UNIVERSITÉ DE GENÈVE

On the connection between Turbulent Motions and Particle Acceleration in Galaxy Clusters

Using X-ray surface brightness observations to probe turbulence

D. Eckert et al., ApJ, 843, L29 (2017)

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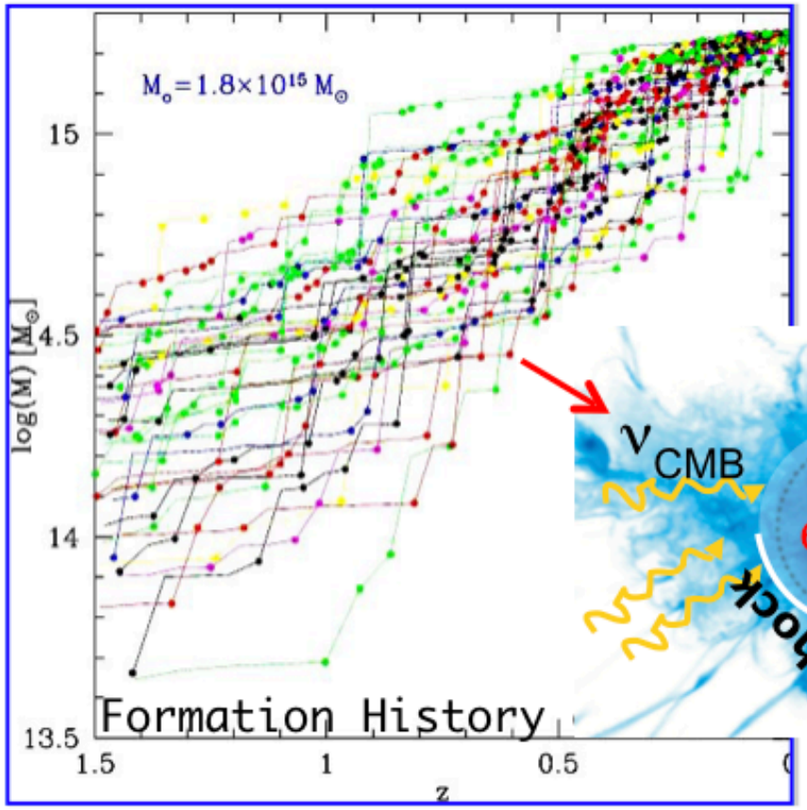
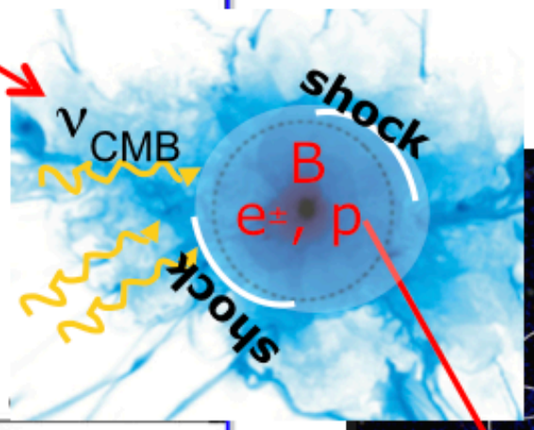
Diffuse Synchrotron Emission in Clusters of Galaxies - What's Next?

Motivation… taken from Rossella

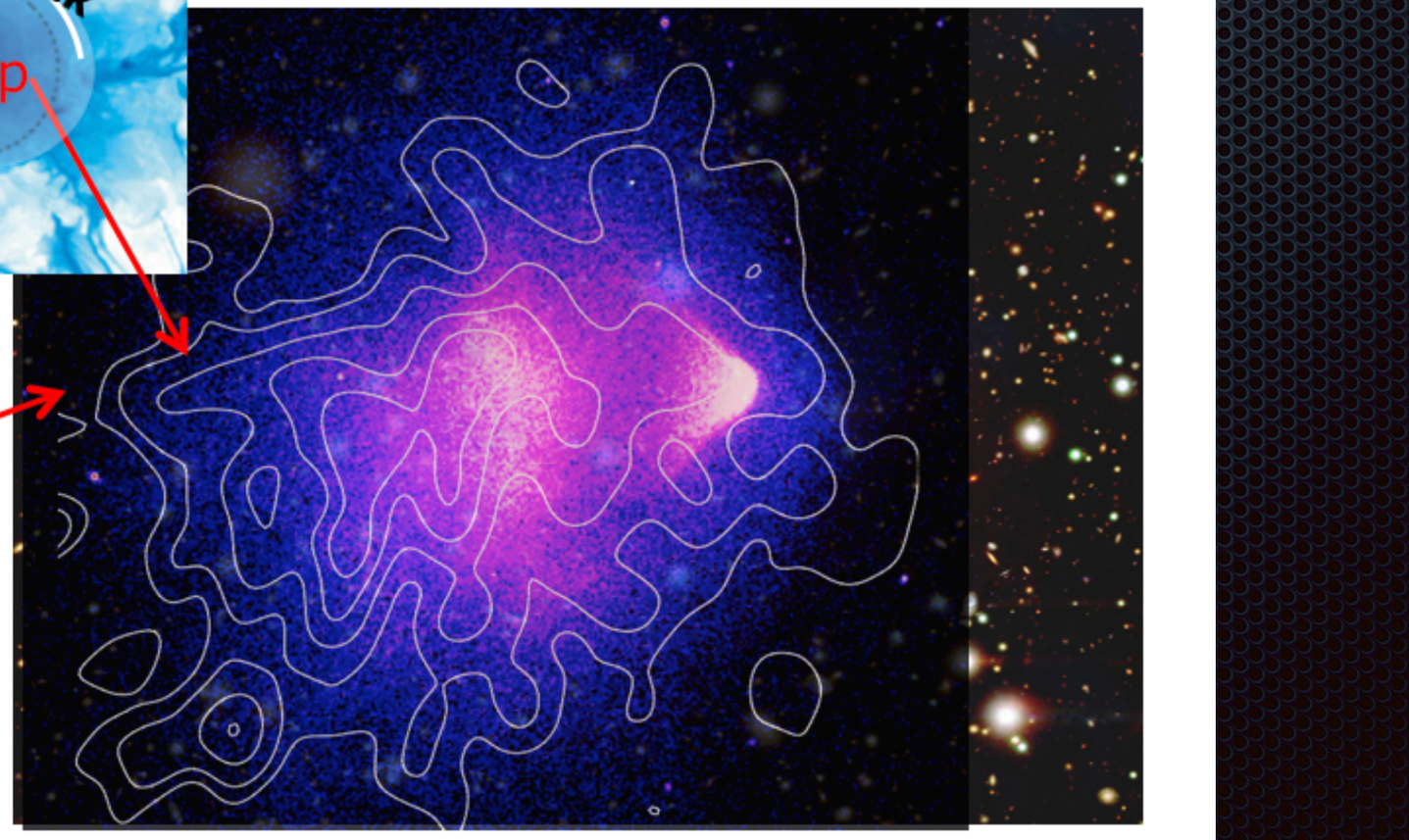
Theoretical (cartoon) picture for GRH in GCs

