

Dinamica dei plasmi astrofisici: dall'eliosfera agli oggetti compatti

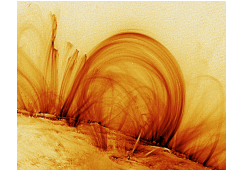
Marco Velli e Luca Del Zanna

ASAP – Arcetri Space & Astrophysical Plasmas

<http://www.astro.unifi.it/gruppi/plasmi/>



Gruppo Plasmi Astrofisici



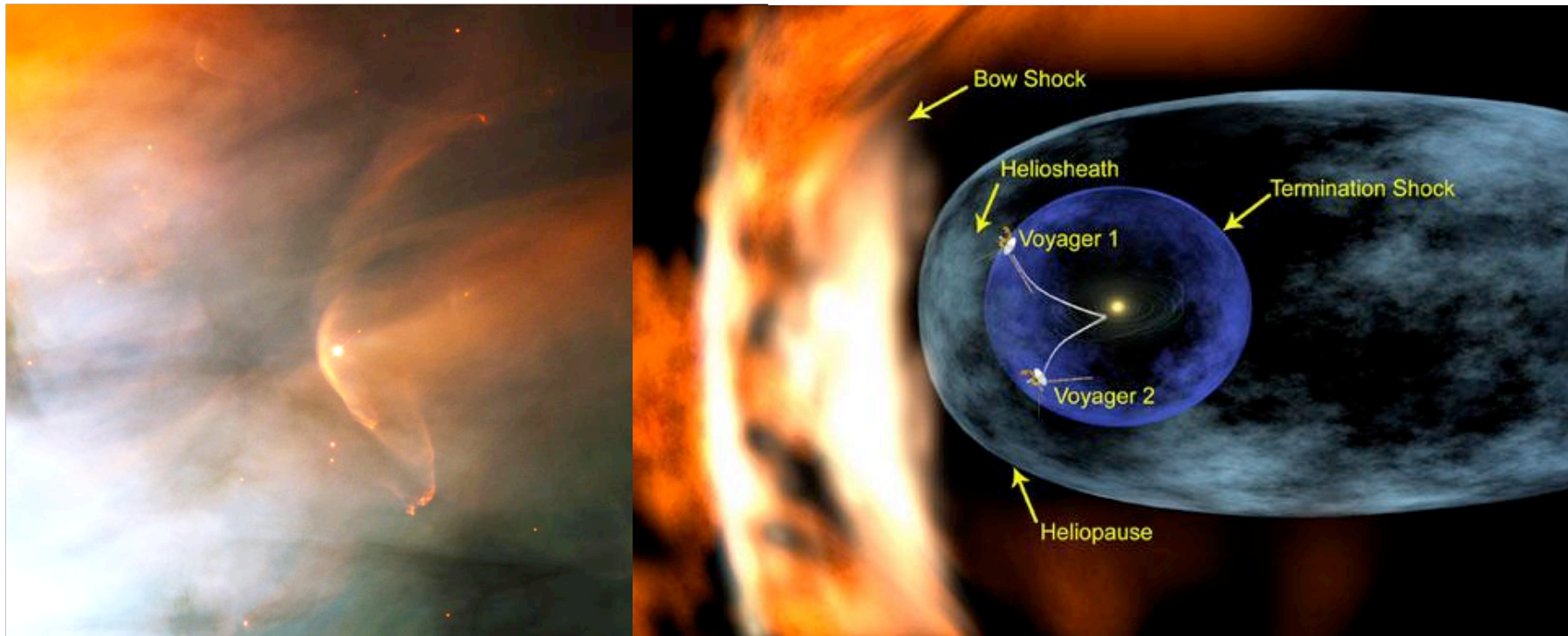
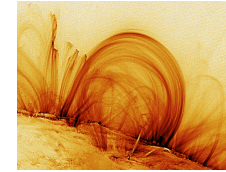
Membri del gruppo: C. Chiuderi, F. Rubini, L. Del Zanna, S. Landi
Studenti/Post-doc: E. Buchlin, A. Verdini, L. Bettarini, L. Matteini, F. Rappazzo

Collaborazioni:

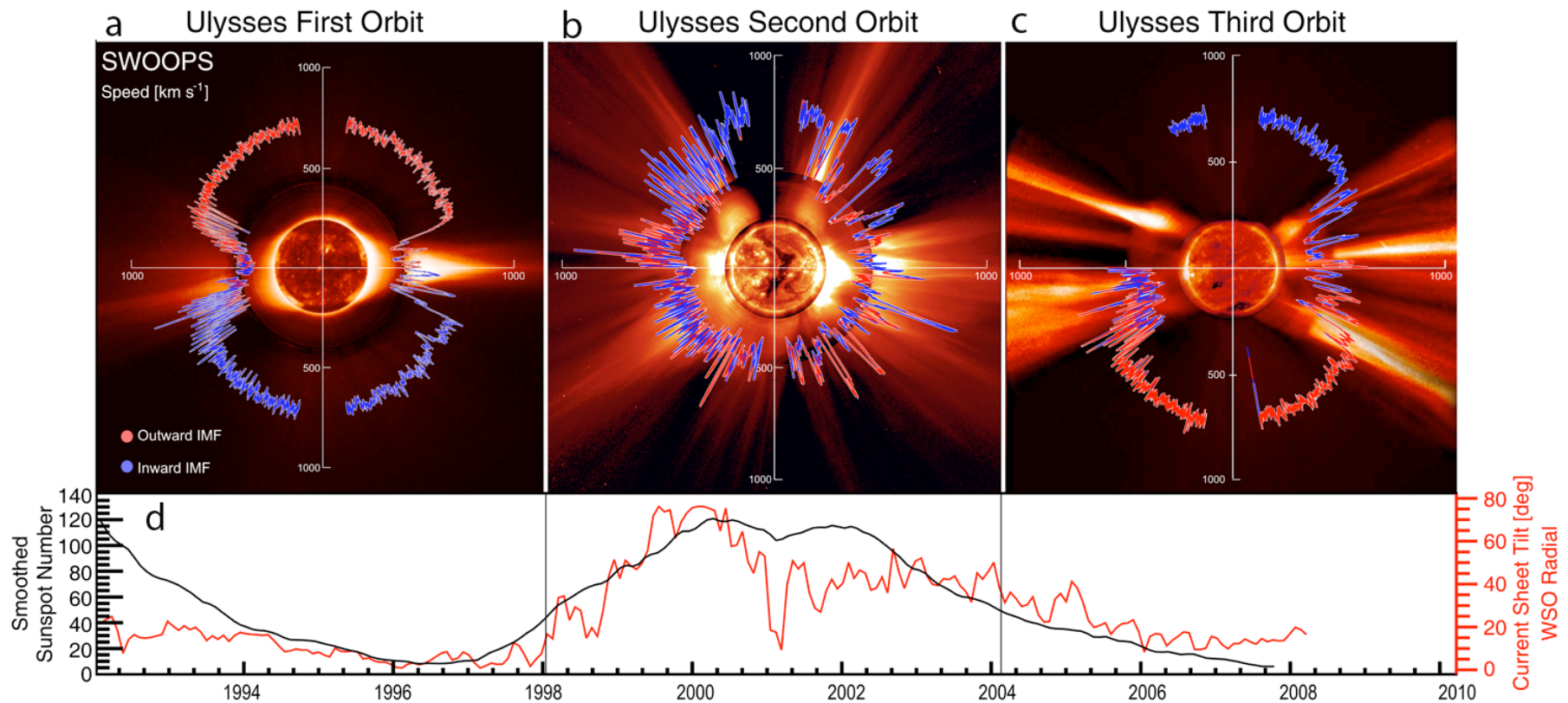
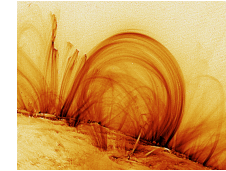
**Arcetri-INAf, Università di Pisa, Università della Calabria,
Observatoire de Paris-Meudon, Observatoire de la Côte d'Azur,
Jet Propulsion Laboratory (Pasadena, CA), University of
Delaware, UCLA, Naval Research Laboratory (Washington, D.C.),
Predictive Science (San Diego)**

Finanziamenti: ASI / NASA ; UniFi ; PRIN ?

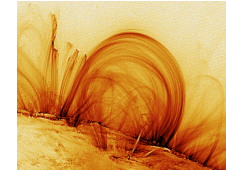
Eliosfera ed Astrosfere



The Solar Wind at ULYSSES



Argomenti di Ricerca



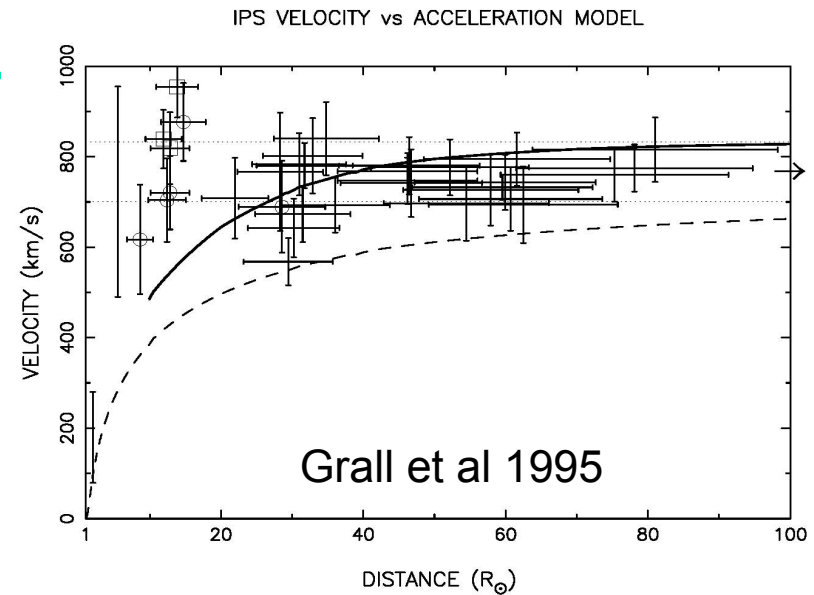
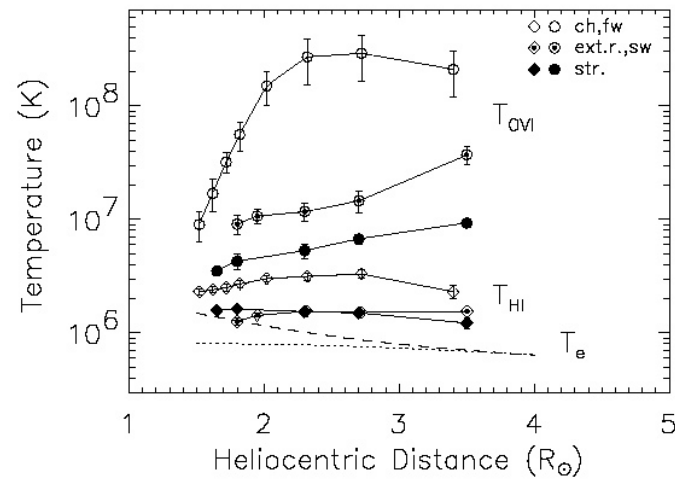
⊙ **Riscaldamento della corona solare ed accelerazione del vento solare: modelli di turbolenza magnetoidrodinamica.**

