WHAT YOU CAN ALREADY DO IN CLASSIC AIPS

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Magnitude of the wide-field problem

$$V(u, v, w) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} I(l, m) \exp^{-2\pi i \left[ul + vm + w\left(\sqrt{1 - l^2 - m^2} - 1\right) \right]} \frac{dl\, dm}{\sqrt{1 - l^2 - m^2}}$$

Approximation of worst phase error leads to limit on full facet diameter, all angles in same units.

$$\phi_{\text{error}} \simeq \pi(l^2 + m^2)w$$
$$w \leq D_{\max} \simeq 1/\theta_b$$
$$\phi_{\text{error}} < \phi_{\text{Emax}}$$
$$\theta_{\text{facet}} < \sqrt{\theta_b\, \phi_{\text{Emax}}}$$

Note that synthesized beamwidth and single-dish beam size are both proportional to wavelength, making this limitation more serious at longer wavelengths.

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The simplest solution
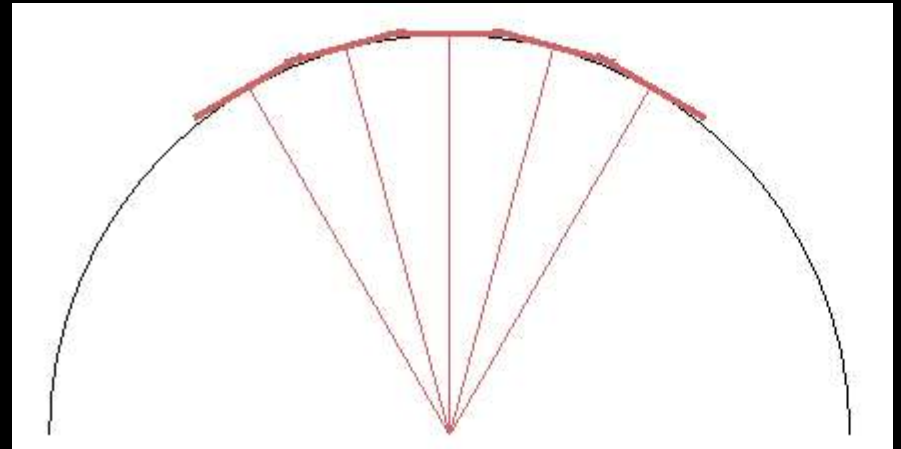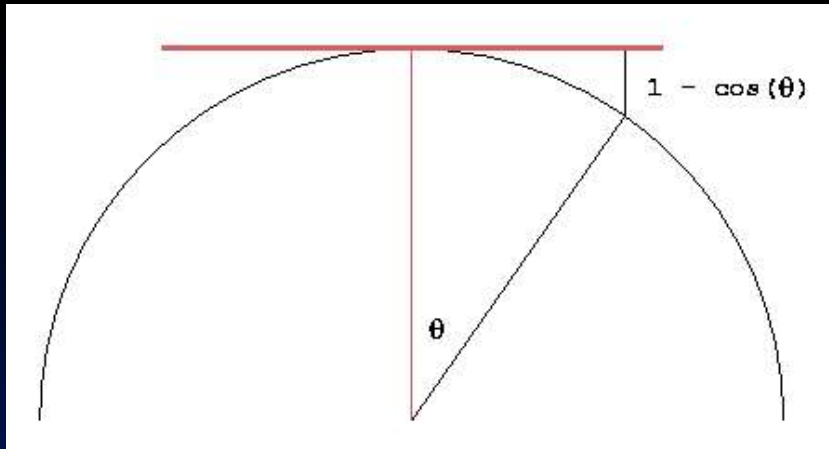
- Left: single large field develops large phase errors away from the center
- Right: multiple small facets approximate the sphere with greatly reduced phase errors
- Requires re-computation of (u,v,w) and adjustment of visibility phases for each facet

What you can already do in AIPS

Usage in AIPS

- SETFC: task to recommend cell and image sizes, placement of facets and default Clean windows
- CHKFC: task to make image of facets and Clean windows written by SETFC
- IMAGR: task to image and Clean the facets
- FLATN: task to re-grid the facets from IMAGR and CHKFC onto a single image
- CALIB: task to improve the calibration of the data using the full model in the multiple facets
- Numerous other tasks use these models too

What you can already do in AIPS

Costs and benefits
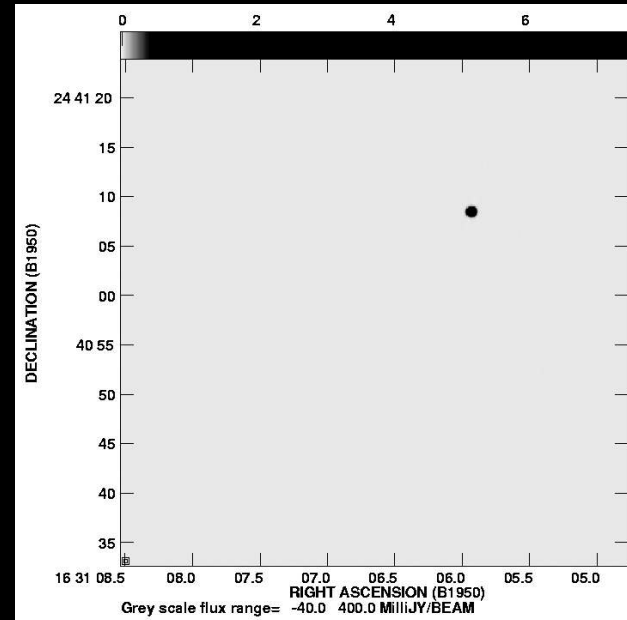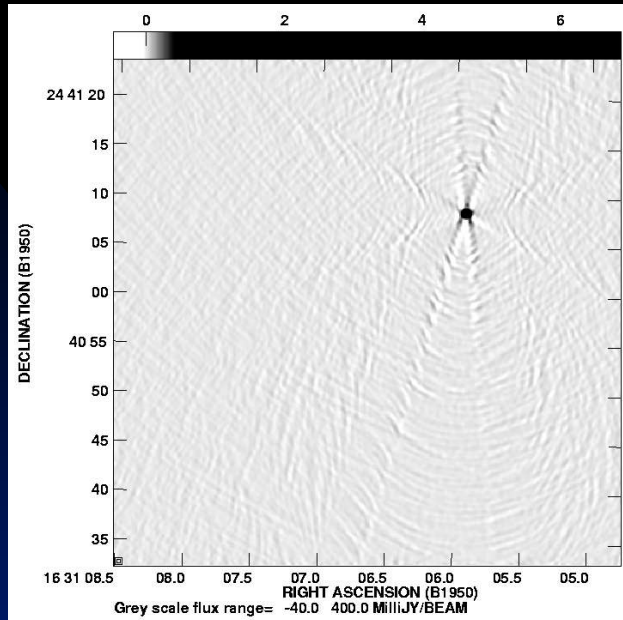
- Left: source phase corrected to facet center only
- Right: phases and (u,v,w) corrected for facet center shift. Both images Cleaned and displayed equally.
- Cost: 1 % in cpu when not needed, speeds Clean when it is needed
- Weighting best only for center facet

