Inhomogeneous stellar jets: tomographic reconstruction

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Protostellar Jets in Context, 2008

In collaboration with:

- Carlos del Burgo (DIAS)
- Alejandro Raga (ICN, UNAM)

See:

De Colle, F., del Burgo, C., & Raga, A.C., A&A 485, 765 (2008)

Aim

How to extract from observations the “real” 3d jet structure?

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How to extract from observations the “real” 3d jet structure?

- To have a better understanding of the jet physics
- To compare numerical simulations/disk-wind/x-wind models with observations

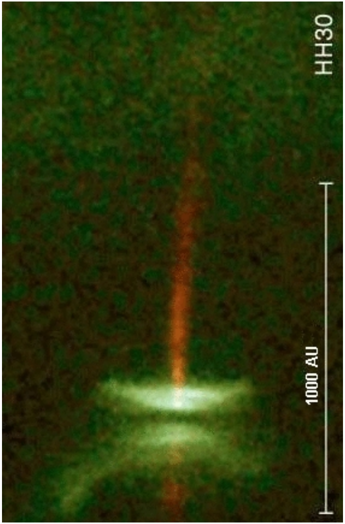
Outline

1. **Introduction**
   - Jet diagnostics
   - Interpretation problems
2. **Reconstructing the jet structure**
   - Abel transform
   - Inversion of the Abel transform
3. **Application**
   - Data: HH30
   - Data inversion

Jet diagnostics

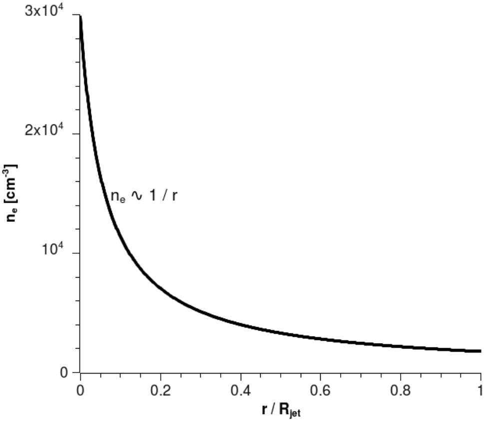
1. Using line ratios
   - Density determination by [SII] lines (*e.g. Osterbrock 1989*)
   - BE method (*Bacciotti & Eisloffel 1999*)
   - Near-IR + optical diagnostics (*Nisini et al. 2005, Podio et al. 2006*)
   - Extended to include more line ratios (*Hartigan & Morse 2007*)
2. Shock models
   - *e.g. Hartigan et al. (1987, 1994)*

Interpretation problems



- Observing conditions (seeing)
- Instrumental effects
- Projection/convolution effects

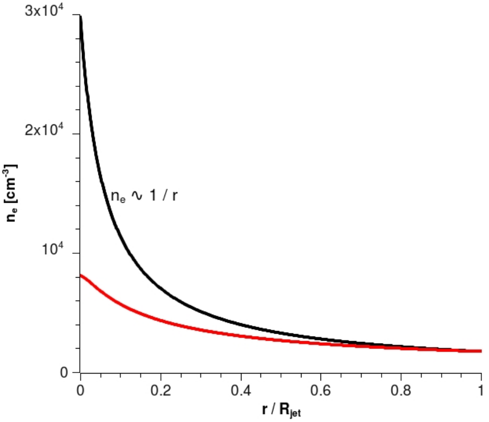
Projection and convolution effects



Axisymmetric jet , $T_e = 10000$ K, $n_e \sim 1/r$

1. $n_e \rightarrow [SII]\lambda 6716, 6731$
2. $[SII] \rightarrow [SII]_{obs}$
3. $[SII]_{obs} \rightarrow n_{e,obs}$

Projection and convolution effects



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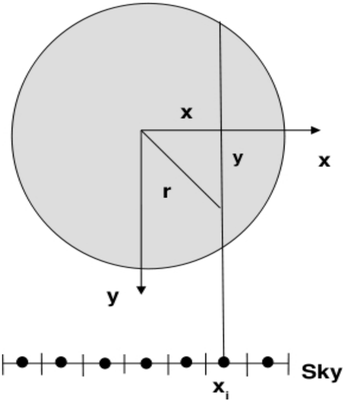
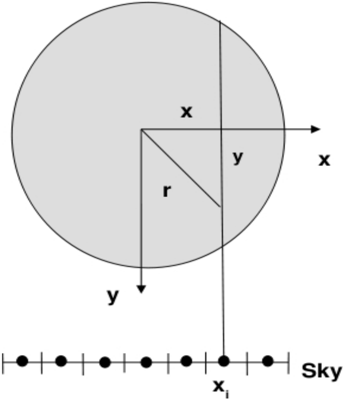
Abel transform



