Solar and stellar plasma physics

Instituto de Astrofisica de Canarias
PI.: Fernando Moreno-Insertis

TEAM MEMBERS

- **Staff and senior postdocs:**
  - **Fernando Moreno-Insertis** (Full Professor, IAC & ULL)
  - **Lena Khomenko** (Senior postdoc, RyC, IAC & ULL)

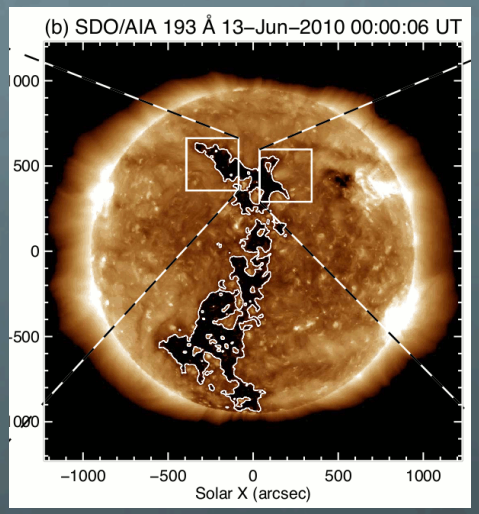
- **Postdocs:**
  - **Damian Fabbian** (PostDoc MINECO PN AYA)
  - **Nikola Vitas** (PostDoc ERC / EU)
  - **Manuel Luna** (PostDoc ERC / EU)

Computational Research Projects

- Flux emergence and giant eruptions in stars (F. Moreno-Insertis, K. Galsgaard, J. Martinez-Sykora, V. Hansteen)
- Element abundances in the cosmos: 3D magnetoconvection models (D. Fabbian, F. Moreno-Insertis, E. Khomenko, A. Nordlund)
- Wave propagation in the solar atmosphere: 3D computer simulations (E. Khomenko, T. Felipe, P. Cally)
- Partially ionized plasma models of the atmosphere (E. Khomenko, M. Collados, F. Moreno-Insertis)

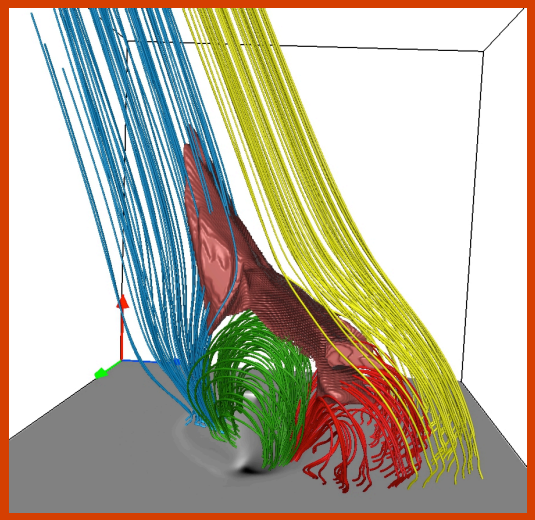
Research Highlight 1

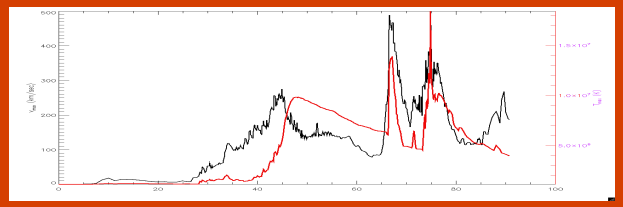
3D plasma physics models for solar X-ray jets and eruptions



- High-resolution satellite observations show frequent high-temperature and velocity jets followed by large eruptions
- There was no full 3D theoretical model for those spectacular events

- **We have obtained 3D computer models of this process which allow understanding of the underlying physical processes**





