IRIS-9
2018.6.28. 15:00-15:15
Goettingen, Germany

THE UNIVERSITY OF TOKYO

ALMA and IRIS observations of the solar chromosphere on the polar limb

Takaaki Yokoyama

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Yokoyama et al., 2018, submitted to ApJ

ALMA proposal, Cycle 4 Project 2016.1.00201.S

Iijima, H., 2016, PhD thesis, UTokyo

Iijima & TY, 2015, ApJL, 812, L30; Iijima & TY, 2017, ApJ, 848, 38

IRIS-9, Göttingen, 25-29 June 2018

Contributed Talk

5. Opportunities and challenges

ALMA and IRIS observations of the solar chromosphere on the polar limb

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We report results of the Atacama Large Millimeter/sub-millimeter Array (ALMA) observations of the solar chromosphere on the southern polar limb. The coordinated observation with the Interface Region Imaging Spectrograph (IRIS) is also carried out. From Cycle-4 of the ALMA proposal period, solar observation capability became open to the community. ALMA has provided us unprecedented high spatial resolutions (approximately 2.0 arcsec) in the millimeter band at 100 GHz frequency with very high cadence (20 sec). The results are as follows: (1) A clear solar limb in the millimeter band is located at approximately 5 arcsec above the photosphere. Many dynamic saw-tooth patterns are identified on the chromospheric edge. They are co-located with the similar structure in the EUV emission taken by SDO/AIA 171 band and can be interpreted as low-temperature high-density materials. (2) A blob-ejection event is found. By comparing with the UV images taken by IRIS Mg slit jaw, the trajectory of the blob is located along the spicular patterns. The ejection is accompanied by a brightening jet event at the footpoint area.

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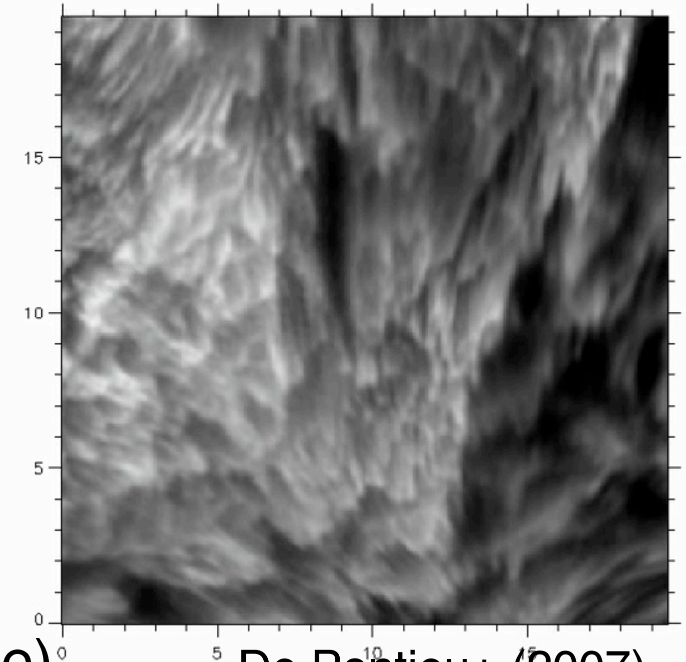
Chromospheric jets

- Spicules in quiet regions and coronal holes
- Dynamic fibrils in active regions

...

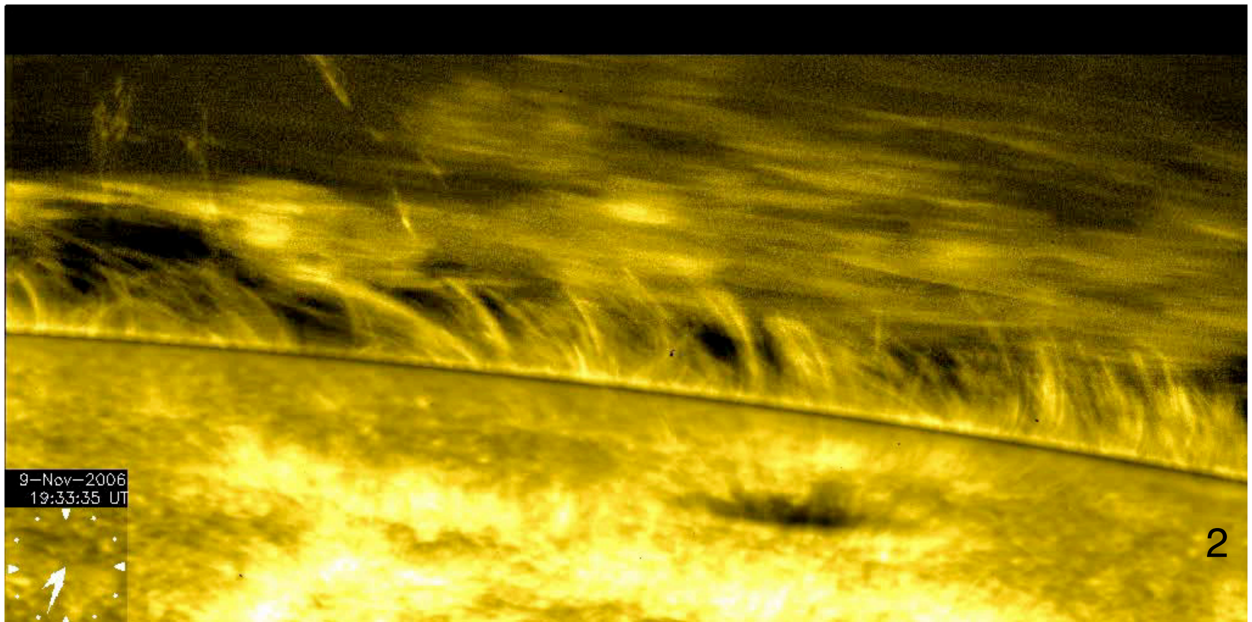
Manifestation of dynamic plasma processes

- Plasma flows (super-sonic speed)
- Magnetic fields (from high- to low-beta regime)
- MHD waves, Shock waves (mode conversion, non-linear procs.)
- Thermal processes: Radiative cooling, shock heating
- Ionization, recombination ...



