

Radio flares from young stars in Orion

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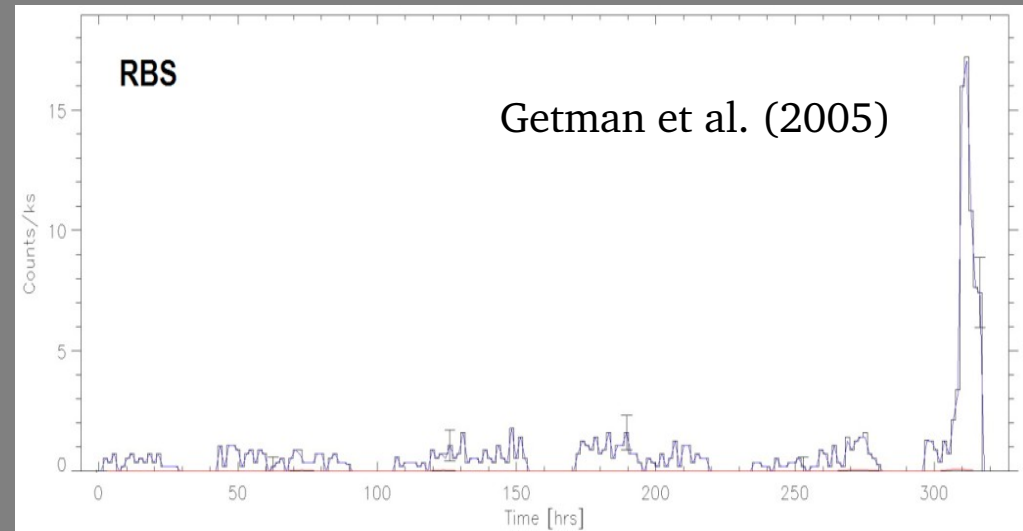
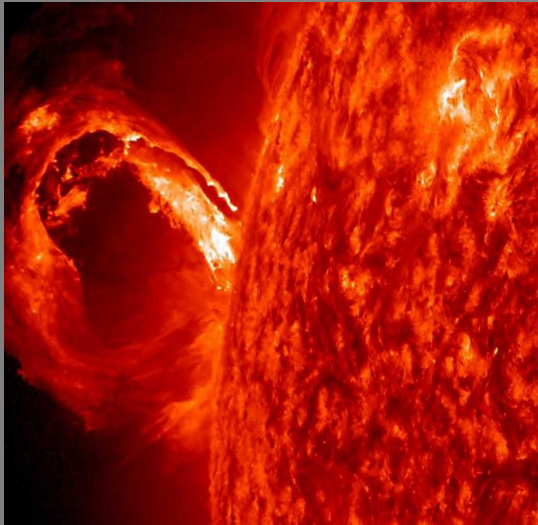
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Terzo workshop sull'Astronomia (sub)millimetrica in Italia



Flares from young stars

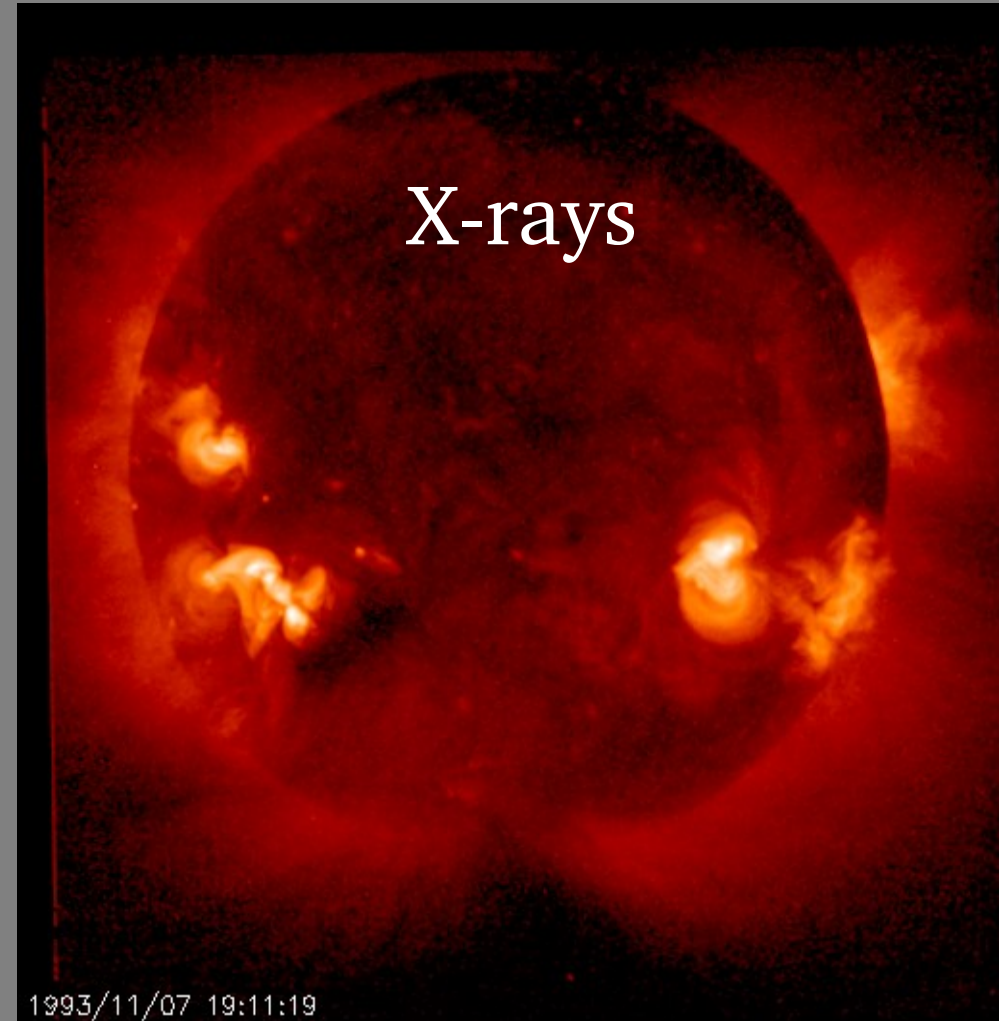
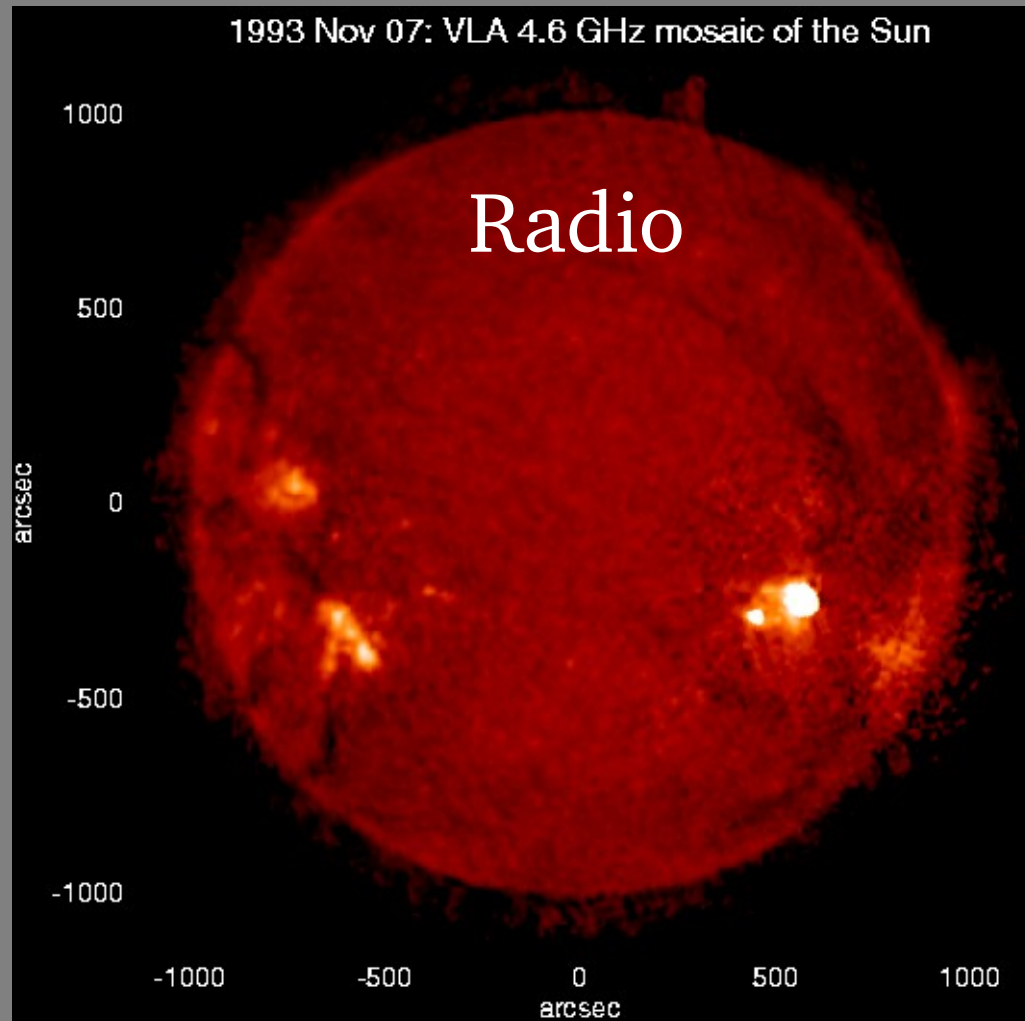
- Pre-main sequence (PMS) stars exhibit spectacular flares events detected in X-rays (1000 times solar flares).



