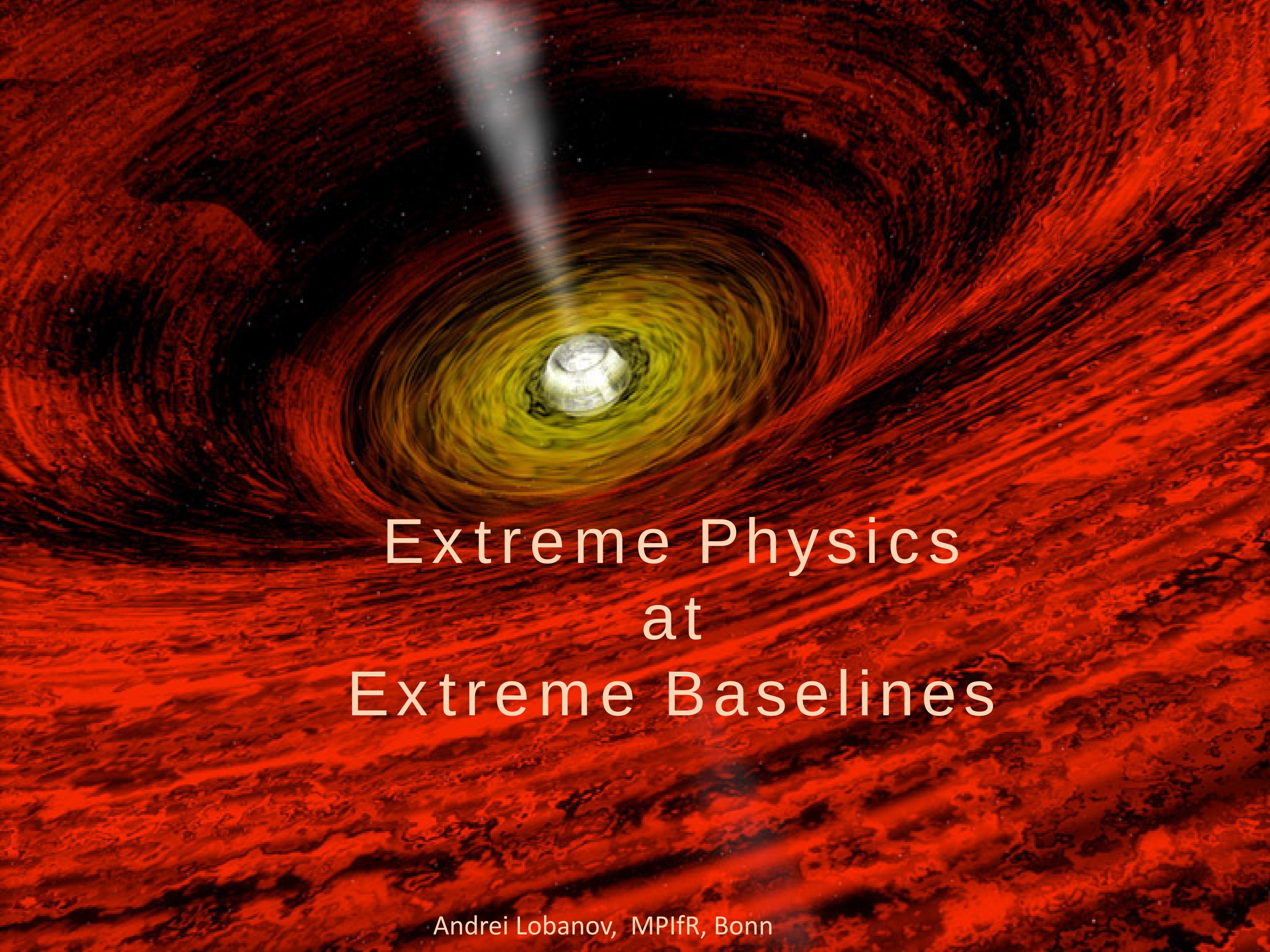

Extreme Physics at Extreme Baselines

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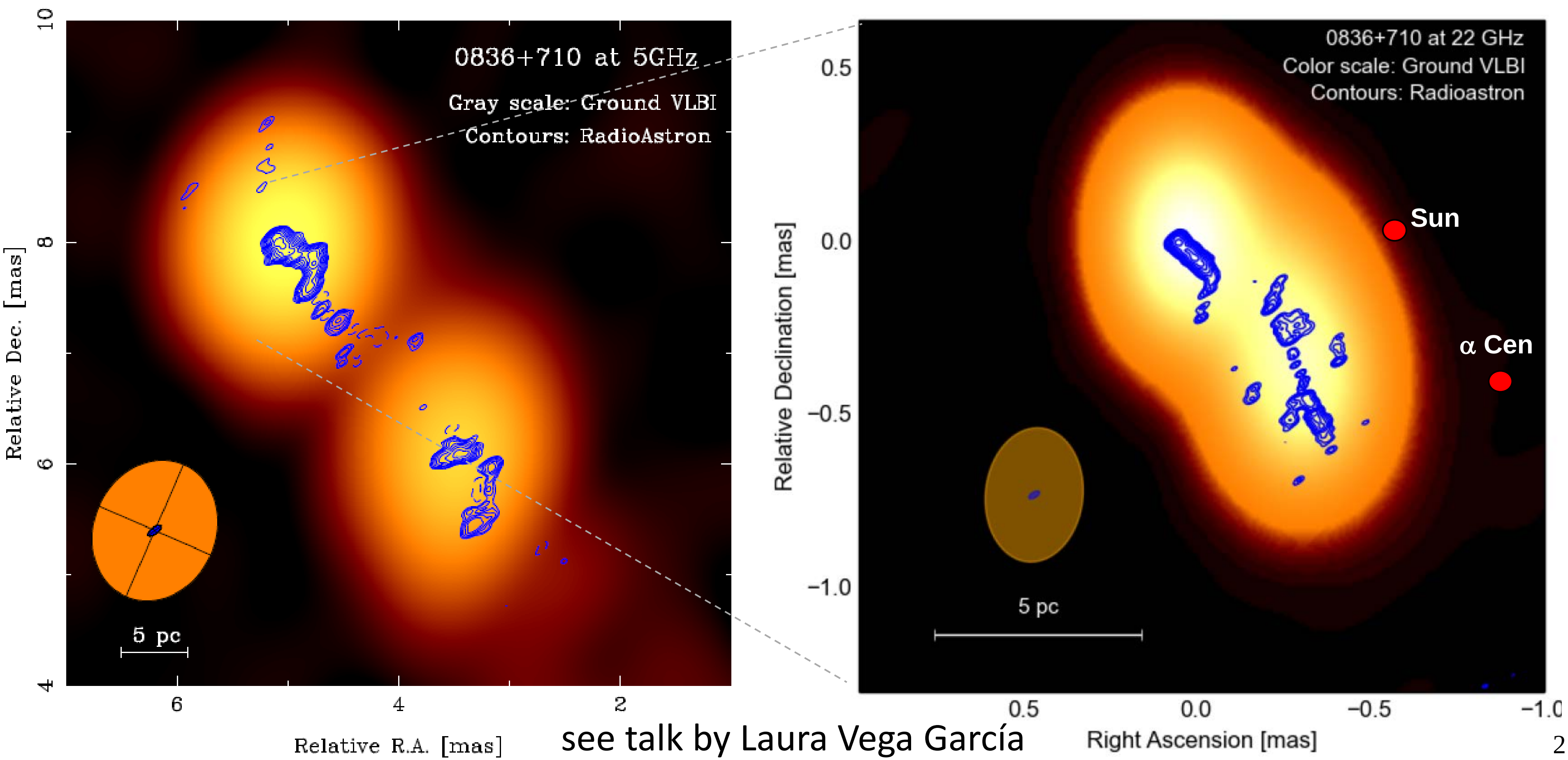
A Step Further with RadioAstron

RadioAstron observations provide a factor of ~10 improvement in angular resolution, revealting the structural detail down to the linear scales below 1000 R_g (and reaching ~10 R_g in close objects). What is the physics there?

