Relativistic jets from XRBs with LOFAR.

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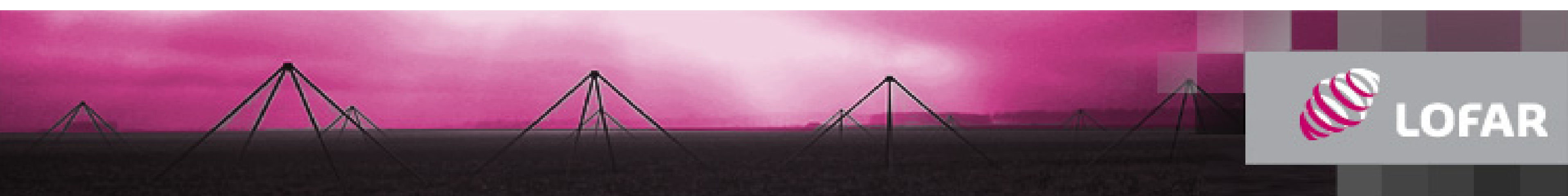

Outline

- Introduction: X-ray binaries and flavors of relativistic jets
- LOFAR Contributions
- Conclusions

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Introduction: X-ray binaries

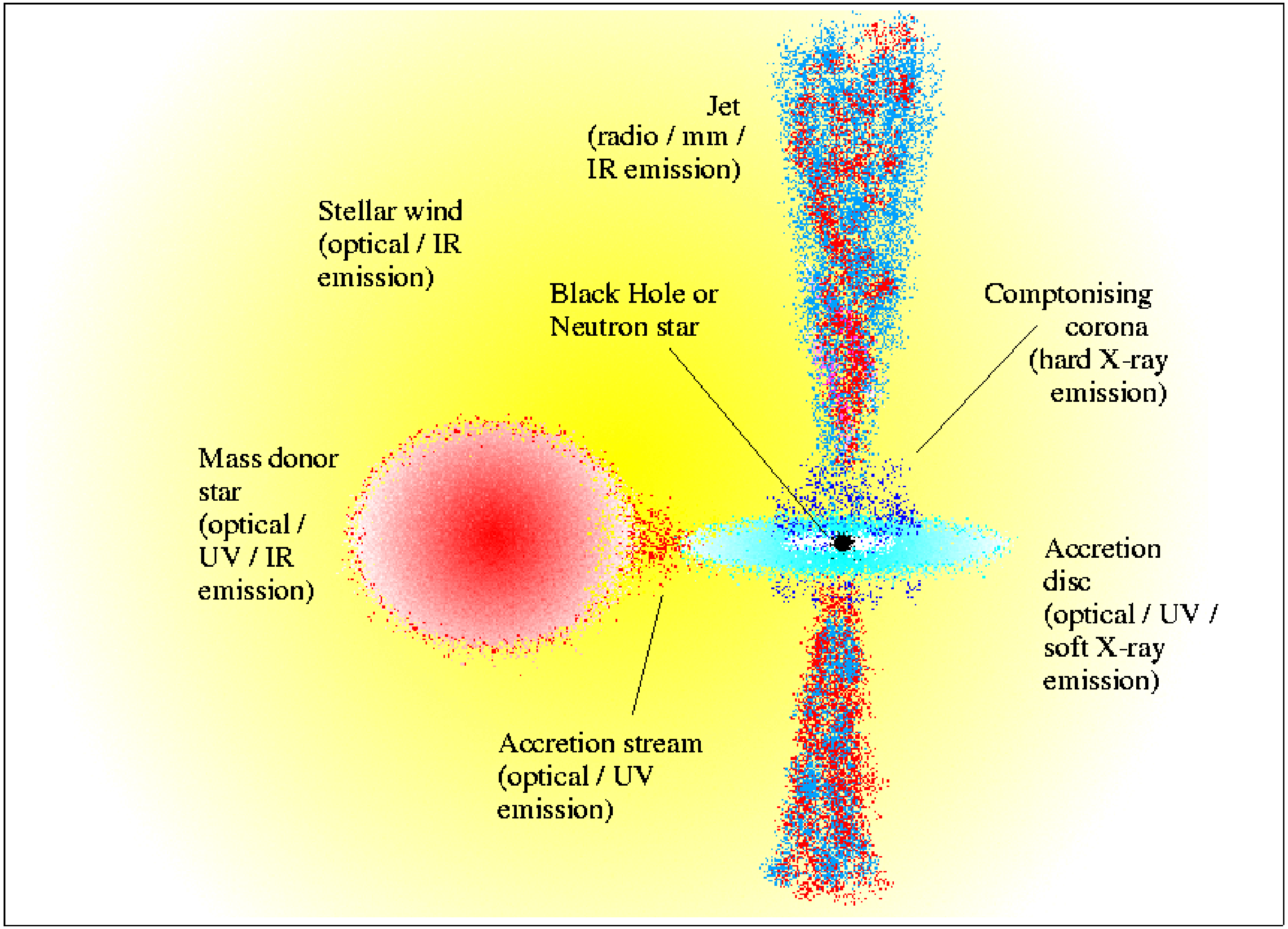
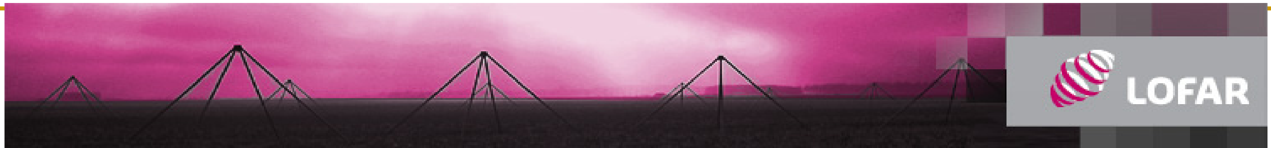
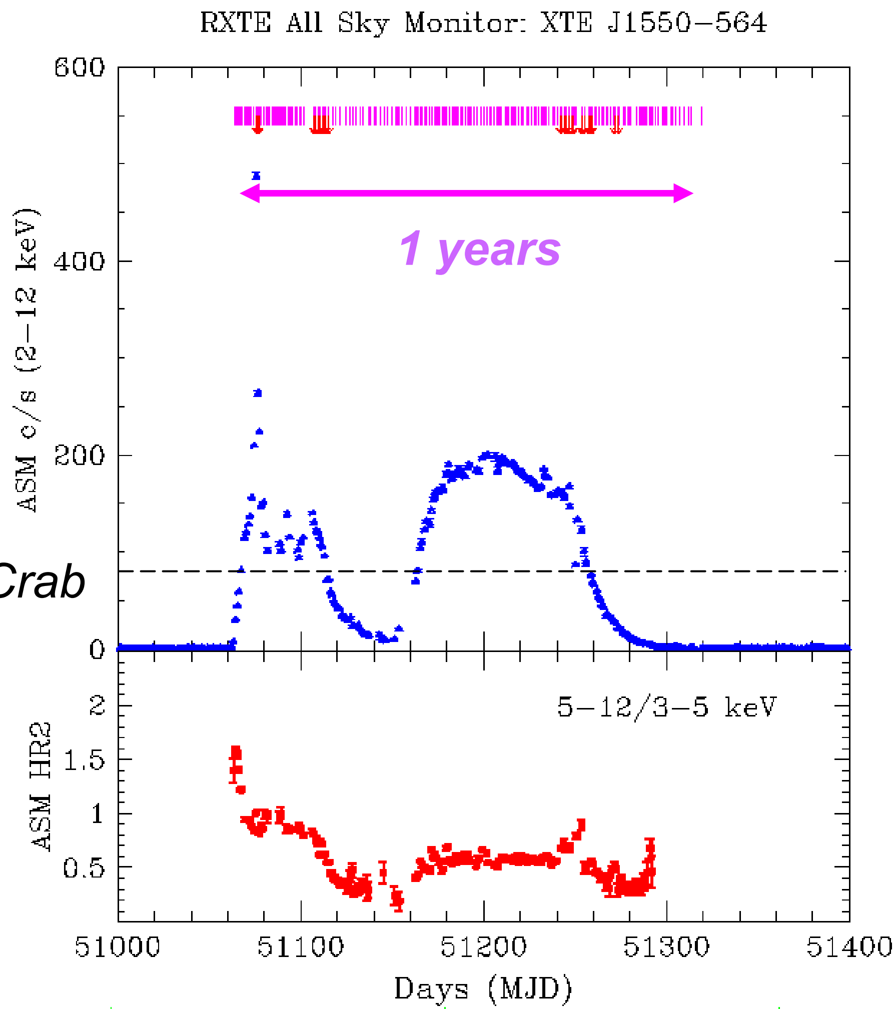