⊙ **Dinamica del vento solare: passaggio dalla fisica fluida a quella cinetica.**

Sviluppo di modelli e codici numerici multi-scala: MHD, Ibridi, PIC Analisi dati sonde spaziali

⊙ **Esplorazione dell' Eliosfera mediante nuovi progetti spaziali: ADAHELI, (PHOIBOS), Solar Orbiter, Solar Probe**

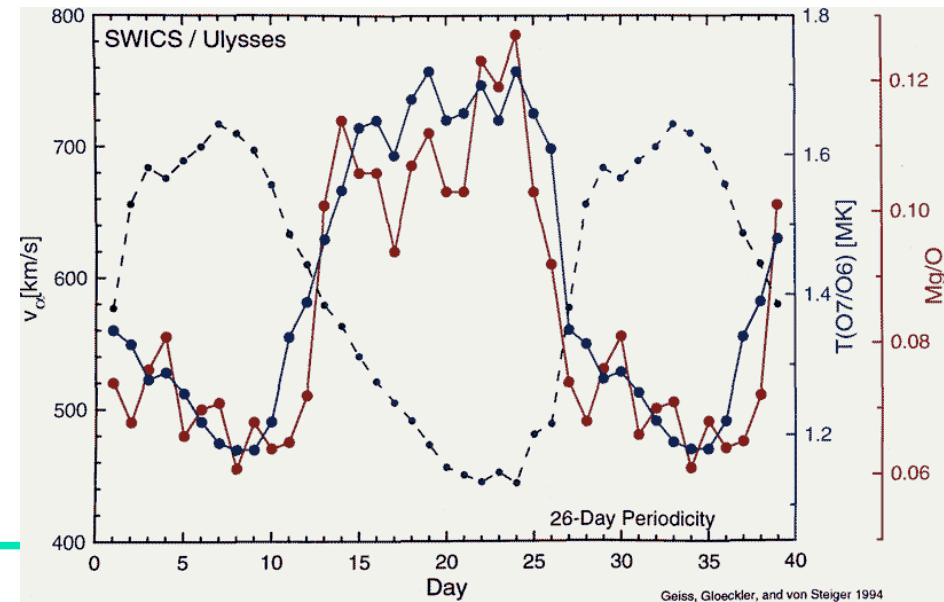
- OVI, HI and e- temperature gradients according to source



Antonucci , SSR 2006

	fast	slow
<i>speed (km/s)</i>	600–800	300–500
T_p (10^5 K)	2.4	0.4
T_e (10^5 K)	1.0	1.3
T_{ion} / T_p	$> m_{\text{ion}}/m_p$	$< m_{\text{ion}}/m_p$
$\text{O}^{7+}/\text{O}^{6+}, \text{Mg}/\text{O}$	low	high

5 febbraio
2009



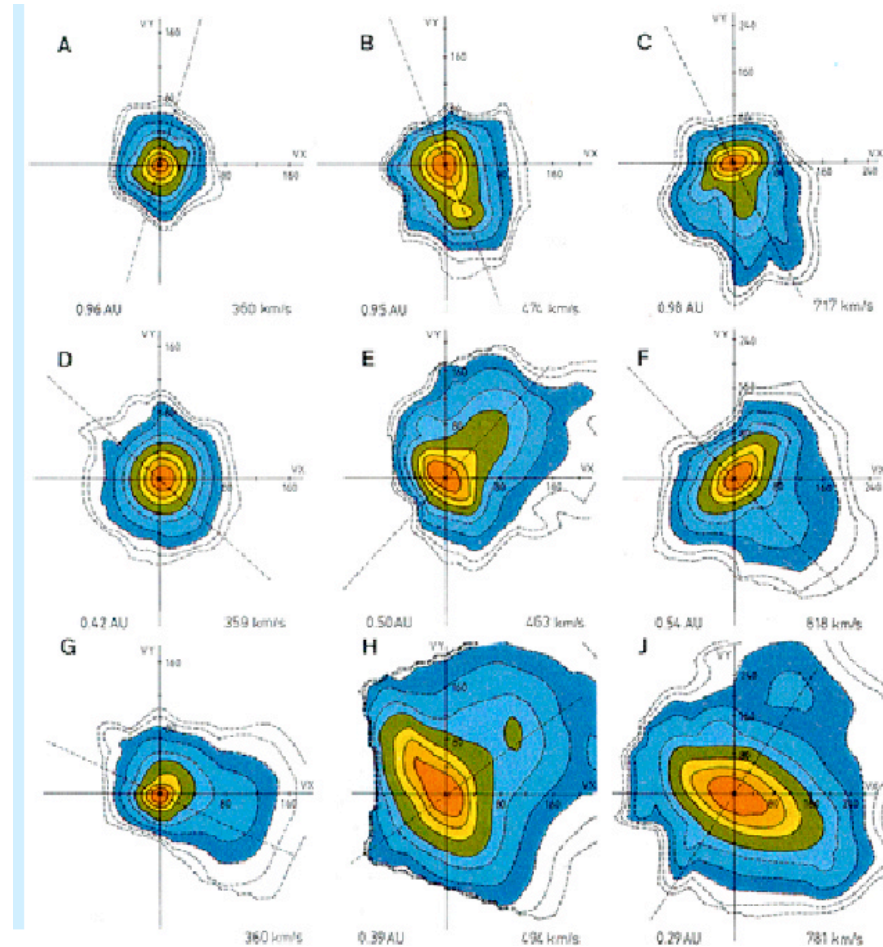
ASI/ESS Firenze

Proton solar wind
distribution functions
Marsch et al., 1982,
(Helios data)

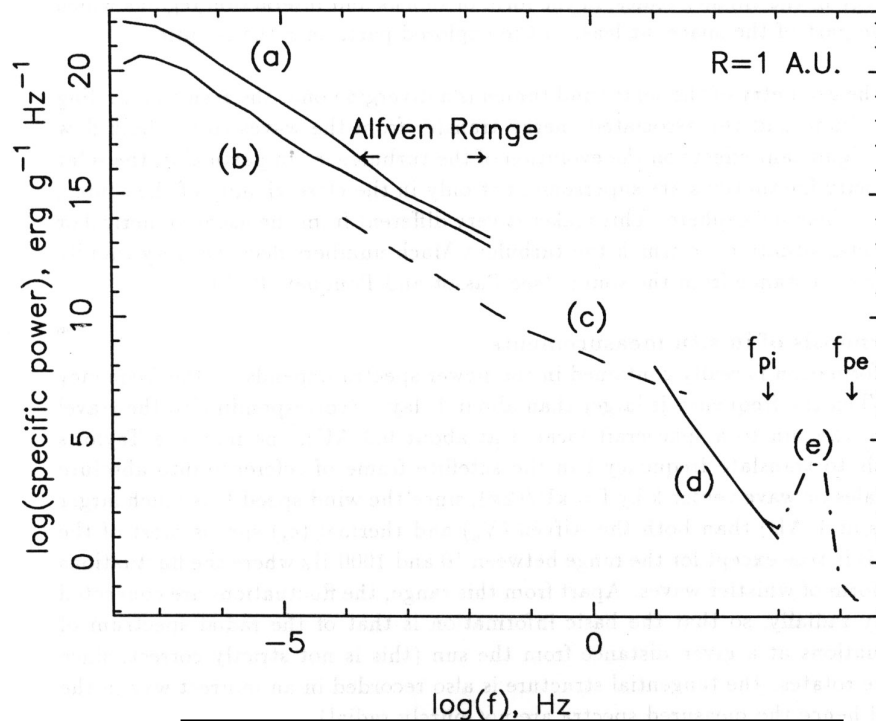
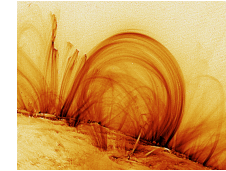
ANISOTROPIC

+

BEAM!



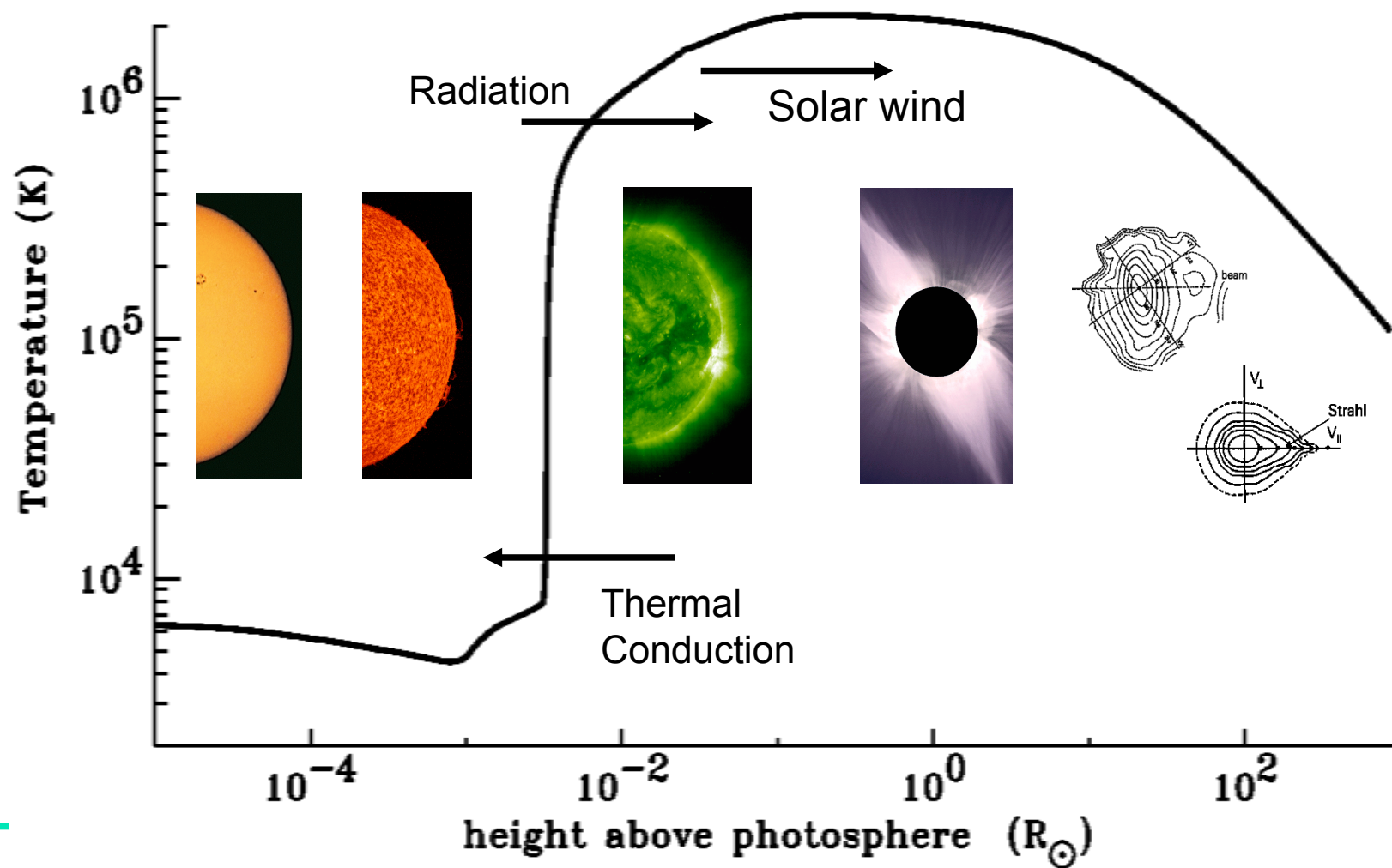
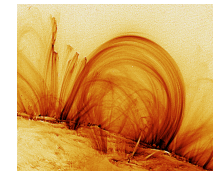
Alfvén Waves and Alfvénic Turbulence :



