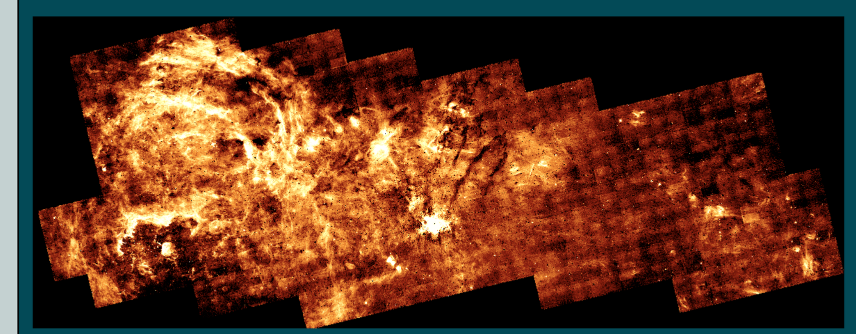
Characterizing Filamentary Structure in Images from a Paschen-α Survey of the Galactic Center



Mills, E.[1], Morris, M.R.[1], Lang, C.C.[2], Wang, Q.D.[3], Dong, H.[3], Mauerhan, J.[1], Stolovy, S.[4], Cotera, A.[5], Muno, M.[4], Calzetti, D.[3], Ramirez, S.V.[4], Schneider, G.[6]

We present images from a large-scale Paschen α survey of the Galactic center undertaken with NICMOS on HST. We focus our analysis on the structure in the gas ionized by the Arches and Quintuplet clusters -- the Arched filaments and the Sickle, respectively. We adopt the hypothesis that the extensive fine-scale, aligned filamentary structure seen in this gas is due to a magnetic Rayleigh-Taylor instability.

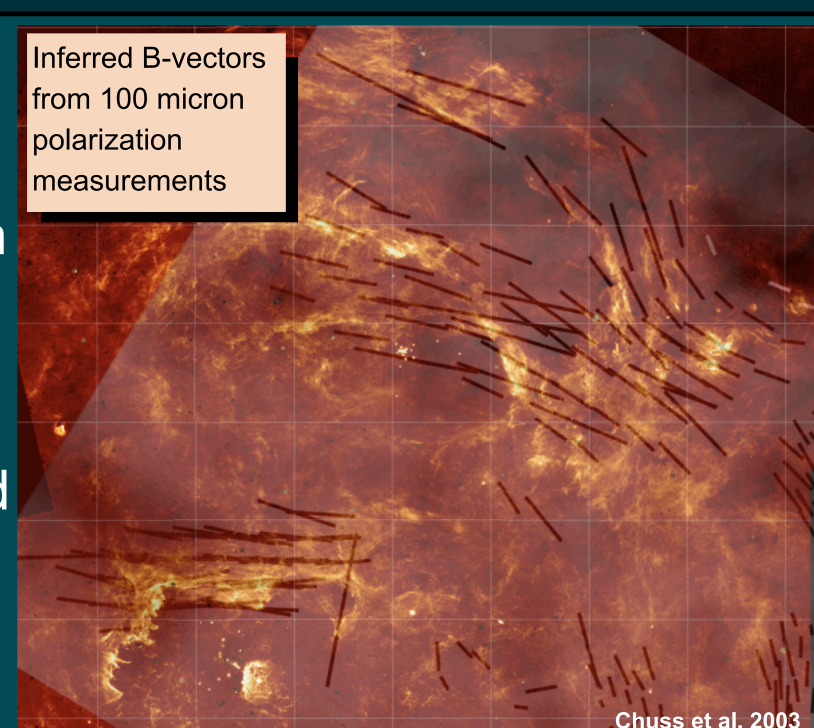
The Filaments

The filamentary Paschen alpha emission traces the ionized surfaces of molecular clouds in the region. The filaments discussed here are presumably overdense ridges in this magnetized thermal plasma, which appear especially prominent due to the n^2 dependence of density on the Pa- α emission.

