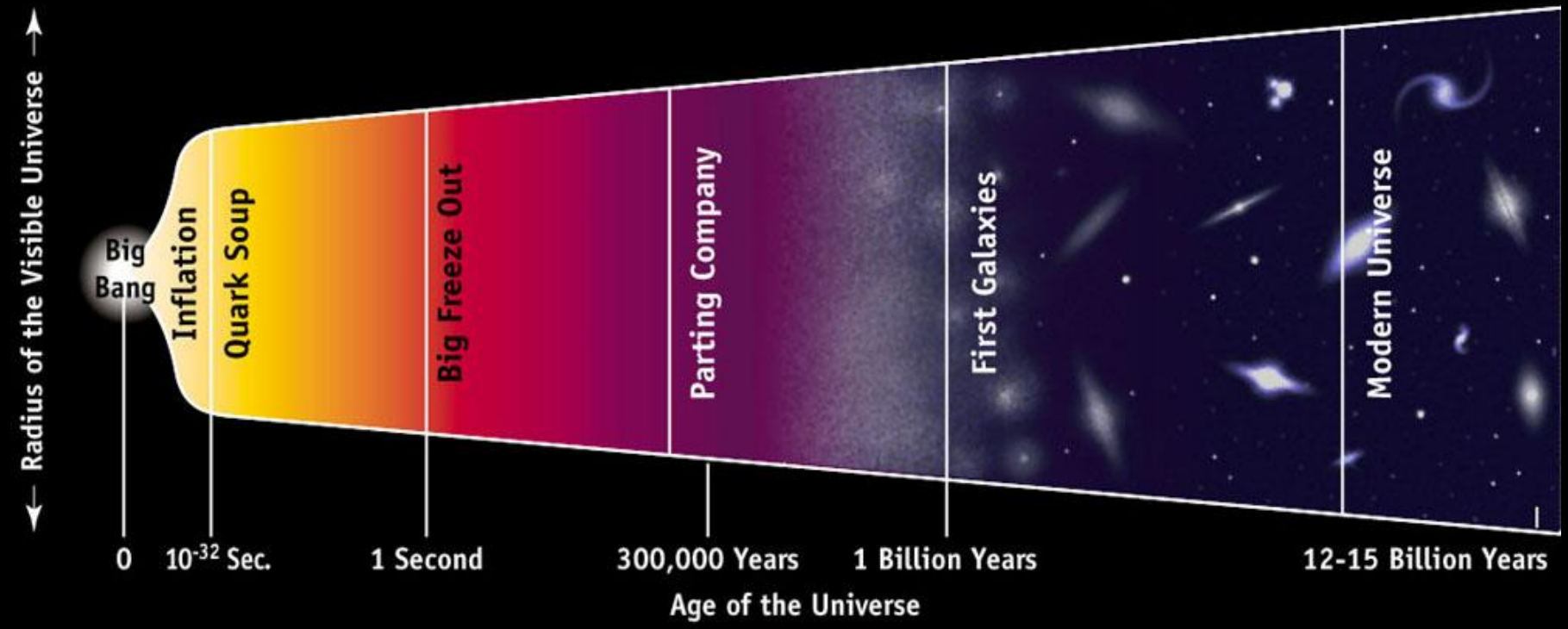


Amplificacao por turbulencia

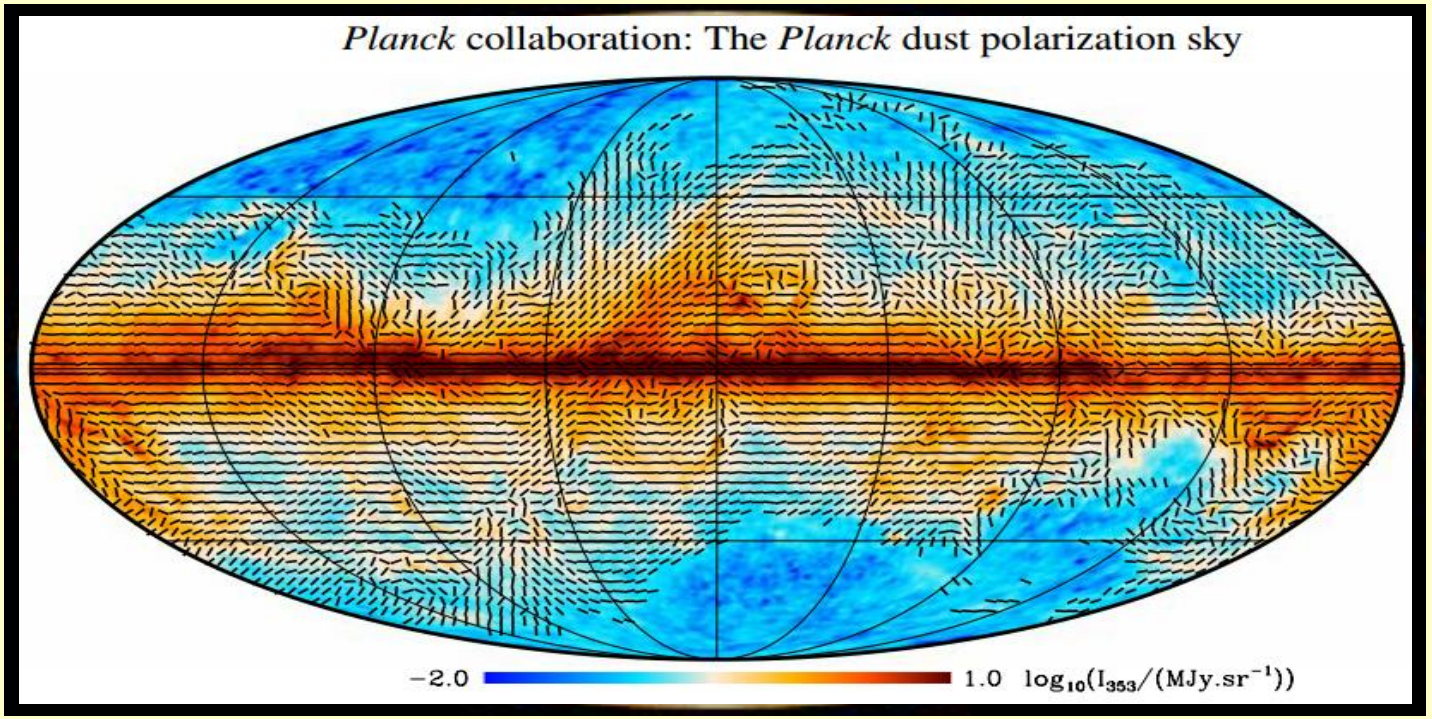
Ventos e jatos de Galaxias

Campos Magnéticos no Universo Primordial?