De Pontieu+ (2007)

Clue for understanding the transport of energies to the corona

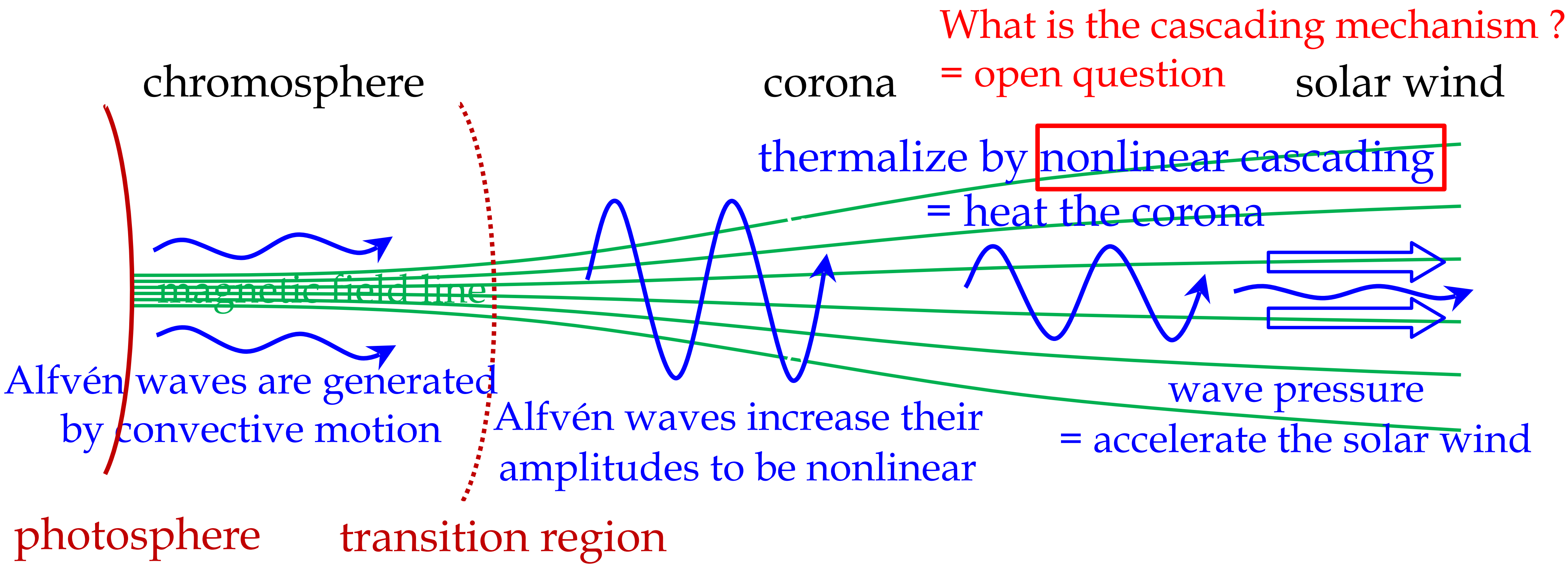


Courtesy T. J. Okamoto, Hinode SOT, JAXA / NAOJ

Solar wind acceleration by waves

(Courtesy M. Shoda, UTokyo)

Standard Alfvén-wave modeling



Solar wind acc

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Standard Alfvén-wave modeling

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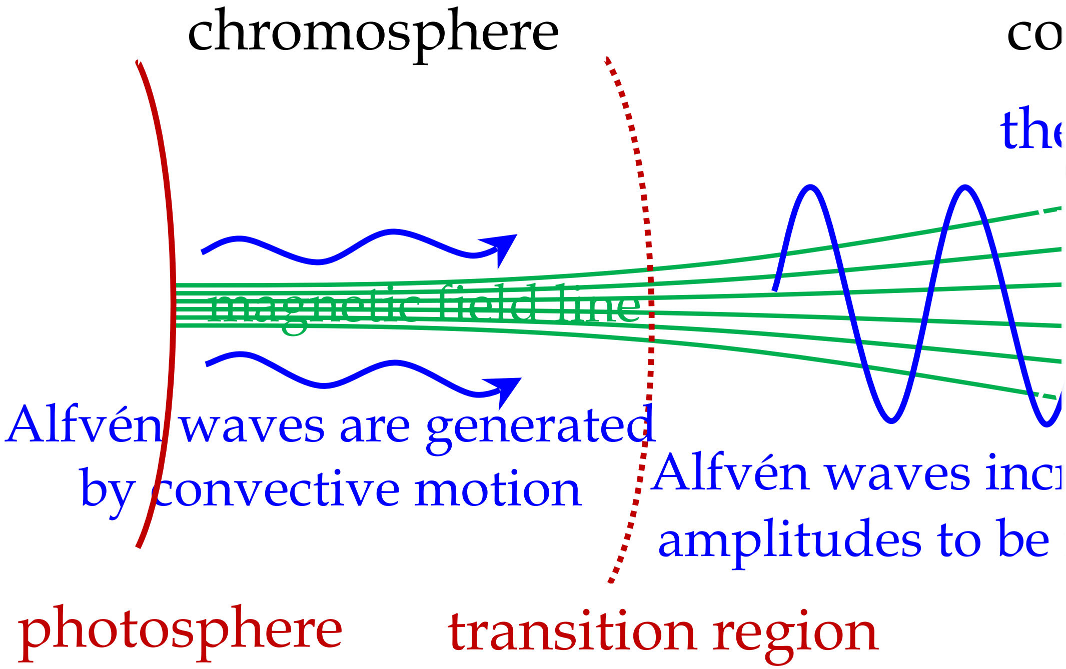
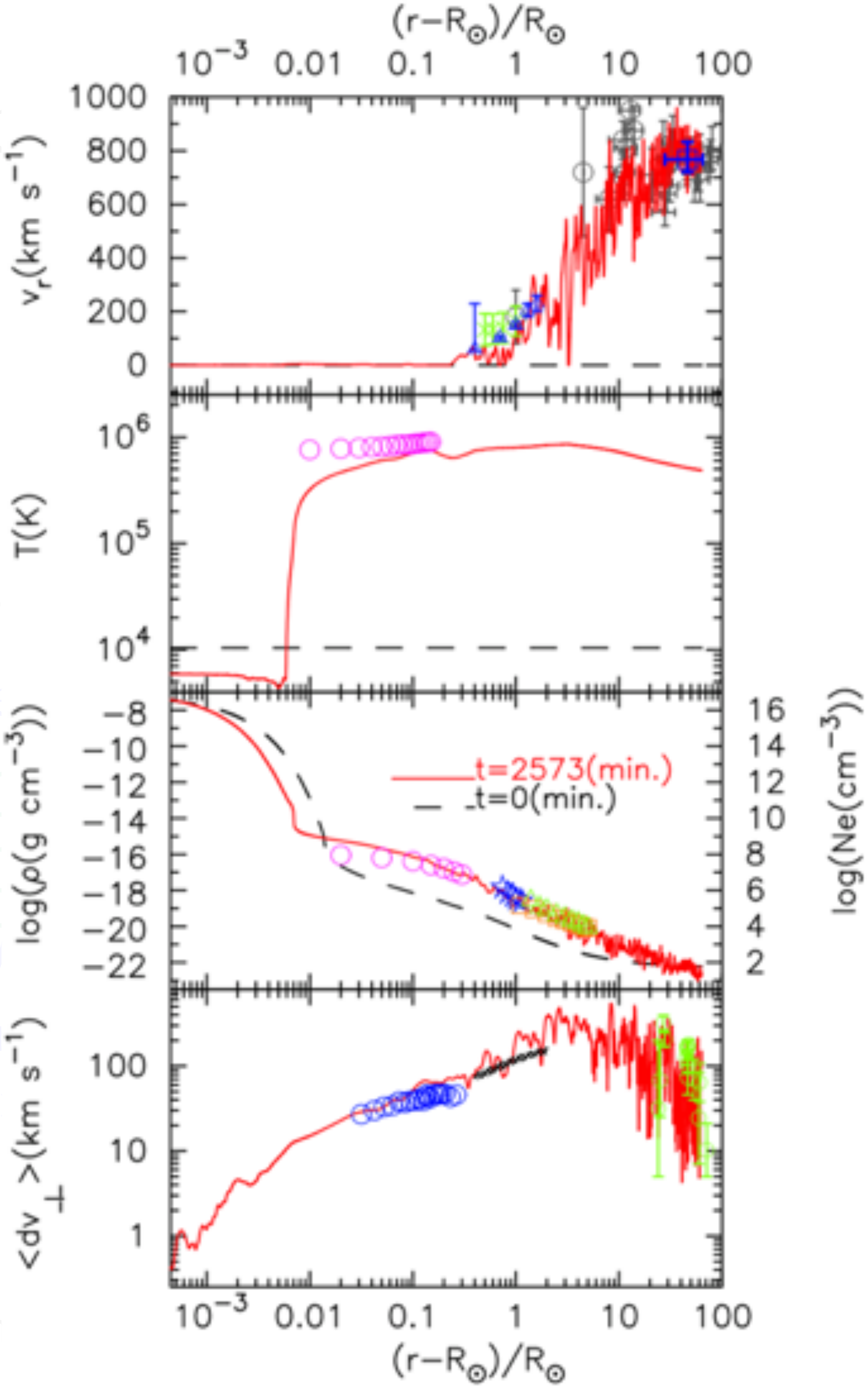