What you can already do in AIPS

Example field

- VLA D array 20-cm wavelength continuum
- Observed with only 1 channel in 50 MHz, multiple narrower channels would be better
- Facet size rules allow a single facet to cover well beyond the half-power point of the single-dish beam pattern
- Imaged over a larger area of necessity – 19 central facets used plus one on a 3C source
- Data on Abell 2256 from Tracy Clarke and Torsten Ensslin

What you can already do in AIPS

Facet selection illustrated

Output of CHKFC after FLATN. The facet numbers are shown in the center of the default circular Clean windows. Note the large area covered – each facet covers ~40 arc minutes while the primary beam to half power is only 30. These facet centers and Clean windows are then used by IMAGR.

What you can already do in AIPS
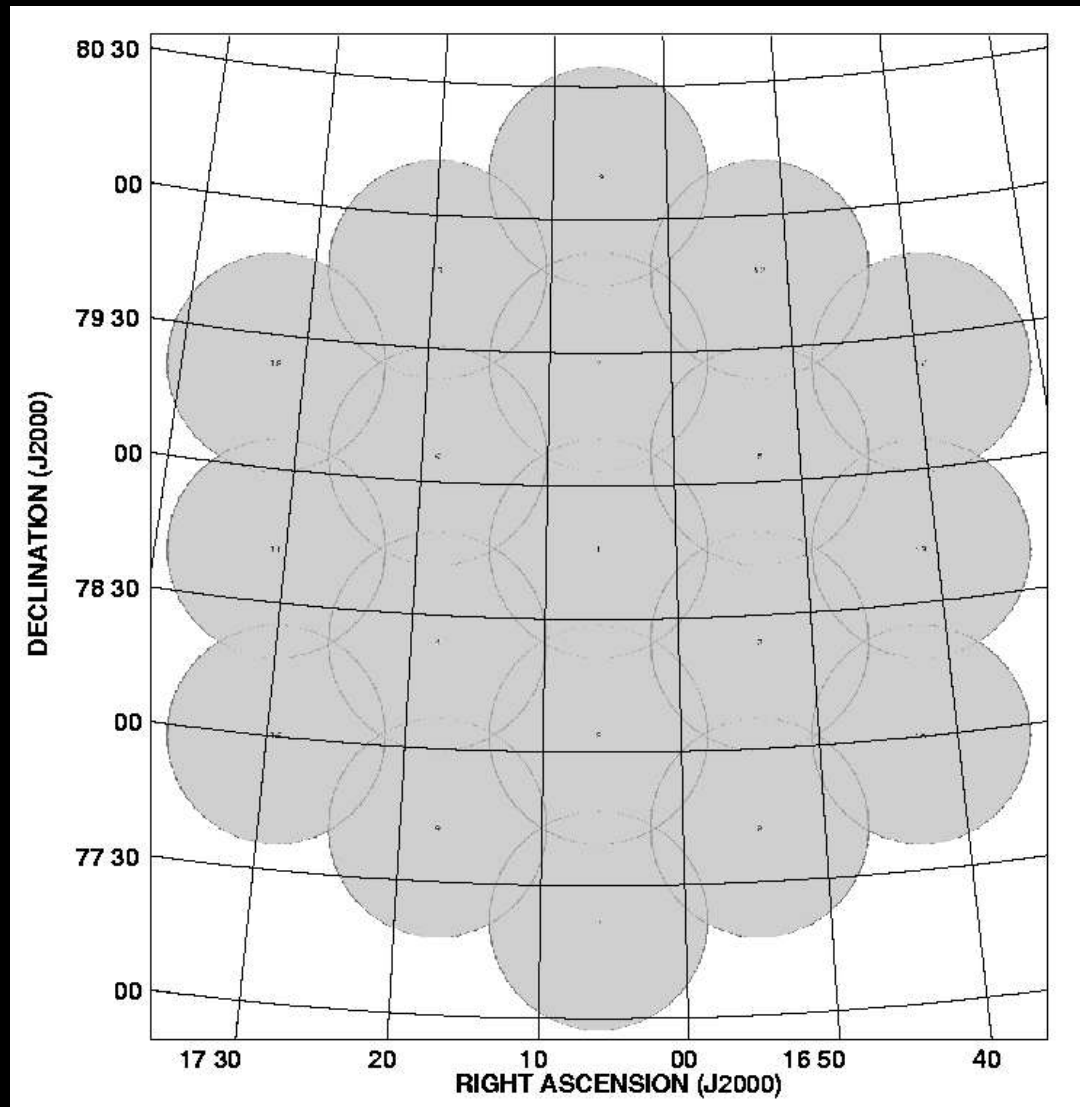
Cleaning all facets by "overlap 2" mode

Field Cleaned over all facets with overlap=2 mode. The strong source in the outer sidelobe has been Cleaned rather well, including sidelobes passing through the center region. Residual calibration, beam, and pointing effects remain.

