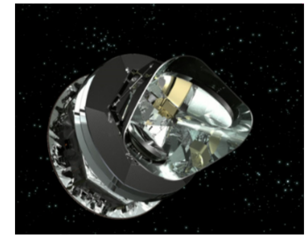
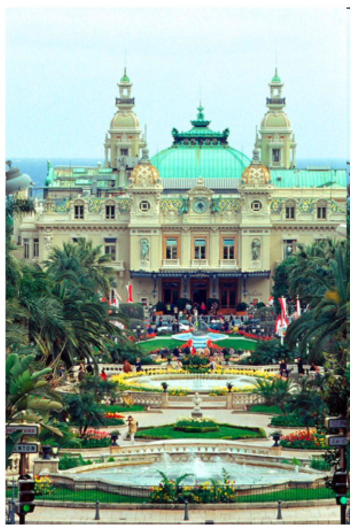
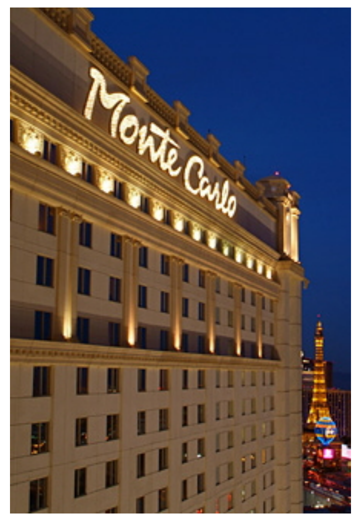


Monte Carlo Quality Assessment (MC-QA)

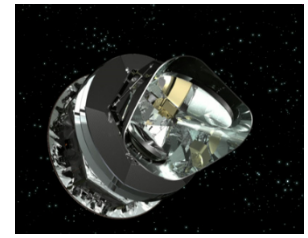
For the Planck ERCSC Team





Planck Early Results VII, 2011, A&A
& Chary et al. 2004, ApJ

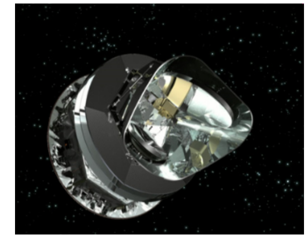
Jun 2011
rchary@caltech.edu



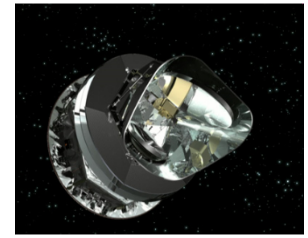
Motivation

- Any data product needs to go through quality assessment
- At the image level, they can be radhits, asteroid stripes, detector/instrument artifacts
- At the catalog level, it involves guaranteeing the existence of the source and the reliability of flux densities, positions, source sizes.

Goals of Quality Assessment (QA)



- To quantify flux biases and flux errors as a function of background (latitude ≠ bg)
- To quantify completeness in extracted sources as a function of flux density
- To quantify contamination or "spurious sources" as a function of flux density
- To measure positional offsets between extracted and input sources
- Assess systematics associated with scan strategy, beam shape, gaps in coverage etc.

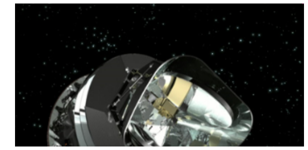


Techniques to do QA

- Compare with a real catalog of the sky
  - Needs comparable data at comparable spatial resolution and wavelength
  - Sources can vary in brightness
  - Source statistics at bright end are often lacking
- Jackkknife splits
  - Use half the data run the catalog and see if sources are present in both halves
  - Run into problems at sensitivity threshold of a catalog
- Map Inversion
  - Fails if noise is non-Gaussian
- Monte Carlo QA
  - Involves injection and extraction of artificial sources

