



**VAULT Lya Telescope:  
The First Sub-arcsecond Images of the Sun's  
Atmosphere**

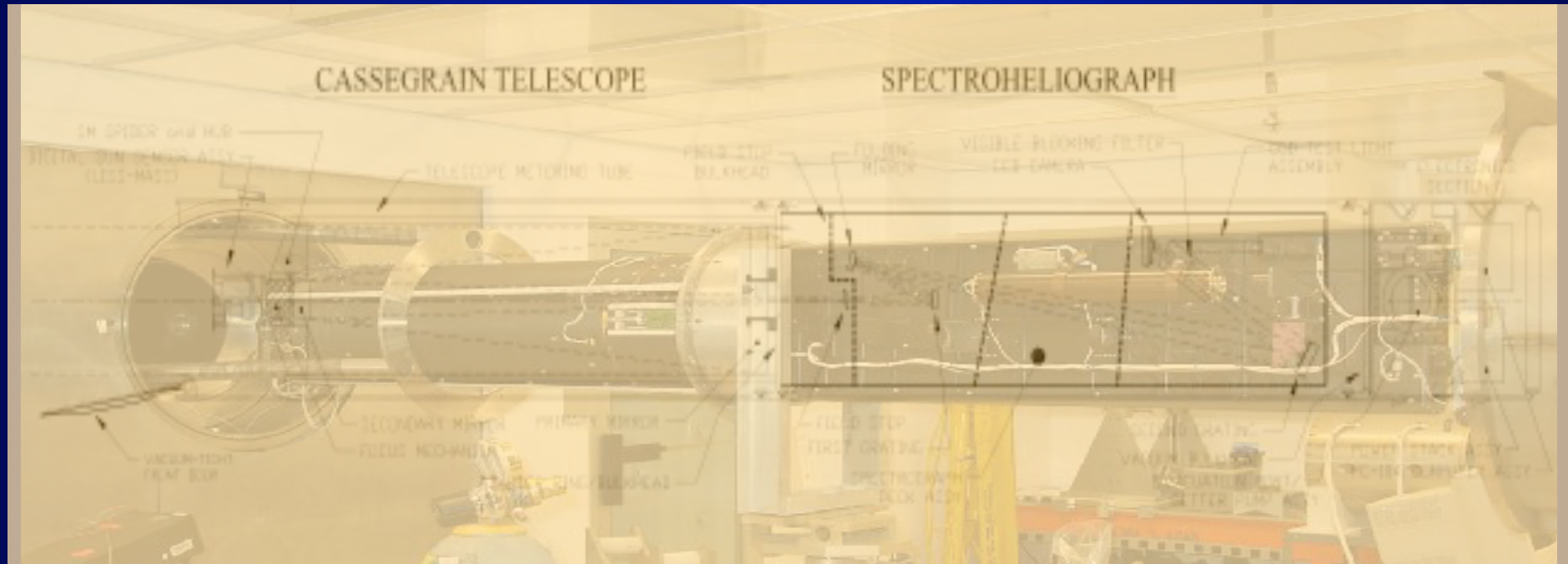
**Angelos Vourlidas**  
*VAULT Project Scientist*

# Very Advanced ULtraviolet Telescope (VAULT) PI: Dr. Clarence Korendyke (NRL)

- OBJECTIVES

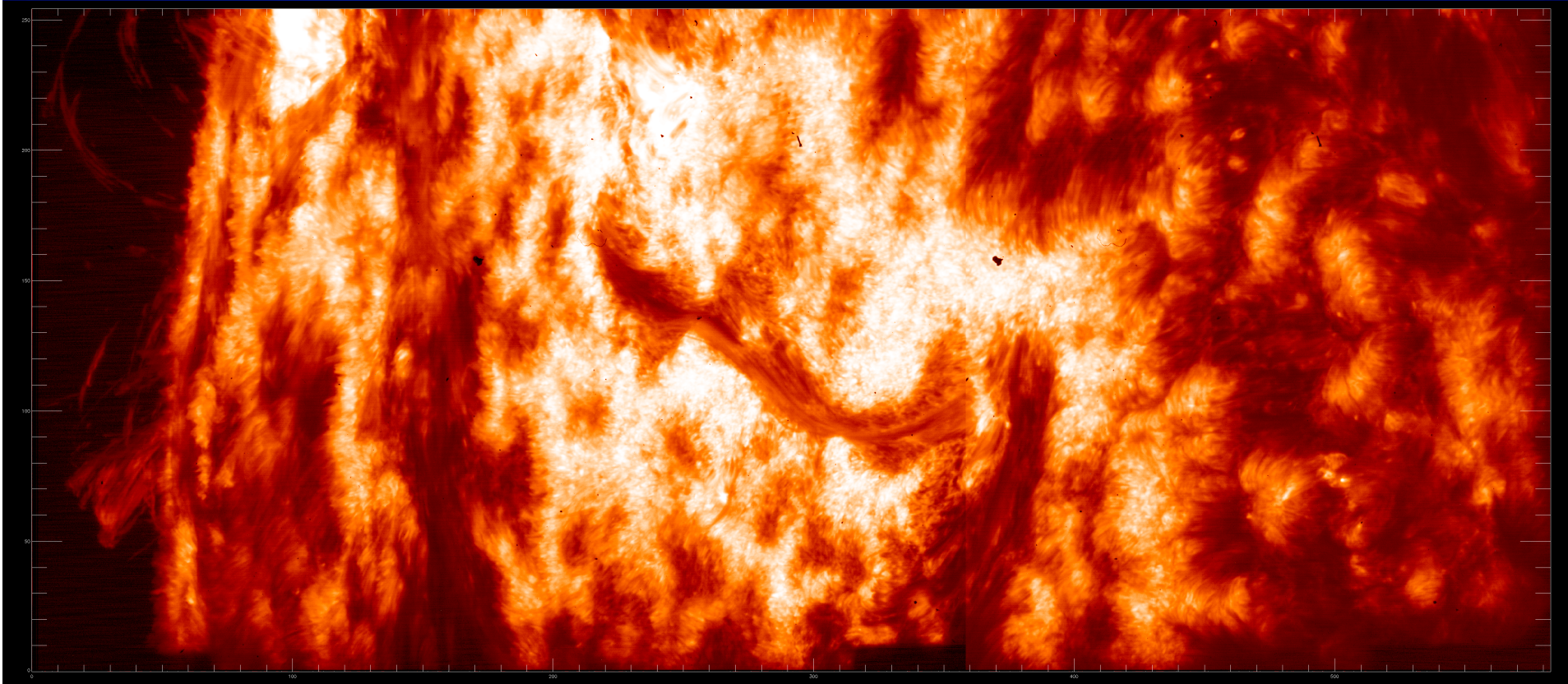
- Investigate the fine scale structure of the solar atmosphere (see *G. Doschek's talk for details*).
  - Loop connectivity from the photosphere to the corona
  - Coronal heating mechanisms (footpoint motions, nanoflares)
- Demonstrate that ultra-high resolution imaging (~200 km) is achievable with a moderate telescope.
- Develop and qualify future space instrumentation and techniques.

