Magnetic field extrapolations

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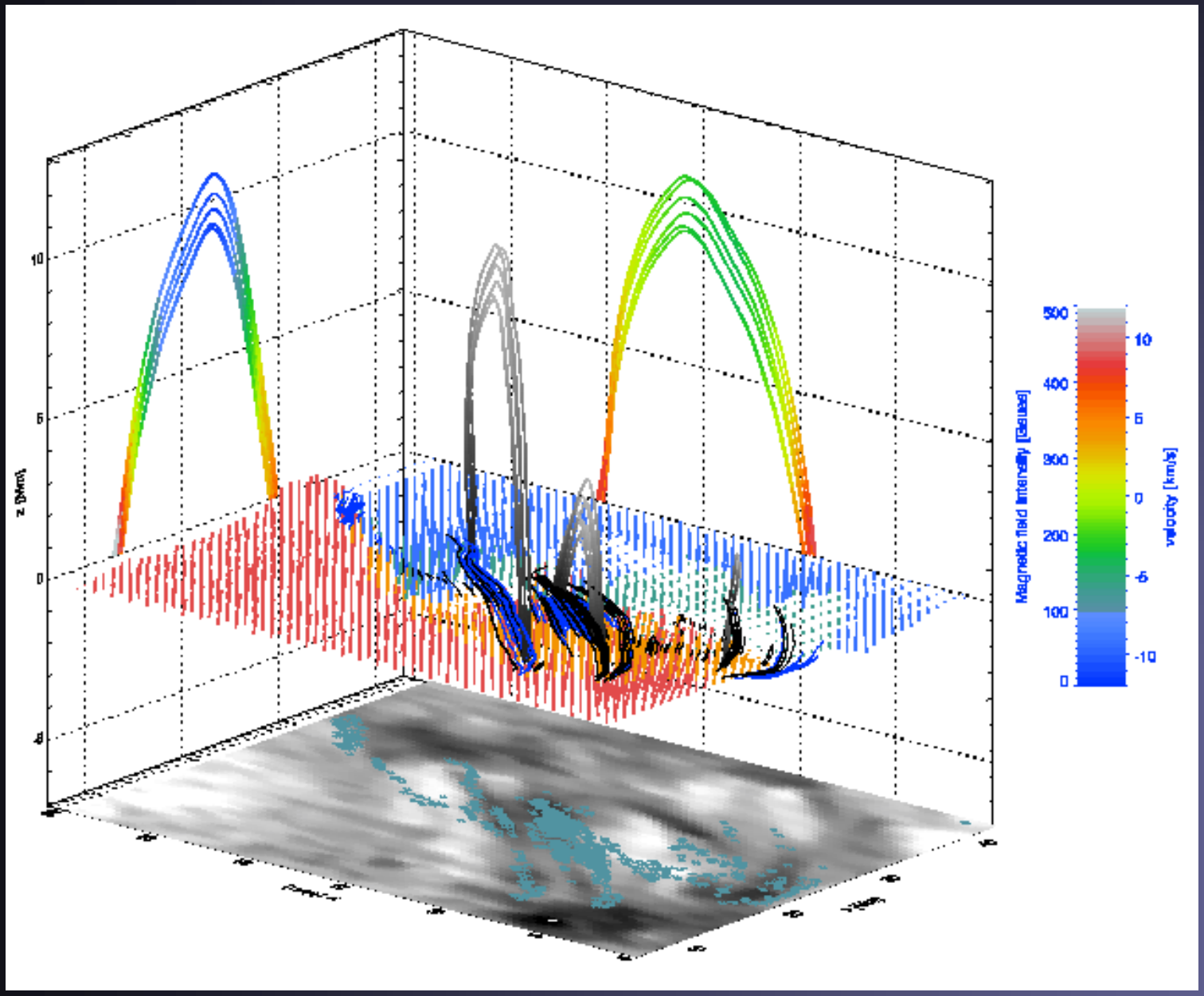
Magnetic loops from new diagnostic of magnetic vector at coronal base



Magnetic loops deduced from measurements of He I 10830 Å

Stokes profiles in an emerging flux region.