rchary@caltech.edu

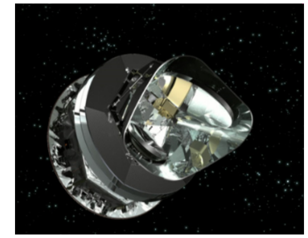
Features of Planck

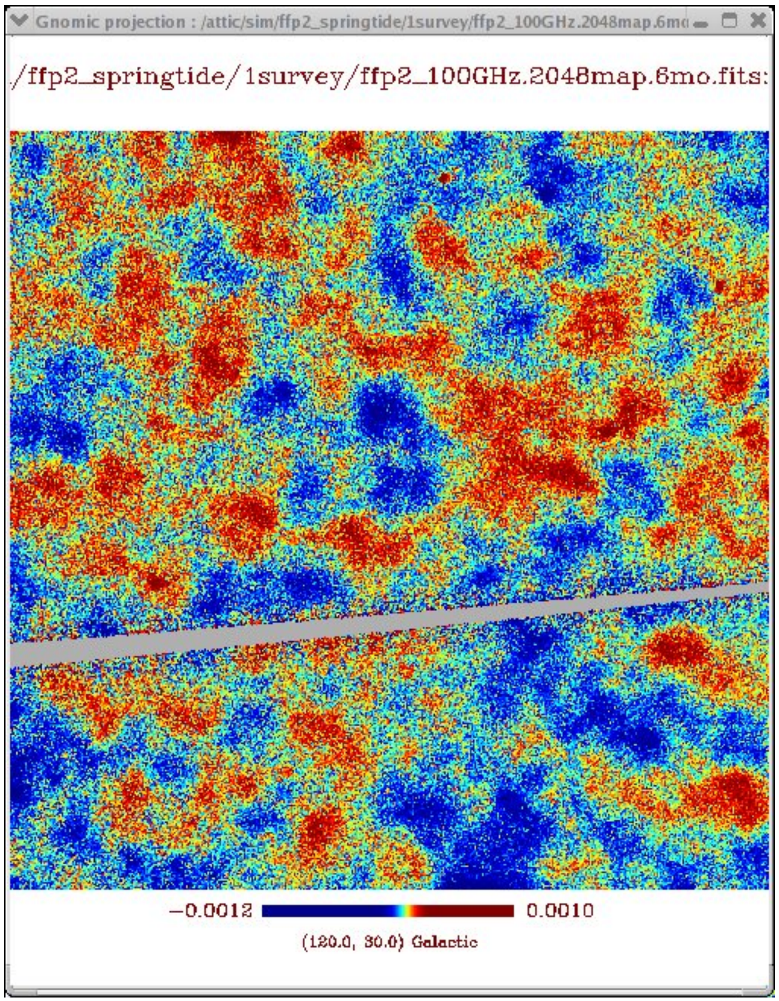


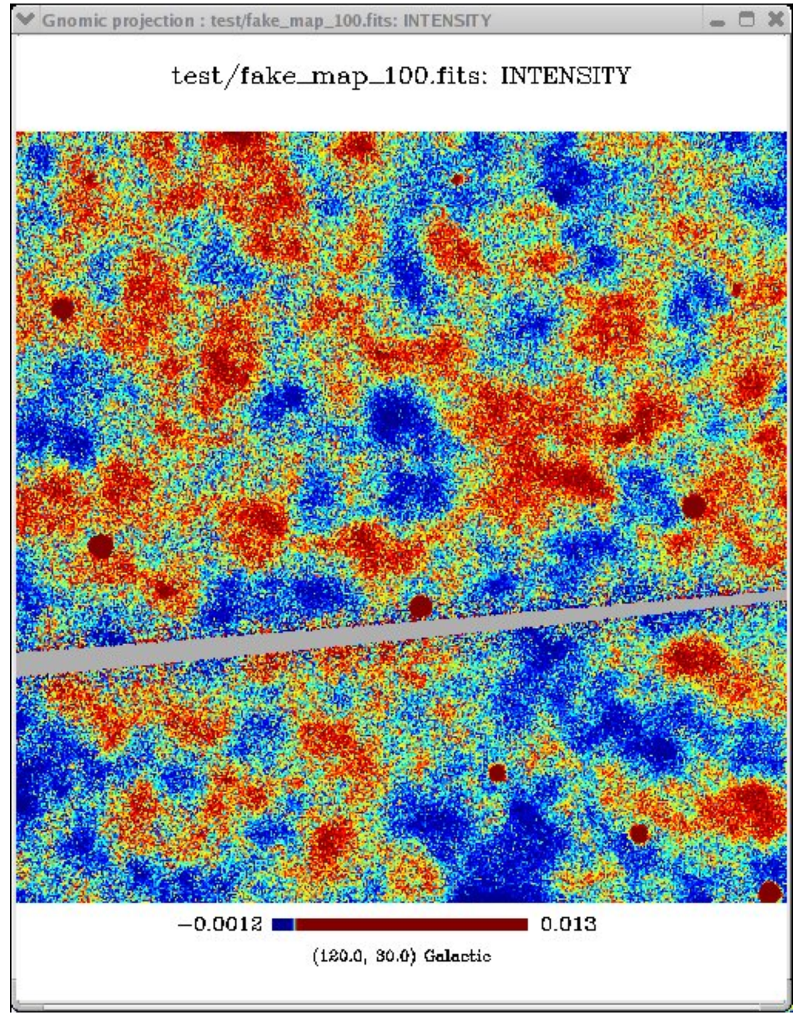
DMR		*WMAP*		*Planck*		*Akari*		*IRAS*		*WISE*	
ν	FWHM	ν	FWHM	ν	FWHM	ν	FWHM	ν	FWHM	ν	FWHM
		23	53								
32	420	33	40	30	32.65						
		41	31	44	27.00						
53	420	61	21	70	13.01						
90	420	94	13	100	9.94						
				143	7.04						
				217	4.66						
				353	4.41						
				545	4.47						
				857	4.23						
						1.9×10^3	0.8				
						2.1×10^3	0.7				
						3.3×10^3	0.45	3×10^3	5.2		
						4.6×10^3	0.32	5×10^3	3.9		
						16.7×10^3	0.09	12×10^3	4.5	13.6×10^3	0.2
						33×10^3	0.05	25×10^3	4.7	25×10^3	0.11
										65×10^3	0.11
										88×10^3	0.1