What you can already do in AIPS
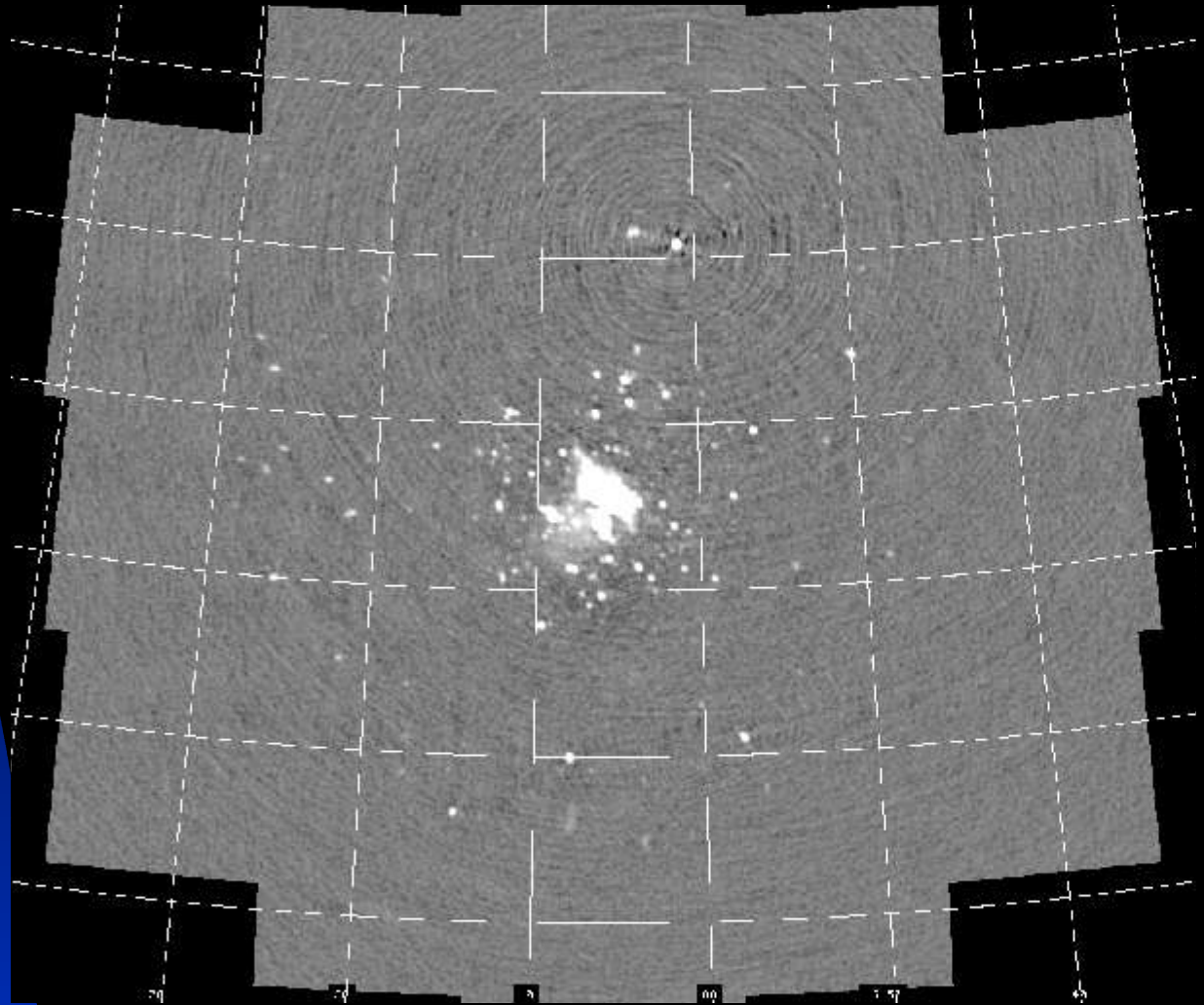
Were 3D facets really needed?

Single large facet imaged and Cleaned with no geometrical corrections. Note remaining unCleaned sidelobes and defects all of which are worse than in the 3D multiple-facet image. Note also several sources in the second outer sidelobe of the single-dish beam.

What you can already do in AIPS
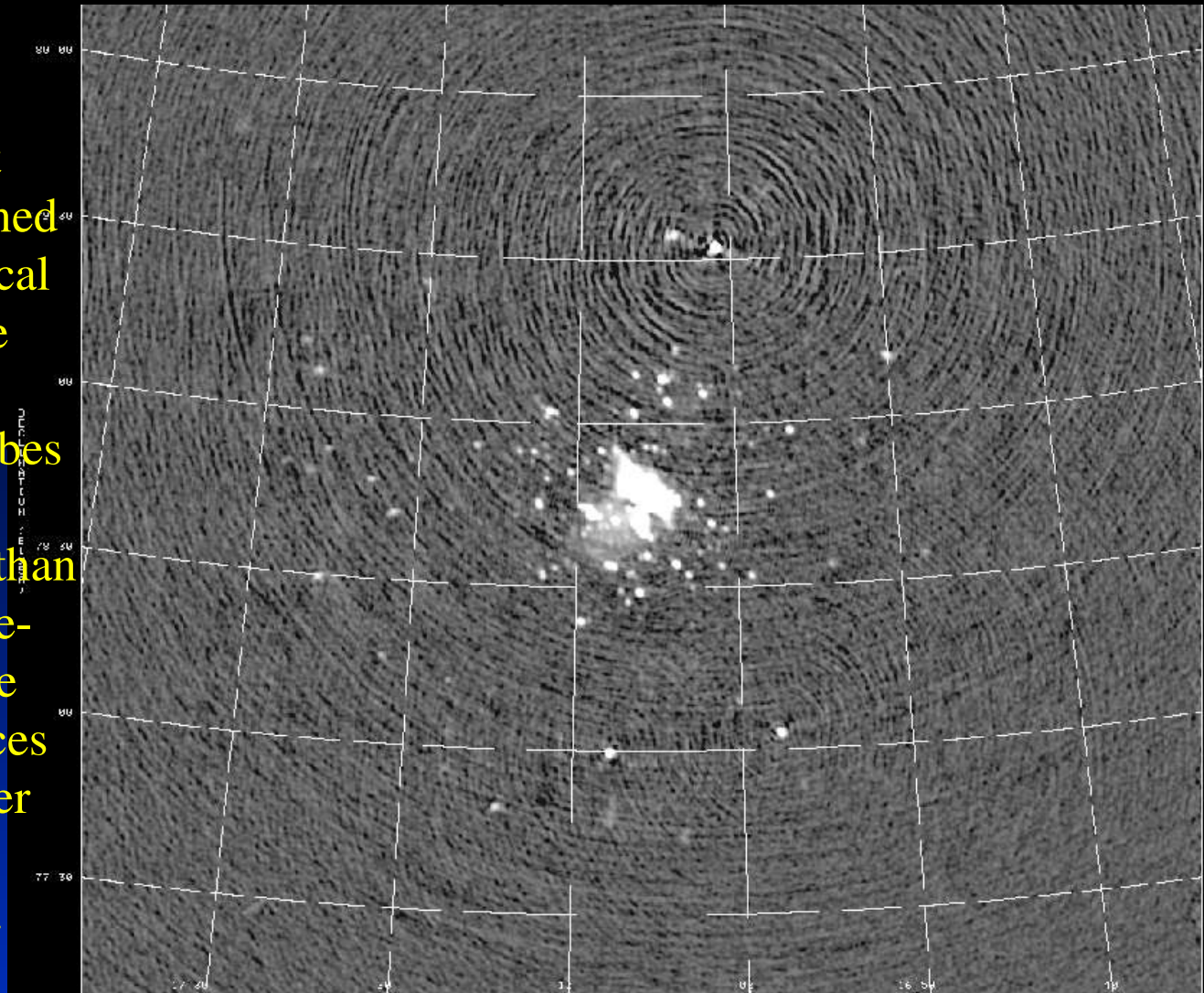
Multi-scale Clean