Brunetti & Jones 14 for a review





- **Giant Radio Halos** are generate in connection with galaxy cluster **mergers**
- Mergers drive **turbulence** and **shocks** in the ICM



Stochastic turbulent re-acceleration of CRe (fossil and secondaries) via Fermi II-type mechanisms generates **Giant Radio Halos (GRH)**

Clowe et al. 06; Markevitch 2010

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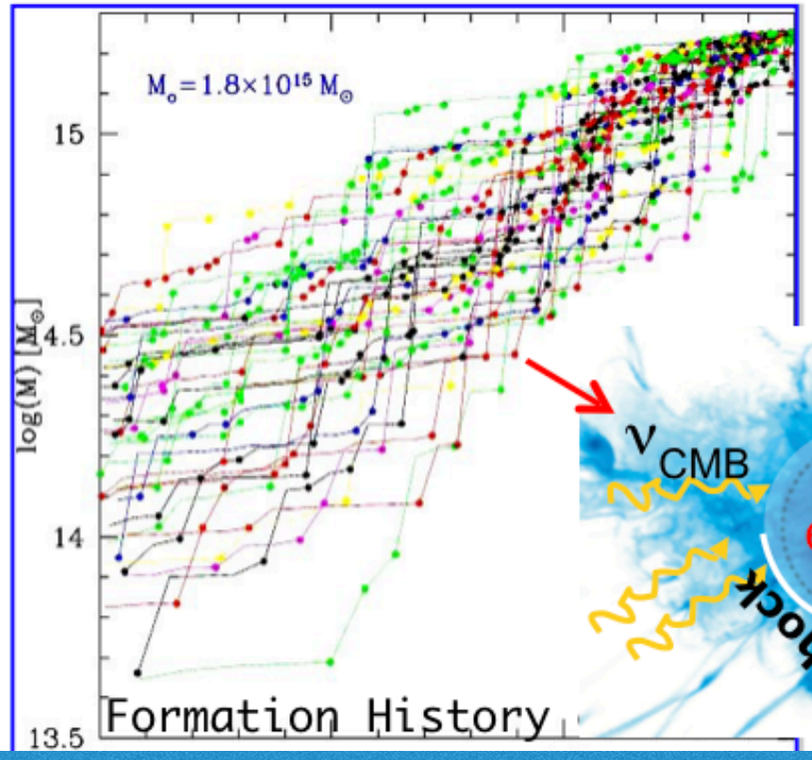

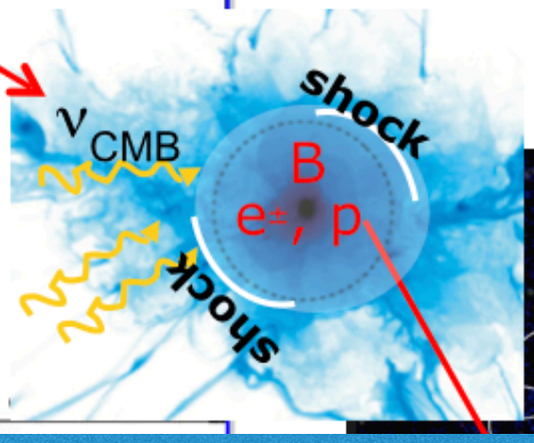

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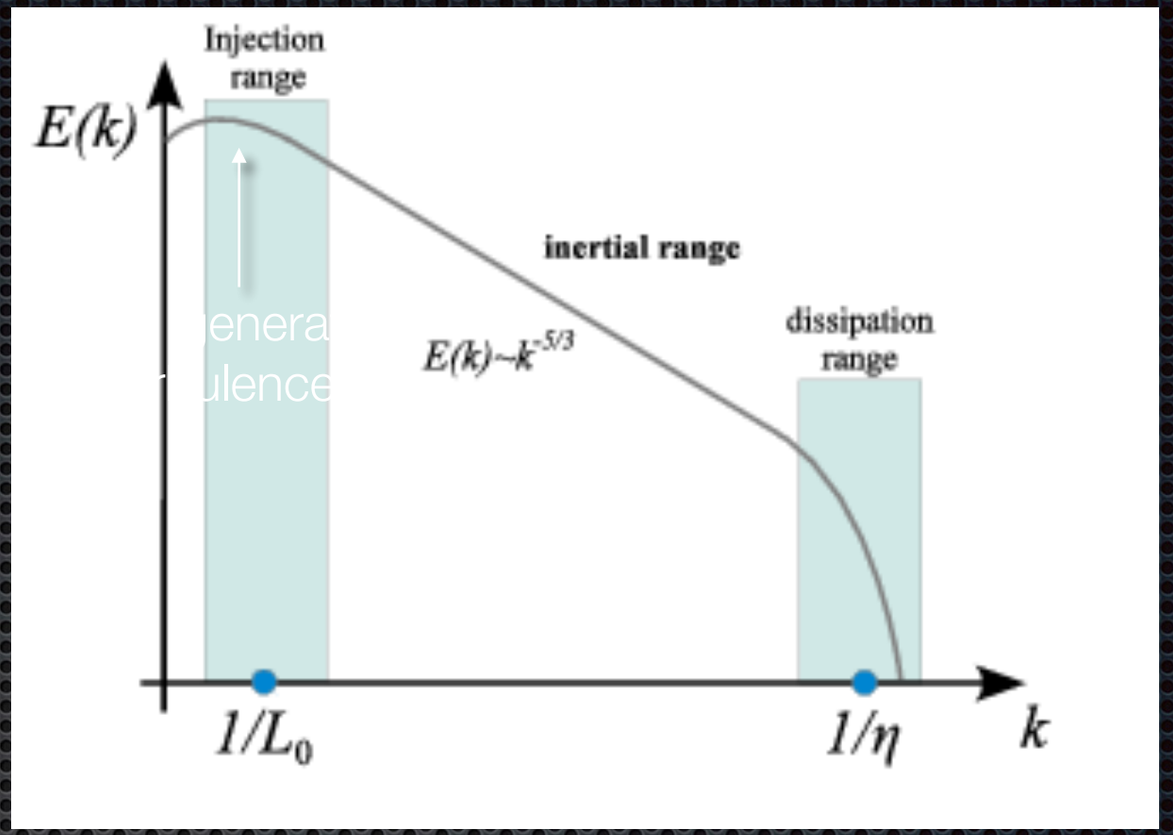
Can we test this directly? - i.e. are turbulence and GRHs connected?