# Instrument Description



- 30cm, f/24.6 Cassegrain
- Zero-dispersion spectroheliograph
- Ly $\alpha$  (1216 Å),  $\Delta\lambda=70\text{\AA}$
- 3072 $\times$ 2048, 9 $\mu\text{m}$  CCD
- 0.25" angular resolution
- 90% spectral purity

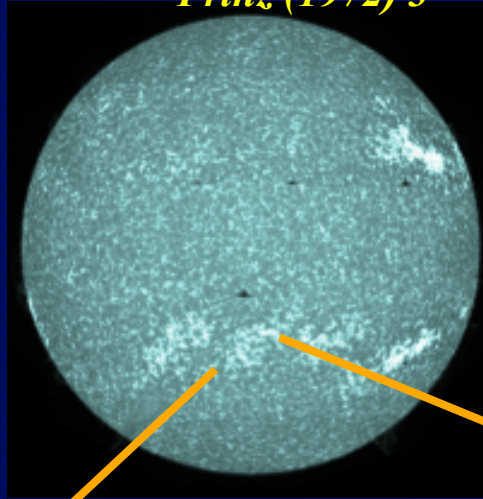
# VAULT-II



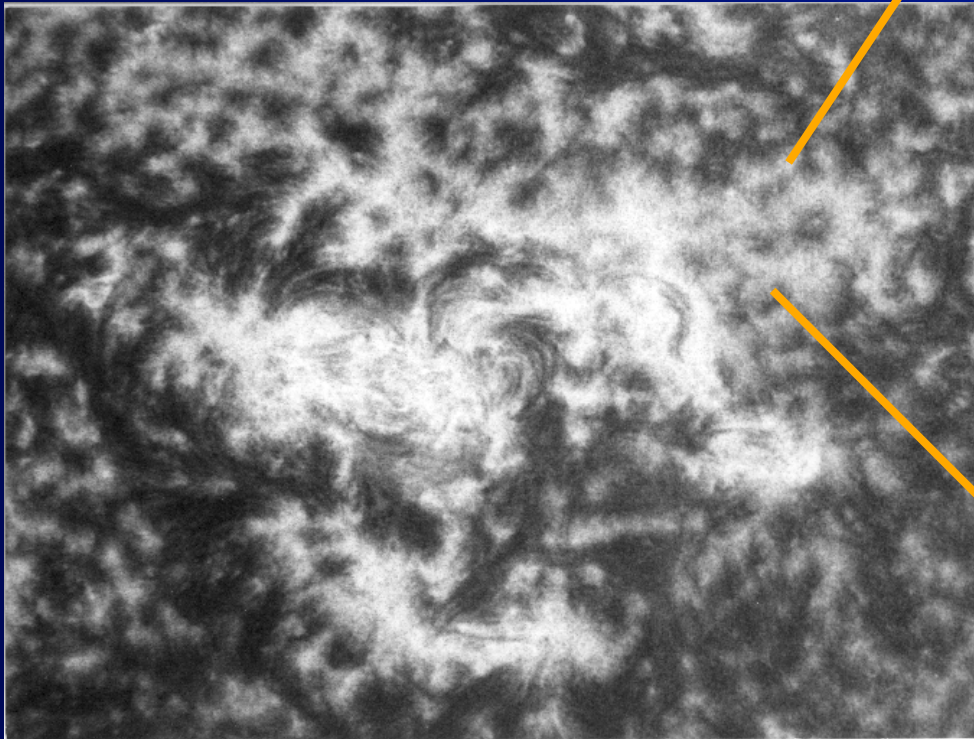
583" × 234" @ 0.3" or 423 × 170 Mm @ 210 km

