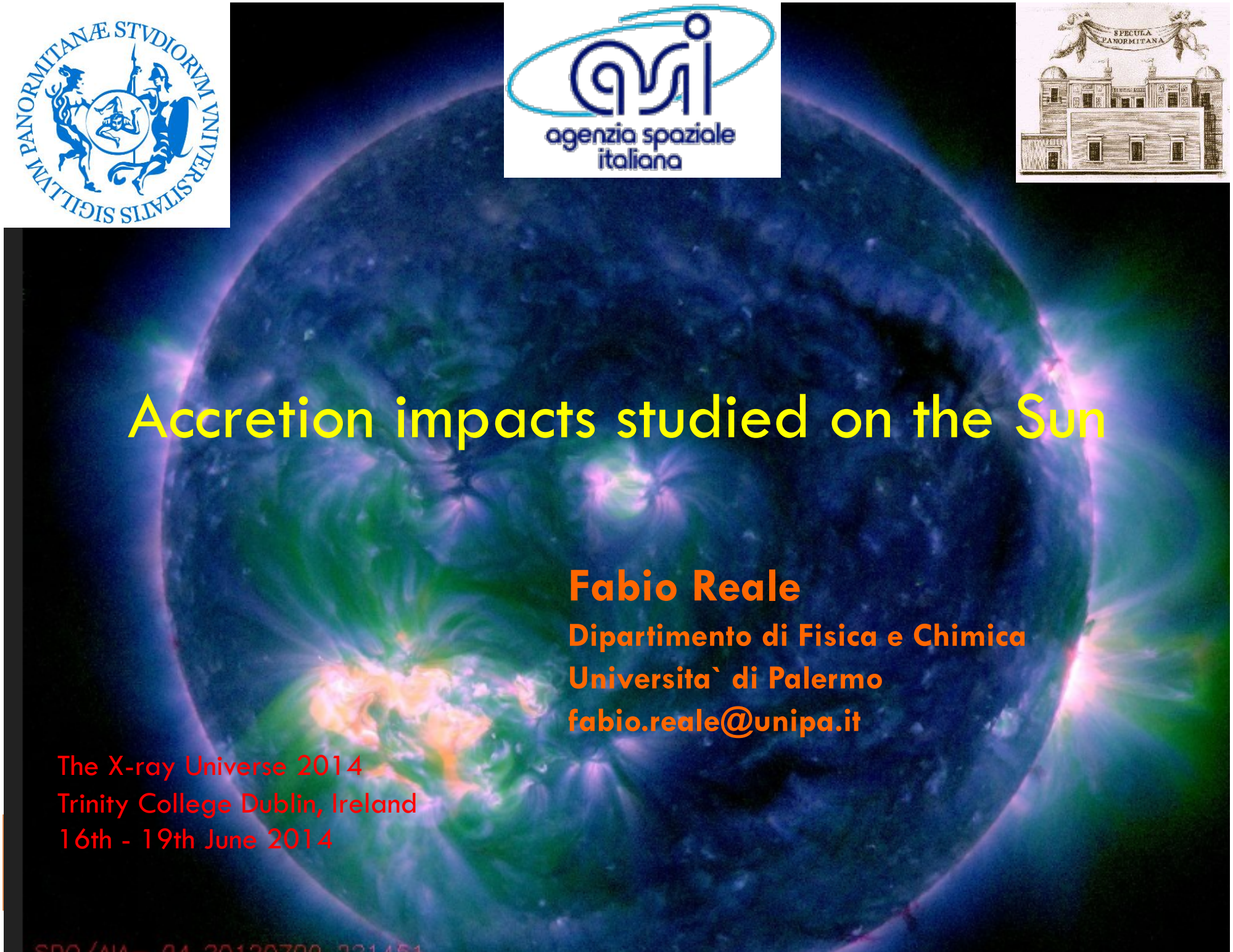

Accretion impacts studied on the Sun

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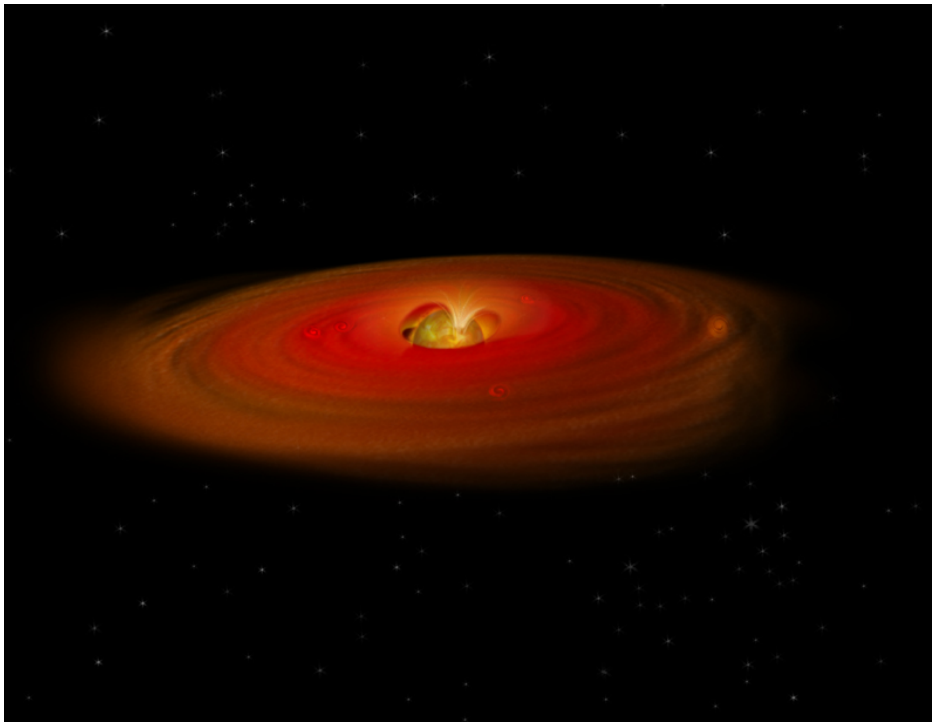
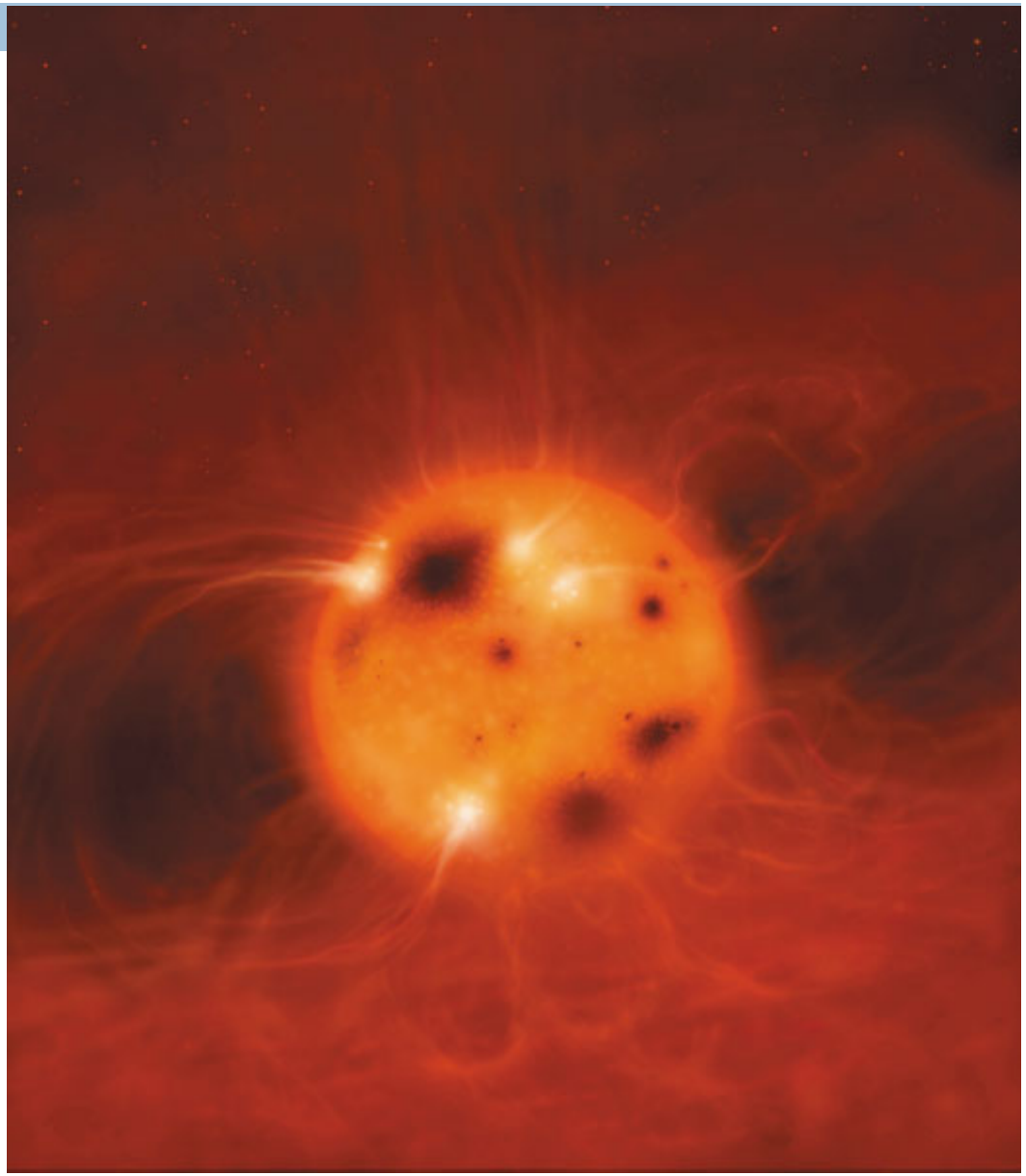
The X-ray Universe 2014
Trinity College Dublin, Ireland
16th - 19th June 2014