Stochastic turbulent re-acceleration of CRe (fossil and secondaries) via Fermi II-type mechanisms generates **Giant Radio Halos (GRH)**

Clowe et al. 06; Markevitch 2010

Observables

- Radio: $P_{1.4GHz}$
- use X-rays to probe ICM:
  - gas density fluctuations passively trace velocity fluctuations in the ICM (☞Irina's talk)
    - $M_{turb} \sim 4A_{max}$ *Gaspari+2014*
    - reproduces Hitomi measurements (☞Irina's talk)
- **IDEA**: extract amplitude, A_{max}, of $\delta\rho/\rho$ at fixed spatial scale for 1 Mpc region (k^{-1}=660 kpc) and correlate with $P_{1.4GHz}$

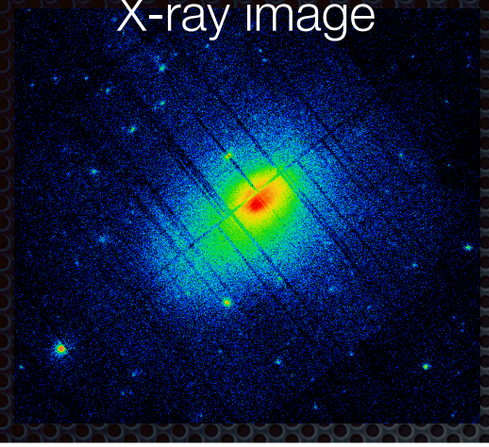


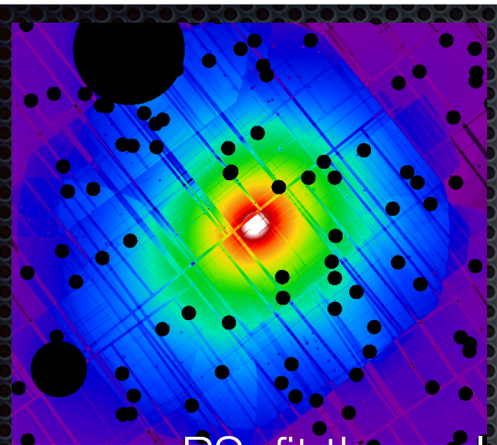
c.f. Zhuravleva+2015, Arévalo+2016, Hofmann+2016, Khatri & Gaspari 2016

How to get A_{max}?

Δ-Variance method by Arévalo+2012

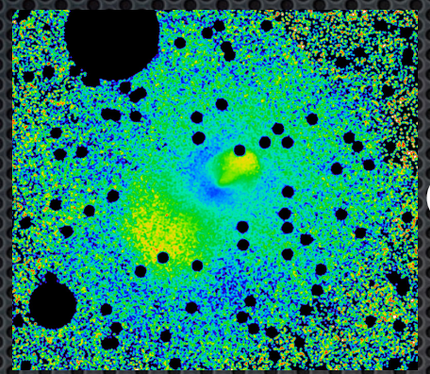
X-ray image



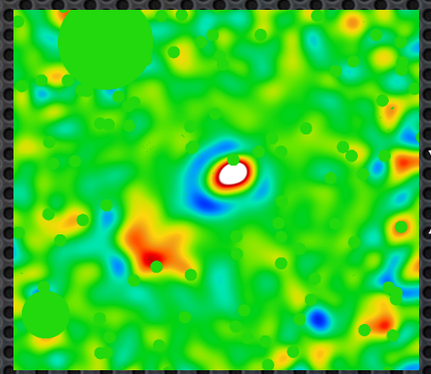


remove PS, fit thermal distribution (β-model)

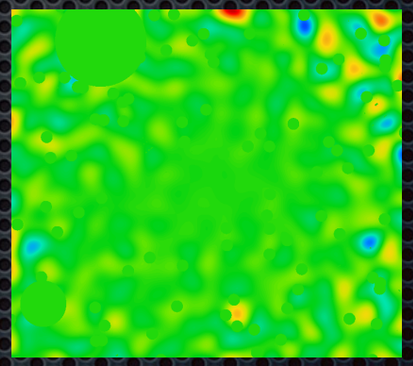
= residual image (exp. corrected)



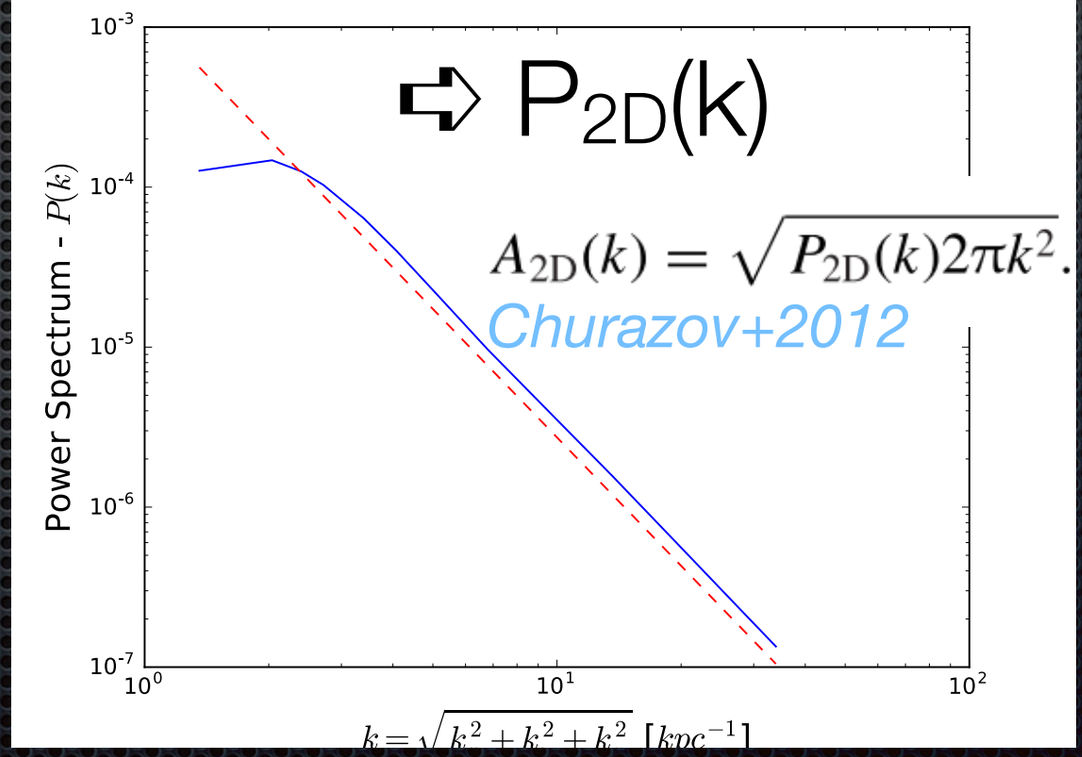
⊗ F(k) = V(filtered image at scale k)