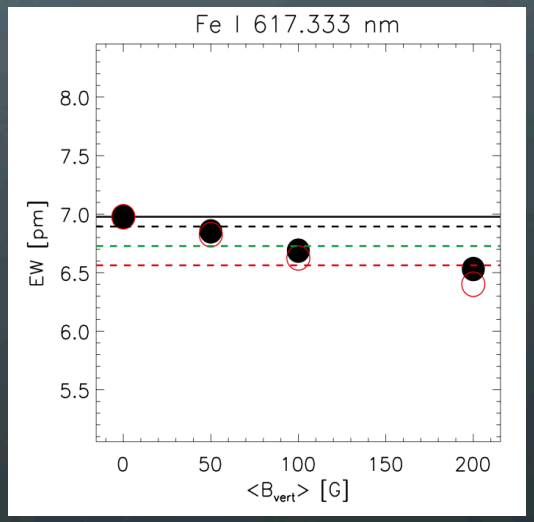
Moreno-Insertis et al, 2008, 2013

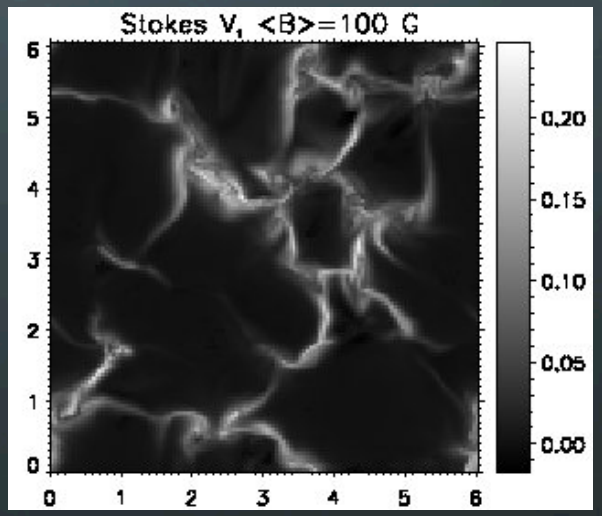
Research Highlight 2

Atomic abundances in the cosmos

- **The determination of cosmic abundances is crucial to understand the evolution of the Universe**
- **Simple 1D models of stellar atmospheres are insufficient .**
- **3D convection models so far did not contemplate the (crucial) magnetic effects**

- We are using 3D computer models of convection in the solar envelope **with magnetic field**
- We have **confirmed that magnetic effects are important** when determining cosmic abundances.

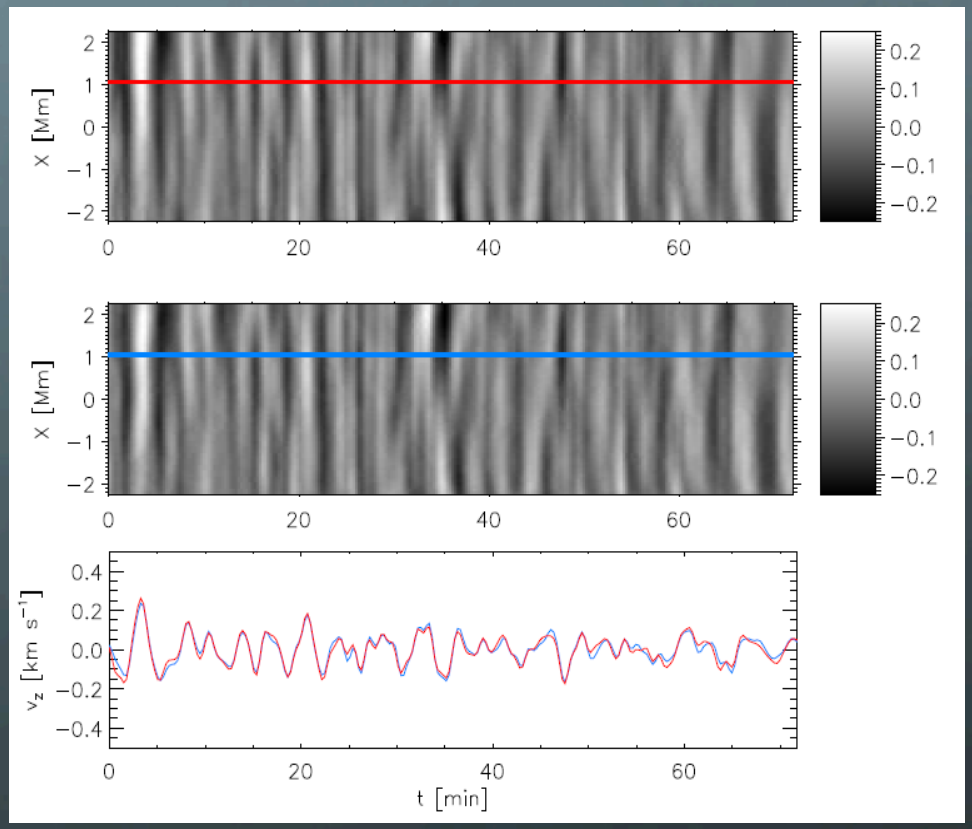




Fabbian, Moreno-Insertis, Khomenko & Nordlund (2012)