Image: R. Fender



X-ray States of Black Hole Binaries

RXTE/ASM lightcurve of a typical X-ray nova



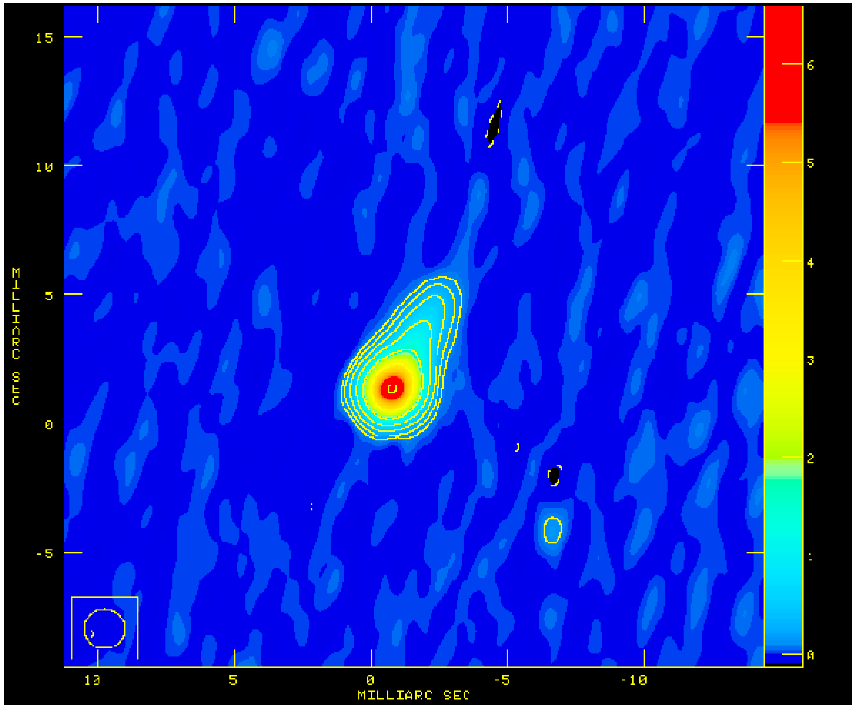
Hardness of the X-ray spectra

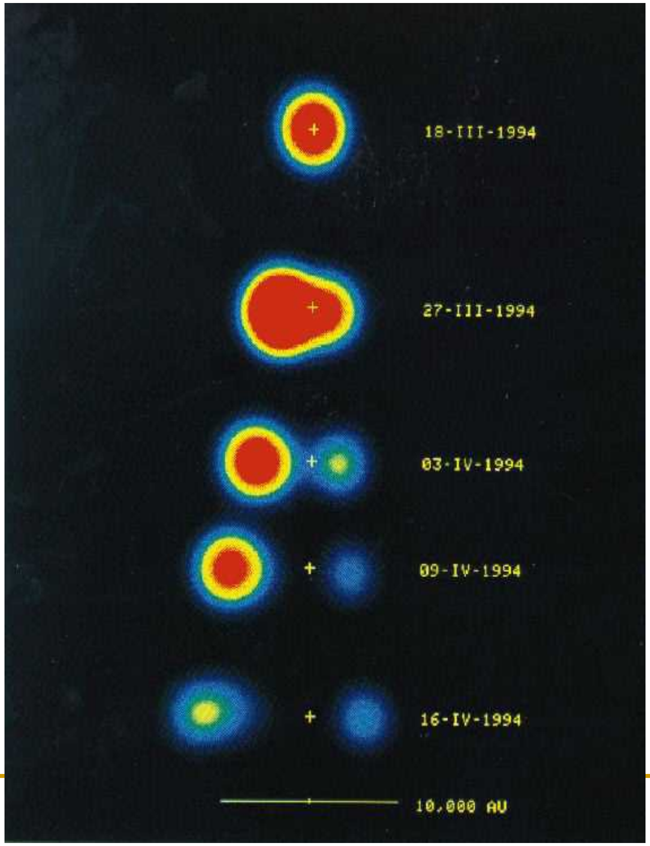
X Variable on many different timescales !!

- quiescence to outburst: days
- outburst : from s to days
- Radio properties : also very variable

Two flavors of relativistic jets from microquasars: two very different scales !!!!

- Compact, self-absorbed jets (on mas scale = 10s a.u.).
- Discrete ejections (superluminal, ballistic).