# Evolution of Ly $\alpha$ imaging

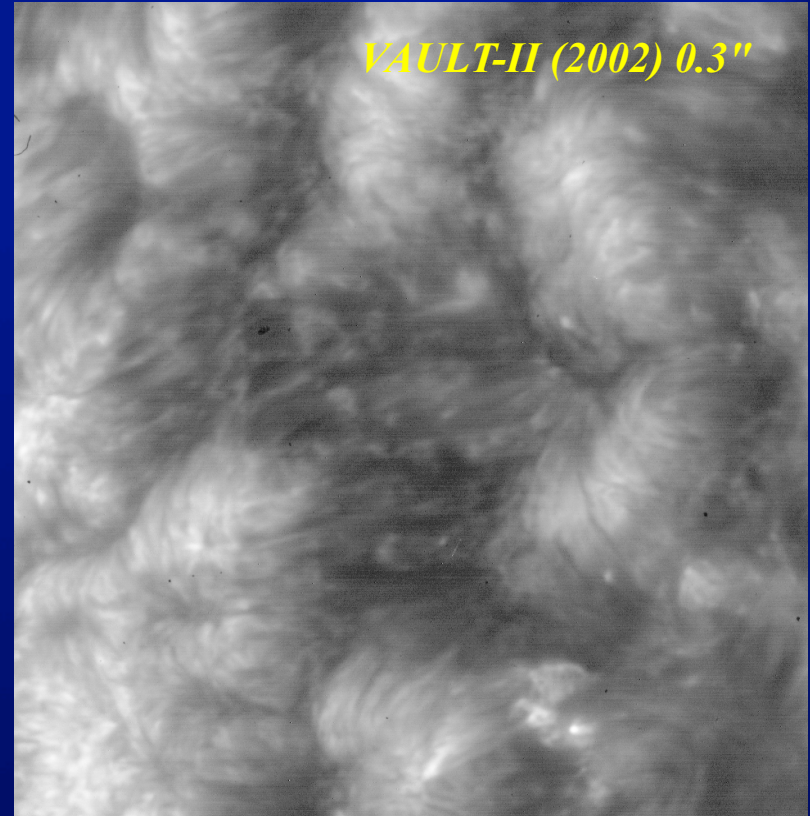
*Prinz (1972) 3"*

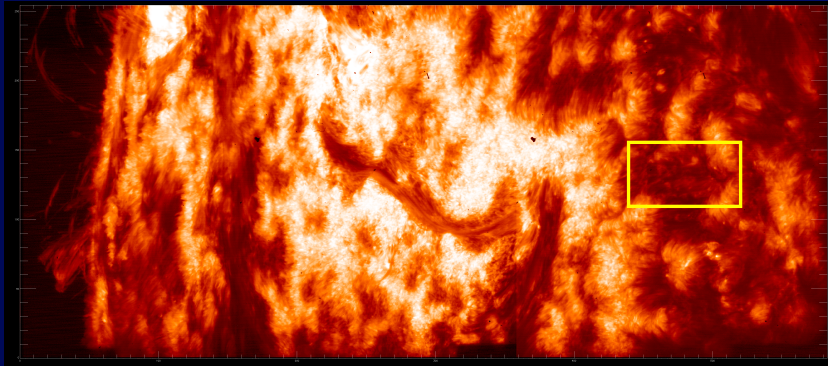


*Bonnet et al (1979) 1"*



*VAULT-II (2002) 0.3"*



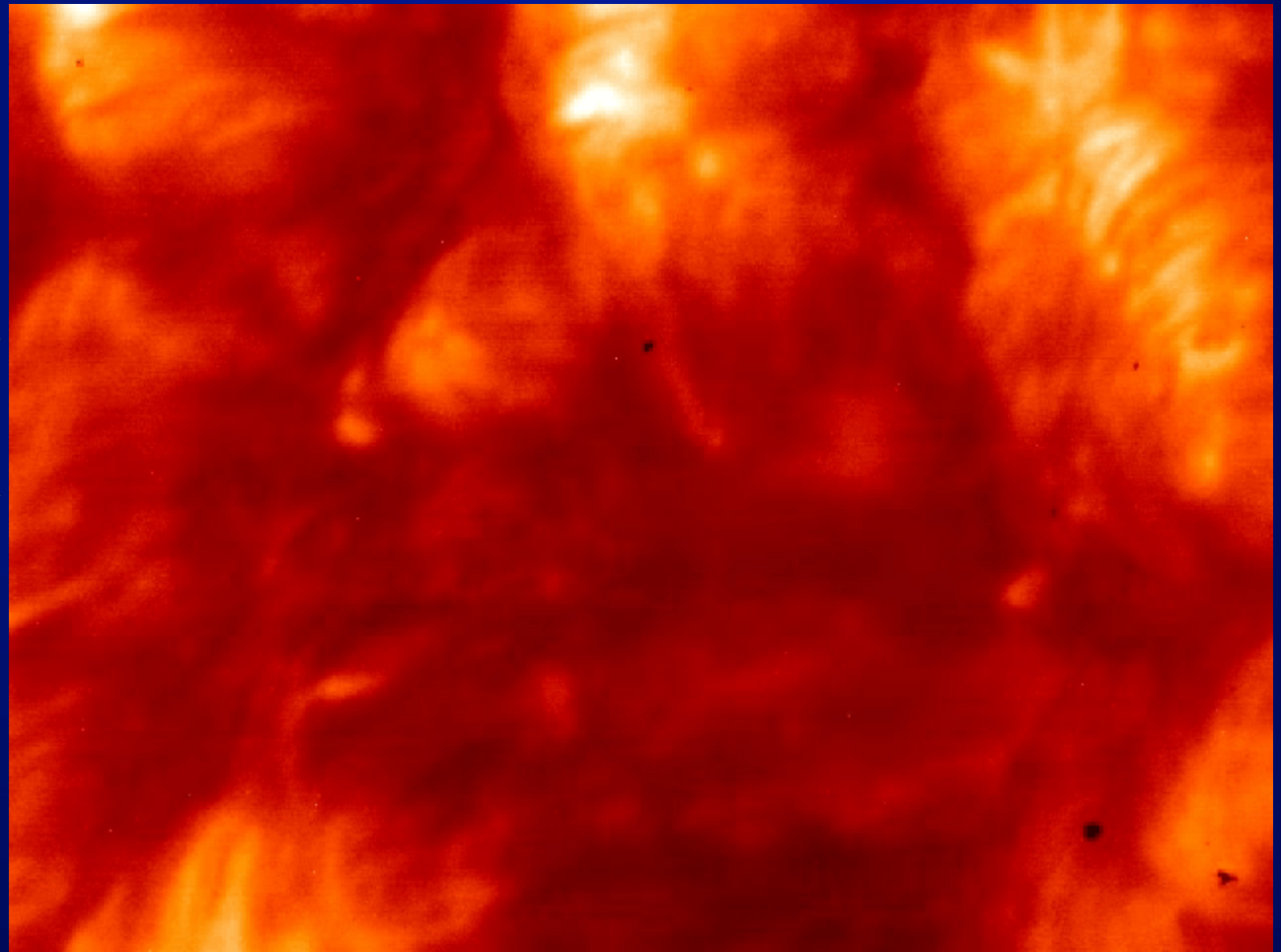


# Quiet Sun

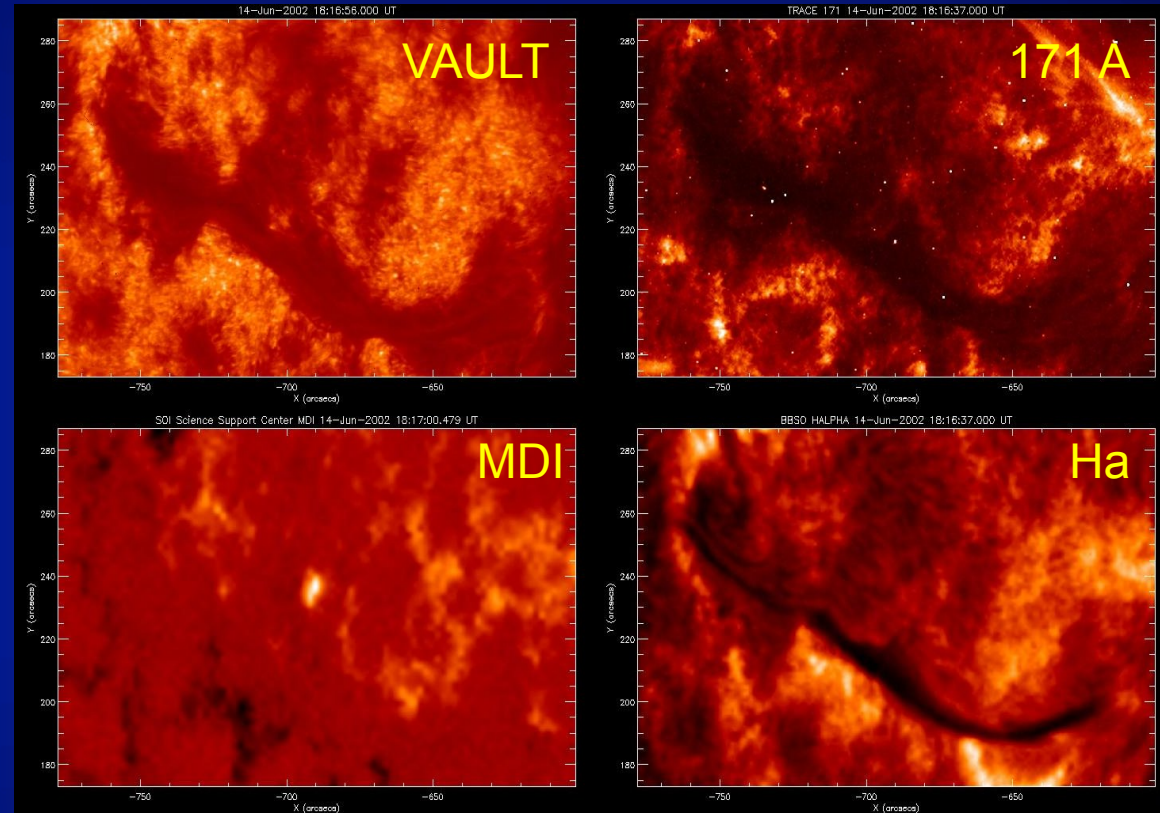
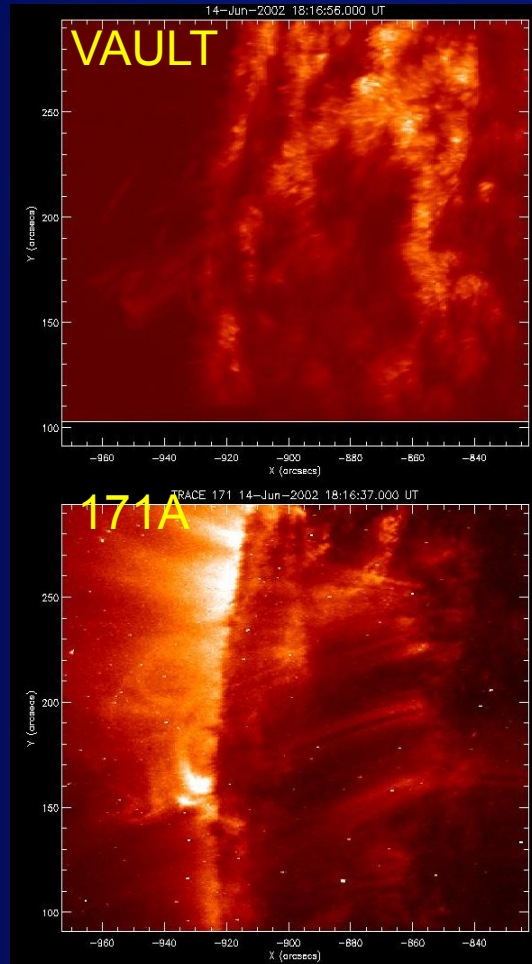
Peering into a single supergranule...