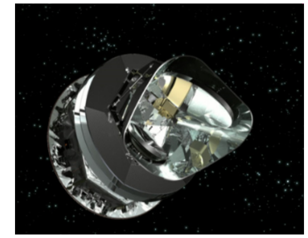
- Unique phase space – the first simultaneous radio through submillimeter all sky survey
  - Fills in the gap in phase space between WMAP and Akari/IRAS
  - Probes both the dusty infrared luminous sources and the synchrotron sources
- Spatial resolution well matched to IRAS at ×3 longer wavelengths
- Improved spatial resolution and sensitivity compared to WMAP in the radio

Comparison b/w true map and map with fake sources added



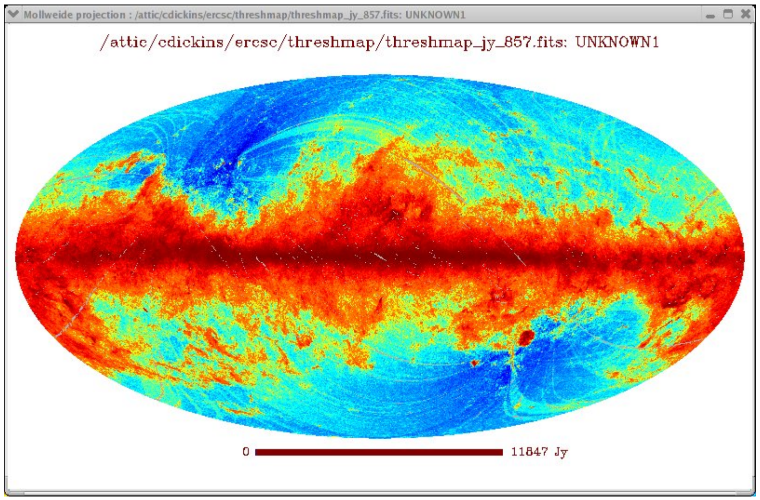


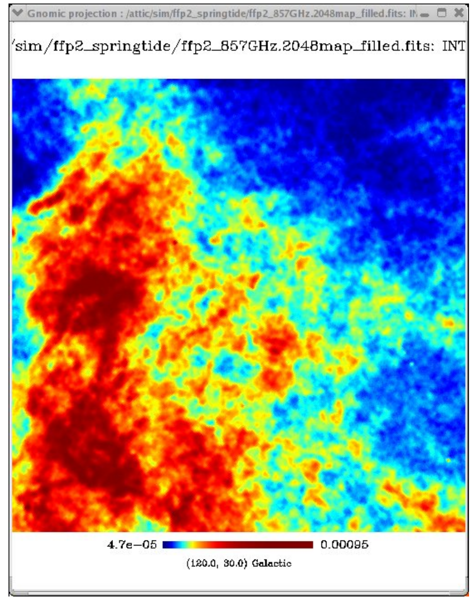




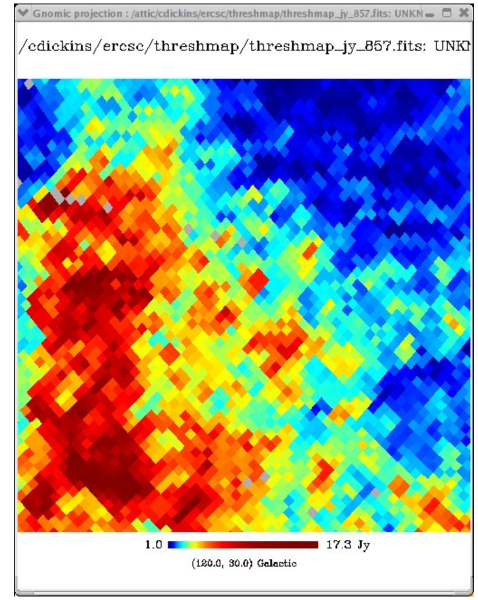
The Sky is a Complex Place

All Sky Threshold Map



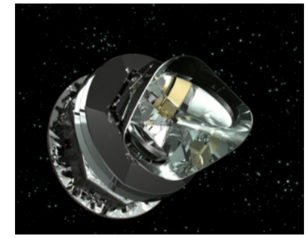


True Map (zoom)