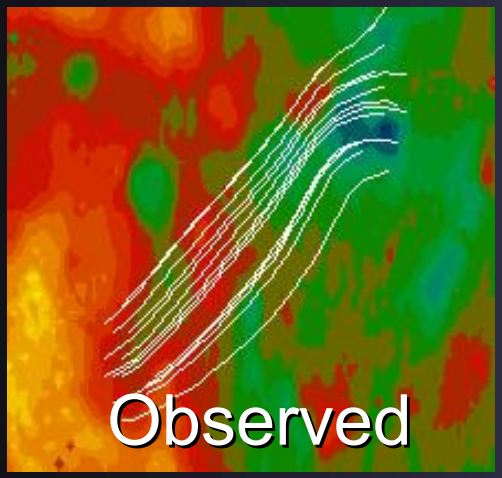
Left projection: Field strength

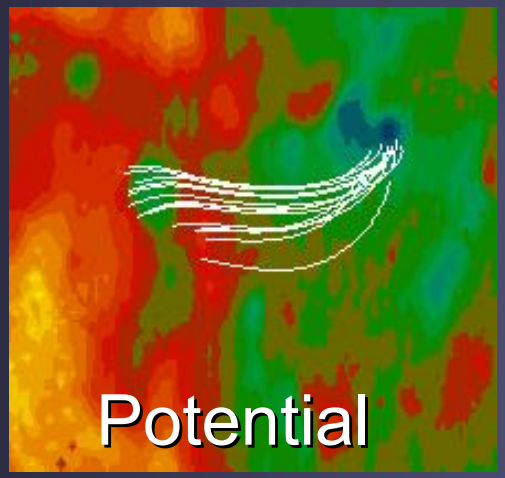
Right projection: Vertical velocity

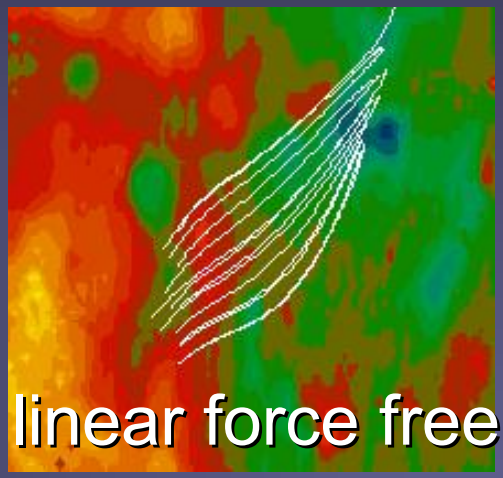
Solanki et al. 2003, Nature

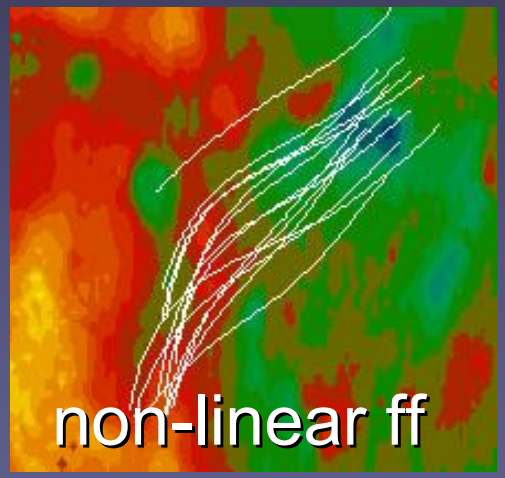
Testing Magnetic Extrapolations using B measurements

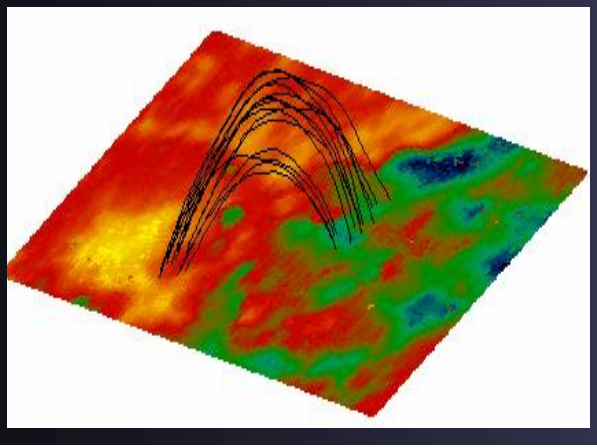
- Non-linear force-free fields reproduce the loops reconstructed from observations signif. better than the linear force-free ones which are much better than potential fields.
- Loops harbour strong currents while still emerging.