80" (58 Mm)

55" (40 Mm)

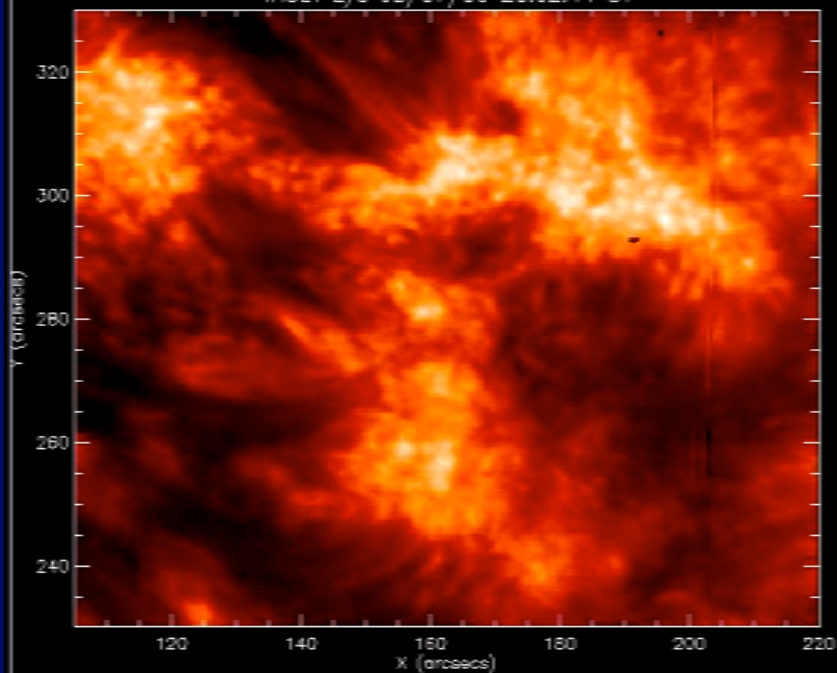


# Comparison with other wavelengths

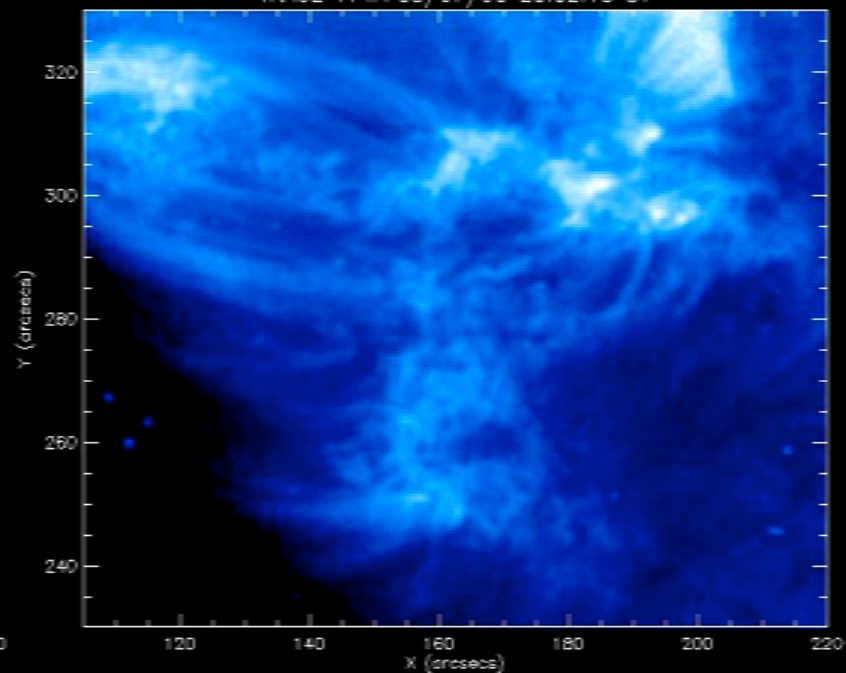


Alignment accuracy of 2 pixels ( $\sim 0.24$  arcsec).

