Rosseland
Centre
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New insights from umbra modelling and new questions for cycle 25

Vasco M. J. Henriques, Sven Wedemeyer,
Mikołaj Szydlarski, Jaime de la Cruz Rodríguez
Rosseland Centre for Solar Physics, Univ Oslo
ESPM, Rome, Italy, 8 September 2021

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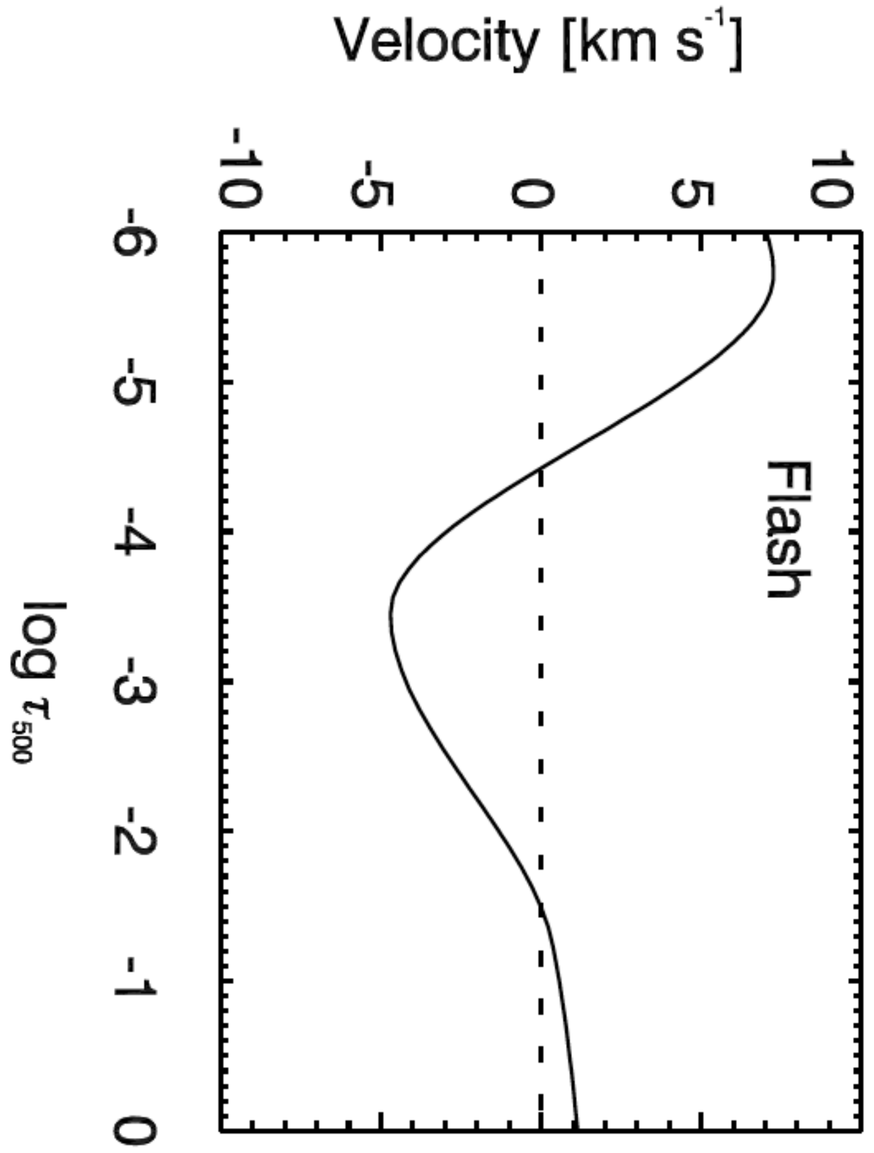
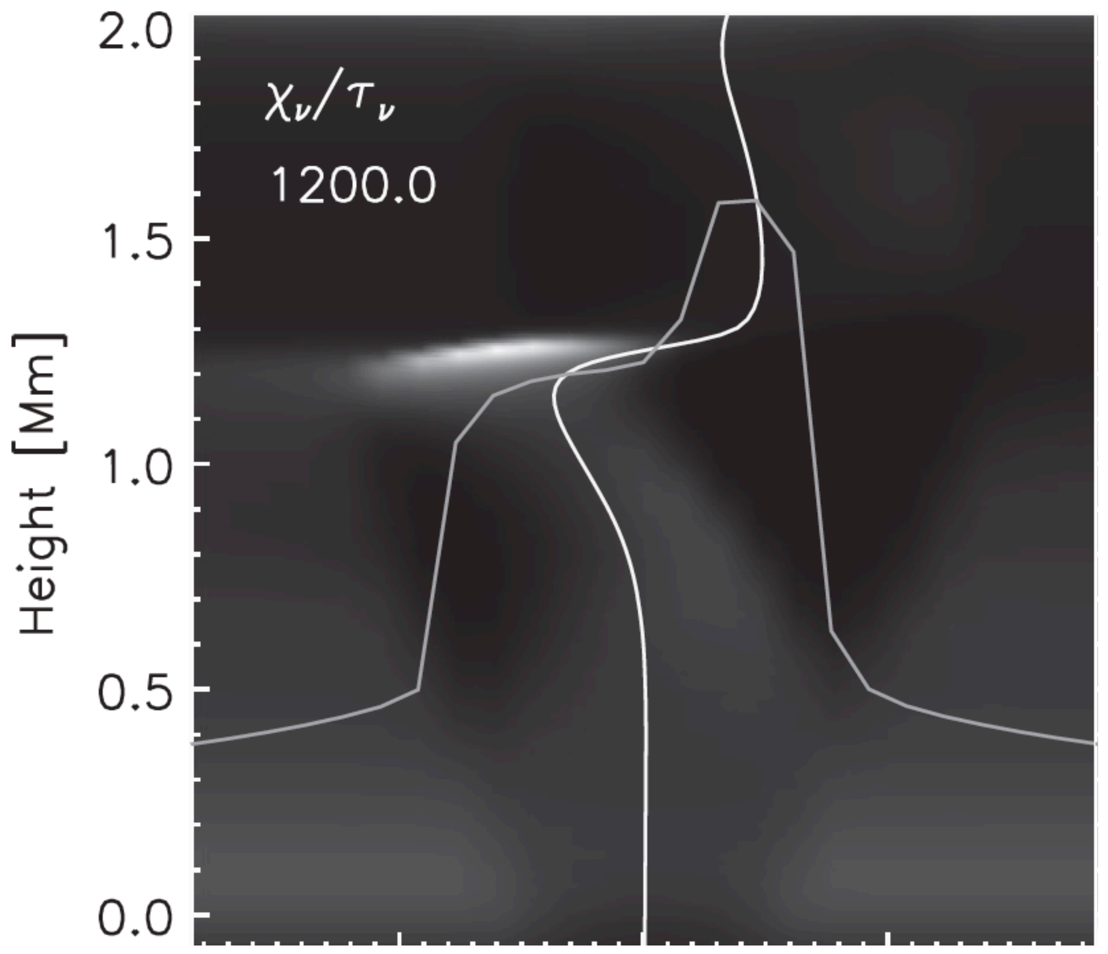
Umbral flash semi-empirical modelling featuring opposite sign flows agrees with classical simulations



Henriques et al. (2020)



Bard and Carlsson (2010)

it is a natural outcome of steepening waves and evidence beyond inversions of the downflowing region contributing to formation is found in Bose et al. (2019), Henriques et al. 2020 and Felipe et al. (2021)

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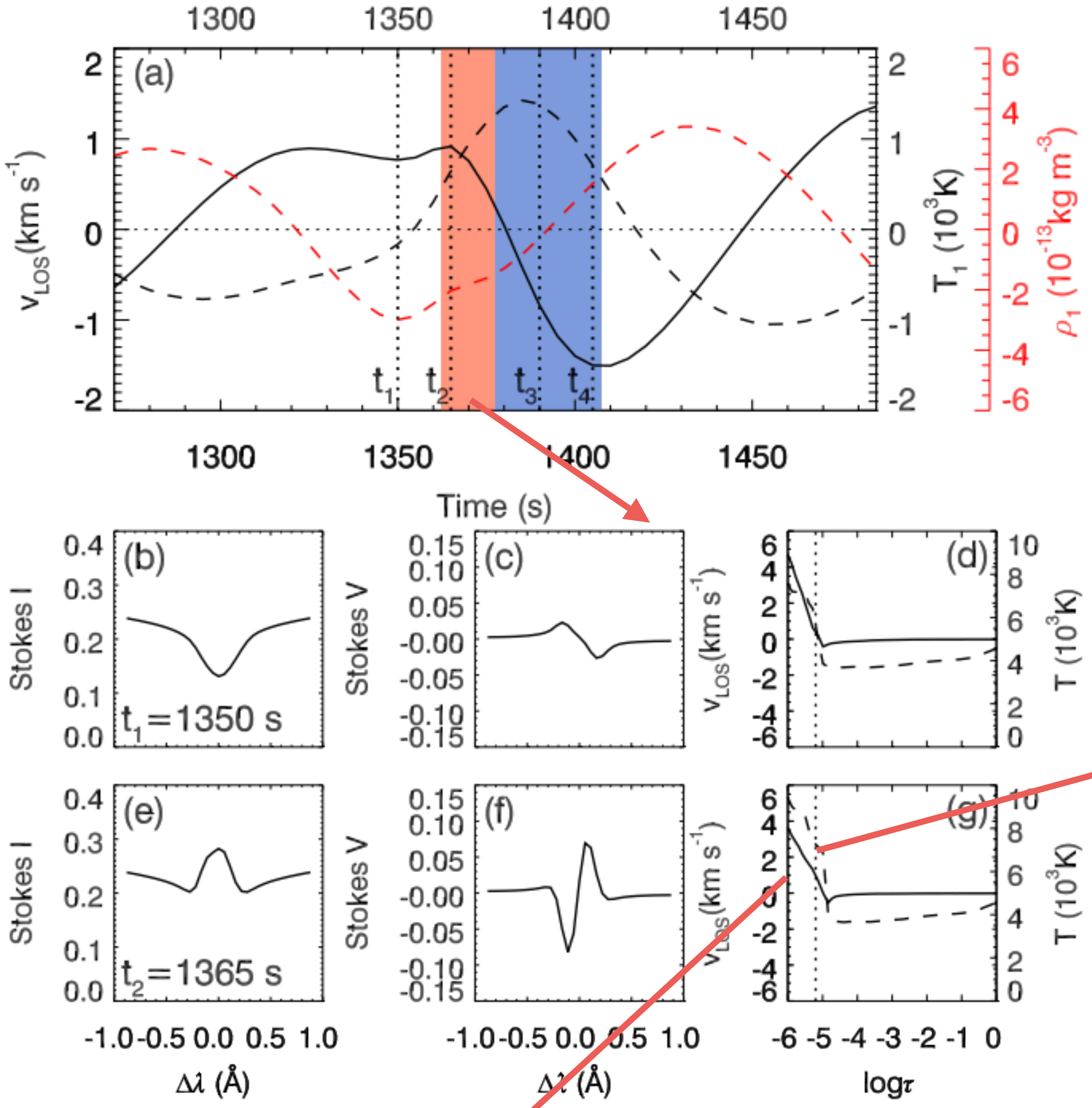
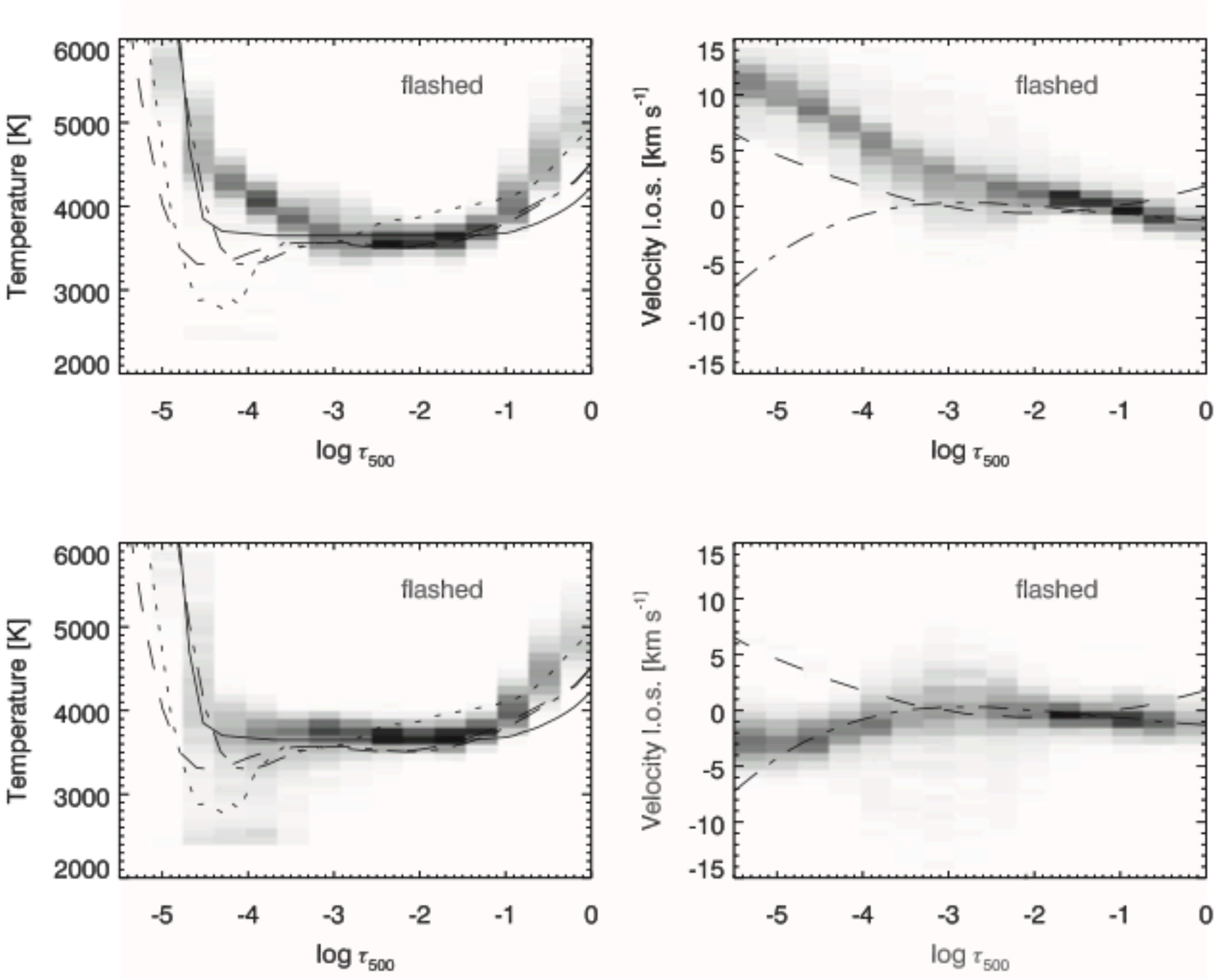
from Felipe et al. (2021)



Downflow

...but velocity stratification GREATLY simplifies with resonant cavities for which there is independent empirical evidence (Jess et al 2019, Felipe et al. 2019)

...so we have to consider again the possibility of simpler monotonic stratifications at the instant of the flash



from Henriques et al. (2017)

Downflowing models

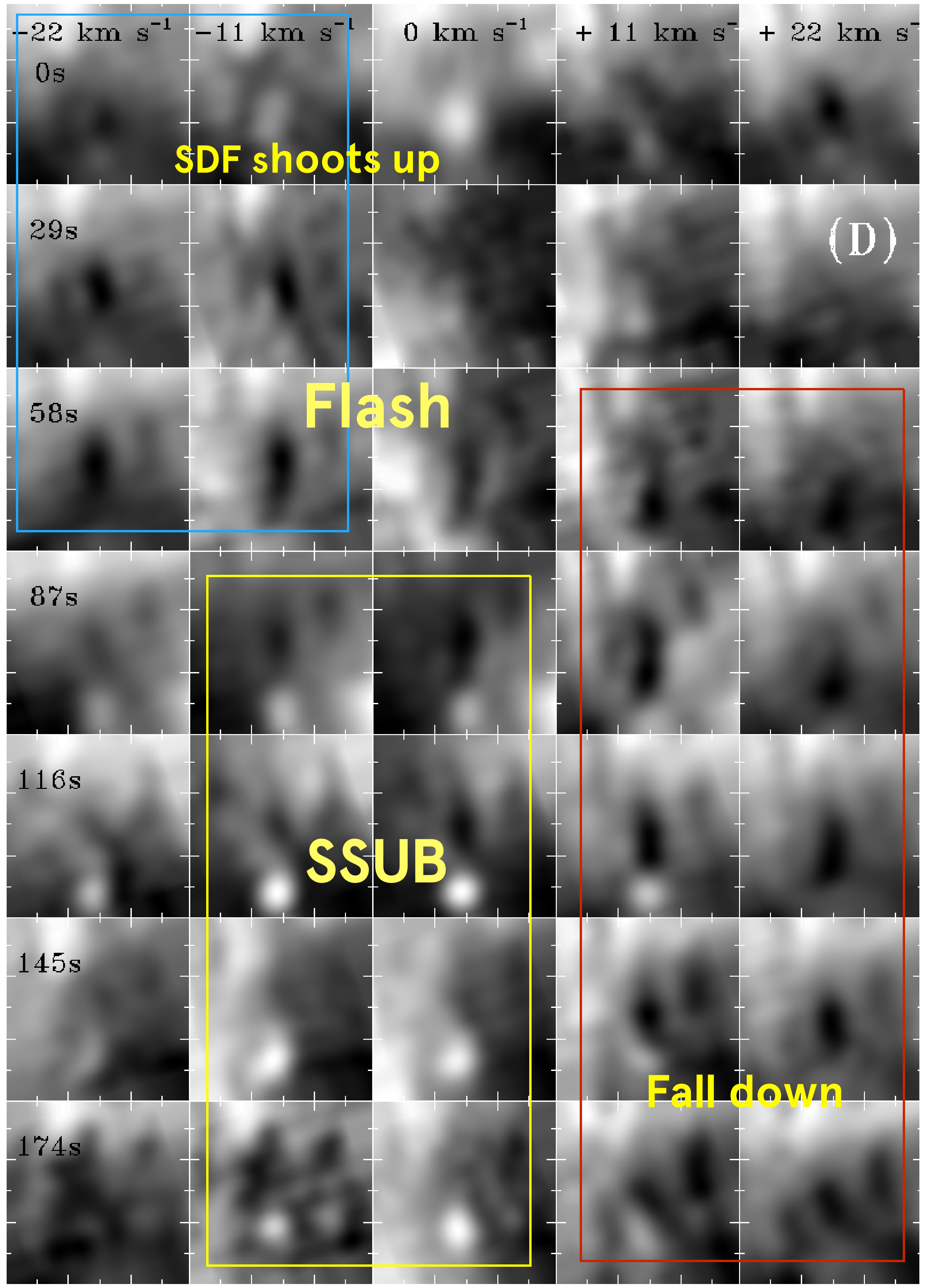
Socas-Navarro (2001)
Henriques et al. (2017)
Houston et al. (2019)
Bose et al. (2019)