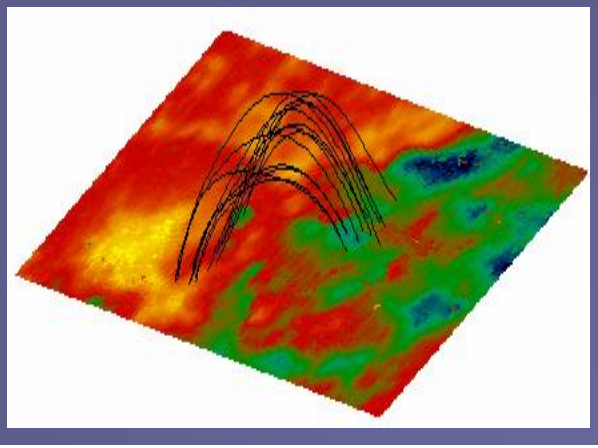








Wiegelmann et al. 2005



What if coronal B-field is not known?

- Extrapolate from photospheric magnetic field
  (if linear force-free field, then with arbitrary value of α)
- Compute magnetic field lines and their projection onto an EUV-image.
- Use EUV-image to compute intensity and intensity gradient along the projected field lines.
- Check how well field lines and plasma features agree (See next slide for a quantitative measure, *C*)
- For a linear force-free model repeat procedure with different value α until global minimum in C is reached

Check how well projected field lines and plasma features agree

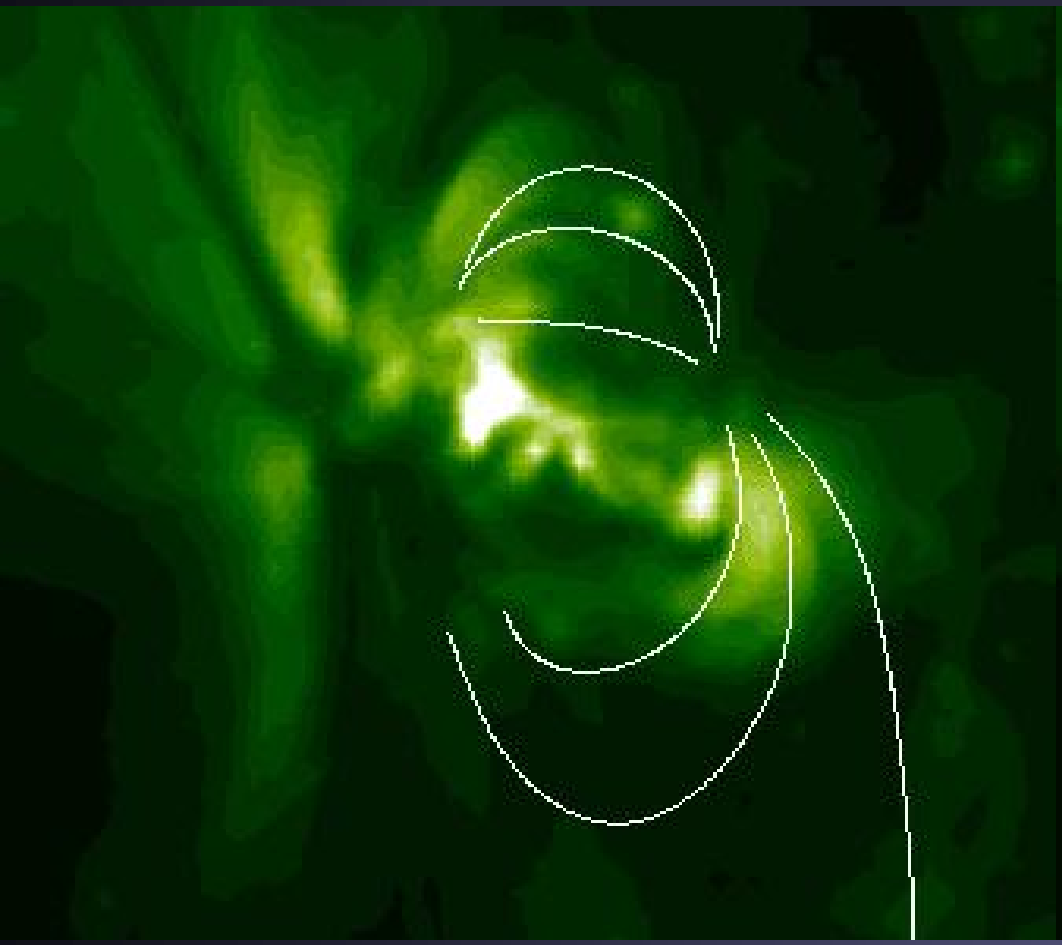
$$C = \frac{\int_0^l |\nabla \rho| ds}{l\left(\int_0^l \rho \, ds\right)^2}$$