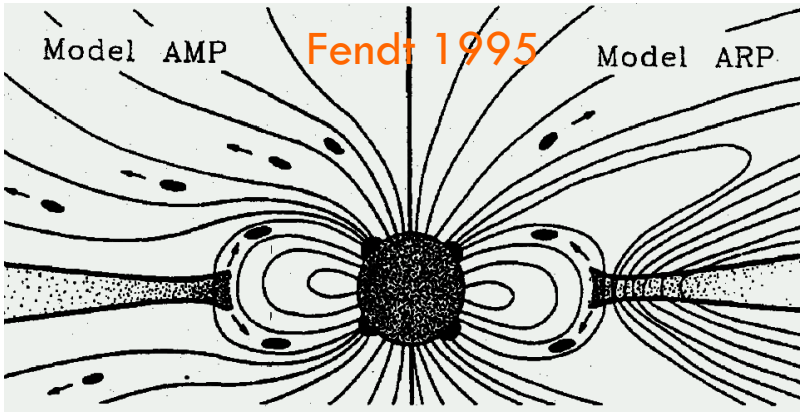
Accretion flows on young stars (T Tauri)

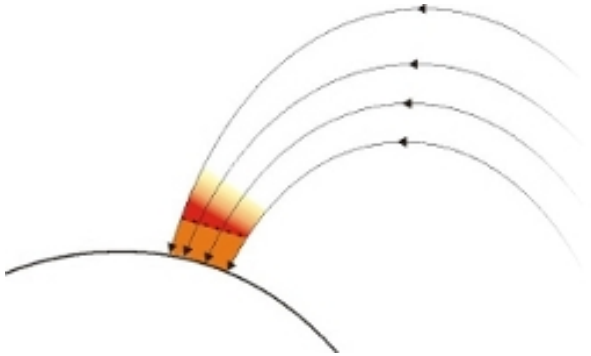




Accretion in YSO

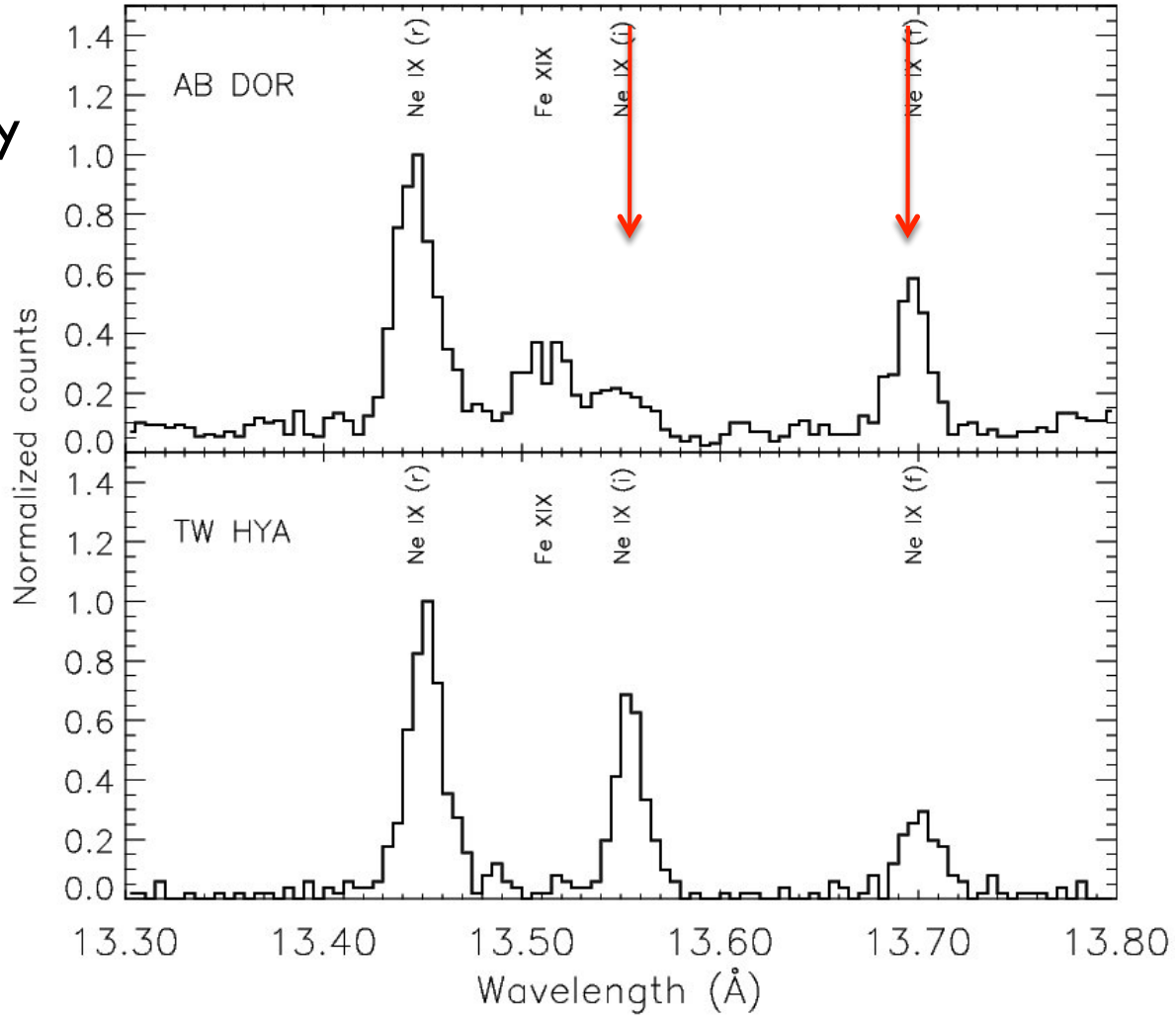
- Disk-star: magnetic funnels (Königl 1991)
- Accretion flows: V≫100 km/s
- Impact: IR/V/UV excess (Bertout+ 1988, Natta+ 2006, Herczeg & Hillenbrand 2008, Donati+ 2008)
- +Soft X-ray excess (Chandra, XMM-Newton): dense ($10^{11} - 10^{13}$ cm^{-3}) and hot (2-4 MK) plasma (Kastner + 2002, Argiroffi+ 2004, 2007, Schmitt+ 2005, Guenther+ 2007, Telleschi+ 2007)