Fisica de Particulas ⟷ Astrofisica



O eco do Big Bang e o eco do Universo magnético?



Fundo Cósmico da Radiacao de Microondas (satelite PLANCK)

Campos Magnéticos podem haver afetado a flutuacoes da Radiacao Cósmica?

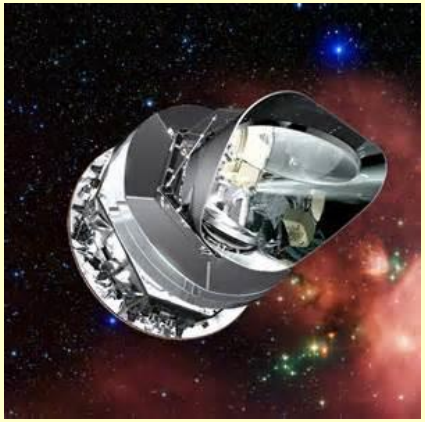
Instrumentos do Seculo 21

ALMA

LOFAR

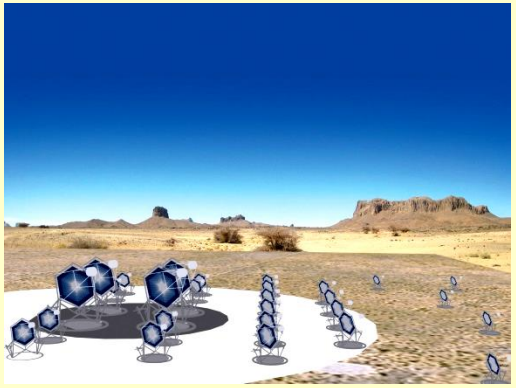
LLAMA (Argentina-Brazil) (2016)

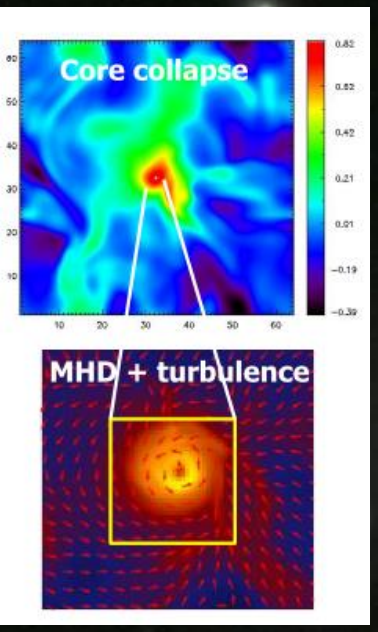
PLANCK

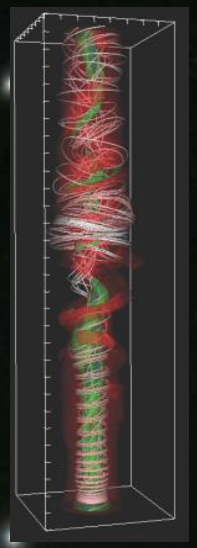


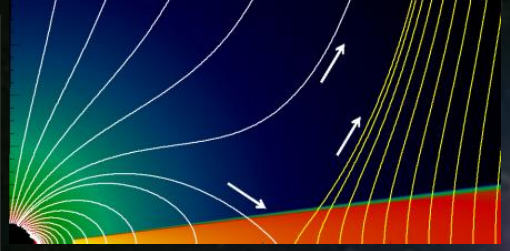
SKA (2020)

CTA (2020)

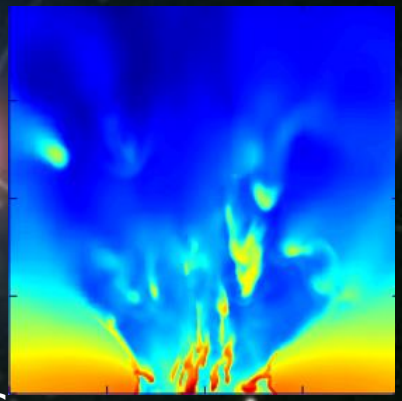








Jets & accretion disks

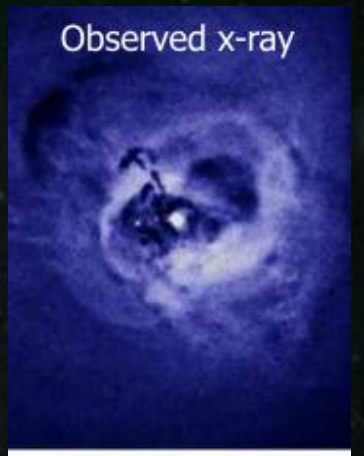


Galactic winds

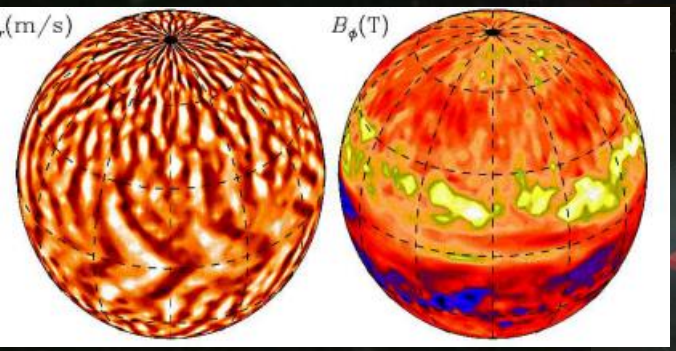
Star Formation - Magnetic turbulence connection