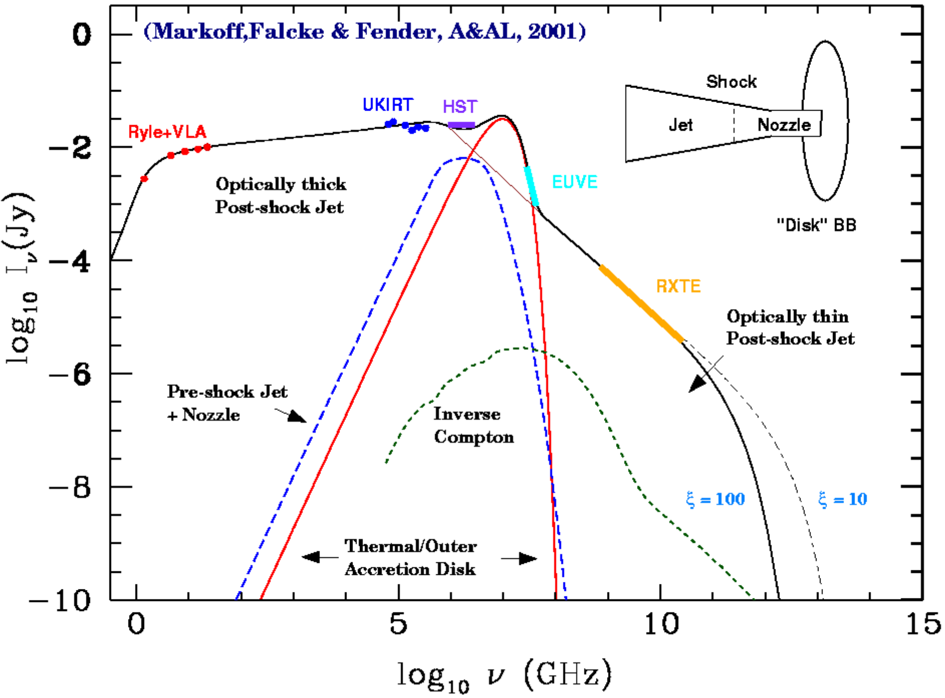


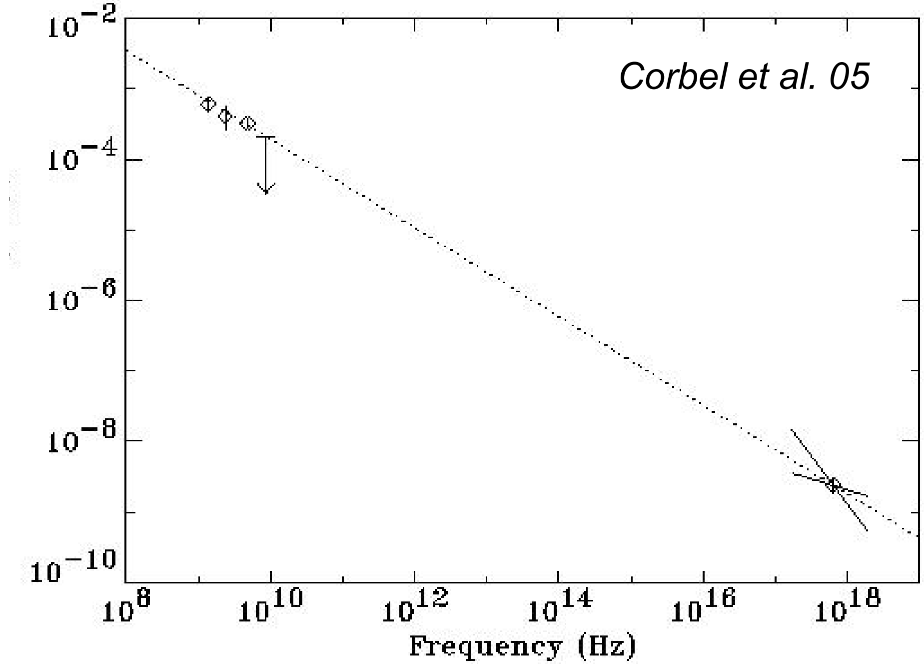


Stirling et al. 2001

Mirabel et al. 94

Spectral extent of these <u>small</u> scale jets

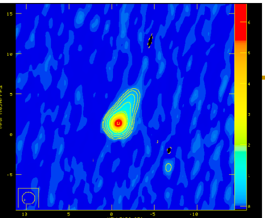


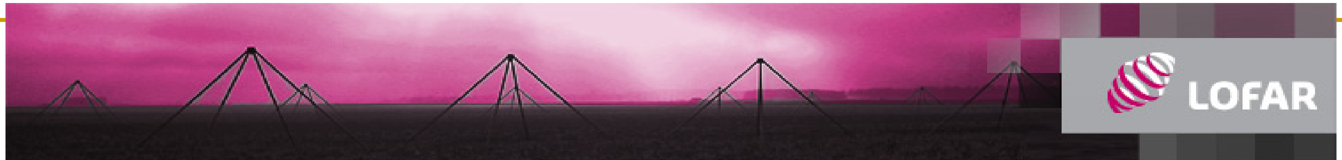


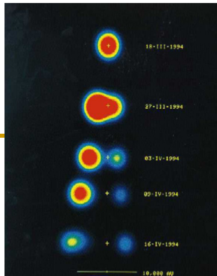
❖ <u>Compact jet</u>: flat spectrum, but self absorption in LOFAR frequency range