X-ray Accretion in T Tauri stars

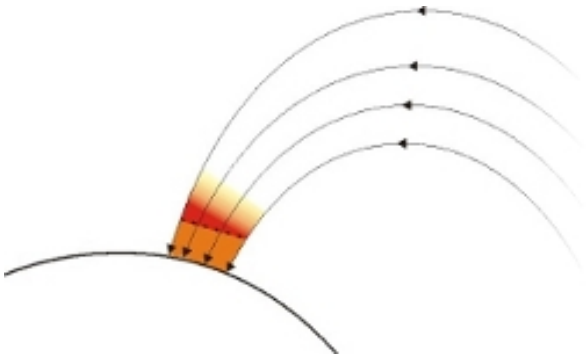
- High density in relatively cool X-ray lines (e.g. NeIX, low f/i ratio)



Argiroffi+ 2004, ApJ, 609, 925.

Accretion impacts

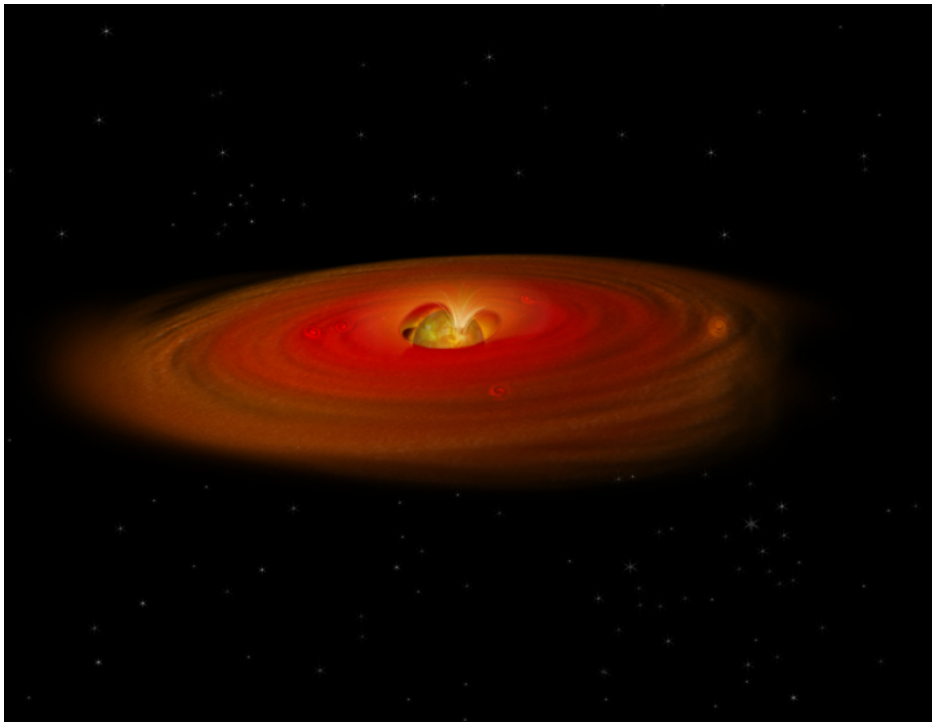
- Models explain the X-ray emission from steady impact shock of continuous accretion column (e.g. Sacco+ 2010)

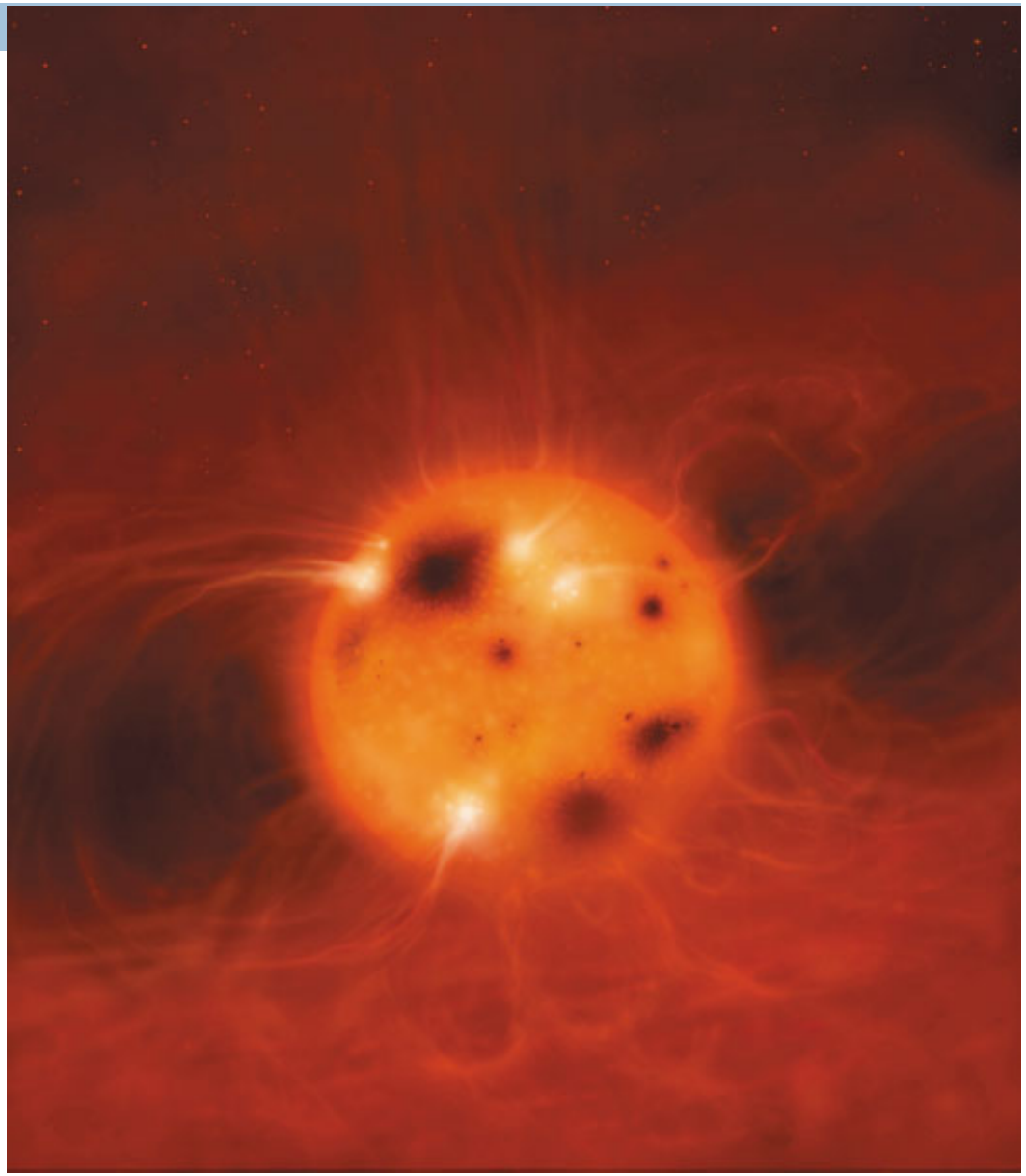


- Questions:
  - Accretion rate: UV/V/NIR $\gg$ X. Why?
  - What is the role of absorption?
  - What is the role of stream structuring?