Suzuki & Inutsuka (2005)



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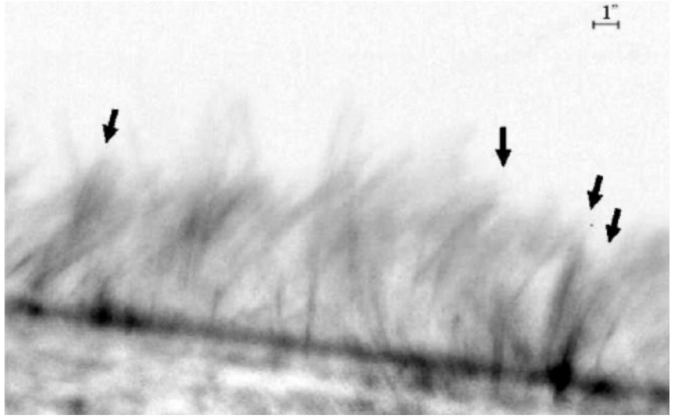
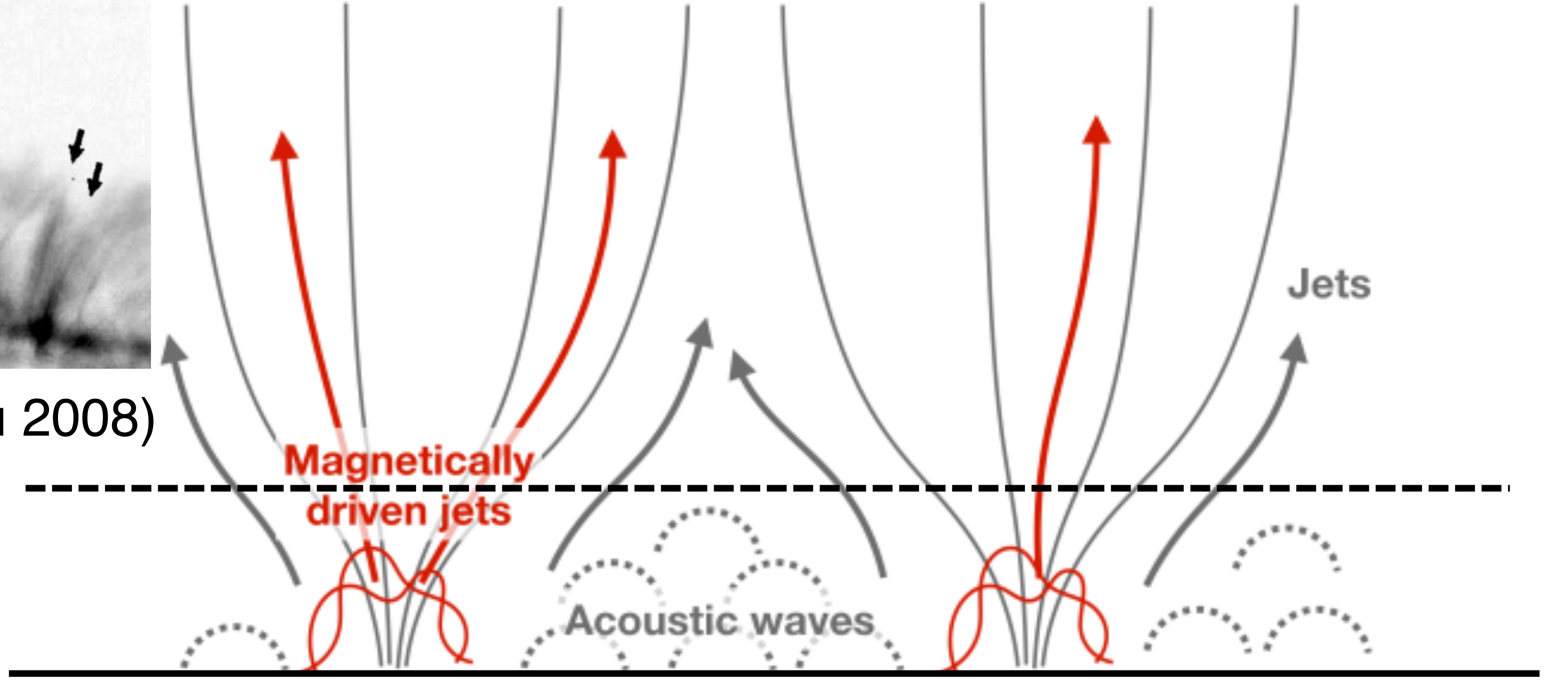
Chromospheric jets: model