- IMAGR implements a multiple-scale form of Clean suggested by Wakker & Schwarz and extended by Holdaway & Cornwell.

- The multiple facets are used to Clean full resolution images of each facet with a point model plus tapered images of each facet with one or more Gaussian source component models.

- Cotton/Schwab/Clark Clean is used to subtract the model visibilities in the uv plane and then re-image.

- Scaling option is employed to reduce the tendency to favor the lowest resolution (since it integrates over the greatest flux).

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Point versus multi-scale: Facet 1
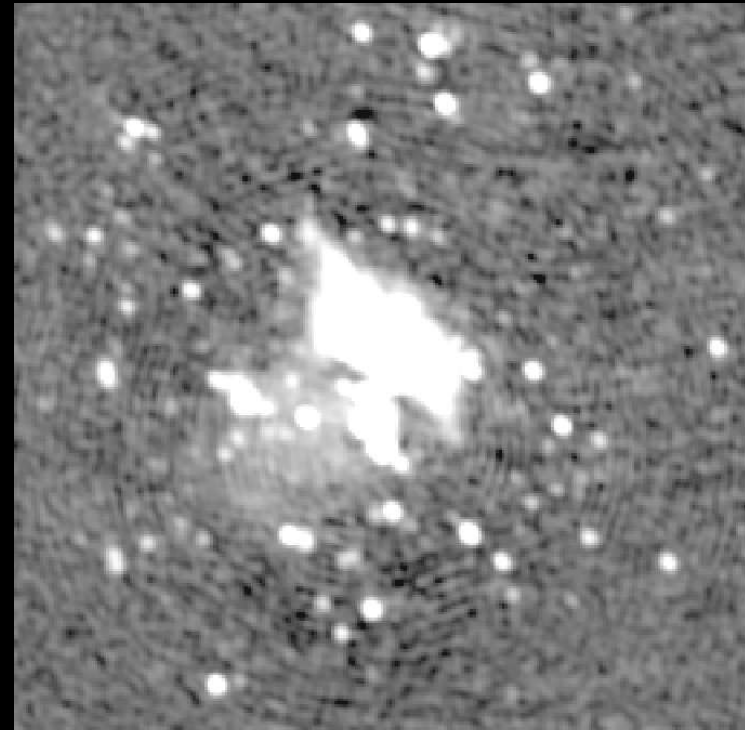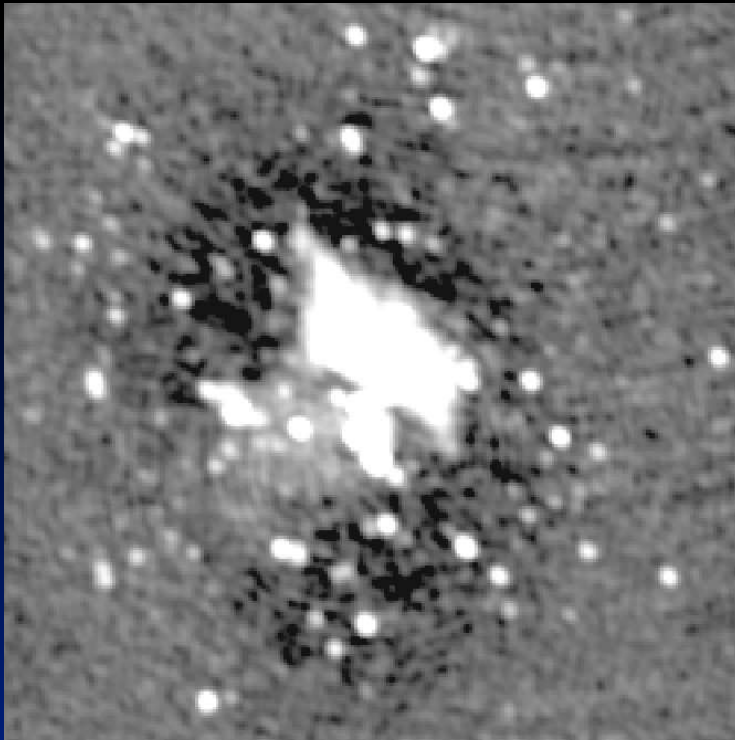
- Point-source model only Clean (left) leaves a negative "bowl" around and in the cluster due to absence of very short-spacing data.
- Multi-scale Clean (right) reduces this effect.