- V(filtered poisson noise at scale k)



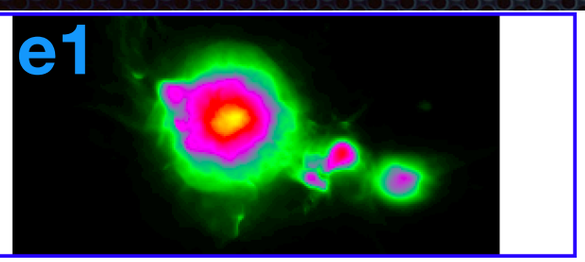
➪ $P_{2D}(k)$

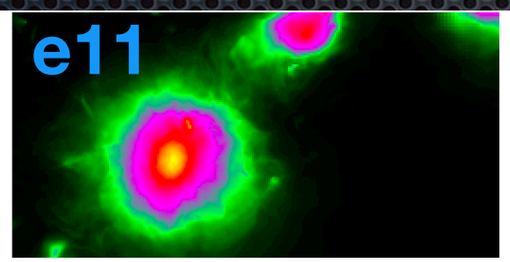


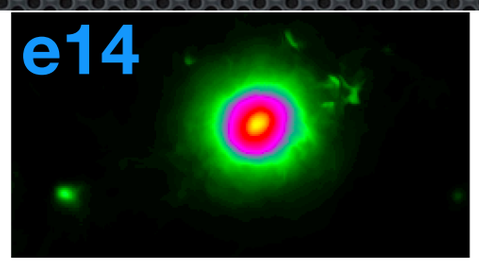
$$A_{2D}(k) = \sqrt{P_{2D}(k) 2\pi k^2}.$$

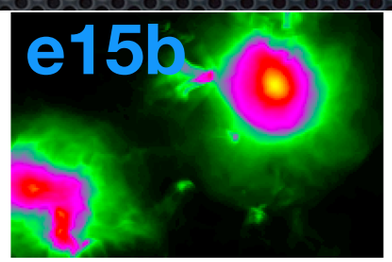
Churazov+2012

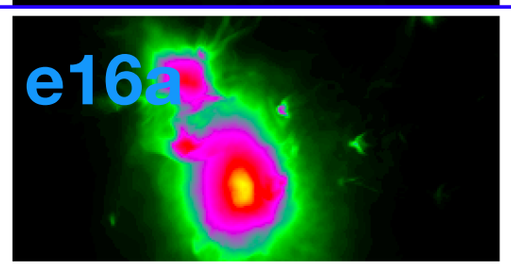
Validation.