❖ <u>Discrete ejections events</u>: optically thin, but opacity delays for LOFAR

Note: important connection with high energy properties



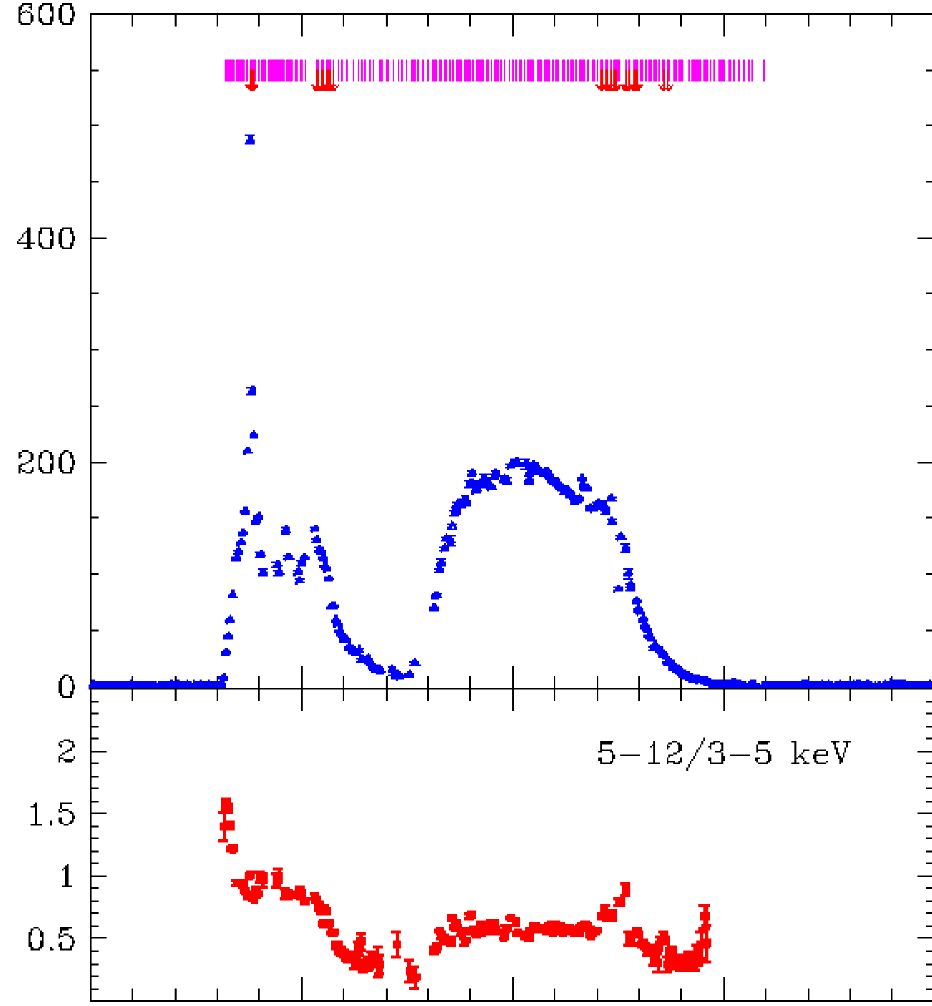




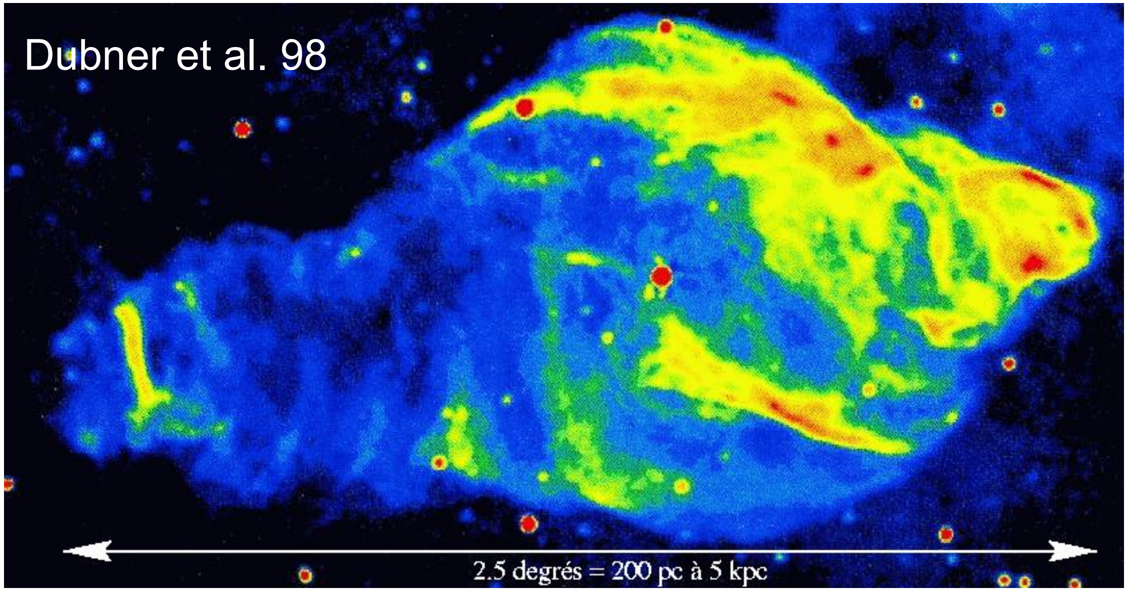
Jet unification

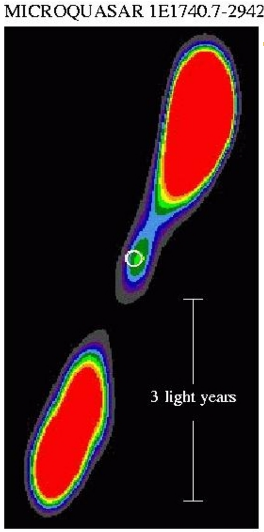
- Unification of jet properties:
  - Hard state: compact jet
  - Thermal state : no jet
  - Transition hard IS to soft IS: Discrete and transient massive ejection event(s).

(Corbel et al. 04, Fender et al. 04):

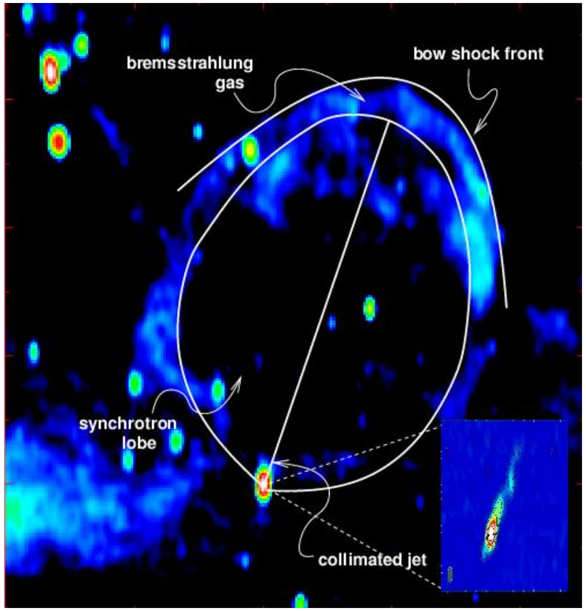


Large scale jets (or lobes)





Mirabel et al. 92



Gallo et al. 2005