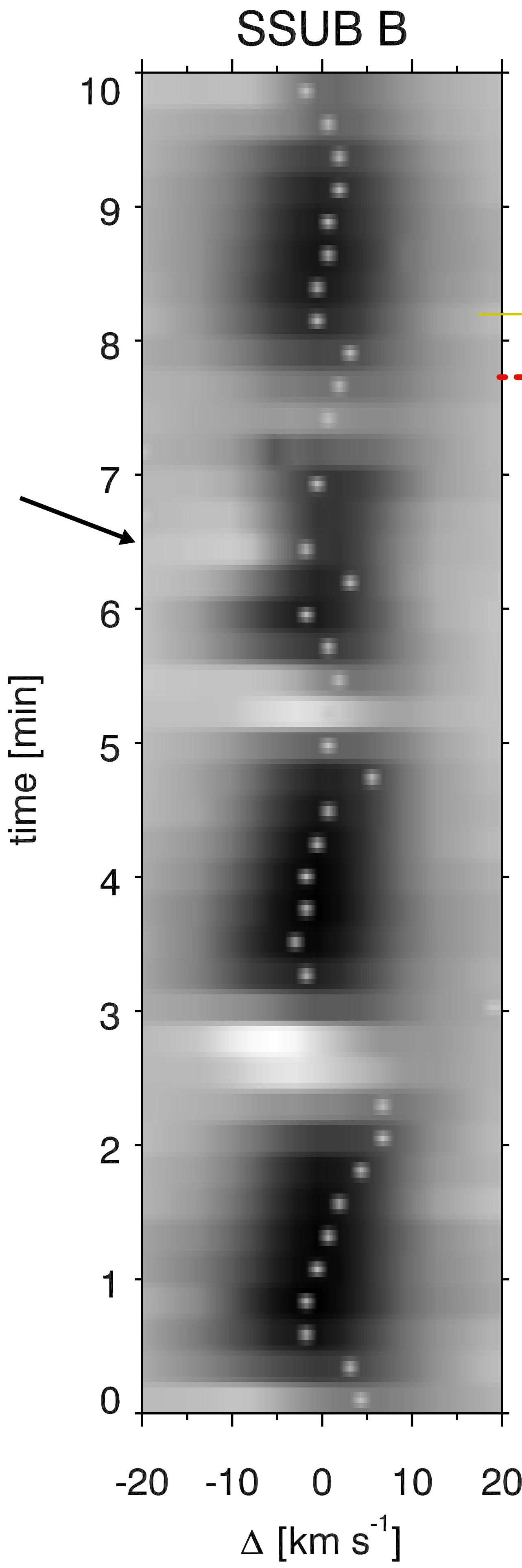
Upflowing models

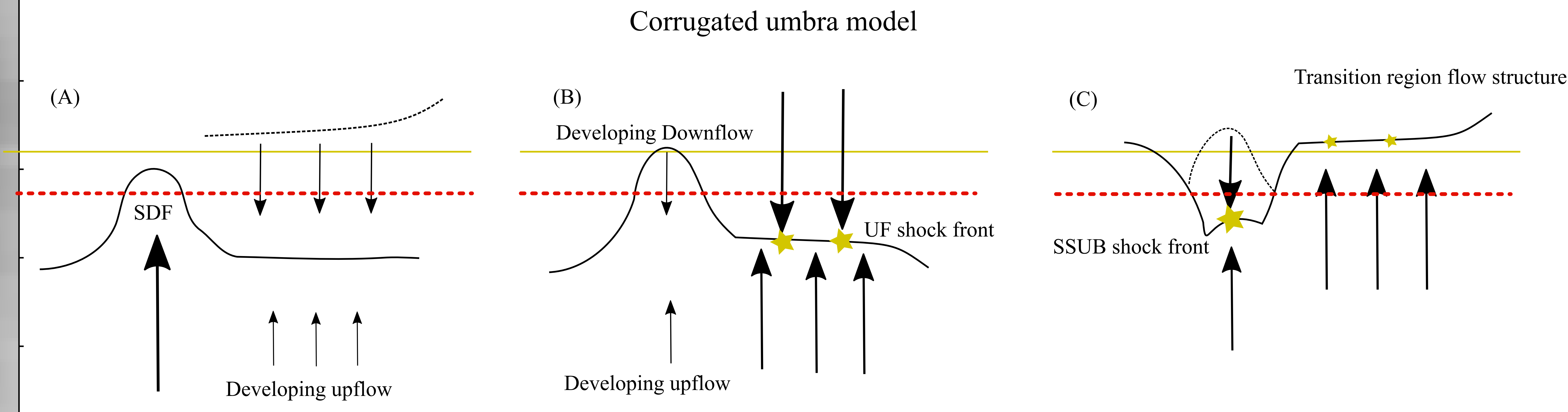
Socas-Navarro (2001)
d.l.c.Rodríguez and R.v.d.Voort (2013)
Henriques et al. (2017)
Houston et al. (2019)
Joshi et al. (2020)

Grey scale is the density of atmospheres

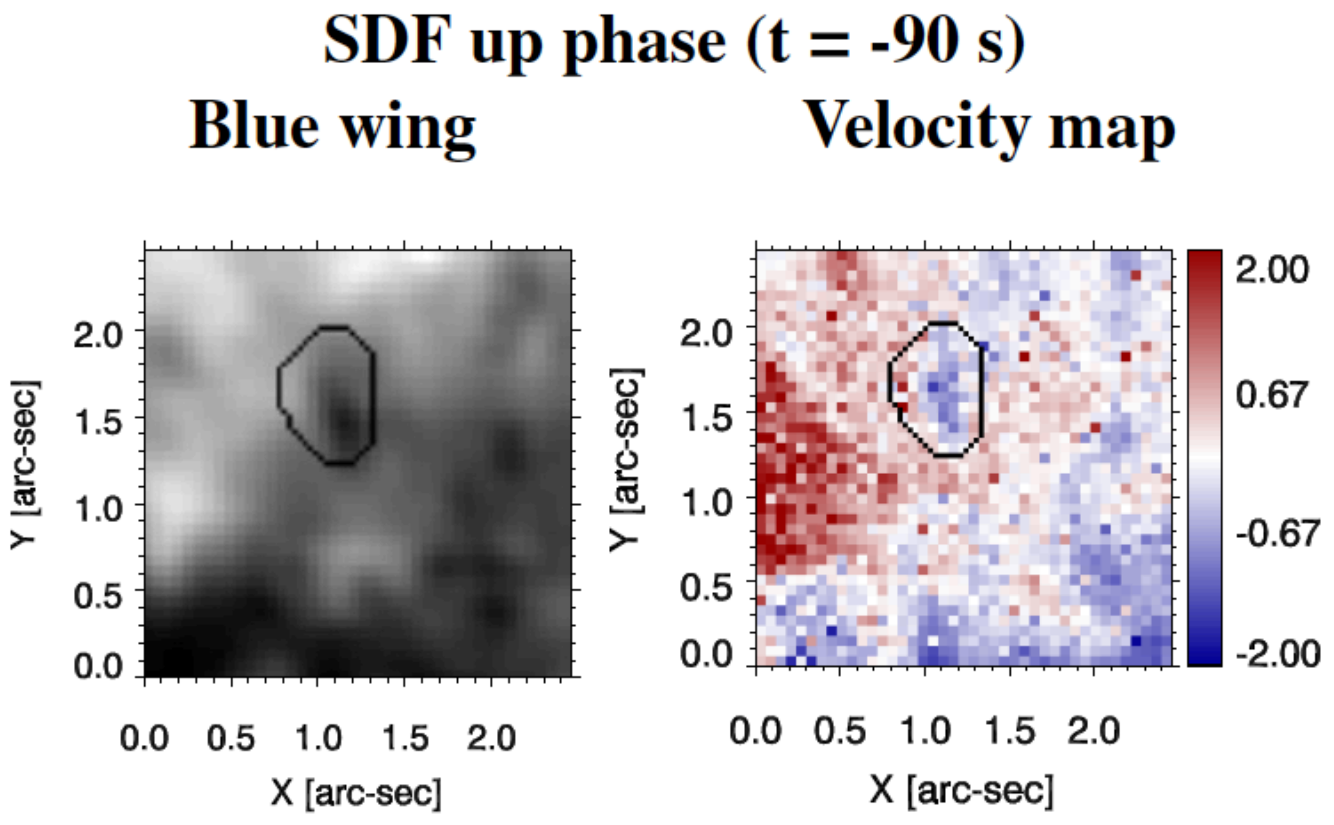
LTE investigation necessary! (Henriques et al., 2020)

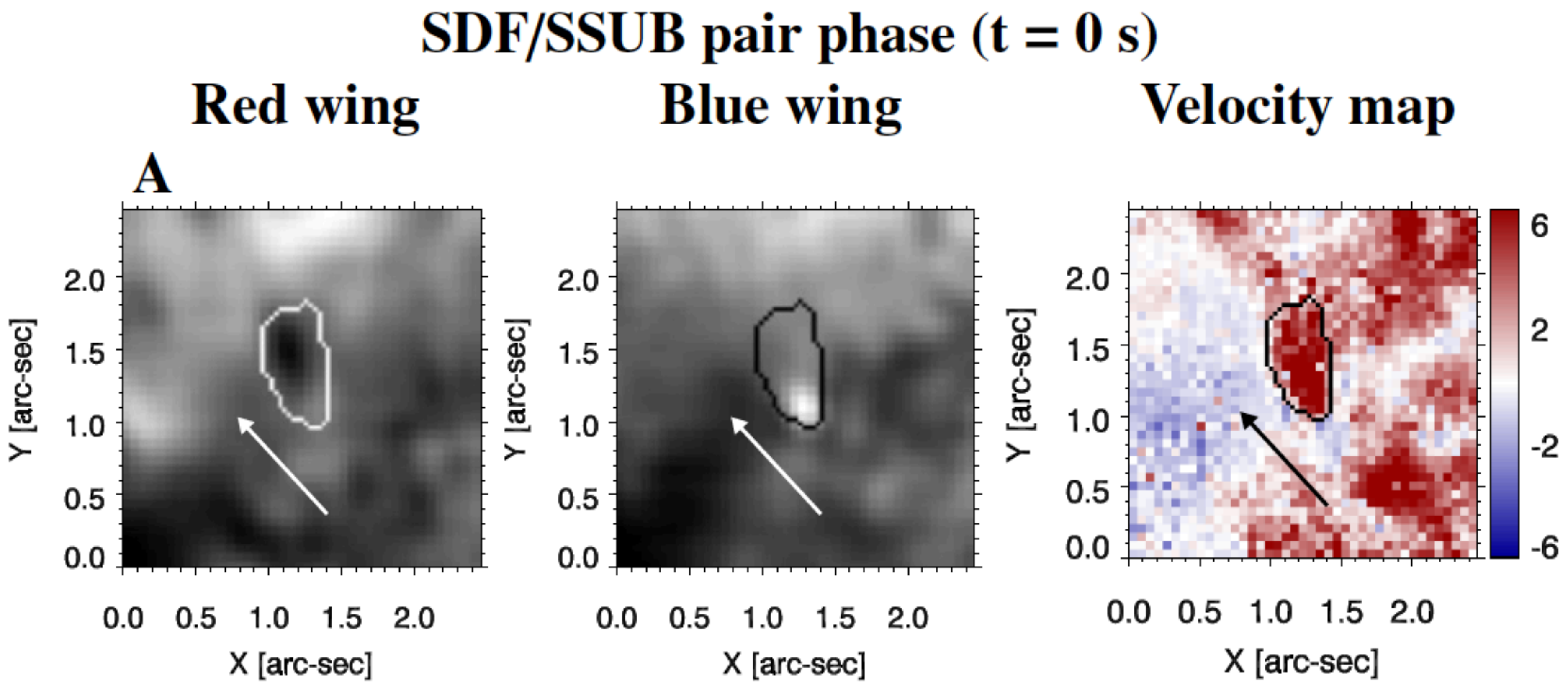


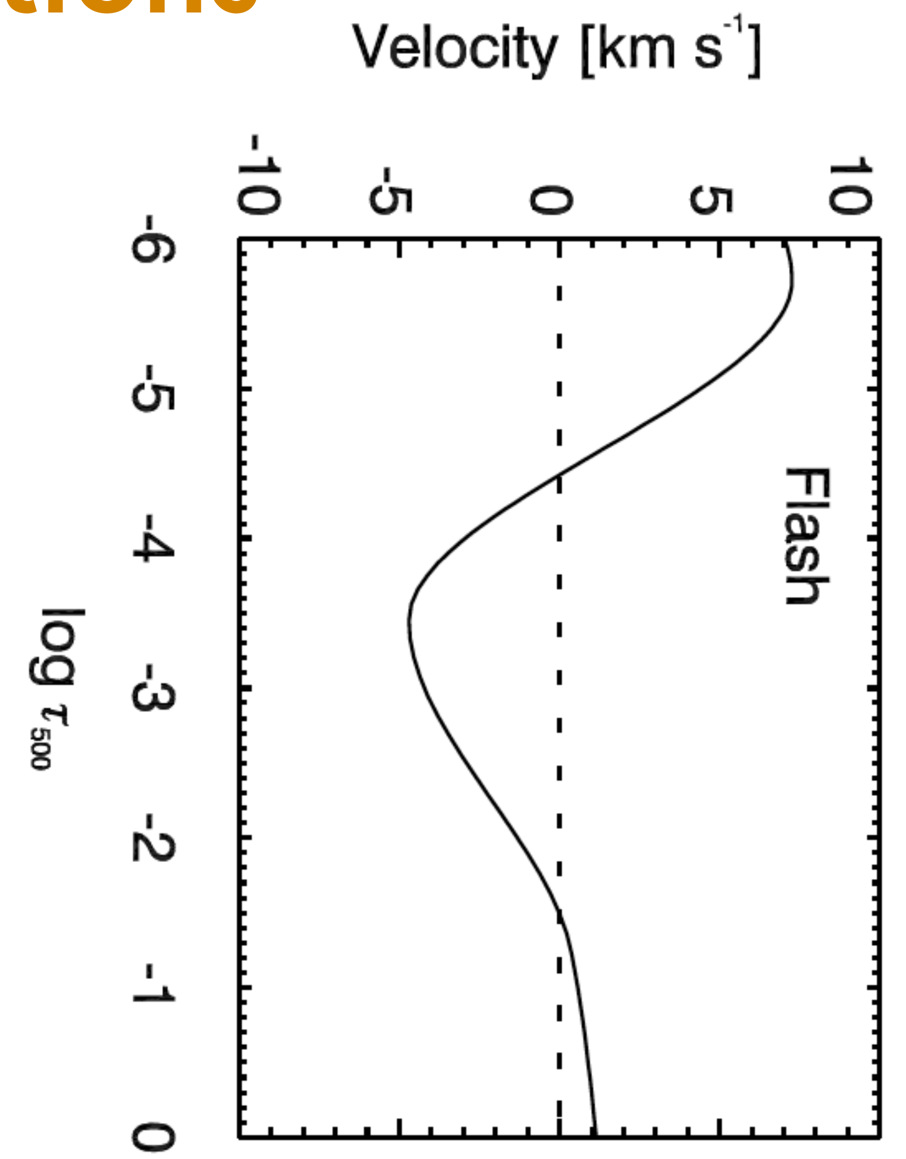




but! Corrugated Umbra model implication:
the <u>flashing process itself</u>
is incredibly fine-scaled in space and time,
not captured by simulations





