VLA/EVLA monitoring of *Planck* sources

Planck Collaboration
presented by Anna Sajina

The scientific results that we present today are the product of the Planck Collaboration, including individuals from more than 50 scientific institutes in Europe, the USA and Canada

Planck is a project of the European Space Agency, with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA) and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

Cross-Calibration of Planck and the EVLA

Planck's calibration on large scales (>> beam size) is now based on the solar-motion dipole (will eventually link to Earth's orbital dipole). This is expected to be accurate to ~0.1%, and details of the beam shape don't matter.

On small scales, including point sources, the beam does matter. The expected accuracy is ~1%.

It is important to check the consistency between the flux densities of Planck detected point sources and ground-based data on the same -- this will both show how close to the expected accuracy we are getting, as well as point out any systematic offsets between different ground/space-based observatories.

Two ground-based programs to check Planck calibration at high ℓ:

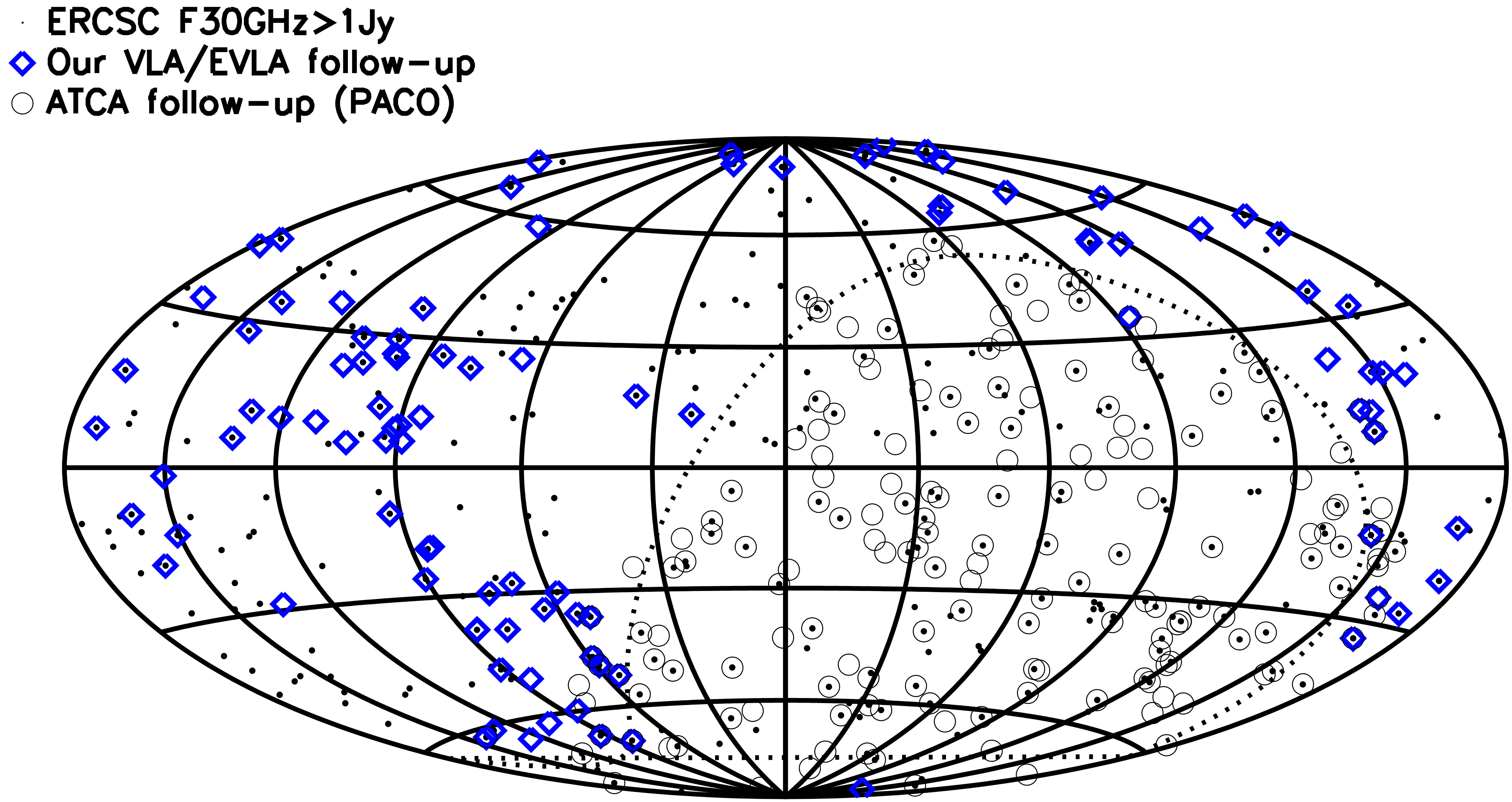
–In the southern hemisphere PACO, using the AT (see talk by Laura Bonavera)

–In the northern hemisphere the VLA/EVLA work presented here

(See P. Giommi’s talk tomorrow to learn more about the blazar physics behind some of the SED properties we see)

VLA/EVLA monitoring of Planck 30GHz sources

- 102 sources selected from the Metsahovi complete northern sample of S37GHz>1Jy sources.
- VLA/EVLA observations at 5,8,22/33, 43GHz
- Typically within 2 weeks of Planck's observations of the same sources
- Observations span July 2009-Dec. 2010 (note extend past the ERCSC!)
- Before comparing the EVLA and Planck/ERCSC flux densities, we apply color corrections to the ERCSC flux densities (based on the 43-33GHz spectral index measured from the EVLA data). We also shift the EVLA data to the nominal Planck bands central wavelengths, using the same spectral indices.



For ERCSC |b|>5, F30>1Jy sources,
>50% of the sources have near-simultaneous ground-based follow-up.

Some background:

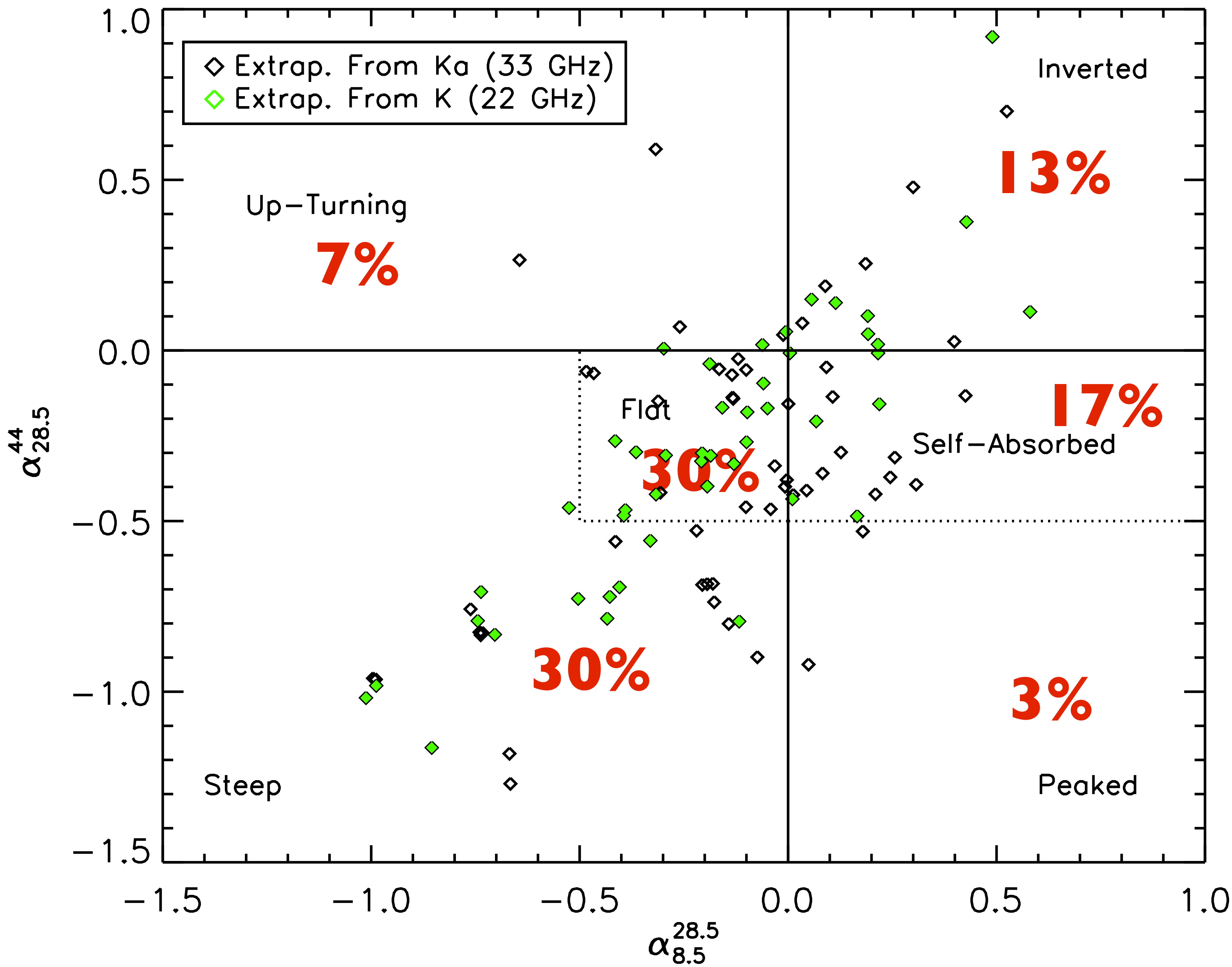
Preliminary results were presented in
Planck early results. XIV. "ERCSC validation and extreme radio sources", 2011, A&A, 536, 14

On the basis of ~20 sources, we found that at 30GHz, Planck flux densities were on average higher than the VLA data suggested by ~8%, and even higher at 44GHz.

This result also mimicked earlier concerns which suggested that the VLA 20GHz scale is too low compared to the ATCA scale (Sajina et al. 2011, ApJ).

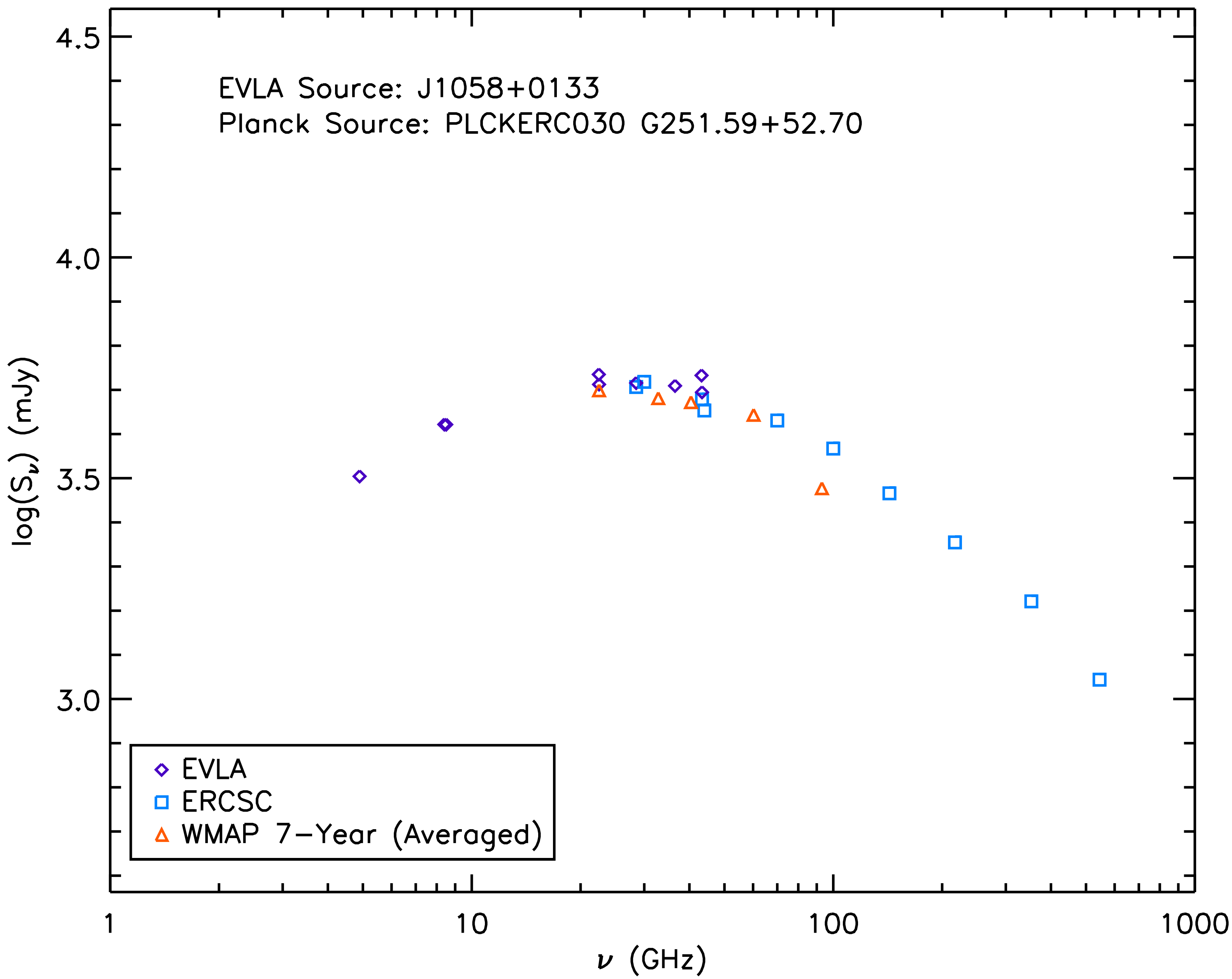
Understanding these offsets is important for both Planck (e.g. differences btw the low-l and high-l calibration can artificially tilt the inferred CMB power spectrum) and for ground-based observers.