Threshold Map (zoom)

rchary@caltech.edu

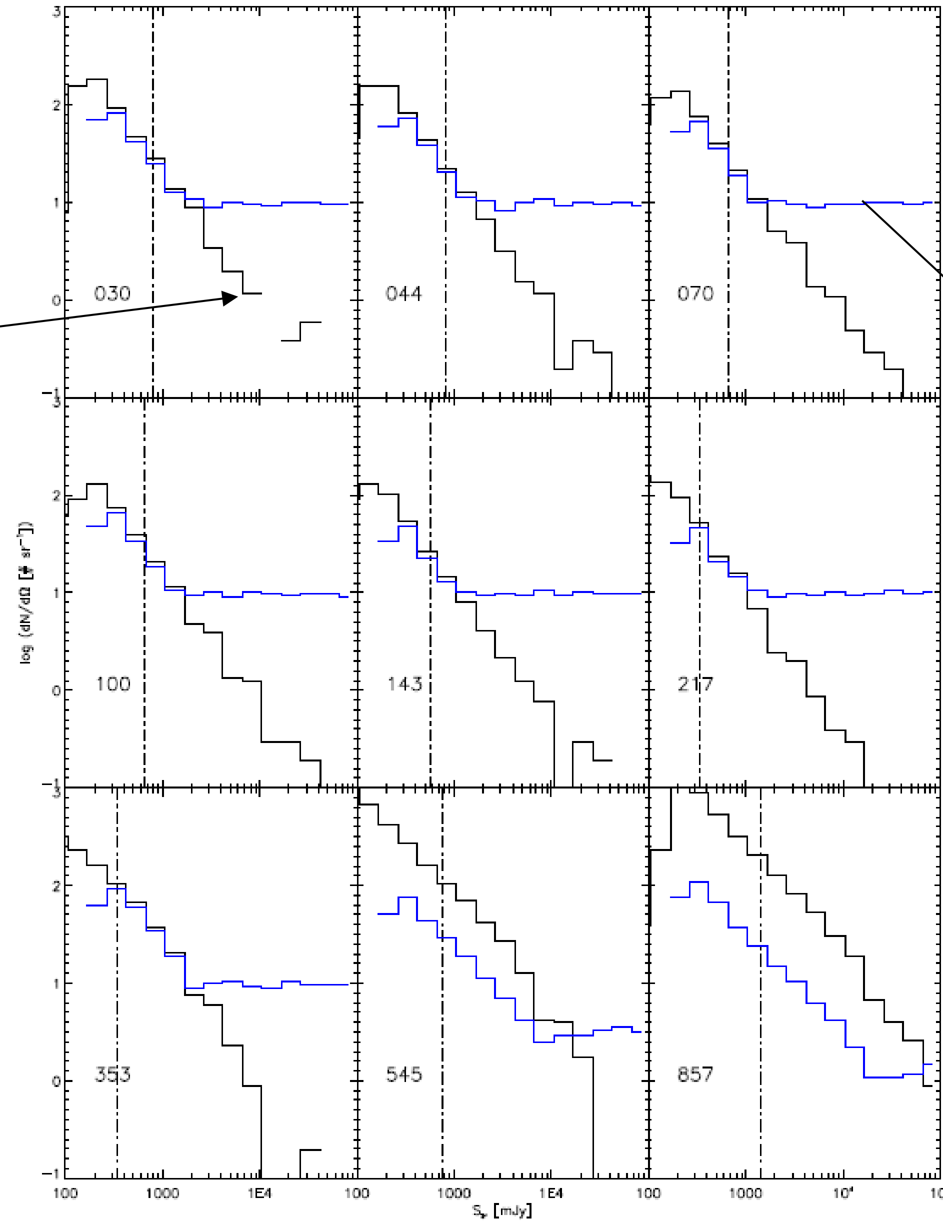


Technical Details

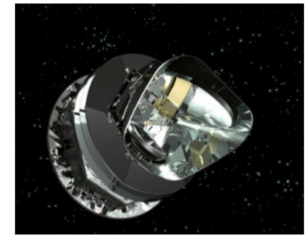
- You don't put in the artificial sources willy-nilly!
- Need to go x10 fainter than expected sensitivity limit
- Need to use a proper source counts distribution
- Need to carefully keep track of sources that were there in the original data.

Shape of Input Source Counts Distribution

Black histogram is the source counts distribution in the level S catalog. Not used for QA now.