- Origin: Violent coronal **MAGNETIC RECONNECTION EVENTS**
- These events are expected to also produce **highly-variable (flaring) non-thermal emission at long wavelengths** → accelerated electrons in magnetic loops producing gyrosynchrotron
- However, the physics and geometry associated with non-thermal cm/(sub)mm emission from young stars are still poorly constrained.

The solar paradigm

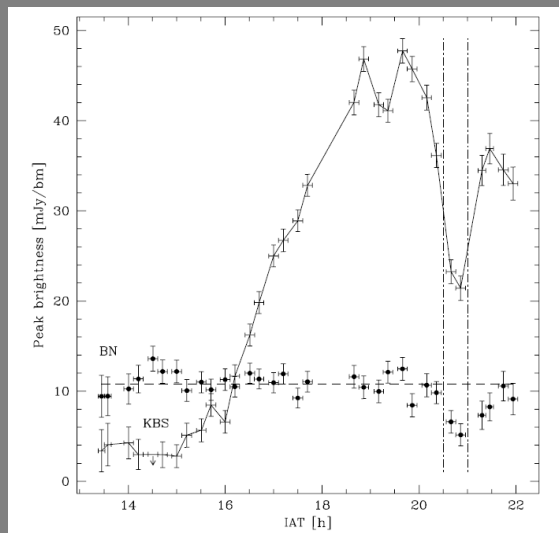
- Radio and X-ray emission are related (magnetic energy release).



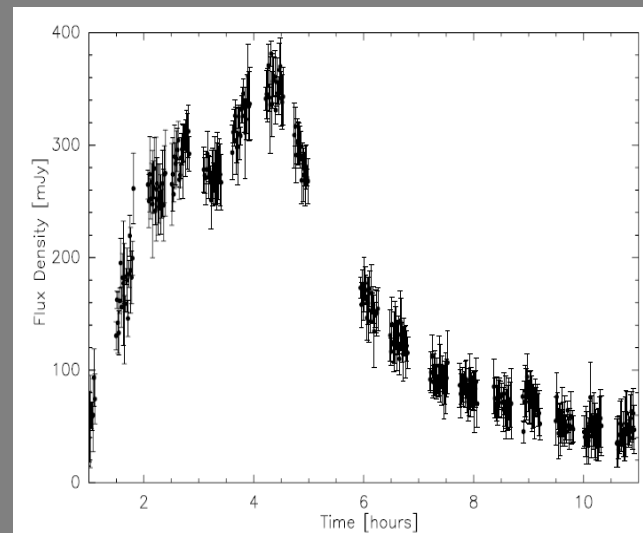
But what about YOUNG STARS ?

Scientific background: cm/mm variability from young stars

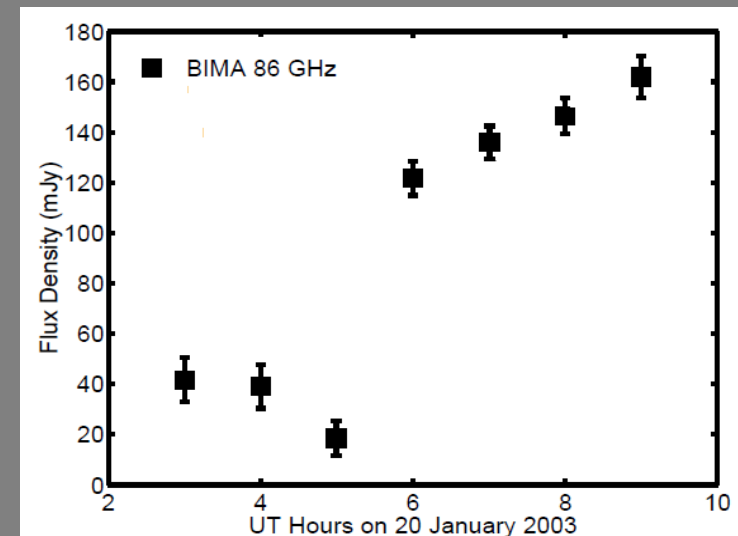
- Centimeter monitorings (2-6 cm) detected LONG-TERM VARIABILITY in timescales of years-months (Felli+93, Zapata+04).
- OPEN QUESTION:** Due to long-term processes or simply a sequence of shorter timescale events?
- Only a few serendipitously detected impressive flares with SHORT-TERM VARIABILITY on timescales of hours to days have been reported.



Forbrich+2008 (VLA)
1.4 cm (22 GHz)



Massi+2006 (PdB)
3 mm (90 GHz)

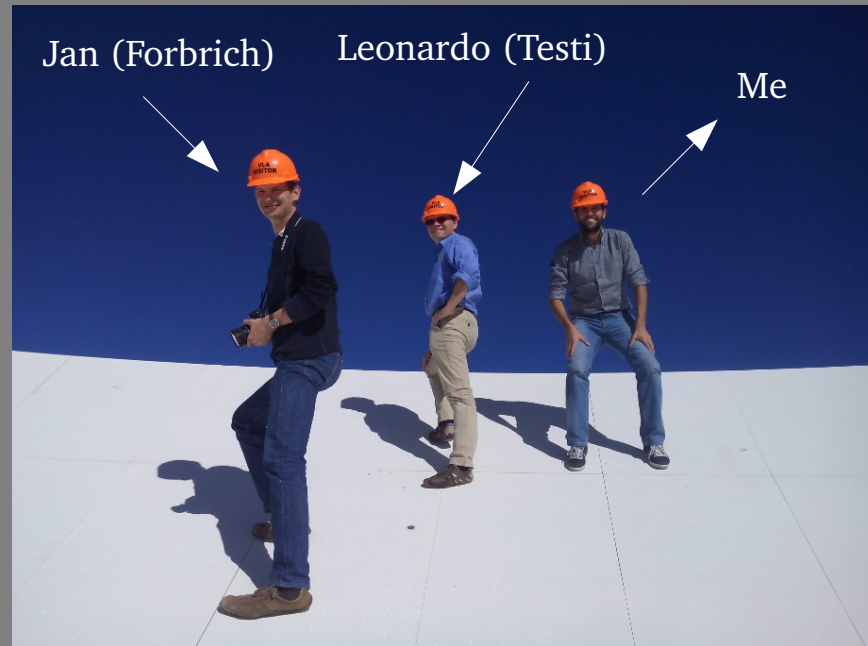


Bower+2003 (BIMA)
3 mm (86 GHz)