The nature of our sources:

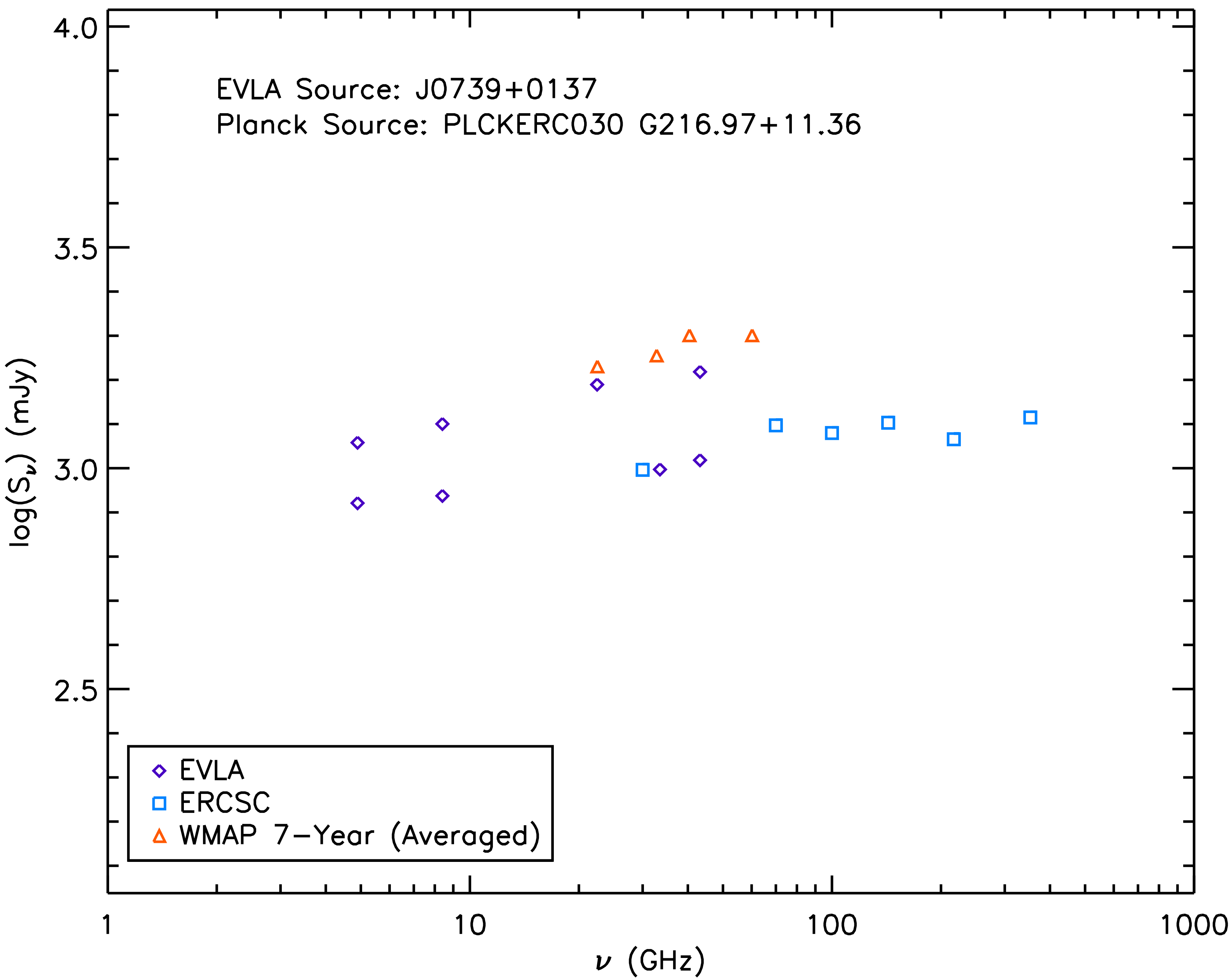


Example peaked SED

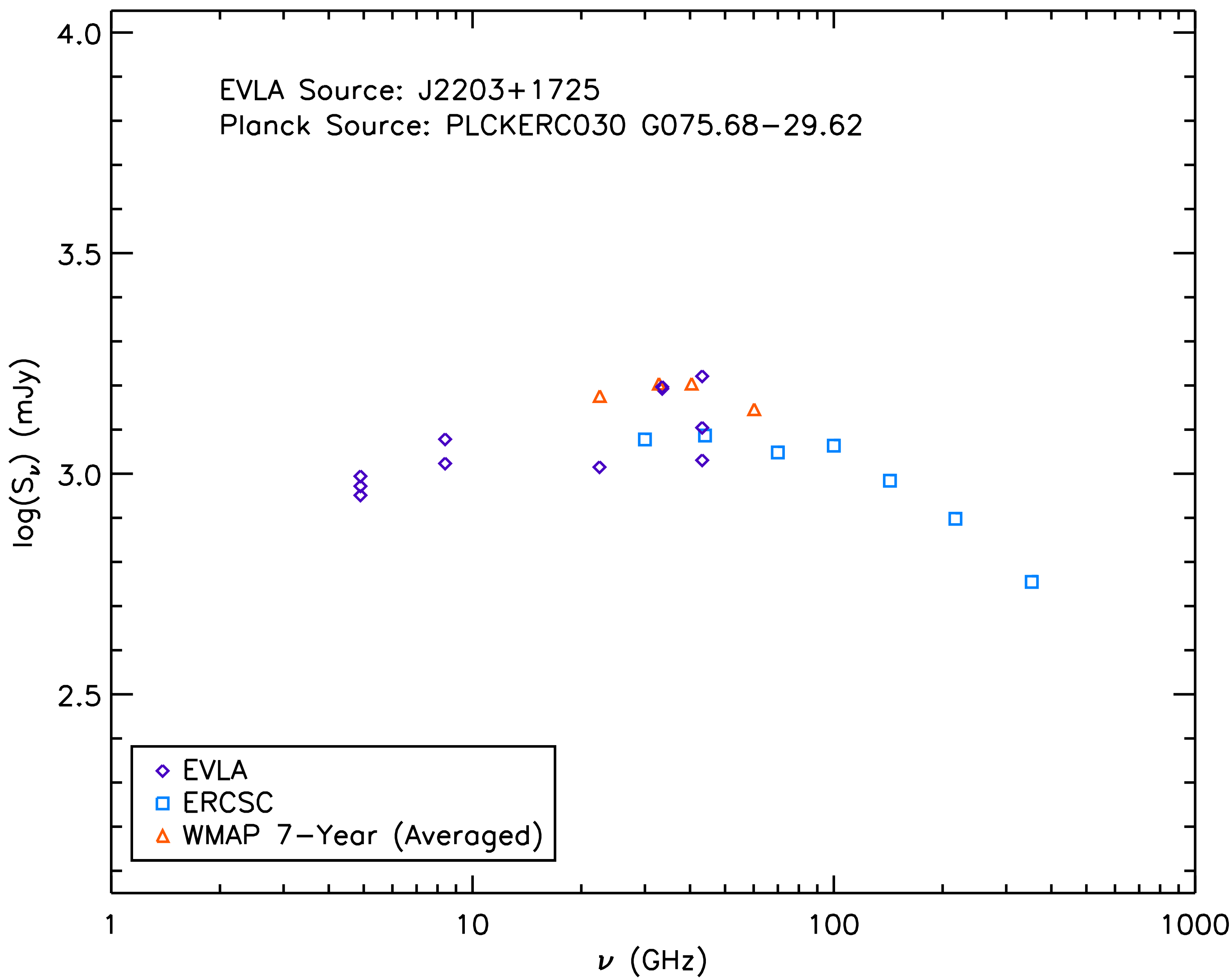
known GPS

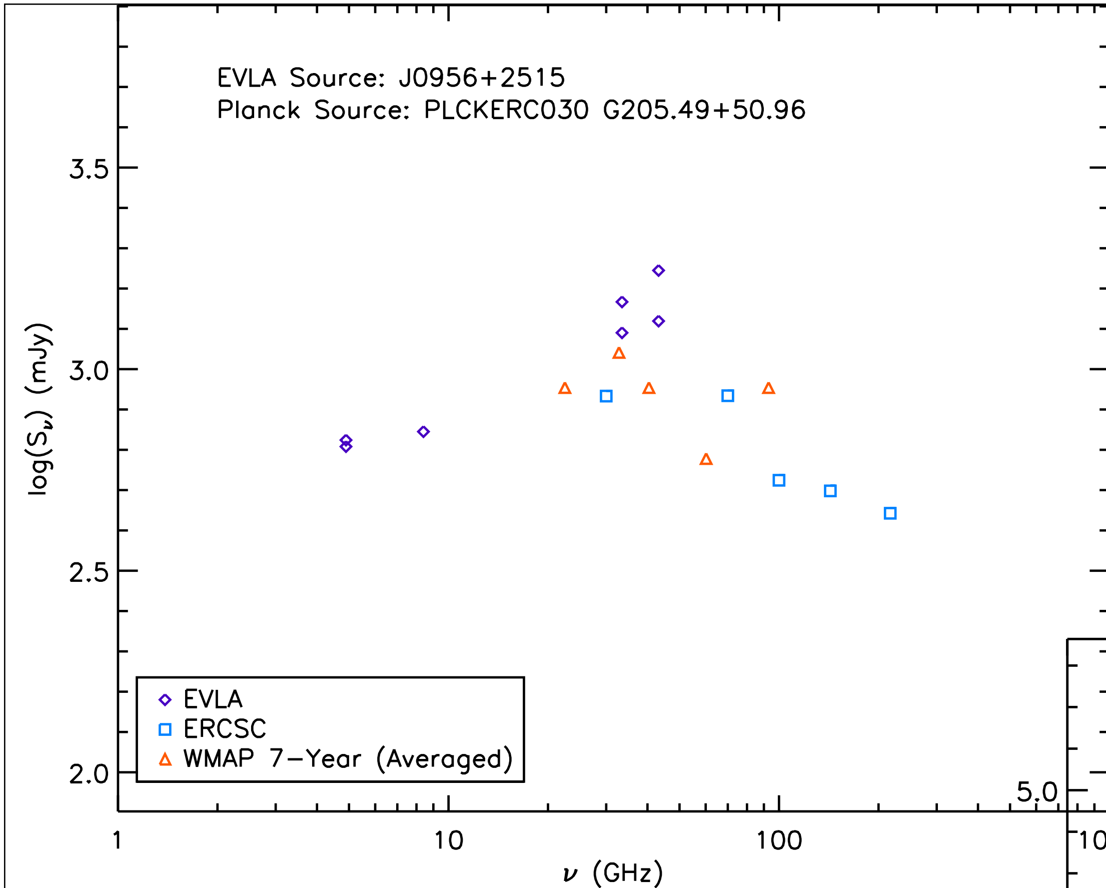