(figure from Suematsu 2008)

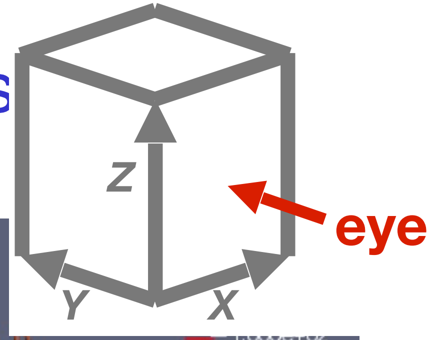


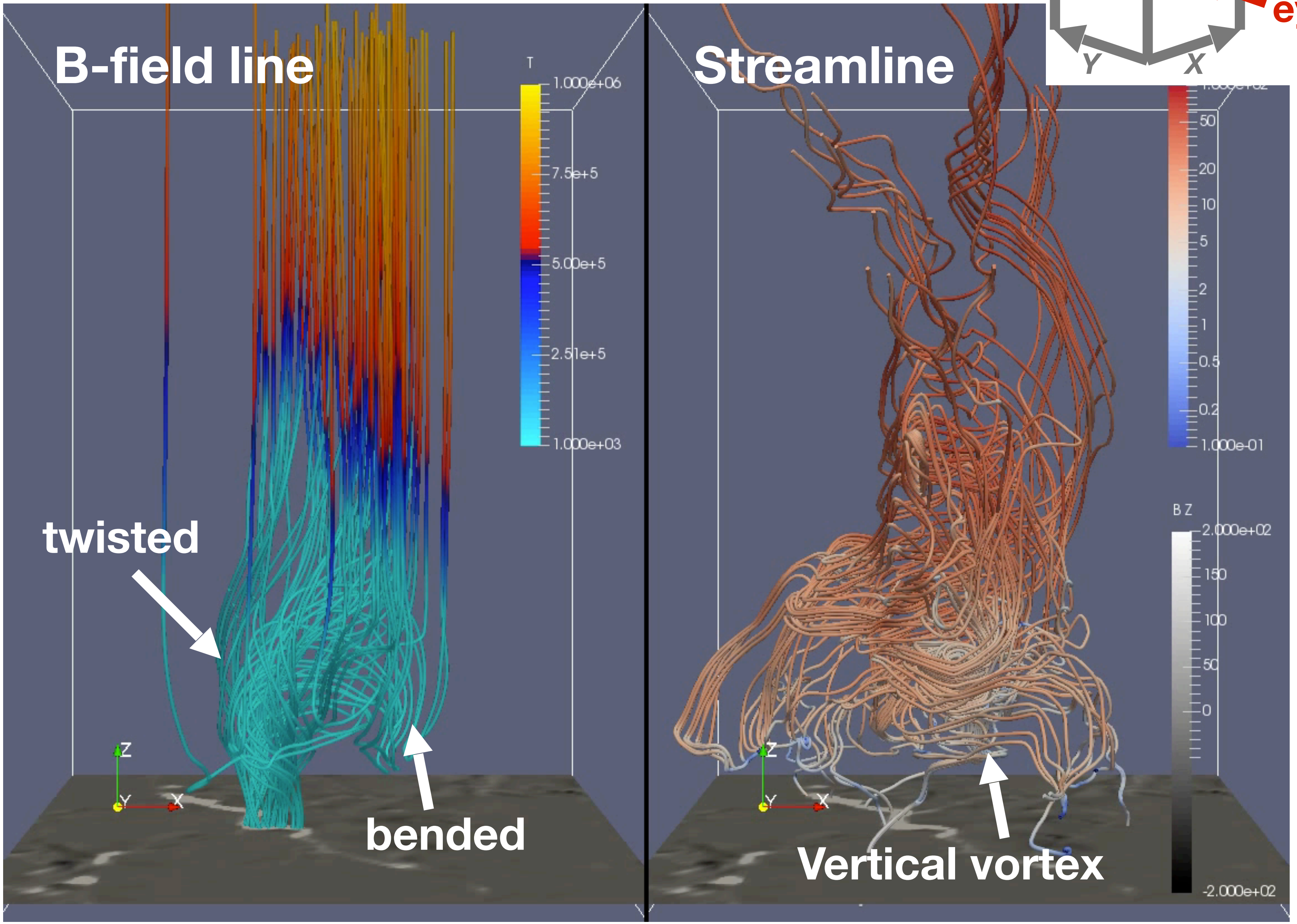
(figure from Iijima 2016, PhD UTokyo)

The dense cool chromospheric plasma is lifted by an interaction of shock waves with transition-region contact discontinuities (Hollweg 1982, Suematsu+ 1982). But as for the generation of shock waves, it is still under debate.