Large scale lobes = long term action of impulsive relativistic events. Constant radio flux

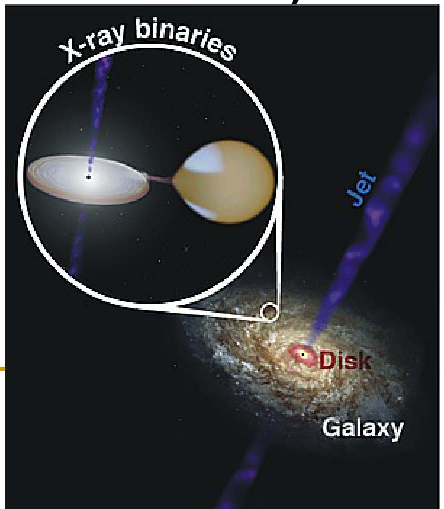
ISM = calorimeter

→ *See talk by C. Kaiser*

LOFAR

Topics addressed

- Jet physics:
  - Particles acceleration in accreting compact objects: shock acceleration, interaction with ISM, synchrotron radiation, explosive events, jet collimation.
  - Jet energetics, Phase of energy loss that could be energy dependant (sync or ic loss) or energy independent (adiabatic loss), all convolved with evolution of optical depth (important for LOFAR).
  - Accretion — ejection coupling.
  - Impact of jets on ISM or IGM ?
- Similarities XRB/AGN (ULX ?)