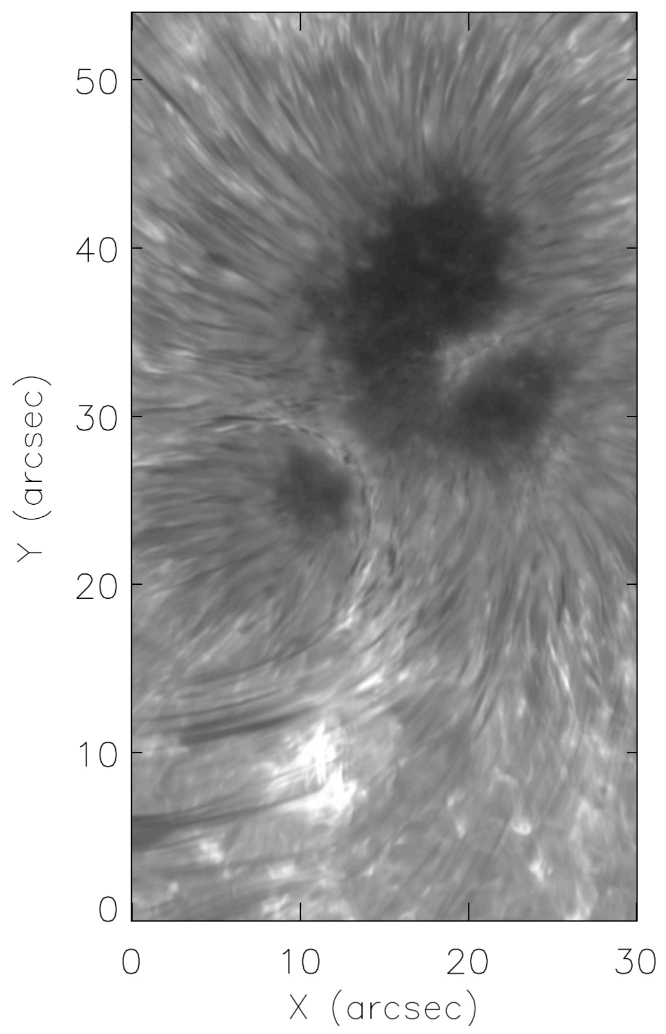


Solution

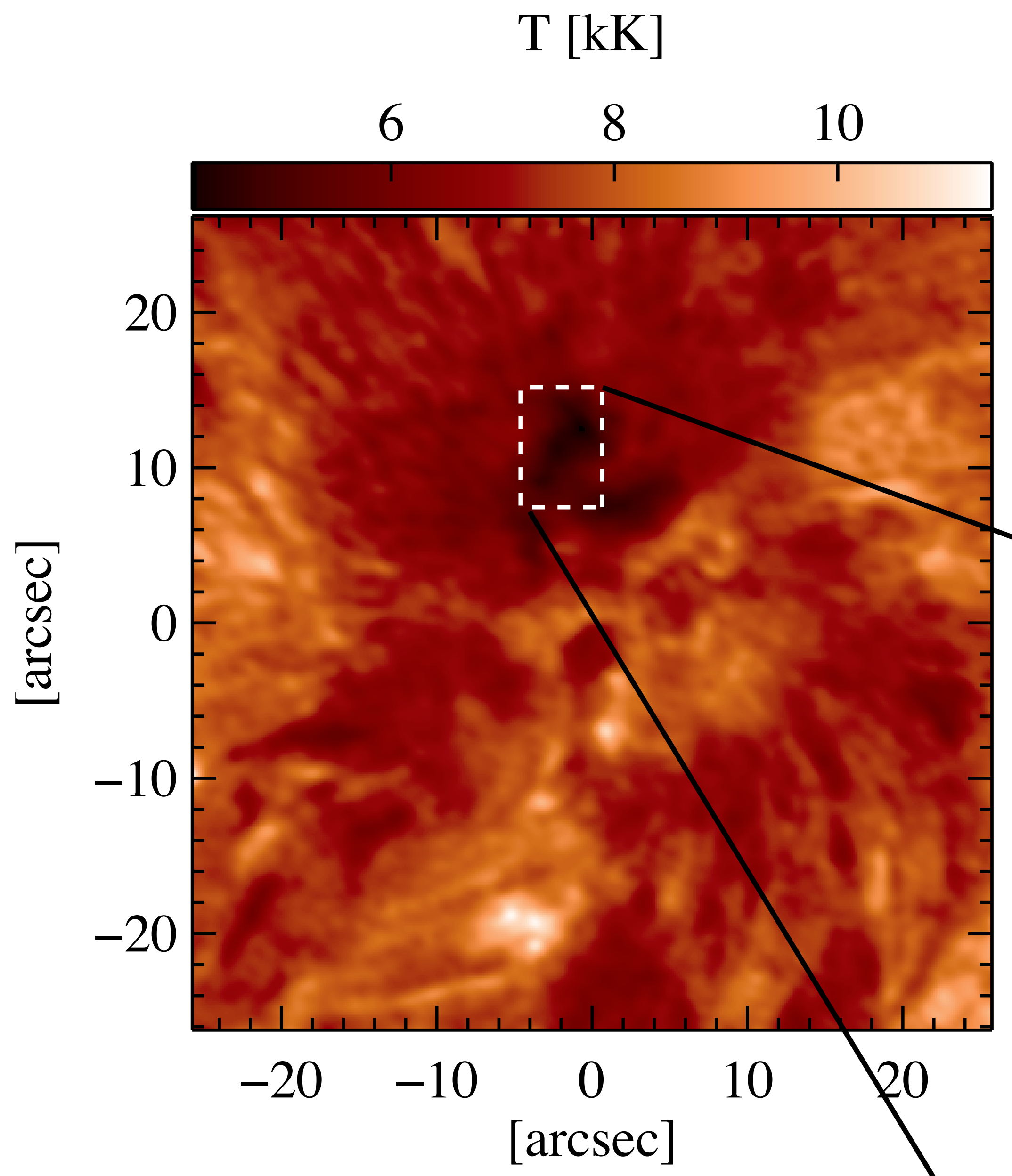
observations (SST) -> small but full cube delta manipulation on all profiles and weights to trigger local solutions (i.e. allow degeneracy to go one way or the other for larger areas) -> invert models (NICOLE) -> mm radiative transfer (ART) + ALMA configuration-dependent realistic beam shapes

Testable ALMA predictions to resolve non-LTE caused degeneracy

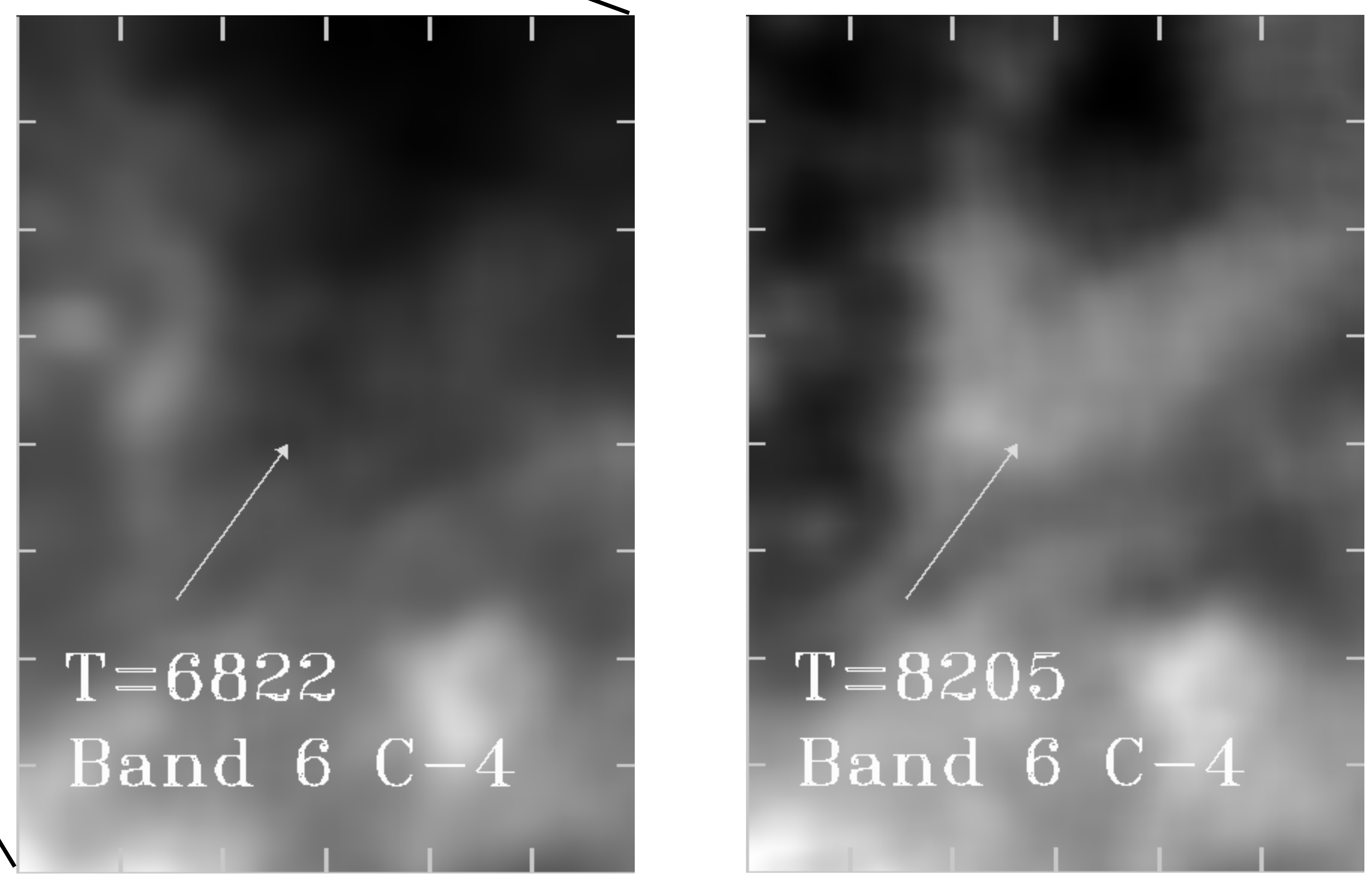
SST



ALMA from SST



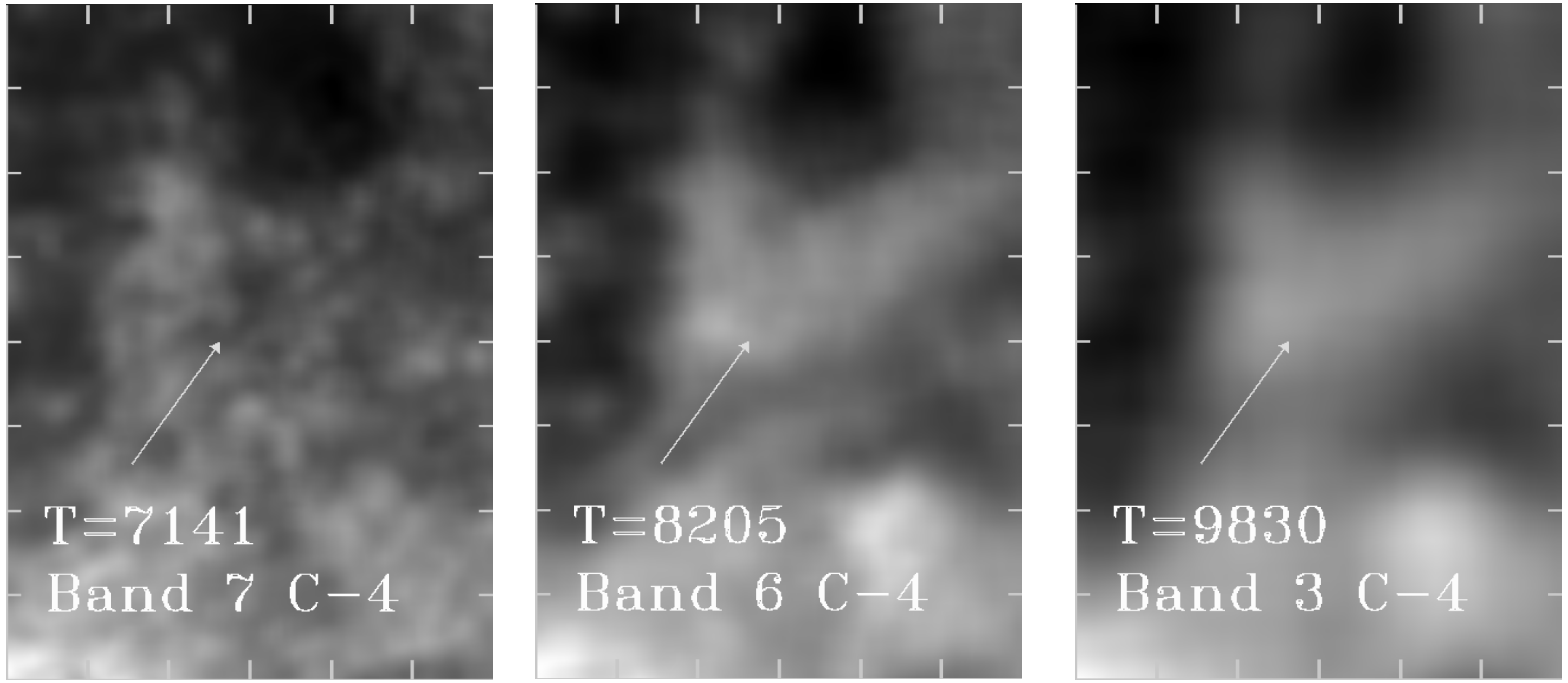
Forecasting an UF in ALMA from SST observations



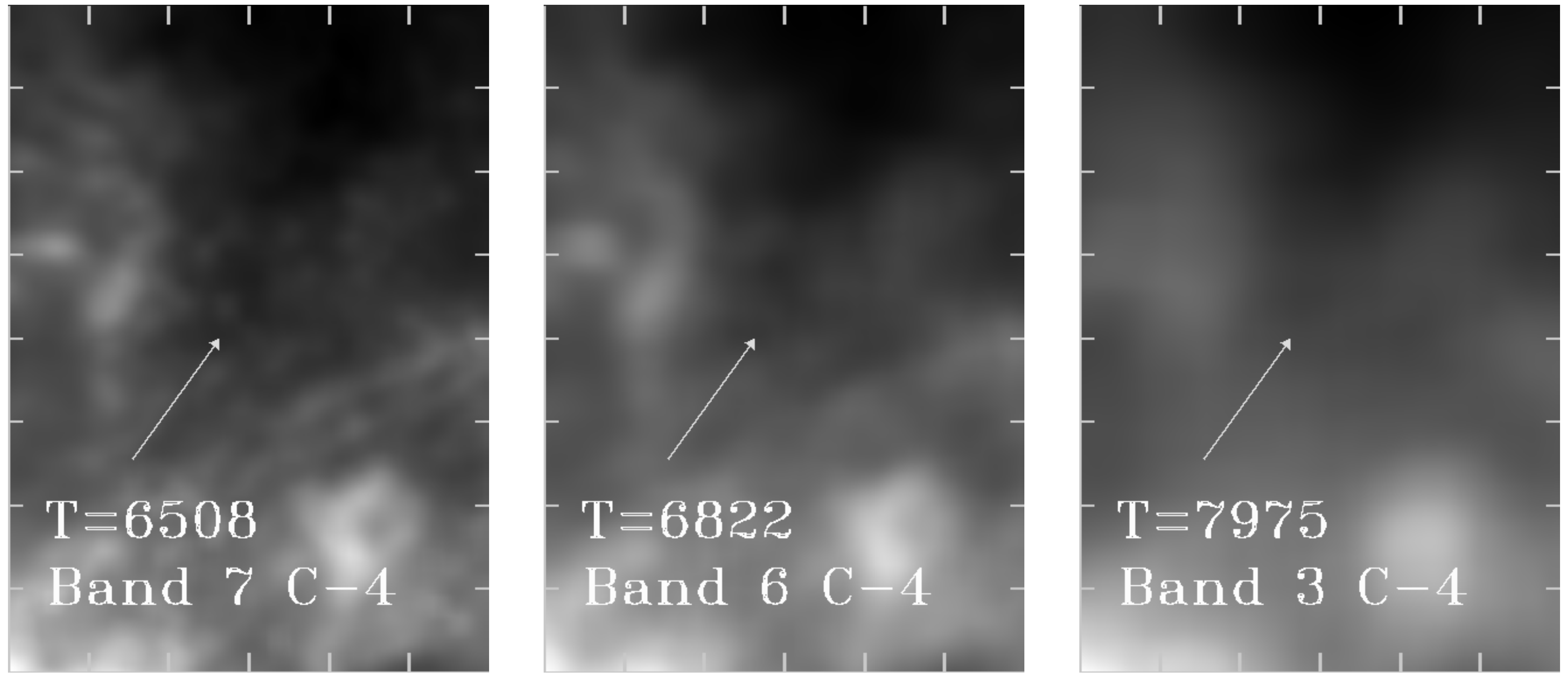
Quiescent **Flash**

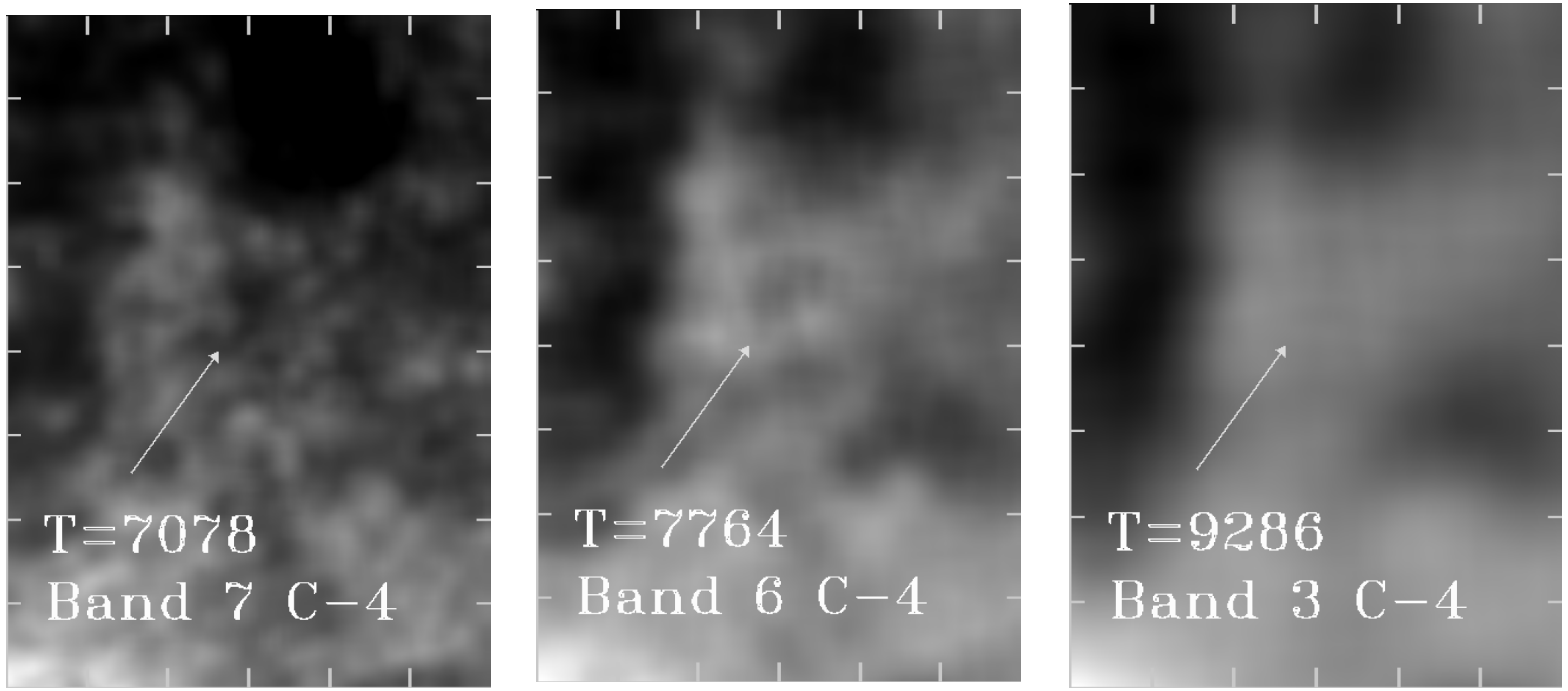
ALMA synthetics for two umbral flash scenarios