(Wiegelmann et al. Sol. Phys. 2005)

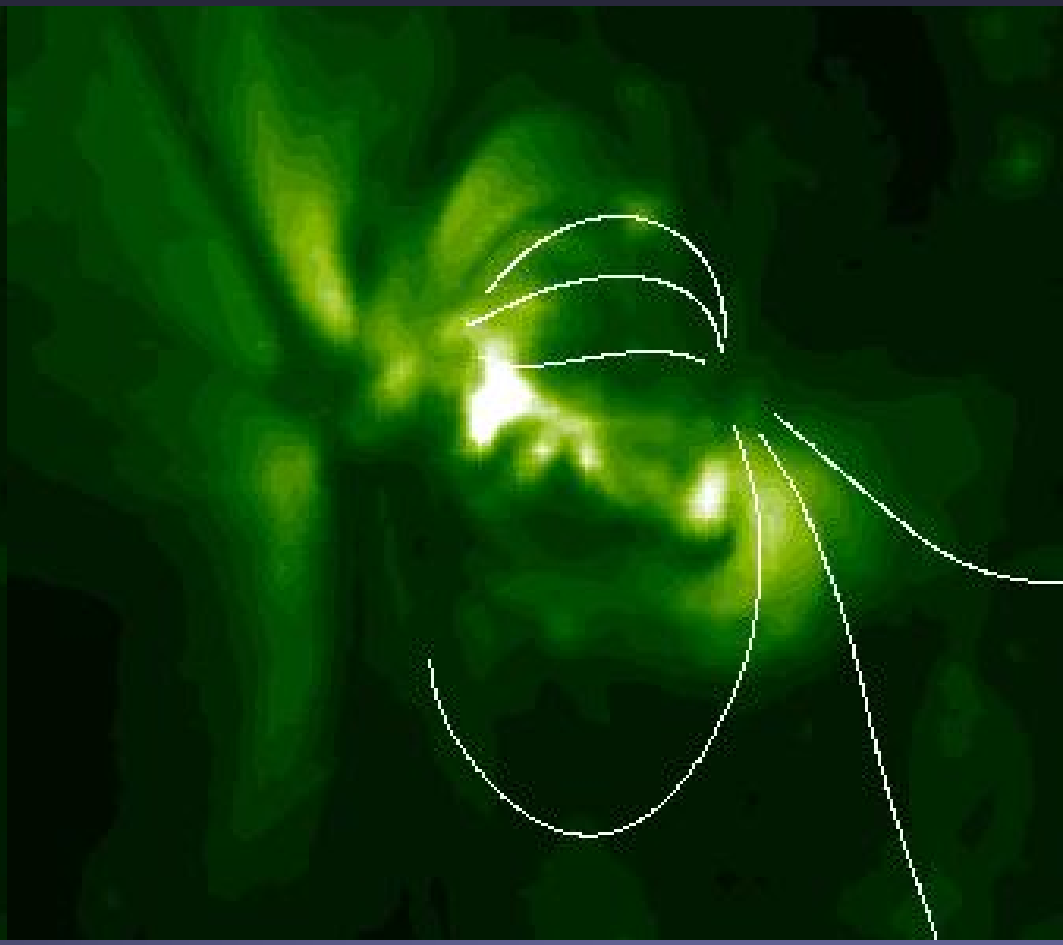
where l is the projected loop length, ρ the intensity, $\nabla\rho$ is the gradient along the field line.
The smaller the C, the better the reconstruction.
This measure gives higher weights to bright and long loops. (Used/Optimized for SOHO/EIT)