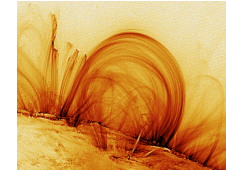
$$z^{\pm} = u \mp \text{sign}(B_r) b / \sqrt{4\pi\rho}$$

First recognized in solar wind fast streams by Belcher and Davis (1971) ($10^{-4} \text{ Hz} < w < 10^{-2} \text{ Hz}$). Transverse waves that propagate at the Alfvén speed

Energy flux balance



Sorgente di energia



Photospheric motions produce field line “tangling” and emerging flux resulting in a Poynting flux crossing the photosphere:

$$\vec{S} = \frac{c}{4\pi} \vec{E} \times \vec{B}$$

$$\vec{E} = -\frac{1}{c} \vec{V}_{ph} \times \vec{B}$$

$$\vec{S} \cdot \vec{n}_{ph} = \frac{B_{\perp}^2}{4\pi} \vec{V}_{ph} \cdot \vec{n}_{ph} - \frac{\vec{B} \cdot \vec{n}_{ph}}{4\pi} \vec{V}_{ph\perp} \cdot \vec{B}$$

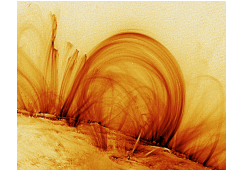


Emerging Flux



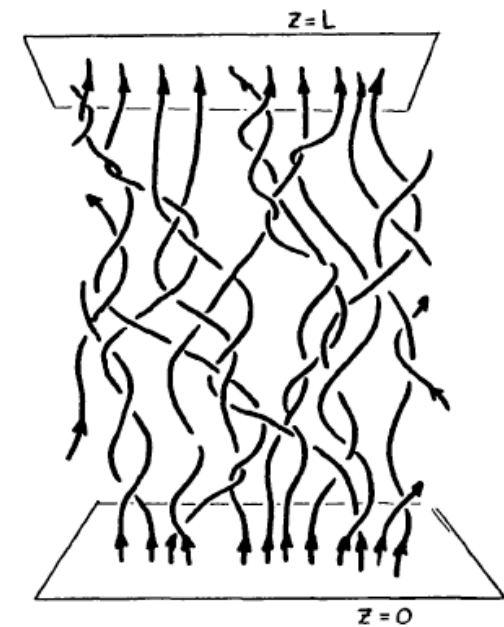
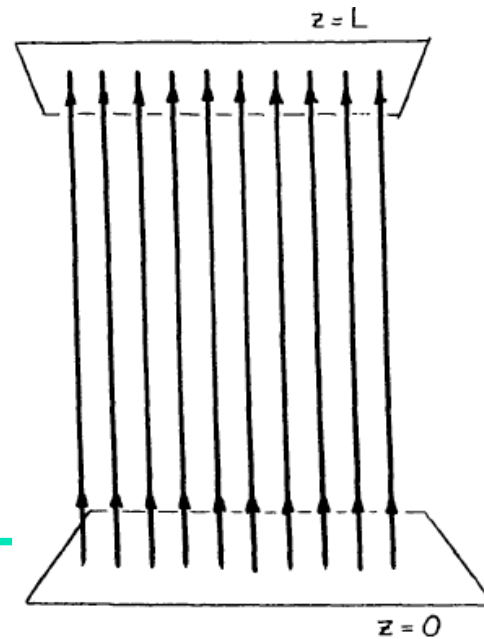
Waves and Turbulence

Turbolenza nella corona solare confinata

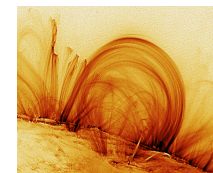


← Reality

Model

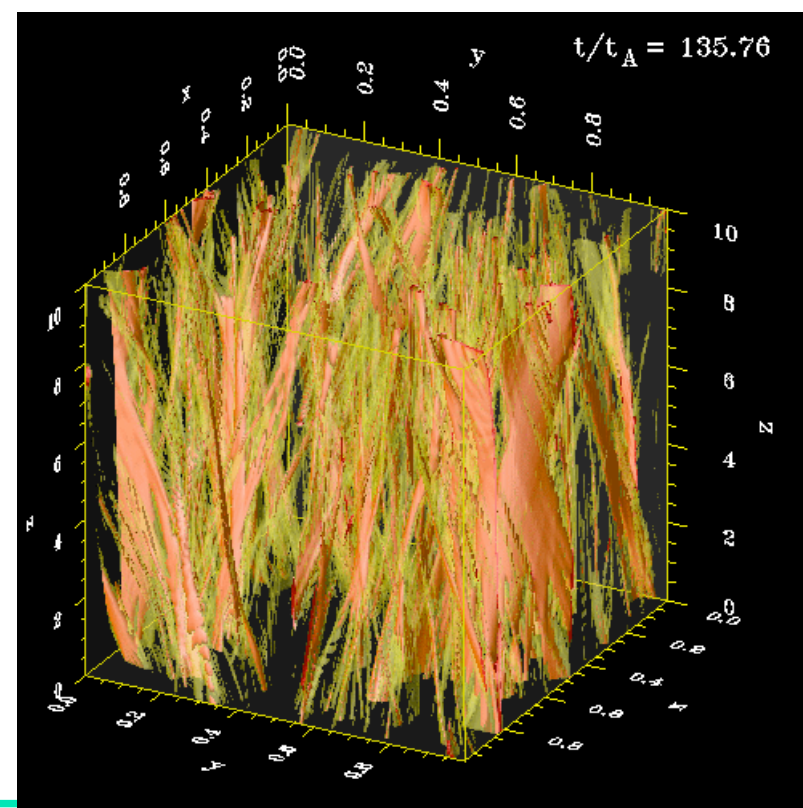
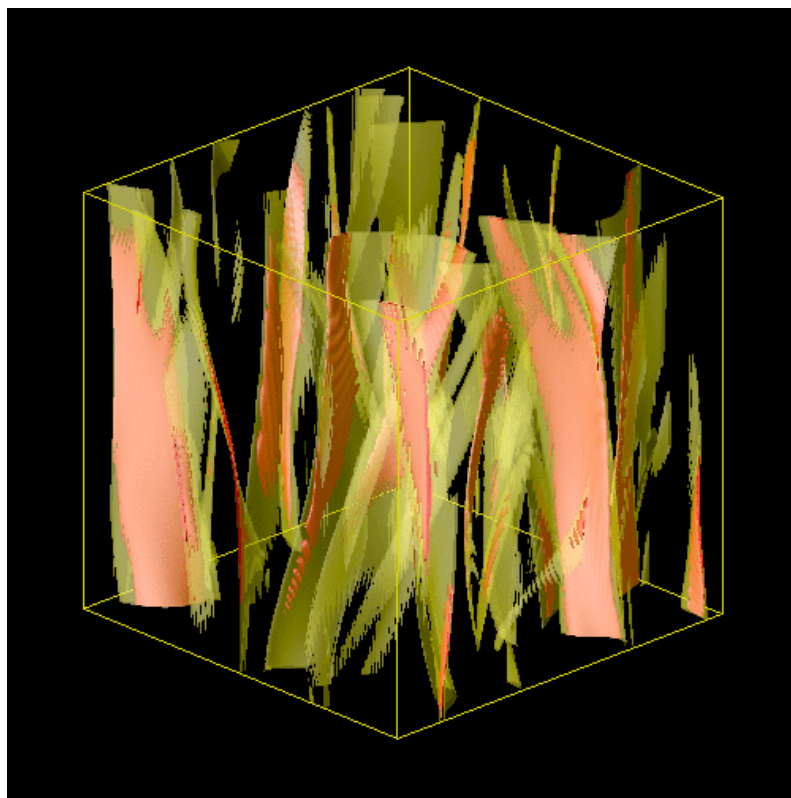


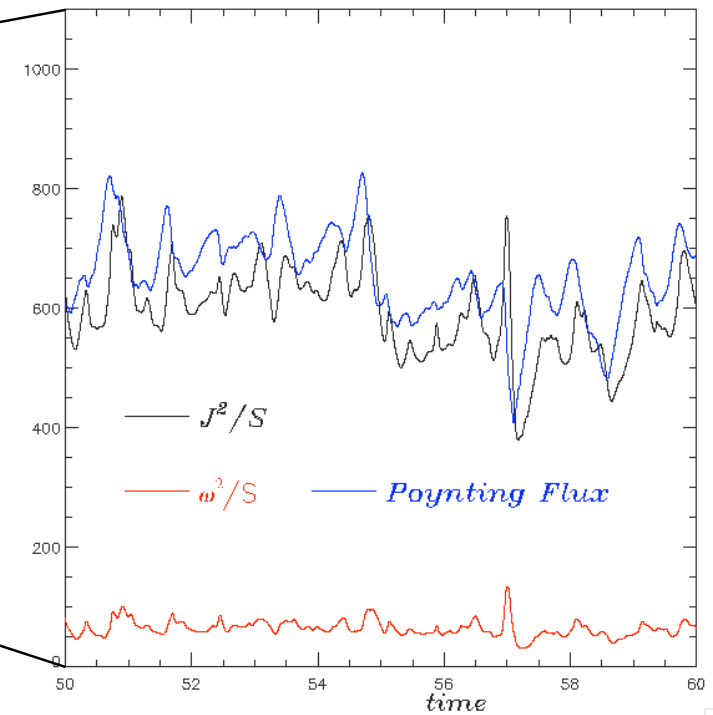
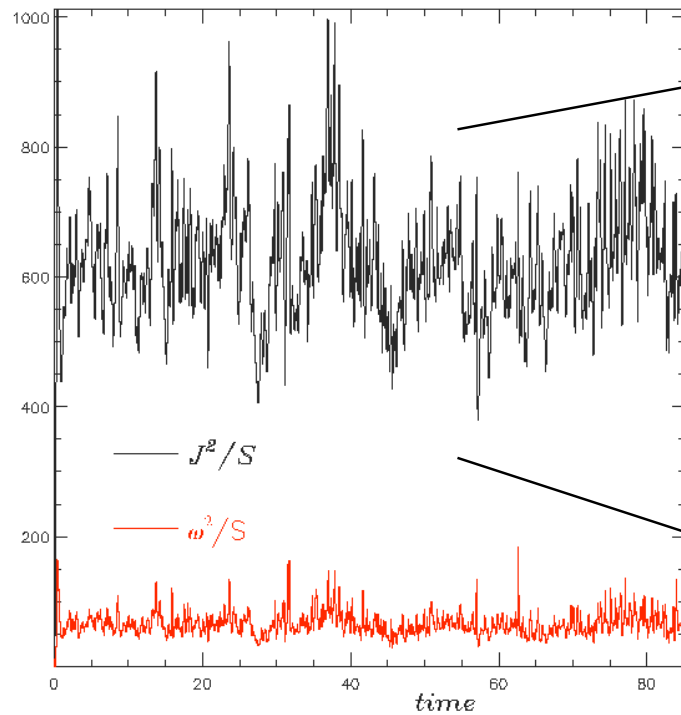
Simulazioni RMHD