Properties:
Filament lengths ~ **0.4 - 2 pc**
Density contrast between filaments, gaps ~ **20% - 30%**
Filament widths ~ **0.02 - 0.08 pc**

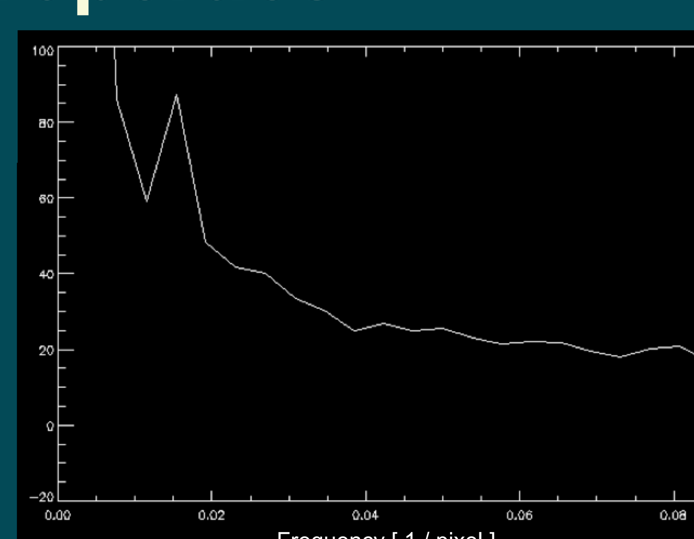
Magnetic Field

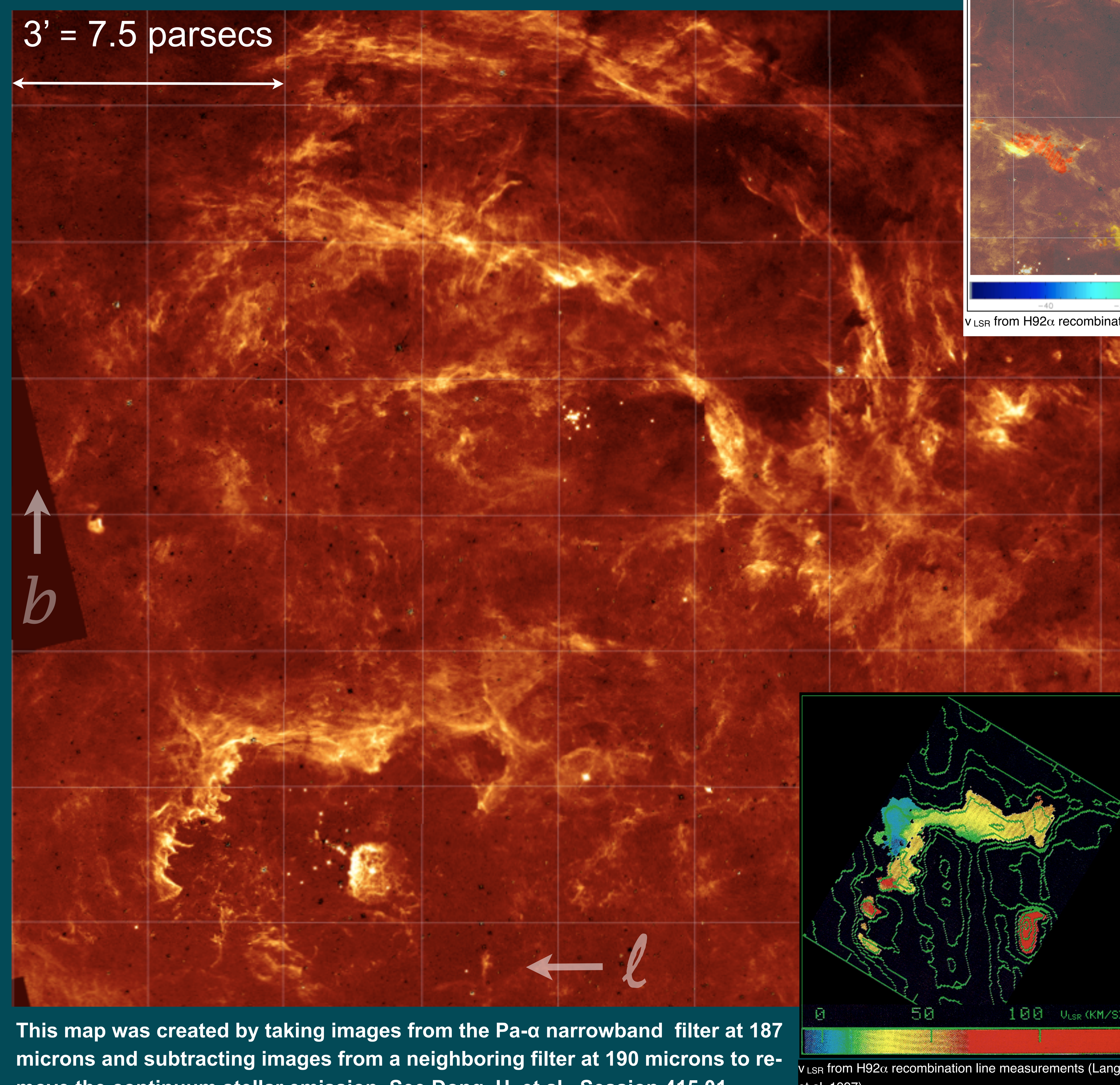
The orientation of filaments in the Pa-alpha images is generally well-aligned with the magnetic field as measured by far-IR polarimetry [1]. Field strengths in this region are measured to be ~ 0.1-1 mG