3D radiative MHD simulations of chromospheric jets

Iijima (2016, PhD thesis UTokyo), Iijima &TY (2017)





Nobeyama Radioheliograph (NoRH) to ALMA

	Obs. Freq.	Spatial res.	Time res.	FoV	Obs. Style
NoRH	17GHz	10 arcsec	0.1 sec	Full Sun	dedicated
	34GHz	5 arcsec	0.1 sec	Full Sun (w/ aliasing)	
ALMA (Cycle 4, C40-3)	100GHz (3mm)	1.5 arcsec	2 sec	60 arcsec ϕ	Limited period only
	239GHz (1mm)	0.6 arcsec	2 sec	25 arcsec ϕ	

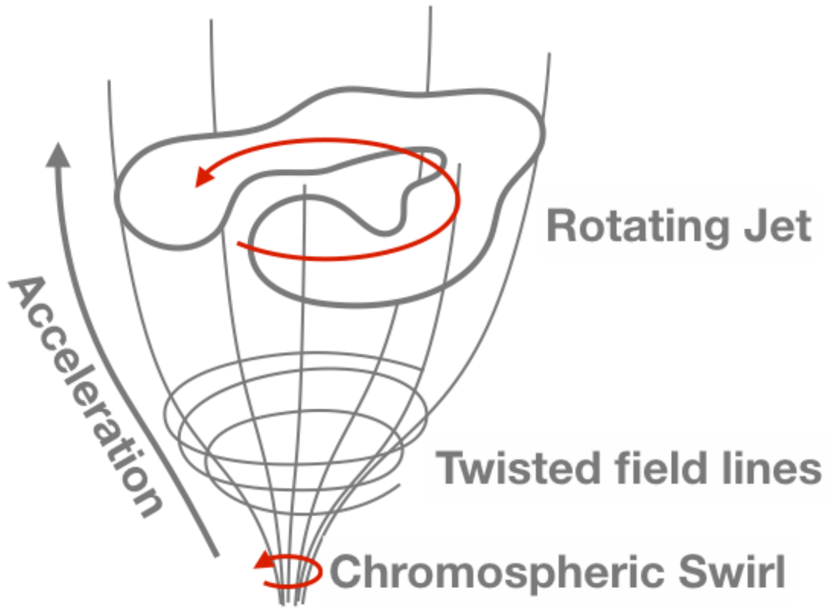
ALMA has better spatial resolution.

ALMA Cycle 4 Project 2016.1.00201.S
"MHD mechanisms of jets in the solar chromosphere"

Target: Our observation target in this proposal is spicules in coronal holes on a solar limb.

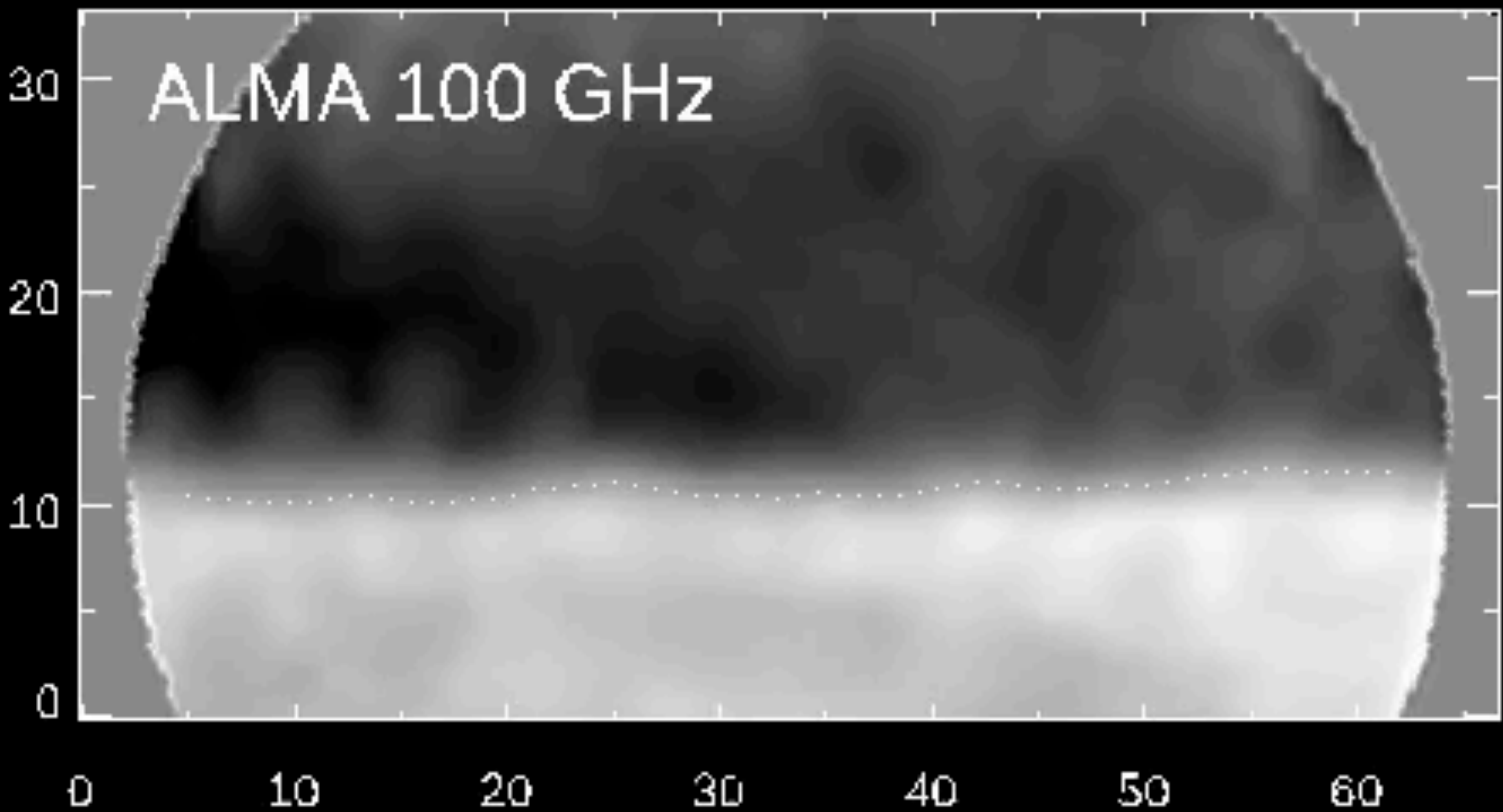
Aim: For a detection of a horizontal motion of the chromospheric plasmas of jets as a manifestation of the twisting Lorentz motion.

Observations: The sit-and-state mode with C40-3 configuration in Band 6 and Band 3. We use two bands for the general structure of spicule's basement at different altitudes. The required duration is 2 hours with cadence of 2 sec for each band.