Research Highlight 3

Magnetofluid wave propagation in strongly stratified media



- Magnetofluid waves are fundamental to explain the structure of stellar atmospheres
- But the domain is strongly stratified by gravity!
- We have developed 3D computer models to study the structure of sunspots and other magnetic structures in the solar atmosphere
- We have performed simulations directly reproducing observed wave pattern in sunspots, explaining their nature as due to slow MHD waves.

T. Felipe et al (2011)

SUPERCOMPUTING TOOLS

- ***Computer codes*** *(all propietary)*
  - 3D magnetofluid code by E. Khomenko
    (AMR code with multifluid and radiation transfer capabilities)
  - 3D magnetohydrodynamics (MHD)+ radiation transfer code by A. Nordlund
  - 3D MHD code by K. Galsgaard + A. Nordlund

ALL HAVE EXCELLENT MPI-SCALING

- ***3D visualization:***
  - *NCAR's VAPOR software (public domain)*

- ***Supercomputing-time allocation***
  - PRACE, Tier-0, 2011-2012: 60 million CPU-h , JUGENE supercomputer (Jülich) *(with A. Nordlund et al)*
  - PRACE, Tier-0, 2012-2013: 64 million CPU-h , JUQUEEN supercomputer (Jülich) *(with A. Nordlund et al)*

- ***Contracts financed by the CSD2007-SyEC project:***
  - A.F. Rappazzo
  - L. Yelles Chaouche
  - D. Fabbian

- ***Organization of international conferences 2008-2012:***
  - SOLAIRE network meeting (Catania, Jan 2009)
  - 3rd FEW Flux Emergence Workshop (La Laguna, Nov 2009)
  - Solar magnetic connectivity conference (Teistungen, May 2011)
  - Magnetic connectivity through the Solar Partially Ionized Atmosphere. (Puerto de la Cruz, June 2012)

Grupo de Astrofísica y Cosmología Computacional

Universidad Autónoma de Madrid
PI.: Prof. Gustavo Yepes Alonso

PARTICIPANTES

- **Profesores Permanentes:**
  - Rosa Domínguez Tenreiro (UAM)
  - Gustavo Yepes Alonso (UAM)
  - Arturo Serna Ballester (UMH)
  - Fernando Atrio Barandela (USAL)
  - M. Angeles Gómez- Flechoso (UC M)

- **Postdocs:**
  - José Oñorbe Bernis (UCI)
  - A. César González García (IAC)
  - Steffen Knollmann (SyeC-UAM)
  - Tobias Goerdt (UAM)
  - A. Knebe (RyC- UAM)
  - Francisco J. Martínez Serrano (UMH)
  - D. Ceverino (JdC – UAM)
  - O. Zamora (SyeC – UAM)
  - F. Campos (Syec-UAM) (tech. eng.)

- **Estudiantes de doctorado:**
  - F. Sembolini (UAM)
  - P. Alprese (UAM)
  - A. C. Obreja (UAM)
  - S. Robles (UAM)
  - I. de Martino (USAL)
  - J. Vega (UAM)
  - E. Carlesi (UAM)
  - A. di Cinntio (UAM)
  - J. Casado (UAM)

TEMAS DE INVESTIGACIÓN

- ***Simulaciones cosmológicas de la formación de estructuras en el Universo a distintas escalas***

Supercúmulos, filamentos, vacíos etc.
(> 10 Mpc)

Cúmulos y Grupos de Galaxias (1-10 Mpc)

Galaxias (< 1 Mpc)