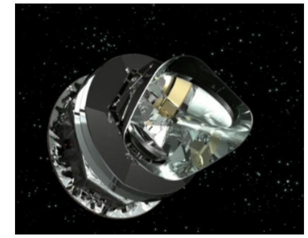
Blue line is the input source counts distribution for the MC analysis at each frequency



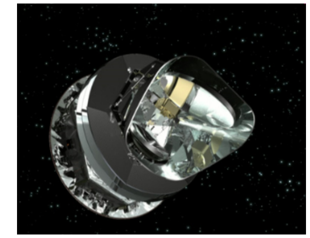
Jun 2011

rchary@caltech.edu

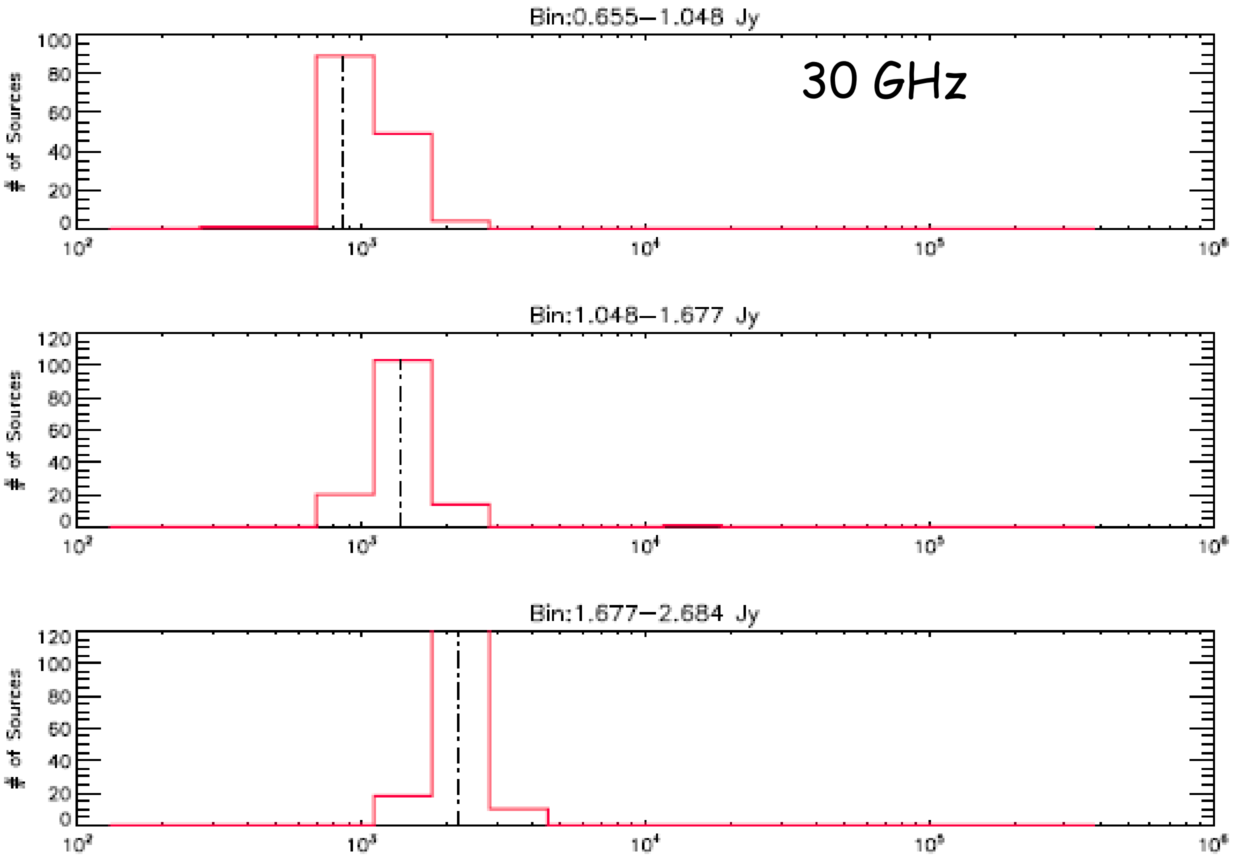
The Pij Matrix to Determine Completeness and Contamination



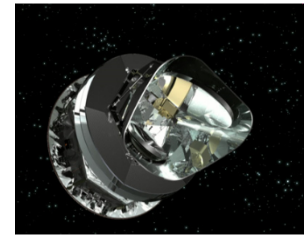
- The Pij matrix contains a distribution of input fluxes (i) vs output fluxes (j)
- If an input source has true flux F_i but it extracted with F_j then Pij = Pij+1
- If N input sources with a particular F_i, then 100% completeness implies $\Sigma P[i,*] = N$
- In reality $\Sigma P[i,*] = M(<N)$ and M*100/N is the % completeness
- Contamination is $\Sigma P[i,k]*100/M \ \forall k \neq i$ and with flux bins of 30%.
- Reliability is simply 1-Contamination
- Technique has been demonstrated for ultradeep, confusion-limited data sets e.g. Spitzer-GOODS. See Chary et al. (2004) and Frayer et al. (2006) for more details