Observation results

45 min. around 14:30 UT on 2017-4-29 on the coronal hole at the solar southern pole only in Band-3 (100GHz)

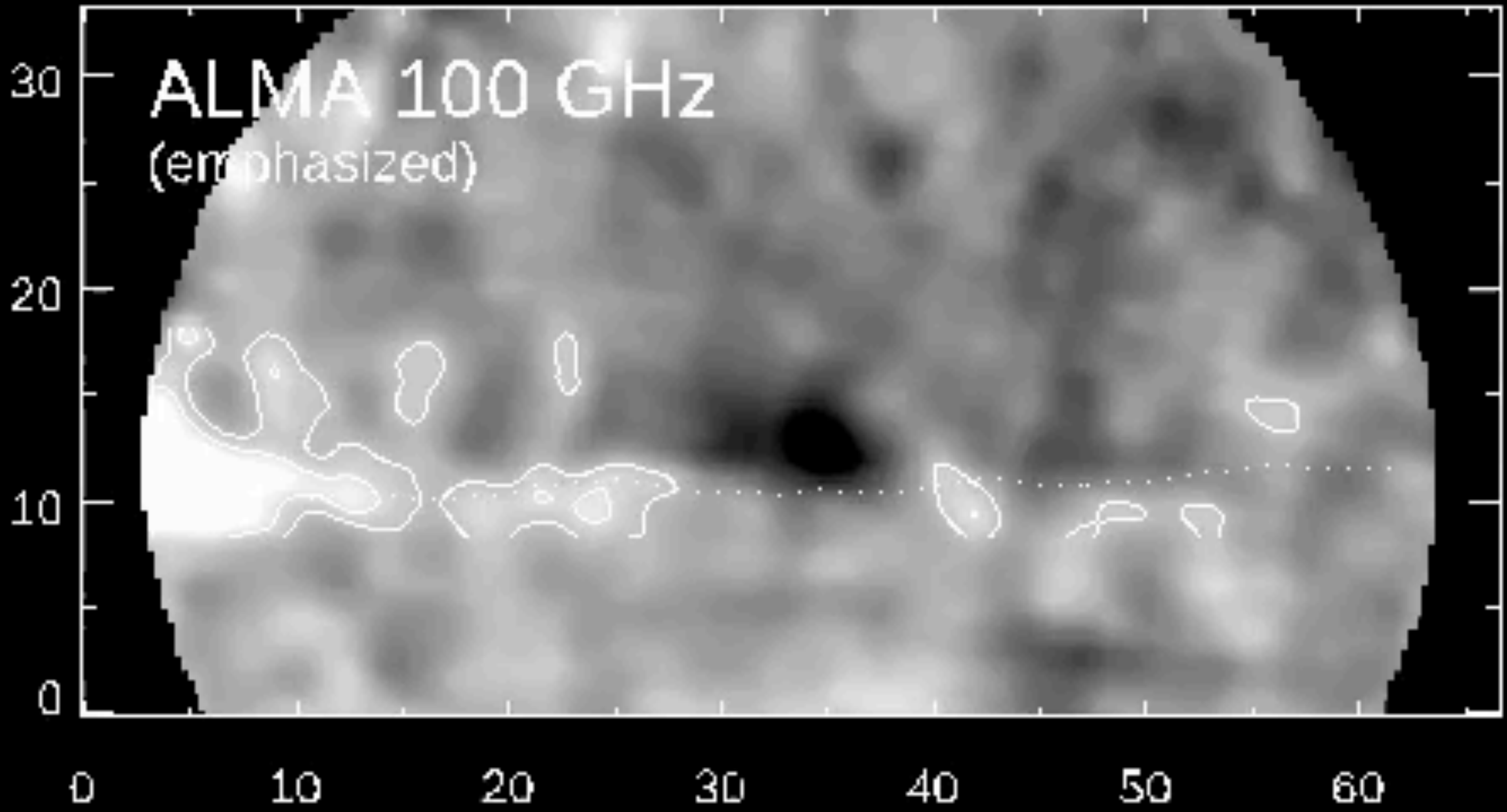


Observation results

45 min. around 14:30 UT on 2017-4-29 on the coronal hole at the solar southern pole only in Band-3 (100GHz)