Example inverted spectrum, really flattish given Planck data

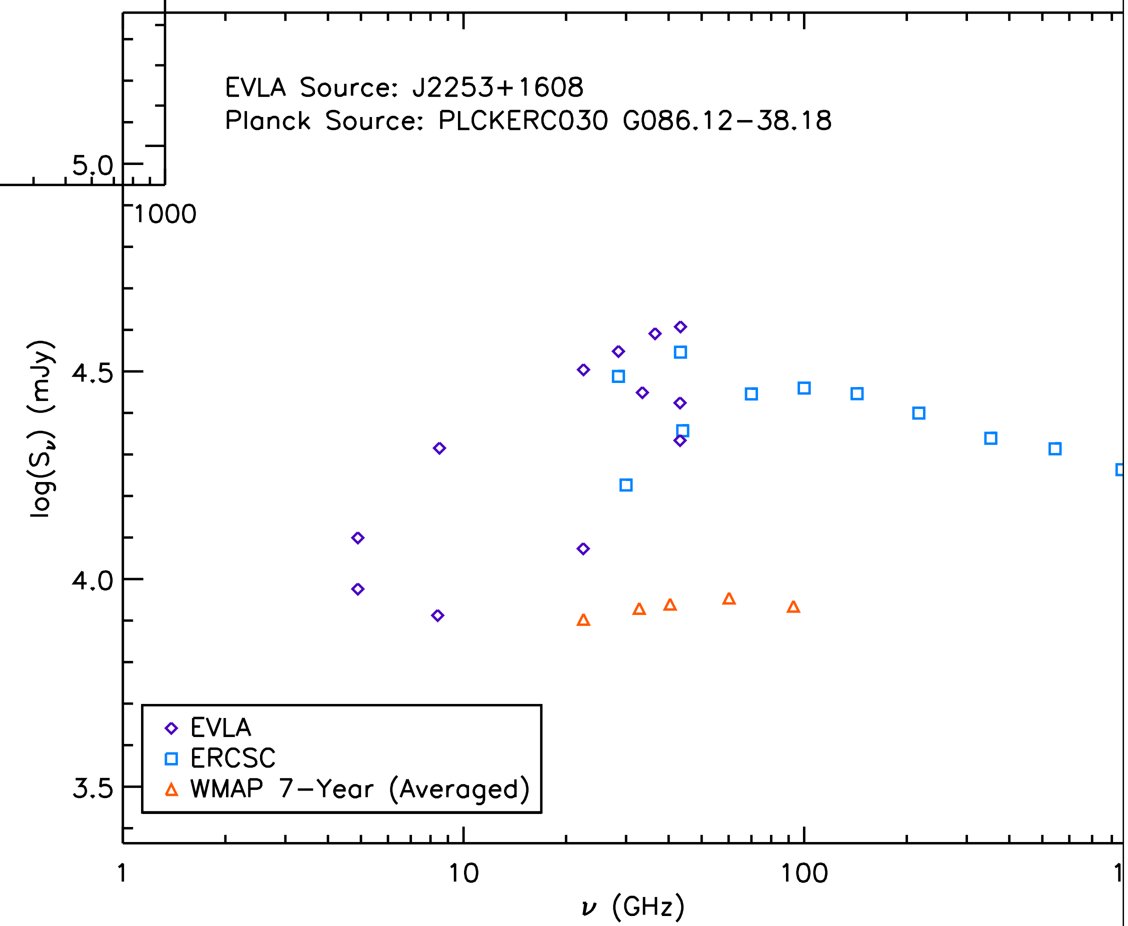


Example inverted spectrum really peaked given Planck data