New 7 & 9 mm VLA monitoring of Orion

2 MAIN AIMS

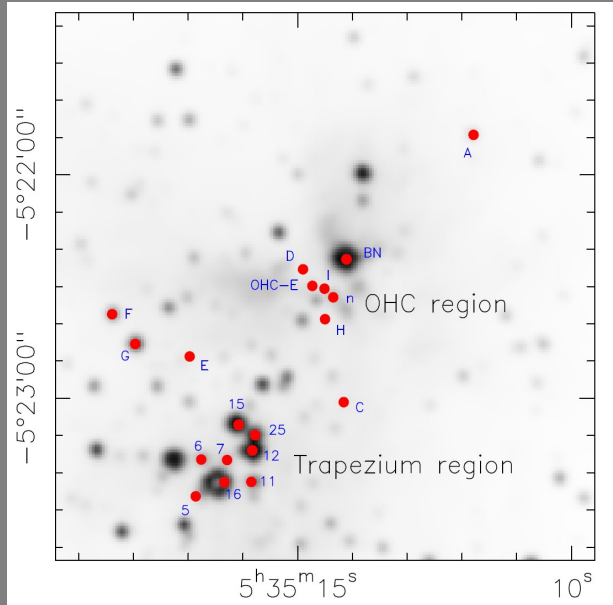
- Monitoring at higher frequencies (33-45 GHz)
- Study of long-term and also **short-term variability** (different separation between epochs between hours and months).



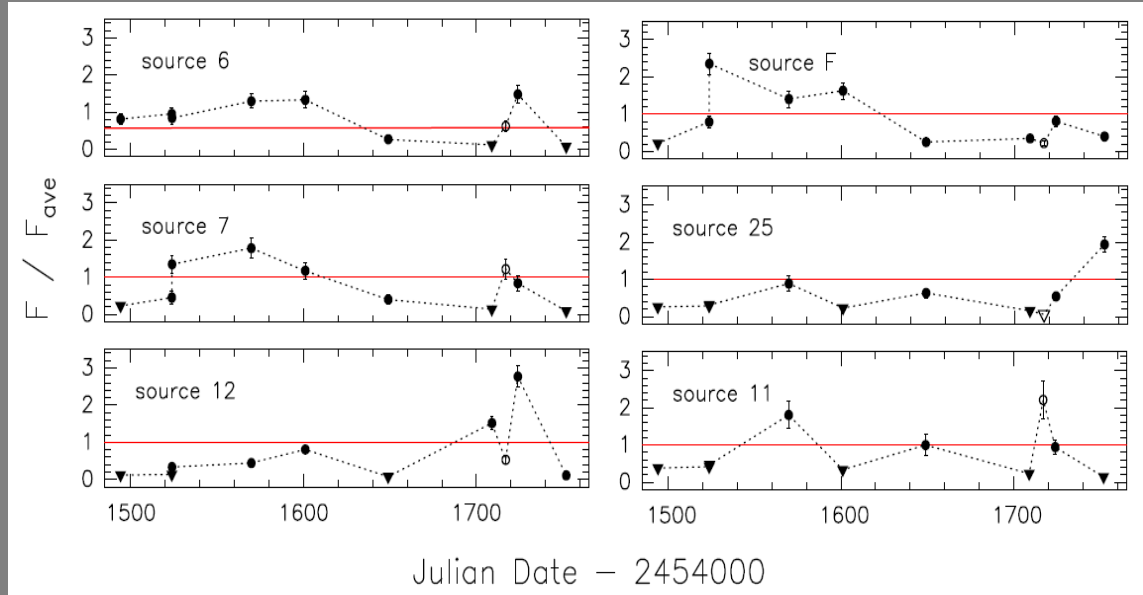
Orion is a perfect target because it harbors a dense population of PMS low-mass stars.