$$\tilde{T}_{\rm b} = T_{\rm b}/\langle T_{\rm b}\rangle$$

$$\langle T_{\rm b}\rangle = \frac{1}{\Delta t}\int T_b dt$$

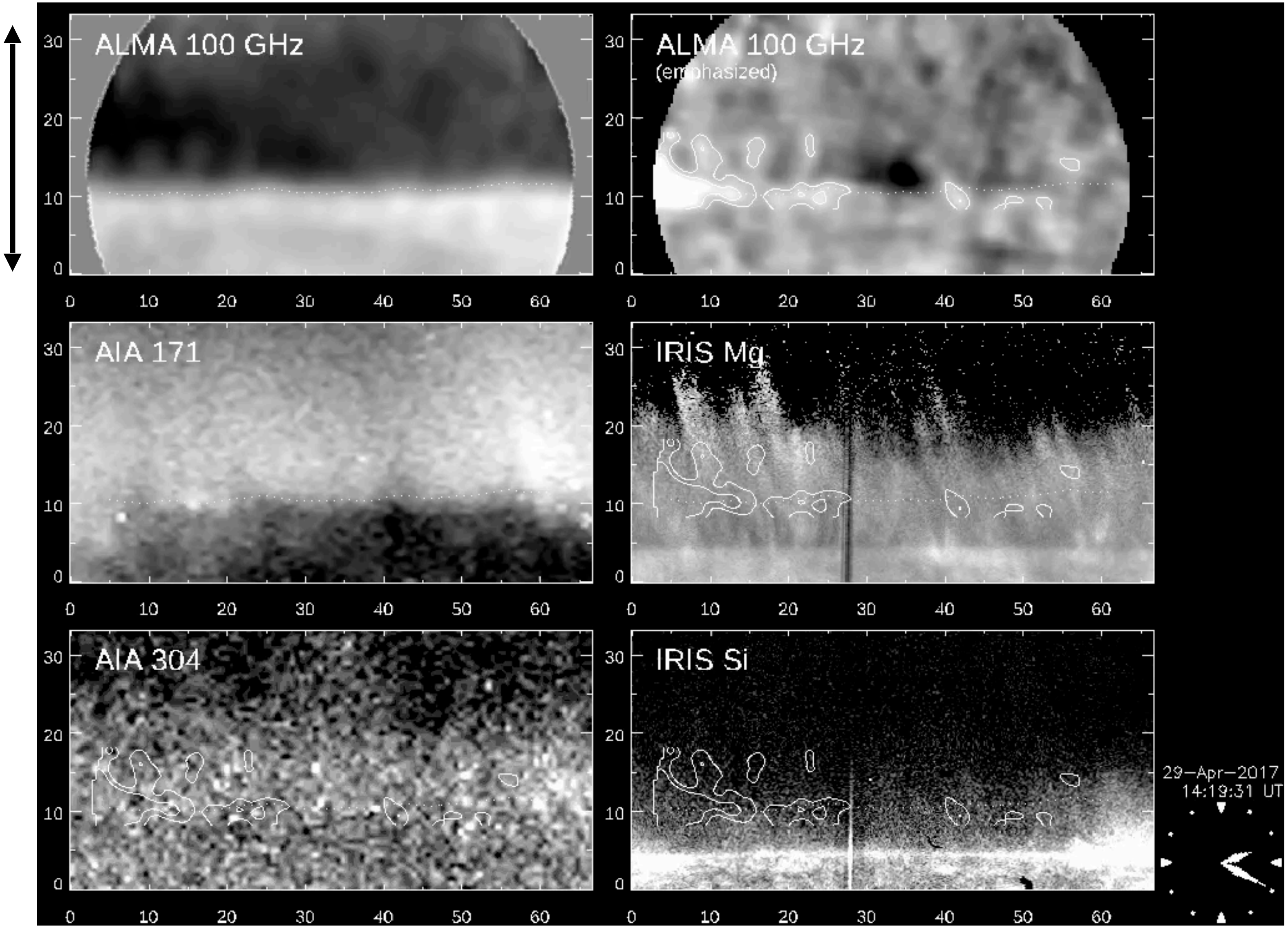


Observation results

45 min. around 14:30 UT on 2017-4-29 on the coronal hole at the solar southern pole only in Band-3 (100GHz)

with IRIS observations, movie: 20-sec cadence

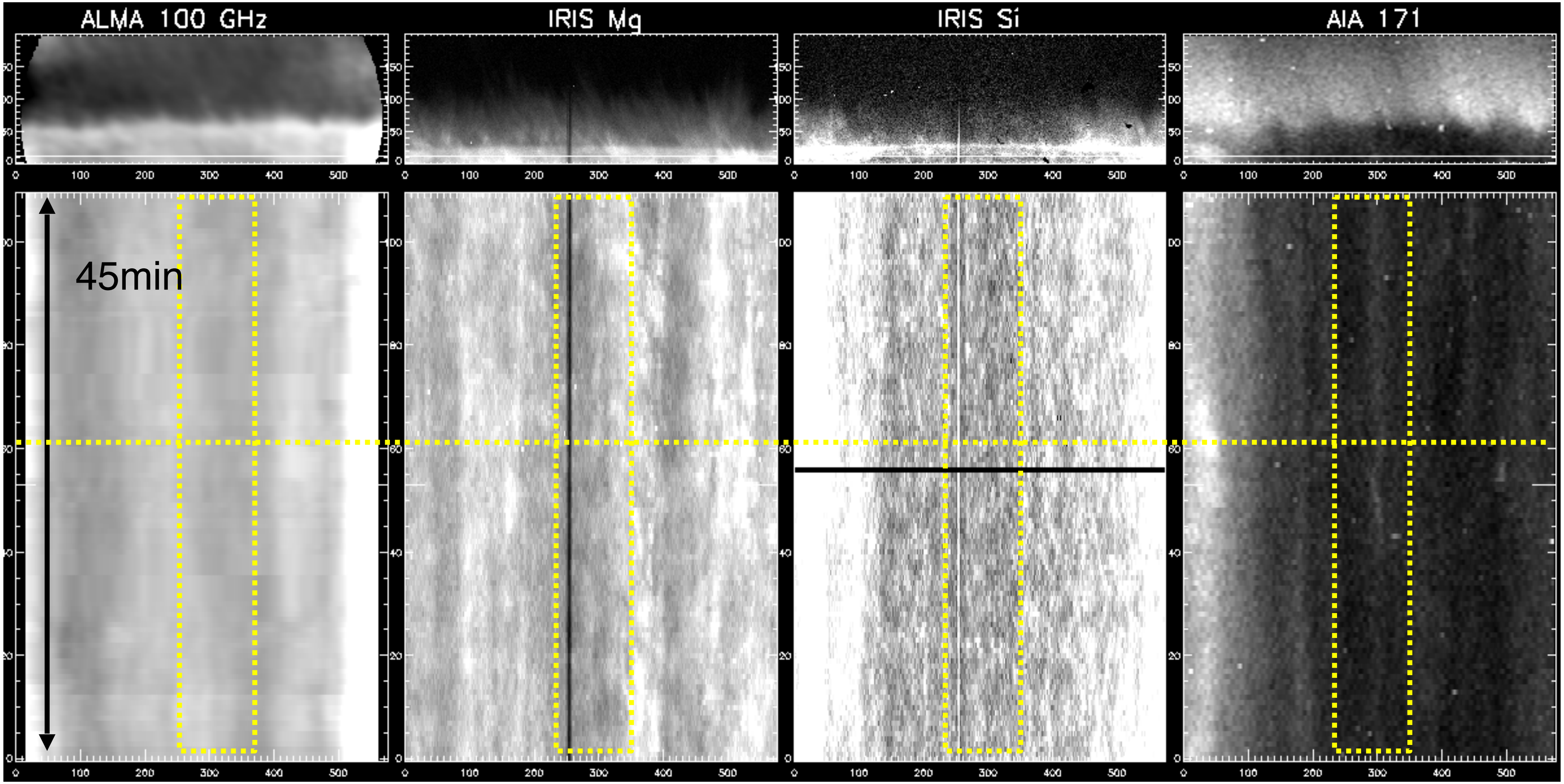
32 arsec
20 Mm



What we found from this observation

1. The ALMA 100 GHz images show saw-tooth patterns on the limb, and a comparison with SDO/AIA 171˚A images shows a good correspondence of the limbs with each other.
2. The ALMA 100 GHz movie shows a dynamic thorn-like structure elongating from the saw-tooth patterns on the limb, with lengths reaching at least 8”, thus suggesting jet-like activity in the ALMA microwave range. These ALMA jets are in good correspondence with IRIS jet clusters.
3. A blob ejection event is observed. By comparing with the IRIS Mg slit-jaw images, the trajectory of the blob is located along the spicular patterns.

xt plot (horizontal vs time)