Measuring Filament Properties

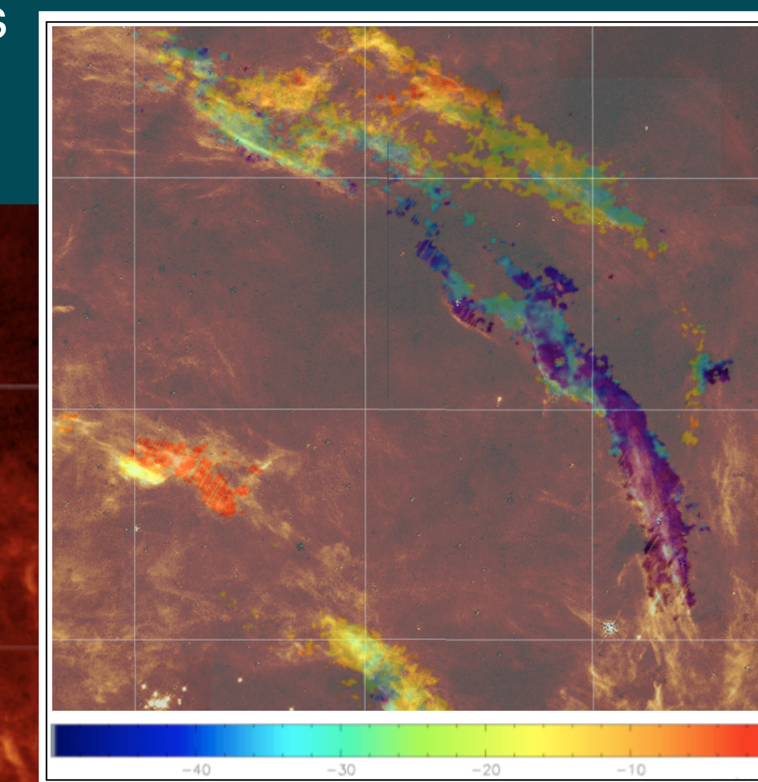
Taking the 1D Fourier transform of selected strips within the image, we are able to measure characteristic spacings between filaments and fingers, as shown below for the Sickle. All physical distances are computed assuming a distance to the Galactic center of 8.0 kpc.





This map was created by taking images from the Pa-α narrowband filter at 187 microns and subtracting images from a neighboring filter at 190 microns to remove the continuum stellar emission. See Dong, H. et al. Session 415.01

v_{LSR} from H92α recombination line measurements (Lang et al. 1997)



v_{LSR} from H92α recombination line measurements (Lang et al. 2001)

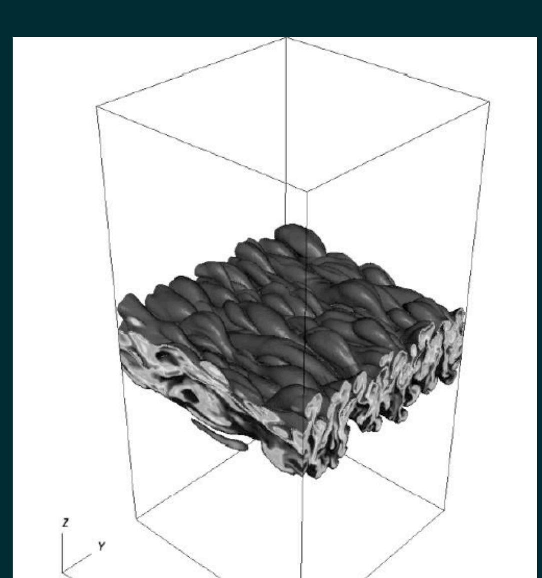
Velocity Structure

Radial velocity measurements of these ionized regions show large-scale velocity gradients along the lengths of the Arched Filaments and in the Sickle [2], [3].

Limitations of these data are that they do not resolve the fine-scale filamentation we observe, and give no information on motion in the plane of the sky.

Higher spatial resolution radial velocity data as well as proper motion data would allow a more detailed determination of filament kinematics, and help distinguish between models of filamentation, including shearing and Rayleigh-Taylor instabilities (See following sections)

Filaments as Magnetic Rayleigh-Taylor Instabilities



Isodensity surfaces from an MHD simulation of Stone & Gardiner 2007. There is a uniform magnetic field running along the x-axis.