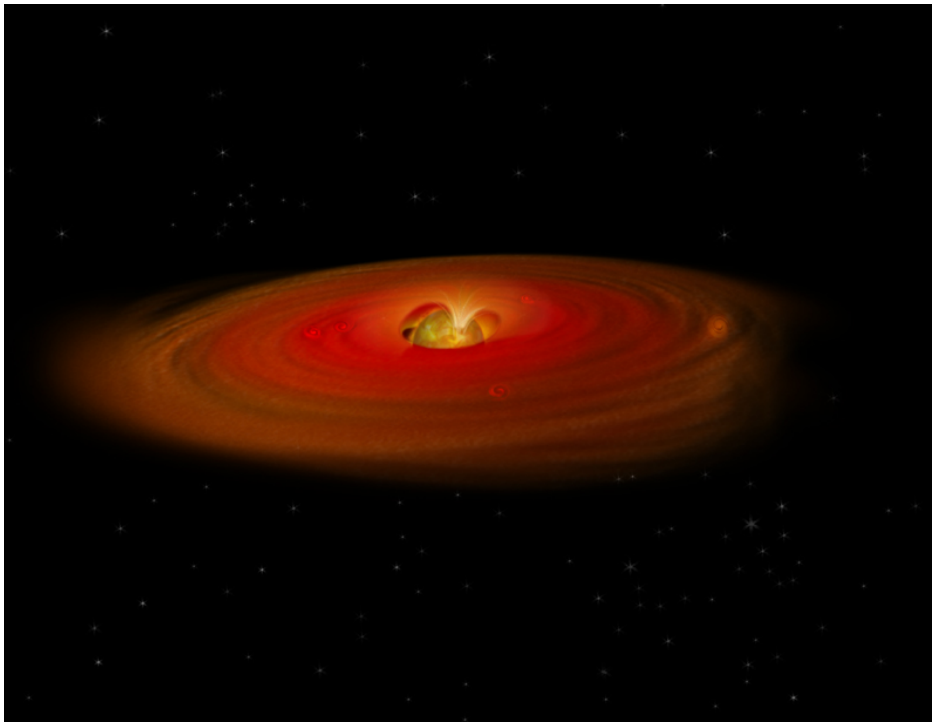
- Concept: use the Sun as a template

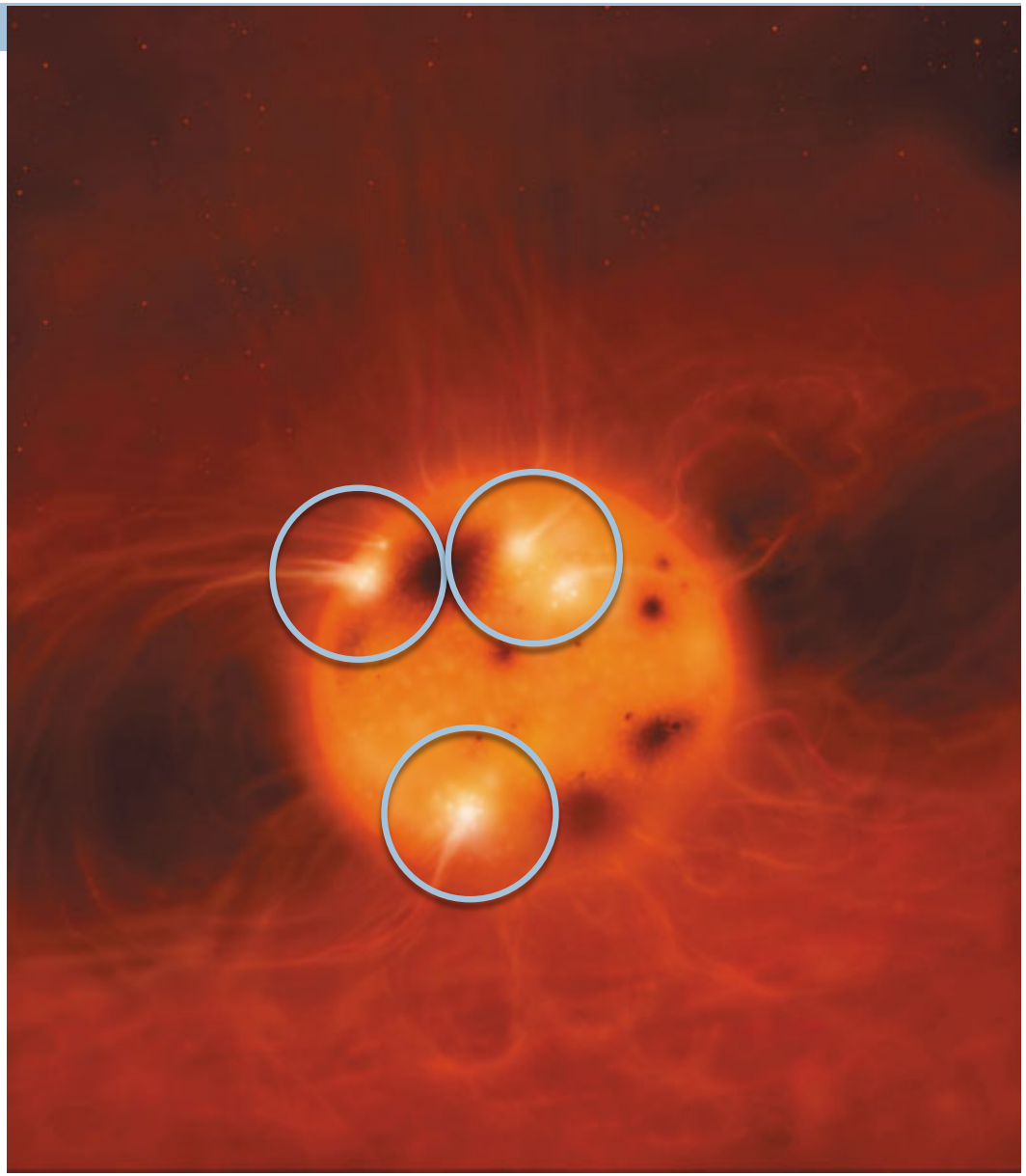
Accretion flows: impact region

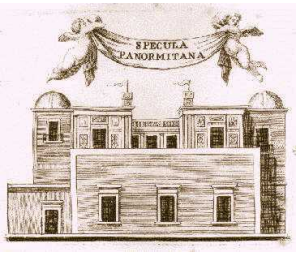




Accretion flows: impact region







Bright hot impacts by erupted fragments falling back on the Sun: a template for stellar accretion