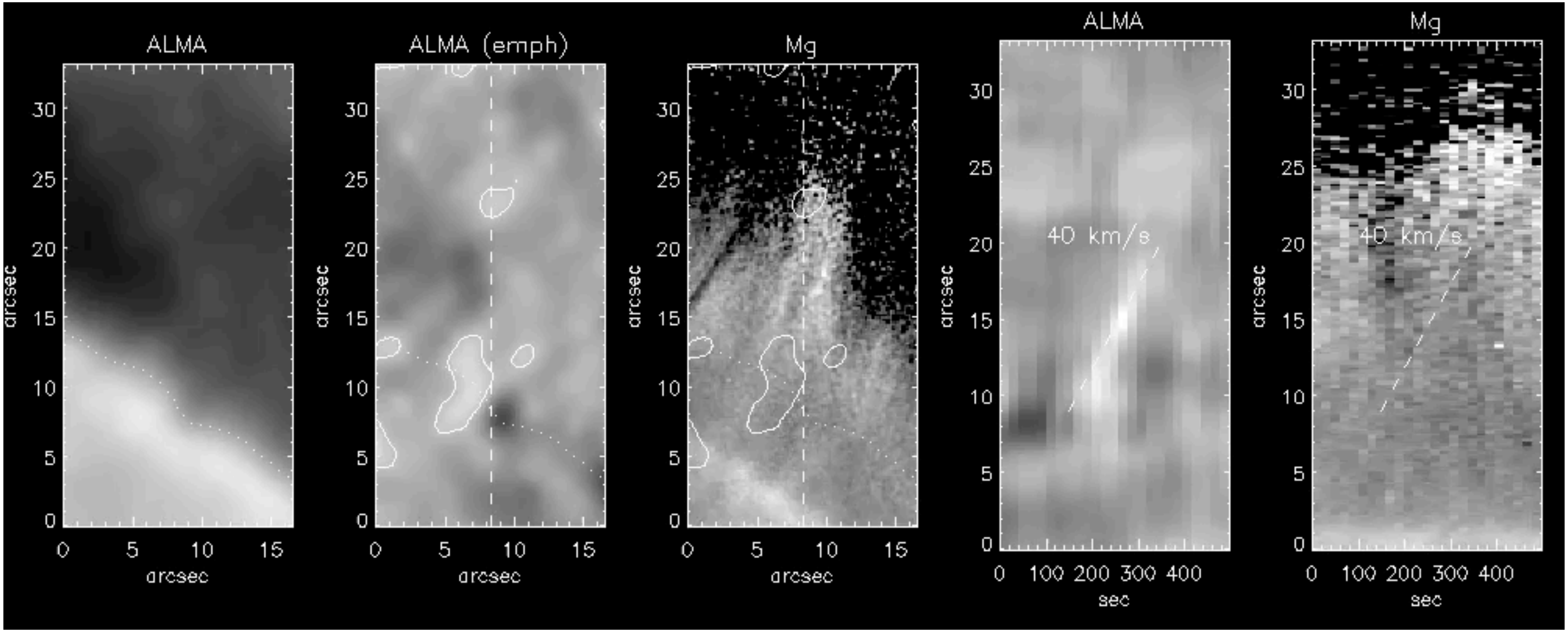
No significant features found in the footpoint area.

Due to lack of spatial resolutions yet (hopefully).

Focusing event: tall jet & radio blob ejection

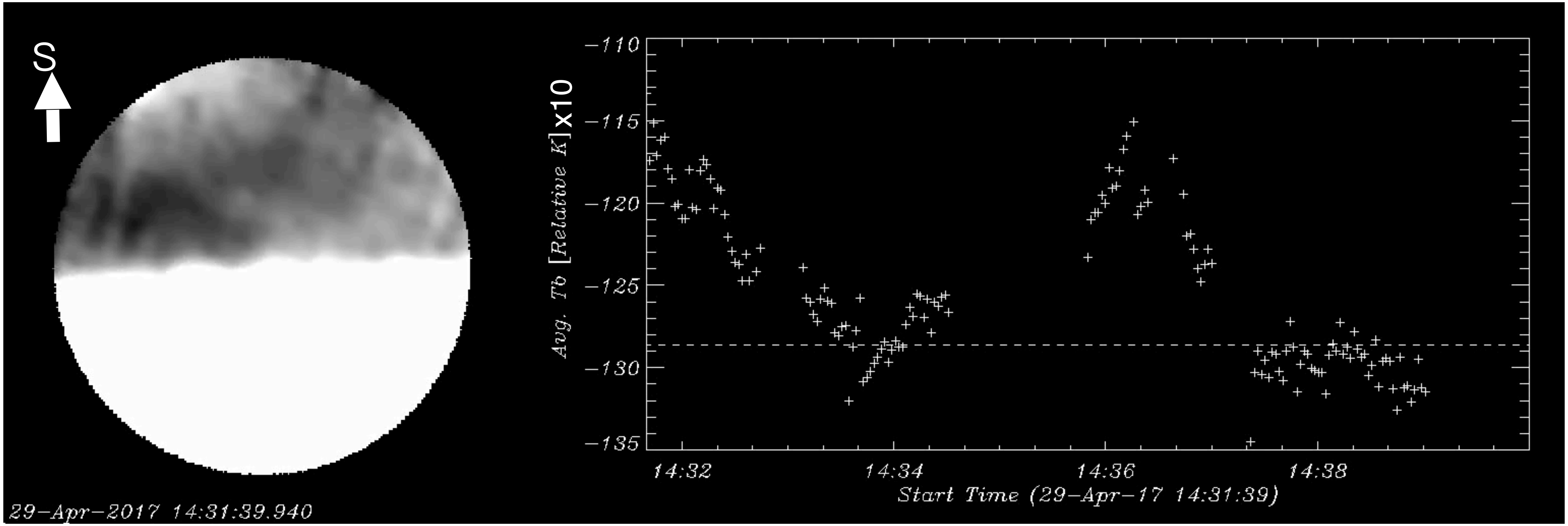
45 min. around 14:30 UT on 2017-4-29 on the coronal hole at the solar southern pole in Band-3 (100GHz)

movie: 20-sec cadence



time ⟶ time ⟶

Blob ejection: signal strength and density



Brightness enhancement caused by a blob = 135 K [Peak]
This is ~ 10σ level.
n~(6-9)x10^9 cm^{-3} assuming thin-thermal emission in LTE

Summary: What we found from this observation

1. The ALMA 100 GHz images show saw-tooth patterns on the limb, and a comparison with SDO/AIA 171˚A images shows a good correspondence of the limbs with each other.
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End