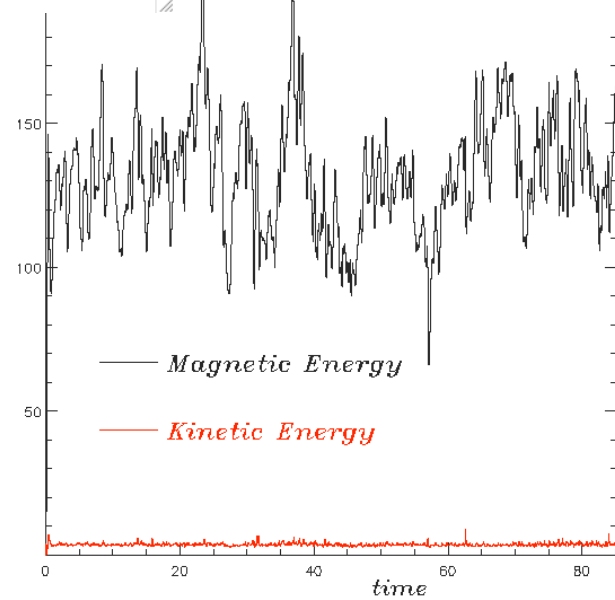
$$J^2/R$$

Red = 1000 Yellow = 350 Max = 2.7×10^4 min = 0

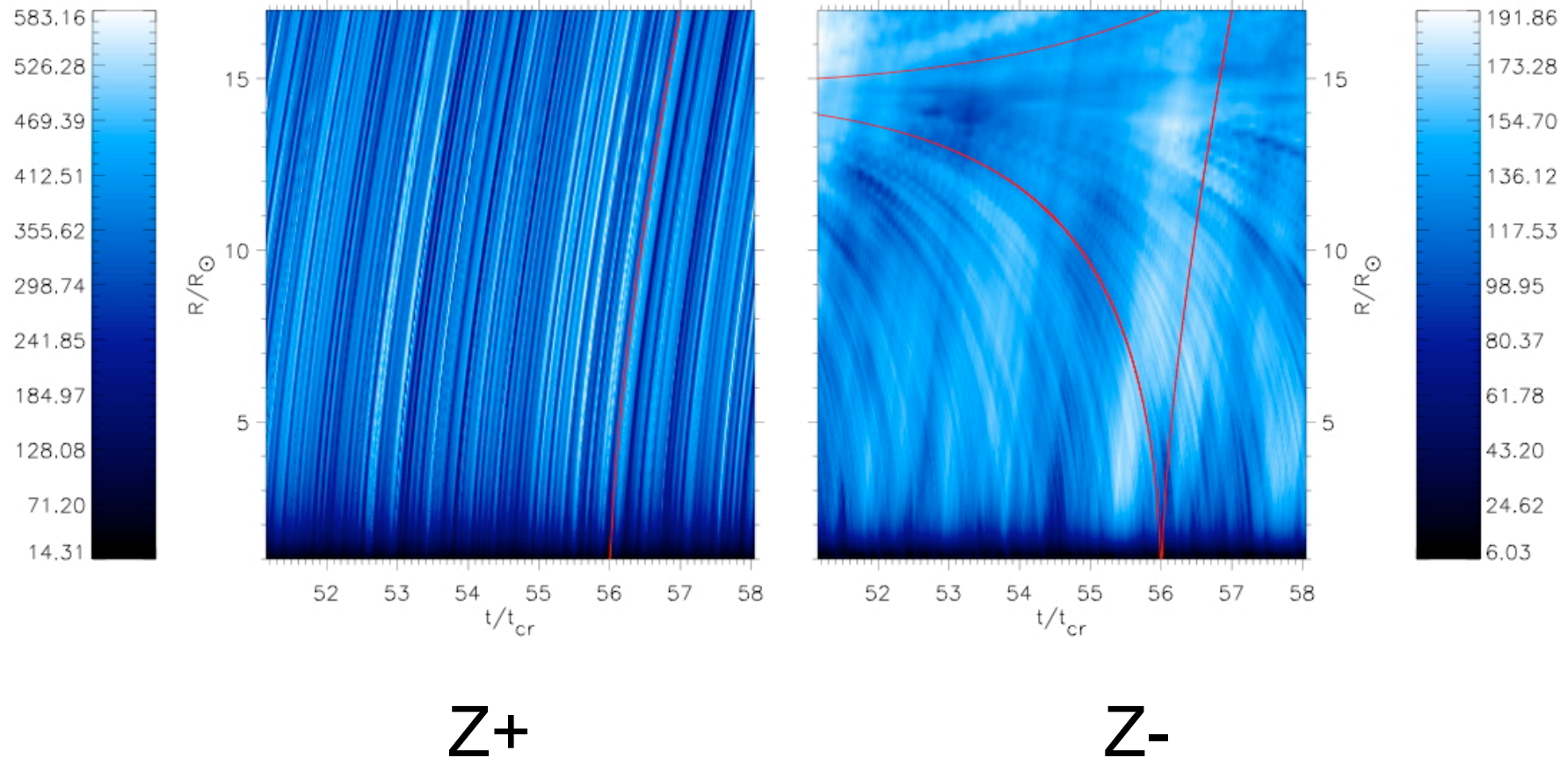
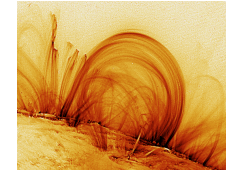




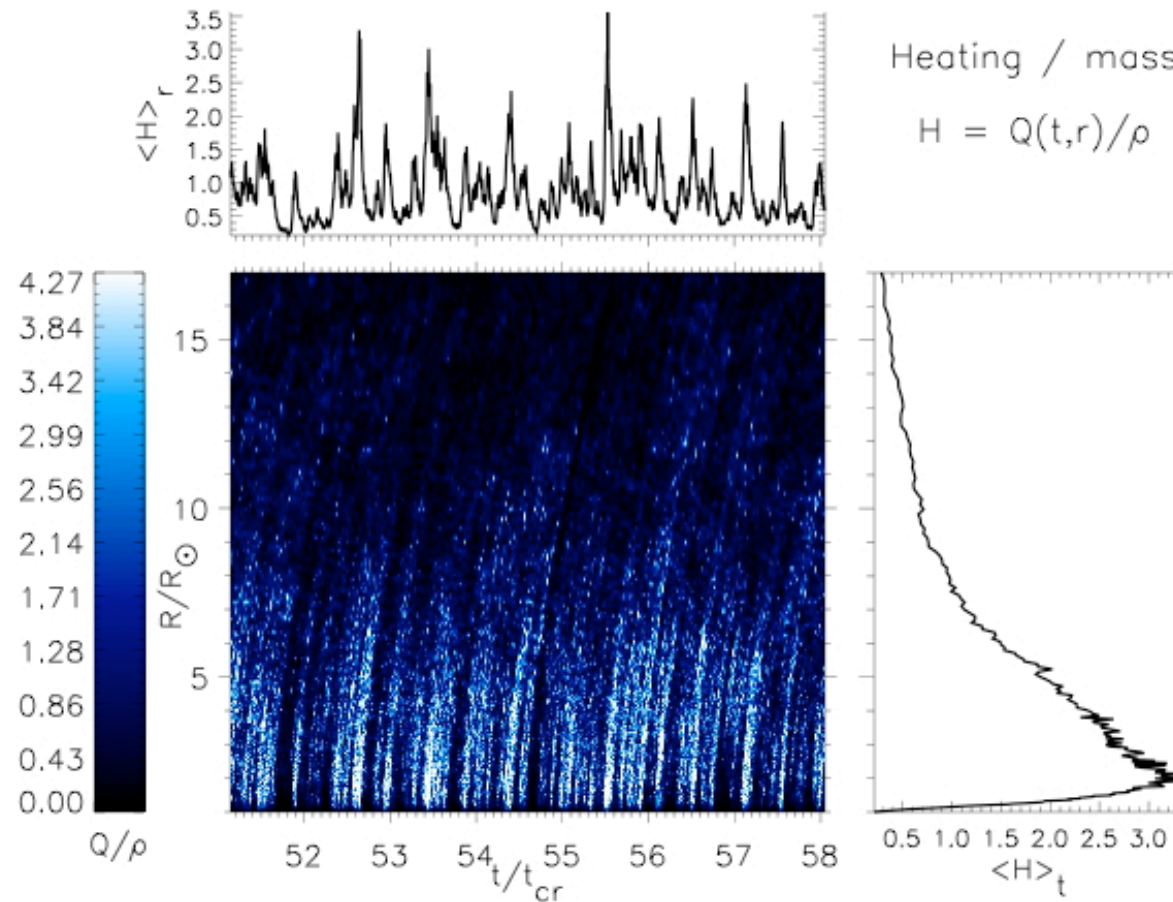
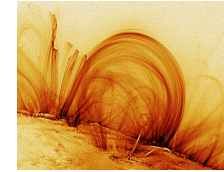
*Chaotic
time-series*