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Salvatore Orlando (INAF-OAPa)
Paola Testa (Harvard CfA, USA)
Giovanni Peres (Univ. Palermo)
Enrico Landi (Univ. Michigan, USA)
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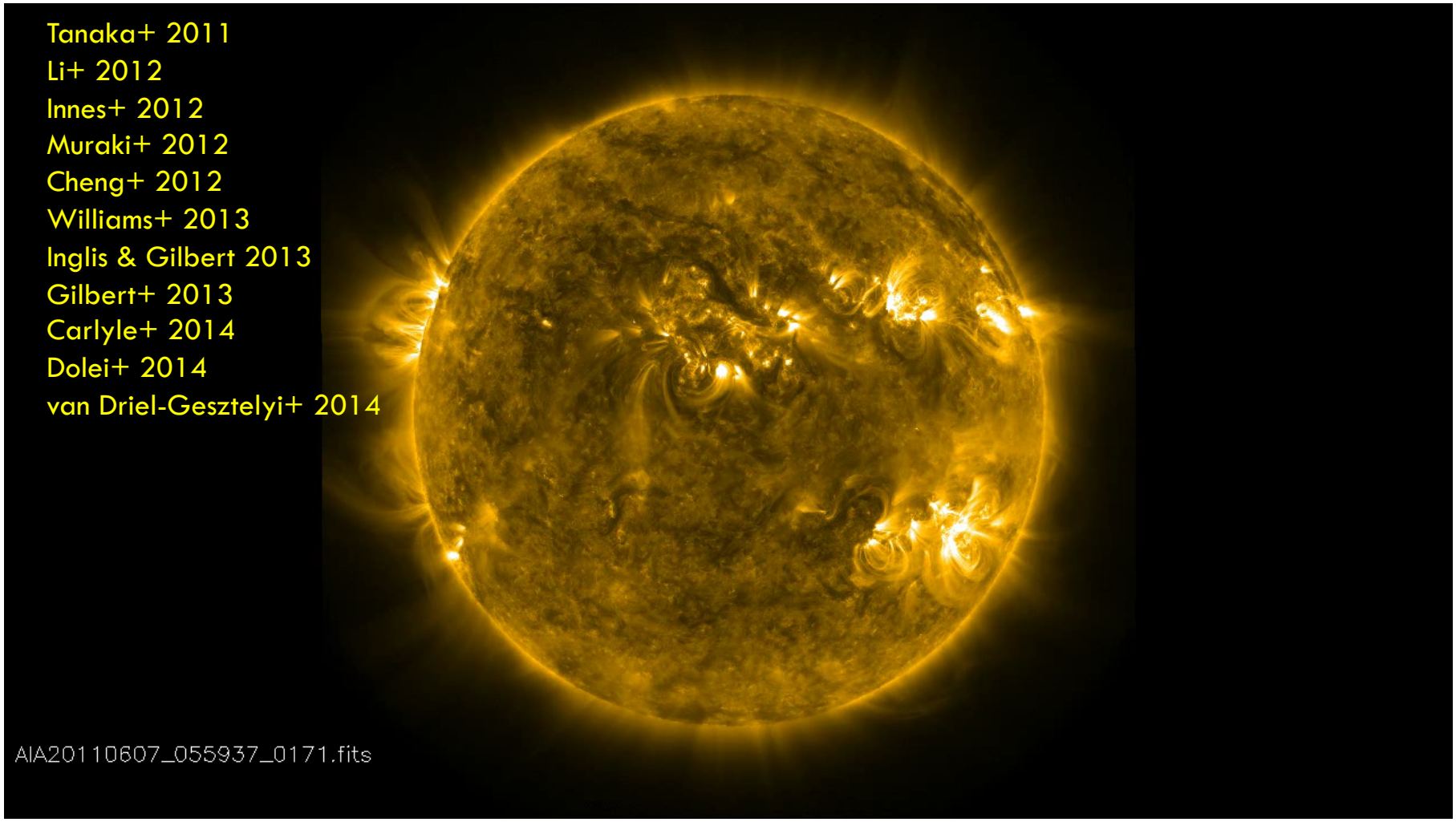
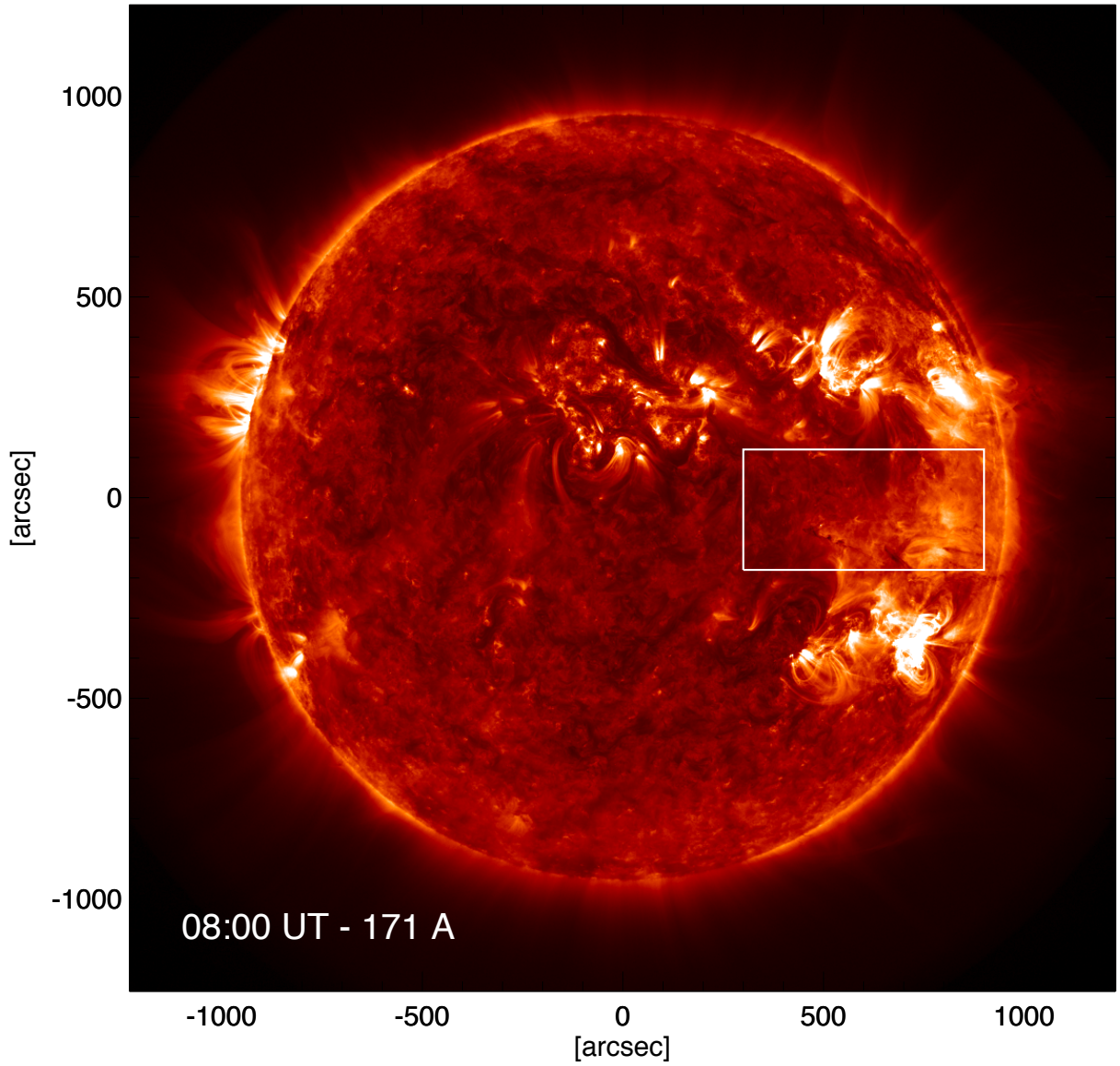
Science
AAAS

Bright Hot Impacts by Erupted Fragments Falling Back on the Sun: A Template for Stellar Accretion
Fabio Reale *et al.*
Science **341**, 251 (2013);
DOI: 10.1126/science.1235692