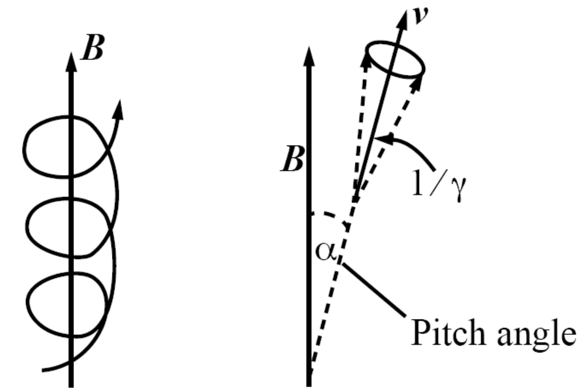


see talk by Laura Vega García

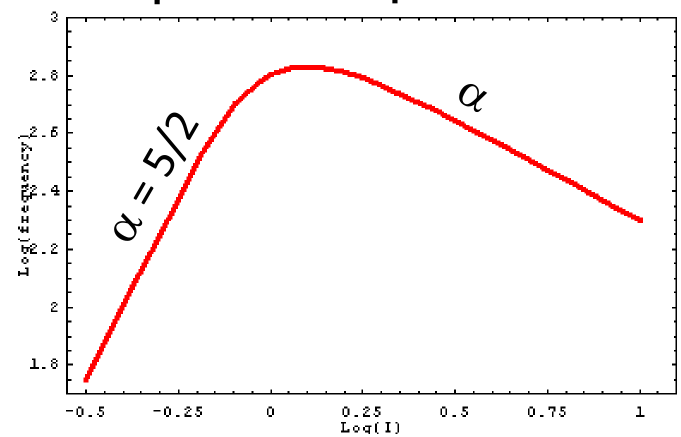
Diagnostics of Synchrotron

- Emission from a single particle:

$$P(\omega) = \frac{\sqrt{3}}{8\pi^2\varepsilon_0 c}\frac{q^3 B\sin\alpha}{m}F(x)$$



- Canonic assumptions: random pitch angle and a power law particle energy distribution $N(\gamma)\mathrm{d}\gamma = N(\gamma_0)\,\gamma^{-s}\mathrm{d}\gamma$



- Maximum brightness temperature set by inverse-Compton losses, with $\boldsymbol{T_{b,C} \cong 5\times 10^{11}\mathrm{K}}$, if $L_{IC} = L_{synch}$ or $u_{ph} = u_B$ (Kellermann & Pauliny-Toth 1969), or by equipartition, with $\boldsymbol{T_{b,e} \cong 5\times 10^{10}\mathrm{K}}$, if $u_p = u_B$ (Readhead 1994).

- Growing number of observations of much higher values of T_b.

Interferometric Measurements

- Interferometry: measuring visibility amplitude, *V*, at a spatial (Fourier) frequency, *q*. Then for a source with

$$T_b = \frac{I_\nu c^2}{2k\,\nu^2} = \frac{S\,\lambda^2}{2k\,\Omega}.$$

-- and a single measurement of *V* on a baseline *B*,
-- with the proxies $S \rightarrow V$ and $\theta \rightarrow 1/q$ $(\Omega \rightarrow {}^{\pi}/_{q^2})$,
-- and recalling that $q = {}^{B}/_{\lambda}$,

one gets

$$T_b = \frac{I_\nu c^2}{2k\,\nu^2} = \frac{V\,B^2}{2\pi\,k}$$

- That is: going to longer baselines is the best way to detect extreme brightness temperatures

Visibility Based Constraints on T_b

- To get to T_b from V_q, need to know V_0
- ... or use $V_q < V_0$ and $V_q + \sigma_q \leq V_0$ to constrain T_b:
- From $V_q < V_0$, can arrive at the minimum T_b supported by V_q

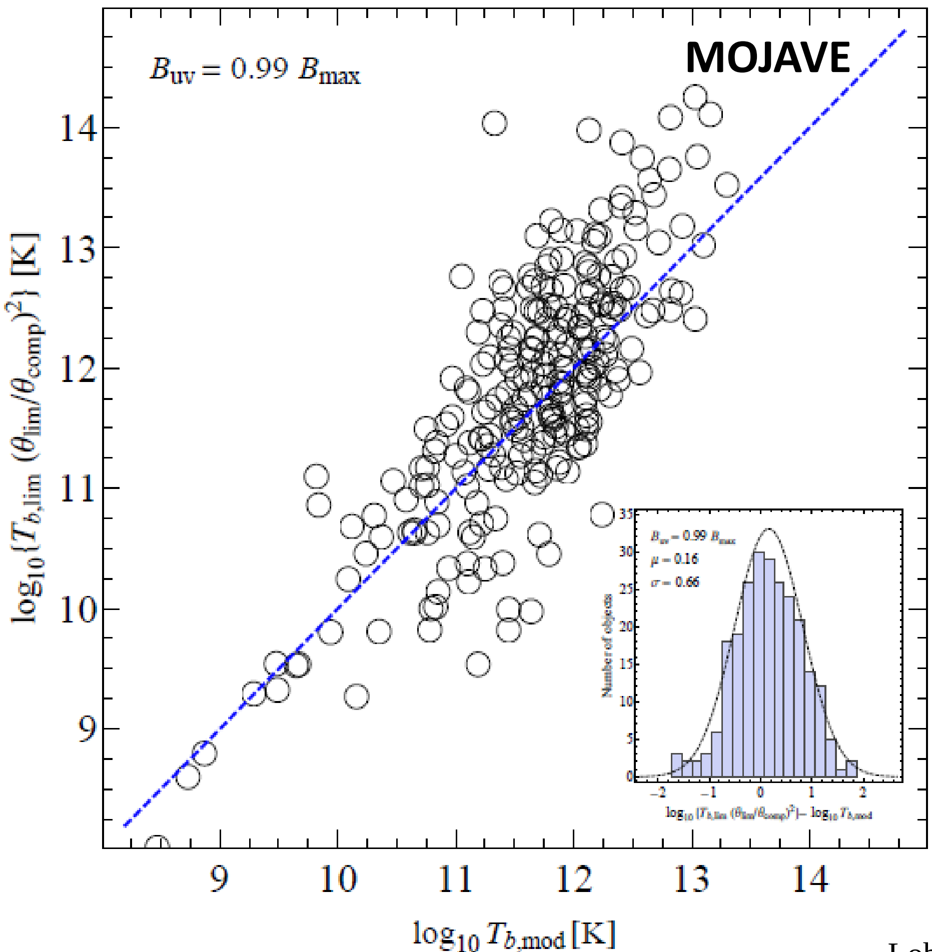
$$T_{\mathrm{b,min}} = \frac{\pi e}{2k} B^2 V_\mathrm{q} \approx 3.09 \left(\frac{B}{\mathrm{km}}\right)^2 \left(\frac{V_\mathrm{q}}{\mathrm{mJy}}\right) [\mathrm{K}]$$