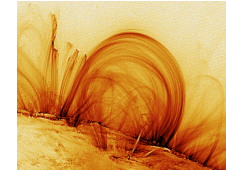
Shell model cascade and heating



Shell model cascade and heating

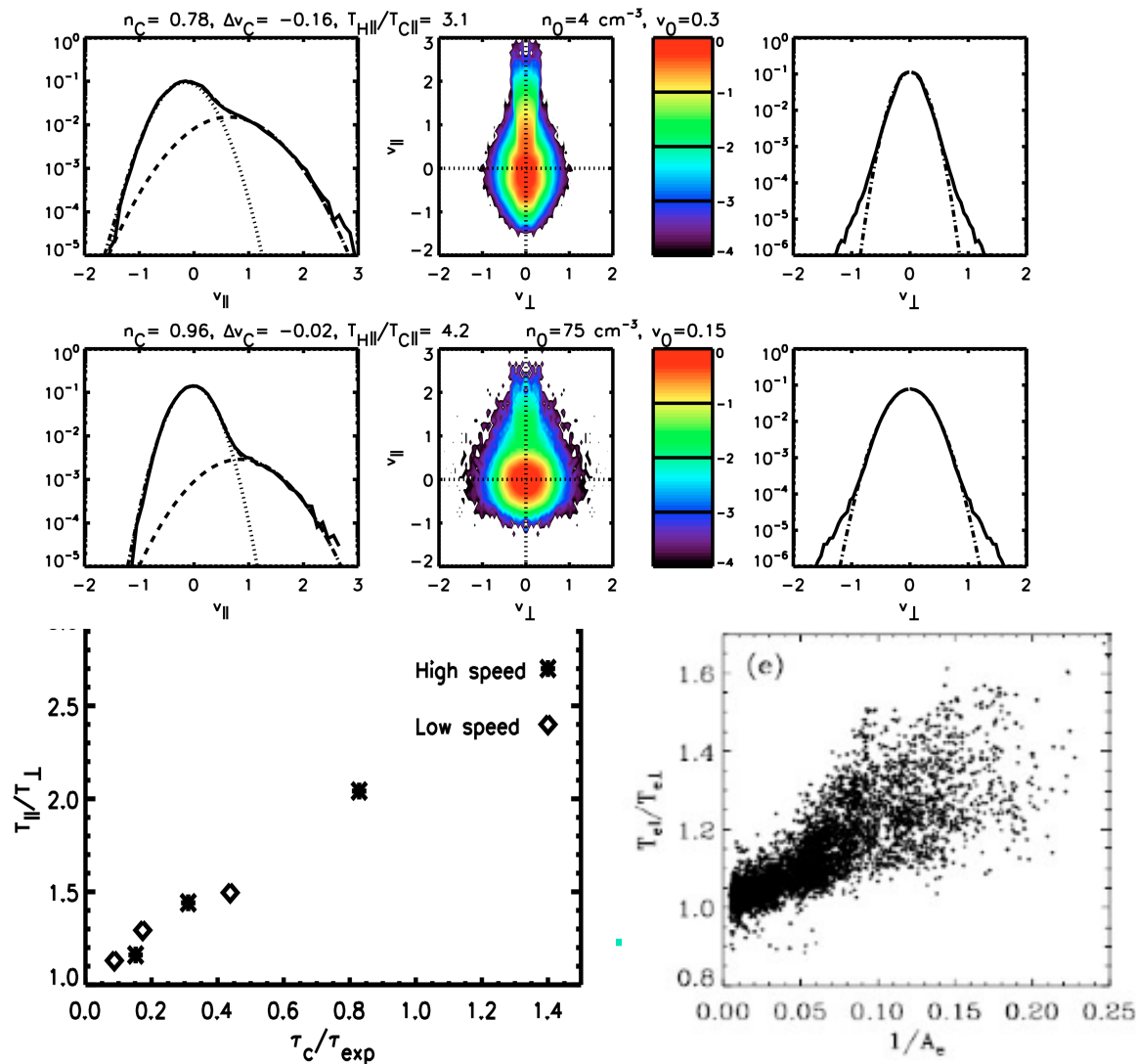
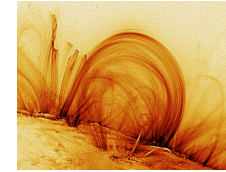


Dinamica del vento solare: passaggio dalla fisica fluida a quella cinetica.



- Effetti sul trasporto di energia causato da distribuzioni non maxwelliane in corona e nel vento solare
- Ruolo del flusso di calore degli elettroni nella formazione ed accelerazione del vento per effetto di espansione e collisioni
- Ruolo delle interazioni e delle instabilità onda-particella nel vento solare

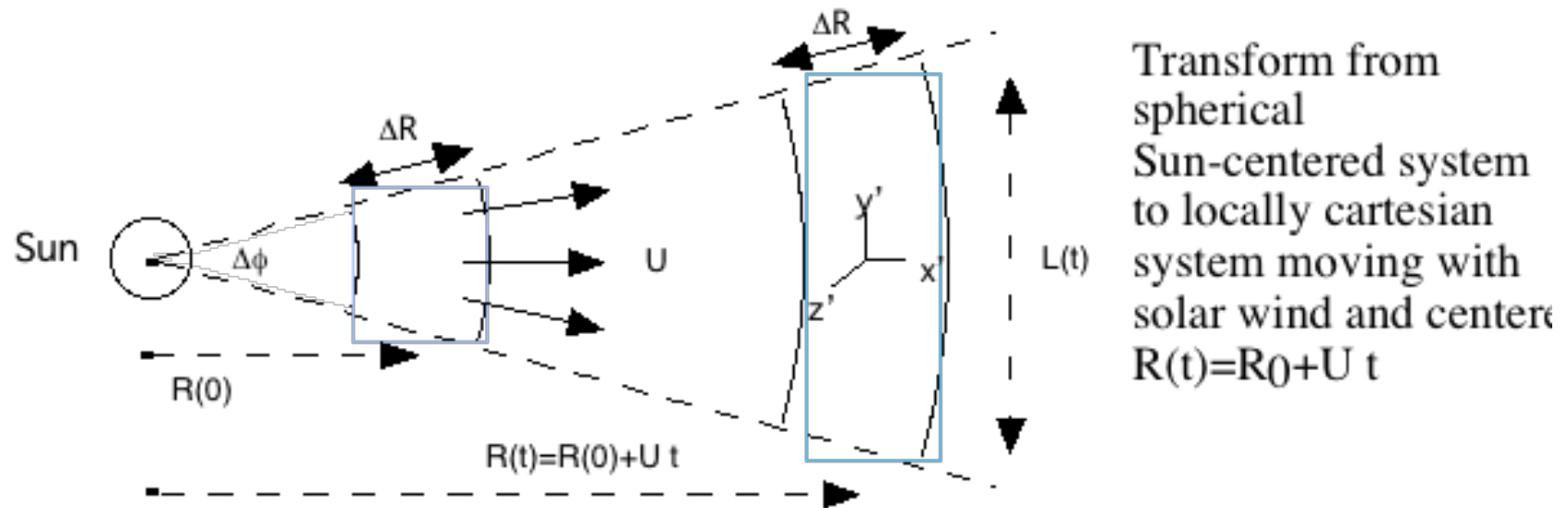
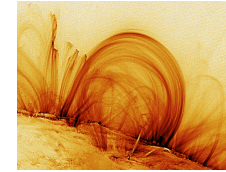
Flusso di calore degli elettroni



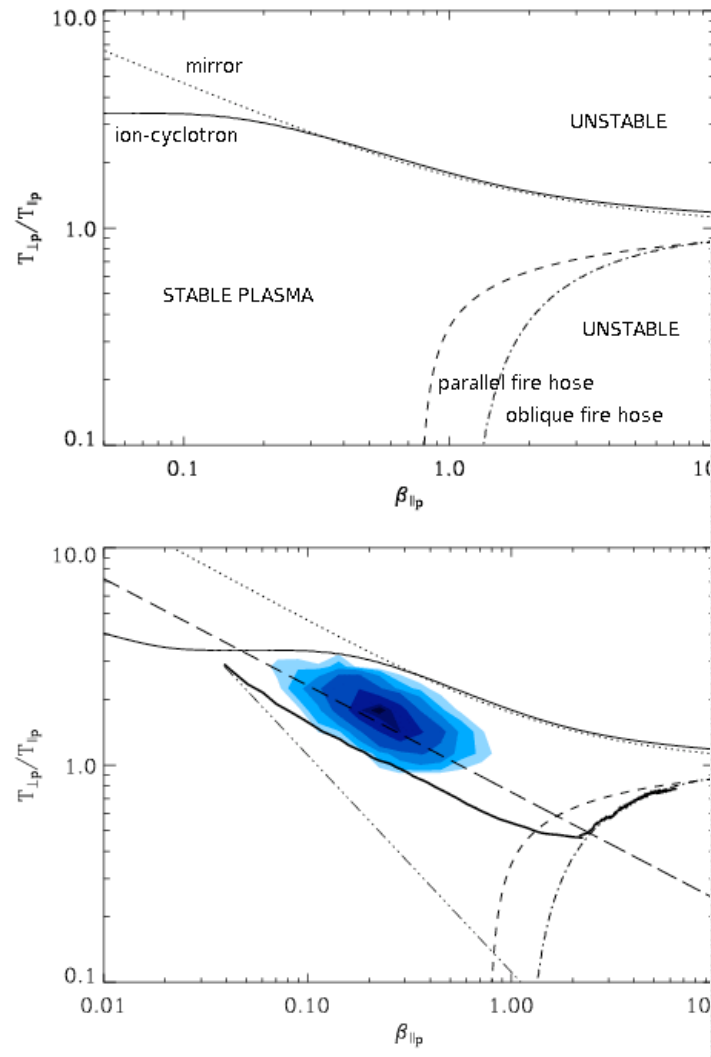
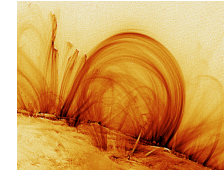
L'effetto combinato delle collisioni e dell'espansione produce la caratteristica struttura core-halo osservata nel vento solare (Landi et al., 2010)

Le caratteristiche macroscopiche sono ben correlate con le caratteristiche collisionali del plasma come nel caso del vento (Landi et al., 2010)

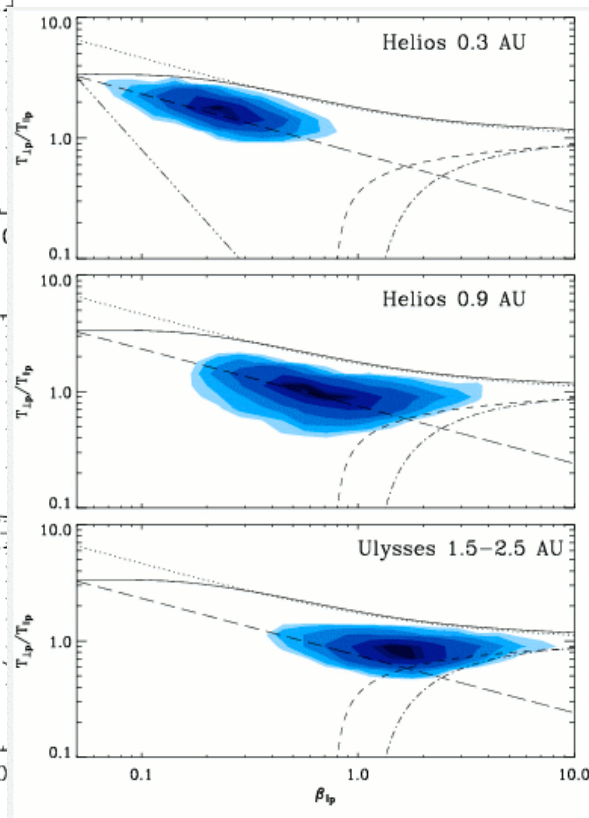
Simulazione “in espansione”