What you can already do in AIPS

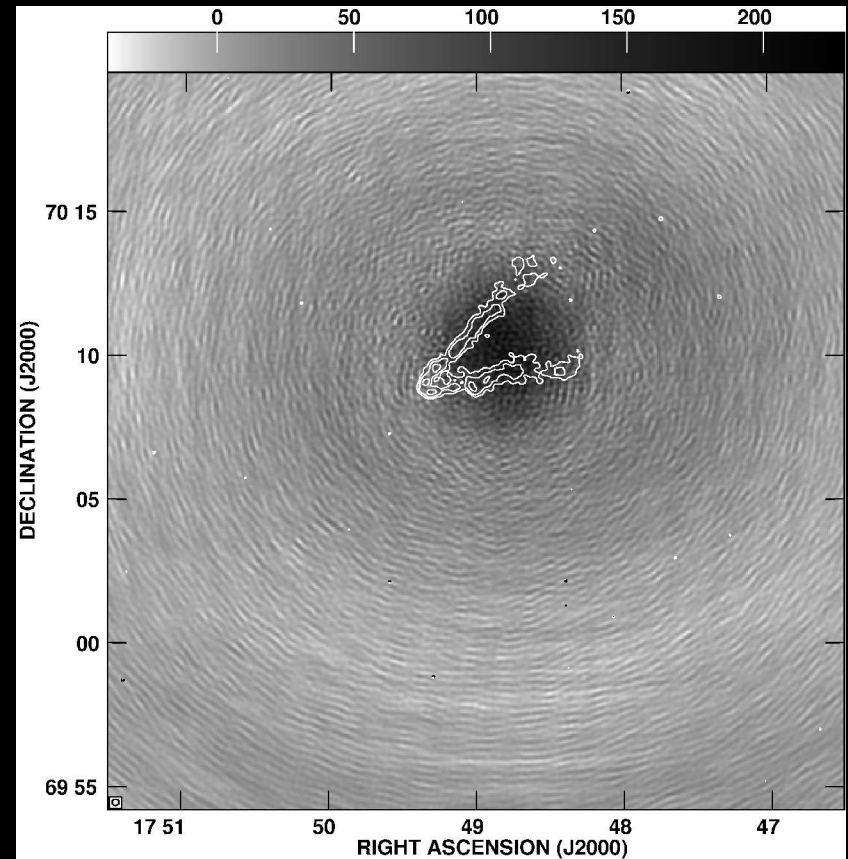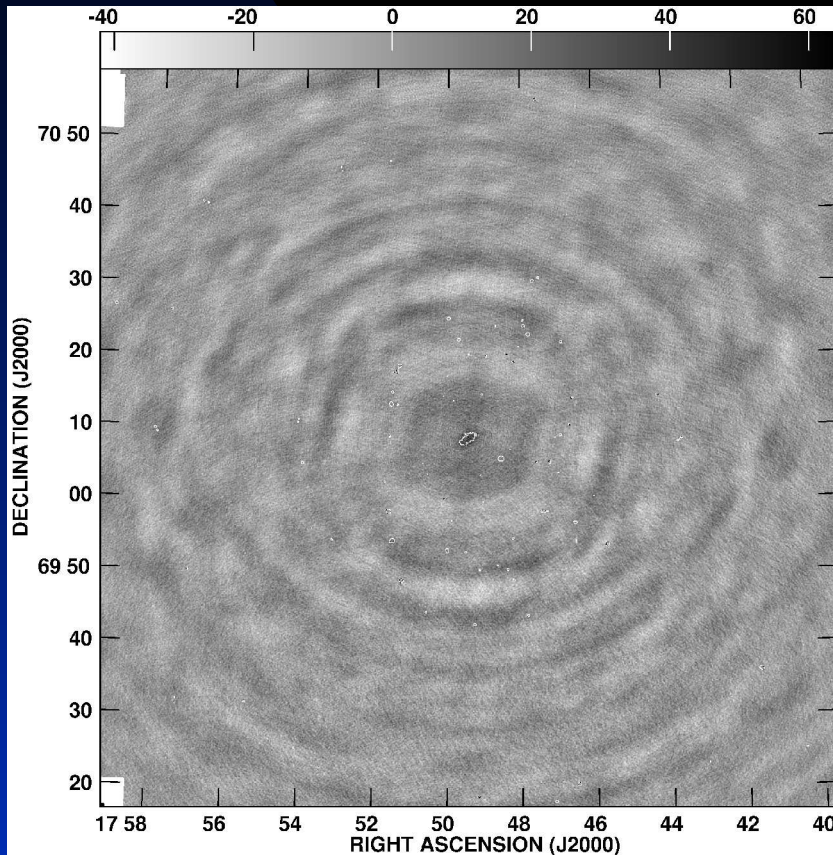# Point versus multi-scale: Full image

Blue:
  facet image,
Green:
  point image,
 Red:
  Multi-scale
image

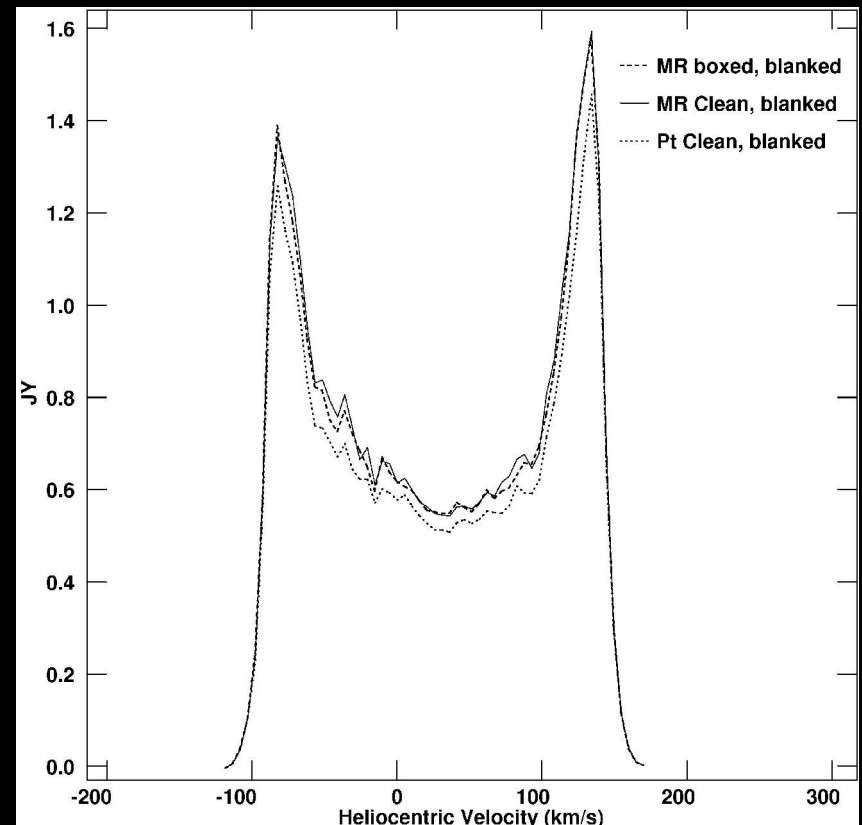Note: grating rings
of inner "bowl" in
point-model Clean