7 & 9 mm VLA monitoring: results

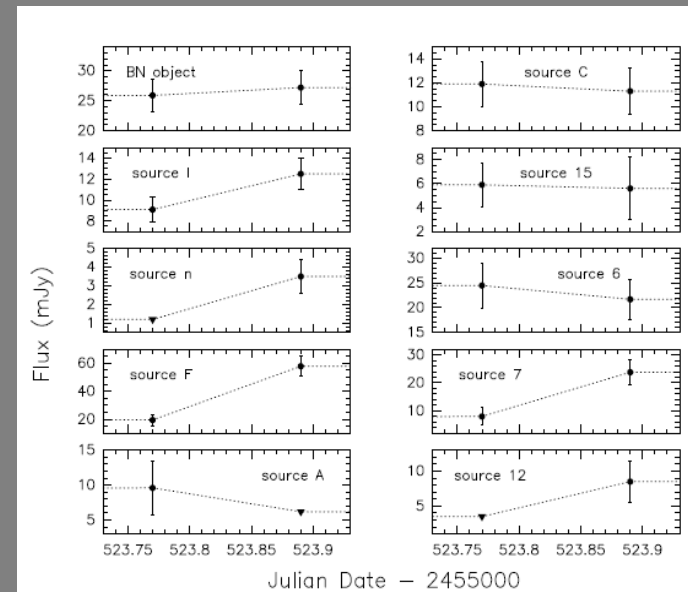
- We detected 19 radio sources



- Radio variability is very common

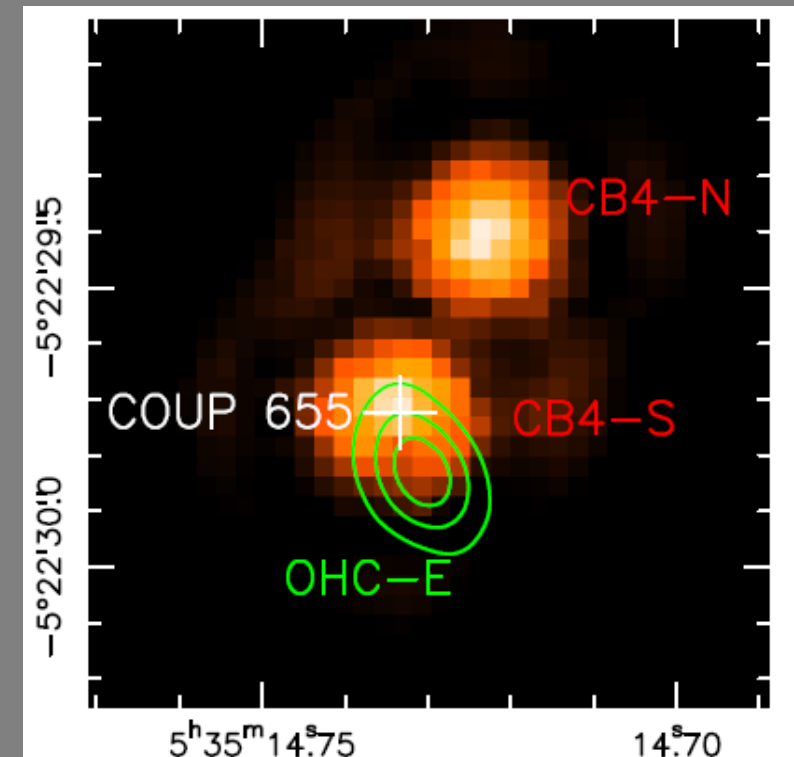
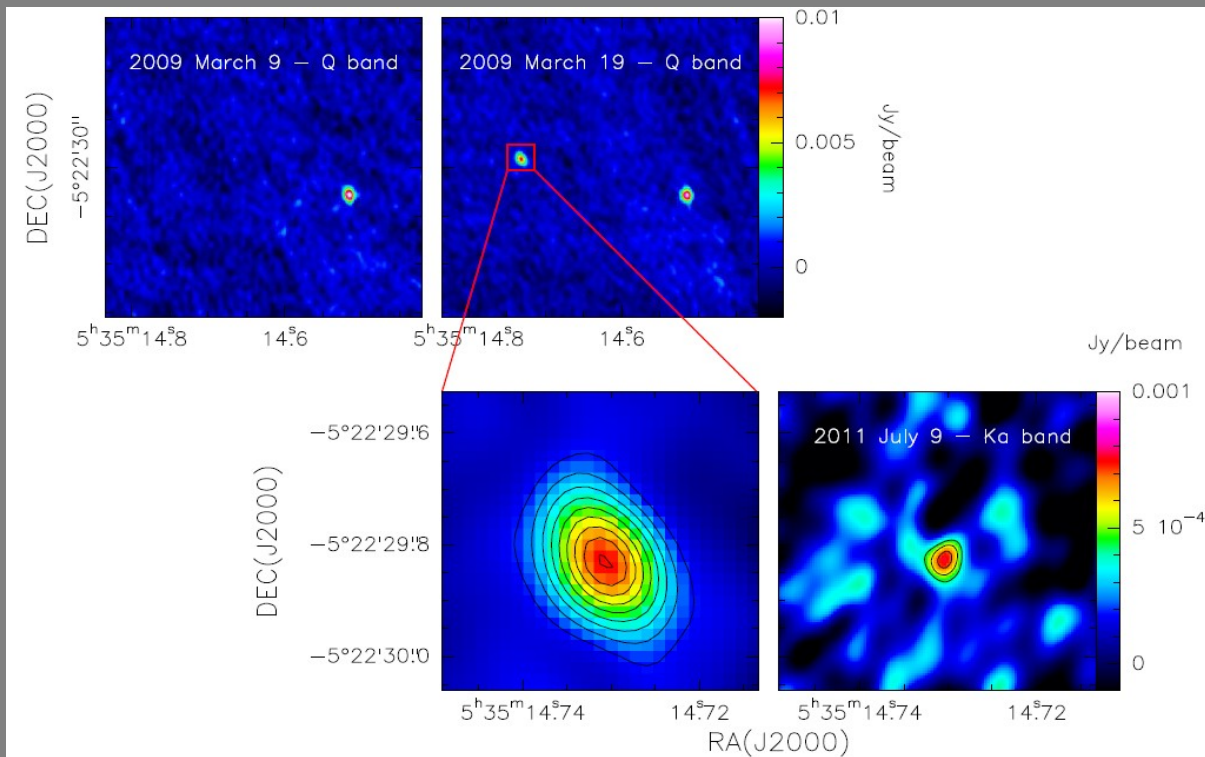


- Significant flux density variation even in scales of hours!
- Rough estimate of flaring rate detected in Orion (0.14 flares/day)



Detection of a new radio source: OHC-E

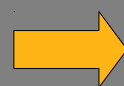
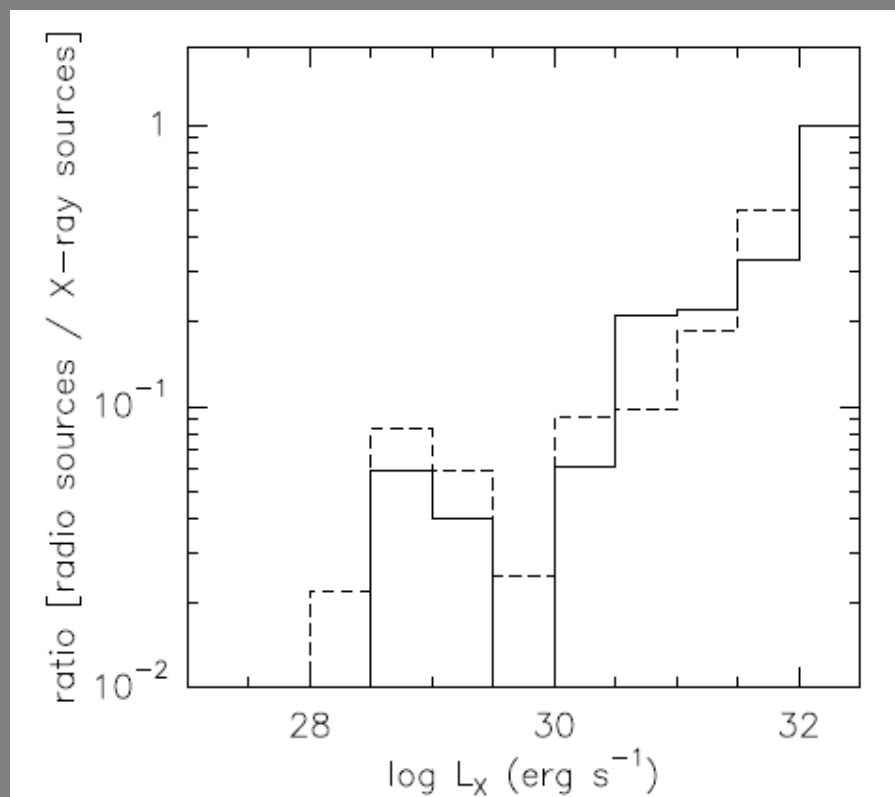
- Two 7 mm observations separated by only 10 days.



Rivilla et al., submitted

Comparison with X-ray detections

- The non-thermal emission is expected to arise from the same magnetic reconnection events that produce X-ray emission.
- The radio detections correspond with the brighter X-ray stars.