Galaxias espirales

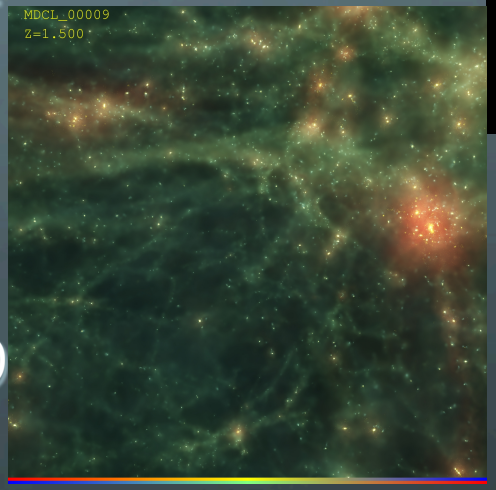
Galaxias elípticas

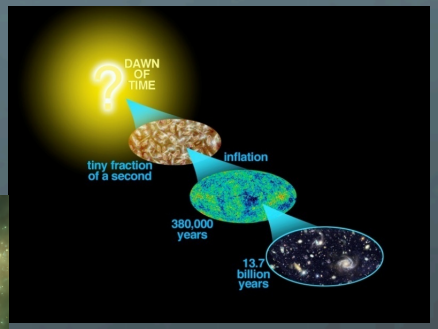
Galaxias enanas

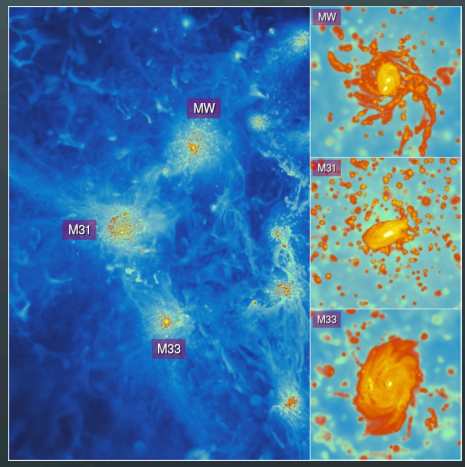
El Universo Local:

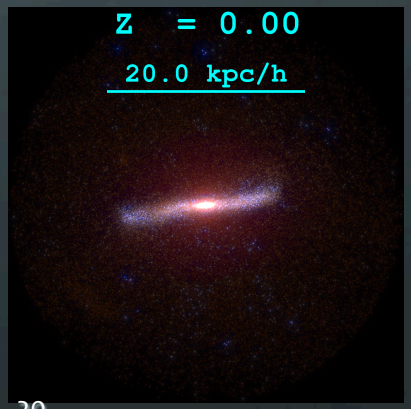
Proyecto CLUES

Colab. con Consolider MULTIDARK









Proyectos de Investigación

- Large Scale Structure (LSS) Simulations:
  - JubiLEE: (CubeP3M N-body simulations in Juropa)
    - P.I: Gottlober, S. Yepes G., Iliev, I. Martinez-Gonzalez, E. Diego, J.)
    - (6 Gpc)^3 Volume and 6000^3 (216 billions) particles.
    - Goal: Measure the Integrated Sach-Wolf effect + LSS clustering simultaneously for the first time in simulations
    - Simulations done:
      - 3072 Mpc^3 volume with 3072^3 particles completed
      - 6000 Mpc^3 volume with 6000^3 particles up to z=1
  - BigMD: (PRACE project GADGET N-body simulations)
    - P.I.: G. Yepes, F. Prada, A. Klypin, S. Gottlober, S: Hess
    - 22.5 million hours in SUPERMUC
    - GOAL: Make mock catalogs to compare with BOSS (SSDS III) results on galaxy clustering and B.A.O
      - 2.5 Gpc^3 volumes with 3840^3 particles in different cosmological models.
      - Collaboration between SyeC and MULTIDARK Consolider members

Proyectos de Investigación

- Cosmic Microwave Background Anisotropies
  - PLANCK collaboration (F. Atrio-Barandela)
    - Implementation of a pipeline to estimate the residual dipole in galaxy clusters from WMAP and PLANCK data.
    - Numerical Method to estimate the power spectrum of density fluctuations in dark energy models from the LCDM model.