Interazioni e instabilità onda-particella

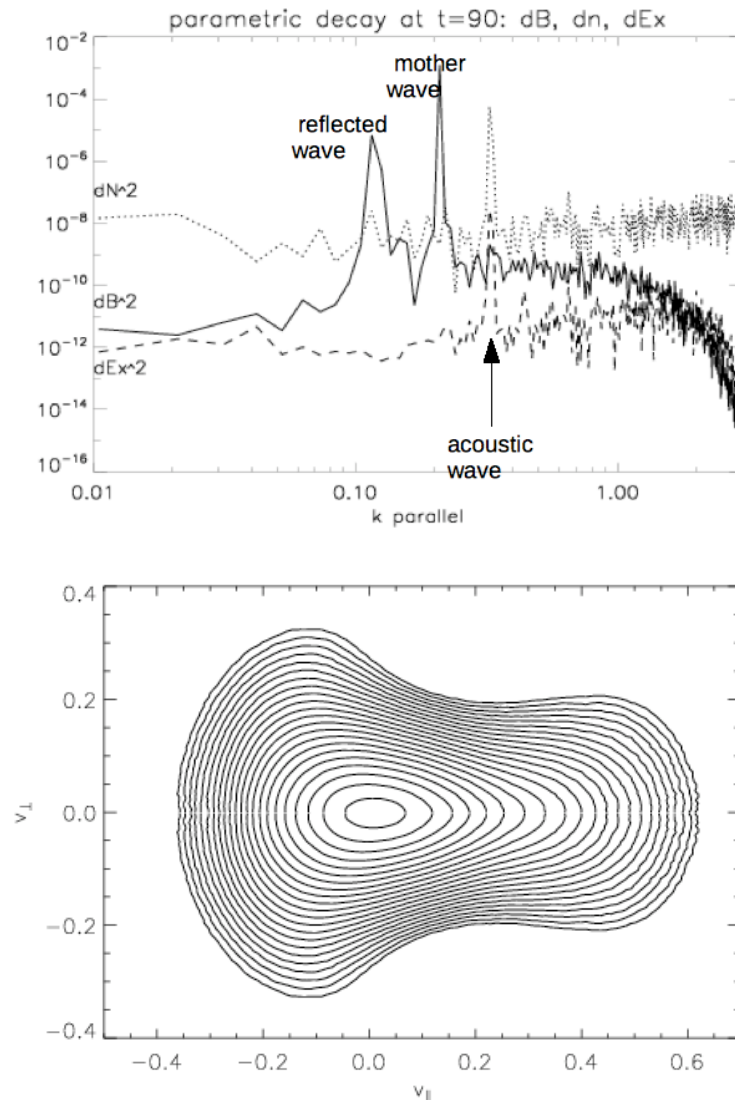
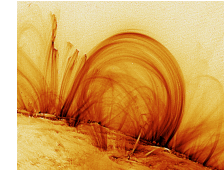


- L'espansione del vento solare avviene non adiabaticamente (Matteini et al., 2007). Energia viene ceduta ai protoni.



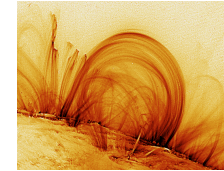
Simulazioni numeriche mostrano che il processo di riscaldamento può avvenire per interazione tra onde di Alfvén e protoni (Matteini et al., 2010)

Interazioni e instabilità onda particella



- Interazioni non lineari onda-onda (instabilità parametriche) possono generare onde di tipo acustico (Matteini et al., 2010)
- Il campo elettrico associato alle onde acustiche scalda ed accelera una parte dei protoni. Le funzioni di distribuzioni sono simili a quelle osservate nel vento solare (Matteini et al., 2010)

Piccola Missione ASI – Fase A svolta



ADAHeli *ADvanced Astronomy for HEliophysics*

✓ **Imaging spectroscopy in NIR and Visible**

Determine thermodynamical properties of fibrils, and relation to photospheric driver.

- **Imaging spectroscopy in Ca II 854.2 nm and photospheric lines**
- **Spectral resolution: 100,000 or higher**
- **Temporal resolution: full spectral scan in 5-10 s max.**
- **Duration: 2+ hrs**
- **FOV: 1'x1' minimum, containing magnetic network points.**
- **Pixel size: 0.1"**

✓ **Imaging spectro-polarimetry in NIR and Visible**

Magnetic field in chromospheric fibrils. “Magnetic transition zone” ($\beta=1$ surface)

- **Imaging spectro-polarimetry in one photospheric line and Ca II 854.2 nm. More spectral points are needed: at least 25 + 15.**
- **Spectral resolution: 100,000 or higher**
- **Temporal resolution: full polarimetric scan in both lines within 20-30 s.**
- **Duration: 1-2 hrs**
- **FOV: 1'x1' minimum, containing magnetic network points.**
- **Pixel size: 0.1"**

Solar Orbiter

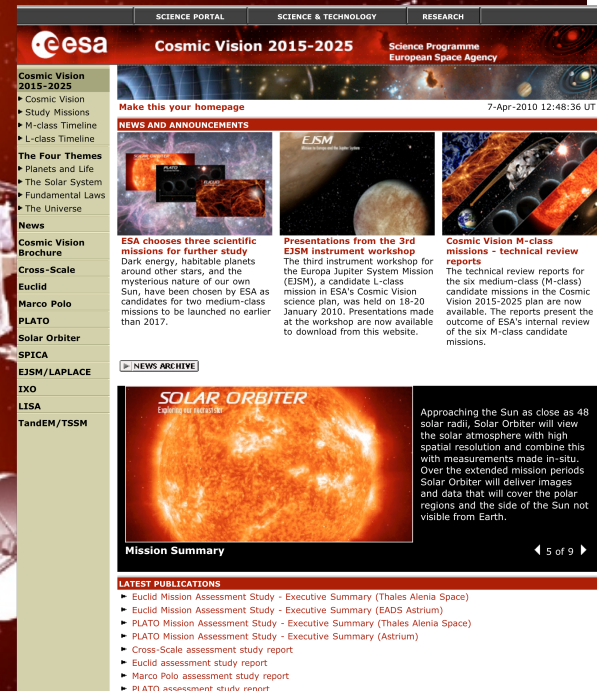
Exploring the Sun-Heliosphere Connection

Marco Velli

Università degli Studi, Firenze

and the Solar Orbiter Science Working Team

PARIGI 1 DICEMBRE 2009



SCIENCE PORTAL SCIENCE & TECHNOLOGY RESEARCH

esa Cosmic Vision 2015-2025 Science Programme European Space Agency

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NEWS AND ANNOUNCEMENTS

ESA chooses three scientific missions for further study
Dark energy, habitable planets around other stars, and the mysterious nature of our own Sun, have been chosen by ESA as candidates for two medium-class missions to be launched no earlier than 2017.

Presentations from the 3rd EISM instrument workshop
The third instrument workshop for the Europa Jupiter System Mission (EJSM), a candidate L-class mission in ESA's Cosmic Vision science plan, was held on 18-20 January 2010. Presentations made at the workshop are now available to download from this website.

Cosmic Vision M-class missions - technical review reports
The technical review reports for the six medium-class (M-class) candidate missions in the Cosmic Vision 2015-2025 plan are now available. The reports present the outcome of ESA's internal review of the six M-class candidate missions.

SOLAR ORBITER
Exploring the Sun-Heliosphere Connection

Approaching the Sun as close as 48 solar radii, Solar Orbiter will view the solar atmosphere with high spatial resolution and combine this with measurements made in-situ. Over the extended mission periods Solar Orbiter will deliver images and data that will cover the polar regions and the side of the Sun not visible from Earth.

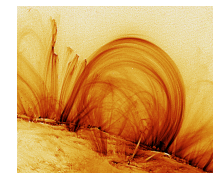
Mission Summary 5 of 9

LATEST PUBLICATIONS

- Euclid Mission Assessment Study - Executive Summary (Thales Alenia Space)
- Euclid Mission Assessment Study - Executive Summary (EADS Astrium)
- PLATO Mission Assessment Study - Executive Summary (Thales Alenia Space)
- PLATO Mission Assessment Study - Executive Summary (Astrium)
- Cross-Scale assessment study report
- Euclid assessment study report
- Marco Polo assessment study report
- PLATO assessment study report



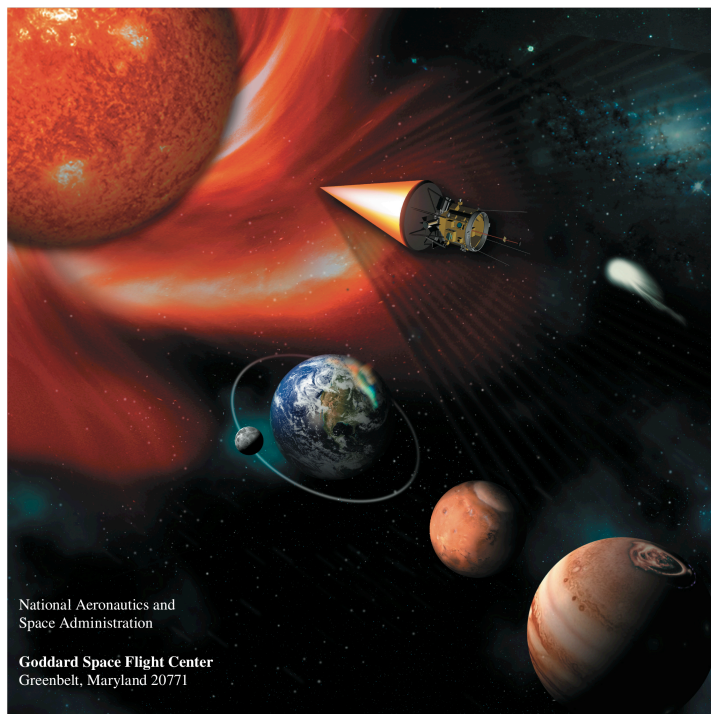
AO: Bando scaduto 26 Marzo Fase A Ottobre 2010