GAPAE: MHD Simulations

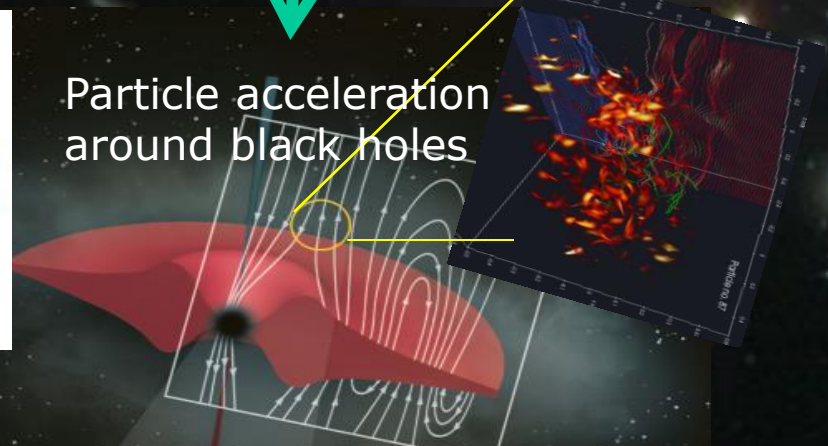
Clusters of Galaxies



Solar Dynamo



Particle acceleration around black holes



ASTROPHYSICAL FLUIDS: MHD DESCRIPTION

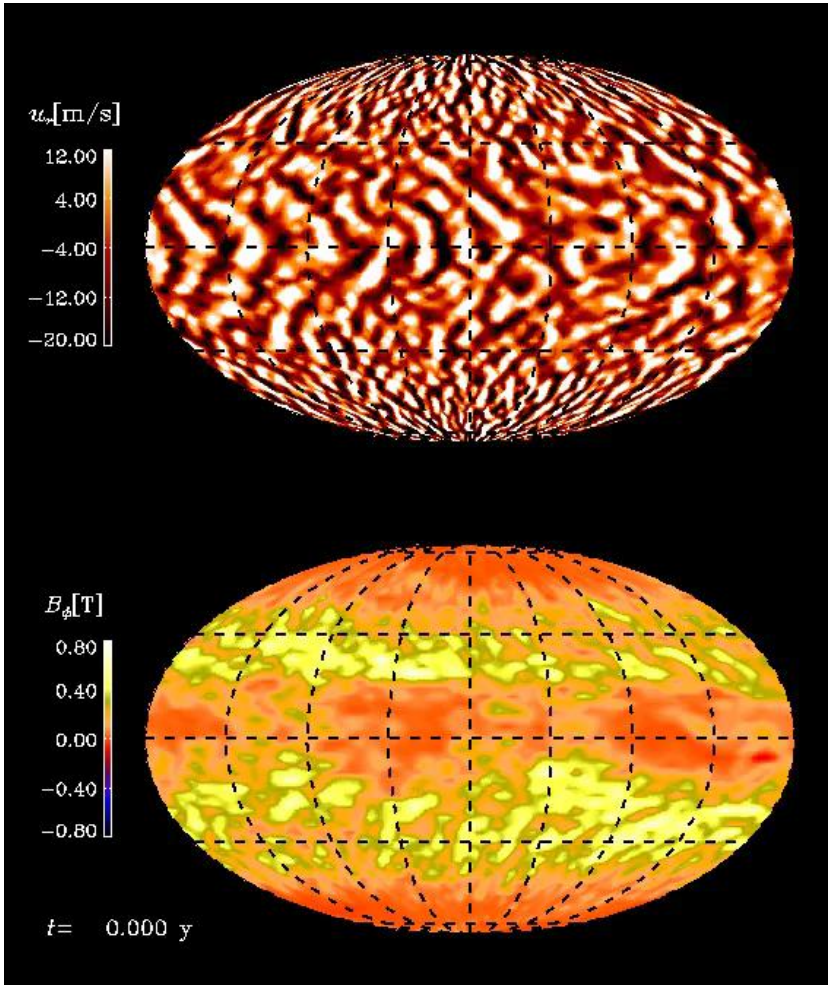
$$\frac{d\rho}{dt} = -\rho \nabla \cdot \mathbf{v},$$

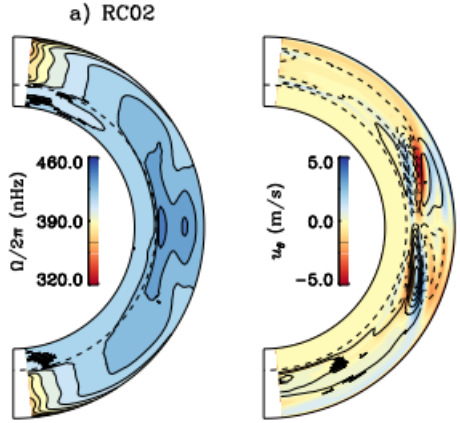
$$\rho \frac{d\vec{v}}{dt} = -\vec{\nabla} p + \rho \vec{g} + \frac{1}{c} \vec{J} \times \vec{B}$$