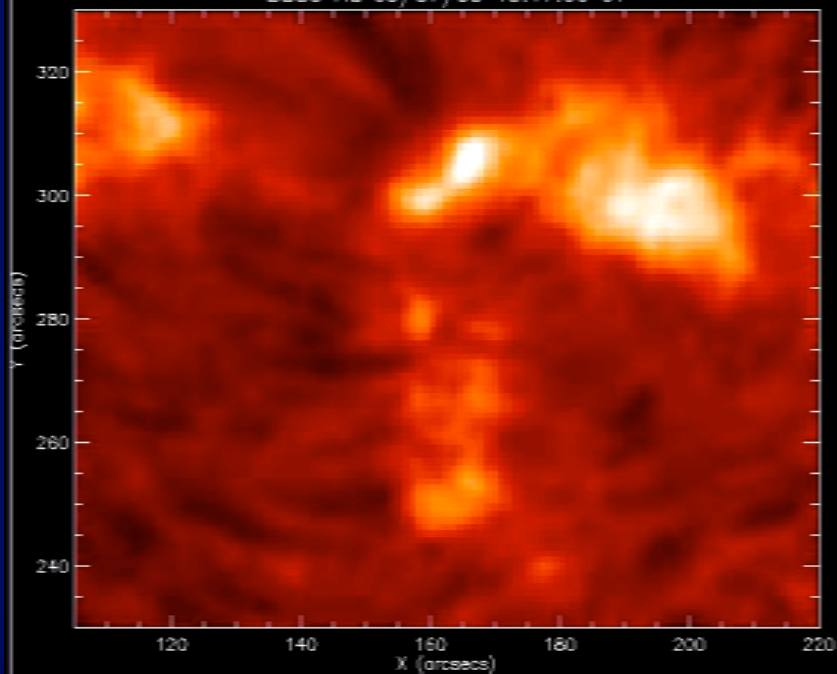
VAULT Ly $\alpha$  05/07/99 20:02:44 UT



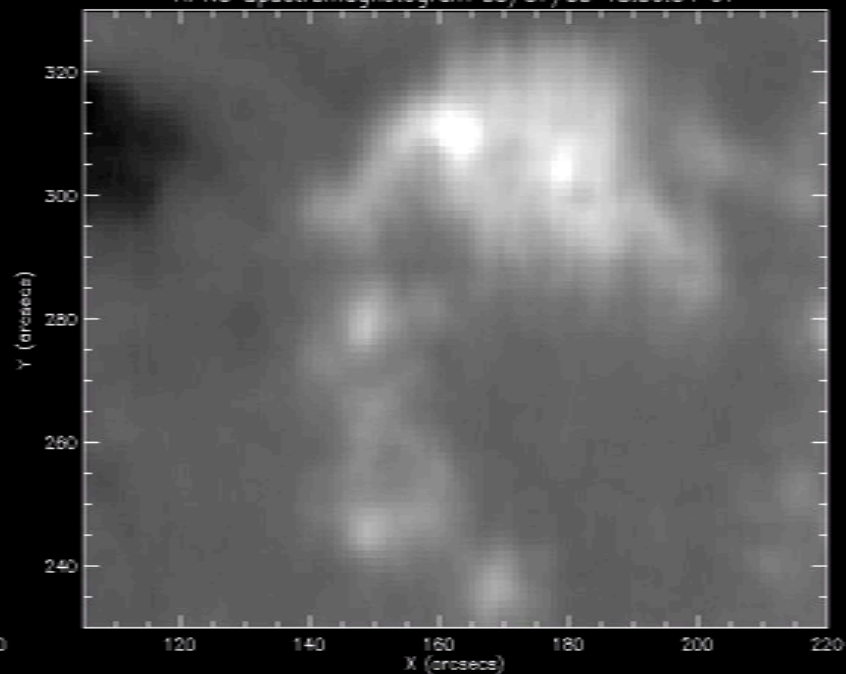
TRACE 171A 05/07/99 20:02:13 UT



BBSO H $\alpha$  05/07/99 15:17:06 UT

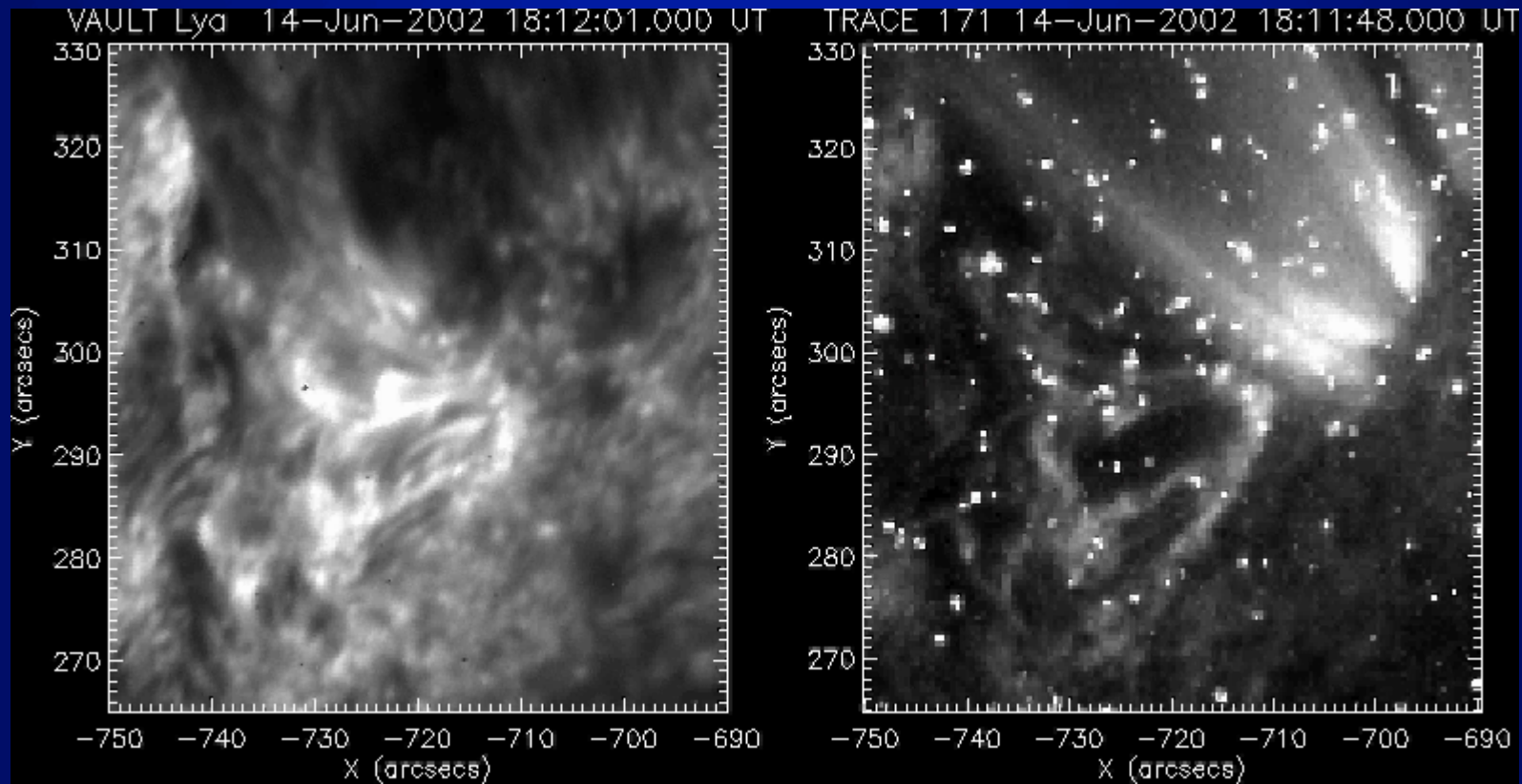


KPNO Spectromagnetogram 05/07/99 18:06:54 UT





# Loop Structures in Ly $\alpha$ /171Å

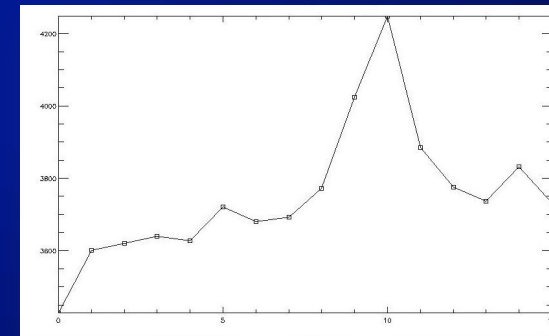
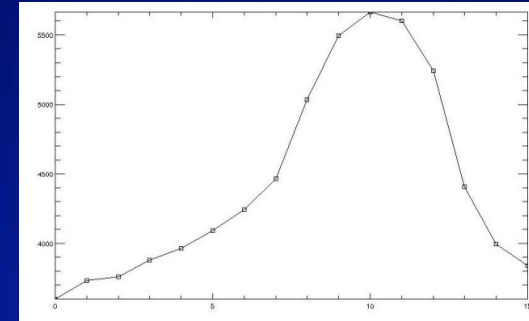
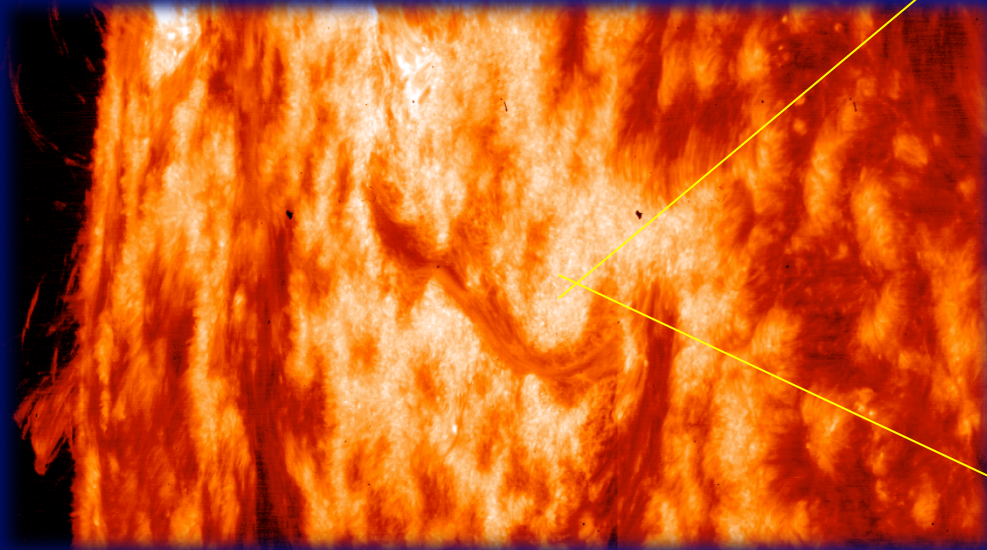


Ly $\alpha$  ( $1-5 \times 10^4$  K)

171Å ( $\sim 10^6$  K)

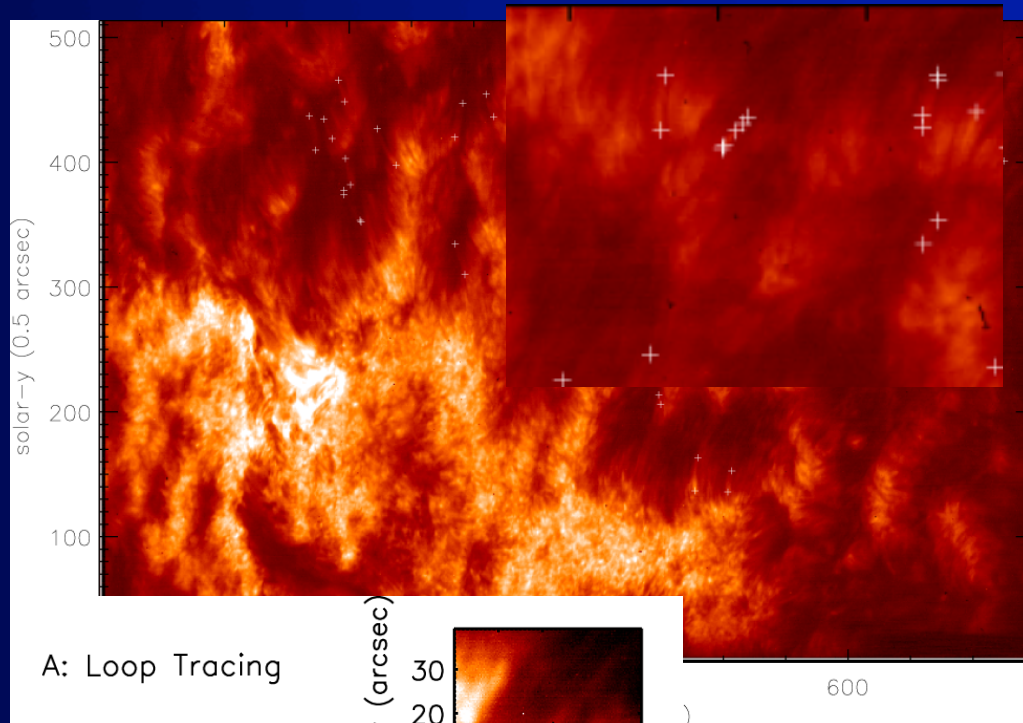
# Energetics (Nestoras et al, in preparation)

Energy estimate  $\sim 10^{22}$  erg (1/100 of a nanoflare)

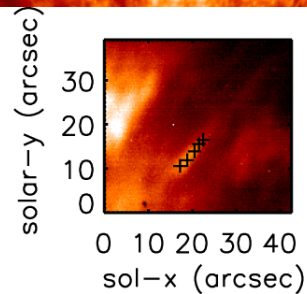


Examples of transient brightenings  
in the VAULT data.