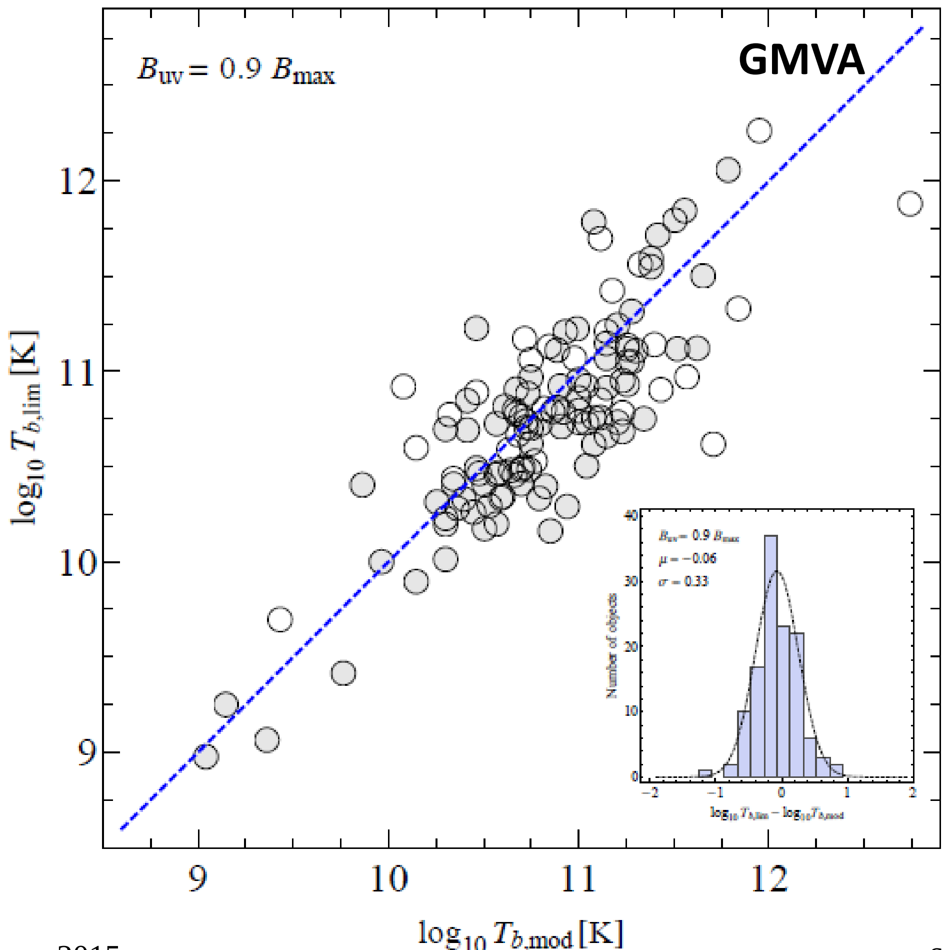
- With $V_q + \sigma_q \leq V_0$, can obtain a limiting T_b for a structure which is resolved at the Fourier spacing q

$$\begin{aligned} T_{\mathrm{b,lim}} &= \frac{\pi B^2 (V_\mathrm{q} + \sigma_\mathrm{q})}{2k} \left[\ln \frac{V_\mathrm{q} + \sigma_\mathrm{q}}{V_\mathrm{q}}\right]^{-1} \\ &= 1.14 \left(\frac{V_\mathrm{q} + \sigma_\mathrm{q}}{\mathrm{mJy}}\right) \left(\frac{B}{\mathrm{km}}\right)^2 \left(\ln \frac{V_\mathrm{q} + \sigma_\mathrm{q}}{V_\mathrm{q}}\right)^{-1} [\mathrm{K}] \end{aligned}$$