Radio and X-ray emission
are indeed somehow related

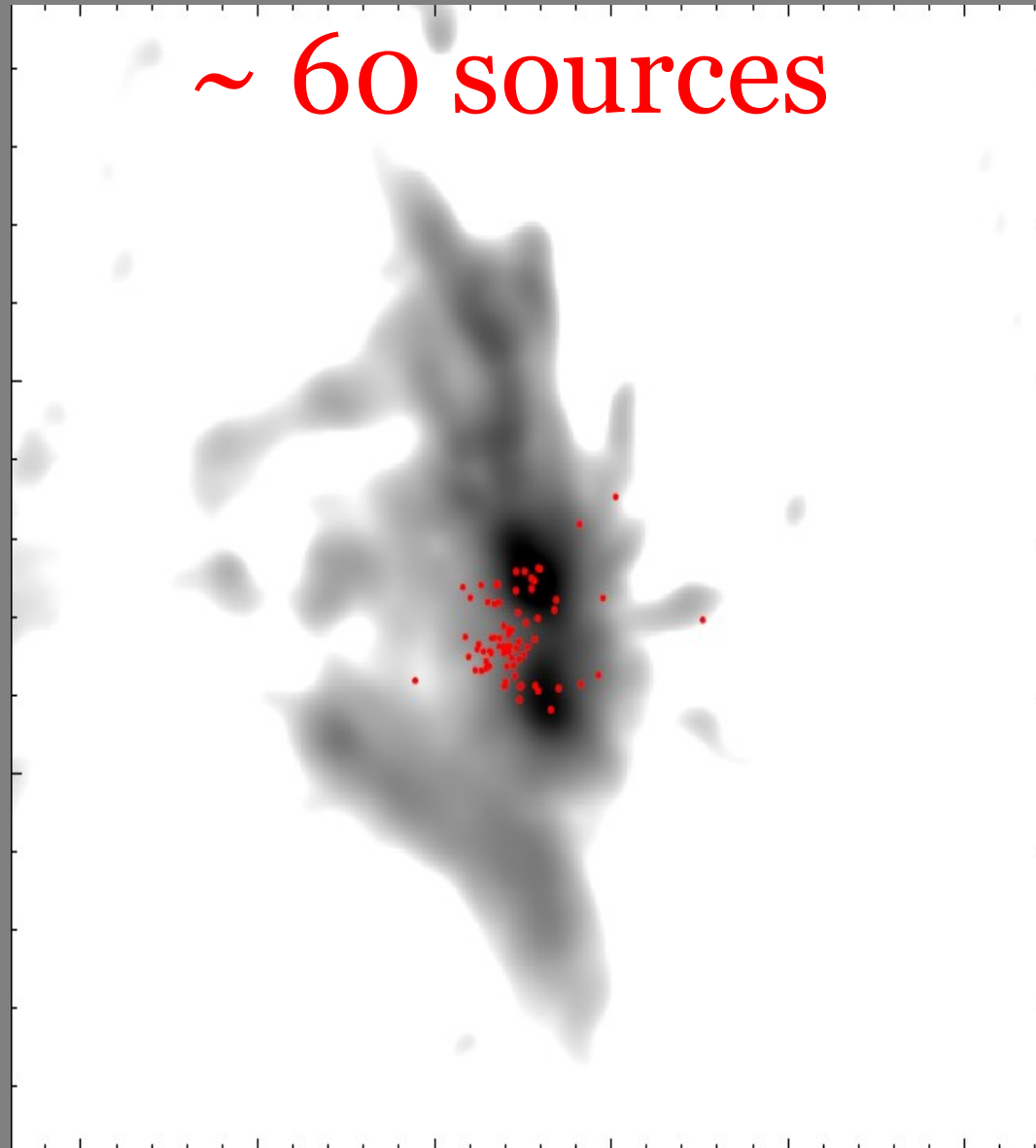


**We were strongly
limited by sensitivity !**

Improved VLA: much more sensitive observations

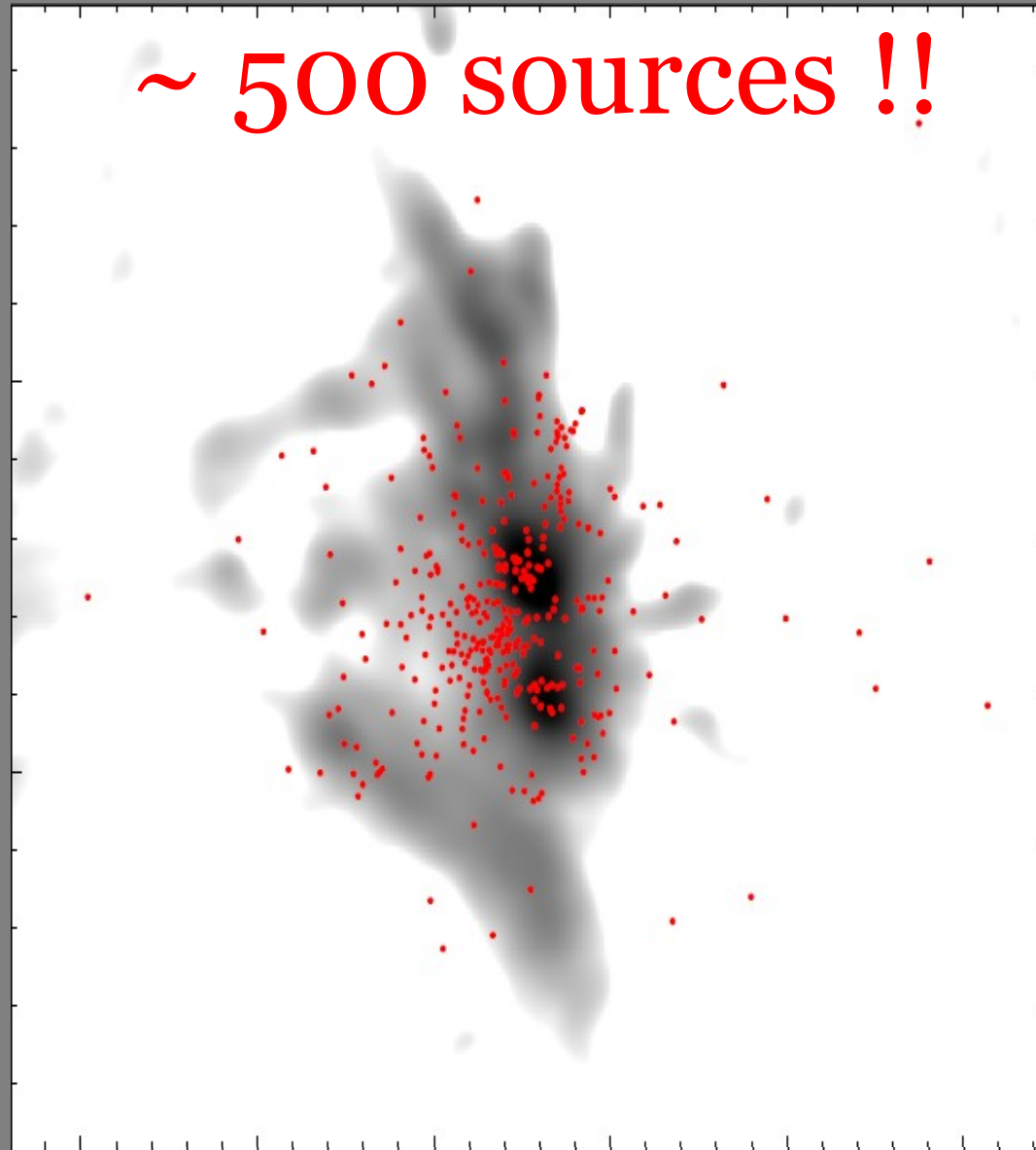
Improved VLA: much more sensitive observations

Zapata et al. 2004, “old VLA”, 3.6 cm



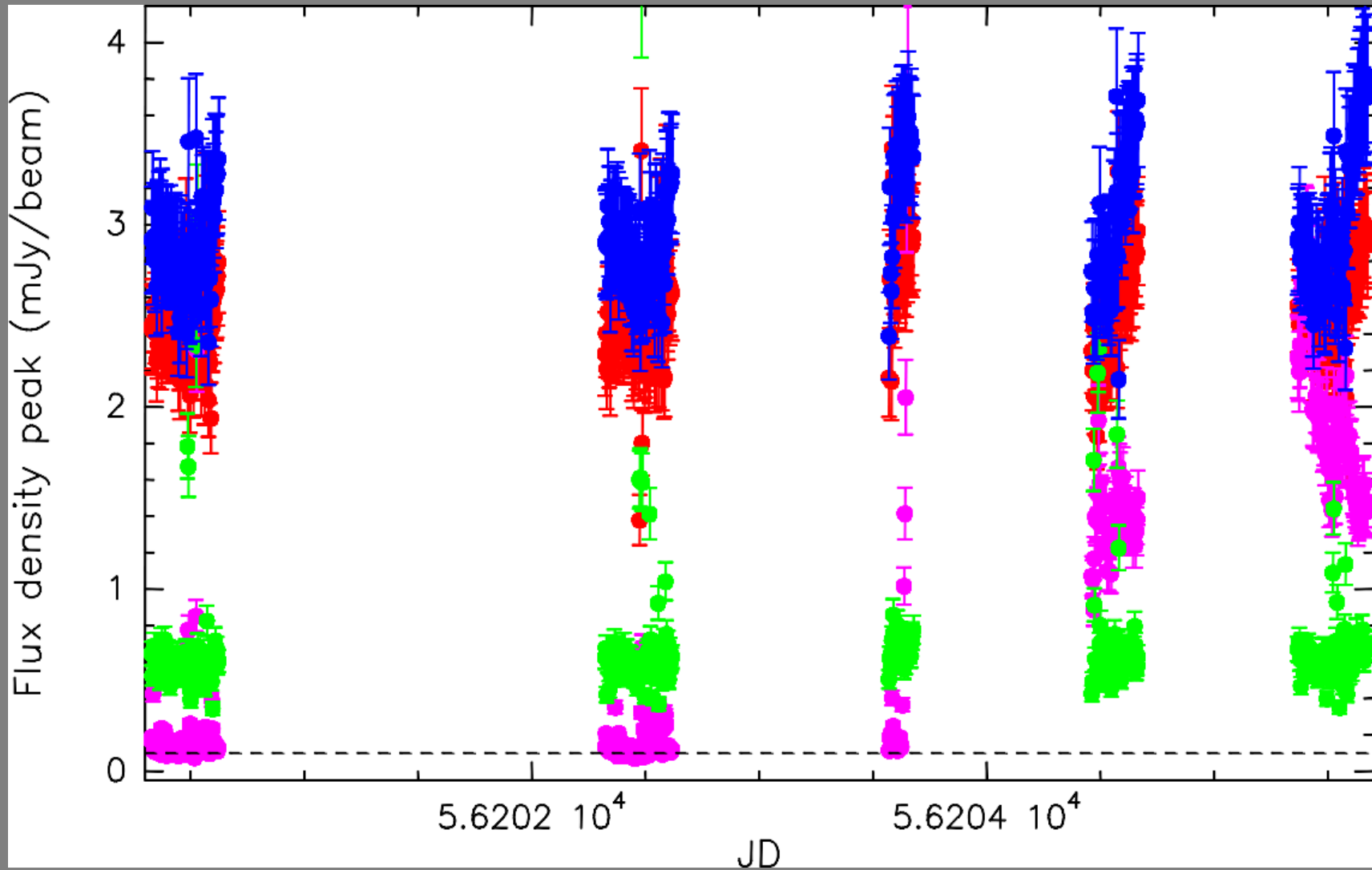
Improved VLA: much more sensitive observations