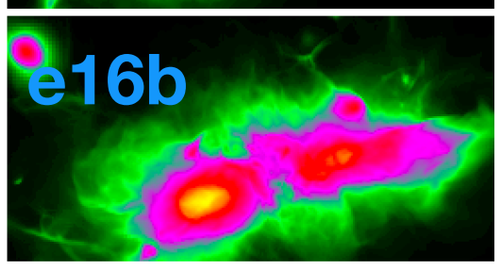


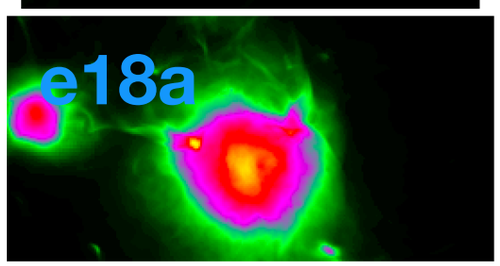


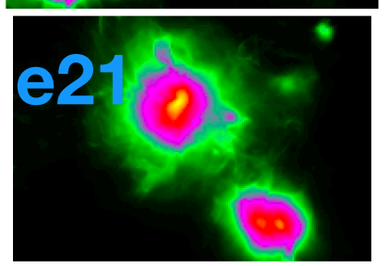


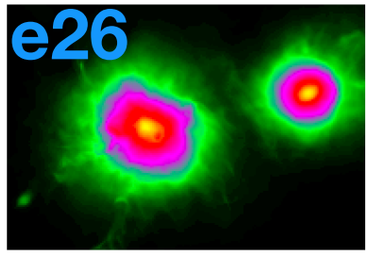


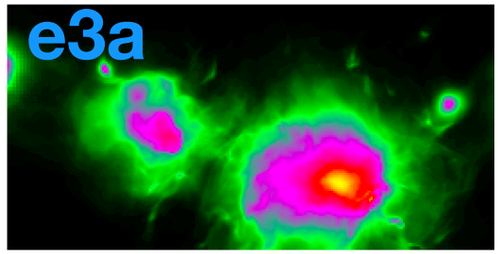


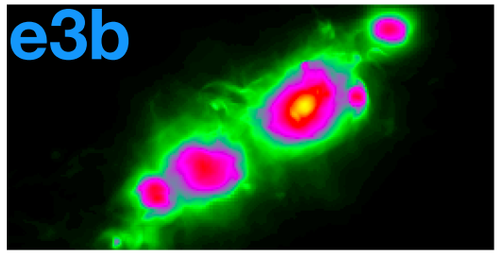


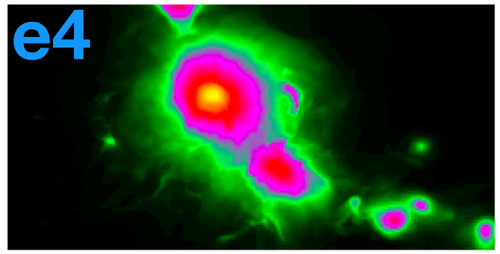


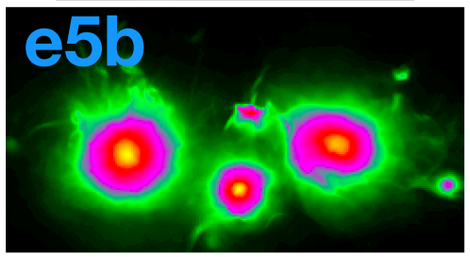


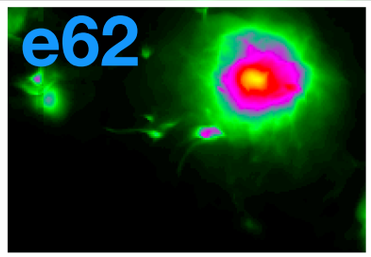


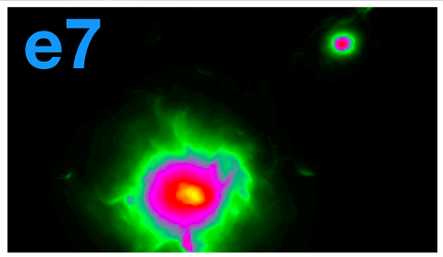






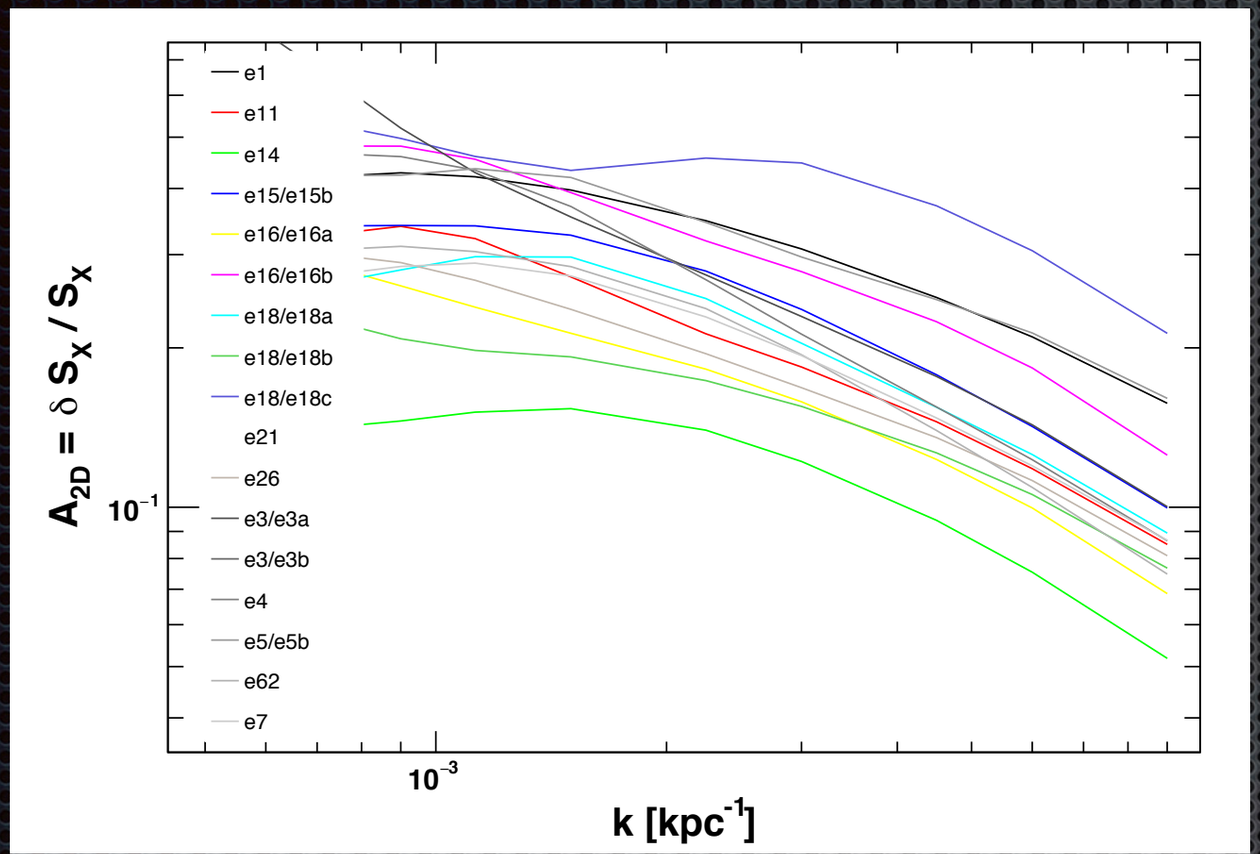


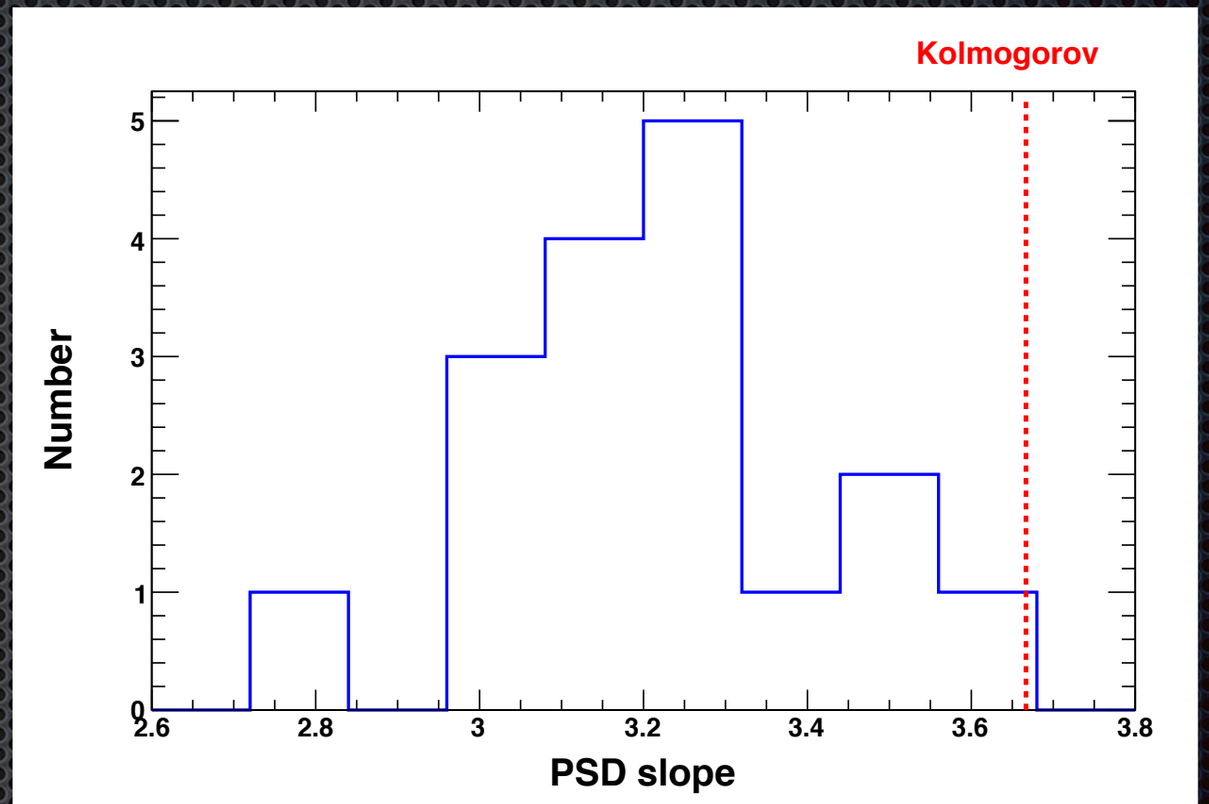




ENZO simulations by Franco, L_X,x

Does it work?