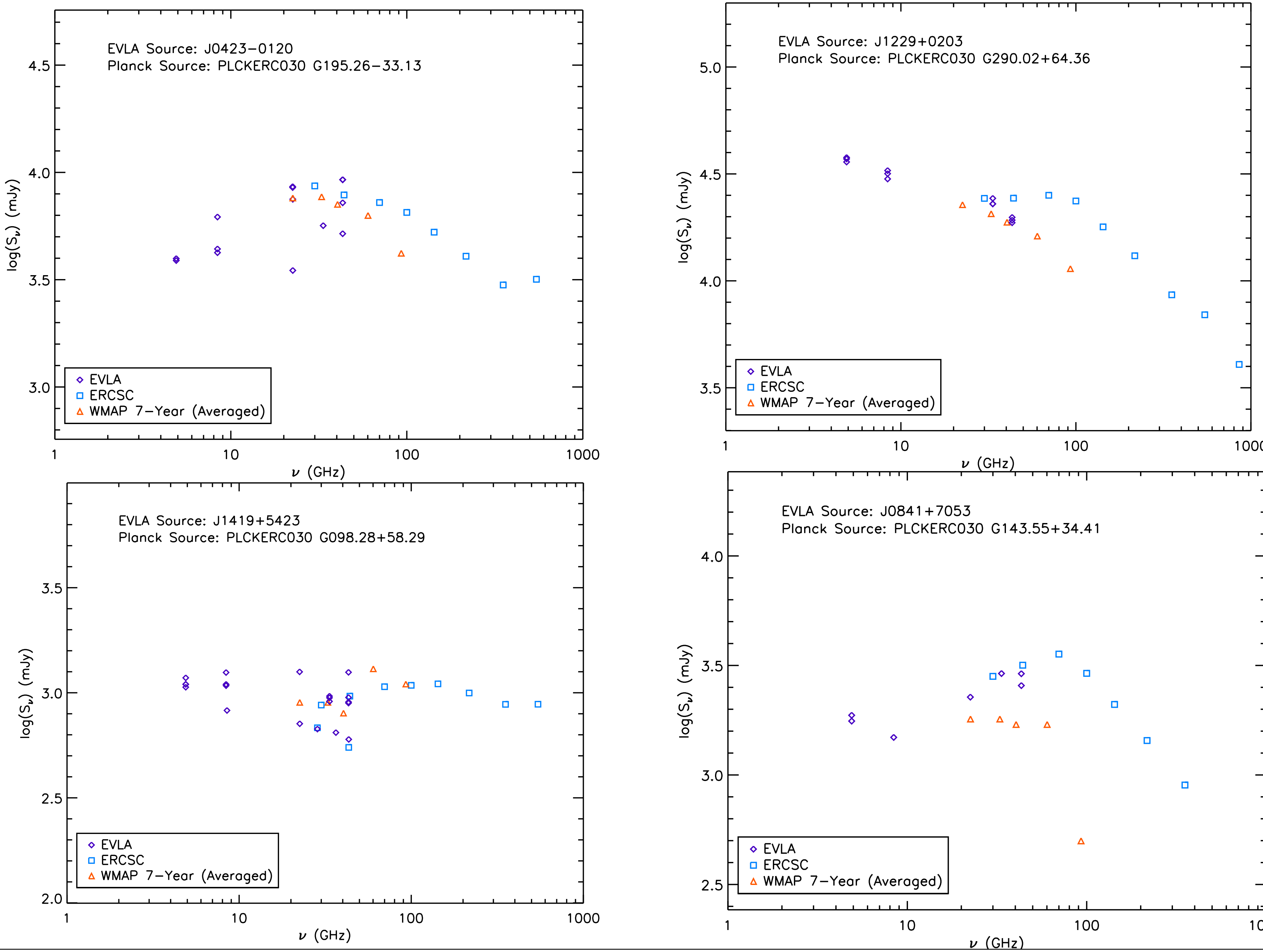




Our most strongly inverted spectrum sources, show evidence of being strongly flaring objects.



Sources typically variable, and show complex SEDs.