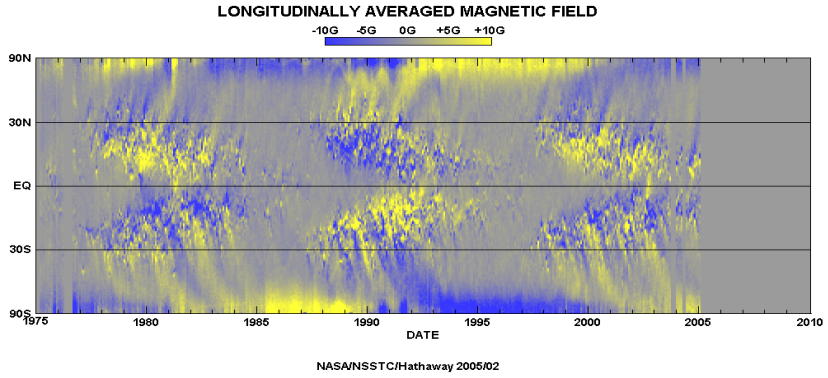
$$\frac{du}{dt} = -\frac{p}{\rho} (\nabla \cdot \mathbf{v}) - \mathcal{L},$$

$$\frac{d\mathbf{B}}{dt} = -\mathbf{B}(\nabla \cdot \mathbf{v}) + (\mathbf{B} \cdot \nabla)\mathbf{v},$$

Solar Dynamo 3D MHD simulations

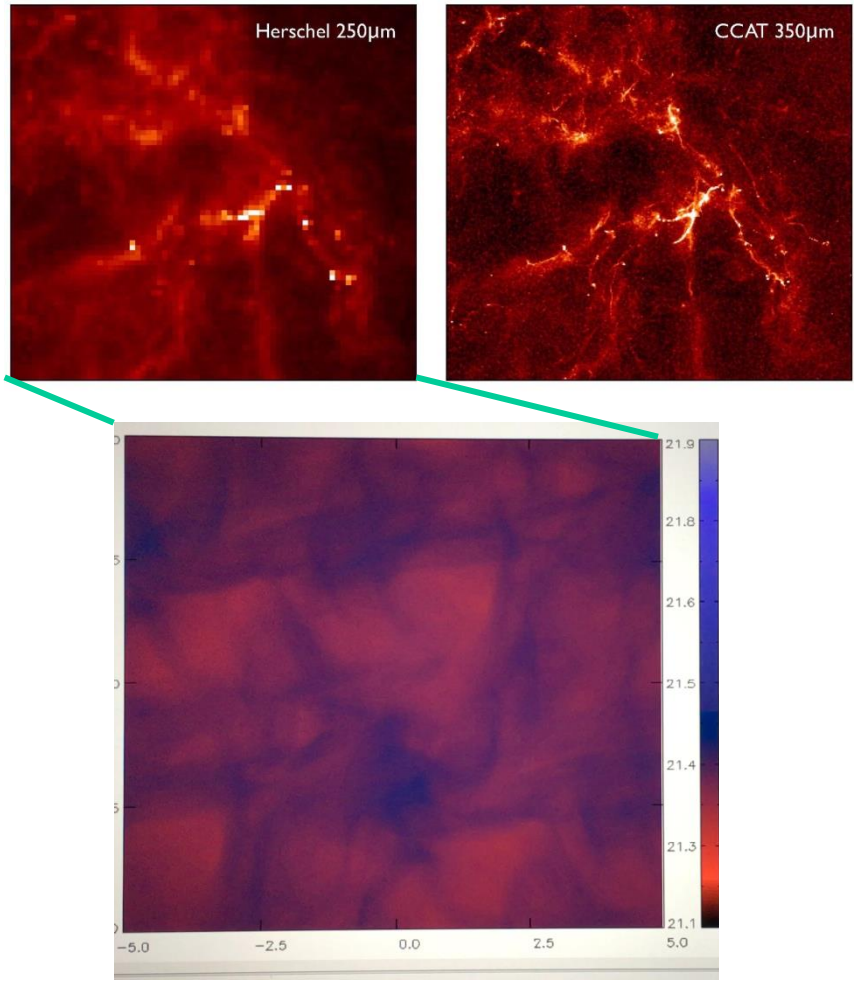




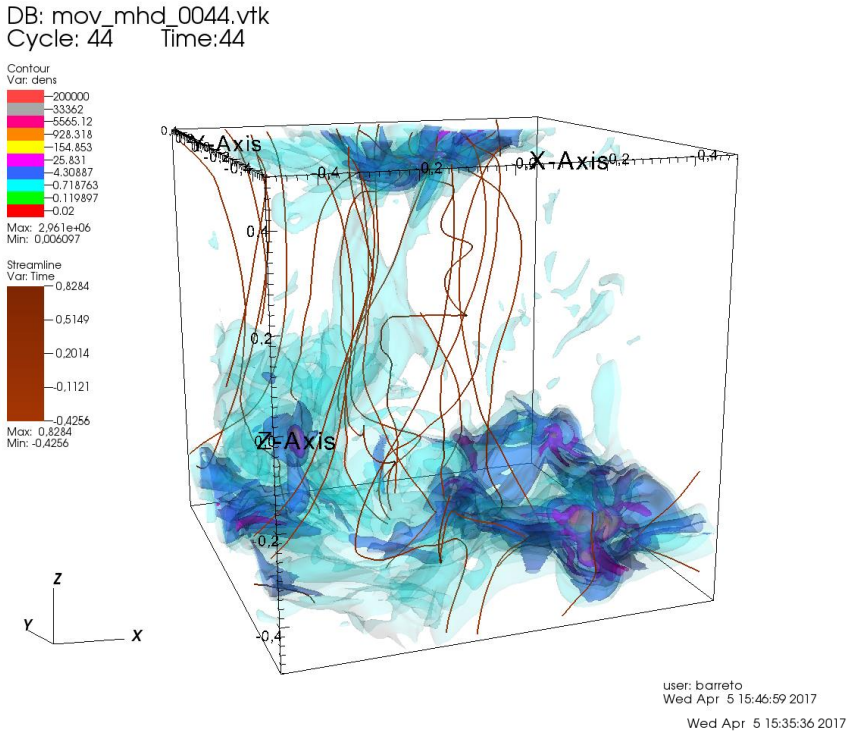


Guerrero, Smolarkiewicz, de Gouveia Dal Pino, Kosovichev, & Mansour, ApJ 2016a, ApJ *Letters* 2016b