Franco's ENZO simulations

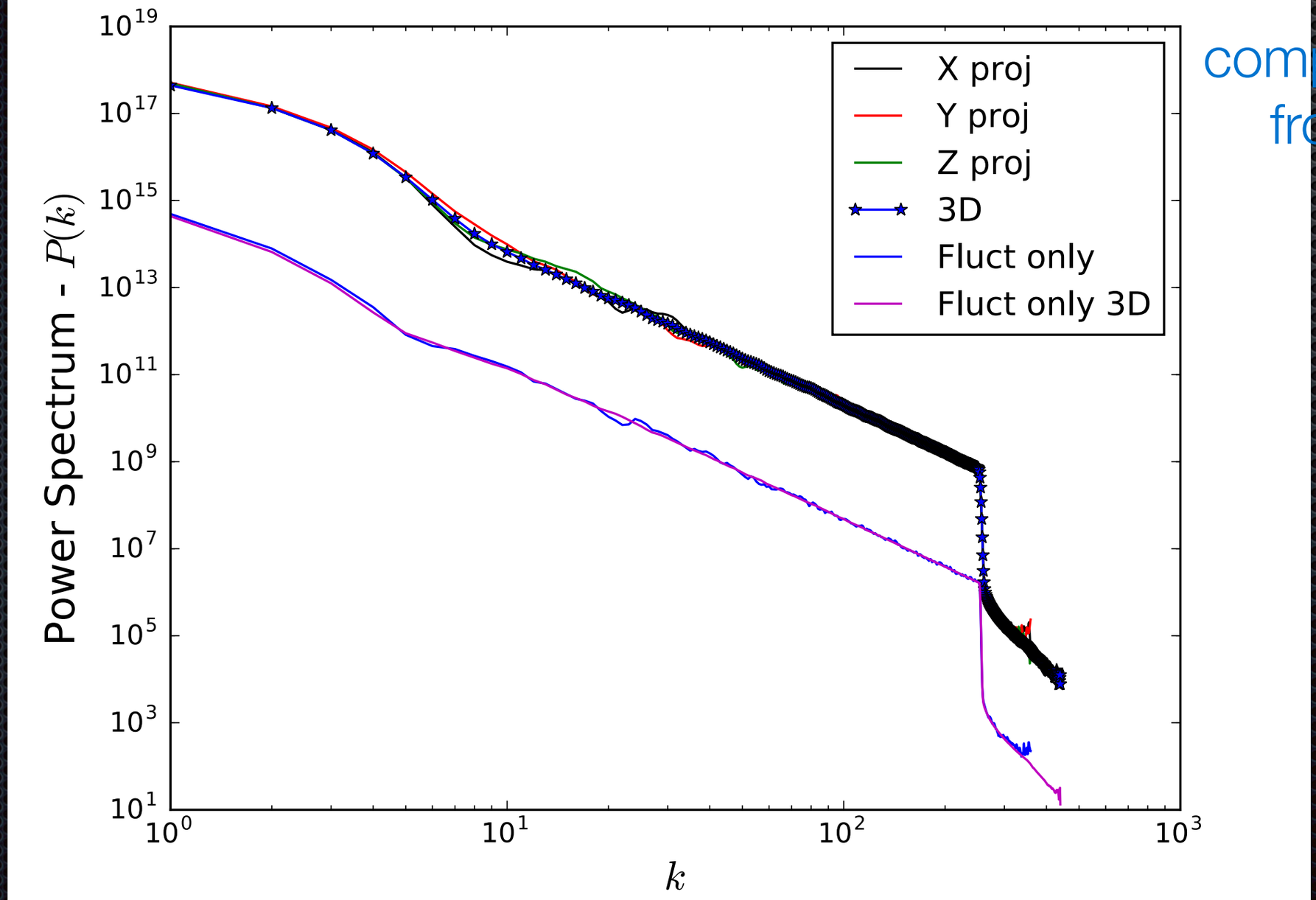
=> normalization varies, but spectral index nearly universal

2D → 3D?