Forbrich & Rivilla, in prep; new VLA, 4-6 cm



Flux density curves (only 4 sources)

5 epochs in (almost) 5 consecutive days



KM Ori

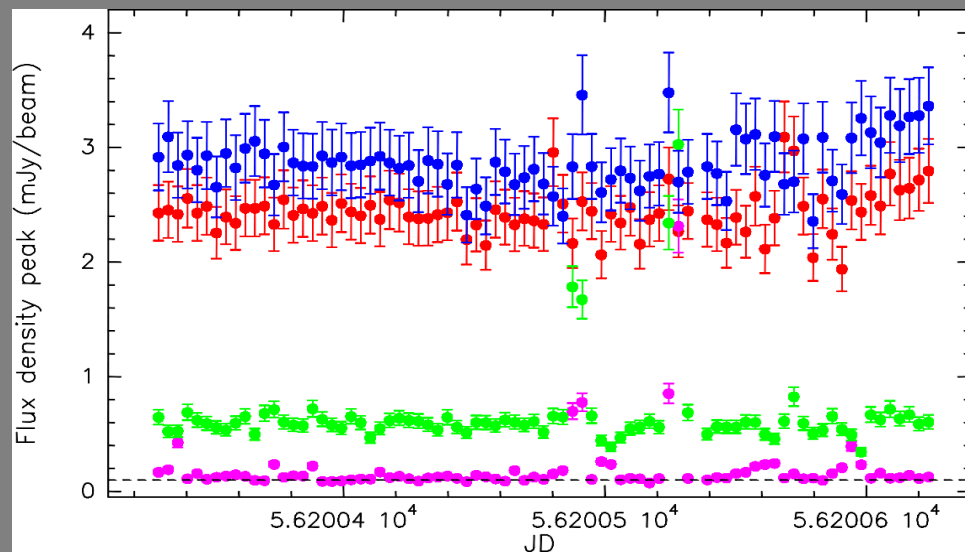
BN Object

Source I

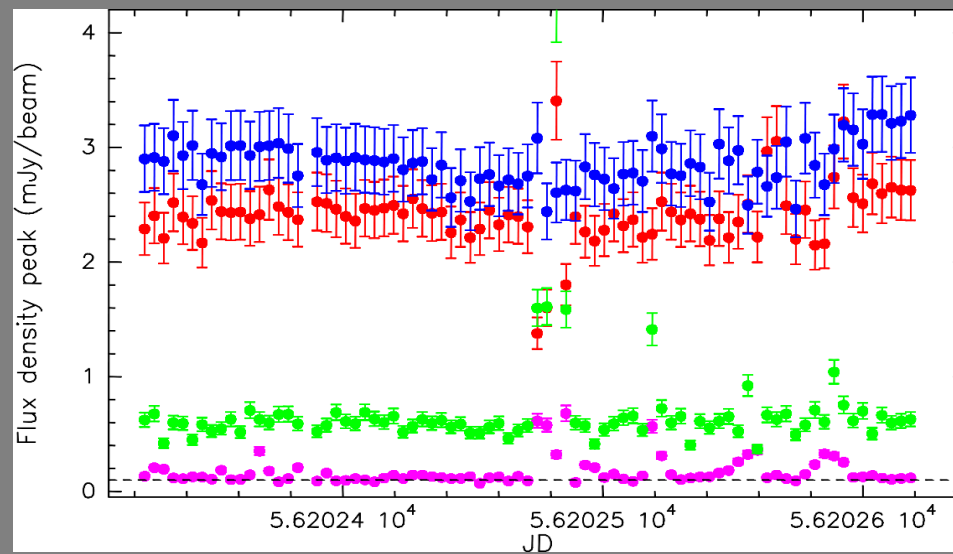
COUP 1232

Flux density curves: 6 min resolution!

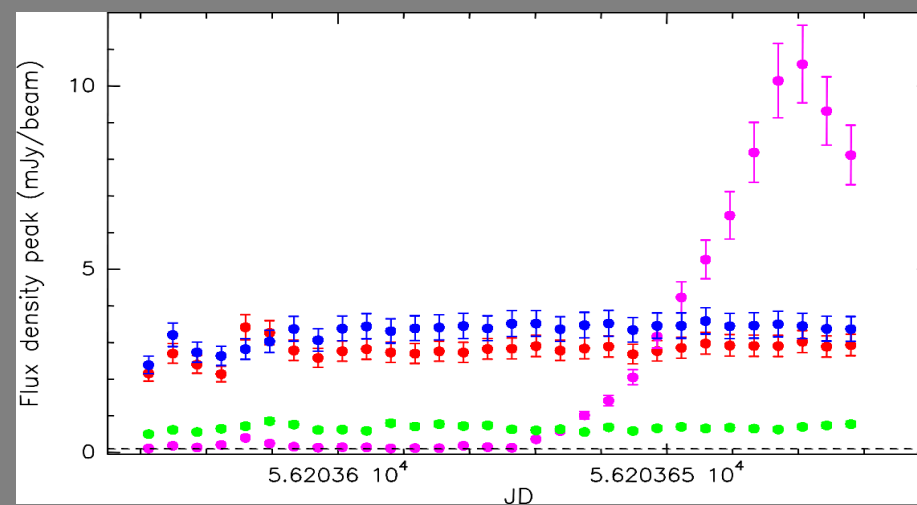
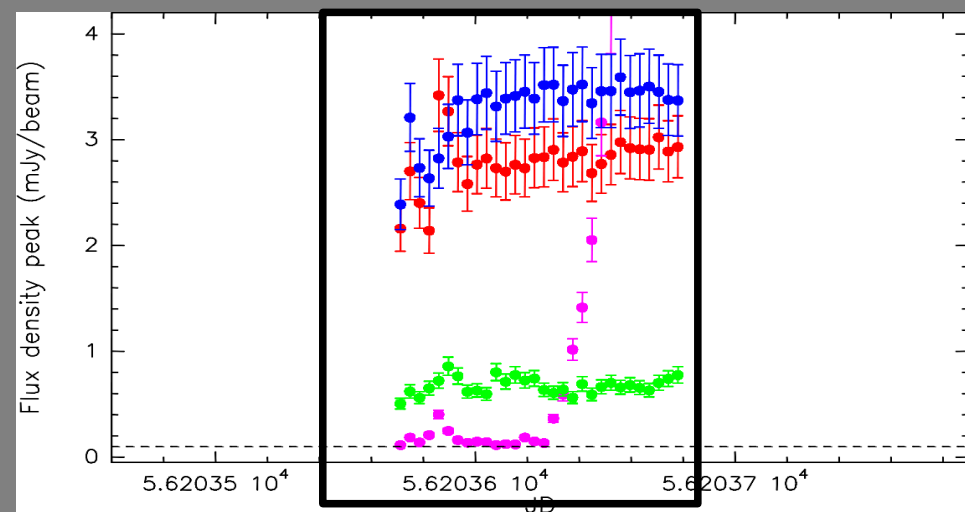
Epoch 1