What you can already do in AIPS
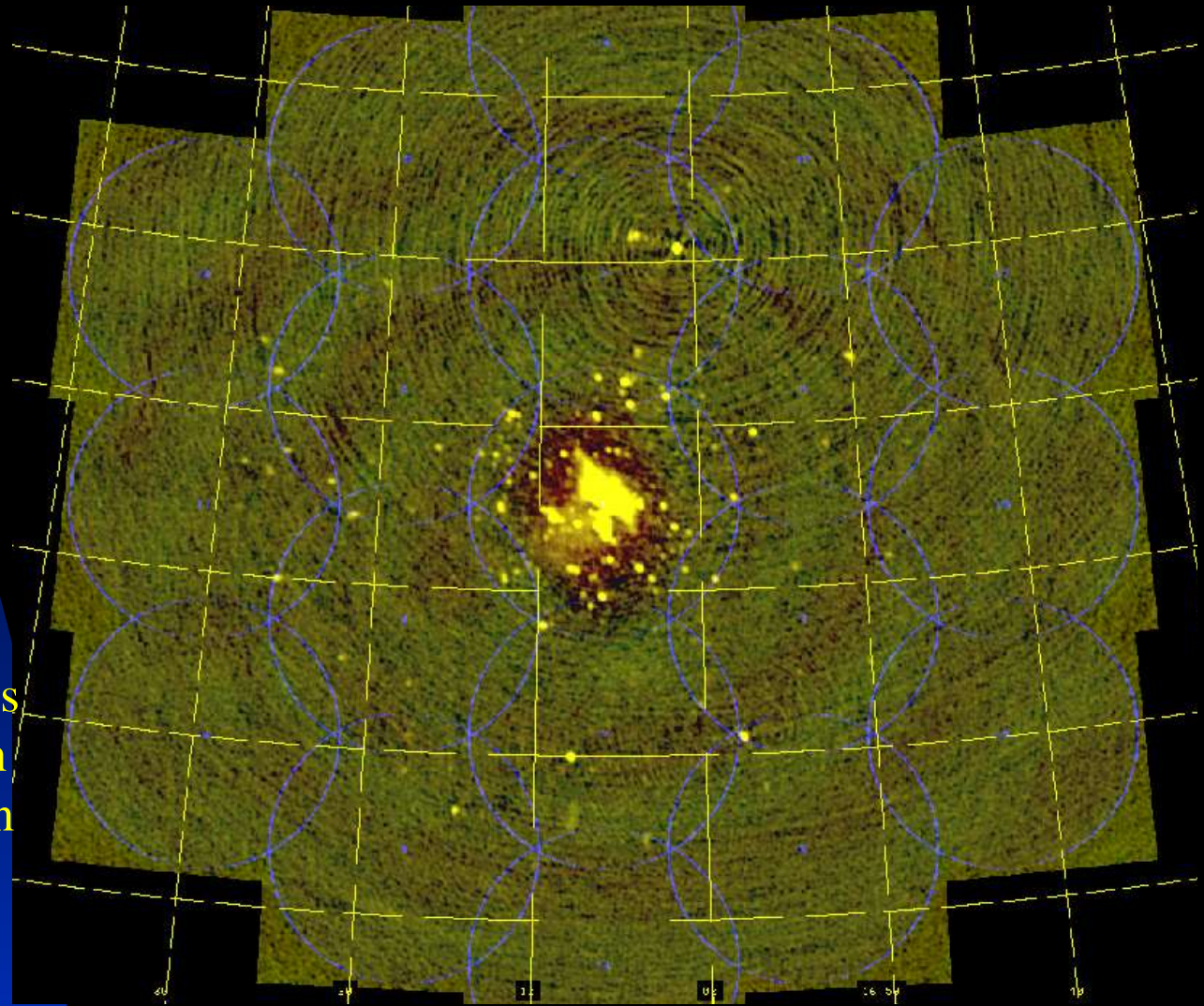
Differences: MS – pt Cleans

- Continuum and a line channel: contours sketch the final image

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Total HI spectra: MS vs pt Clean

- No blanking (left), with blanking applied (right)