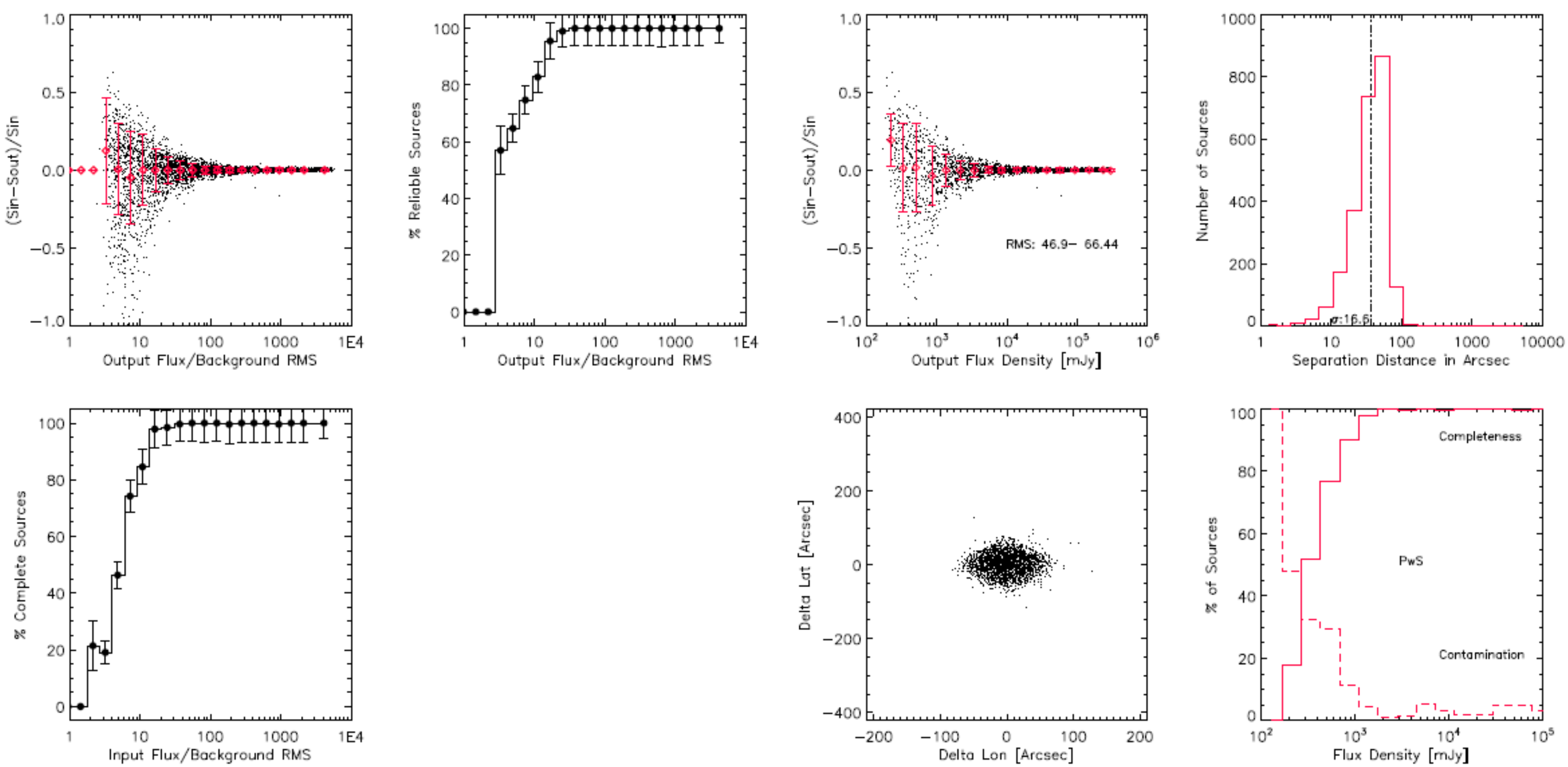
WYSIWYG:
Output Flux Distribution in Each Input Flux Bin



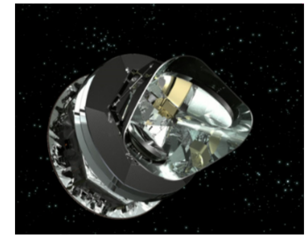
Spread is Decreasing With Increasing Flux Density As expected