Epoch 2



Epoch 3



KM Ori

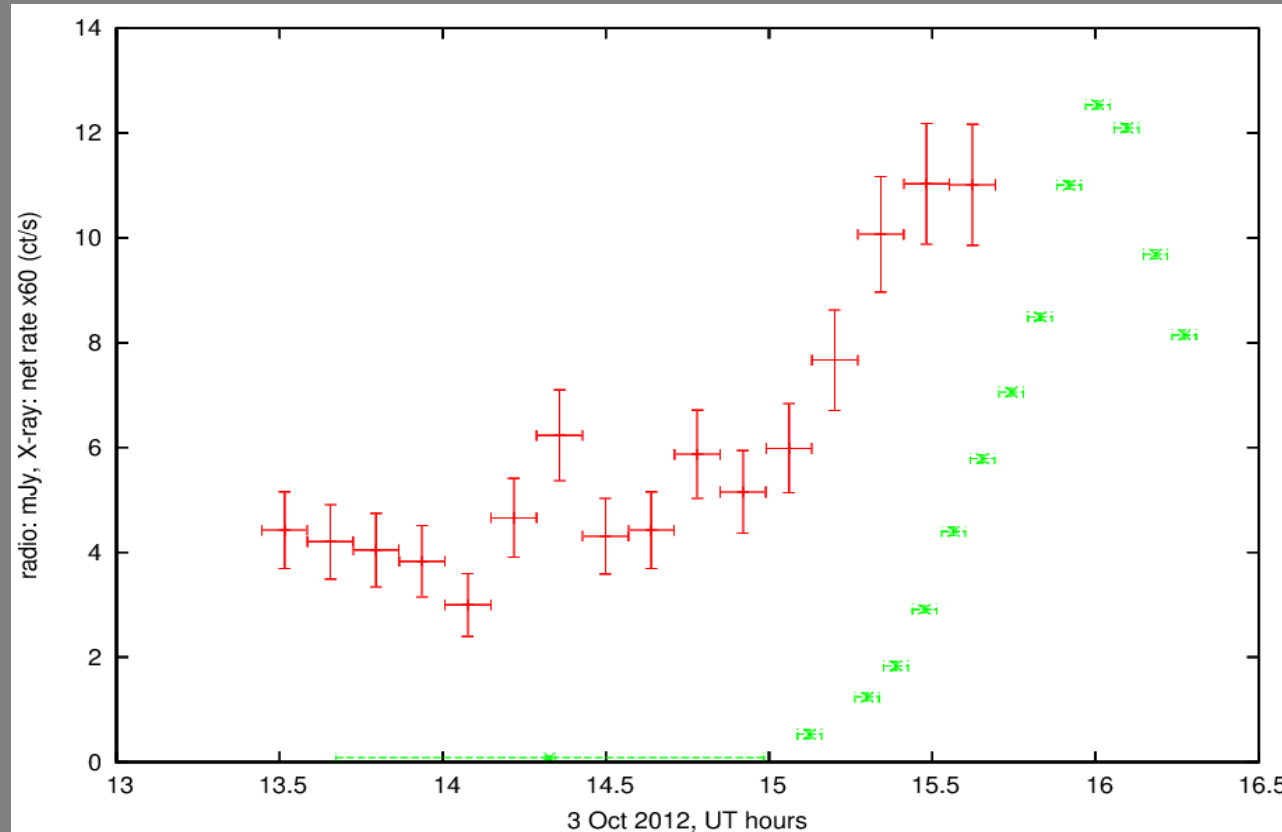
BN Object

Source I

COUP 1232

Simultaneous VLA and Chandra observations

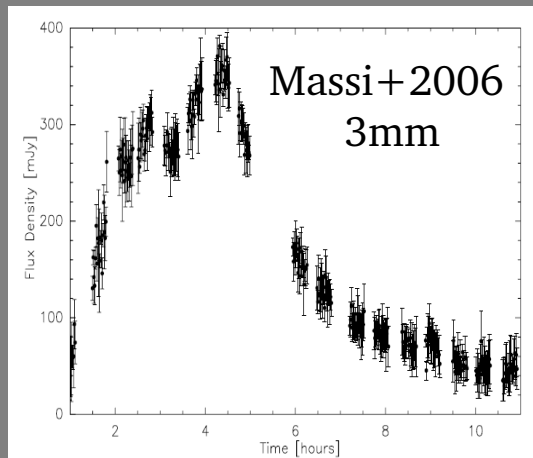
- Radio and X-ray flares are correlated!!!



- Exciting... but sometimes the situation is different...

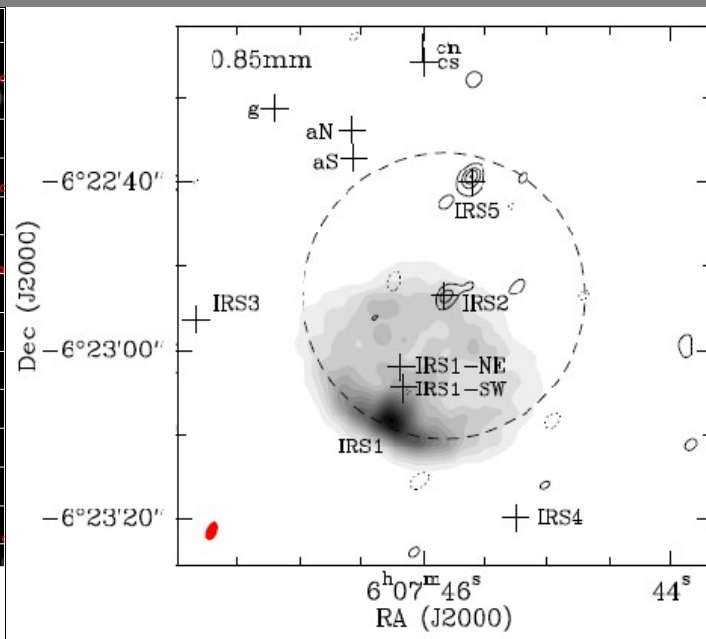
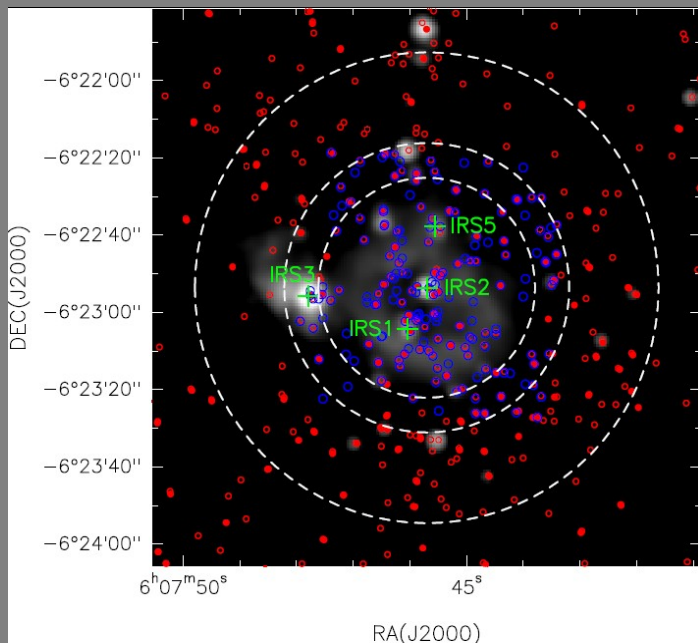
➡ Radio flares without X-ray flare, or viceversa...