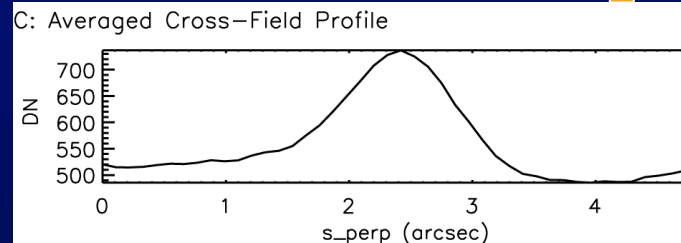
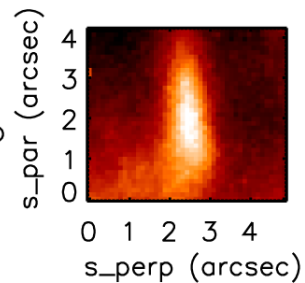
# Loop Analysis (Patsourakos et al 2007)



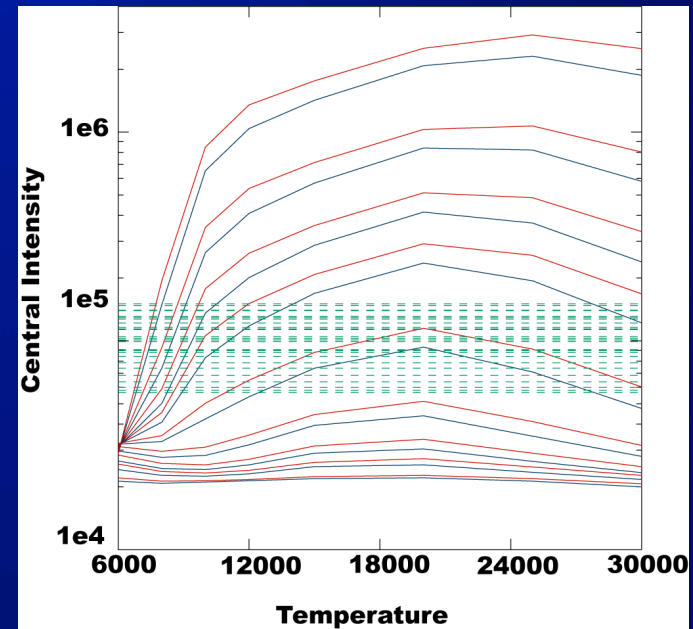
A: Loop Tracing



B: Straightened Loop

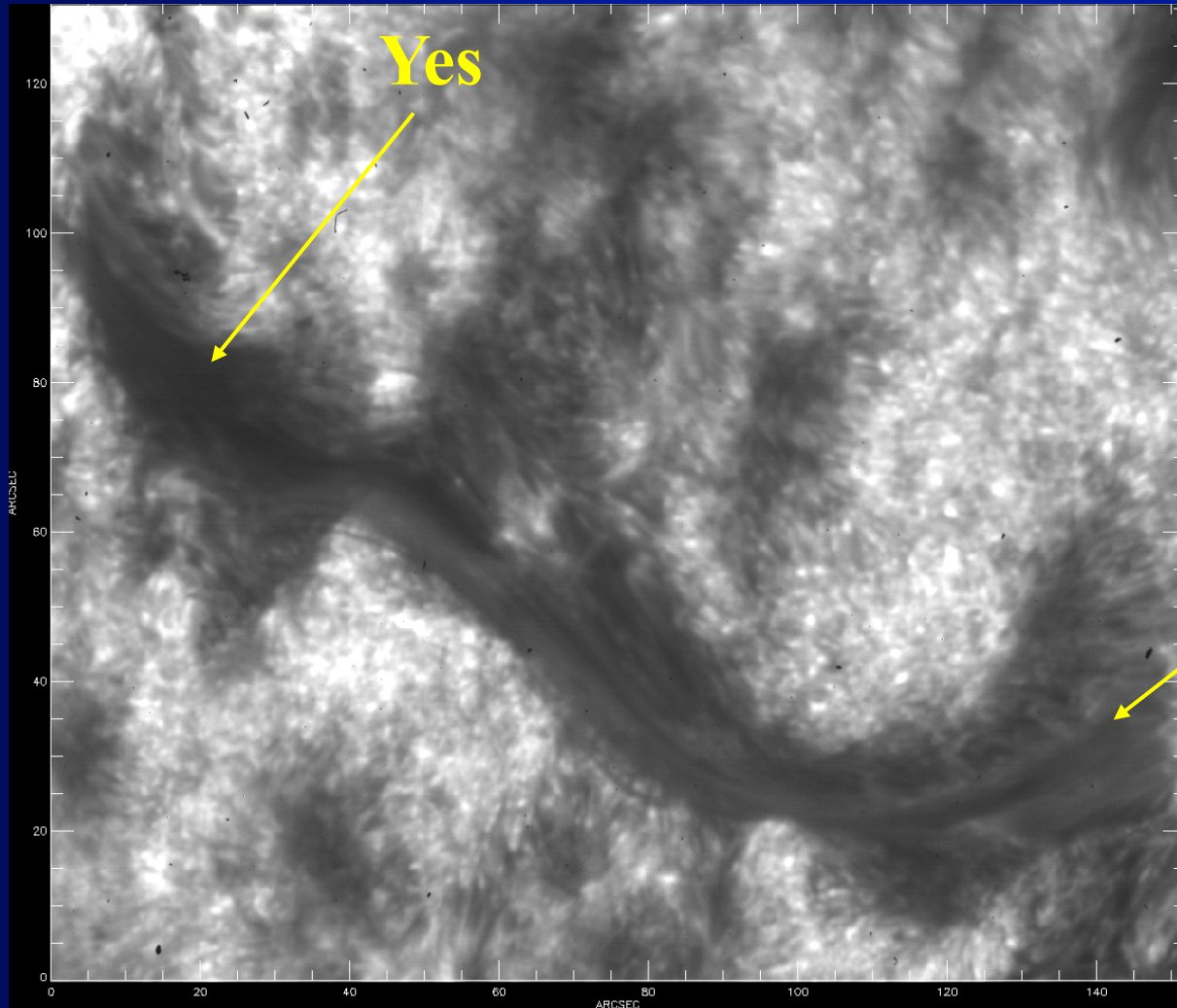


**VAULT intensities consistent with  
1-3x 10<sup>4</sup> K material  
at <0.2 dyn/cm<sup>3</sup>**