- Galaxy Cluster Simulations
  - MUSIC (Multidark Simulations of galaxy Clusters)
    - PI: G. Yepes, S. Gottolober, F. Sembolini, J. Vega, M. de Petris)
    - GOAL: Complete volume limited sample of resimulated galaxy clusters from MULTIDARK simulation (http://www.multidark.org)
      - More than 500 clusters resimulated with gas physics and radiative modeling.
      - MUSIC: Large database of numerical clusters that is publicly available thru: http://music.ft.uam.es

MUSIC
MUltidark
SImulations
of galaxy
Clusters

Proyectos de Investigación

- **Galaxy Formation Simulations:**

- **Ly-α and Ly-Break galaxies at High Redshift**
  - **(CURIE+ MARENOSTRUM)**
  - P.I: G. Yepes, S. Knollmann, S. Gottlober, D: Ceverino, J. Forero, F. Prada, T. Goerdt, A. Knebe. 5 Million hours in CURIE. CODES: (GINNUGAGAP + GADGET + ART + CLARA(RT code)
  - GOAL: Simulate from the first galaxies in the universe up to z=3. Compare with High-z Lya and Lyb galaxies using a large statistical sample of simulated objects
  - 200 Mpc Volume. Zooming technique to resimulate a complete volume limited sample of individual objects down to a maximum resolution of 16384^3 effective particles.

CLUES
Constrained Local UniversE Simulations

http://www.clues-project.org)

  - **Juropa, Pleiades, SuperMUC, MareNostrum, + DECI proposals**
  - P.Is: G. Yepes, S. Gottlober and Y. Hoffman
  - GOAL: Simulations of the Formation of the Local Group and Local Universe.
  - CODES (GAGDET- ART hydro codes +SFR modeling)
    - Different models to account for radiative processes

- **GALFOBS + GALACTICA (BSC ALTIX 4700 system + DECI proposal)**
  - P.I. R. Domínguez Tenreiro, J. Oñorbe, A. Serna, F. Martinez-Serrano
  - GOAL: Simulations of galaxy formation in an 80 Mpc box with different resolutions using zooming techniques.
  - CODE: OpenMP P-DEVA SPH code.

Recursos computacionales conseguidos 2009-2013

- **PRACE:**
  - Simulations of High-z Universe. (P.I. G. Yepes) (5 Millones horas concedidas en CURIE 2011 + 2.5 milions in 2012)
  - Large Scale Simulations (P.I. G. Yepes 22.5 Million hours in Supermuc, 2012)
  - Reionization of the Local Universe (P.I. Iiev. 25 milion hours in Supermuc 2012
- **Red Española Supercomputación (RES):**
  - Marenostrum Numerical Cosmology Project (MNCP) (P.I. G. Yepes)
    - (> 20 Millones cpu hours in 1 MareNostrum 2008-2013)
  - GALFOBS (P.I. R. Domíguez Tenreiro). (400 K horas en BSC Altix)
  - GALACTICA (P.I. R. Domíguez Tenreiro). (200 K horas en BSC Altix)
- **Leibnitz RechenZentrum (LRZ).**
  - The Short Scales structure problem of CDM: (P.I. S. Gottlöber, AIP). (20 Million hours in SuperMUC 2008-2013)
- **Jülich Supercomputer Center (FZJ)**
  - The CLUES project (S. Gottlober, G. Yepes, Y. Hoffman) (1 M hours in Juropa)
  - The JuBiLEE project. (S. Gottlober, G. Yepes, I. Iliev et al). A 6000^3 particle simulation in 6 Gpc volume. (5 Million hours in Julich.)

DESARROLLOS DE SOFTWARE

- ***GENERADOR DE CONDICIONES INICIALES TOTALMENTE MPI -PARALELO:***
  - GINNUNGAGAP (full MPI cosmological initial conditions generator) S. Knollmann
- ***CODIGOS DE SIMULACIÓN:***
  - **P-DEVA (OPENMP) . Paso a MPI (A. Serna, O. Zamora, en coll. Con J. Cela del BSC)**
- ***ANÁLISIS Y VISUALIZACIÓN DE SIMULACIONES:***
  - AHF (Amiga Halo Finder): Codigo de identificacion de halos en Simulaciones: OPENMP+MPI (S. Knollmann)
  - JUMP: Detector Algorithm, para encontrar con precisión posiciones y masas estelares de satélites dentro de halos. (Oñorbe, Dominguez-T.)
  - Desarrollo de plataforma web para bases de datos en MySQL. Colaboracion con el Leibinz Astrophysical Institut de Potsdam. (F. Campos). Desarrollo de un motor sql de *queries* paralelo: DAIQUIRI en opensource.
    - http://jubilee-project.org
    - http://music.ft.uam.es
    - http://curiehz.ft.uam.es