What about higher frequencies (3, 2, 1 mm ...) ?



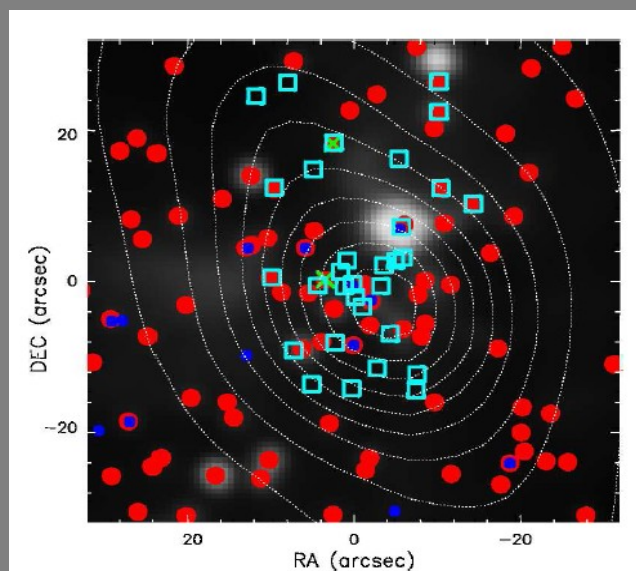
SMA continuum observations of the MonR2 cluster

- MonR2 is a crowded stellar cluster with many PMS stars.
- Our submm SMA observations (sensitivity 10 mJy) have not detected emission from any of the low-mass stars .
- Assuming the flaring rate detected in Orion and the sensitivity, we would expect ~ 0 flares/day!!!



NEED OF HIGHER
SENSITIVITY
($\sim 10 \mu\text{Jy}$)

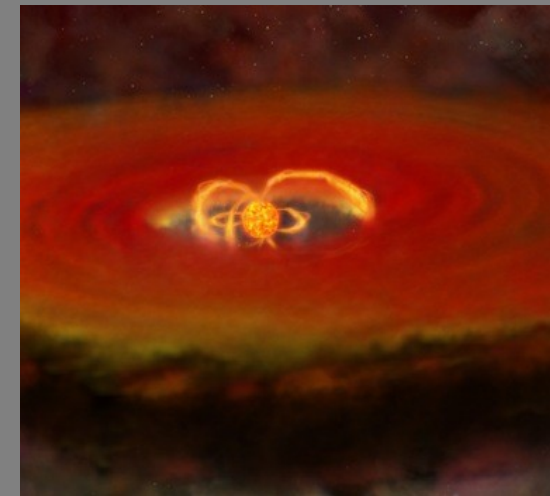
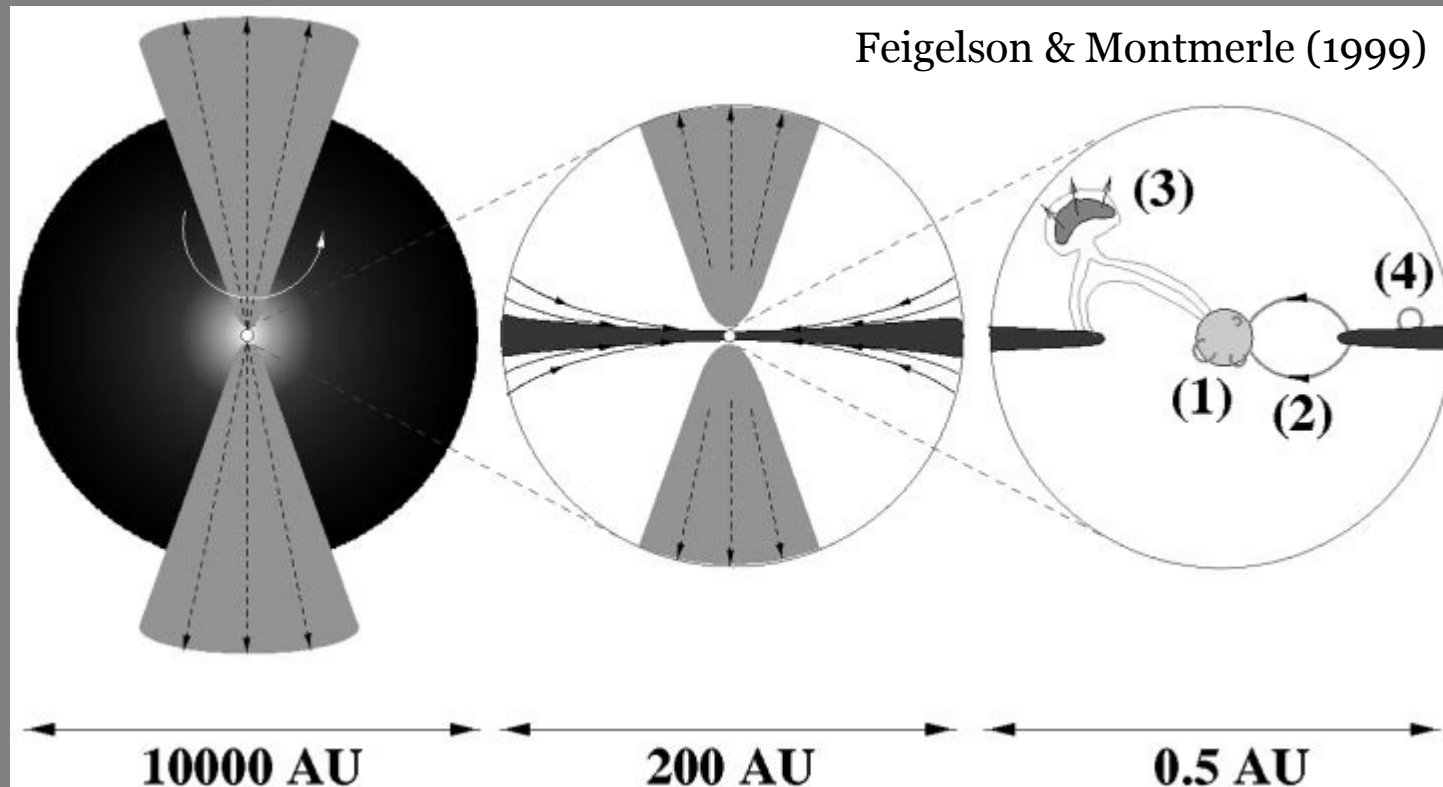
So... ALMA, of course!



- A pointing of ALMA observation will provide a catalogue of many PMS stars with (sub)mm emission.
- A single polarization ALMA observation at band 3 (90 GHz) with full BW of 7.5 GHz and 50 antennas can reach $8 \mu\text{Jy}$ sensitivity limit in only < 3 hr of on source observing time → **6 radio flares in a single observation!**
- Cycle 2 proposal 3 mm (90 GHz) rejected.

But we need not only sensitivity... also spatial resolution

- Only **mm-VLBI (including ALMA)** provides the needed sensitivity and spatial resolution to resolve the small-scales (< 0.1 AU; $\ll 1$ mas) of magnetic loops involving the central star and the circumstellar disk.



- FURTHER IMPLICATIONS:** high energy irradiation of protoplanetary disks, impact on planet formation, improvement of previous derivations of parallax distances, effects on interferometric imaging techniques...

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Grazie!

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