Example: Active Region AR 7953

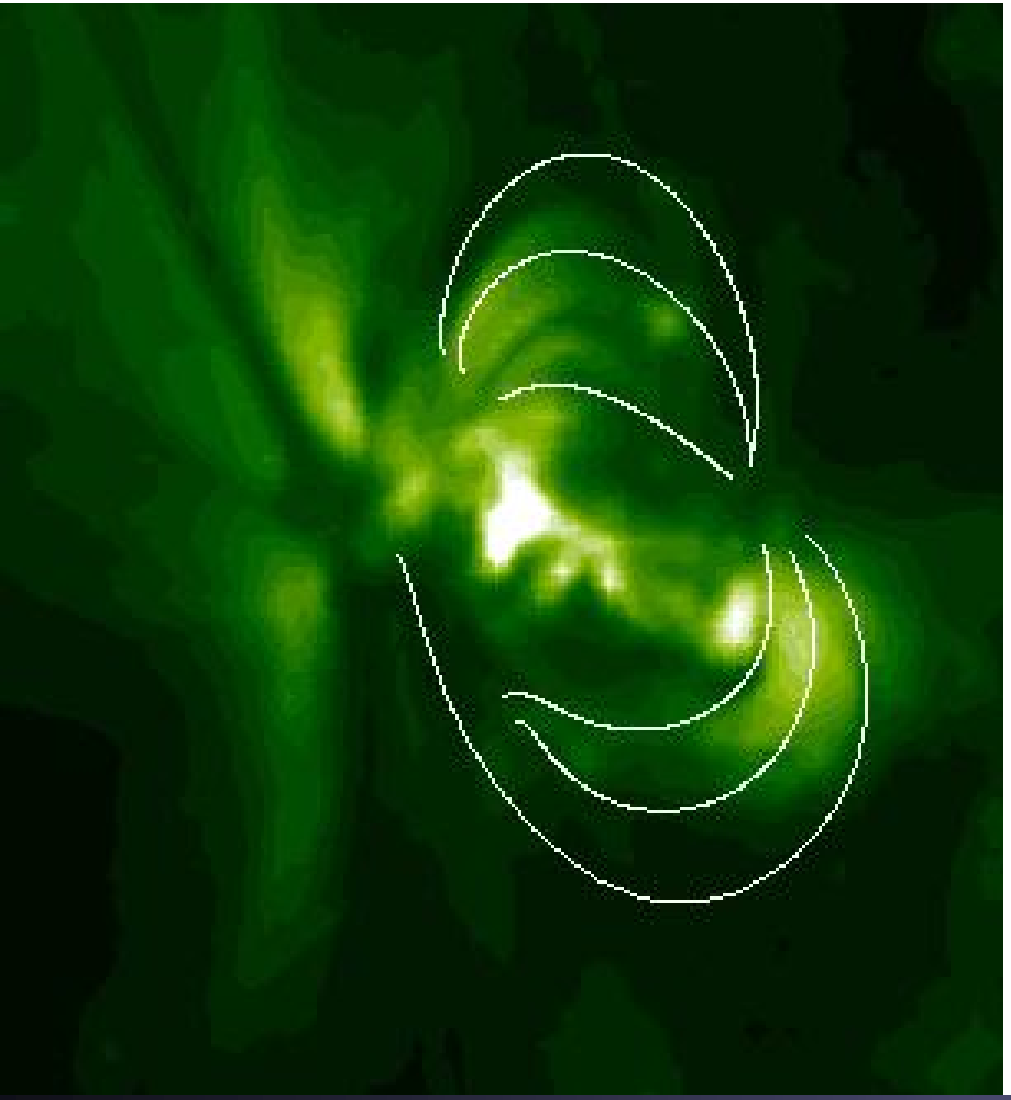
Linear force-free model, different values of force-free parameter α.



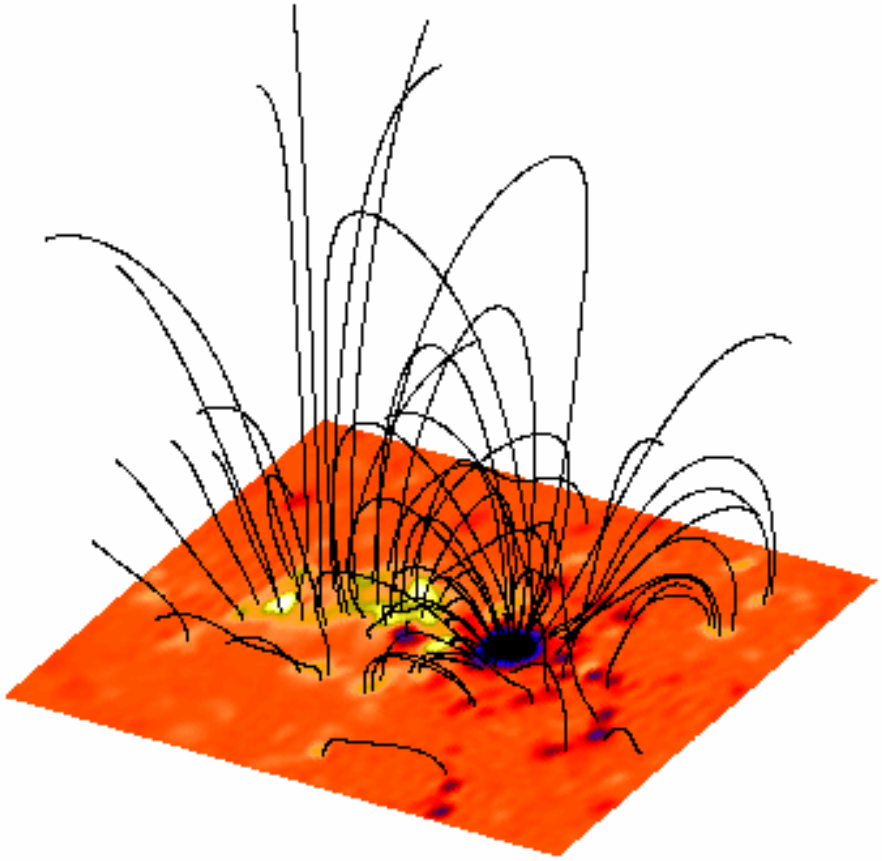
EIT-image & projected magnetic field lines for a potential field ($\alpha = 0$) (poor agreement)