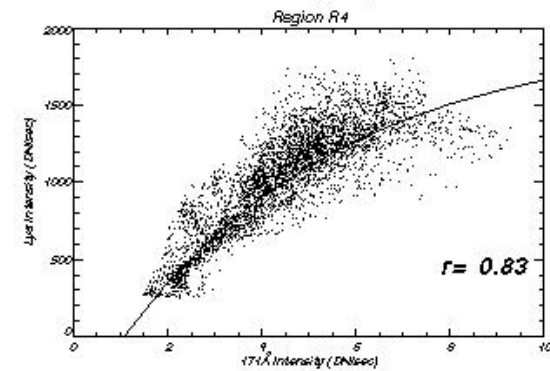
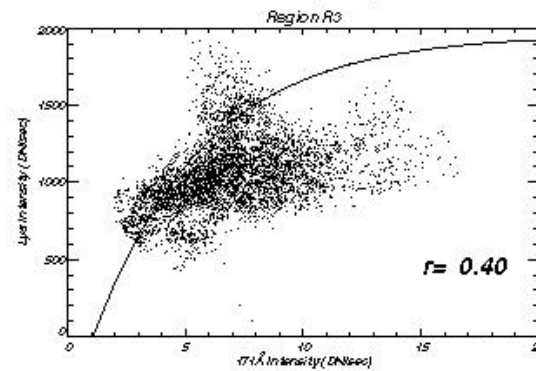
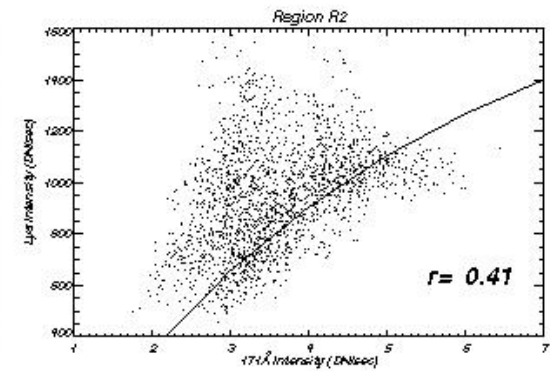
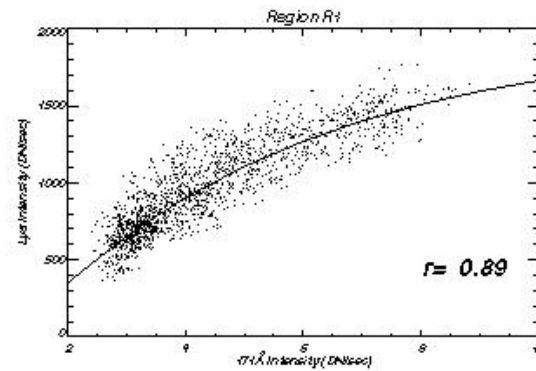
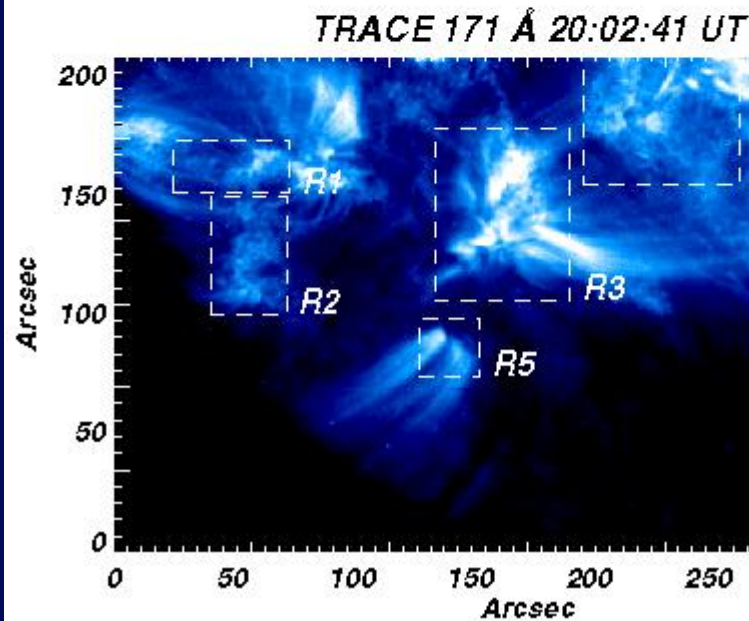
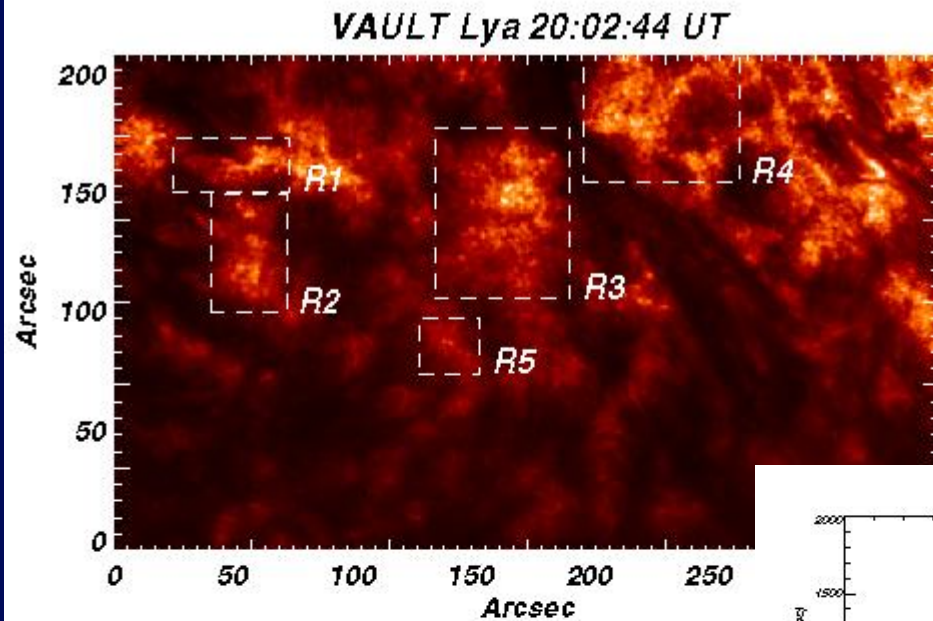


# Filament Studies

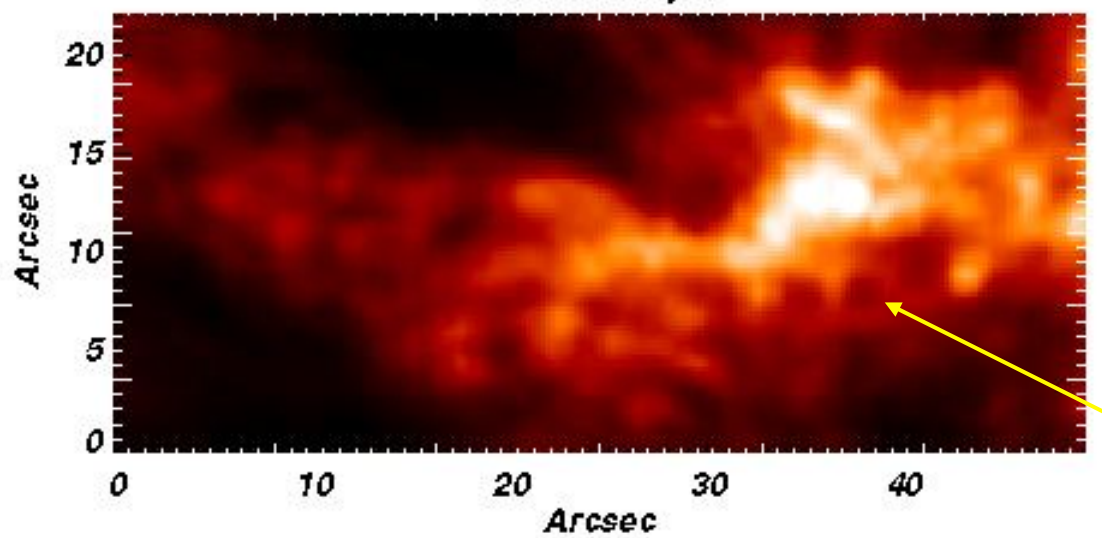
Where is the cool material? (Millard et al 2009)