3D MHD Simulations of Star Formation



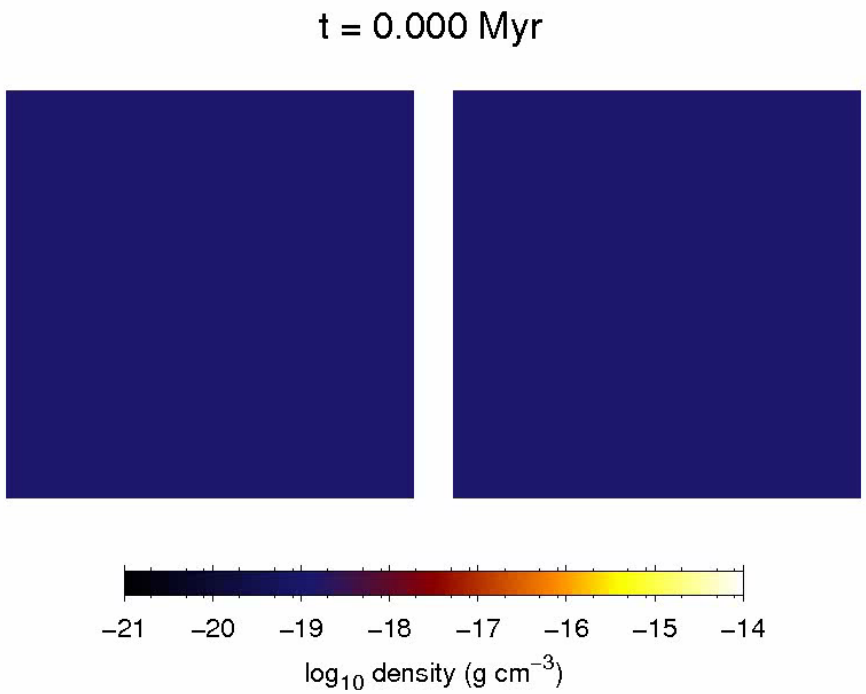
- MFs force the gas to accumulate along the field lines forming filaments as observed in the interstellar medium

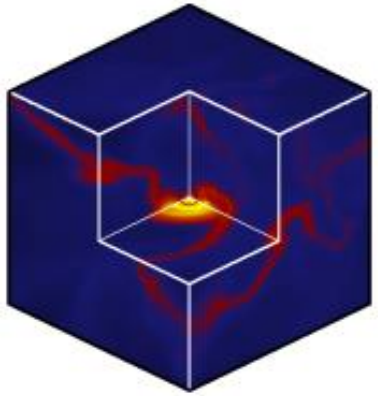


Santos-Lima, de Gouveia Dal Pino, Lazarian, MNRAS 2013; Barreto, de Gouveia Dal Pino, Melioli, Santos-Lima 2017

3D MHD simulations of Star Formation: Core collapse and proto-stellar disk formation

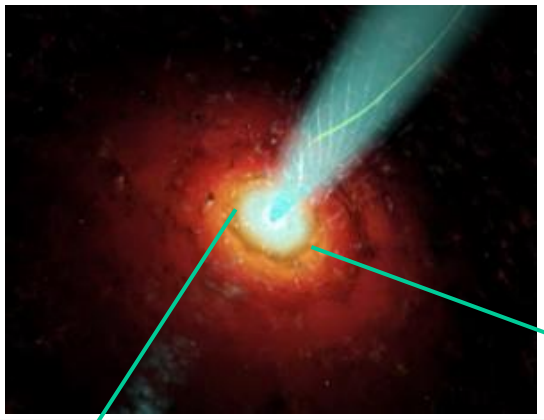
Magnetic fields (MFs) and turbulence influence star formation: turbulence helps the removal of excess of MF that is dragged-in, and allows the core and disk to form under the action of gravity

