Accretion impacts studied on the Sun

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Accretion flows on young stars (T Tauri)
Accretion in YSO

- Disk-star: magnetic funnels (Königl 1991)

- Accretion flows: $V \gg 100 \text{ km/s}$


X-ray Accretion in T Tauri stars

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

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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Bright Hot Impacts by Erupted Fragments Falling Back on the Sun: A Template for Stellar Accretion
Fabio Reale et al.
Science 341, 251 (2013);
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The flare and the eruption:
7 June 2011

Tanaka+ 2011
Li+ 2012
Innes+ 2012
Muraki+ 2012
Cheng+ 2012
Williams+ 2013
Inglis & Gilbert 2013
Gilbert+ 2013
Carlyle+ 2014
Dolei+ 2014
van Driel-Gesztelyi+ 2014
The impacts region

08:00 UT - 171 A
Close up: 171 A (Fe IX, logT~5.9)
Data analysis

- **Impacting plasma:**
  - Density: $2 < n < 10 \times 10^{10} \text{ cm}^{-3}$ (from absorption)
  - Velocity: $300 < v < 450 \text{ km/s}$ (from images and STEREO data)
  - Size: $r \sim 2000-4000 \text{ km}$, $l \sim 2000-10000 \text{ km}$

- **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 ($\sim$1 MK)
  - Impact speed: 400 km/s
  - Density: $5 \times 10^{10}$ cm$^{-3}$ (T$\sim$2000 K)
- 2D cylindrical geometry
- Spatial resolution: 5 km
- Radius: 2000 km
- FLASH code (Fryxell+ 2000)
Train of droplets
Train of droplets: 171 Å emission

- EUV emitting plasma: 7%
We match the observation....
Quantitative agreement: Light curves

- **Data**
- **Model**

![Graphs showing light curves with different time and flux scales, comparing data and model results.](image-url)
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: $5 \times 10^{10}$ 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)