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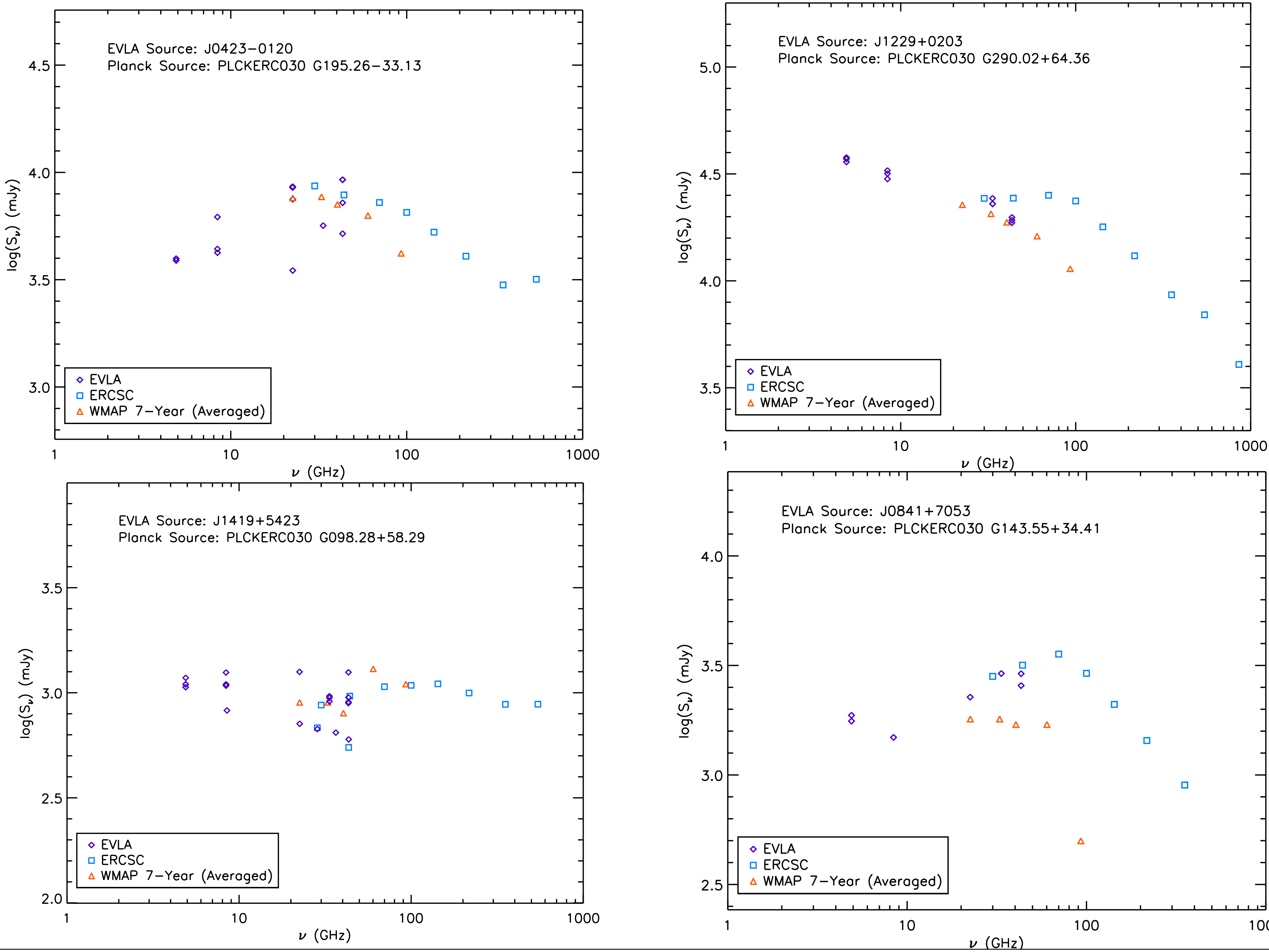
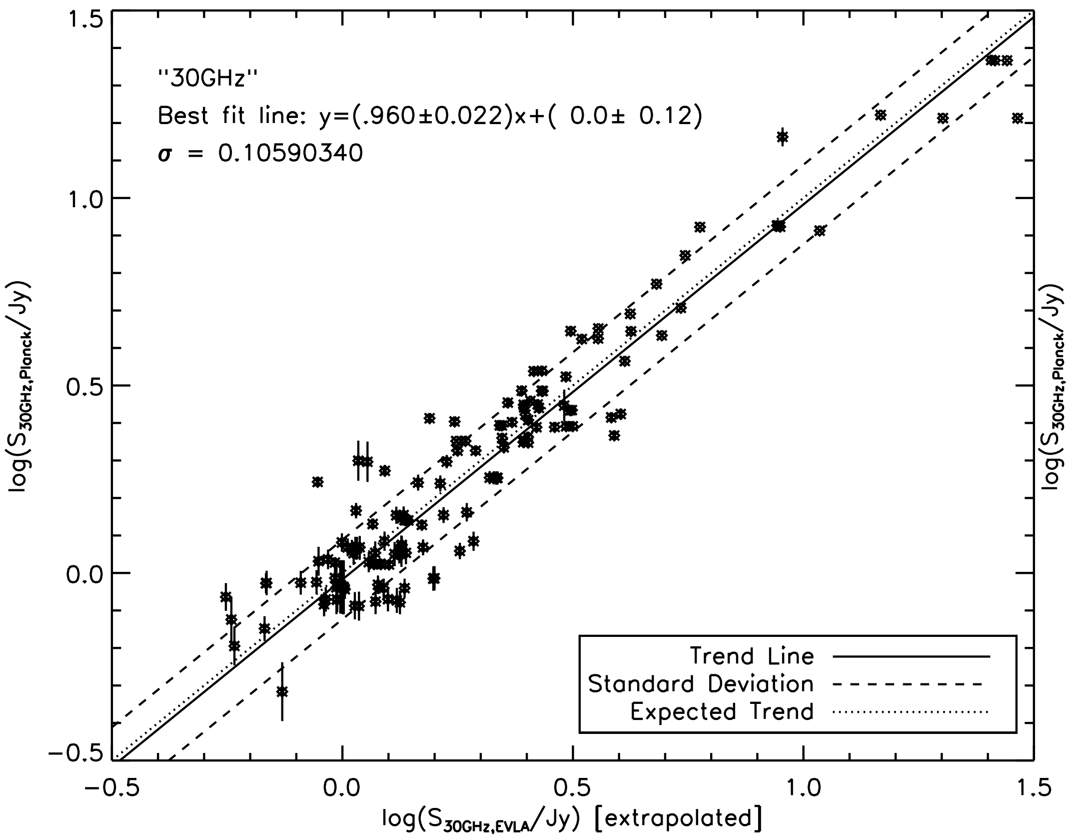
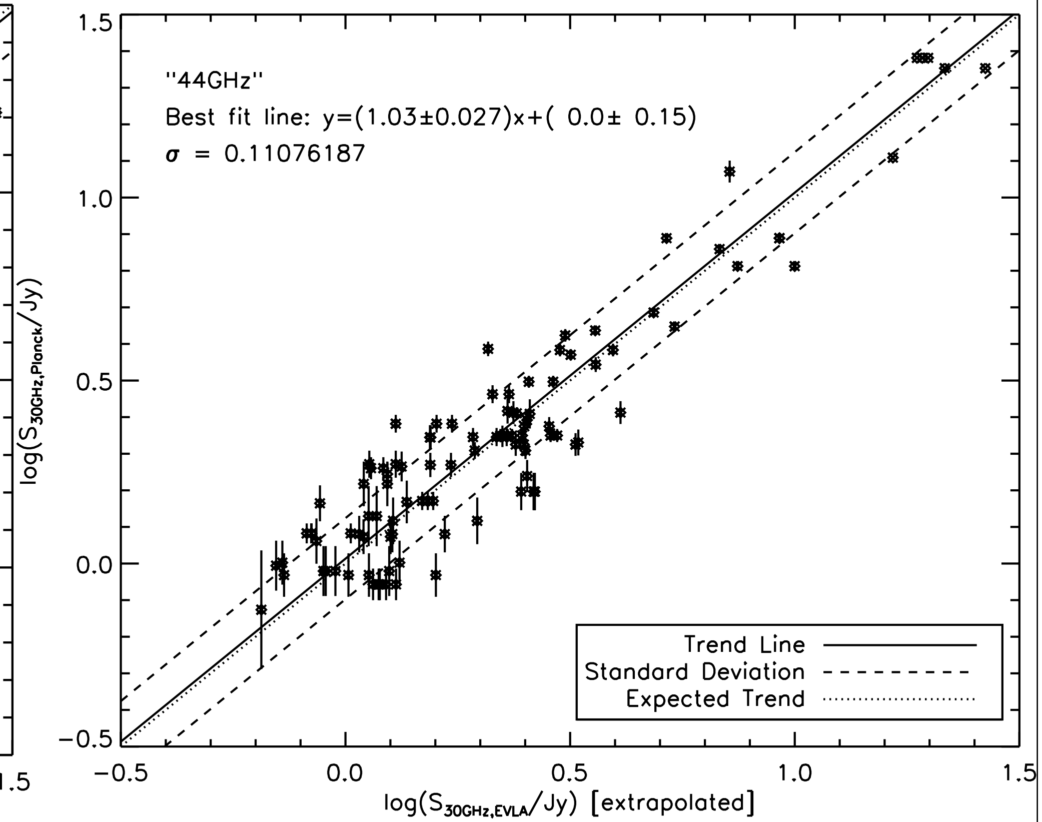