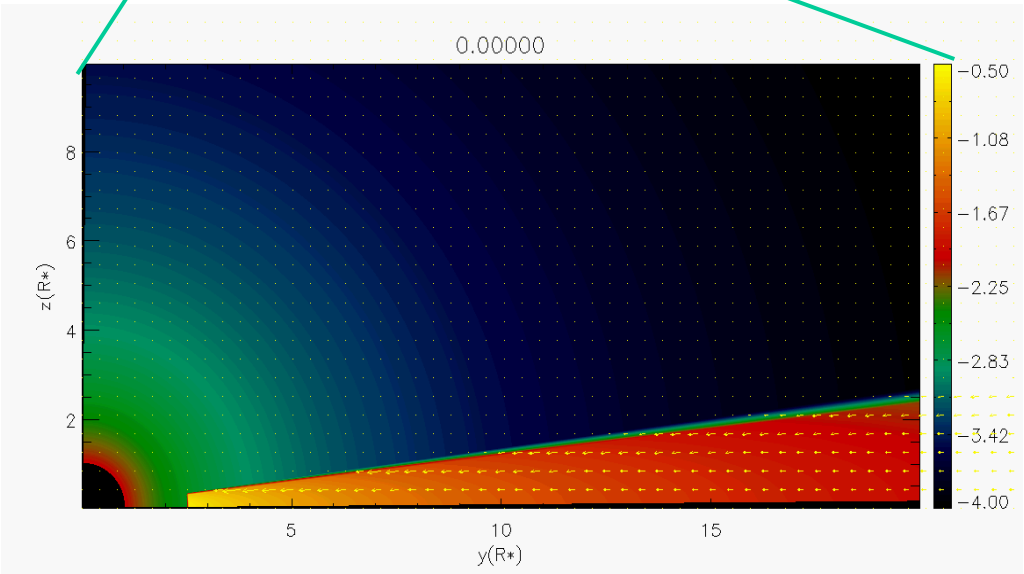




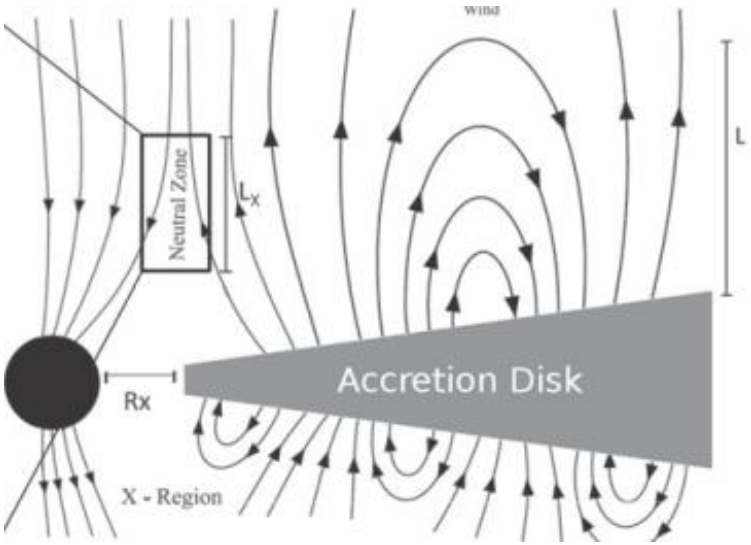
Santos-Lima, de Gouveia Dal Pino, Lazarian, ApJ 2012 MNRAS 2013

MHD simulations of Accretion Disks around compact sources: **Global**





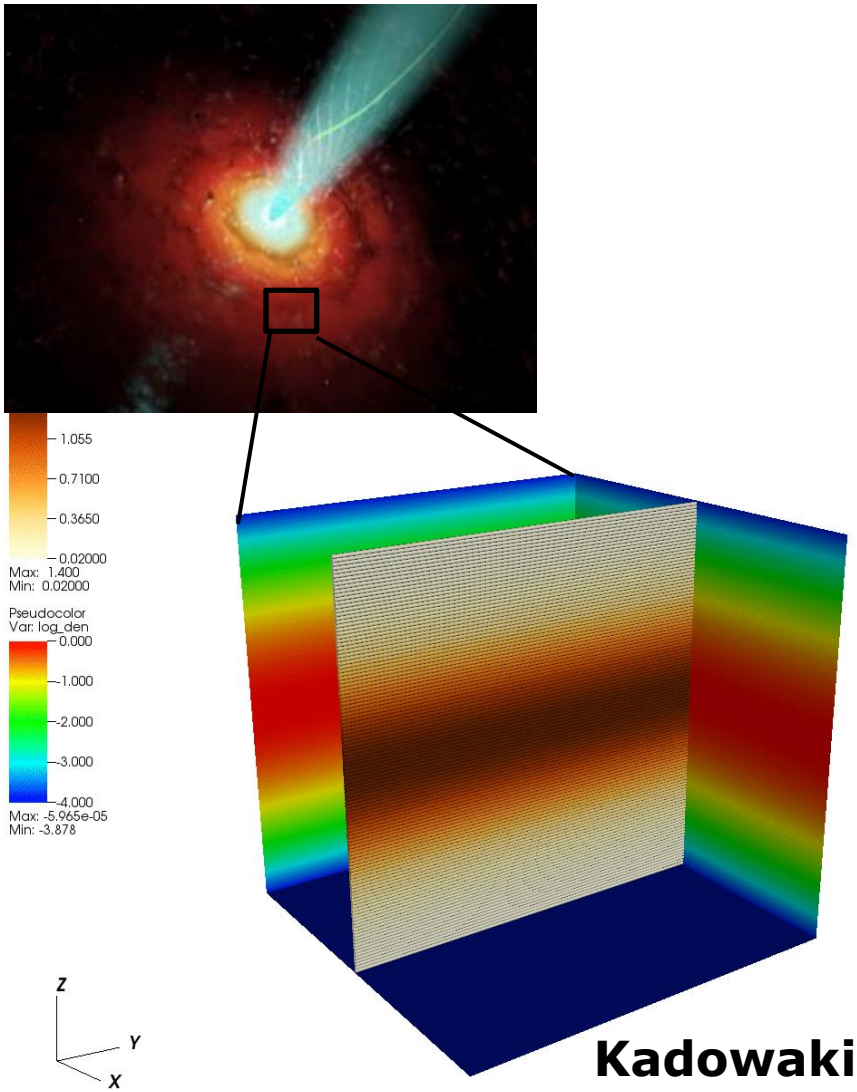
- **Magneticc Reconnection and plasmon ejection: as in the Sun**