Downflow dominated



Quiescent phase





Upflow dominated

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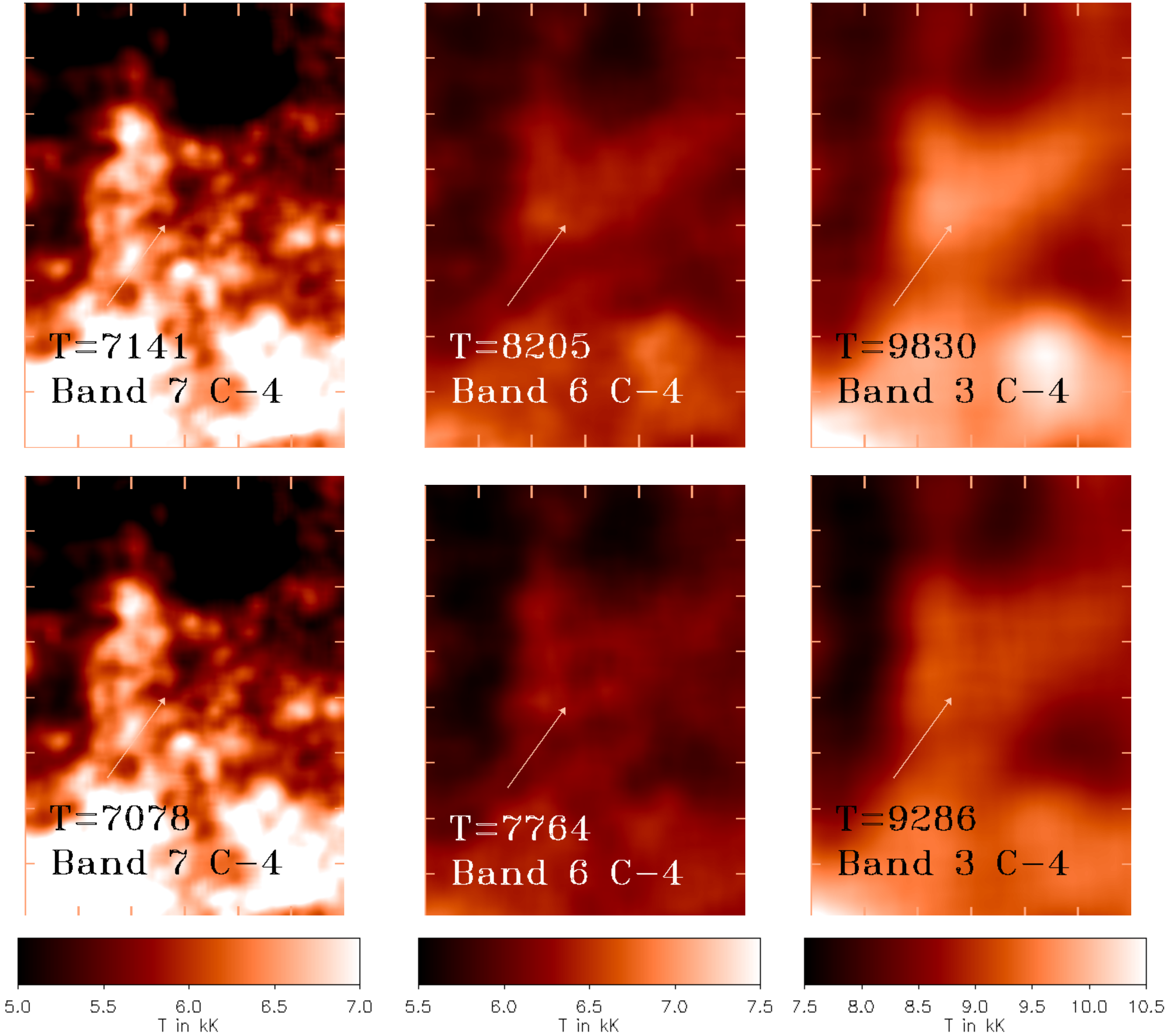
Downflow dominated

Upflow dominated



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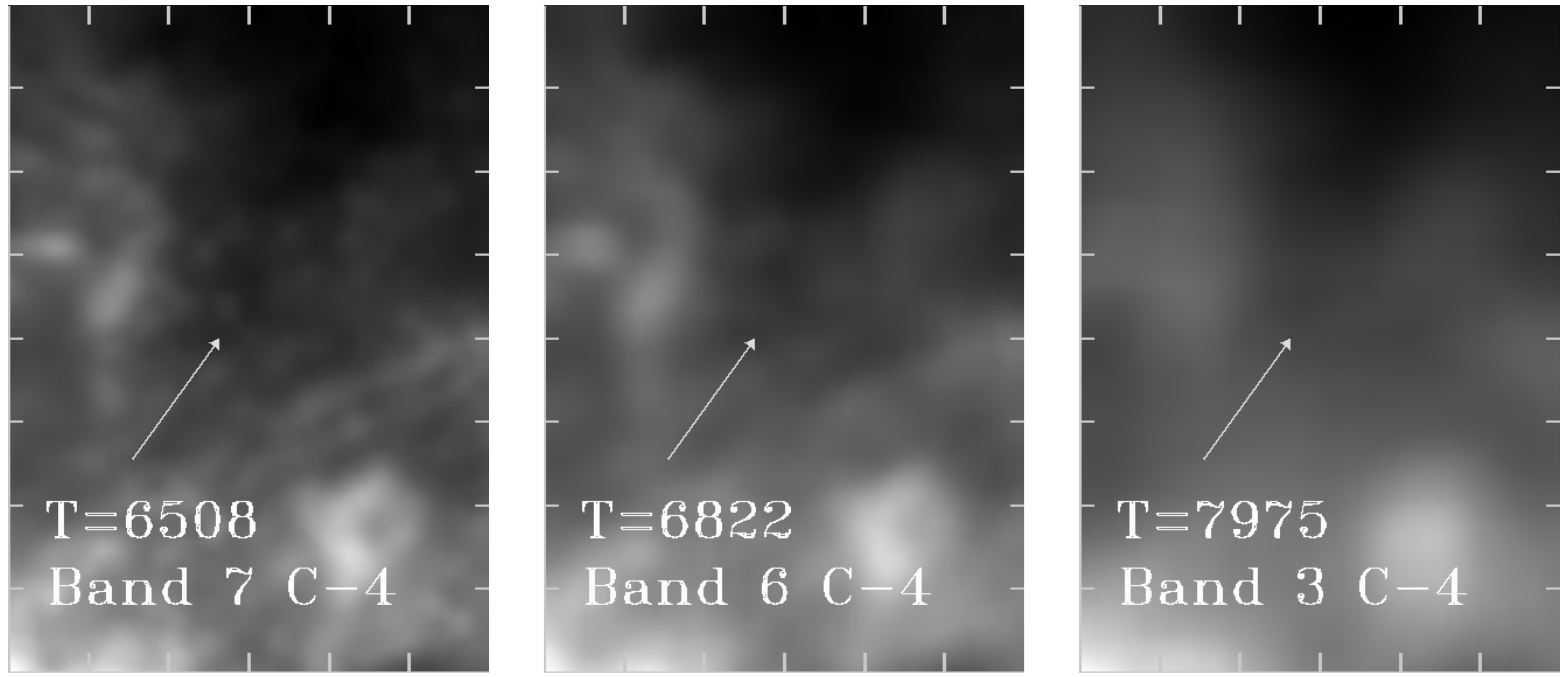
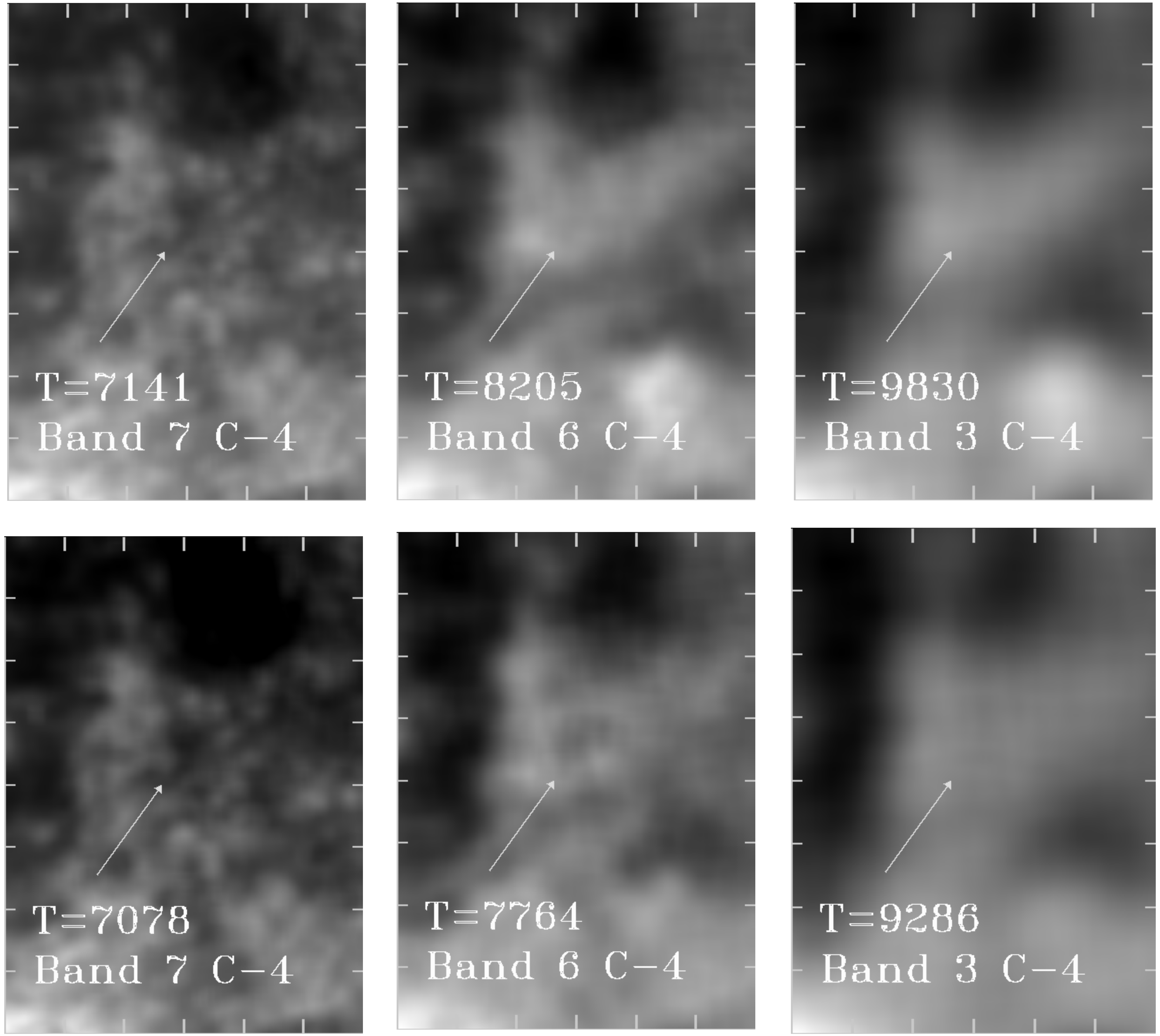
ALMA synthetics for two umbral flash scenarios

Quiescent phase



Downflow dominated

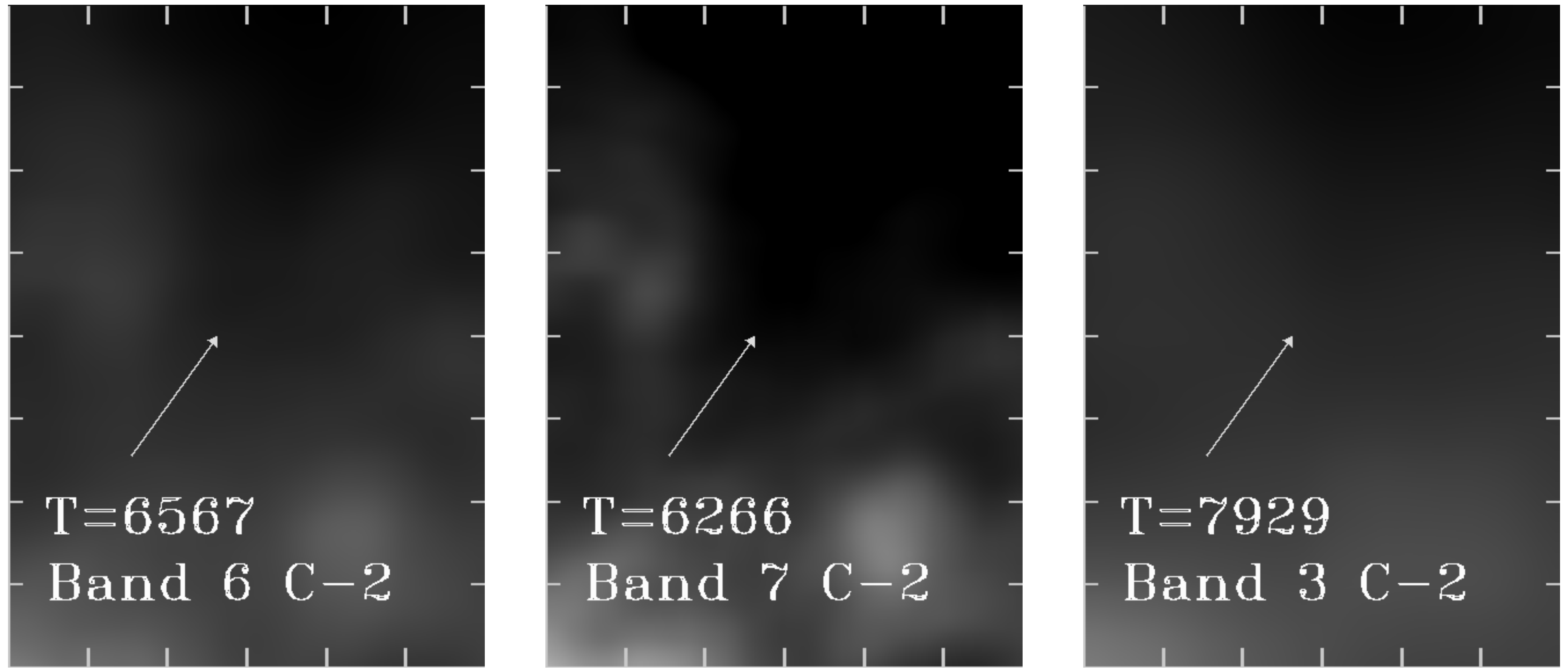


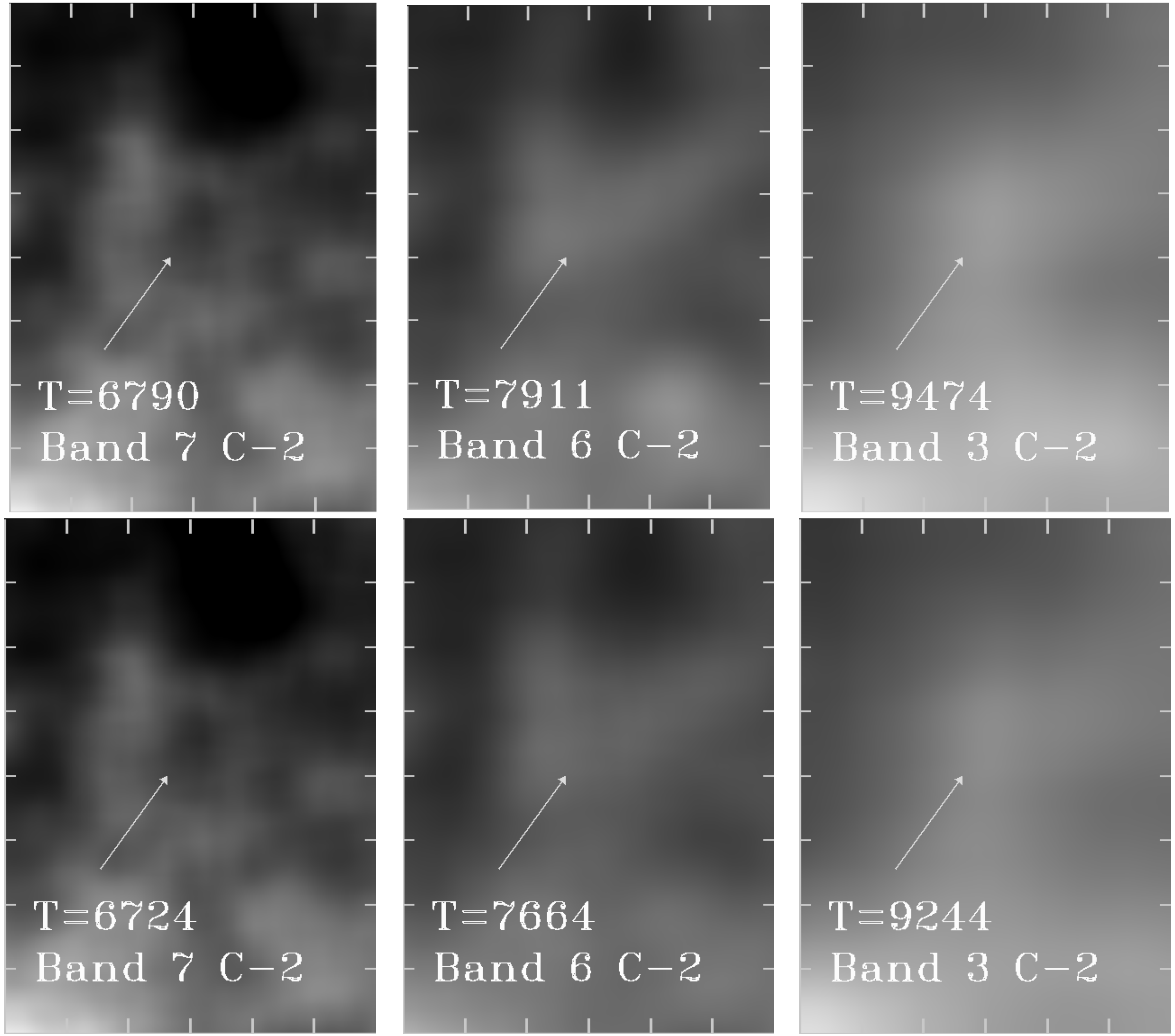
Upflow dominated

Distinction in Band 3 is not possible at array configuration 3 or lower, but possible in Band 6 despite lower delta T

Downflow dominated

Quiescent phase





Upflow dominated

A conditional prediction

Should cavity effects be important for umbral flashes, then Band 3 brightness temperatures will exceed 9500 K for the vast majority of time-resolved ALMA sunspots in the early flash stage, provided array config better than C-3.