What you can already do in AIPS
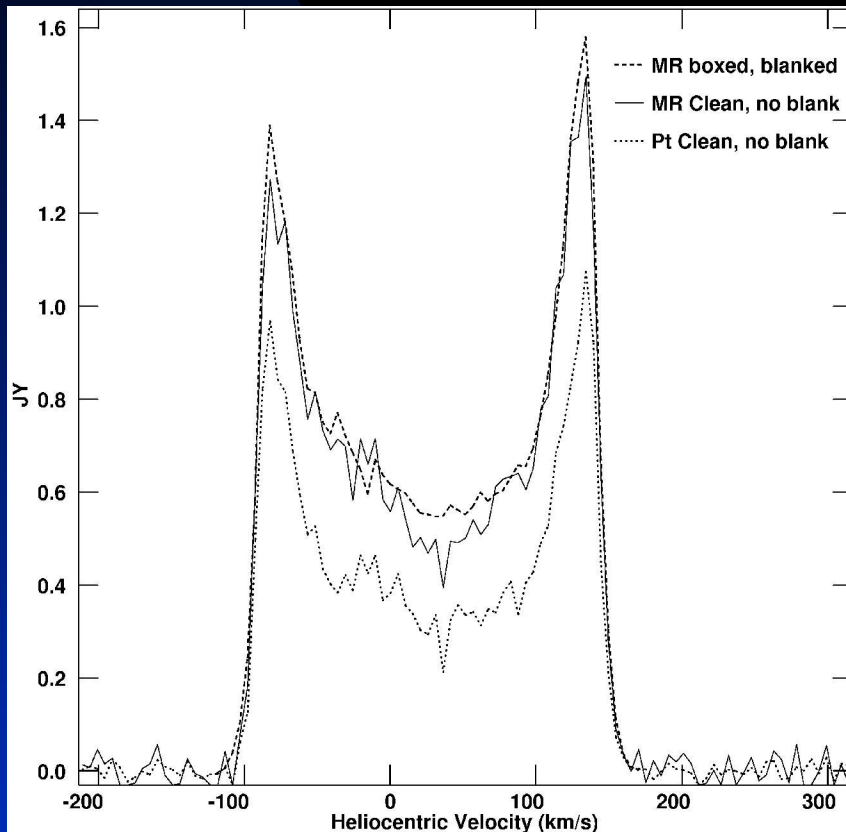
# Other IMAGR options:

- SDI Clean method

- Multi-frequency synthesis beam correction

- MFS correction for images of spectral index and curvature

- Removal of weak/isolated components (or all components in areas that are negative)

- Recently changed modeling and imaging code to use large memory, computing multiple models or facets for a single read of the UV data set

What you can already do in AIPS

PEELR: position-dependent self-calibration

1. UVSUB subtracts full model of all facets from data
2. UVSUB restores model of 1 facet (all scales) to this residual
3. CALIB A&P self-cals with that 1 facet as model
4. UVSUB subtracts 1-facet model from self-calibrated data
5. CLINV inverts the solution table from the self-cal
6. SPLIT applies the inverse SN table to the residual data
7. UVSUB restores full model to data

What you can already do in AIPS

PEELR: Before and after

What you can already do in AIPS
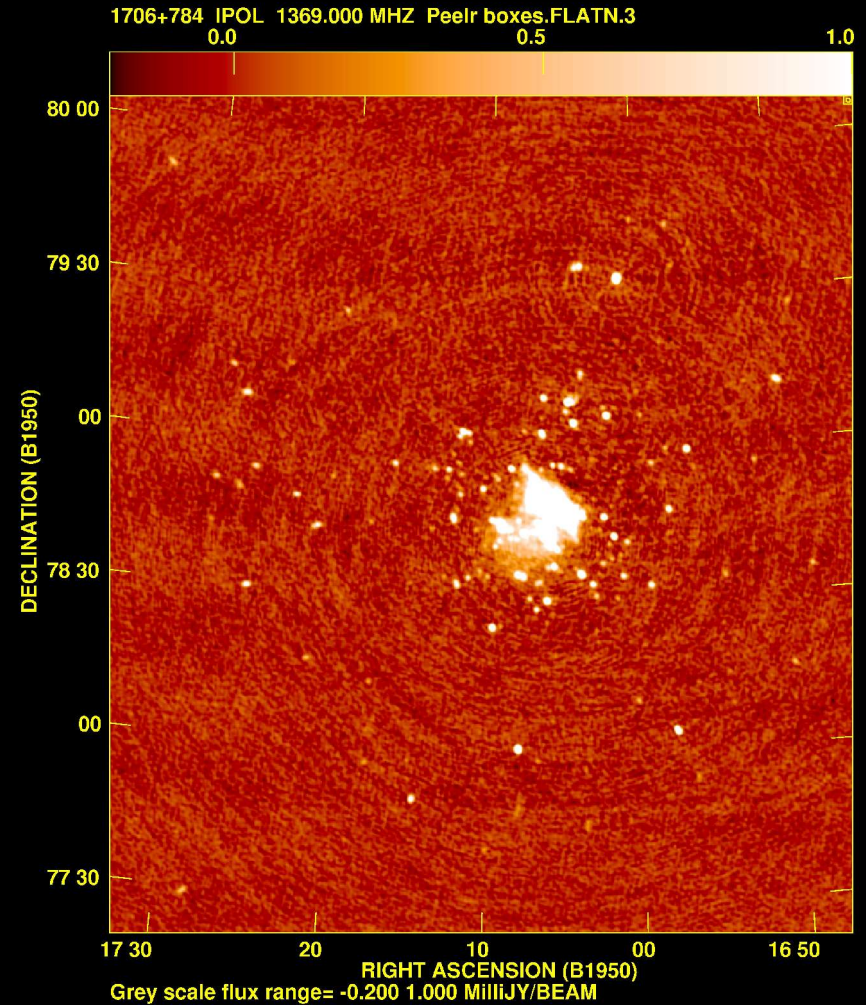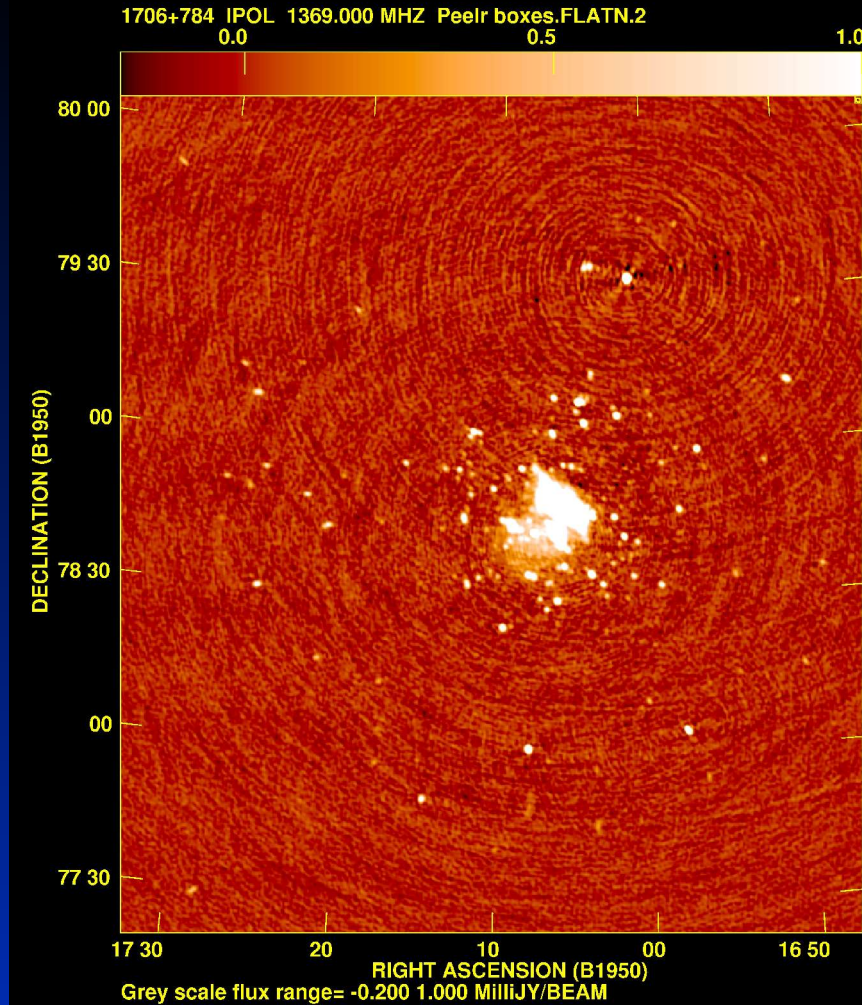
Summary