de Gouveia Dal Pino & Lazarian 2005

Kadowaki, de Gouveia Dal Pino, Singh ApJ 2015

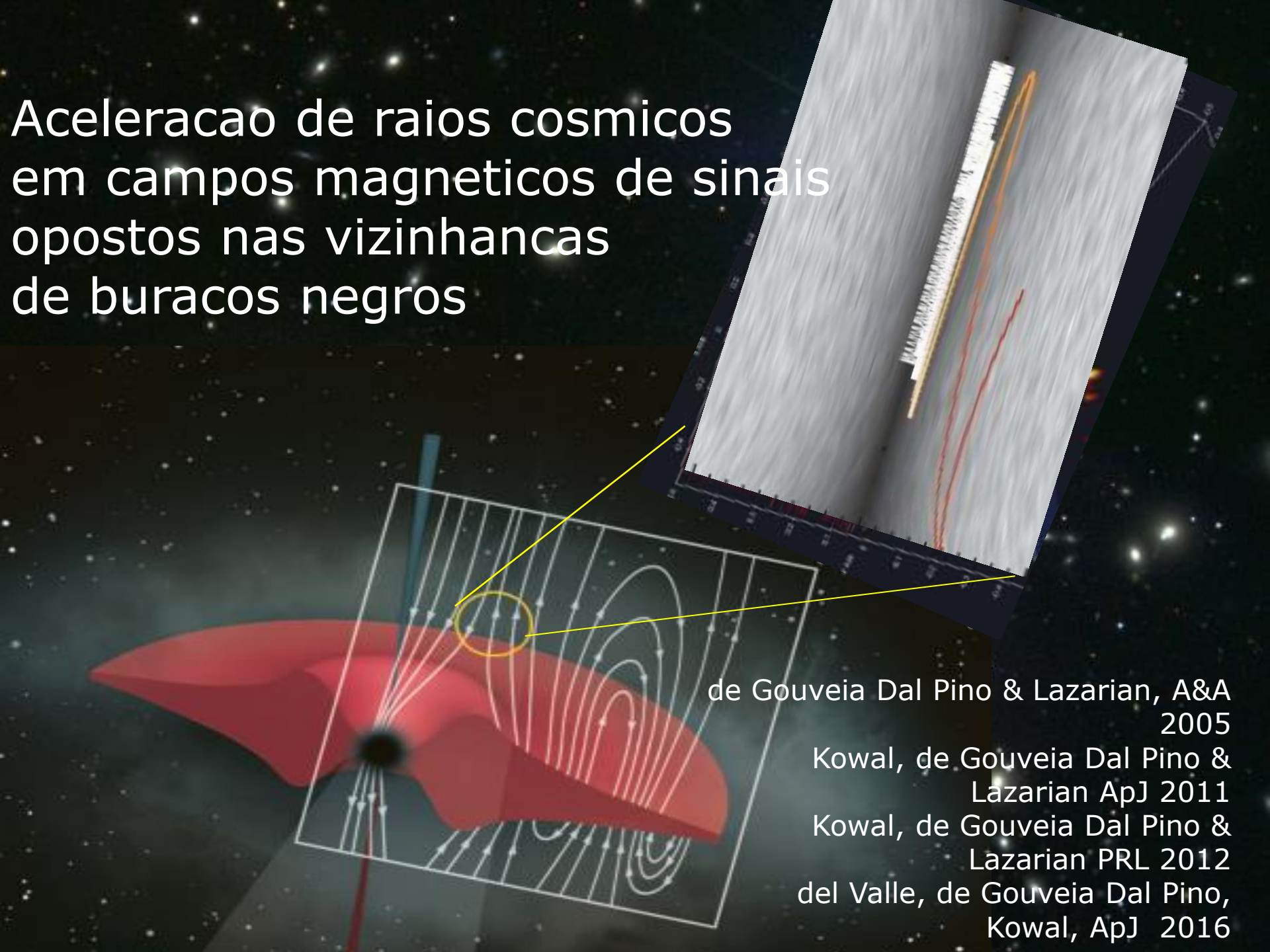
3D MHD Simulations of Accretion disks: **Shearing box**



- Magnetic fields drive the transport of angular momentum
- Magnetic fields arise from the accretion disk and build a corona around the disk just like on the solar surface

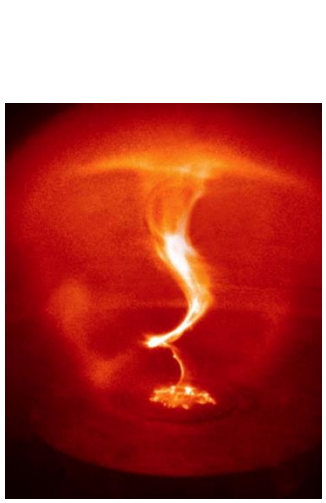
Kadowaki, de Gouveia Dal Pino, Stone 2017

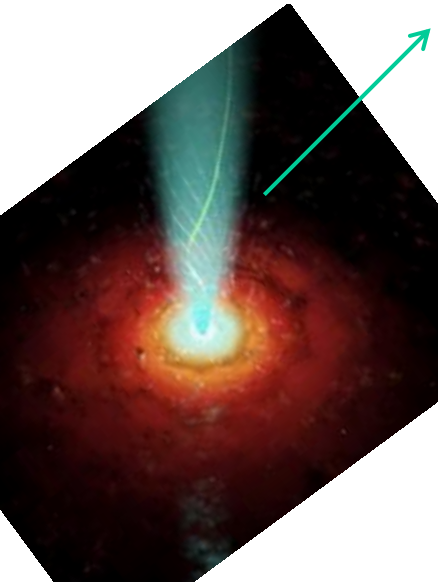
Aceleracao de raios cosmicos em campos magneticos de sinais opostos nas vizinhancas de buracos negros

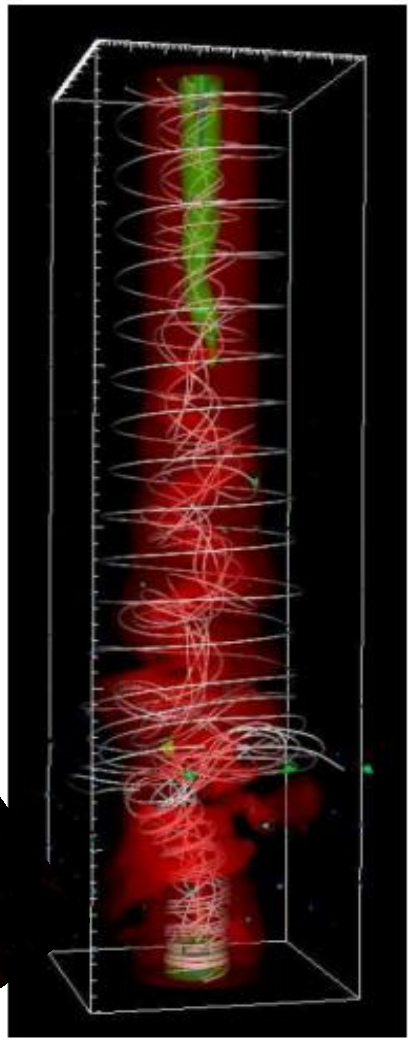


de Gouveia Dal Pino & Lazarian, A&A 2005
Kowal, de Gouveia Dal Pino & Lazarian ApJ 2011
Kowal, de Gouveia Dal Pino & Lazarian PRL 2012
del Valle, de Gouveia Dal Pino, Kowal, ApJ 2016