Here we compare our EVLA flux densities, appropriately inter/extrapolated to the *Planck* bands, with the time-averaged ERCSC data.

Apart from sources near the detection limit, variability should scatter sources evenly in both directions. Therefore, with sufficient number of sources, the best-fit slope should be a good proxy for what we'd get from simultaneous observations.





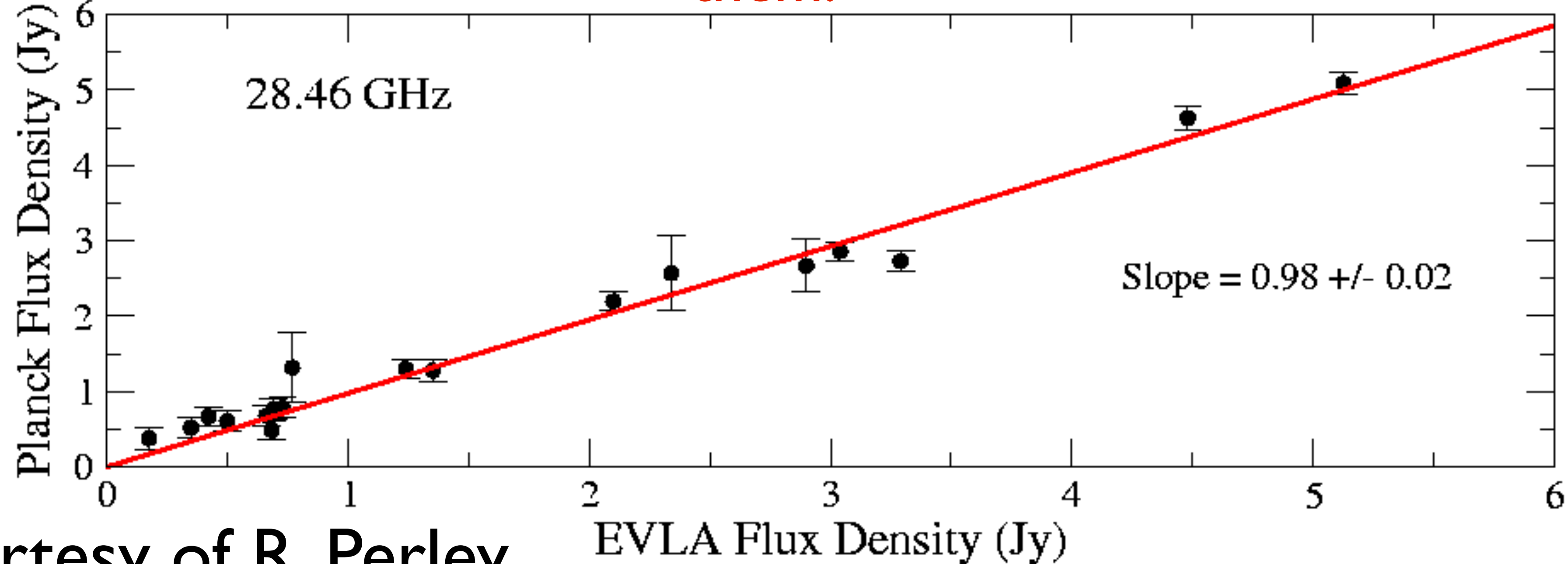
These are all fixed intercept fits.

30GHz best-fit: $y = (0.98 \pm 0.02)x + (0.00 \pm 0.09)$

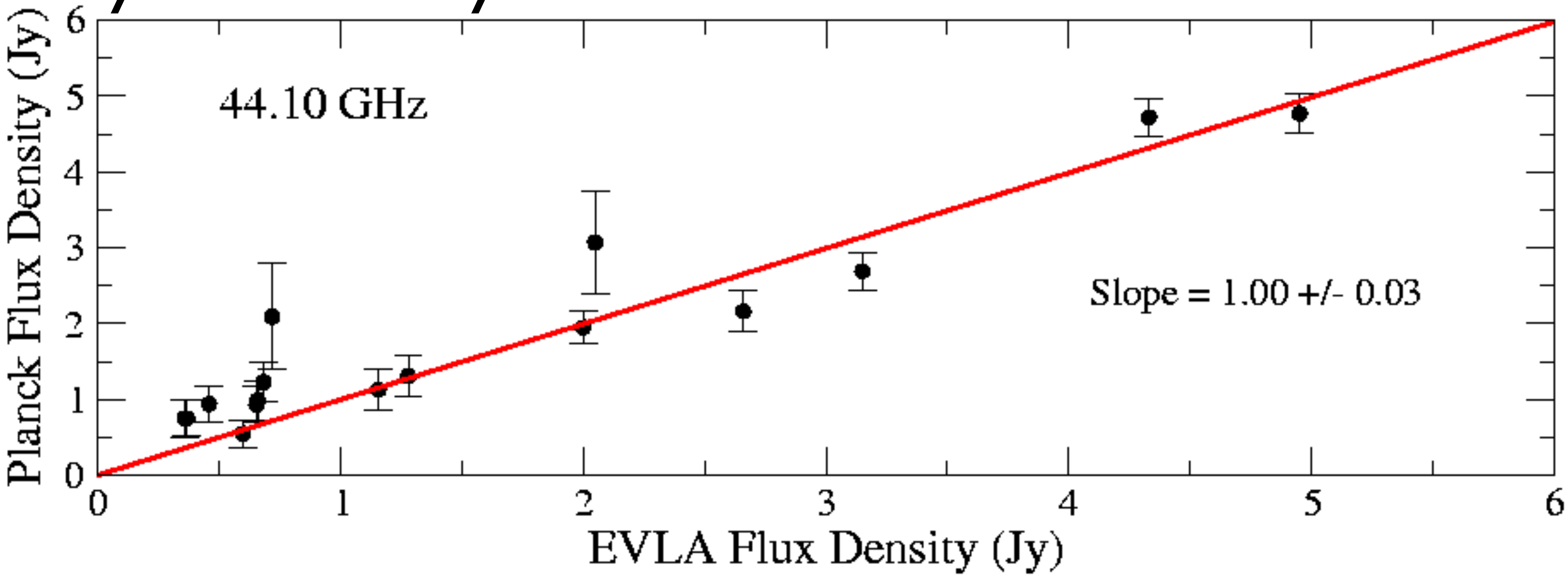
44GHz best-fit: $y = (1.02 \pm 0.03)x + (0.00 \pm 0.16)$

The best-fits are arrived at by *iteratively* examining the effect of removing outliers. After removing just two outliers the fits stablize.