Hp: Axisymmetric jet

Note:
not adding any extra hypothesis.
Homogeneity $\Rightarrow$ axisymmetry

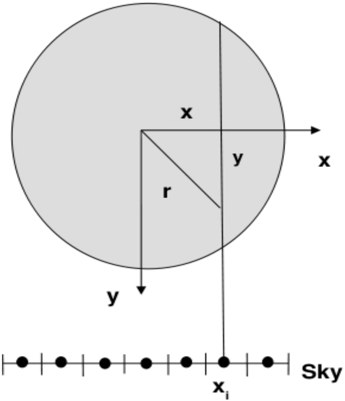
Abel transform



Hp: Axisymmetric jet

$$I(x) = 2\int_x^{\infty} i(y)dy$$

Abel transform



Hp: Axisymmetric jet

Abel transform:

$$I(x) = 2\int_x^\infty \frac{i(r)rdr}{\sqrt{r^2 - x^2}}$$

Solution:

$$i(r) = -\frac{1}{\pi}\int_r^\infty \frac{dI}{dx}\frac{dx}{\sqrt{x^2 - r^2}}$$

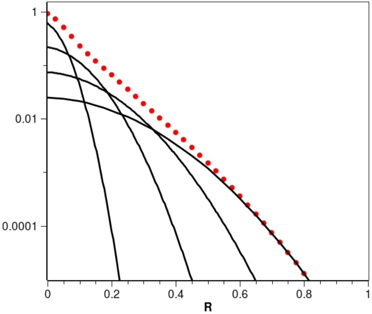
Multi-gaussian approximation

$$i(r) = -\frac{1}{\pi}\int_r^\infty \frac{dI}{dx}\frac{dx}{\sqrt{x^2-r^2}}$$

- "Ill-posed" problem
- MGA (Bendinelli 1991)

$$I(x) = \sum_{i=1}^{n} a_i e^{-(x-x_0)^2/\sigma_i^2}$$

$$i(r) = \sum_{i=1}^{n} \frac{1}{\sqrt{\pi}}\frac{a_i}{\sigma_i} e^{-r^2/\sigma_i^2}$$



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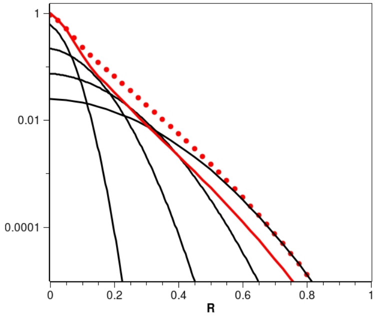
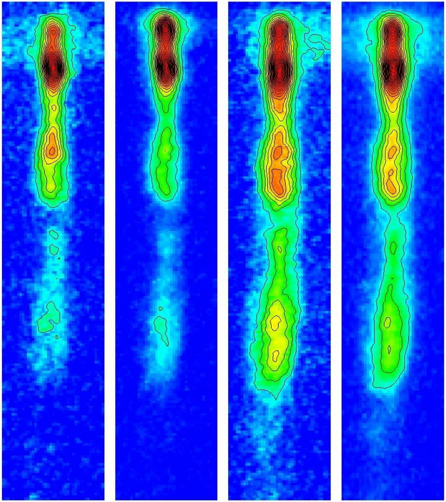


Multi-gaussian approximation

- $\Rightarrow$ smooth solution of noisy data.
- Analytical solution.
- Possible to easily include PSF deconvolution.

Data: HH30

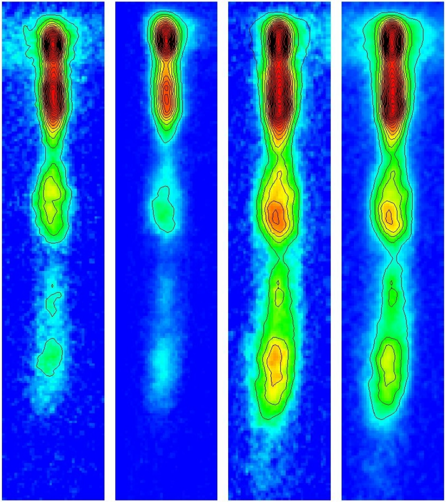


[NII]λ6583, [OI]λ6300, [SII]λ6716,6731

Hartigan & Morse (2007)