3D Relativistic-MHD Simulations of Jets



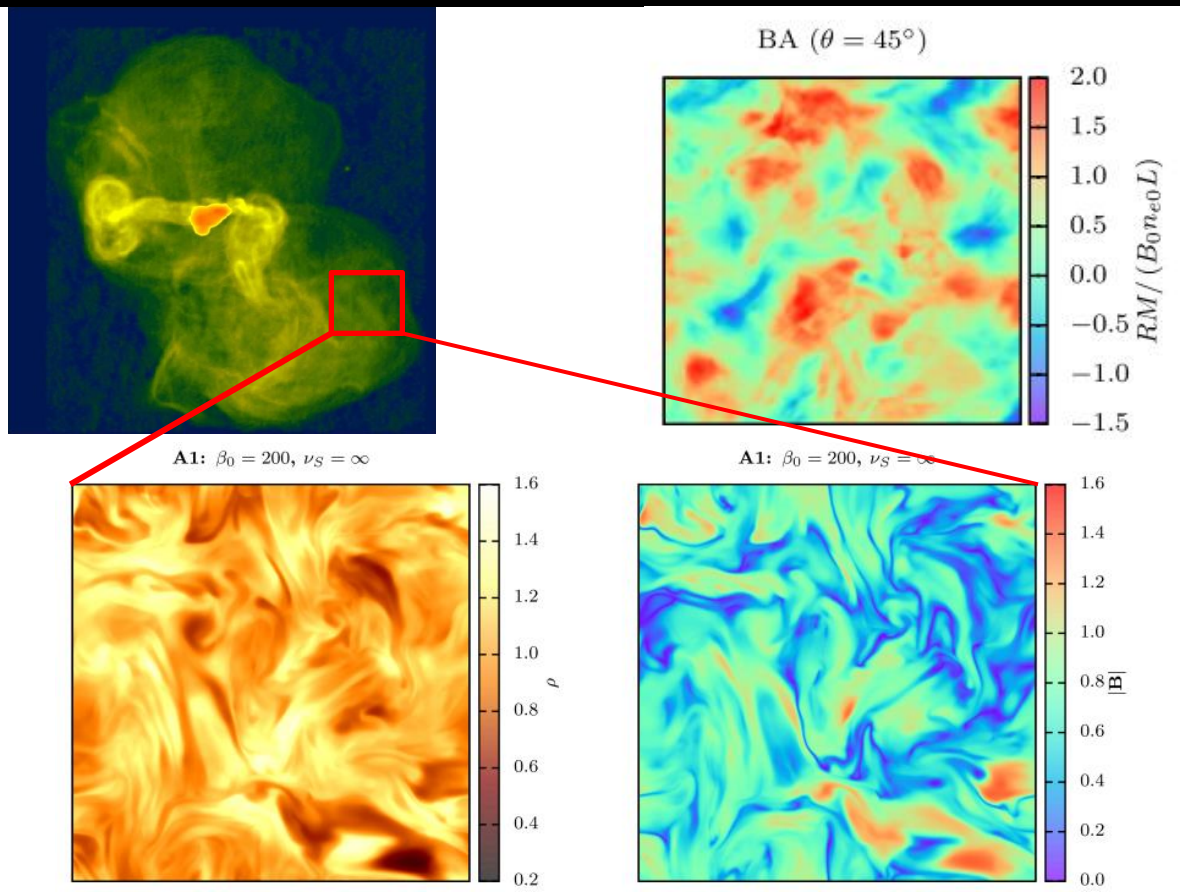




- Magnetic fields influence origin, acceleration and propagation of jets everywhere in the Universe

Singh, Mizuno, de Gouveia Dal Pino, ApJ 2016

3D MHD Simulations of the Intergalactic Medium: magnetic fields amplified by turbulence



- MFs influence galaxies and intergalactic gas evolution and dynamics

Santos-Lima, de Gouveia Dal Pino et al., ApJ 2014
Nakwaki, Kowal, Santos-Lima, de Gouveia Dal Pino, F.-Goncalves, MNRAS 2016
Santos-Lima, Yan, de Gouveia Dal Pino & Lazarian, MNRAS 2016
Santos-Lima, de Gouveia Dal Pino, et al. MNRAS 2016


OBRIGADA

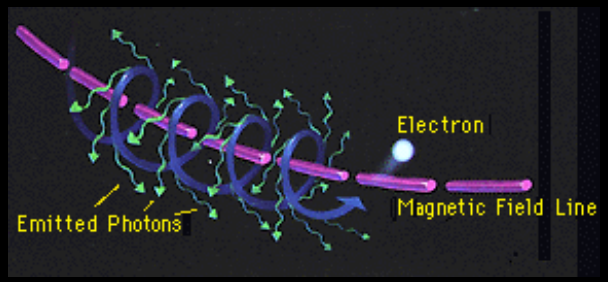
Measuring Magnetic fields

- Zeeman effect (within galaxy):

$$\Delta\nu = e\, B_{\parallel} / 2\pi\, m_e$$

- Polarized synchrotron emission (Beck and Krause 2005):

$$I \propto \int n_{CR}\, B_{\perp}^{1+\alpha}\, dl$$



- Faraday rotation of the diffuse polarized emission:

$$RM \propto \int n_e\, B_{\parallel}\, dl$$