Brightness Temperature Runs

- MOJAVE and 3mm GMVA surveys: Can trust to $T_{b,\rm lim}$ to be a good measure. Hence a good tool for RA AGN survey.





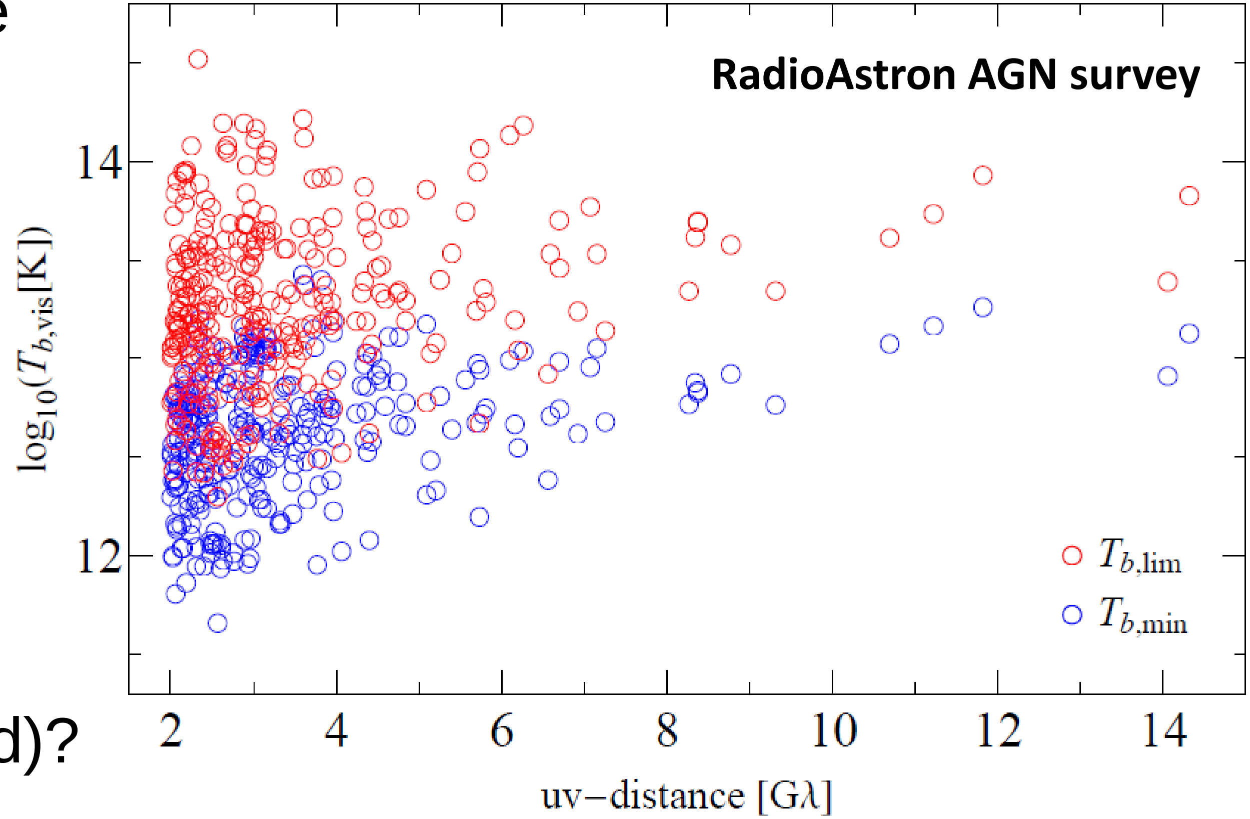
Lobanov 2015

What Do We Get from RadioAstron?