Likewise and with the same conditionality, Band 6 will exceed 7900 K for all array configurations.

If cavities are **not** important, then these temperatures will be rarely obtained at any flash stage of the ALMA observed umbra.

Takeaways

- Sensitivity to different UF models starts at such a low height as that sampled by Band 6 due to significant contribution above log tau $_{500}$ =-3.
- Band 3 has higher response where models diverge but the lower resolution leads to significant mixing of real UF fine-structuring as sampled with SST resolution and not present in simulations. For "down vs up" it is as good as Band 6.
- Umbral flashes can explain mm enhancement, need time series
- Band 7 should be remarkably detailed but upper photospheric in sunspots
- Semi-empirical data, provides a path to synthetics that give insights not possible with those produced from simulations. More than guide they help interpret observations taken with very different instruments.

Two ALMA sunspots

compilation courtesy of Prof. Alissandrakis (UoI)

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So we are looking forward for high-cadence high-resolution sunspots. Like the ones in the Solar ALMA Science Archive (SALSA)

check it out!

sdc.uio.no/salsa

Show 50 entries

Search ....

No	Date	Project ID	Band / λ	Cad.	Obs. Time (UTC)	(x,y)	μ	T_{mean} (K)	bmin / bmaj	Time Series	Data	Co-Obs	Thumbnail	SD Thumbnail
D01	2016-12-22	2016.1.00423.S	3 / 3 mm	2 sec	14:19:31-15:07:07	0,0	0.99	7387 ± 519	1.37 / 2.10	MOVIE	DOWNLOAD	SDO		
D02	2017-04-22	2016.1.00050.S	3 / 3 mm	2 sec	17:20:13-17:42:37	-249,267	0.92	9317 ± 1229	1.69 / 2.21	MOVIE	DOWNLOAD	SDO IRIS		
D03	2017-04-23	2016.1.01129.S	3 / 3 mm	2 sec	17:19:19-18:52:54	-54,251	0.96	7161 ± 1817	1.92 / 2.30	MOVIE	DOWNLOAD	SDO IRIS		
D04	2017-04-27	2016.1.01532.S	3 / 3 mm	2 sec	14:19:52-15:31:17	520,272	0.78	7974 ± 1145	1.74 / 2.23	MOVIE	DOWNLOAD	SDO IRIS		
D05	2017-04-27	2016.1.00202.S	3 / 3 mm	2 sec	16:00:30-16:43:56	172,-207	0.96	7287 ± 1297	1.77 / 1.88	MOVIE	DOWNLOAD	SDO IRIS		
D06	2018-04-12	2017.1.00653.S	3 / 3 mm	1 sec	15:52:28-16:24:41	-128,400	0.90	7586 ± 661	1.77 / 2.55	MOVIE	DOWNLOAD	SDO IRIS		
D07	2017-04-18	2016.1.01129.S	6 / 1 mm	2 sec	14:22:01-15:09:15	-573,230	0.76	7167 ± 1158	0.75 / 2.03	MOVIE	DOWNLOAD	SDO IRIS		
D08	2017-04-22	2016.1.00050.S	6 / 1 mm	2 sec	15:59:07-16:43:26	-261,266	0.92	7496 ± 1014	0.68 / 0.85	MOVIE	DOWNLOAD	SDO IRIS		
D09	2018-04-12	2017.1.00653.S	6 / 1 mm	1 sec	13:58:57-14:32:27	-175,-415	0.88	5700 ± 333	0.80 / 2.22	MOVIE	DOWNLOAD	SDO IRIS		
D10	2018-08-23	2017.1.01672.S	6 / 1 mm	1 sec	16:24:27-17:18:05	68,-211	0.97	6104 ± 497	1.69 / 2.21	MOVIE	DOWNLOAD	SDO IRIS		No SD for this set
D11	2017-03-16	2016.1.00572.S	3 / 3 mm	1 sec	15:22:33-15:32:37	-679,-679	0	7263* ± 148	2.55 / 4.43	MOVIE	DOWNLOAD	SDO		
D12	2017-03-19	2016.1.00030.S	3 / 3 mm	2 sec	18:16:02-19:10:13	-493,-46	0.86	7364 ± 302	2.52 / 5.06	MOVIE	DOWNLOAD	SDO IRIS		No SD for this set
D15	2018-08-23	2017.1.01672.S	6 / 1 mm	1 sec	17:37:00-18:15:57	79,-238	0.87	5814 ± 267	0.82 / 1.31	MOVIE	DOWNLOAD	SDO IRIS		No SD for this set
D16	2017-03-16	2016.1.00572.S	3 / 3 mm	2 sec	16:58:00-17:06:40	-581,-588	0.50	7371 ± 186	2.70 / 4.32	MOVIE	DOWNLOAD	SDO		
D17	2017-03-16	2016.1.00572.S	3 / 3 mm	2 sec	18:40:51-18:50:56	-383,-407	0.82	7323 ± 241	2.54 / 5.17	MOVIE	DOWNLOAD	SDO IRIS		
D18	2017-03-16	2016.1.00572.S	3 / 3 mm	2 sec	17:59:04-18:09:08	-468,-484	0.72	7296 ± 251	2.52 / 4.85	MOVIE	DOWNLOAD	SDO		
D19	2017-03-16	2016.1.00572.S	3 / 3 mm	2 sec	19:23:00-19:33:05	-261,-295	0.91	7416 ± 234	2.46 / 5.77	MOVIE	DOWNLOAD	SDO		
D20	2017-03-16	2016.1.00572.S	3 / 3 mm	2 sec	16:14:48-16:24:53	-686,-666	0.13	4475 ± 256	2.49 / 4.56	MOVIE	DOWNLOAD	SDO		
D21	2018-12-20	2018.1.01763.S	6 / 1 mm	1 sec	13:19:19-14:07:32	880,200	0.38	6181 ± 208	0.60 / 1.05	MOVIE	DOWNLOAD	SDO IRIS		
D22	2018-12-22	2018.1.01879.S	6 / 1 mm	1 sec	15:09:14-15:14:57	-2, 0	1.00	6310 ± 185	0.73 / 1.99	MOVIE	DOWNLOAD	SDO		
D23	2017-04-23	2016.1.01129.S	6 / 1 mm	2 sec	14:23:55-15:11:06	-860,-129	0.41	6643 ± 396	0.71 / 1.72	MOVIE	DOWNLOAD	SDO IRIS		
D24	2017-03-19	2016.1.00030.S	3 / 3 mm	2 sec	15:32:32-16:26:52	-493,-46	0.84	7461 ± 421	2.65 / 4.39	MOVIE	DOWNLOAD	SDO IRIS		No SD for this set
D25	2017-03-19	2016.1.00030.S	3 / 3 mm	2 sec	16:52:52-17:47:11	-483,-45	0.85	7387 ± 415	2.48 / 4.31	MOVIE	DOWNLOAD	SDO IRIS		No SD for this set
D26	2018-04-12	2017.1.00653.S	3 / 3 mm	1 sec	16:43:52-17:16:06	-131,-400	0.90	7553 ± 360	1.84 / 2.82	MOVIE	DOWNLOAD	SDO IRIS		
D27	2018-04-12	2017.1.00653.S	6 / 1 mm	1 sec	14:51:20-15:25:01	145,-400	0.90	5899 ± 157	0.89 / 2.01	MOVIE	DOWNLOAD	SDO IRIS		
D28	2017-	2016.1.00788.S	6 / 1	1 sec	15:09:20-	-190,347	0.91	6157 ±	1.05 /			SDO		

R CS

Bonus online material for fun

See the SDFS + SSUBS from Nelson et al. 2017 and Henriques et al. 2020 in a PDF time series

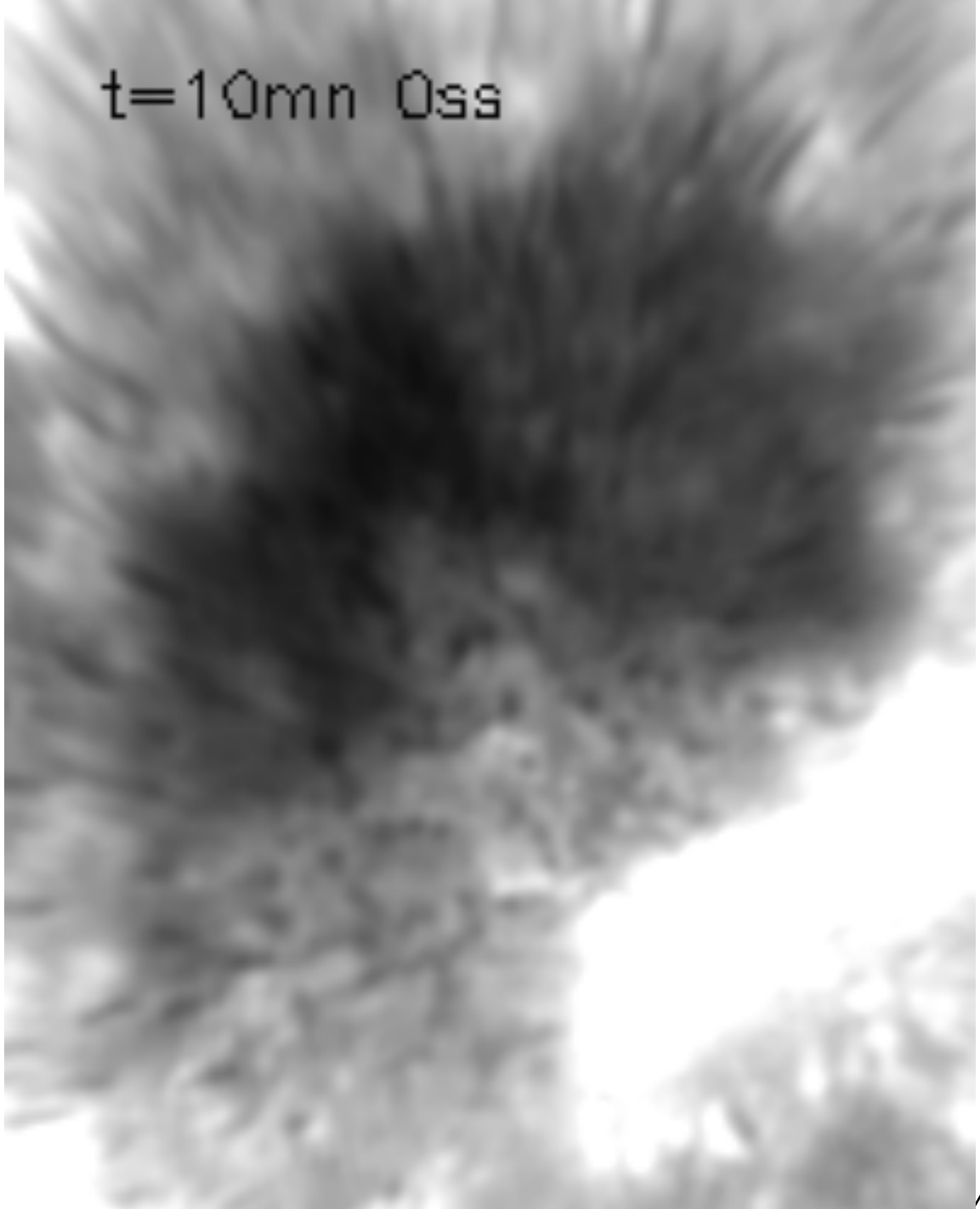
(play with arrow keys in single page mode on your favourite viewer)

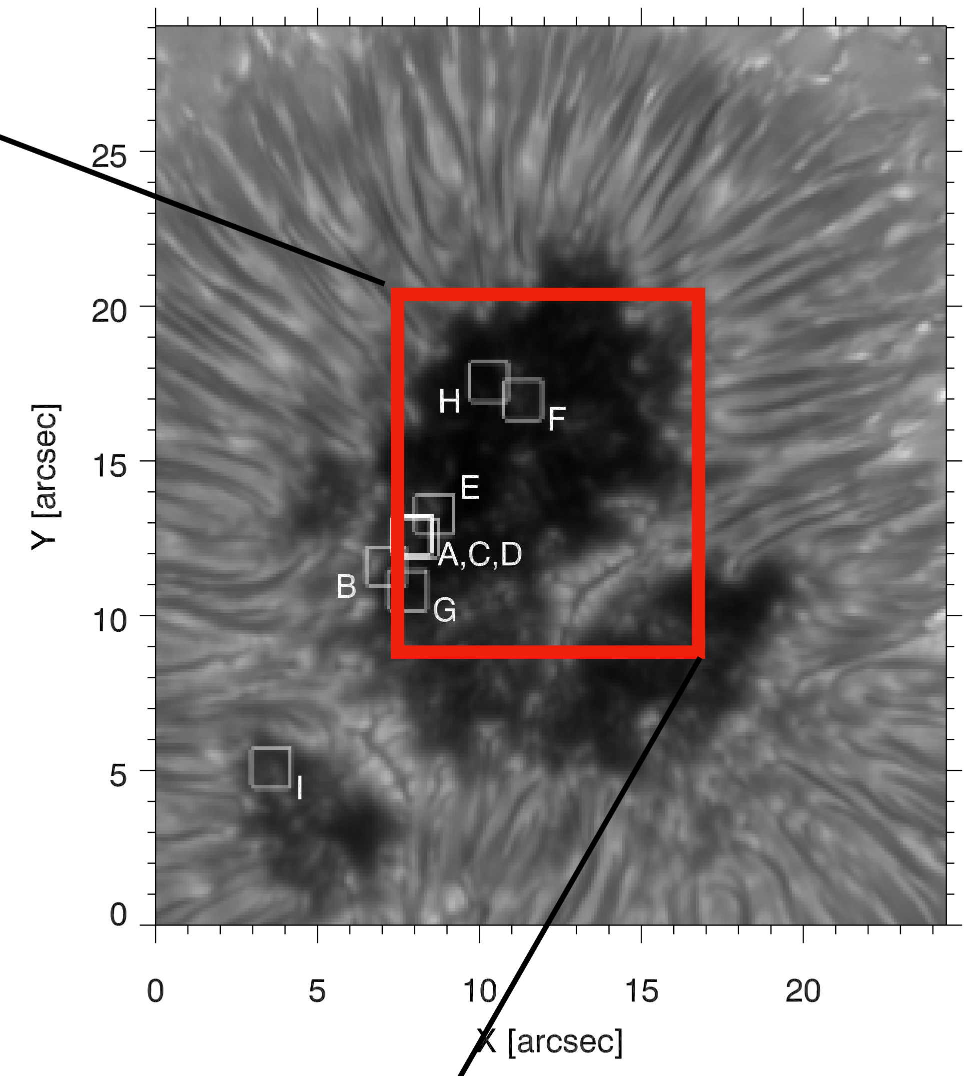
Small-scale umbral brightenings (SSUBs) are distinct from Bharti et al. (2013) umbral microjets as the latter seem to be genuine ejections and likely reconnection events (Bharti et al., 2020) and the former are brightenings at the base of short-dynamic fibrils (SDFs), either ahead or delayed from the umbral flash and, together with other evidence presented in Henriques et al. (2020), are formed as part of a highly corrugated steepening wave-front, interacting with the mass movements of the short dynamic fibrils.