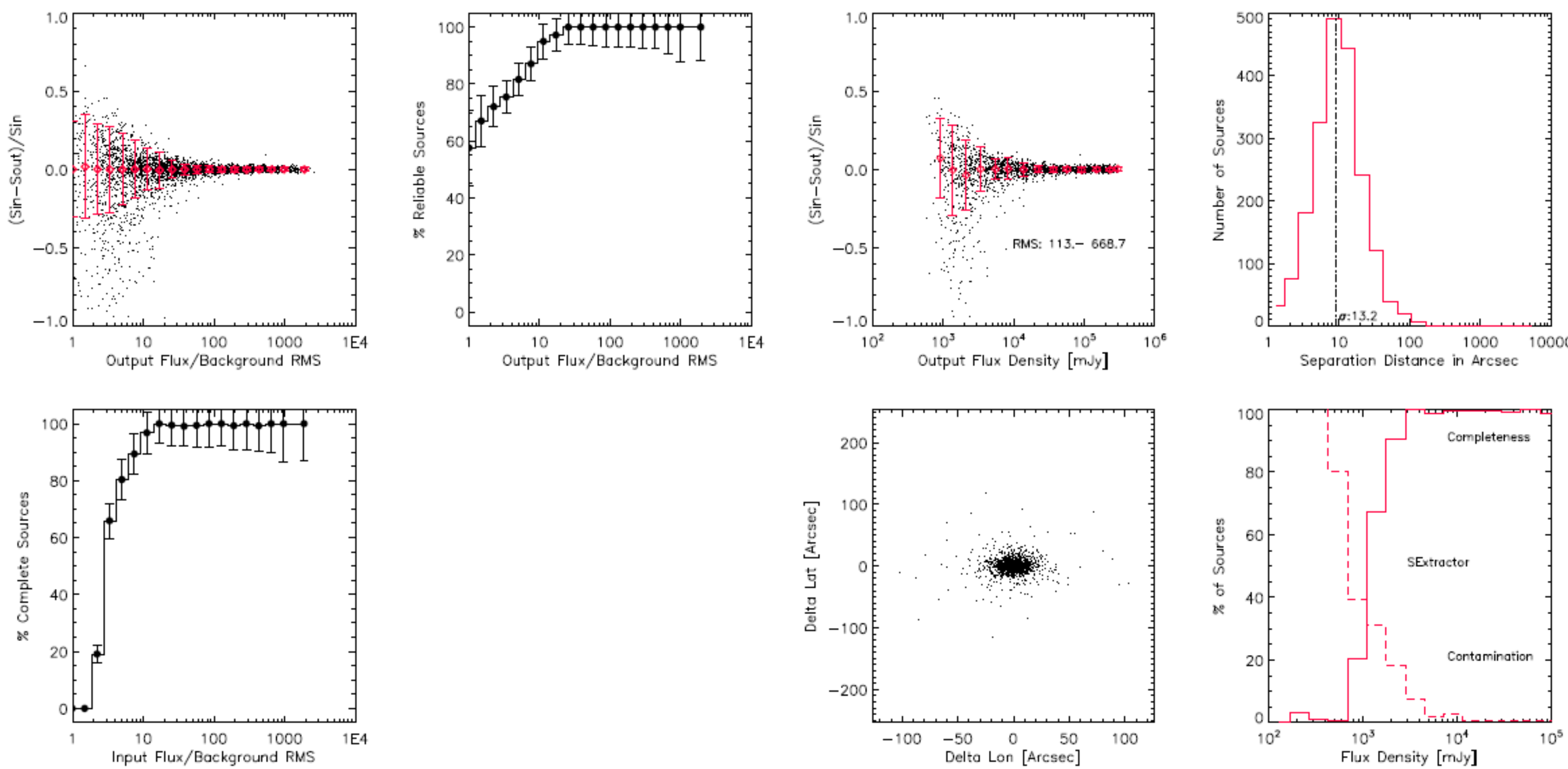


What do the Artificial Sources tell us?

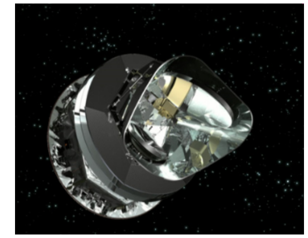


And at a higher frequency?



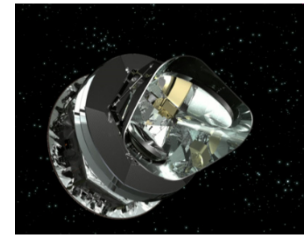


Instead of Latitude, use Background Thresholding



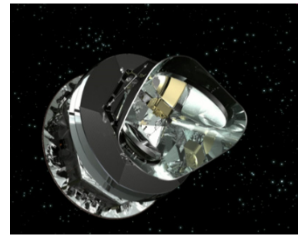
- S/N is a more physical tracer of sensitivity performance than just latitude cuts due to substructure in the background
- So we generate a noise/background map which is a measure of the noise.
- Mask out detected sources before generating background – important at LFI bands
- Scale of annulus used to measure background rms was 2 deg radius