- HST: Space Telescope Imaging Spectrograph (STIS)
- Slitless spectroscopy technique
- Observations: fall 2000 + fall 2002

Data: HH30



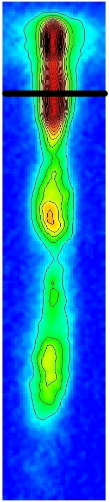
[NII]λ6583, [OI]λ6300, [SII]λ6716,6731

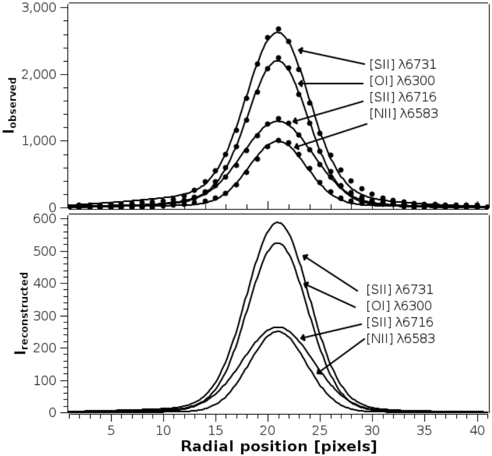
Ideal data for this analysis

- Moving in the plane of the sky
- Nearly axisymmetric
- Res. 3.4 AU pixel^{-1} (41 $\times$ 200 pixels)