- Most of the AGN imaged/modelfitted with RA show $T_{b,min} \geq 10^{13}$ K and $T_{b,lim} \geq 10^{14}$ K

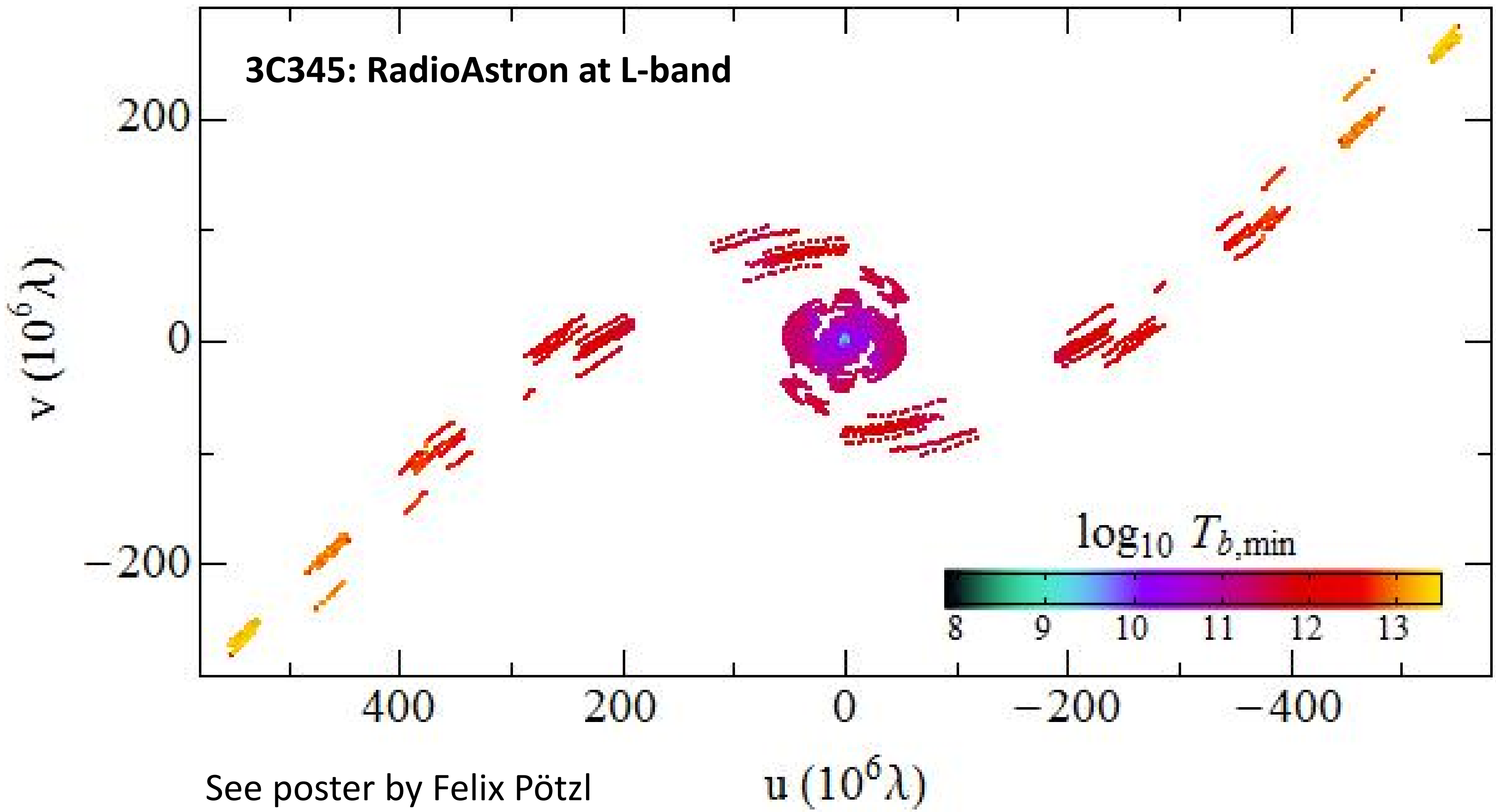
- Similar results are coming from the visibility based estimates made from the RA survey data.

- Should we blame it on Doppler, or believe it (and start to get worried)?



Visibility T_b in the uv-plane

Tells you on which scales the source is the brightest. Perhaps this can be used for modelling the brightness distribution on different scales?



See poster by Felix Pötzl

Multiple T_b components?