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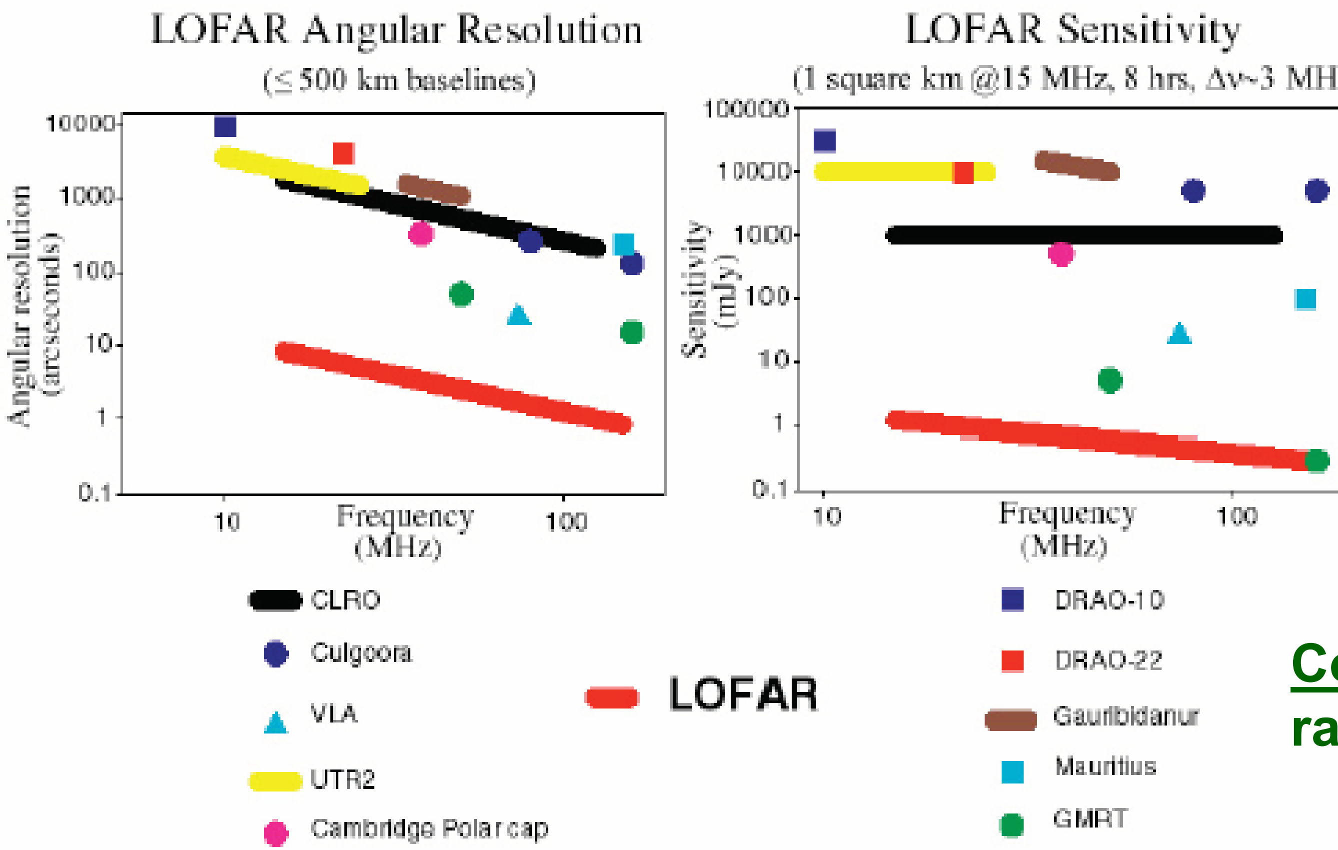
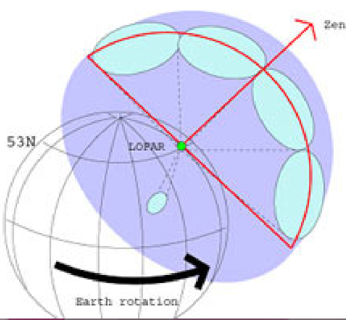


<u>Compact jets</u>: flat radio spectrum

<u>Relativistic ejections</u> and <u>large scale lobes</u>: radio spectrum rising in LOFAR freq range.