$$P_{2D}(k) \approx 4 P_{3D}(k) \int |W(k_z)|^2 \mathrm{d}k_z$$

Churazov+2012

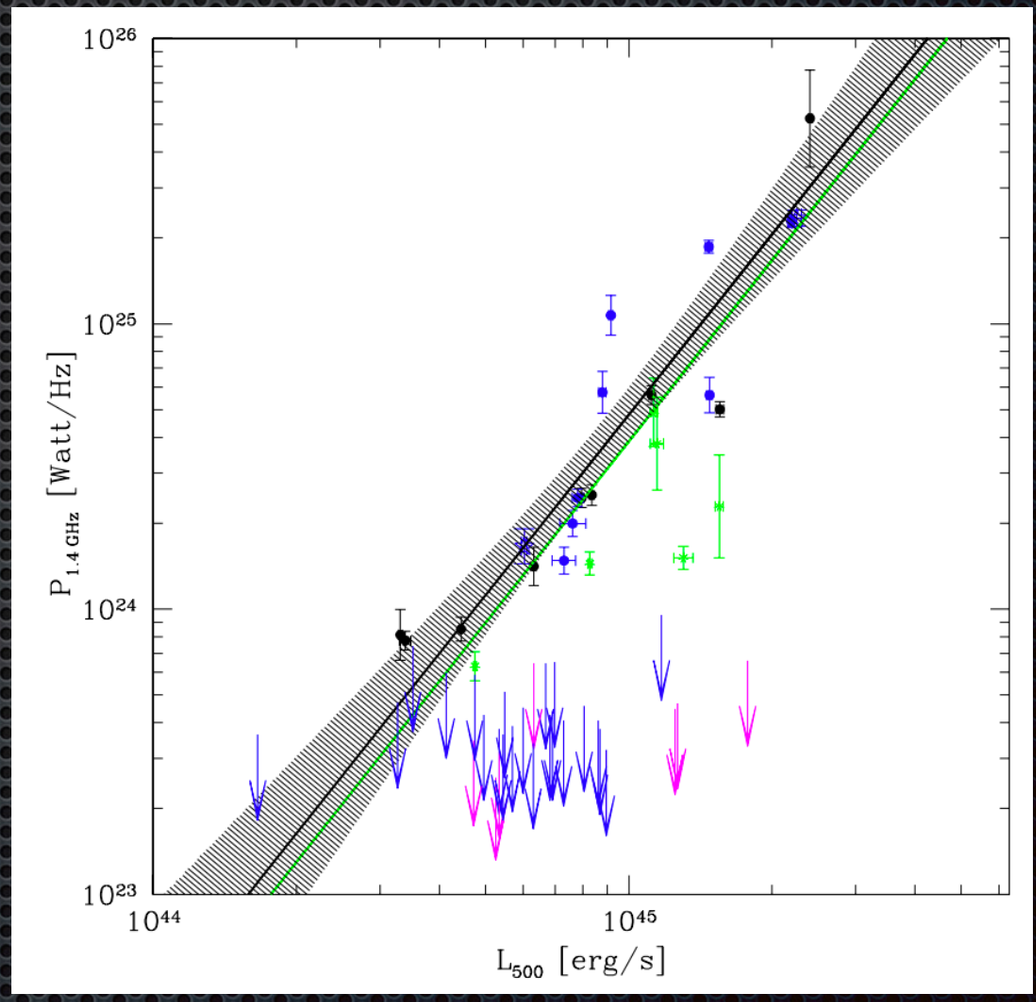
constant, compute numerically from simulation



Sample

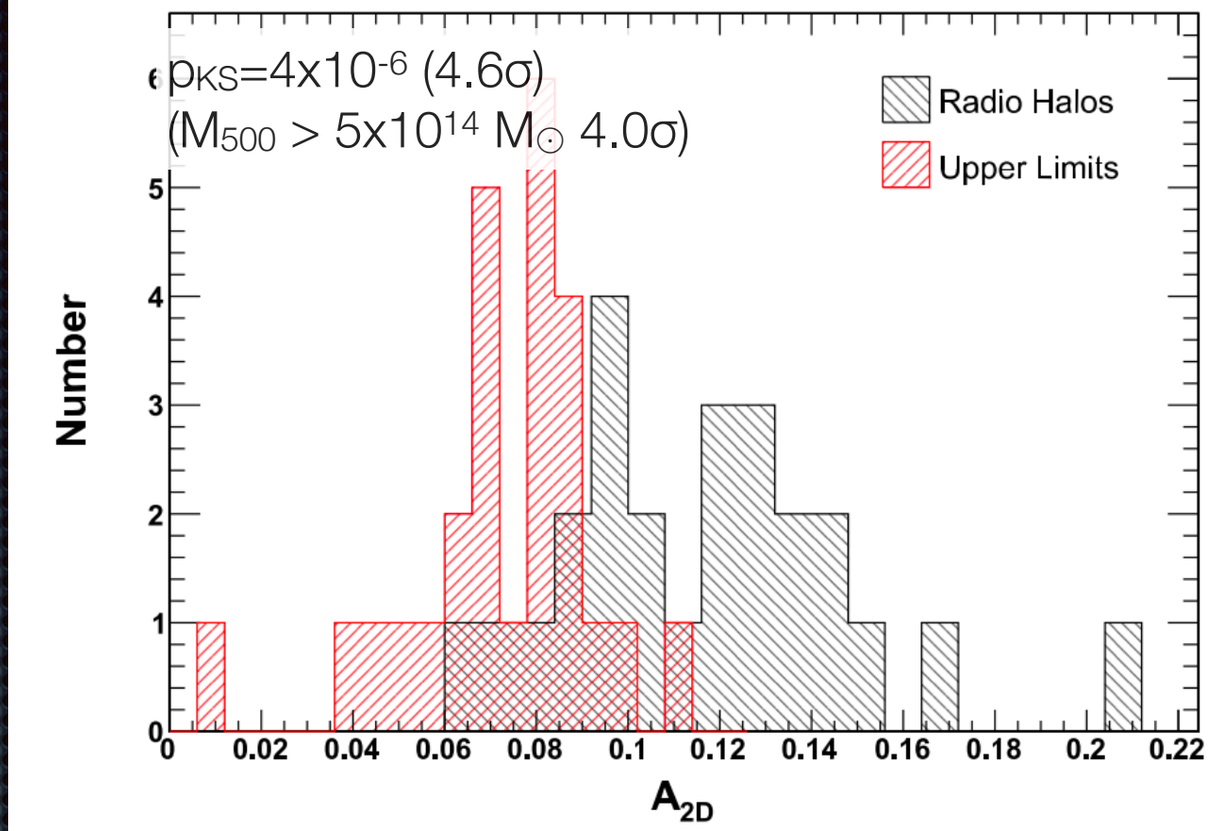
- Cassano+2013 sample (GMRT survey from Tiziana + known GRHs)
- archival X-ray data from ROSAT, XMM & Chandra, sub-sample of 51 clusters (25 w/ GRH, 26 w/o)
  - ROSAT: z<0.1
  - XMM: 0.1 < z < 0.3
  - Chandra: z > 0.3
- use 0.5 - 2 keV band to only capture density fluctuations

