This time for sure!
Fringe-fitting in Casa

Des Small

mm-VLBI Workshop, Leiden, 8 June 2015

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> *"[F]or observations where detections are often marginal (e.g., mm- or space-VLBI), increased interactivity and user-control are highly desirable. A flexible fringe-fitting tool satisfying these needs is currently being developed in AIPS++."*

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Stephen Bourke (JIVE), 2011:

> *"Hope to include a beta or alpha version [of fringe fitting] in next Casa release."*

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Why this time is different

- Previous work has been research oriented
- We are *production* oriented
- We're not researching fringe-fitting algorithms!
- We are implementing "industry standard" methods
- Our goal is to make Casa a useable tool for cm- and mm-VLBI

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Baseline approach

For each baseline we can linearly approximate phase $\phi_{t,v}$ by

$$\phi_{t,v} \approx \phi_0 + \frac{\partial \phi}{\partial \nu}\Delta\nu + \frac{\partial \phi}{\partial t}\Delta t$$

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So 2D Fourier transform of $\phi(t,\nu)$ should be a δ-function at delay and fringe-rates.

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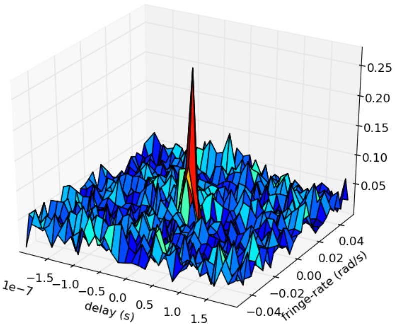
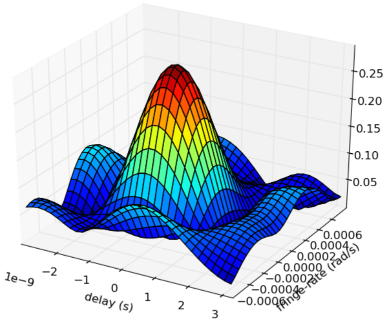
Baseline approach (2)

- Instead of interpolating *after* FFT, pad data with zeros
- A zero-padding factor of eight is a good balance between accuracy and computational effort



Unpadded FFT



Padded FFT (close-up)

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Beyond baselines: Alef and Porcas

- Baseline approach makes inefficient use of data
- Phases may not close
- Can do better with models of station instead of baselines
- Need a source model
- Can refine with a least-squares model of per-station phases
- Still do the optimisation in Fourier transform space
- Algorithm used in Hops, popular with geodesists
- (I haven't implemented it yet)

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Beyond baselines: Schwab and Cotton

- Use a per-station model of ϕ
- Choose a reference station
- Stack baselines and use FFT method for initial guess
- Apply least-squares optimisation in regular t-ν space
- With good estimates non-linear least squares converges fast
- Used in AIPS; current industry standard for non-geodetic VLBI

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Stacking baselines

- Fringe from station i to station j may be weak
- Closure relation $\phi_{ij} + \phi_{jk} + \phi_{ki} = 0$
- Can estimate ϕ_{ij} as $\phi_{ik} + \phi_{kj}$
- For all stations k, so $\sum_{k \notin \{i,j\}} \phi_{ik} + \phi_{kj}$
- Can use longer paths: $\sum_{k \notin \{i,j,l\}} \phi_{ik} + \phi_{kl} + \phi_{lj}$
- Particularly useful with homogenous arrays

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Remarks and current status

- Casa Python includes Numpy and Scipy - we use them!
- Baseline stacking not that helpful with inhomogenous array
- But also doesn't hurt (I have implemented it)
- Built-in scipy least-squares is probably good enough
- (Only a few iterations of Levenberg-Marquardt solver needed for convergence)
- Table for storing delay and rates actively being pondered
- Pecularities of mm-VLBI (incoherent averaging?) yet to be faced

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