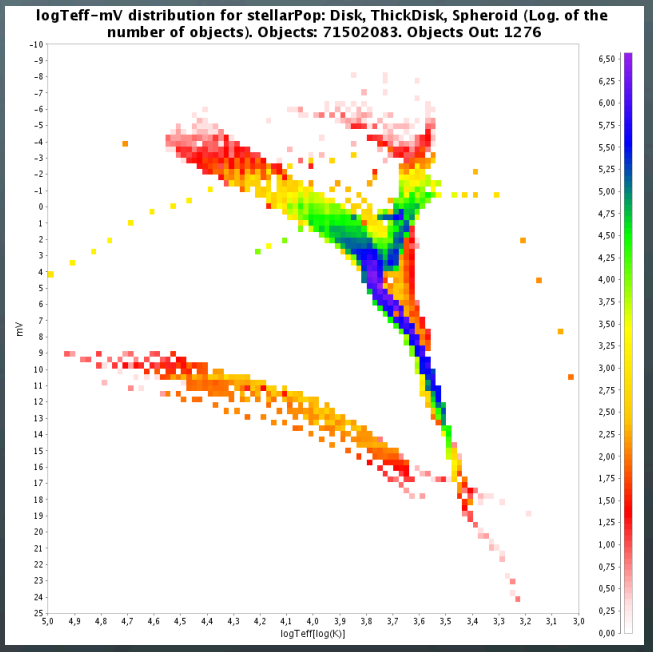
Data simulation and processing for the Gaia space mission

University of Barcelona
PI.: Prof. Jordi Torra

Proffessors: F. Figueras, C. Jordi, X. Luri, E. Masana
Researchers & postdocs: C. Fabricius, L. Balaguer, J. Portell, M. Romero, J.M. Carrasco, H. Voss, M. Weiler, M. Czekaj, A. Fries
Engineers & students: J. Castañeda, F. Julbe, D. Molina, M. Clotet, N. Garralda, E. Gallardo, R. Borrachero, T. Sagristà, S. Roca, J. González, E. Antiche

Gaia-UB: Scientific milestones

- Simulations for testing the whole Gaia-DPAC processing chain including Operation Rehearsals: full-scale sky simulations, long-term reduced-density simulations
- Simulations of the Gaia catalogue
- High-realism instrument & Universe models
- Raw data re-processing and calibration system (IDU): detailed design and first implementation, test on 1.5 years of downscaled data (~2%), assessing feasibility of concept and correct integration in the whole Gaia processing chain