Linear force-free field with $\alpha = +0.01$ [Mm^{-1}] (even worse agreement)

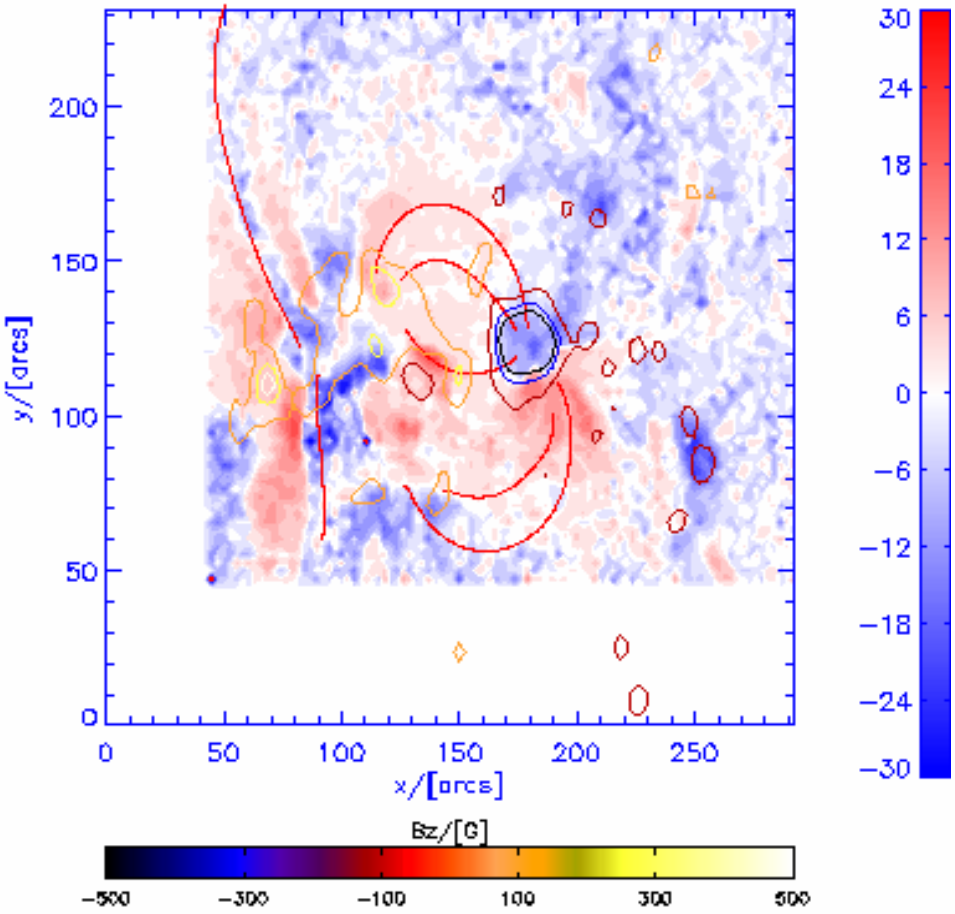


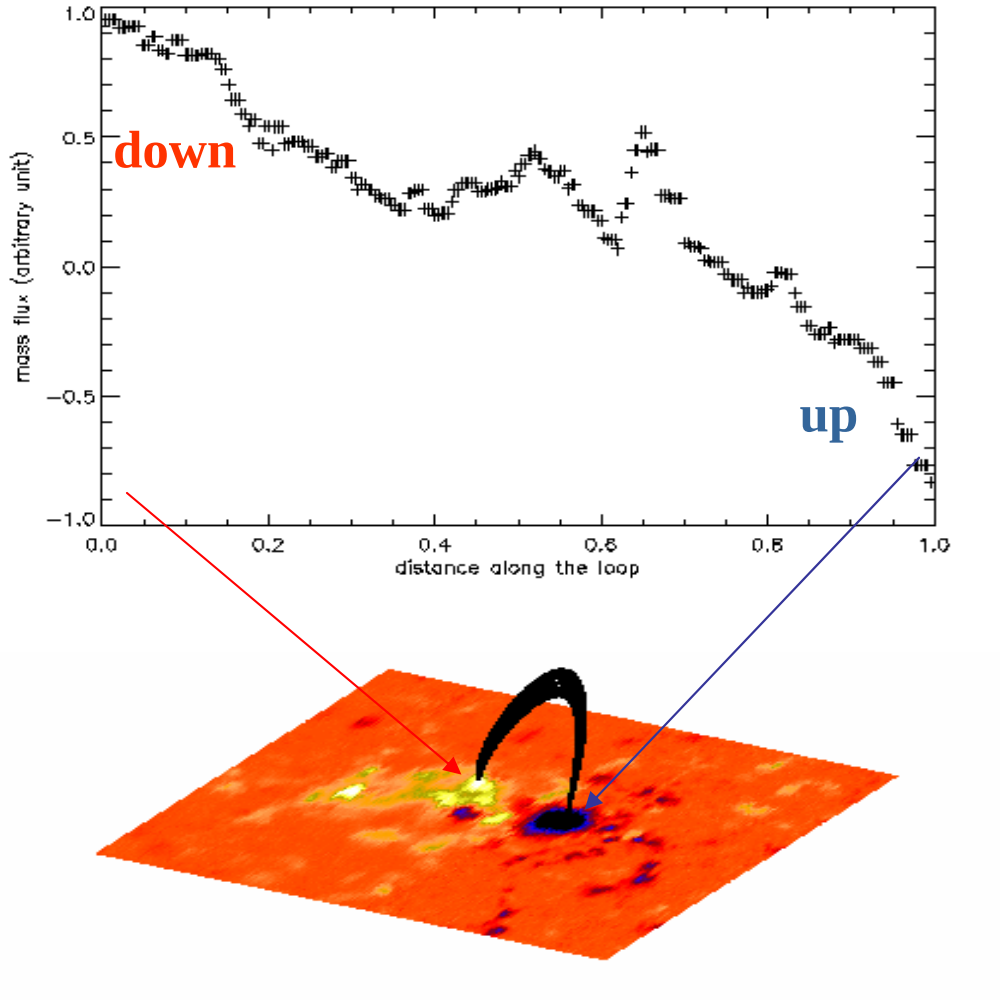
Linear force-free field with
$\alpha = -0.01$ [Mm^{-1}]
(better agreement)



3D-magnetic field lines,
linear force-free $\alpha = -0.01$
[Mm^{-1}]

Example of use of 3D extrapolated magnetic field





SUMER Dopplergram in NeVIII (λ 77 nm) and a 2-D-projection of some field lines.