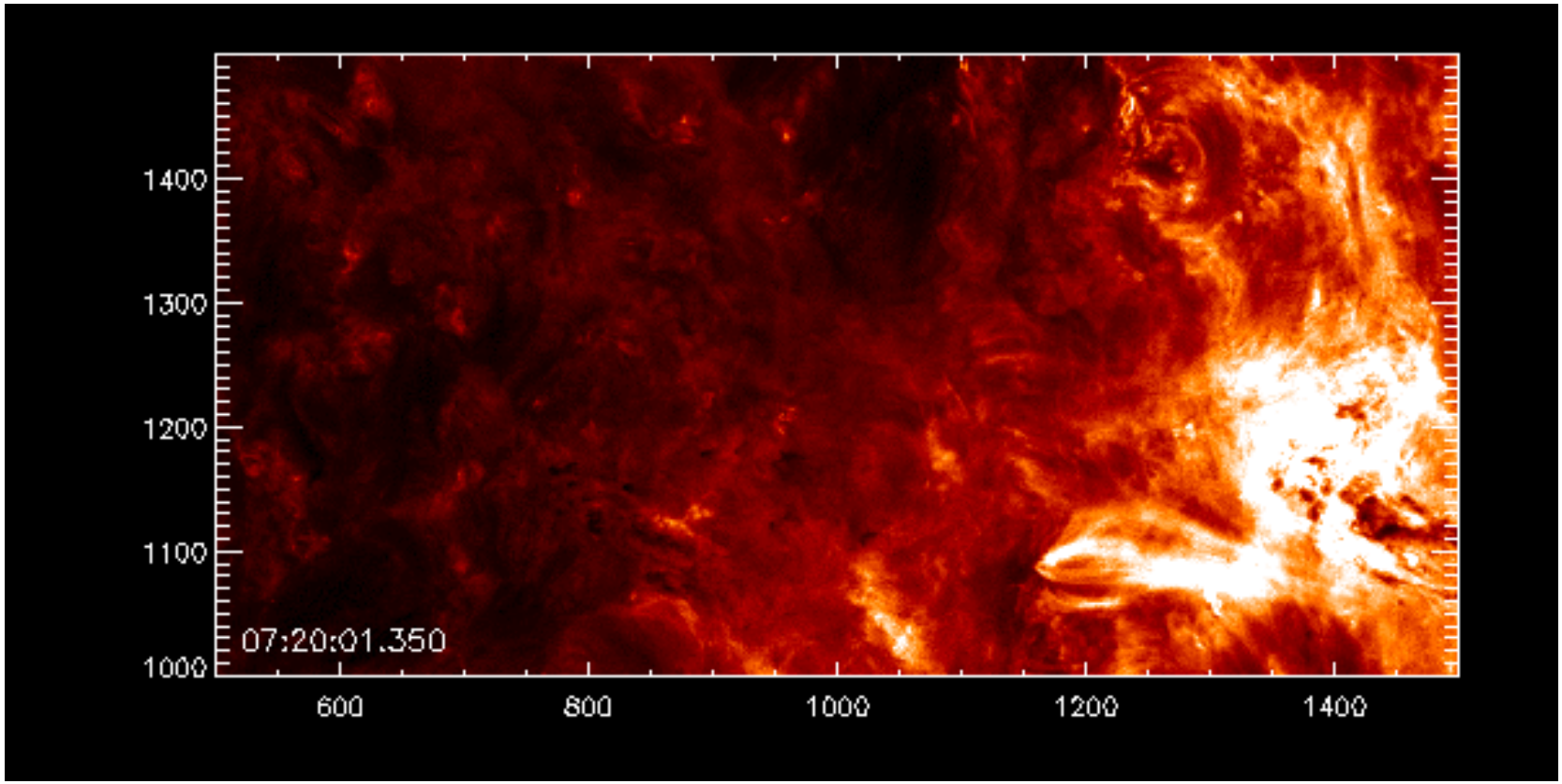
The flare and the eruption: 7 June 2011



The impacts region

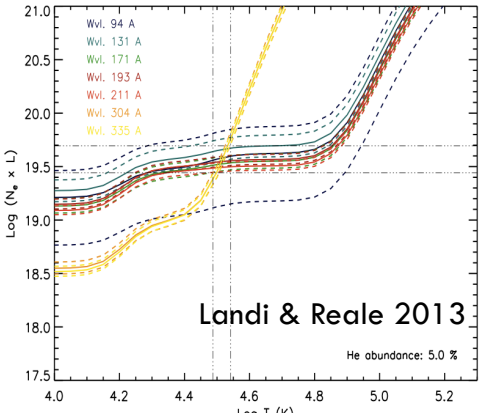


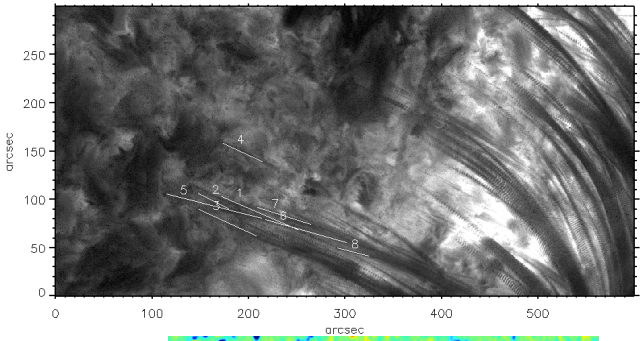
Close up: 171 A (Fe IX, logT~5.9)

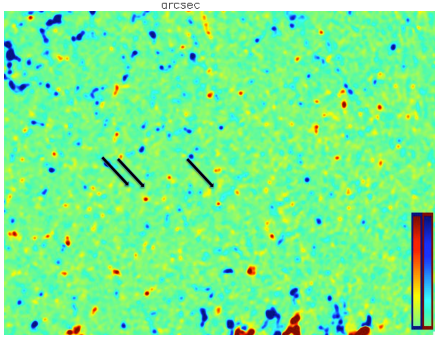


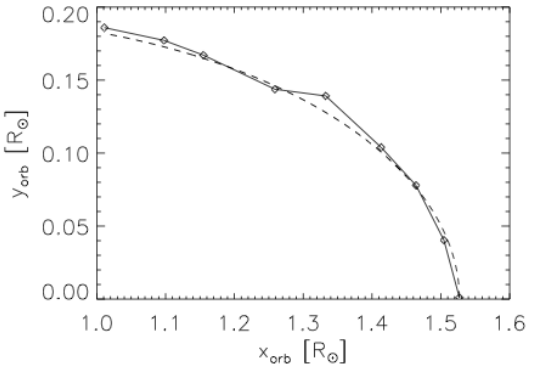
Data analysis

- Impacting plasma:
  - Density: $2 < n < 10 \times 10^{10}$ cm^{-3} (from absorption)
  - Velocity: $300 < v < 450$ km/s (from images and STEREO data)
  - Size: r~2000-4000 km, l~2000-10000 km
- Weak magnetic field ($\beta \gg 1$, SDO/HMI)
- Free fall (STEREO)