NASA/TM—2005-212786



Solar Probe: Report of the Science and Technology Definition Team

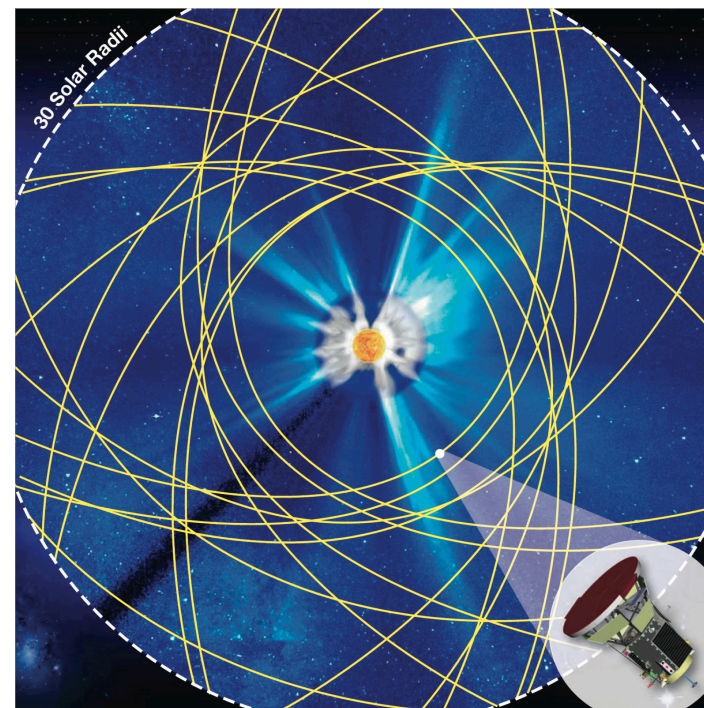


September 2005

NASA/TM—2008-214161

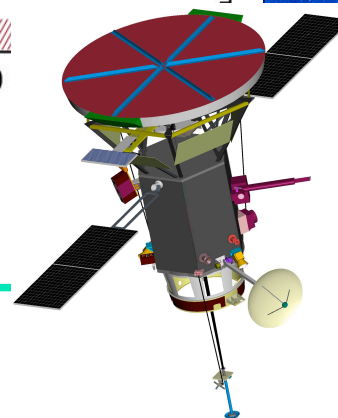
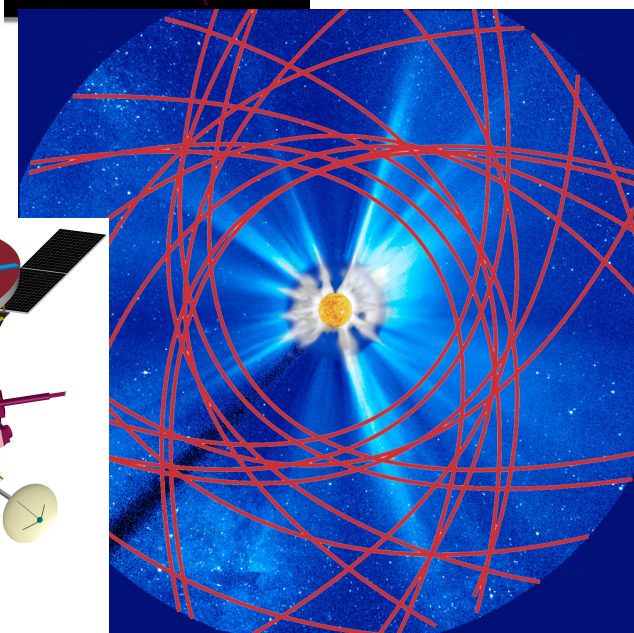
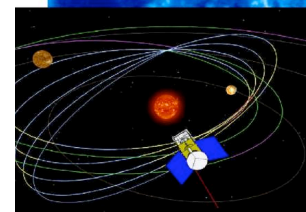
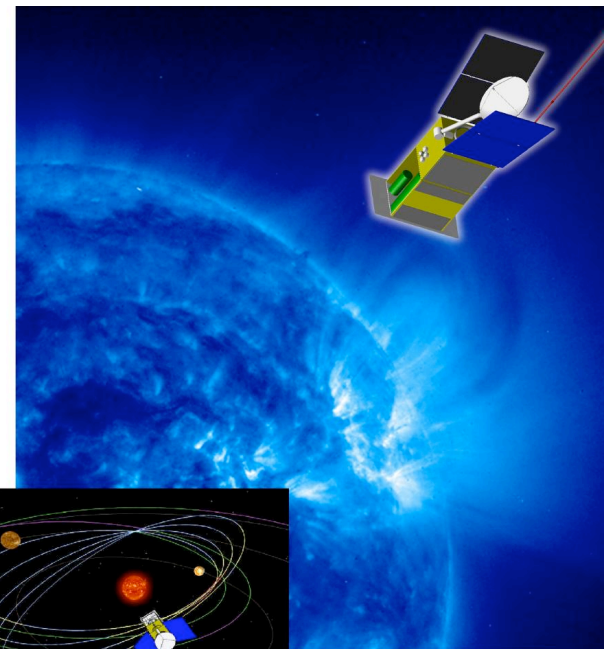
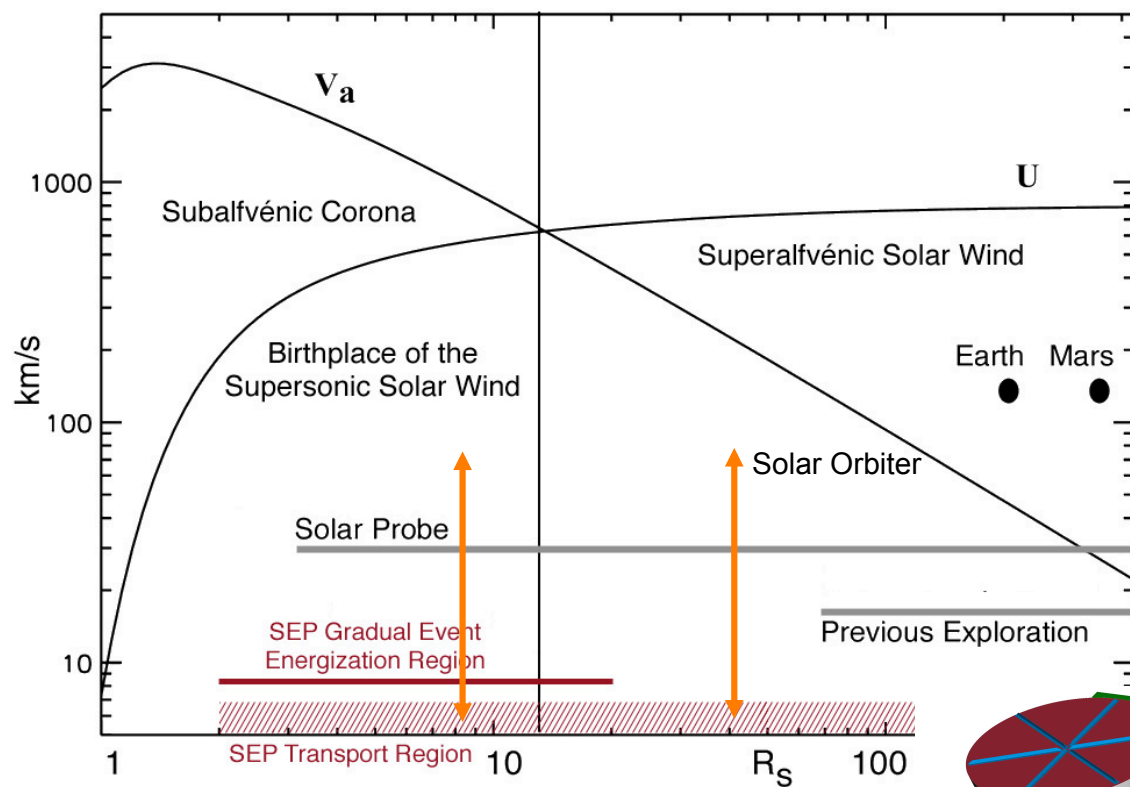


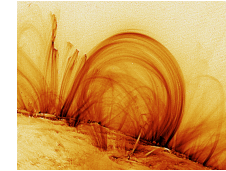
Solar Probe Plus: Report of the Science and Technology Definition Team



July 2008

Orbiter e Probe Plus





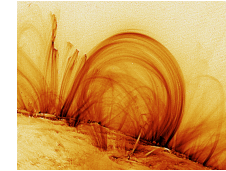
Astrofisica dei plasmi relativistici e degli oggetti compatti

Luca Del Zanna

ASAP – Arcetri Space & Astrophysical Plasmas

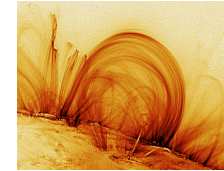
<http://www.astro.unifi.it/gruppi/plasmi/>

Dipartimento di Fisica e Astronomia – Università di Firenze
Sezione di Astronomia e Scienza dello Spazio



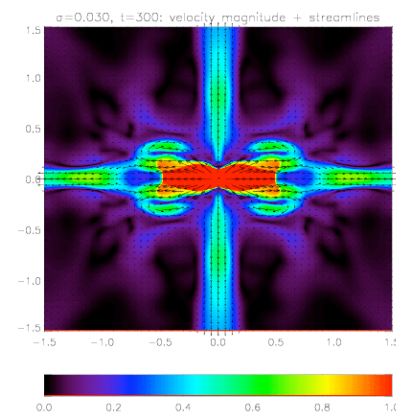
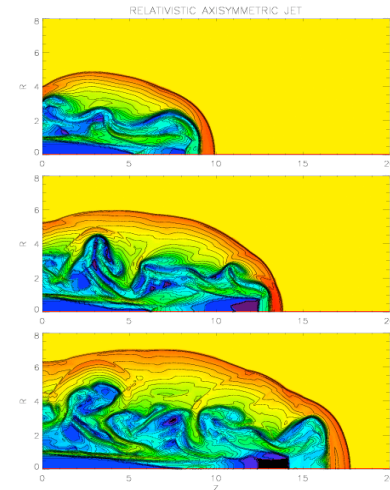
Presentazione

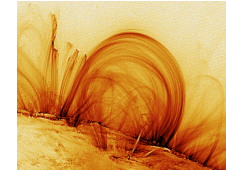
- Campo di ricerca: dinamica ed emissione non termica di plasmi relativistici (principalmente tramite modelli numerici)
- Il gruppo è completato da:
 - E. Amato, N. Bucciantini, D. Volpi, O. Zanotti, L. Franci
- Collaborazioni:
 - Arcetri-INAf, UC Berkeley, Nordita, AEI Potsdam, Univ. Illinois, Torino (INAf e UniTo)
- Pubblicazioni: circa 20 dal 2002 su riviste internazionali con referee
- Finanziamenti:
 - PRIN MIUR 2006 (PI F. Pacini), ASI 2007 (PI R. Bandiera), PRIN INAF 2008 (PI G. Bodo)



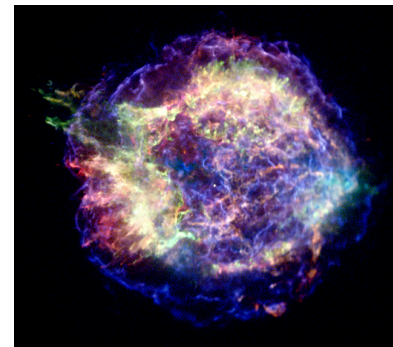
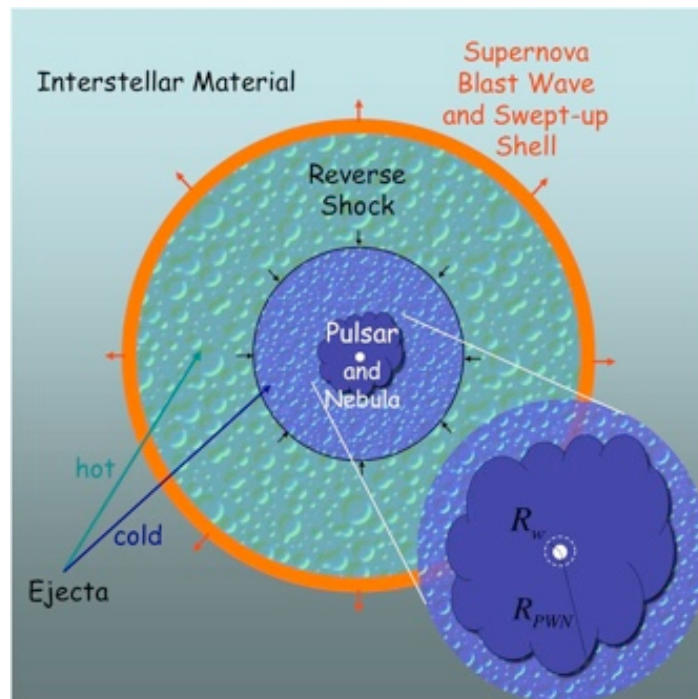
Simulazioni numeriche di plasmi relativistici