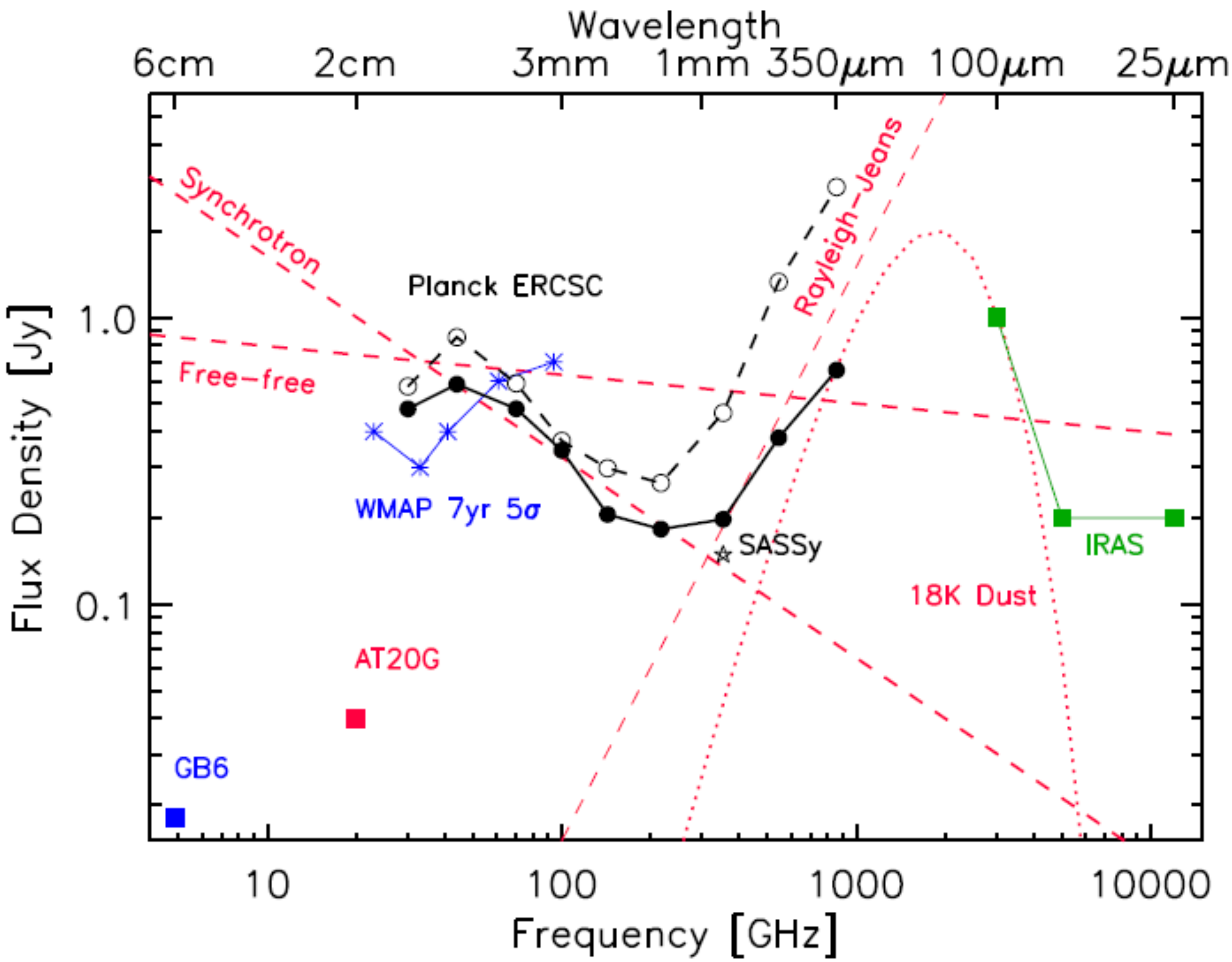
The Final Step



- Once you know what your Monte-Carlo sources are doing, you map their properties to the real sources
- We used the ratio Flux Density/Background RMS as the metric, but one can use size, or shape, or brightness profile or pretty much any metric.
- We throw out about 1/2 of the low (30-70 GHz) frequency and 2/3 (100-857 GHz) of the higher frequency sources

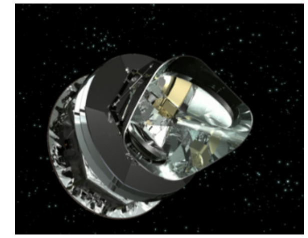
The Planck ERCSC: >15000 unique sources





Jun 2011
rchary@caltech.edu

Monte Carlo QA



Results & Lessons Learnt

- Non-gaussian noise is a challenge:
  - Always present in all sky infrared surveys
  - More of an effect at far-infrared wavelengths where Galactic cirrus is an issue

- Different algorithms behave quite differently even with similar S/N ratio cuts and in regions of different noise properties

- Monte-Carlo QA approaches are the most robust and can be efficiently parallelized. They can be tuned to monitor all aspects of your QA system end-to-end.
  - We cheated because of time and computing limitations so we injected sources into the maps rather than the time ordered data
  - Can be easily run on the cloud
  - Scalable, works with large datasets