LOFAR as a Radio ASM

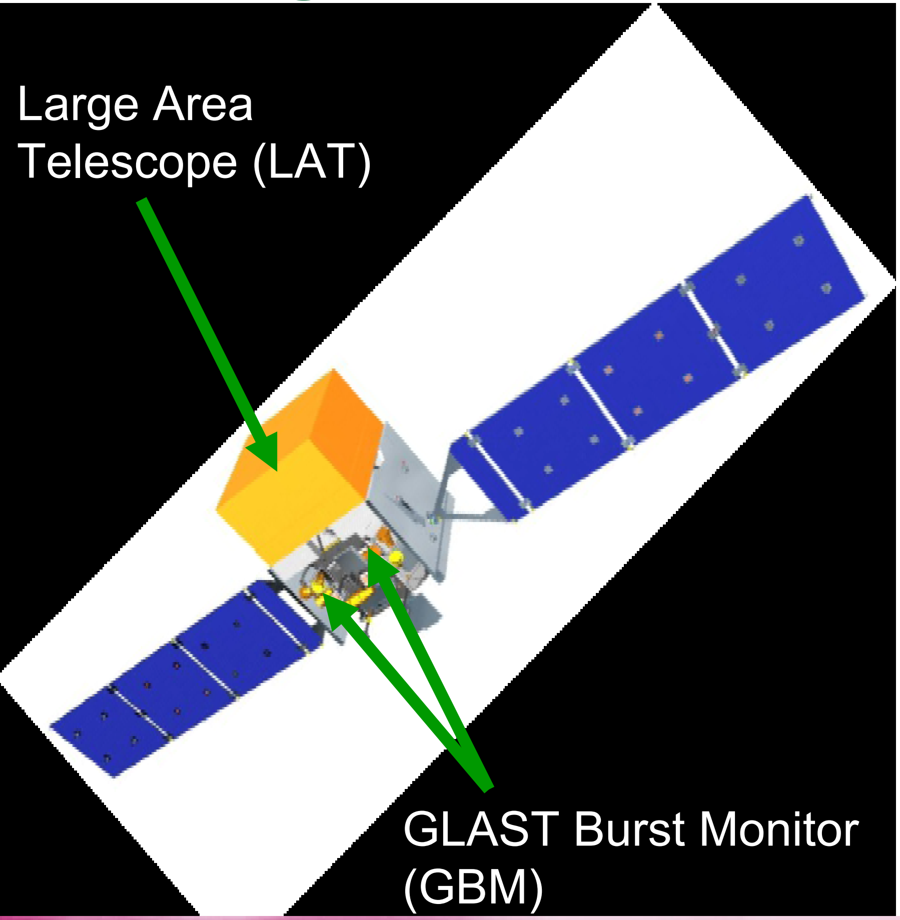
- Currently, any active X-ray sources is usually spotted by RXTE ASM (Movie) → actual trigger for follow-up observations (space +ground).
- However likely no more ASM beyond 2008 !!
- Major issue for transient sources such as XNe
- LOFAR = software telescope. Compact core can monitor large portion of the northern hemisphere sky + normal full-array to observe in more details any new transient



Reactivation of XRBs

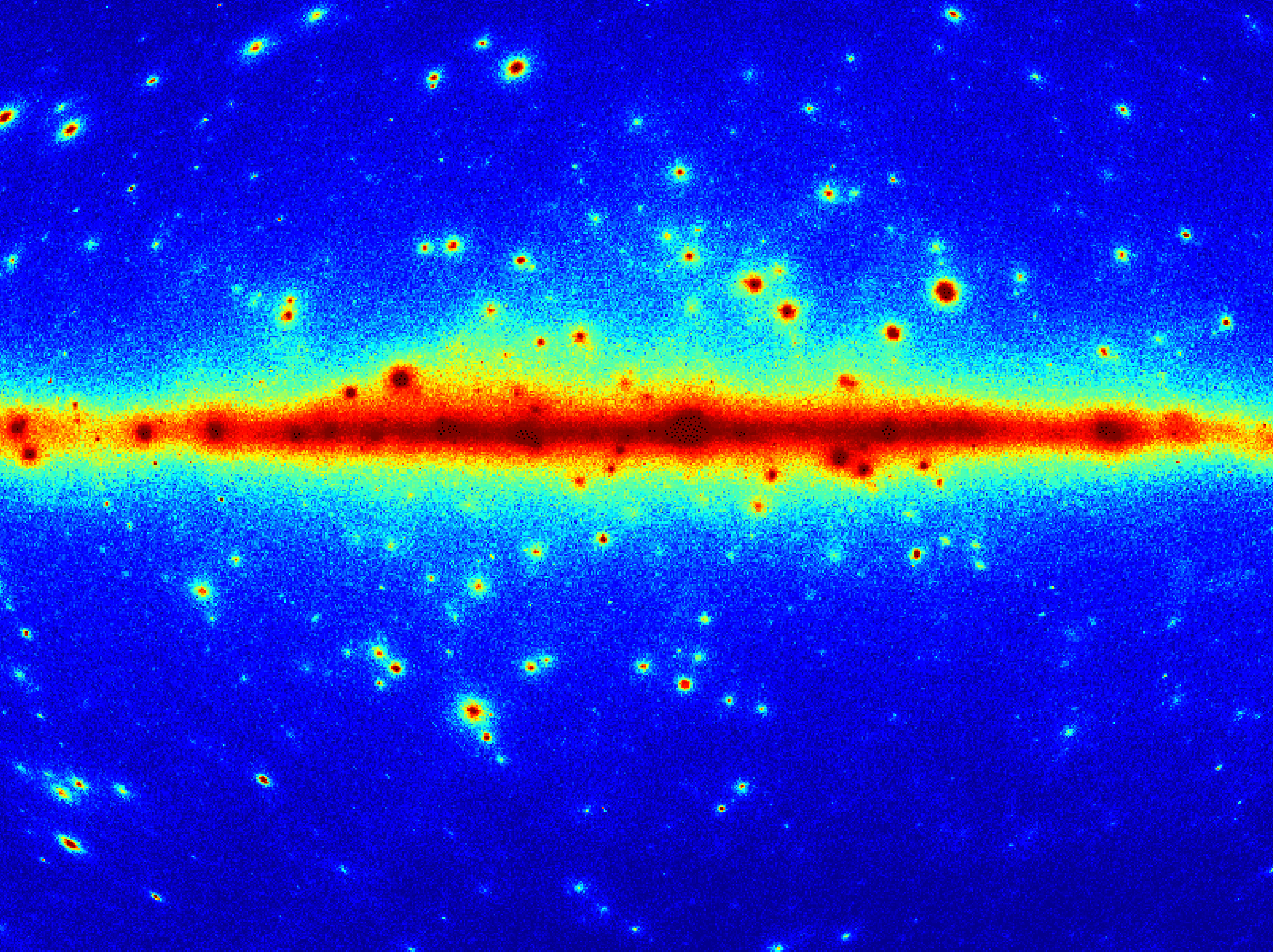
- (Re)Activation of XRBs = hard state = compact jet.
- LOFAR = a much more sensitive ASM.
  - E.g.: RXTE ASM 1 c/s ~ 1 mJy compact jet based on the radio/X-ray correlation that is observed in the associated hard X-ray state
  - LOFAR RSM at 200 MHz has a 12 hr sensitivity of ~40 μJy (25x more sensitive than RXTE/ASM).
- + arcsec position can be delivered quickly
- Radio observations can now be the trigger for X-ray observations (contrary to the past !). Physics under extreme conditions (gravity, pressure, density)
- Serendipitous discoveries !!!
- Will there be any other “ASM” at the same time ?