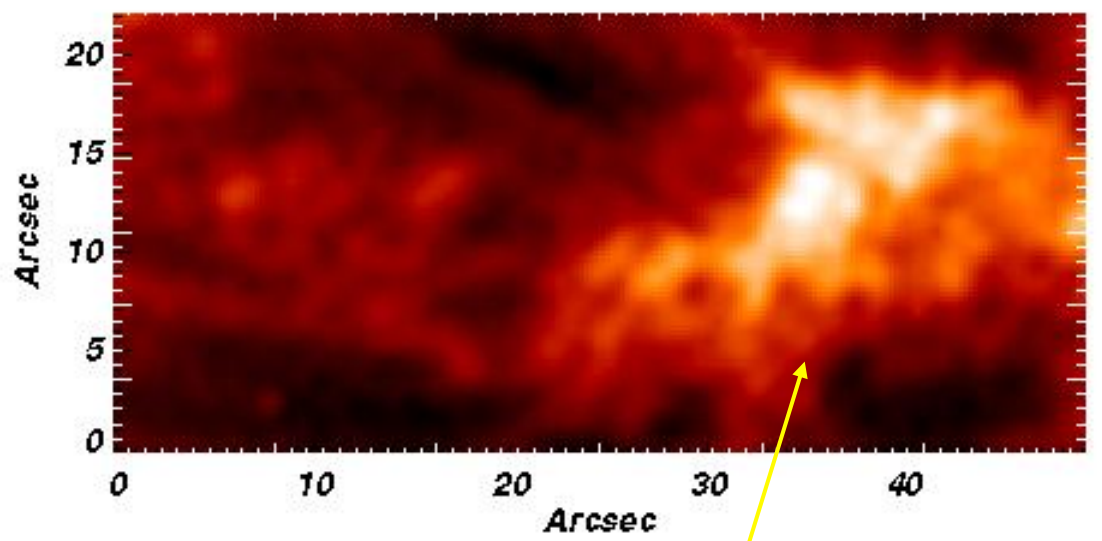
# Chromosphere–Corona Correlations (Vourlidas et al 2001)



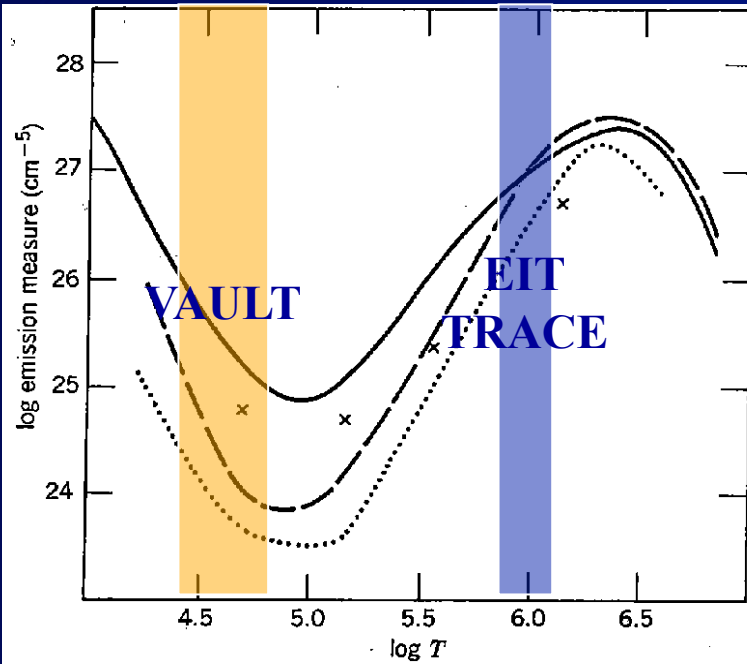
*VAULT Ly $\alpha$*



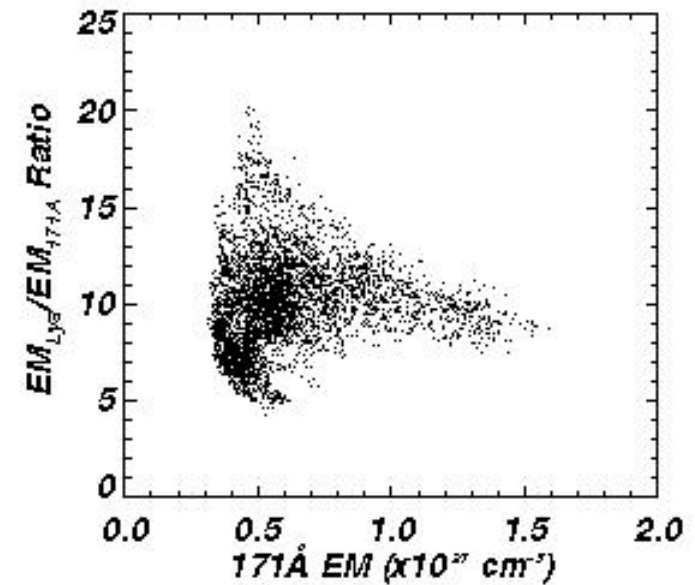
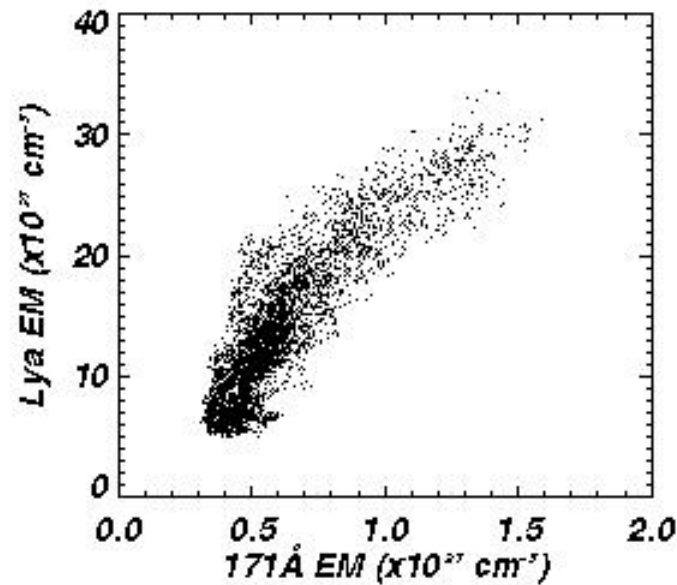
*TRACE 171Å*



# Emission Measure Calculations



$\text{Ly}\alpha$  emission is  $<100\times$  than predicted by standard coronal heating models



# Review

- No significant morphological change at sub-arcsecond scales.
  - Ly $\alpha$  optically thick at 0.5''
  - Only absorption features <0.5''
- Flows ( $\sim 20$  km/s) at  $\leq 0.5''$  scales.
  - Counterstreaming flows detected in filaments
- Brightenings over 1-2 min.
- Possible existence of “atoflares” ( $\sim 10^{22}$  ergs) .
  - But how many are there?
- **Excess** of Ly $\alpha$  material compared to the amount expected from a thermal conduction-dominated CCTR, **even** for “identical” structures.



# Future Plans

- VAULT data is available on line (<http://www.solar.nrl.navy.mil/rockets/vault/>)
- Next step:  
**VERIS Sounding Rocket** = EUV Spectroscopy at 0.3" resolution!
  - investigate most of the problems raised in Plan-B science objectives (resolve flows, loop internal structure)
  - raise TRL, refine design/science objectives for the Plan-B spectrometer
  - First Flight scheduled for end of 2009.

## VERIS Specifications

Plate scale	0.15"/pixel (VAULT= 0.125"/pixel)
Simultaneous Field of view	Slit: 0.15"x150"; Slot: 10" x 150"
Maximum raster width	150"
Wavelength range	515 – 635 Angstroms
Exposure times	5s active regions
Velocity resolution	~8km/s in slot <3km/s classical spectroscopy
Temperature coverage	$3 \times 10^4 - 1.5 \times 10^7$ K
Multiorder imaging of a 40"x150" area	24s (imaging cadence)

## VERIS Instrument