- E' stato sviluppato un codice per lo studio numerico dei plasmi relativistici, quali:
 - Getti da nuclei galattici attivi o sorgenti X compatte
 - Sorgenti di Gamma Ray Bursts
 - Venti di pulsar e resti di supernove
- Recente estensione a GR (ECHO code):
 - Accrescimento su buchi neri
 - Estrazione elettromagnetica di energia gravitazionale da buchi neri rotanti
 - Proto-stelle di neutroni e magnetars

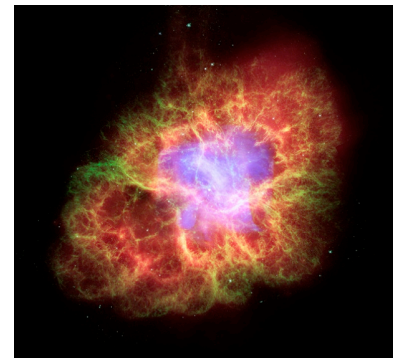




Modelli di Pulsar Wind Nebulae e loro emissione non termica

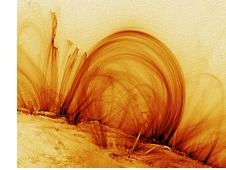


Shell-type



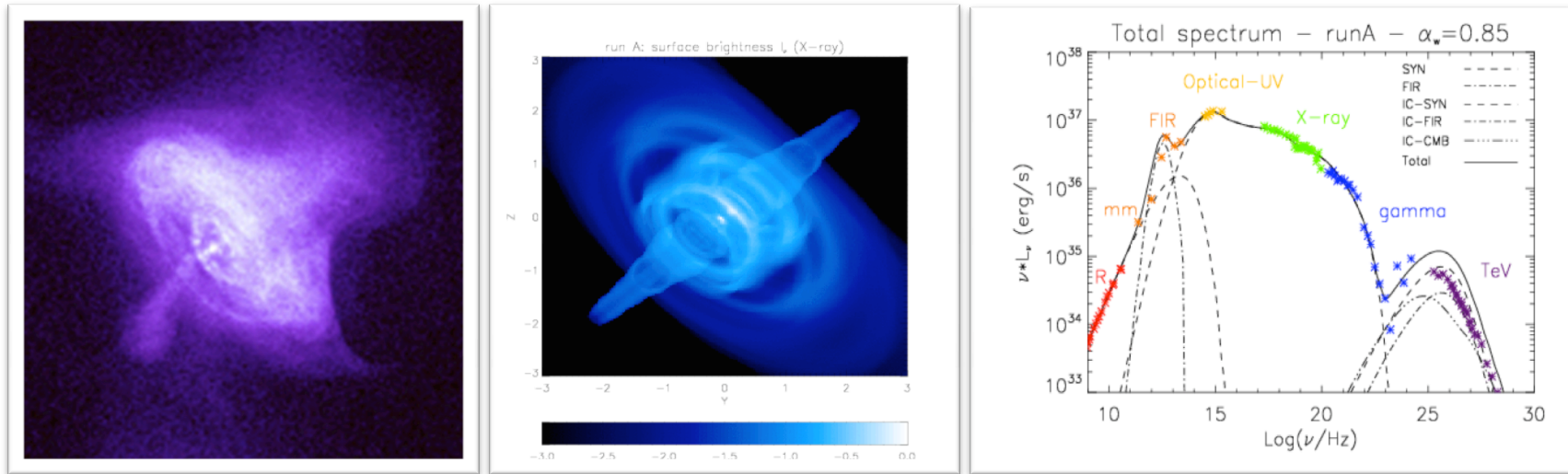
PWN

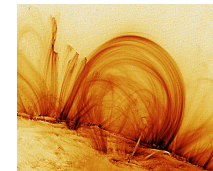
Gruppo Plasmi Astrofisici



Modelli di Pulsar Wind Nebulae e loro emissione non termica

- Mappe di brillantezza in X (Chandra e risultati del codice), spettro globale non termico dal radio al gamma (sincrotrone e Compton inverso di elettroni ultrarelativistici)
- La Crab Nebula e' un acceleratore cosmico al PeV!





Modelli di sorgenti GRBs

- Long duration GRBs potrebbero essere generati da getti collimati dovuti al vento ultrarelativistico di proto-magnetar, in alternativa al modello di collapsar.
- Stesso meccanismo MHD come avviene nelle PWNe?
- Simulazioni numeriche dei primi 10s di evoluzione di una ms proto-magnetar con $B \sim 10^{15}$ G sembrano confermare queste ipotesi (getto con Lorentz ~ 10).

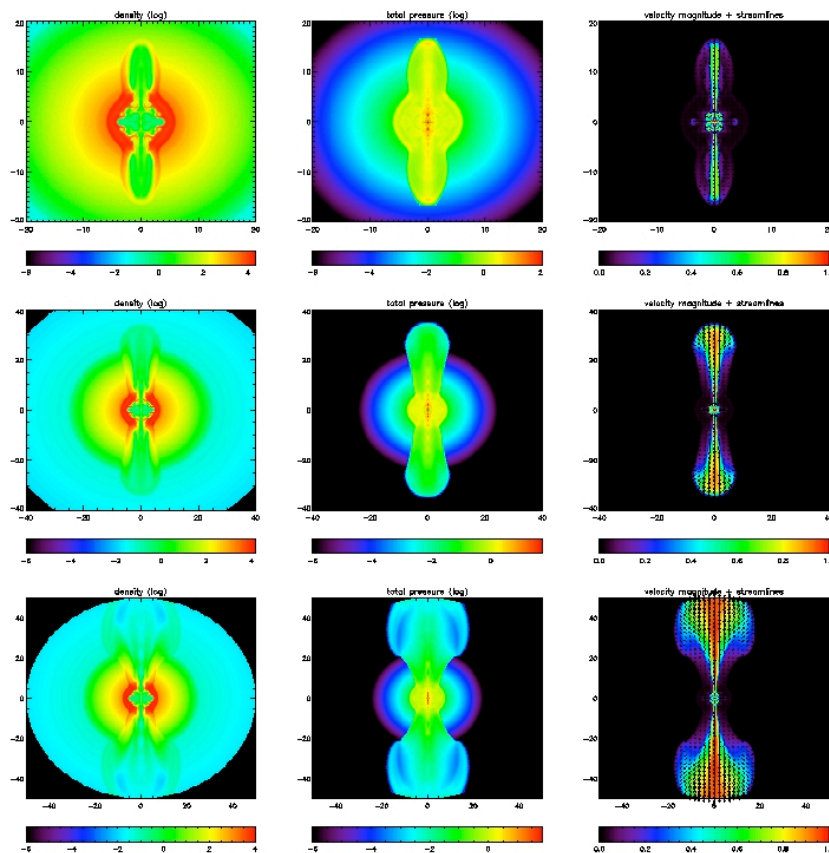
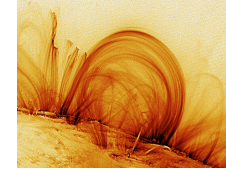
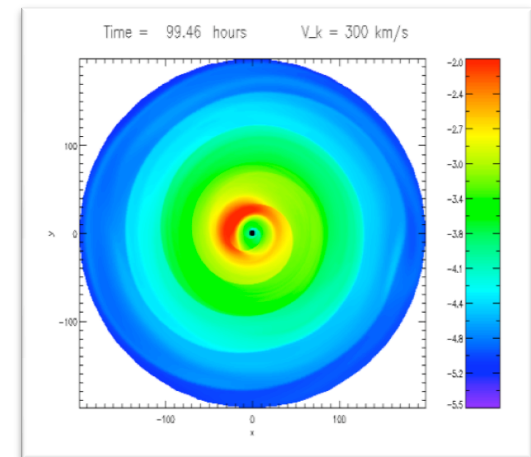
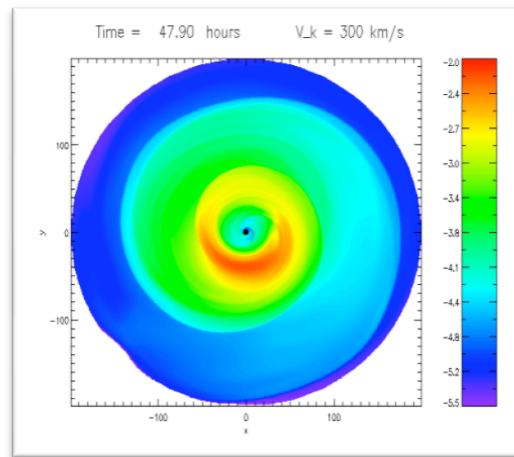
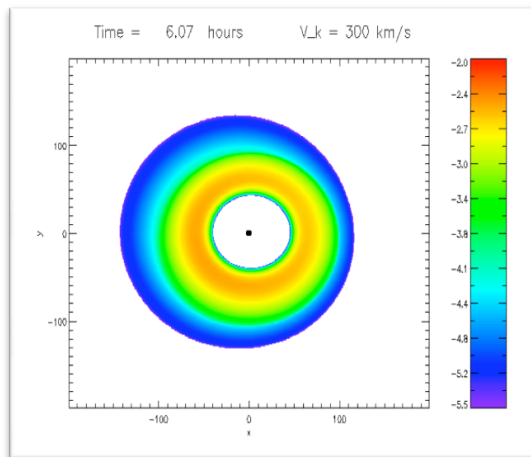


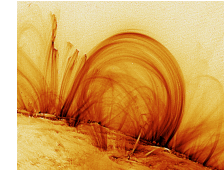
Figure 1. Evolution of a magnetized bubble inflated by a magnetar wind with $E = 10^{51}$ erg s $^{-1}$, $\gamma_w = 10$ and $\sigma = 0.1$, inside a $35 M_\odot$ progenitor star. From left to right: density (g cm $^{-3}$), pressure (g cm $^{-3}$ c 2) and velocity (in units of c). From top to bottom: snapshots at 4, 5 and 6 s after core bounce. Distances are in 10^9 cm; the radius of the progenitor star is 2.5×10^9 cm. By $t = 5$ s (middle panel) the jet has escaped the progenitor star.



Modelli di accrescimento asimmetrico su buco nero

- Due buchi neri supermassicci possono subire un evento di merging e fondersi in un unico buco nero circondato da un disco di accrescimento dotato di moto relativo: emissione di onde gravitazionali (LISA).
- Il tasso di accrescimento, la luminosità e l'emissione dalle regioni di gas *shockato* possono fornire preziose informazioni sull'evento.





Astrofisica computazionale: il codice ECHO

- La ricerca è rivolta anche ad aspetti computazionali: sviluppo di tecniche innovative per schemi shock-capturing di ordine elevato per MHD classica e relativistica
- Il codice ECHO (*Eulerian Conservative High Order code*):
 - Differenze finite, integrazione temporale Runge-Kutta
 - Ricostruzione spaziale upwind di ordine elevato
 - Solver di Riemann approssimati (LLF, HLL, HLLC)
 - Moduli fisici diversi: MHD, RMHD, GRMHD
 - Geometria arbitraria (es. cartesiana, sferica, Kerr, numerica)
 - *Upwind Constrained Transport* per il campo B solenoidale
 - Parallelizzazione tramite libreria MPI (*Messing Passing Interface*)