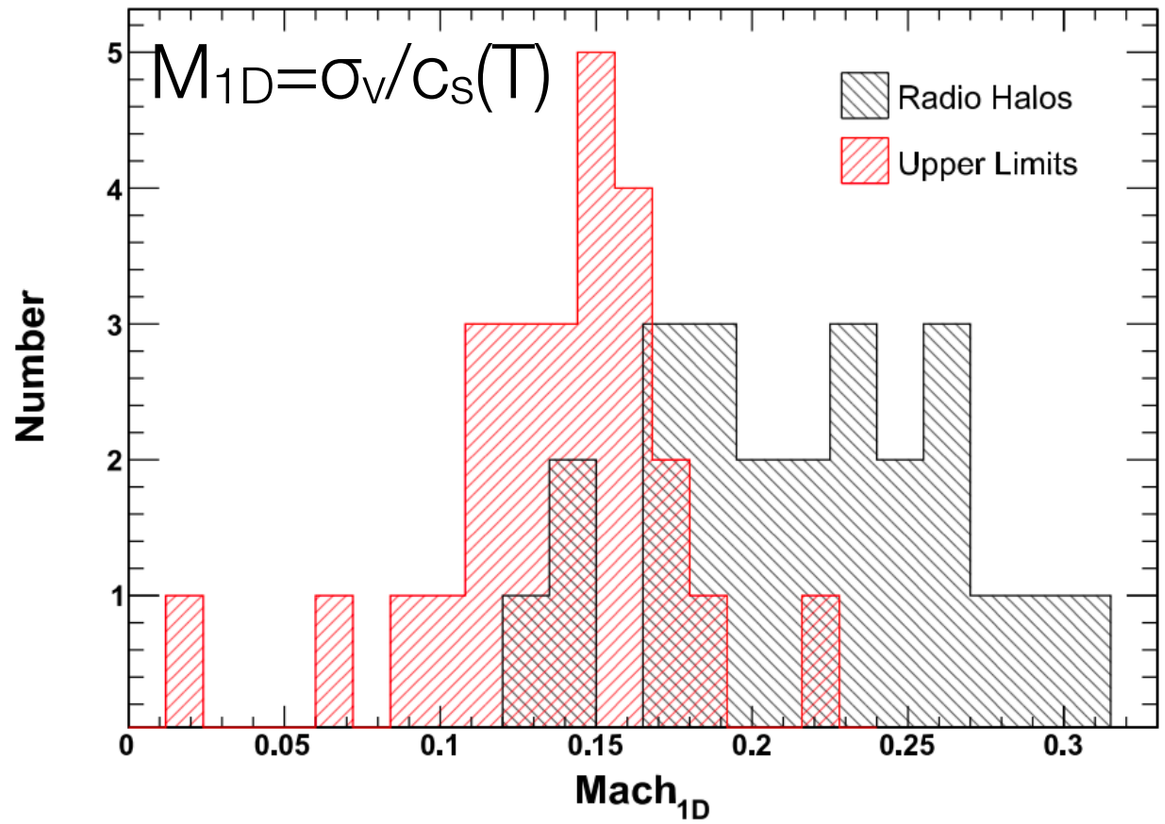
Cassano+2013



Results

➢ **recompute T to calculate c_s**

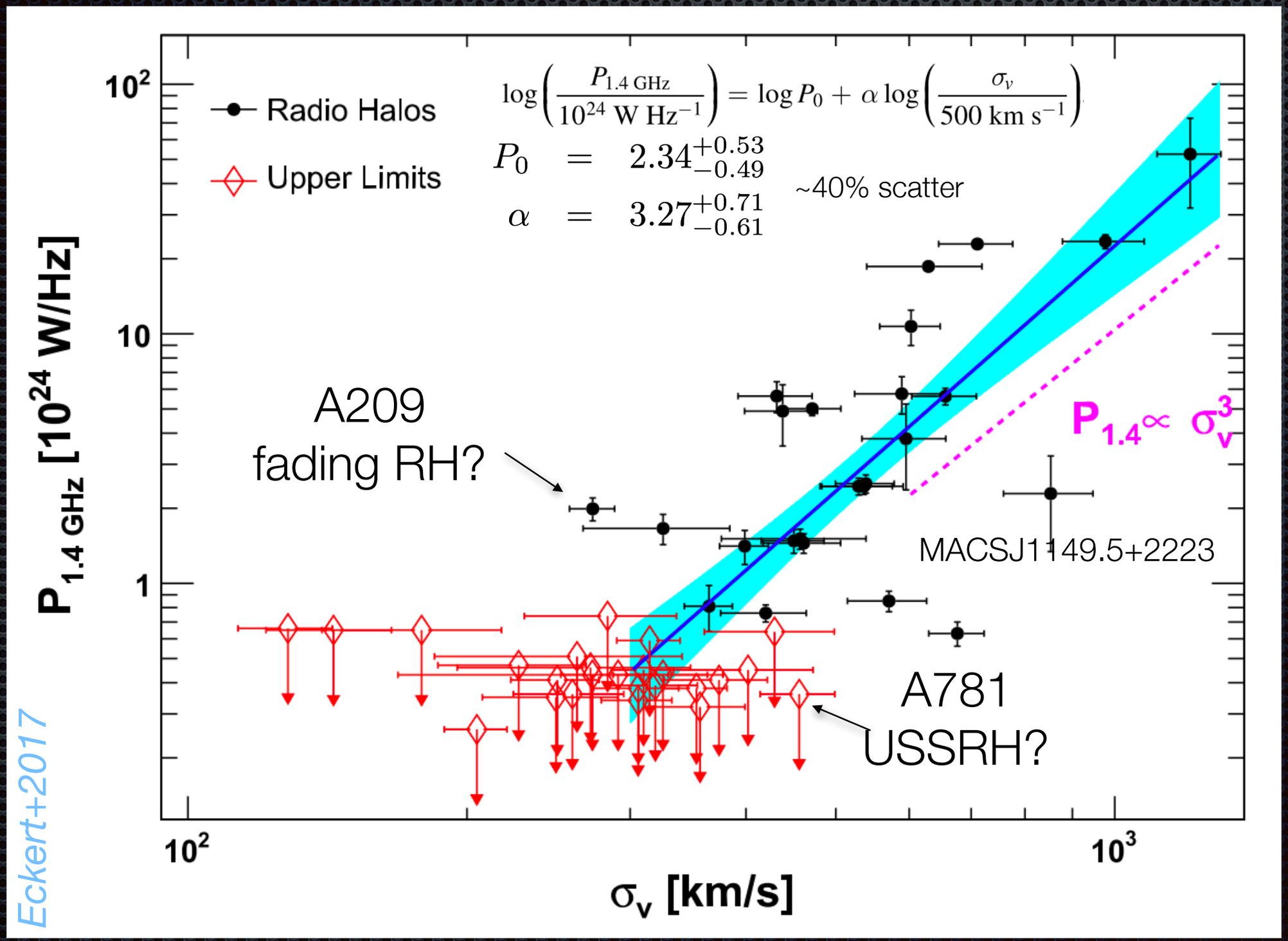




Eckert+2017

Clear separation between GRH & ULs

Correlation with $P_{1.4GHz}$?



Conclusions & Future Work

- observe correlation between turbulent velocity & radio power in clusters with GRHs
- $P_{1.4GHz} \sim \sigma_v^3 \sim P_{turb}$ turbulent energy rate
  - A_{2D} can capture re-acceleration process
    - underlying processes more complex (heating, B-field amplification, accel. of CRe & CRp?)
- results show upper limit, possibly hidden shocks, clumps, AGN that induce power at smaller scales
- future work: limitations of analysis, effect of projection & other samples?

- Thank you! -