Looking at a few sources with timestream Planck data (not the public ERCSC data), compared with EVLA observations within a month of them.



Courtesy of R. Perley



The simultaneous data give consistent results with the non-simultaneous data both in terms of slope and associated errors.

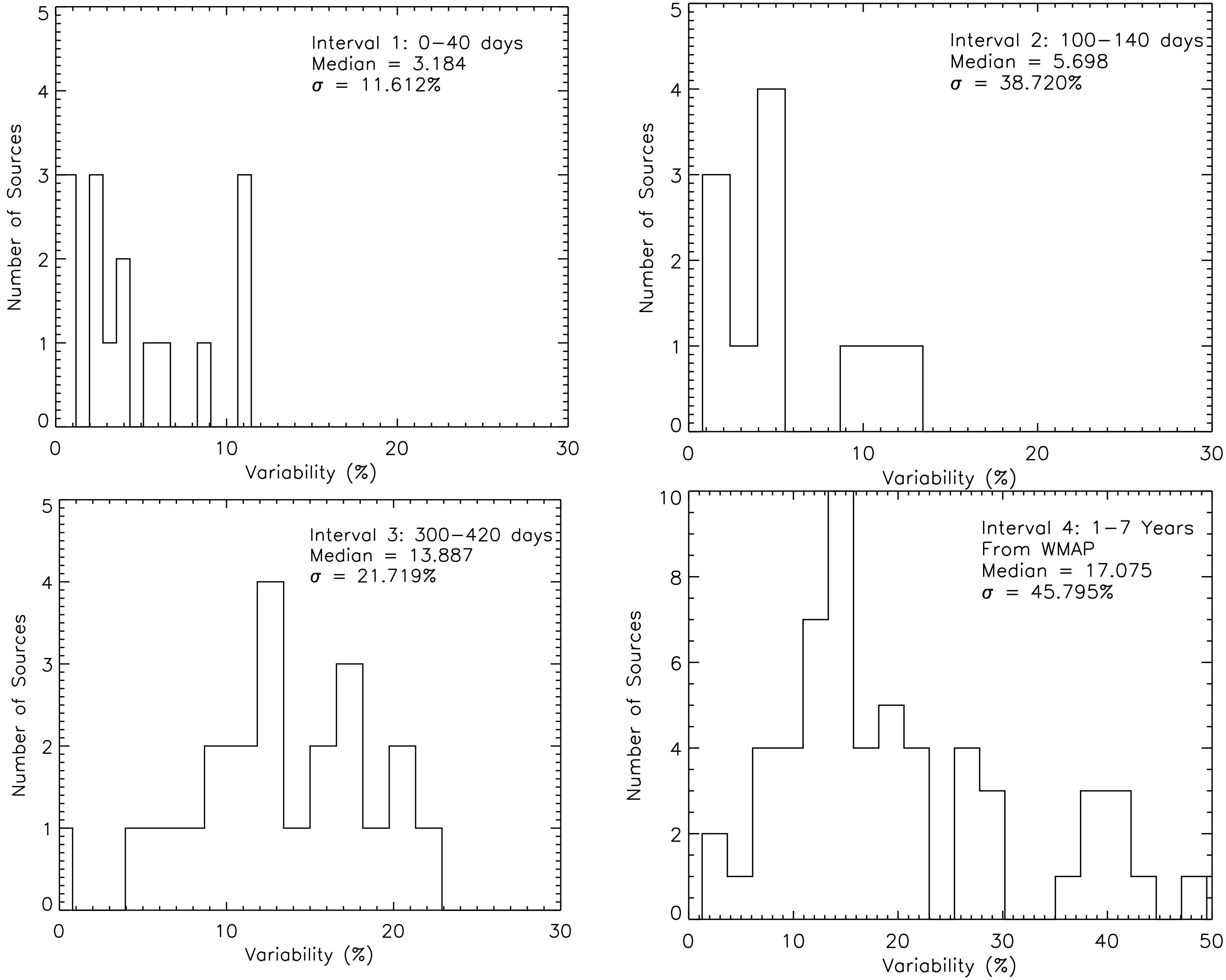
Both suggest that the agreement between *Planck* and EVLA source flux densities is now within ~2%.

What's changed?

- Recall that preliminary results suggested an 8% discrepancy at 30, and 12% at 44GHz.
- Mainly the EVLA flux density scale has been revised (Perley-Butler 2010).
- Calibration is based on very stable well studied calibrators (especially 3C286). Their absolute calibration is based on models of how the brightness of planets varies with time and frequency. The absolute scale is then matched to the absolute brightness of Mars in WMAP, ultimately calibrated on the COBE dipole.
- Corrections to old VLA flux density scale at 30–40 GHz of up to + 3–6% (for 3C286) and + ~10–20% (for 3C48).

Is the scatter consistent with source variability?

For our data, we expect typical variability in the range 6-14%. The observed scatter at 30GHz is10%.



Error budget

- Uncertainty in the VLA/EVLA flux density scale **± 3–5%** (this includes ~2% WMAP calibration uncertainty, planetary model uncertainty and observational uncertainty).
- Observational uncertainty **± 1–2%**
- Planck could have a final calibration uncertainty of **<1%** (on small scales). This can then be used to refine further the EVLA absolute flux density scale.
- Planetary temperature scale (especially at higher frequencies) is then the limiting uncertainty. Moving from Mars to Uranus as the primary EVLA planetary calibrator should help.

Hope we are converging to a common absolute flux density scale whose uncertainty is ~1%.

Due to remaining discrepancies there is a program of more closely co-ordinated observations now underway at the EVLA and Australia Telescope

Led by Rick Perley (NRAO)

Will compare to single-epoch, simultaneous Planck measurements (Jan. 2012)

No results yet

Conclusions

- Comparison between ground-based and Planck flux density scales, has inspired an improved flux density calibration for the EVLA and greater confidence in the high-l Planck calibration. Ultimately, Planck should set the standard for the absolute flux density scale employed by ground-based radio observers.

- The presented near-simultaneous ground-based monitoring of the intrinsically-variable Planck sources increases the usefulness of the Planck source catalogs as it extends their frequency coverage, and helps us understand the variability of the sources, over the range of Planck observations. As such these data could be used in future blazar studies.