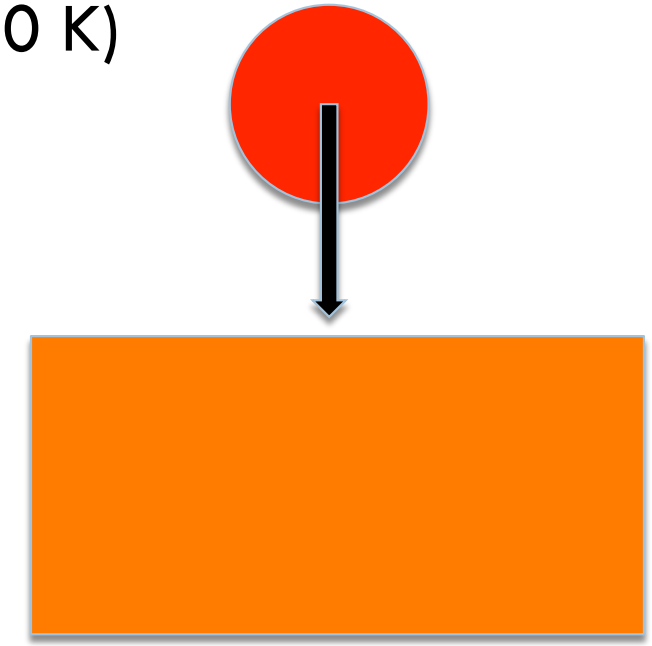




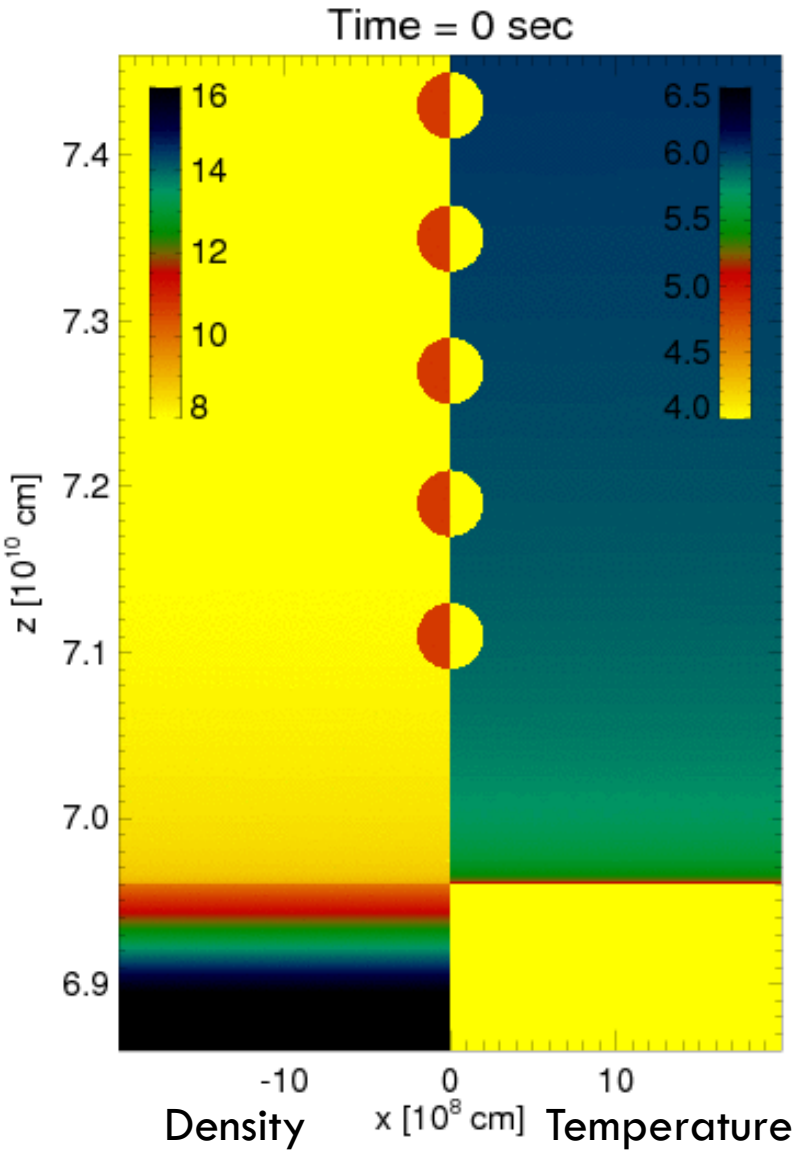


Hydrodynamic simulations

- Hydrodynamic model of plasma blobs downfalling in a tenuous (10^8 cm^{-3}) corona (~1 MK)
  - Impact speed: 400 km/s
  - Density: 5×10^{10} cm^{-3} (T~2000 K)
- 2D cylindrical geometry
- Spatial resolution: 5 km
- Radius: 2000 km
- FLASH code (Fryxell+ 2000)