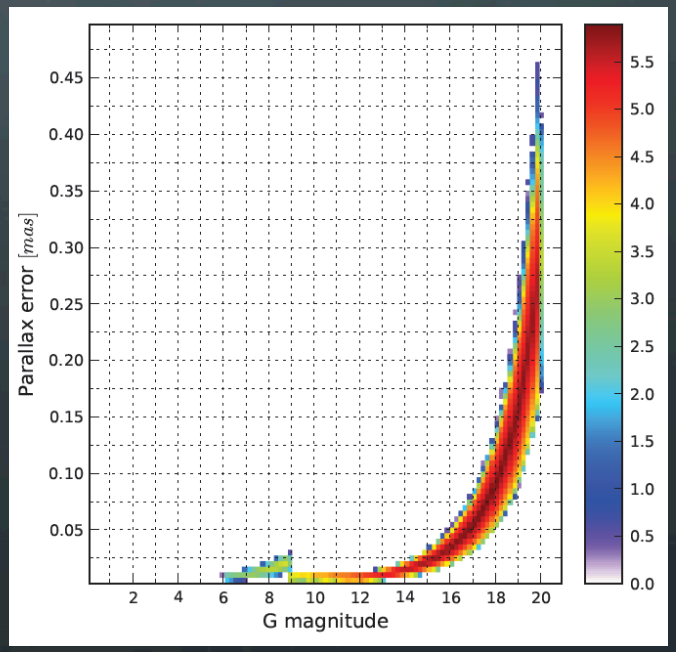


Gaia Simulations

HR diagram of the Operations Rehearsal 2 dataset

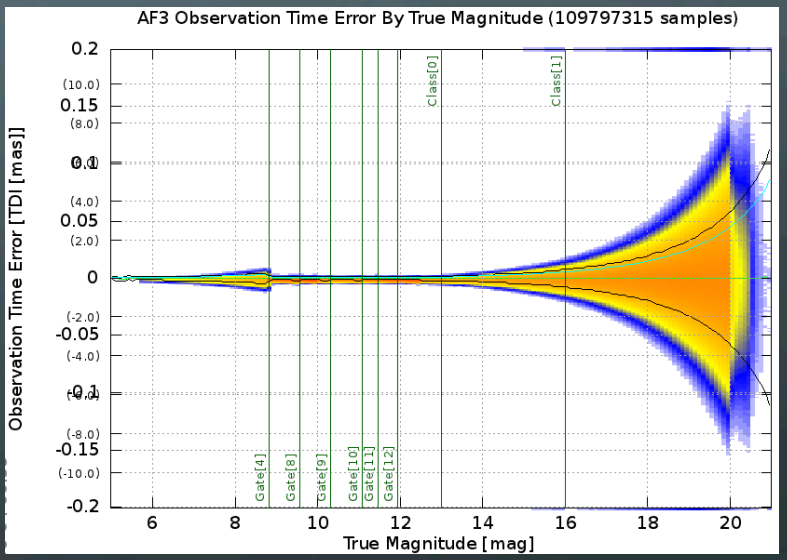
Parallax error

Distribution of the errors in parallax in a simulated Gaia catalogue



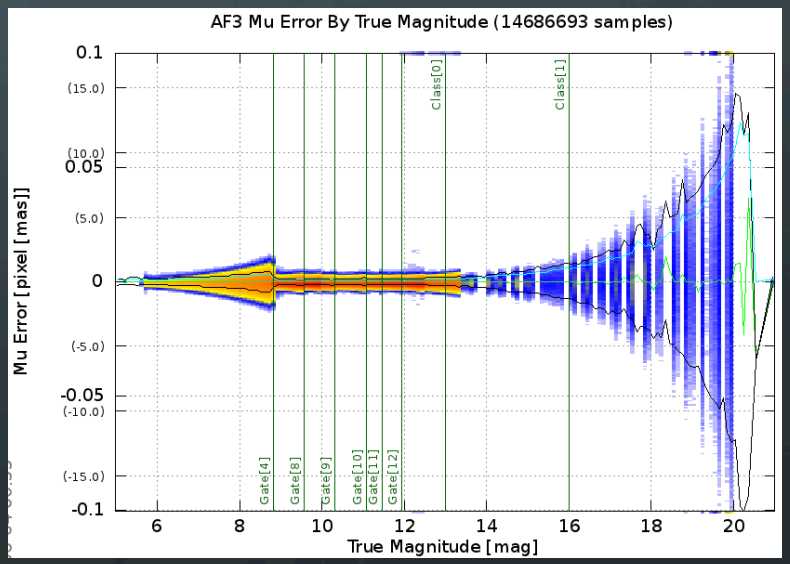
Gaia-UB: Computational milestones

- Optimization of GASS code (memory, local data caching, multi-threading)
- Simulation of several days of observations with realistic sky density (optimisation of memory usage and caches)
- Improvement of HDF5 storage library for raw Gaia data, including compression
- Routine handling (quick analysis and backup) of data transfers to and from ESAC (Madrid) at up to 300 Mbps through an interface server
- Execution of IDU on 1.5 years of downsized data (700M observations, equiv. 8 days mission) in just 5 days using up to 84 MareNostrum II nodes



Gaia raw data re-processing system (IDU):

Determination of the along-scan and across-scan positions of the observations



Gaia-UB: Consolider and collaborations

- Consolider SyeC key for:
  - Contract for two technical positions (Y. Isasi and R. Borrachero)
  - Efficient software deployment (BSC) : Grid SS and COMPS SS
  - PhD Thesis advised by UB+BSC (A. Fries)
  - MPJ-Cache (col. UdC)
- Collaborations:
  - BSC: efficient software deployment in MareNostrum-III, Interface Server support, computational time in MareNostrum
  - Universidade da Coruña: MPJ libraries
- Mass media and outreach:
  - TV, radio, newspapers
  - "Gaia Video": DVD and YouTube with UB having leading role