Marsch et al. A&A 2004

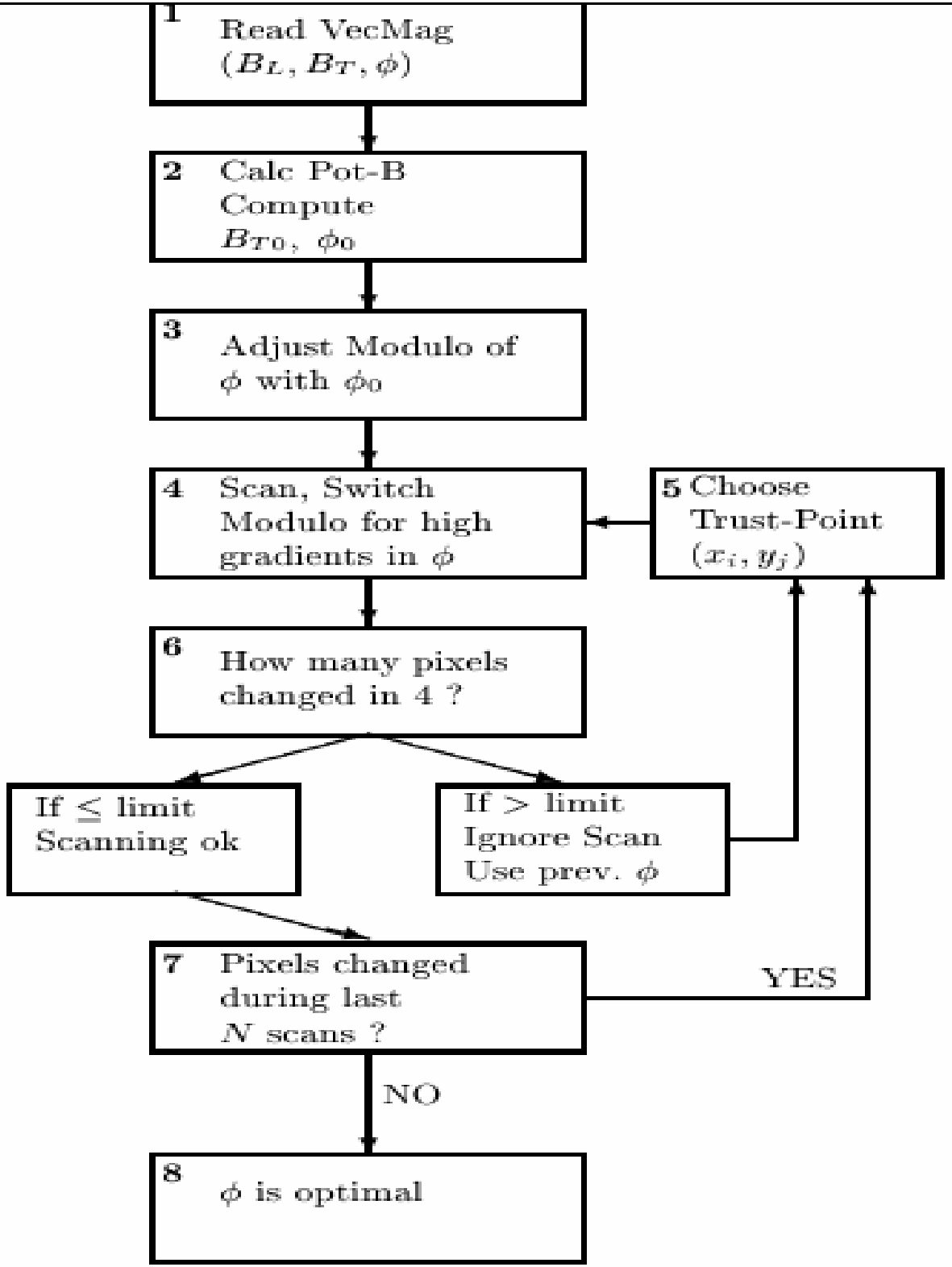
Mass flux density inferred from Dopplershift and intensity from SUMER observations.

Extrapolations: some problems

- How much does noise in magnetograms influence extrapols?
  - White noise has all freq. ➔ affects all layers of extrapols
  - Problem mainly for non-linear ff extrapols, since noise in transverse field > 10x larger than in longitudinal field
- 180^{o} ambiguity, how to get round it?
  - Only affects non-linear ff extrapolations.
  - Major problem: information simply isn't there. All methods to resolve problem make assumptions about field.
  - ➔Use comparison with loops to solve problem?
- Can thermal energy of gas really be neglected?
  - Not a problem for HMI+AIA (lower corona)?

Extrapolations: some problems

- How much does noise in magnetograms influence extrapols?
  - White noise has all freq. → affects all layers of extrapols
  - Problem mainly for non-linear ff extrapols, since noise in transverse field > 10x larger than in longitudinal field
- 180° ambiguity, how to get round it?
  - Major problem: information simply isn't there. All methods to resolve problem make assumptions about field.
  - →Use comparison with loops to solve problem?
- Can thermal energy of gas really be neglected?
  - Mainly a concern in outer corona (streamers)



180 degree ambiguity

The method initially chooses the ambiguity to minimize the angle with a corresponding potential magnetic field. In subsequent steps flips in the ambiguity of adjacent points are removed. The method is limited to strong field regions, where the signal for the transversal field is well above the noise level.

Solar-B and extrapolations

- Solar-B: ideal mission!
  photospheric vector maps ← → coronal structures
  → benefit for extrapolation techniques
- extrapolations fill the observational gap of Solar-B in chromosphere
- additional information from extrapolations (eg. currents)
- helps in resolving 180° ambiguity
  → benefit for Solar-B data interpretation

→ Solar B and extrapolations are complementary