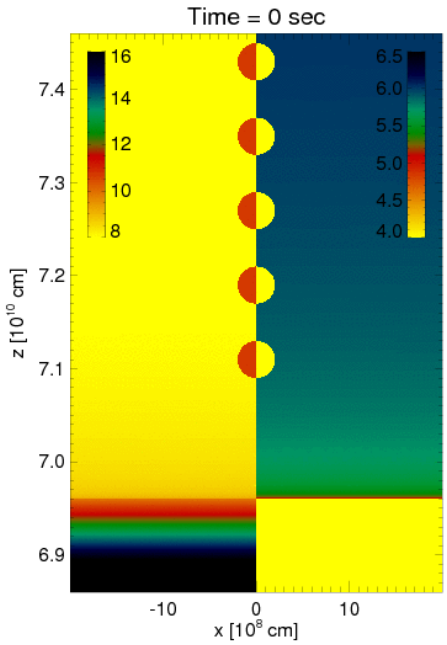


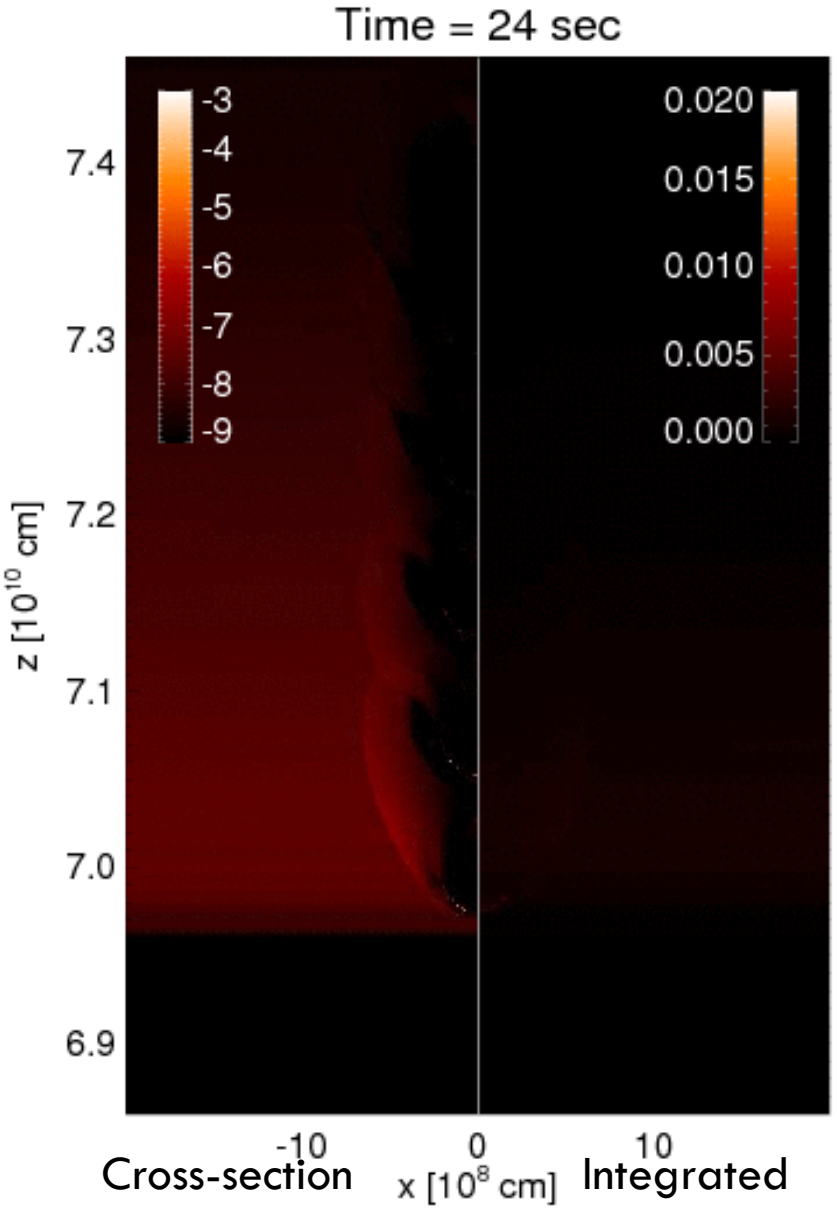
Train of droplets



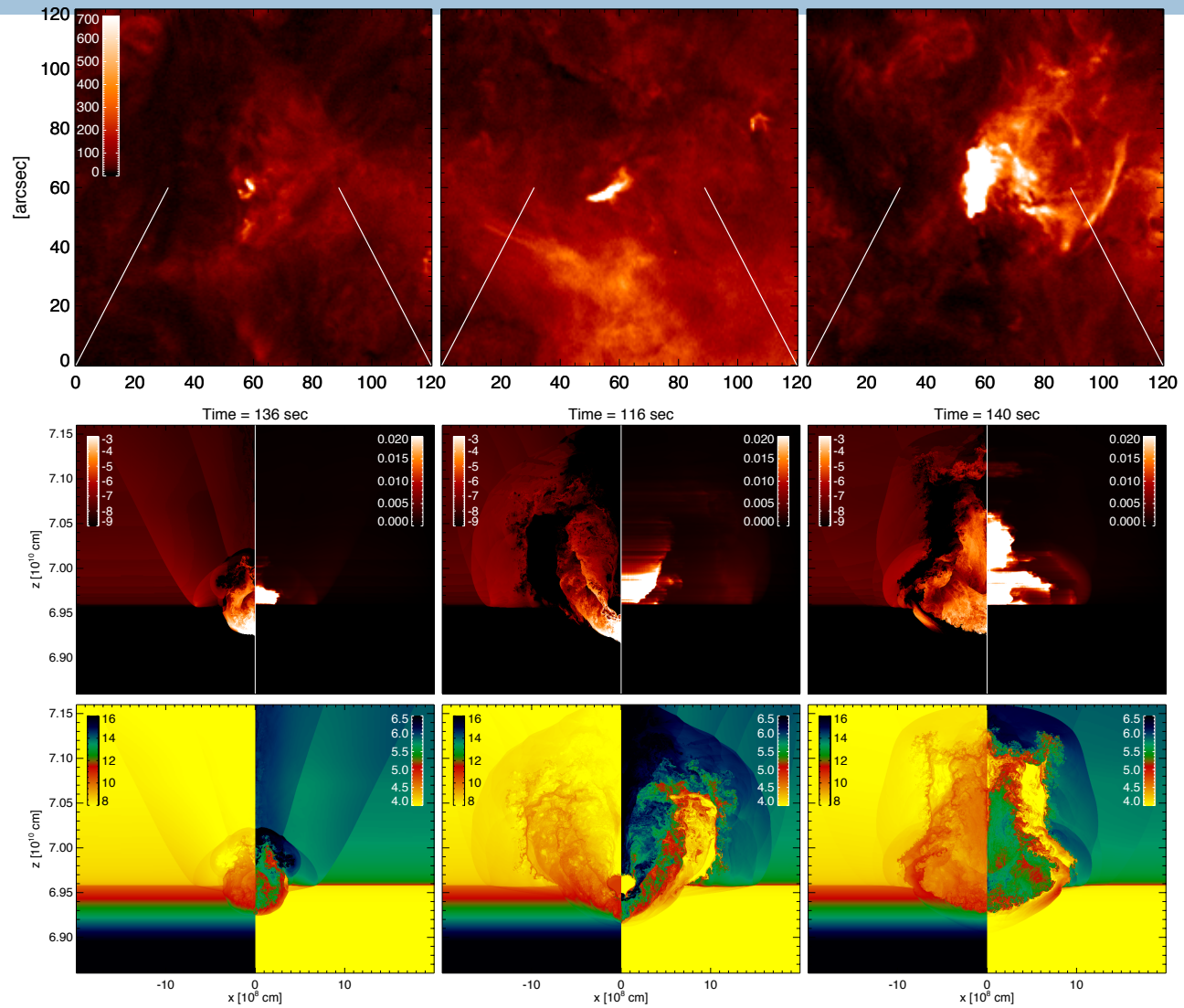
Train of droplets: 171 A emission

- EUV emitting plasma: 7%



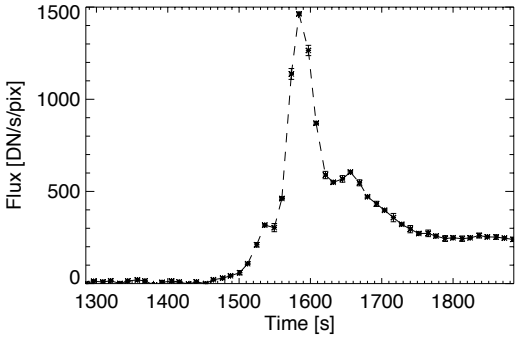


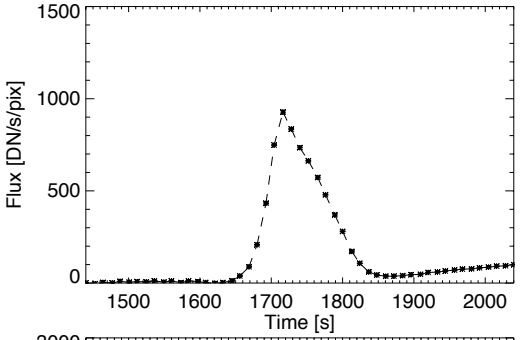
We match the observation….

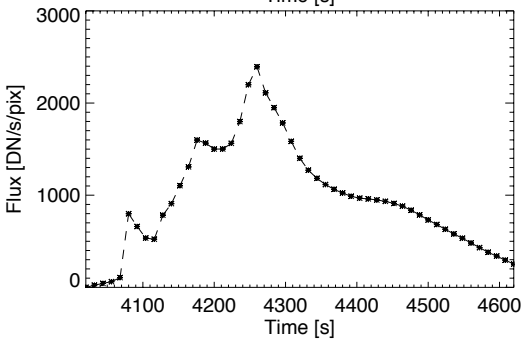


Quantitative agreement: Light curves

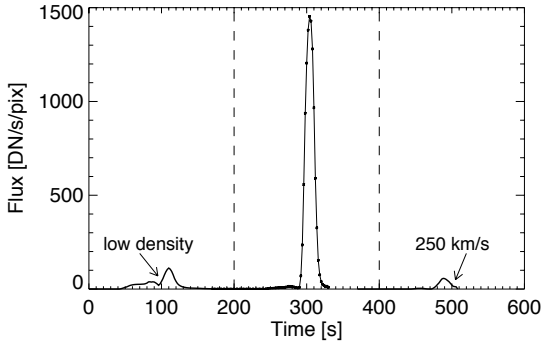
Data

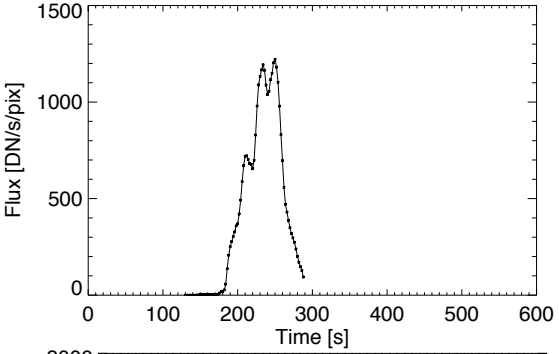


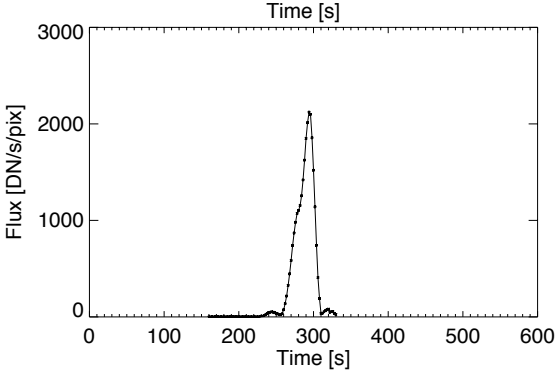




Model







Hints/results stars vs Sun

Stars: X-rays

- Density: 10^{11}—10^{13} cm^{-3}
- Velocity: 400-500 km/s
- Temperature: 2 – 4 MK
- Accretion rate:
  - Total: 10^{-11}- 10^{-7} $M_\odot$/yr
  - X-rays: 10^{-10}- 10^{-9} $M_\odot$/yr
- ?

Sun: EUV

- Density: 5 10^{10} cm^{-3}
- Velocity: 300-450 km/s
- Temperature: ~1 MK
- (Accretion rate: 10^{-14} $M_\odot$/yr)
- Absorption -> Emitting mass: 5-25%
- Emission from disk material
- Role of fragmentation

Conclusions

- Sun as a small-scale benchmark for accretion in YSO in EUV and X-rays
  - Insight: Impact evolution and mechanisms
  - New hints: role of absorption (see talk by S. Bonito)
  - New hints: emission from disk material
  - New hints: fragmentation
  - New hints: Doppler shifts

- Template for other phenomena? (e.g. funnelled flows)