2mas

Modelling of combined L,C,K-band RA data on 0836+710 with multiple regions (scales) of constant brightness temperature

Are these the

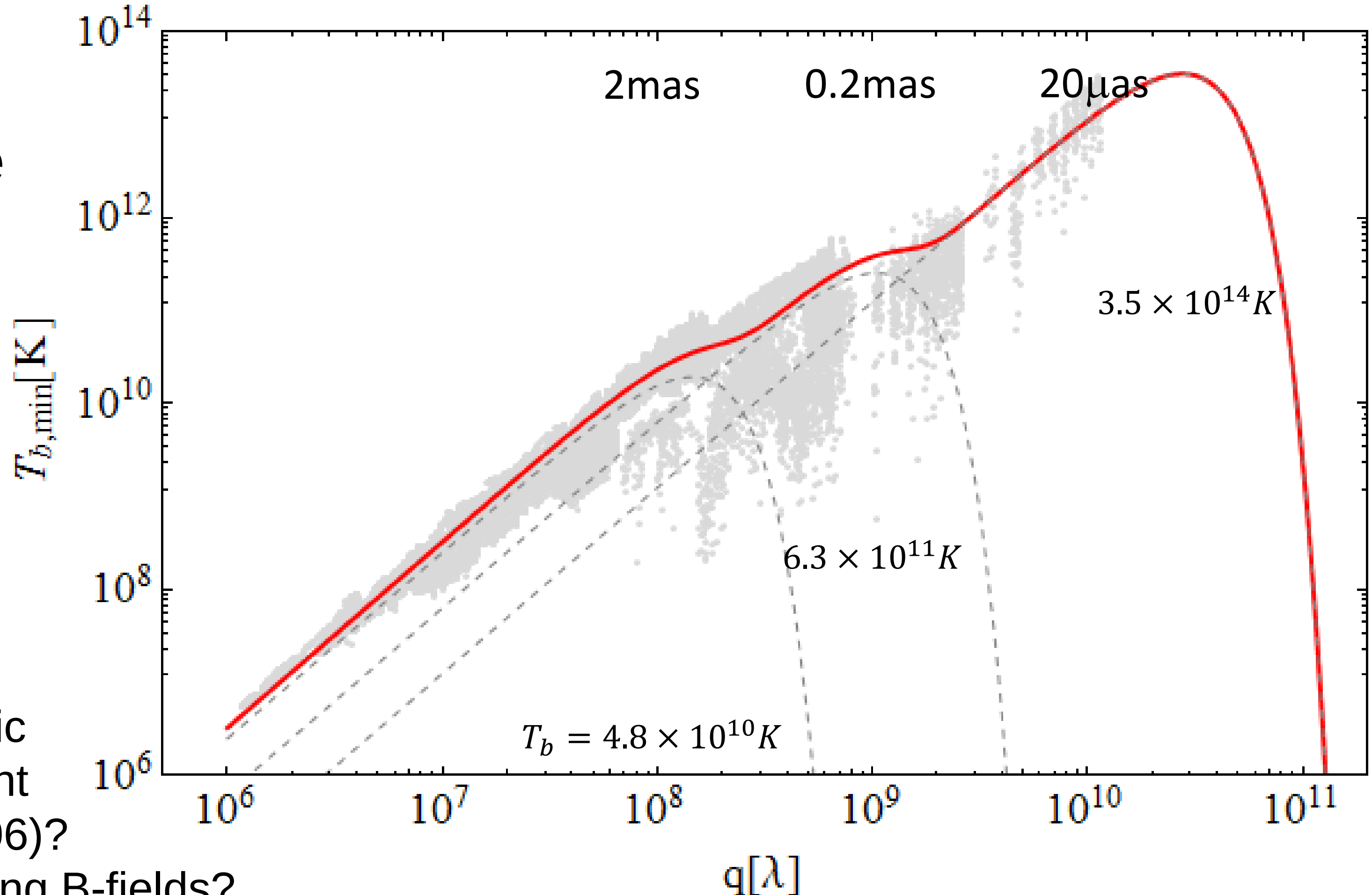
$T_{b,equipartition}$

$T_{b,Compton}$

and

$T_{b,something}$?

-- a monoenergetic plasma component (Tsang & Kirk 2006)? protons? ultrastrong B-fields?



What if You Crank Up the *B*?

- Taking a look at a „normal“ IC-loss dominated plasma in a strong magnetic field gives:

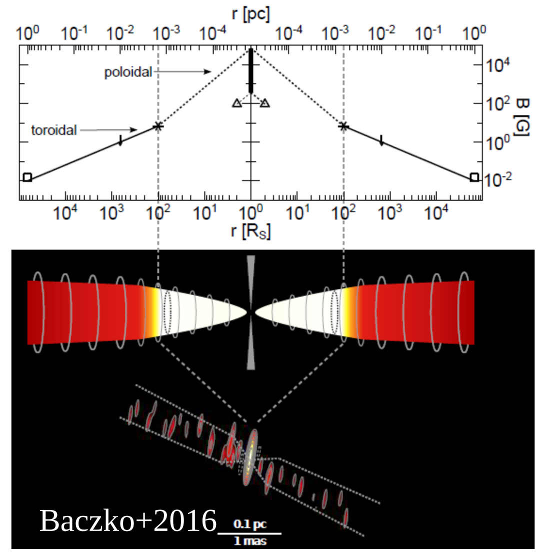
$$T_{b,max} \sim 7 \times 10^9\ \mathrm{K}\ \left(\frac{B^{3/4}}{\mathrm{G}}\right)$$