- All matters presented here should be well known, but imaging beyond the primary beam and multi-scale Clean are little used.
- Wide-field imaging is needed at longer wavelengths to reduce the effects of interfering sources and non-coplanar baselines.
- Multiple facets, each tangent to the celestial sphere, are a good way to solve the "3D" or non-coplanar array problem at surprisingly little cost.
- Cleaning with multiple sizes of component model can reduce effects of missing short spacings and large diameter sources.
- Simplistic beam-pattern and spectral-index correction methods are offered but improved algorithms are required.
- Disk I/O will dominate costs with future data sets.
- Classic AIPS has made these algorithms available to a wide range of users on a variety of computers. Multiple facets with multiple source models are supported in all data modeling used in calibration, editing, and display.

What you can already do in AIPS

Wide-field imaging: the problem
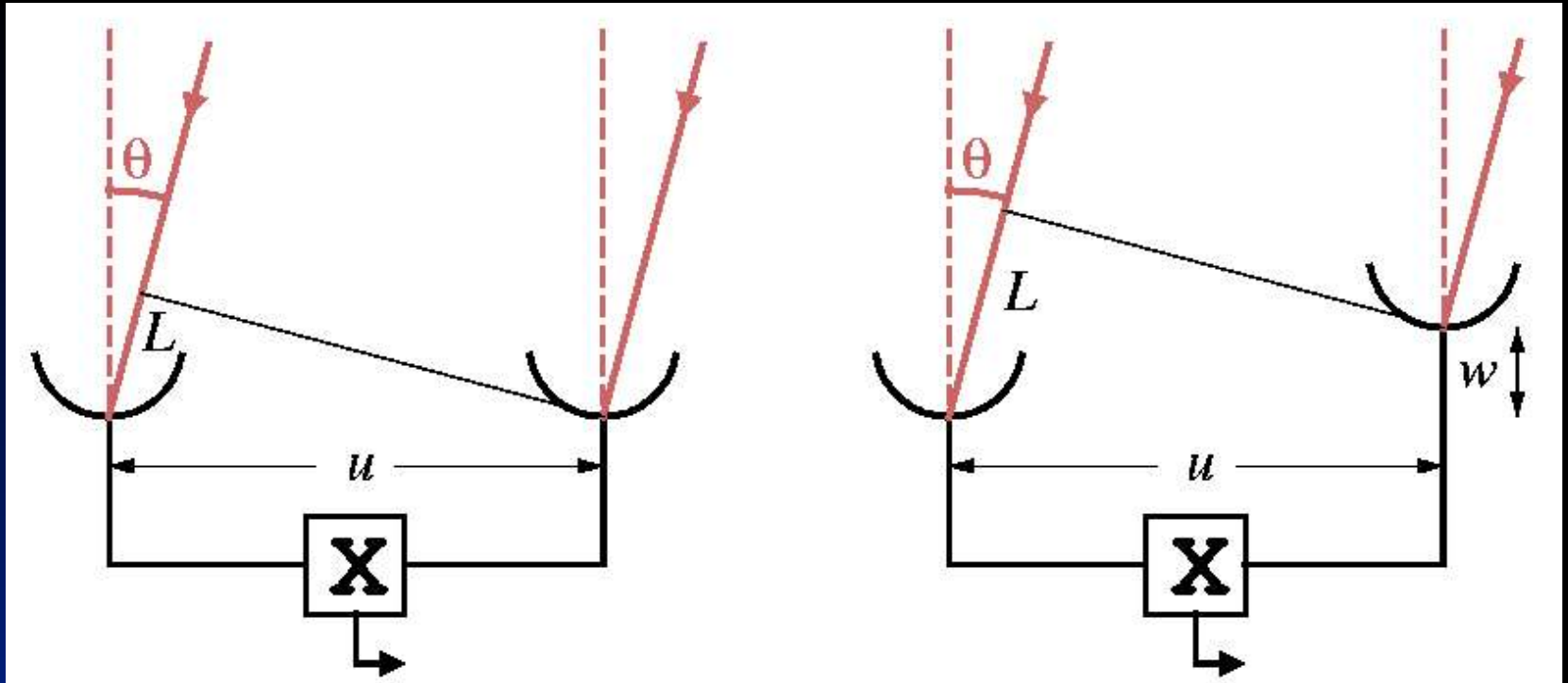
Non-coplanar array has w term in the equation for phase

$$\phi_l = 2\pi ul = 2\pi u \sin\theta$$
$$\phi_r = 2\pi \left[w(\cos\theta - 1) + u\sin\theta \right]$$
$$\phi_r = 2\pi \left[ul + w(\sqrt{1 - l^2} - 1) \right]$$

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