R C S

Once you know where to look

red wing at 156 mÅ





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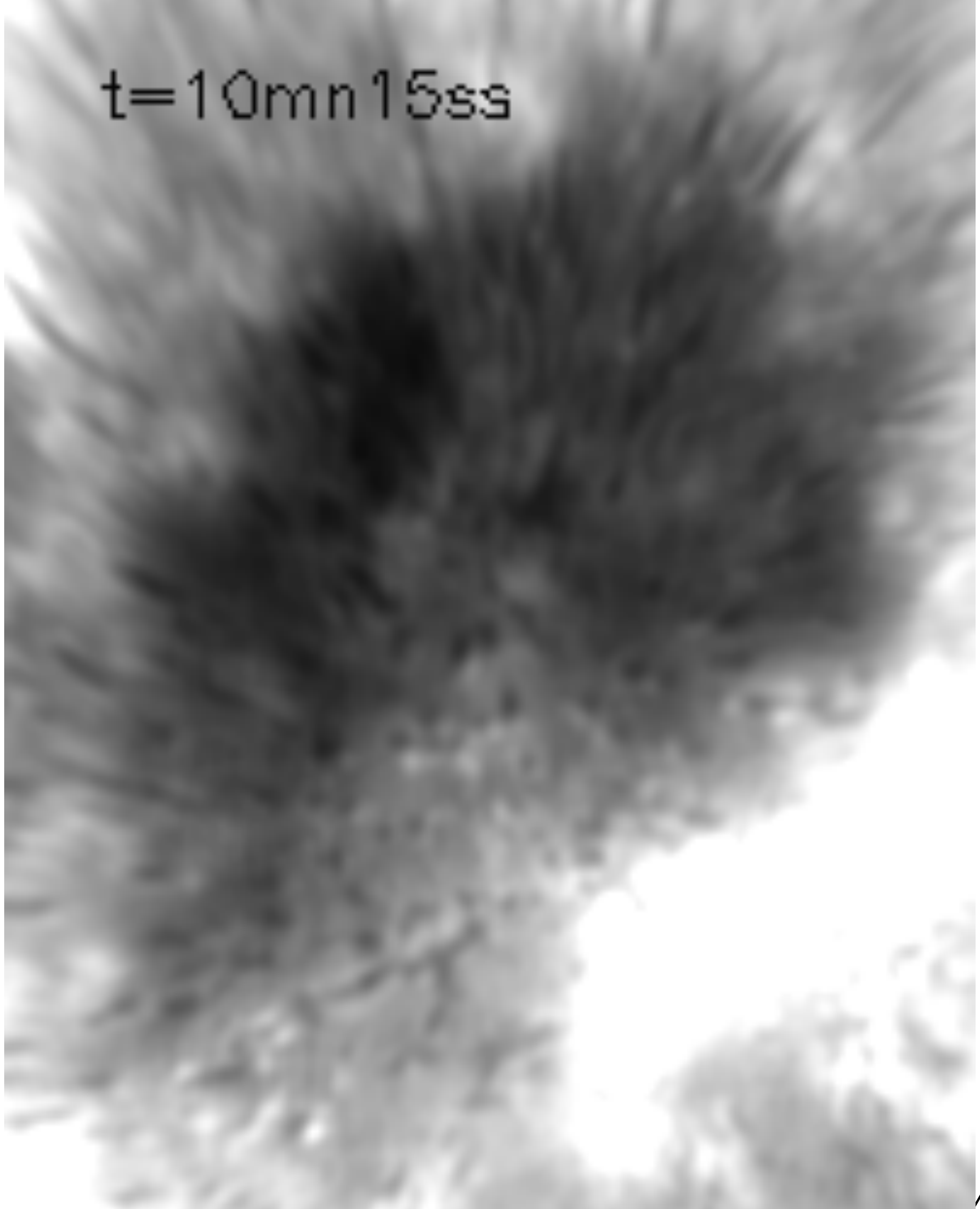

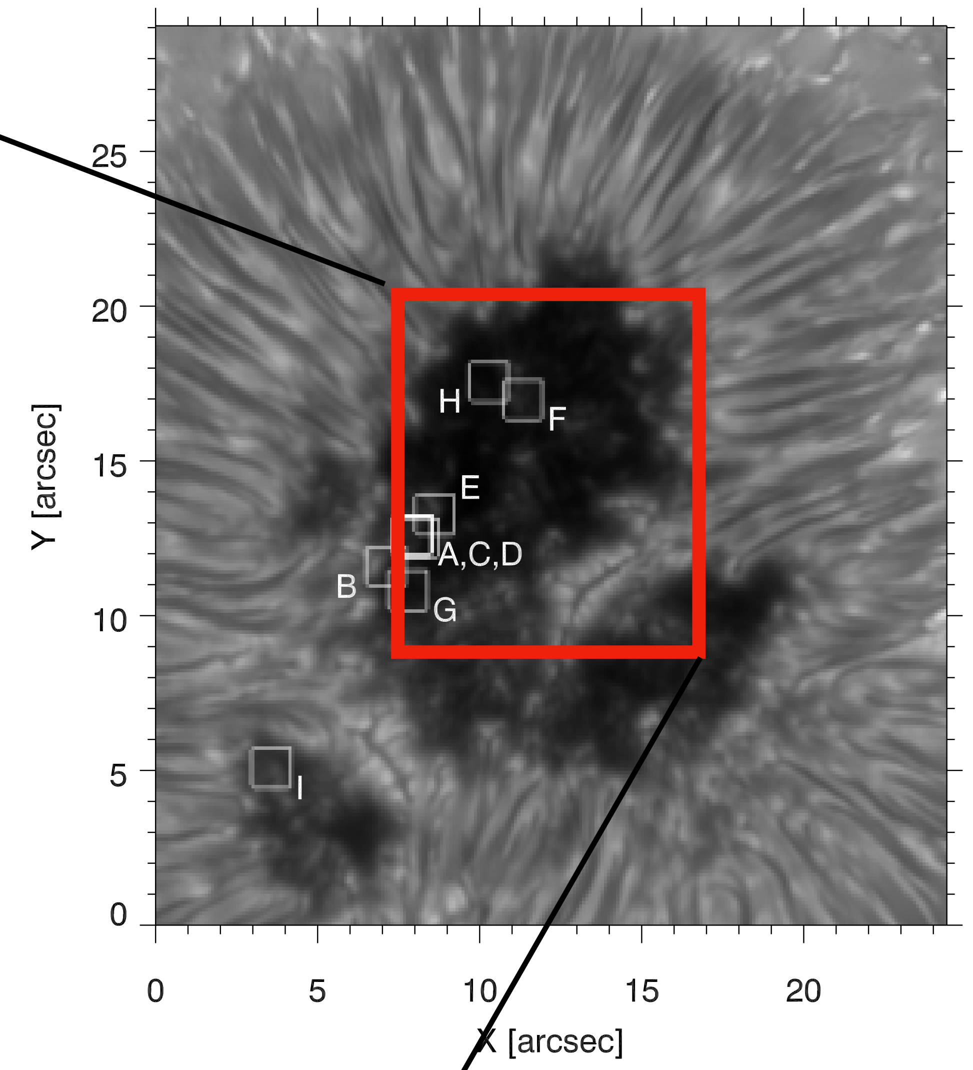

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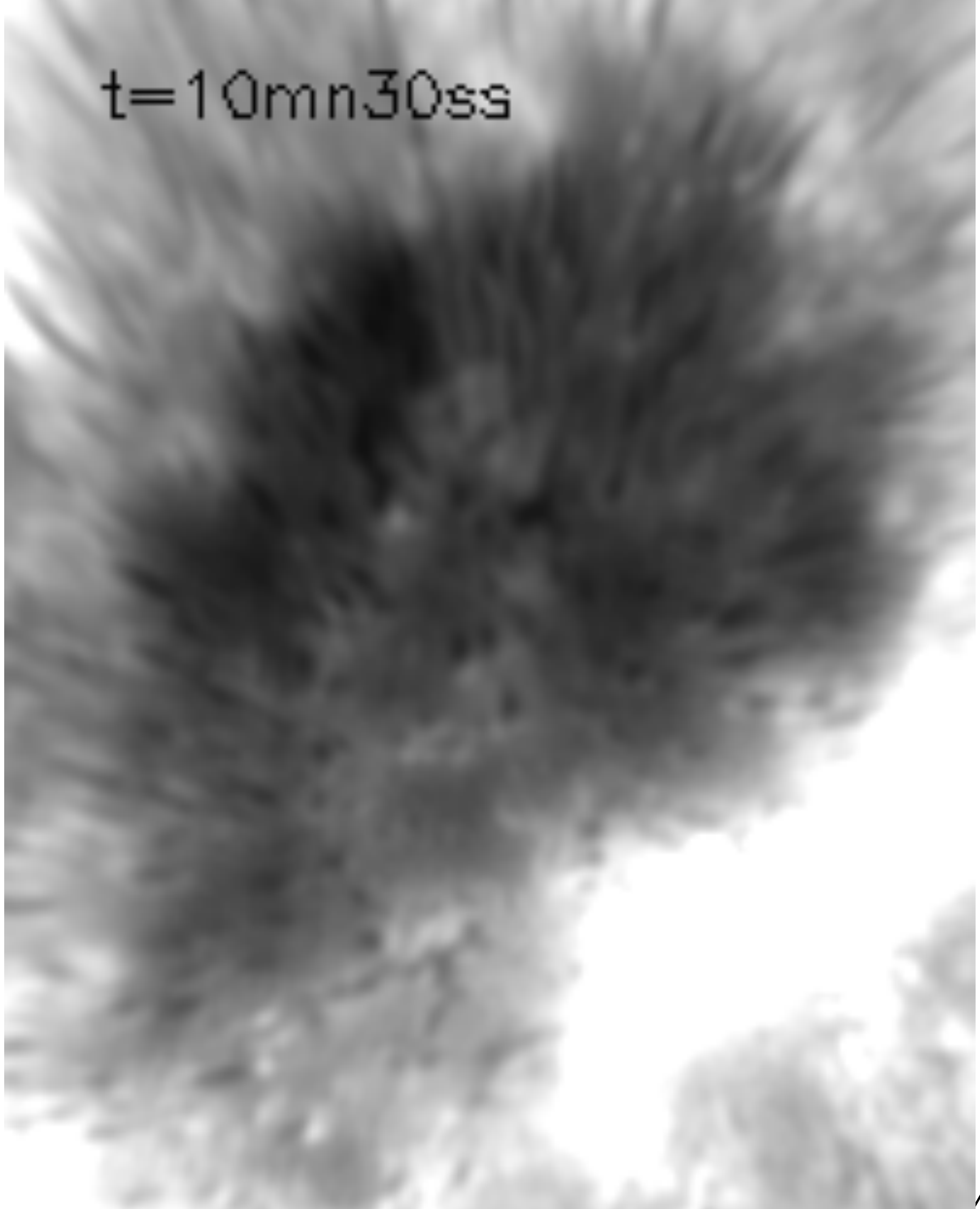

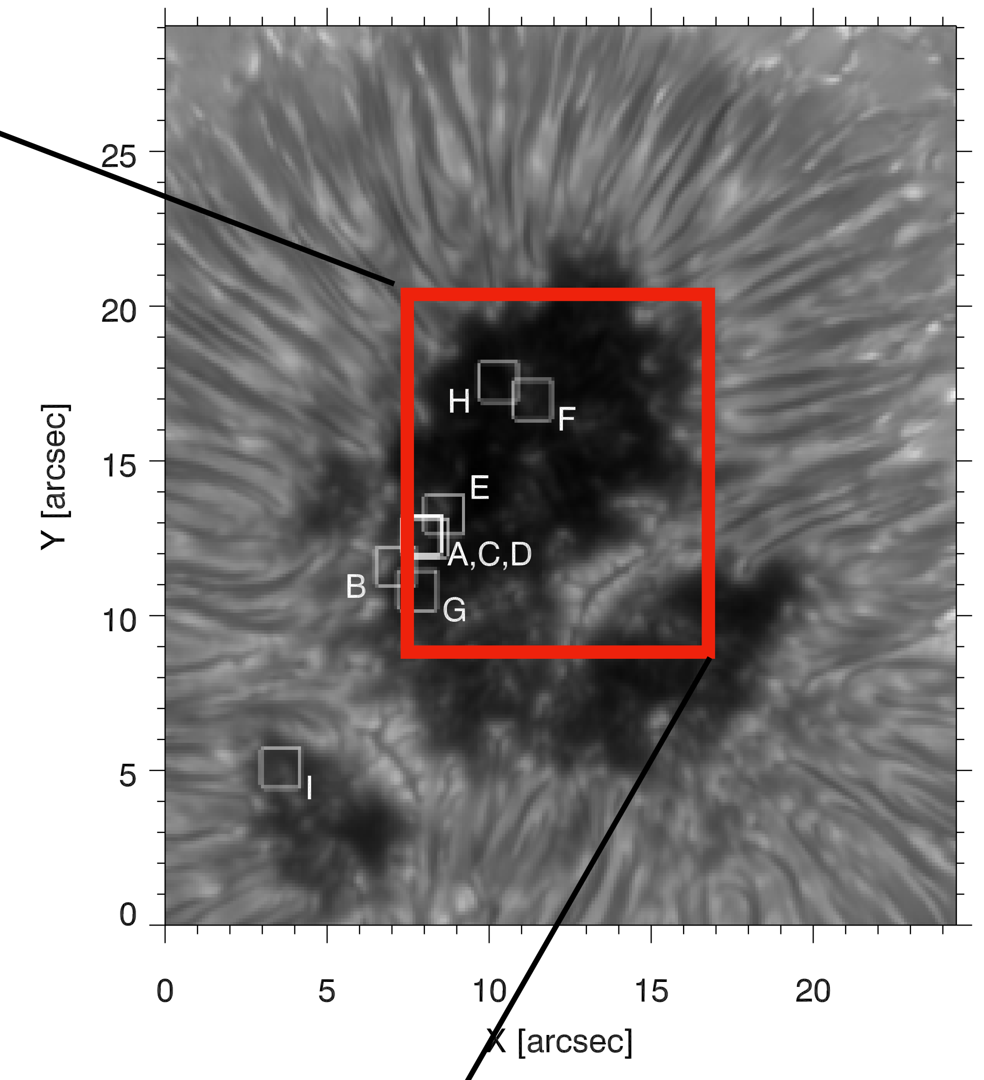

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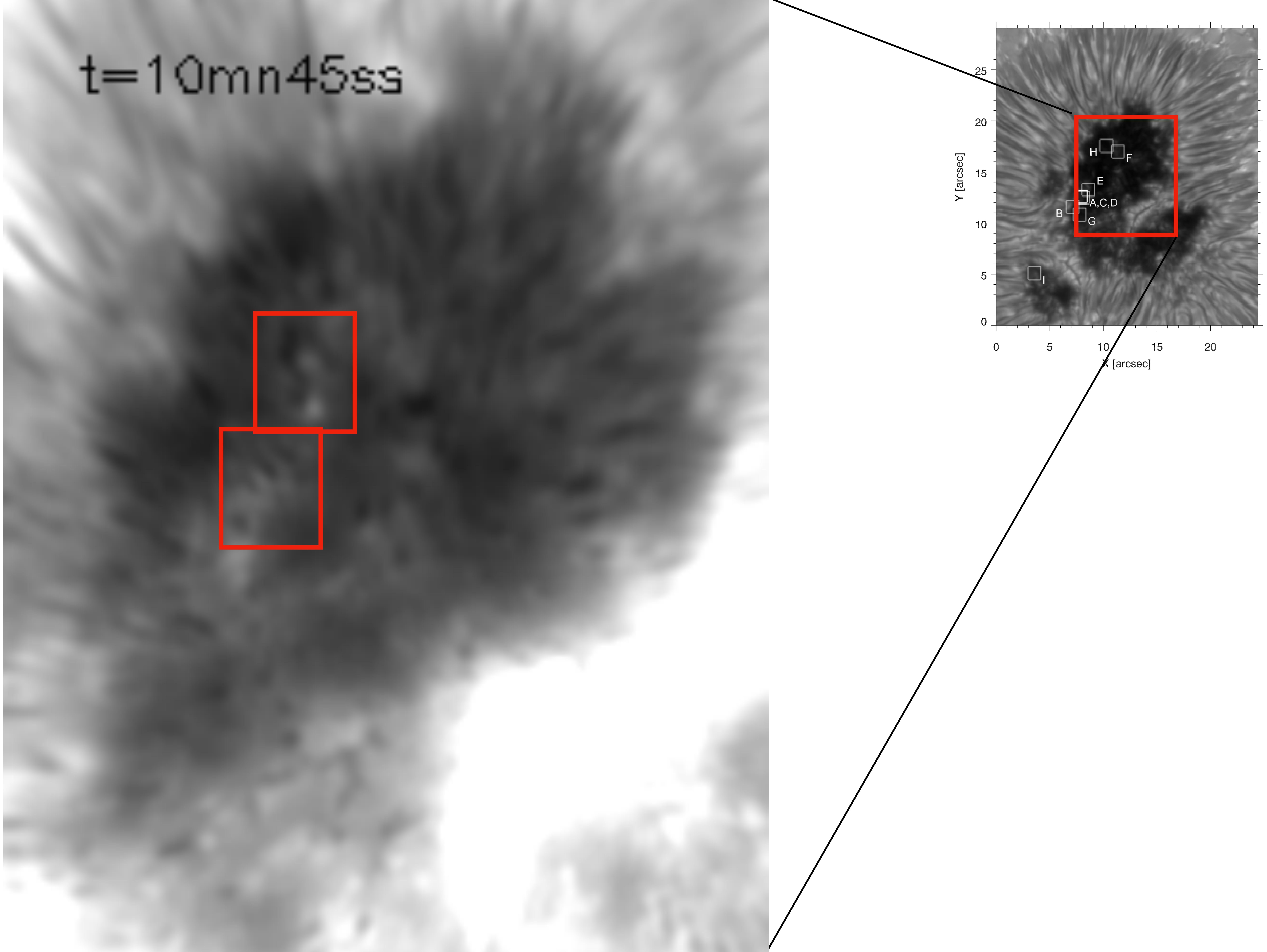