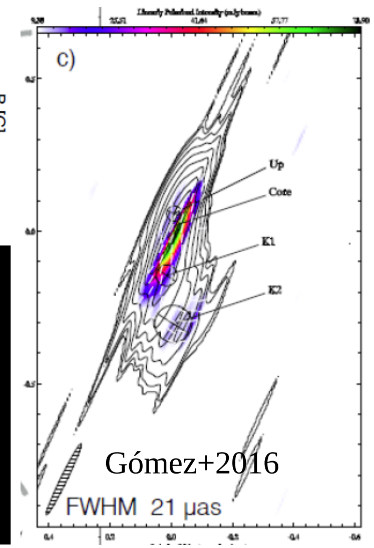
which would indicate $B \cong 10^6 \mathrm{G}$ for $T_b = 3.5 \times 10^{14}$ K.

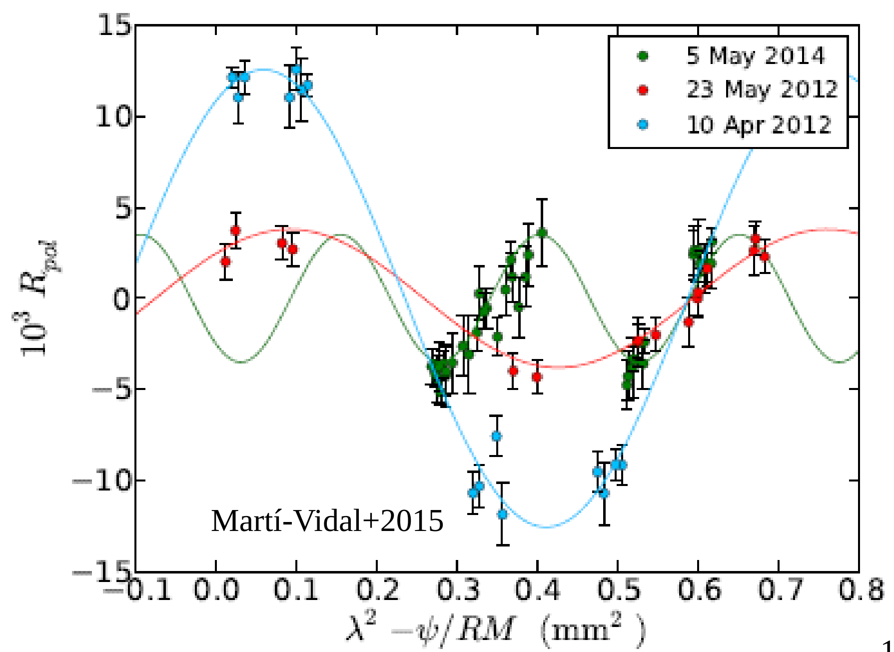
- This, of course, also implies a sky-rocketing $\nu_m \propto B^{1/2}$.
- However, the rogue ν_m can be kept low if the plasma particle density $N_0 \propto B^{-7/2}$.
- This is actualy pretty feasible for:
  – a „runaway“ cell in a turbulent flow;
  – a BZ beam inside of BP jet;
  – a truly „indigenous“ pair creation (for $B > 10^{13}$ G)

Where Else Can Those B-fields Hide?

- In the collimation profiles of inner jet (NGC1052, Baczko+2016) $B > 10^4$ G
- In extremely well structured polarization (Gómez+2016), pointing towards a radial B-field.
- In extreme opacity profiles (e.g. IC 310, Schulz+2016), $B > 10^4$ G
- In extremely high rotation measures (Martí-Vidal+ 2015), RM > 10^8 rad/m^2







Summary

- RadioAstron really detects brightness temperatures in excess of 10^{13} K and likely even larger than 10^{14} K.
- These detections suggest potential emergence of new physics in the immediate vicinity the event horizon.
- A viable possibility for having $B > 10^6$ G on these scales.
- Good evidence for $B \sim 10^3$—10^4 G in the nuclear region (Baczko+ 2016).
- Perhaps even stronger fields are implied by RM > 10^8 rad/m^2 measured with ALMA (Marti-Vidal+ 2015).
- The quest for understanding the high T_b and the actual physical conditions near the event horizon scales must therefore continue.