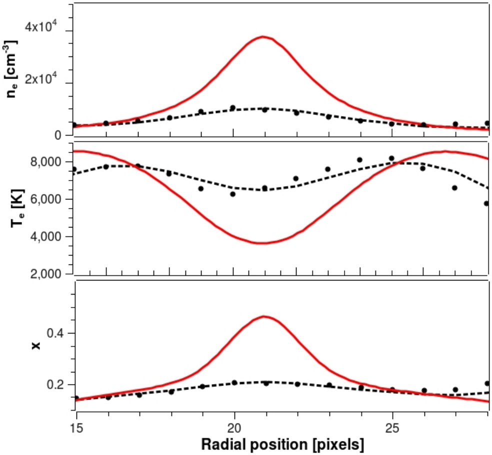
JeTseT

Abel equation inversion: intensities

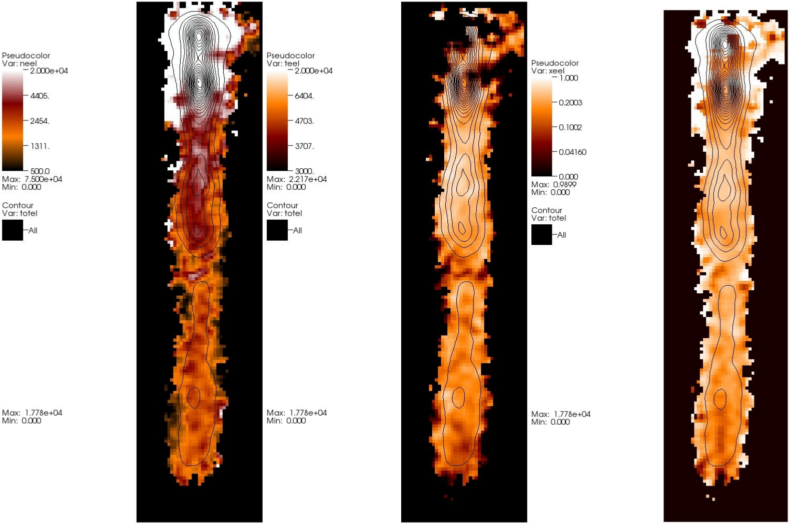




Abel equation inversion: physical parameters



n_e, T_e, x_H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2454.
1311.
500.0
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Min: 0.000
Contour
Var: totel
All
Max: 1.778e+04
Min: 0.000
Pseudocolor
Var: teel
2.000e+04
6404.
4703.
3707.
3000.
Max: 2.217e+04
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Contour
Var: totel
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Min: 0.000
Pseudocolor
Var: xeel
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0.2003
0.1002
0.04160
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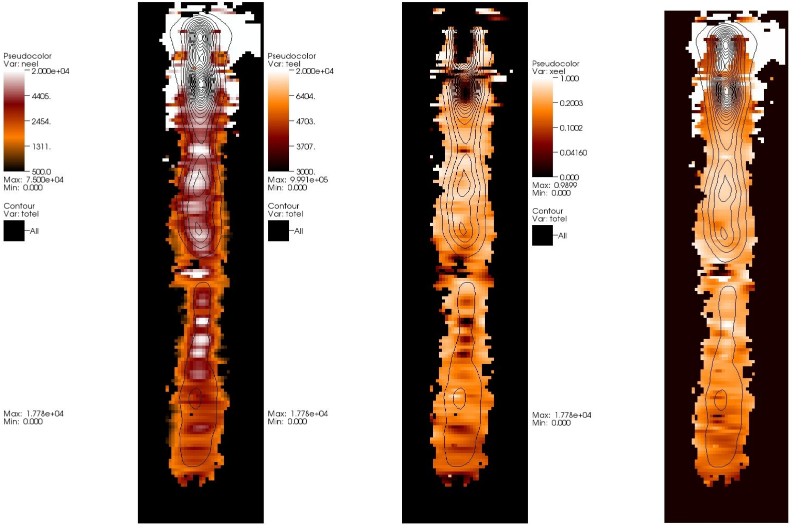
Contour
Var: totel
All
Max: 1.778e+04
Min: 0.000

n_e, T_e, x_H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Max: 7.500e+04
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Pseudocolor
Var: teel
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Var: totel
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Max: 1.778e+04
Min: 0.000
Pseudocolor
Var: xeel
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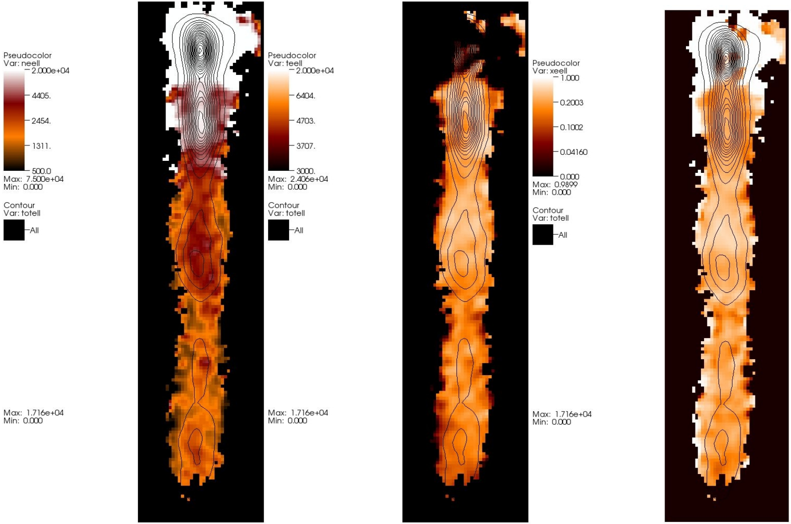
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Pseudocolor
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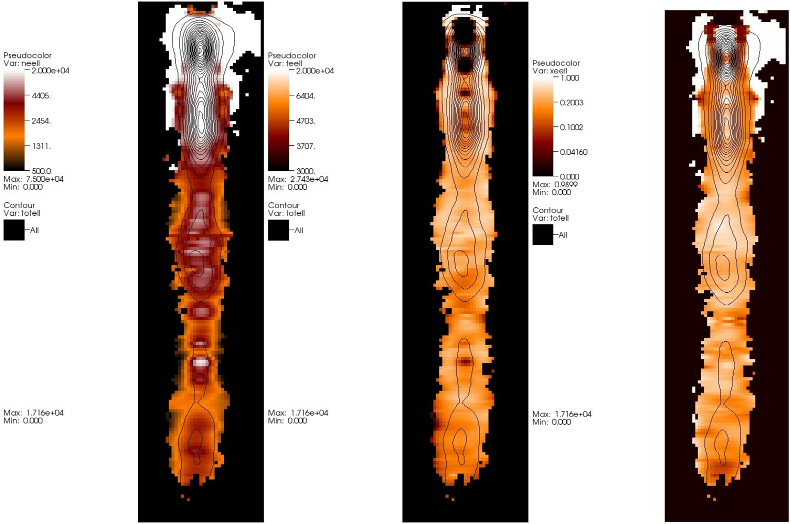
n_e, T_e, x_H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Summary

1. Take care!: jets are not homogeneous
2. But . . . , possible to reconstruct the correct dependence of the physical parameters as function of r using Abel transform.
3. HH30 (qualitative considerations):
    - much denser on the axis,
    - more structures present
    - chaotic ejection velocity variability?

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What's next?

4. Run numerical simulations to compare with the physical parameters obtained