red wing at 156 mÅ

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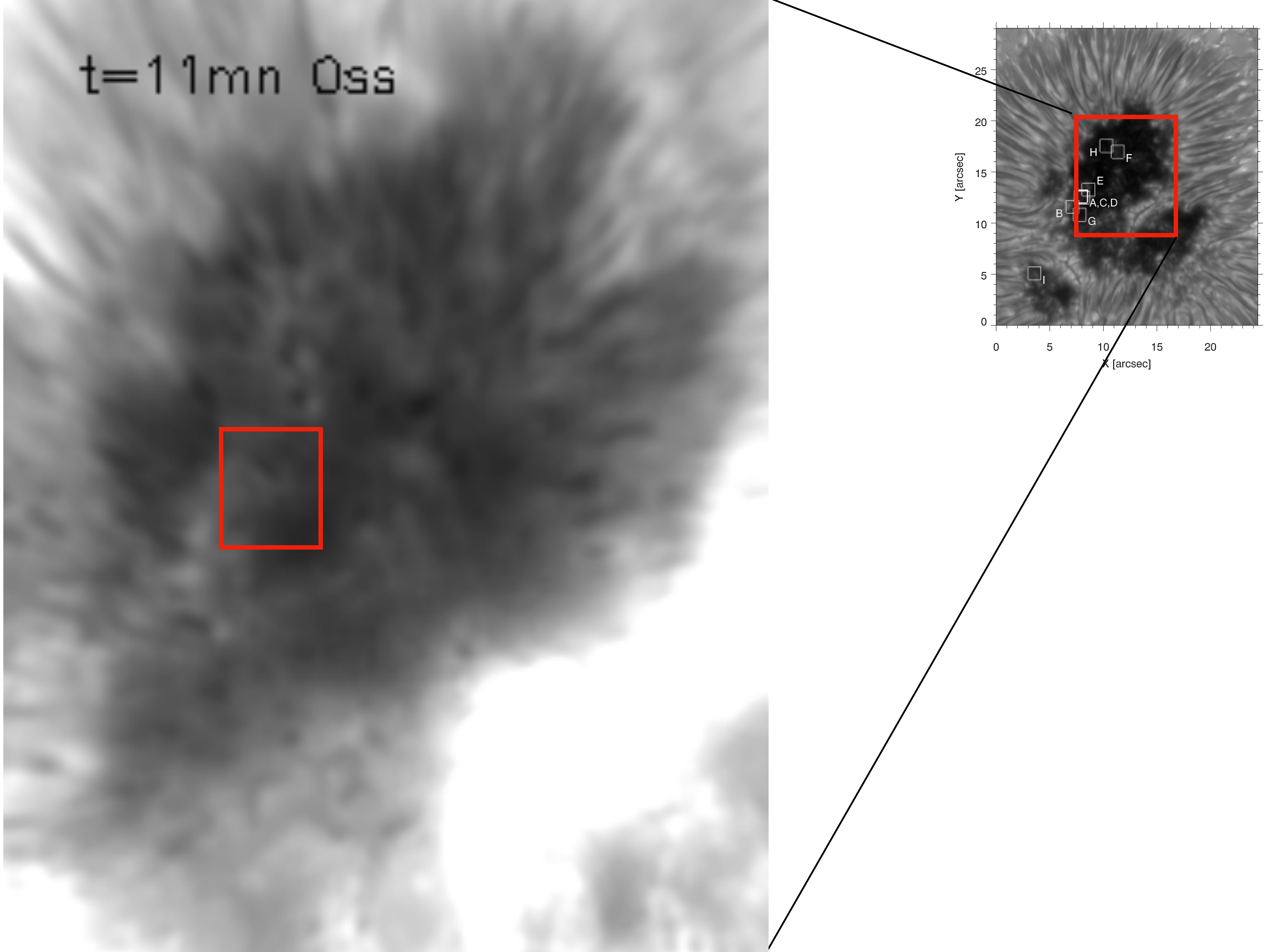

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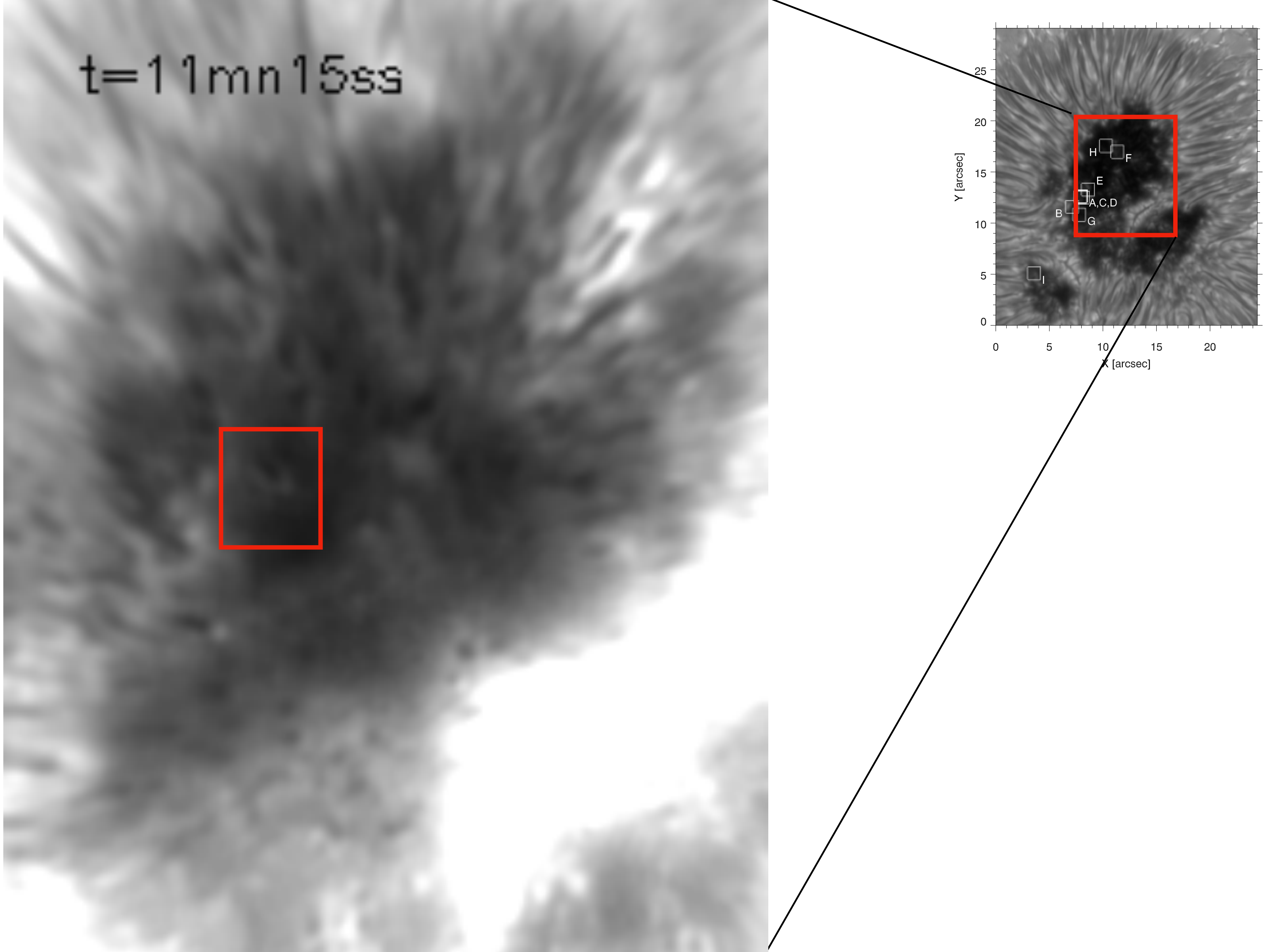

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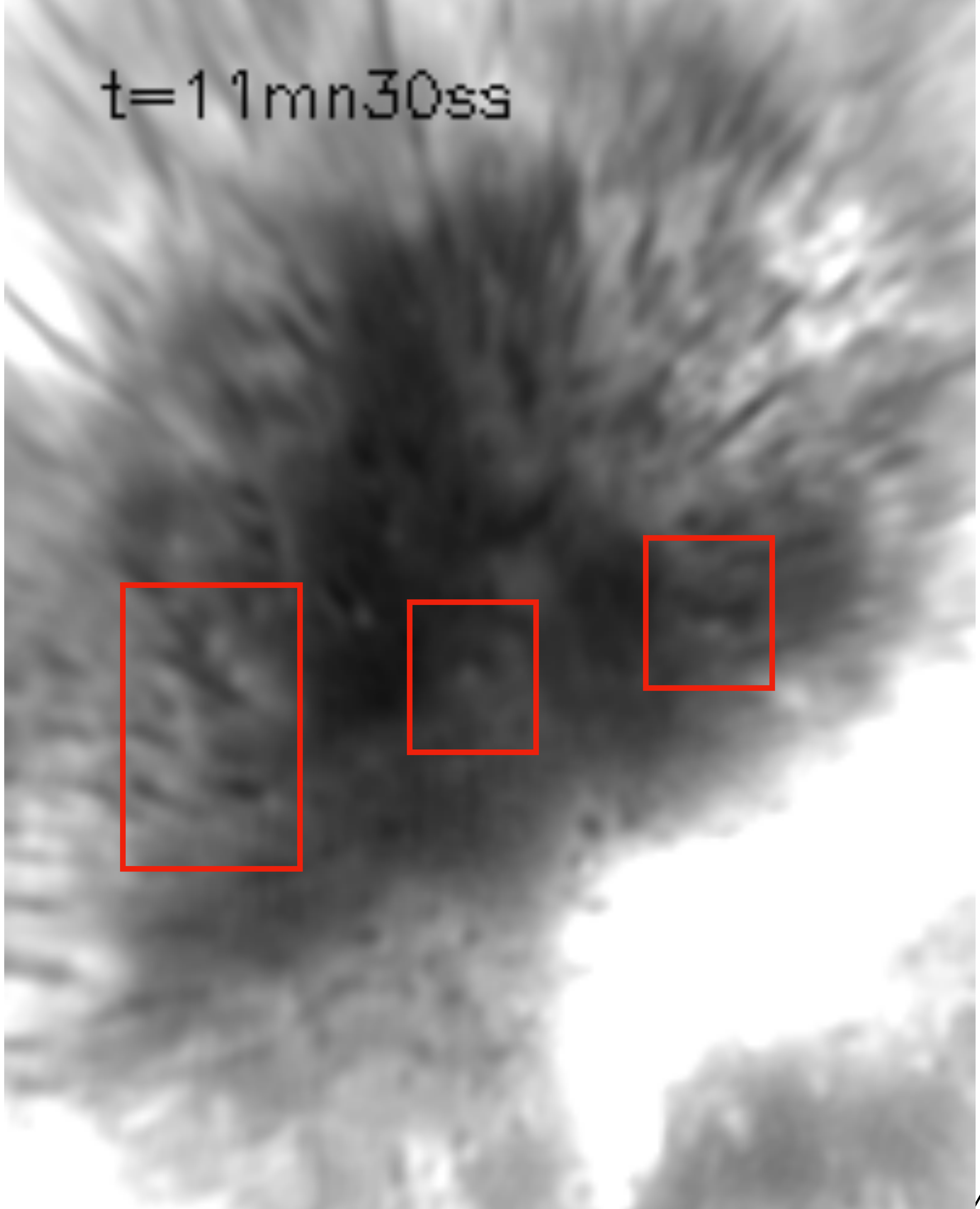

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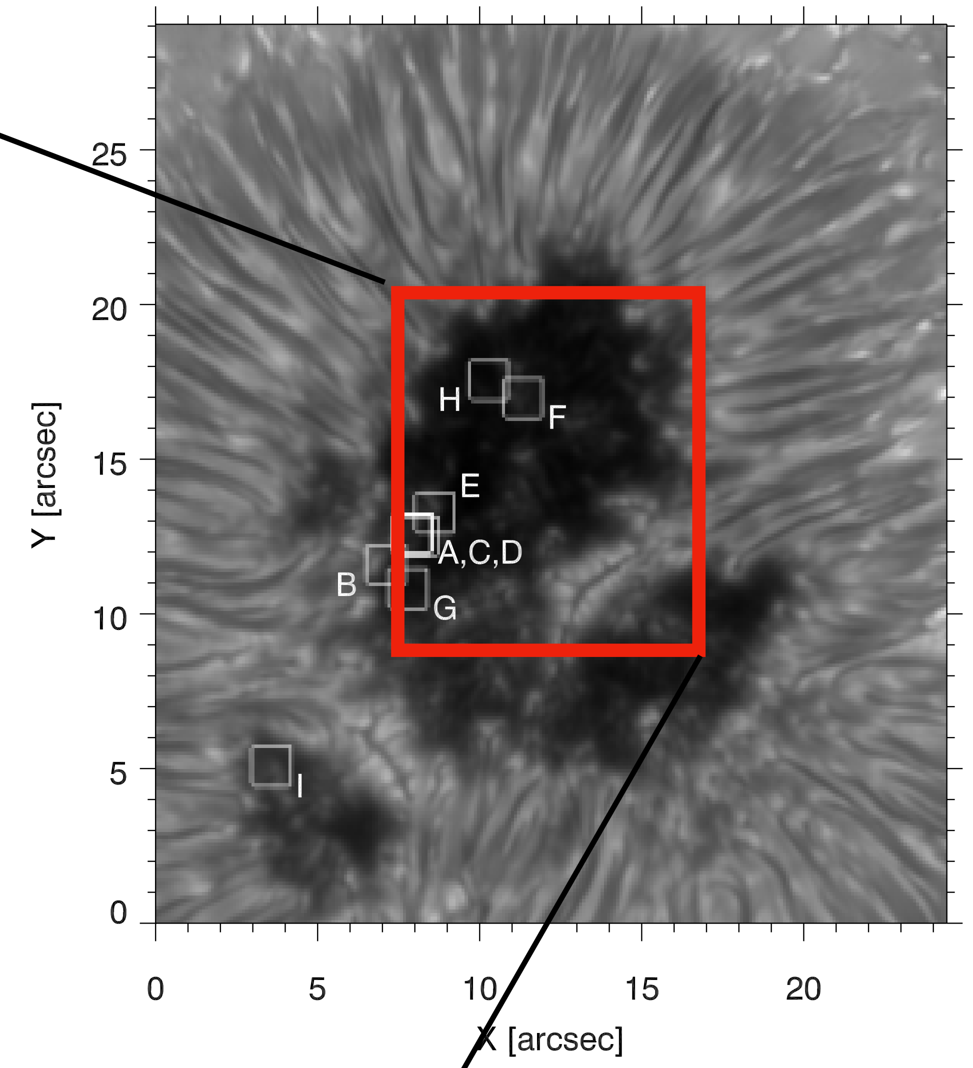