Synergy with the new forthcoming high energy observatory: GLAST



- Large energy range: LAT (20 MeV-300 GeV). GBM (10 keV – 25 MeV)
- Huge FOV:
  - LAT: 20% of the sky at any instant. All accessible sky observed 30 mn every 3 hr. Galactic Plane always visible every day.
  - GBM: all accessible sky at any time
- Launch in December 2007

- 30 x more sensitive than previous similar experiment EGRET. 1 day with GLAST is ~similar to the lifetime of EGRET (9 years).
- Better PSF than EGRET → better position (but at best 0.5 to 1 arcmin). Will need contribution from other facilities.
- Similar scientific objectives
- Probing the non-thermal universe (synchrotron vs. comptonization).
- LOFAR and GLAST together is an excellent opportunity !!!



Transient sources in the Galaxy

- Transient ejections: > Jy @ GHz
- However, peak delayed at low freq + impact of expansion losses : peak ~ 5 times lower in LOFAR range + possibility of low freq self absorption (# from Fender's memo):
  - Detection of initial event at 100s MHz will require the ability to detect a source as weak as 0.15 mJy (worst case for a BH). Feasible for the bright (> 0.5 Crab) transients (1 to 3 per year). No pb to get the peak flux few days later.
  - Ability to detect the peak flux of fainter transients: 12 hr rms of ~ 40 μJy → faint transients with peak flux of 10 mCrab. Up to 10 more sources.

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- Radio emission from a new <u>bright transient</u> will likely be detected at onset and for sure during the peak.
- Possibility to detect <u>fainter transients</u>: only detected several days after activation during the peak. Very rapid detection not possible (with exception if the event is initially opt thin). Pb of the buffer memory ??
- 1 to 15 transient to monitored by LOFAR
- Possibility to first detect radio transient in M31

Searching for microblazar

- Microquasar with a jet pointing towards the observer.
- One possible explanation for the nature of ULX ? But not only, c.f. there should be some Galactic microblazars too !
- $\Delta t\ \alpha\ 1/2\gamma^2$ and $I\ \alpha\ 8\gamma^3$: If $\gamma = 5$, $\Theta < 10^o \Rightarrow \Delta t < 1/50$ and $\Delta I > 10^3$: Fast and intense variation of radio flux density: need a RASM such as LOFAR.
- + Possibility of associated γ-ray inverse compton emission if intense external radiation field density (such as a massive donor star).

Scientific interest for low frequency radio obs

- Very rare observations in this range
- Simultaneous observations at low and high frequency of an ejection event: → compare decay rates: radiative or expansion losses ?
- Extent of the non-thermal electron spectrum: $N(E)dE \alpha E^{-p}$ with p ~2: γ_e ~ 150 @ 5 GHz → γ_e ~ 25 @ 150 MHz. Energetics dominated by kinetic energy of cold proton. Determination of minimum γ_e
- Energy deposited in lobes (cf Cyg X-1): KE → U in shock: steep spectrum : many new lobes
- Low freq abs processes (TR or free-free) : B + n_e
- Unique capability to focus “a posteriori” to some specific event (GRB: prompt emission)

LOFAR

Conclusions

- LOFAR is a new unique opportunity:
  - Radio all sky monitor.
  - Synergy with forthcoming GLAST
- Compact jet sources
- Relativistic ejections
  - Alerts for these explosive events
  - Searching for microblazars
- Large scale jets
- see more in following talks