The magnetic tension in tangential magnetic fields (fields parallel to the interface) will suppress short-wavelength RT instability modes along the field lines, while leaving modes that propagate perpendicular to the lines unaffected. This results in structures that are strongly asymmetric, taking the form of ridges or striping [4].

Examples of such striping are observed in planetary nebulae near the Galactic plane, where a magnetic RT instability occurs in an isothermally cooled post-shock ISM [5].

The magnetic field geometry and isothermal cooling conditions in the GC are consistent with this theory of a magnetic RT instability for the origin of the filaments we observe. In particular, the field geometry in the Sickle is consistent with giving rise to both RT ridges, and classical RT fingers on the eastern edge, where the field is perpendicular to the interface.

Alternative Theories

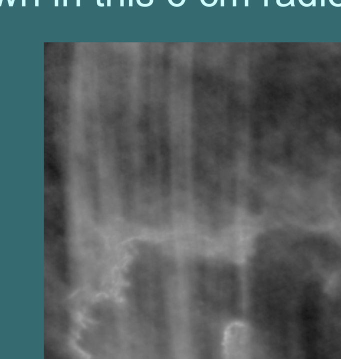
Sheared dust clumps

Filaments such as those in the Pleiades are theorized to be dust clumps in an approaching cloud that are decelerated by the stellar radiation field and then sheared by viscous interaction with faster moving gas [6].

Inconsistencies between the model and our data:
- We observe the filaments to be aligned with the magnetic field which is not predicted by this model or observed in the Pleiades.
- As dusty filaments are sheared by the gas, they should develop strong velocity gradients along their lengths , which is not uniformly observed, particularly in the Sickle.

Plasma pinch

This has been suggested as the origin for the synchrotron-emitting nonthermal filaments shown in this 6 cm radiograph.

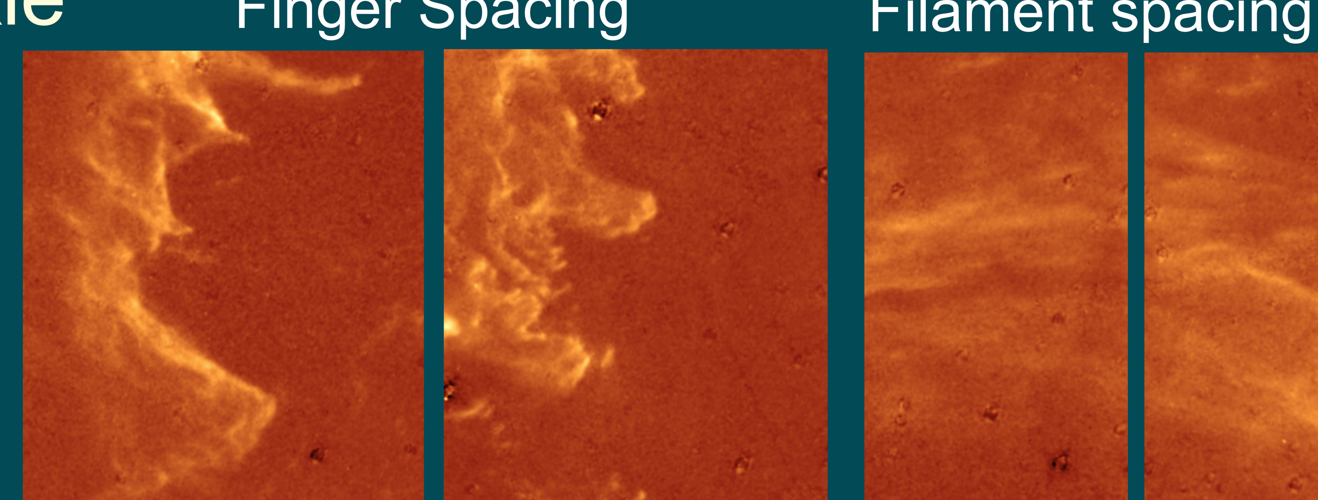


These filaments have inferred field strengths of a milligauss, and are coherent over greater scales than the thermal filaments discussed in this poster.

Filamentary Structure in the Sickle

Order of magnitude calculation of peak wavelengths to further verify consistency with a theory of magnetic Rayleigh-Taylor instabilities.

If both fingers and filaments in the Sickle are due to a Rayleigh Taylor instability, then they should have similar characteristic wavelengths.



References

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