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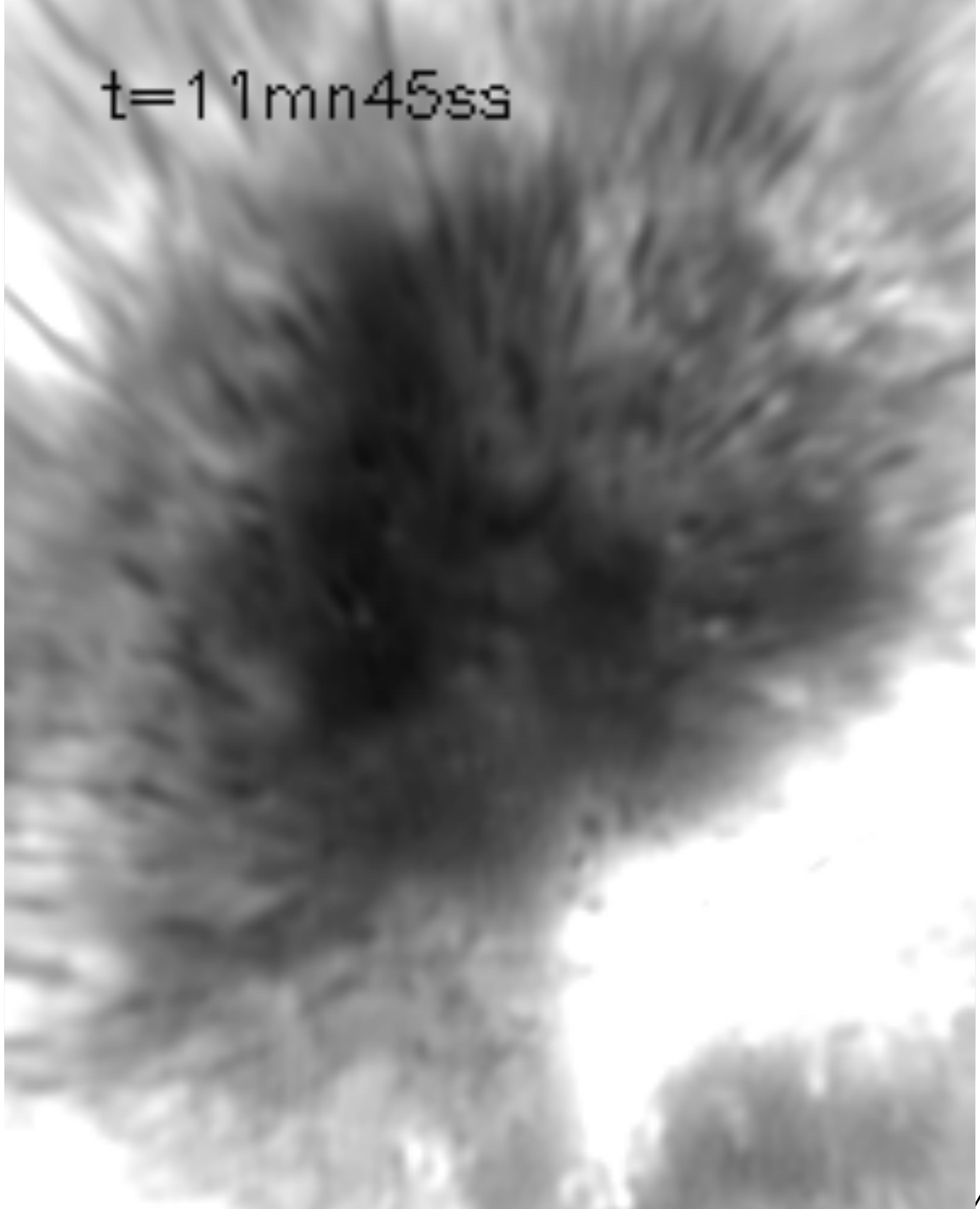
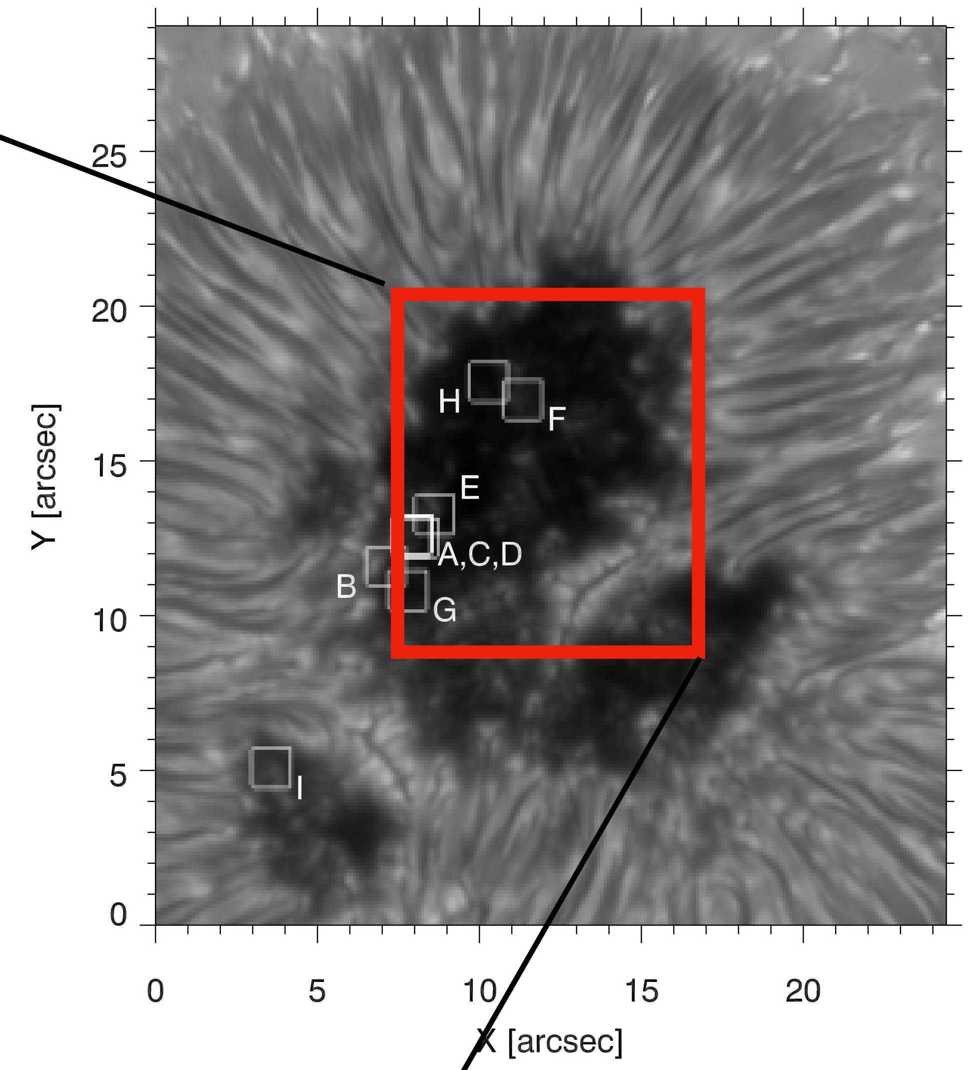
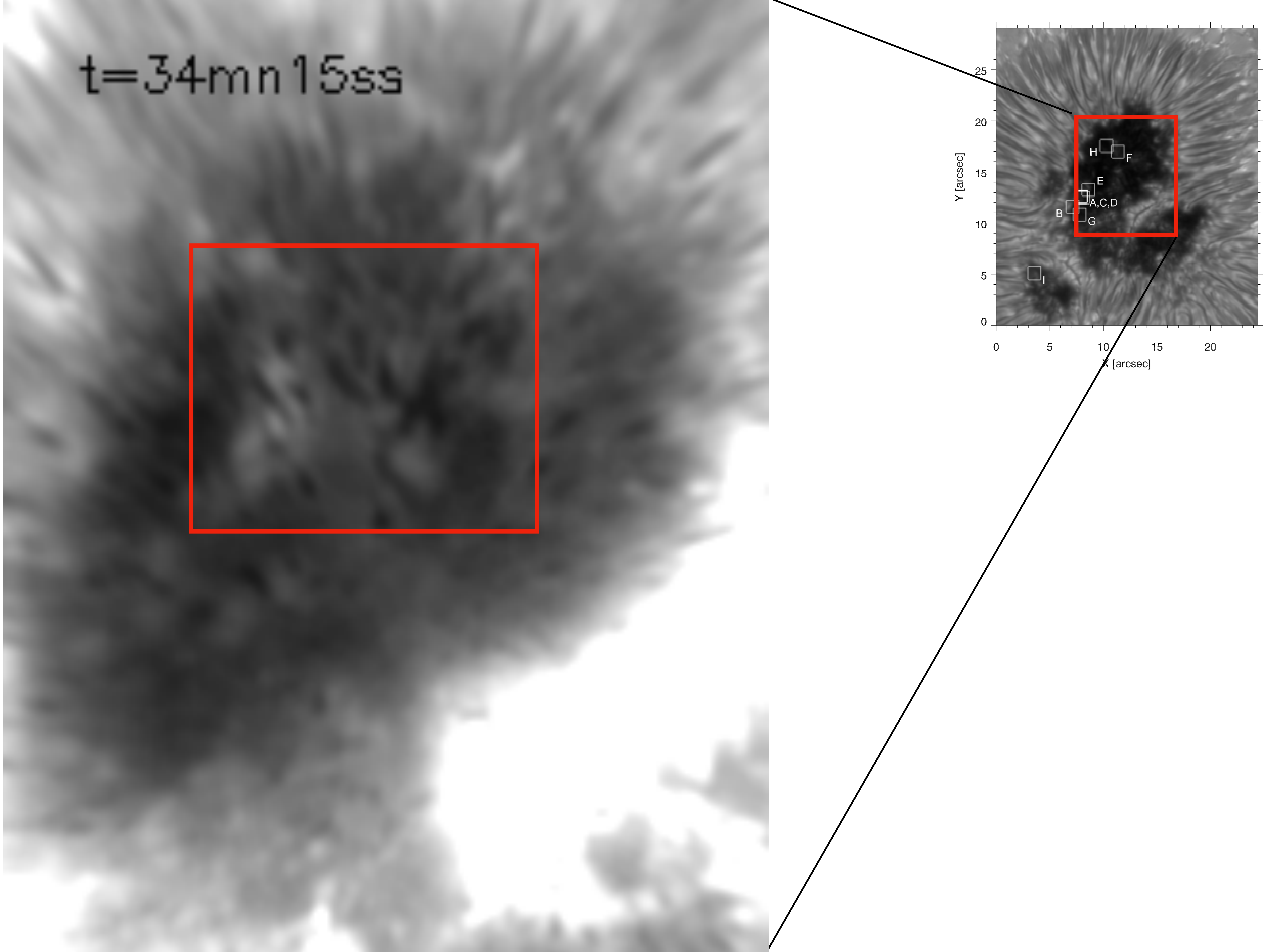




Now just two frames, central flash, lots of SDFs, followed by SSUBs

Once you know where to look



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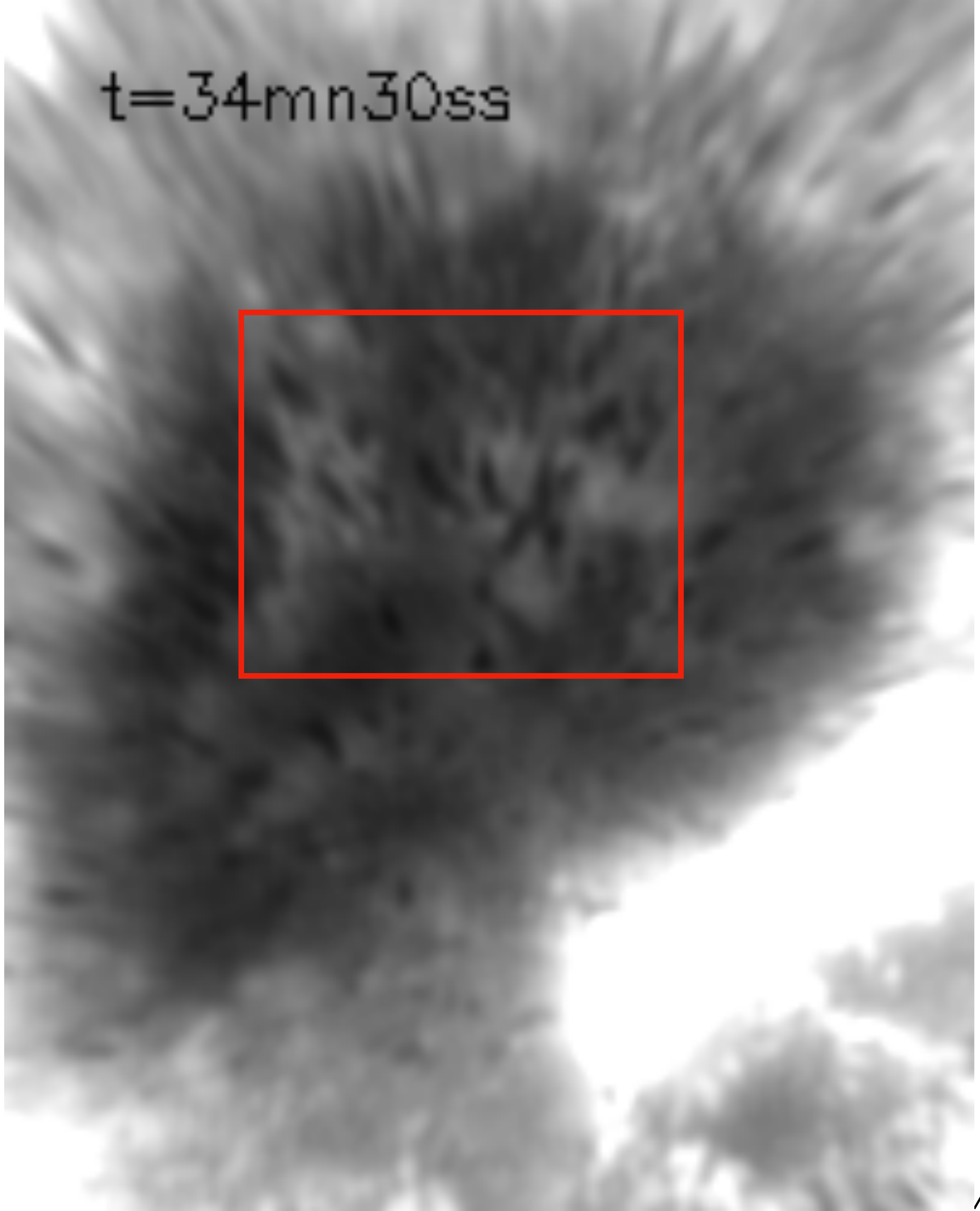

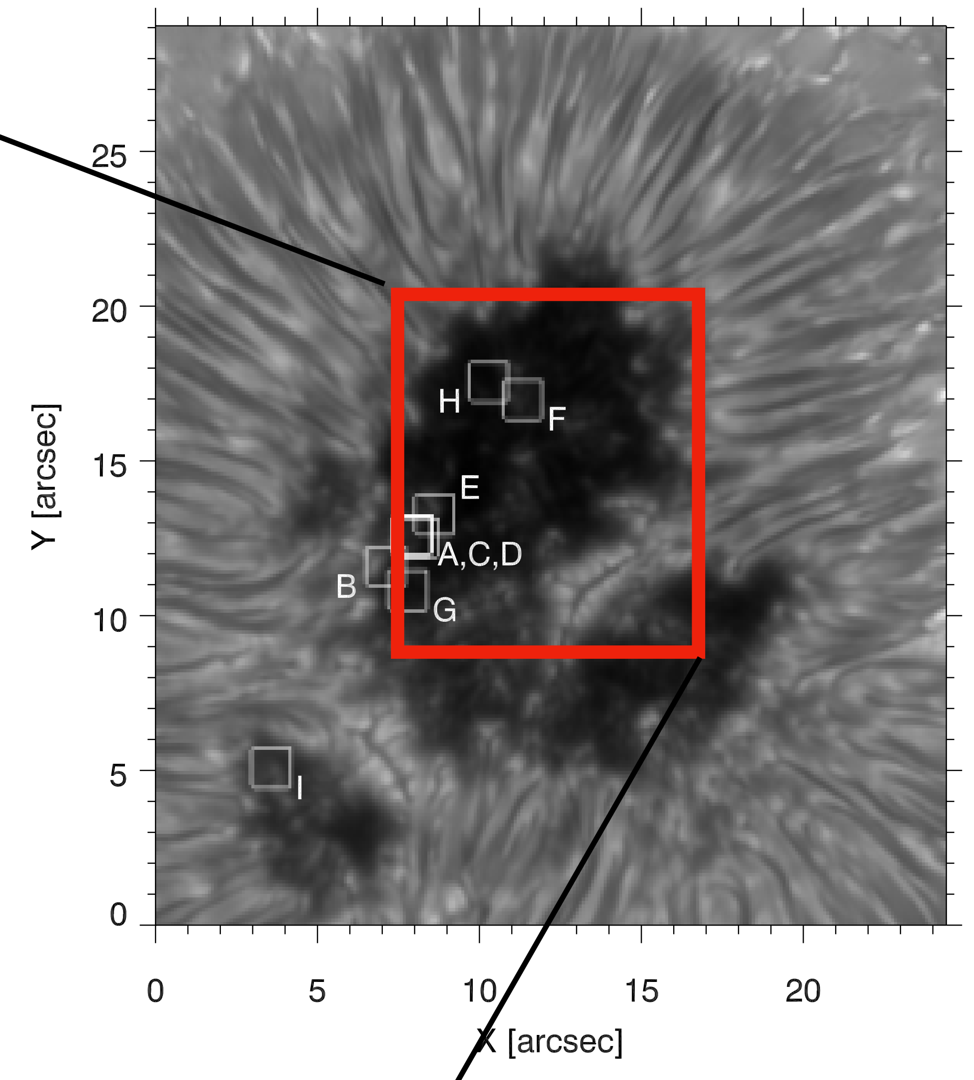

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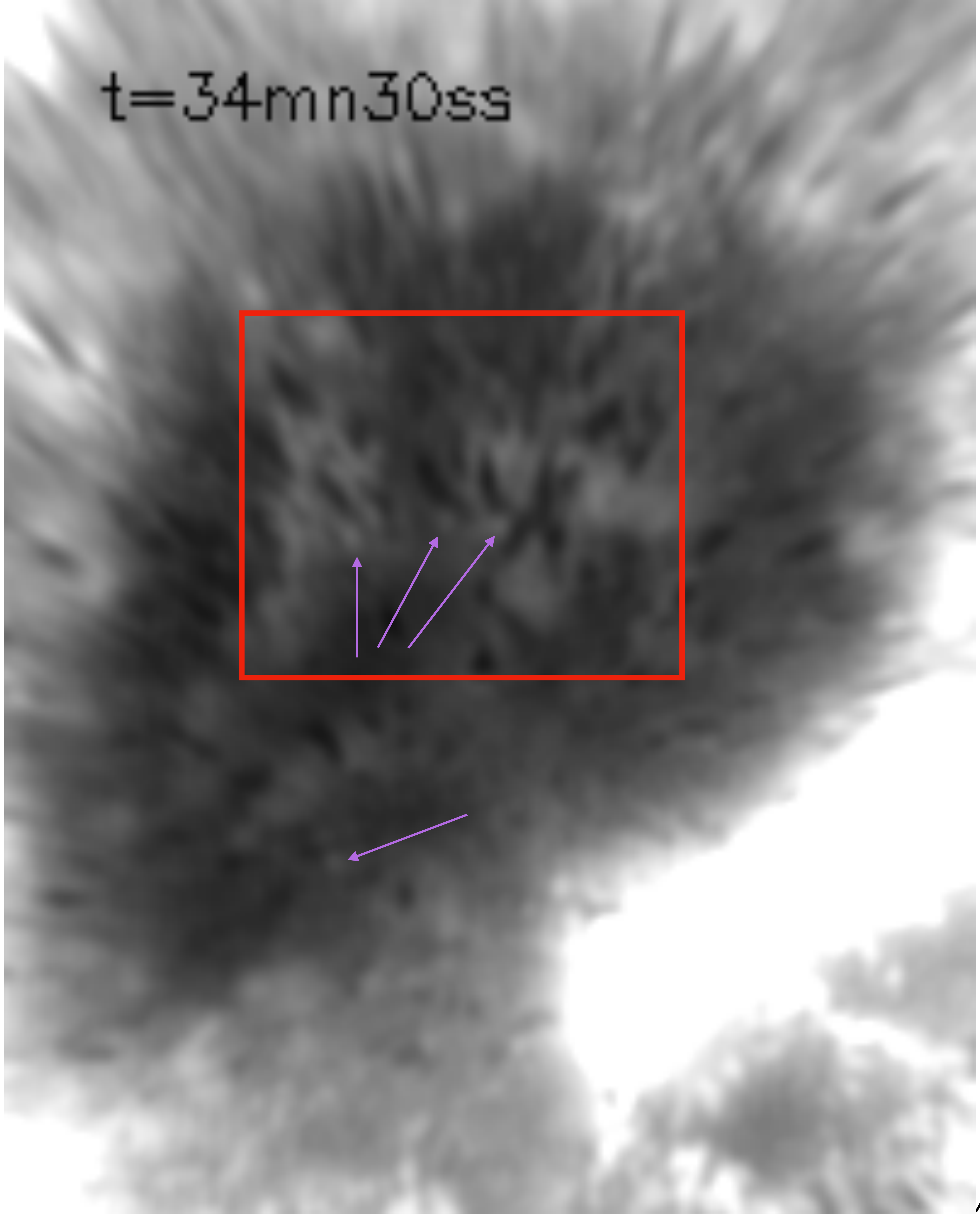

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