Chasing the gas structure around the young B3-B2 star AFGL 490

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Introduction - Motivation

- Formation of high-mass stars – one of the unresolved issues of present research
- Due to many recent observations $\Rightarrow$ evidence that stars with $M_\star \leq 20\ M_\odot$ form by accretion disks

e.g.

⇨ Disks are more massive and larger than disks around T Tauri and Herbig Ae stars

⇨ However - only marginally spatial resolved

Introduction - Motivation

Selection of objects from survey of bright IRAS sources

- H_2O Maser, NH_3, HCO^+ (Henning et al. 1992, Schreyer et al. 1996)
- in sub-mm/mm continuum

(Klein, Posselt, Schreyer, Forbrich, Henning, 2005, ApJS 161, 361)

- Nearby, D ≤ 1 kpc
- Isolated objects, no optical counterpart
- Embedded in dense cloud core + high-velocity outflow

Compromise:

- In D < 1 kpc: no young stellar objects with $M_\star \geq 15(..20)\ M_\odot$

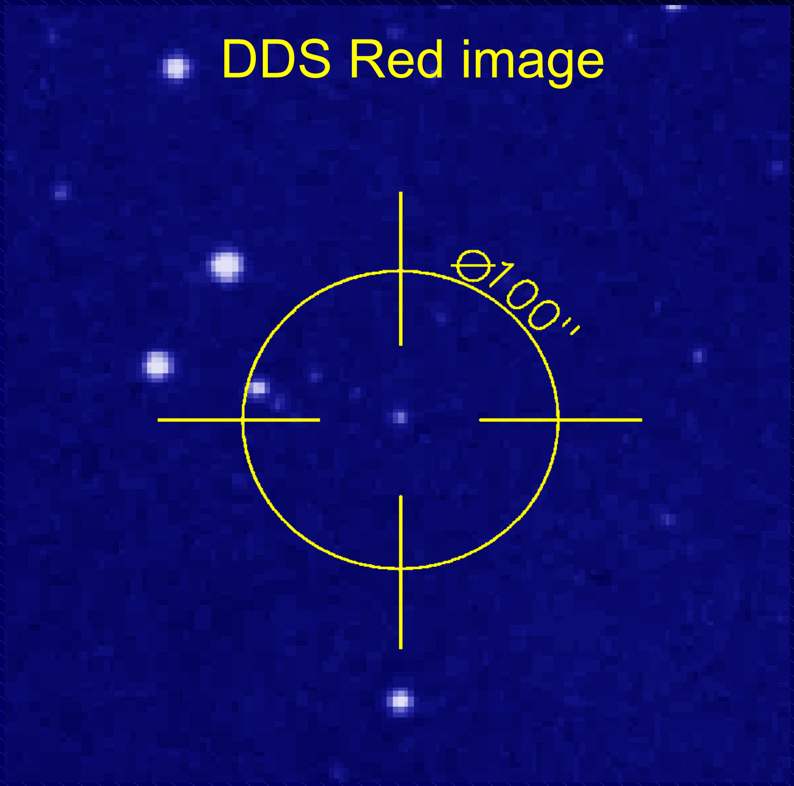
$\Rightarrow$ study of details of these young isolated objects

$\Rightarrow$ for understanding of the more complex regions

$\Rightarrow$ one target of this sample: AFGL 490

Previously known properties of AFGL 490

- Optical: diffuse nebulosity,
  NIR: luminous source
  (Allen, 1972)



Previously known properties of AFGL 490

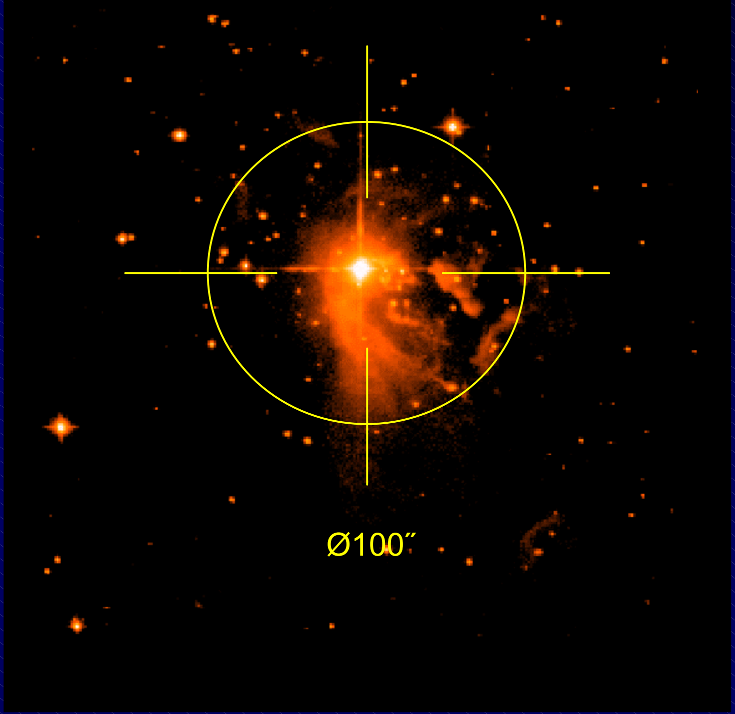
- Optical: diffuse nebulosity,
  NIR: luminous source
  (Allen, 1972)

- D ≈ 1 kpc, L = 1.4 – 4 x 10^3 $L_\odot$
  spectral type B3-B2
  $M_\star$ = 8-10 $M_\odot$

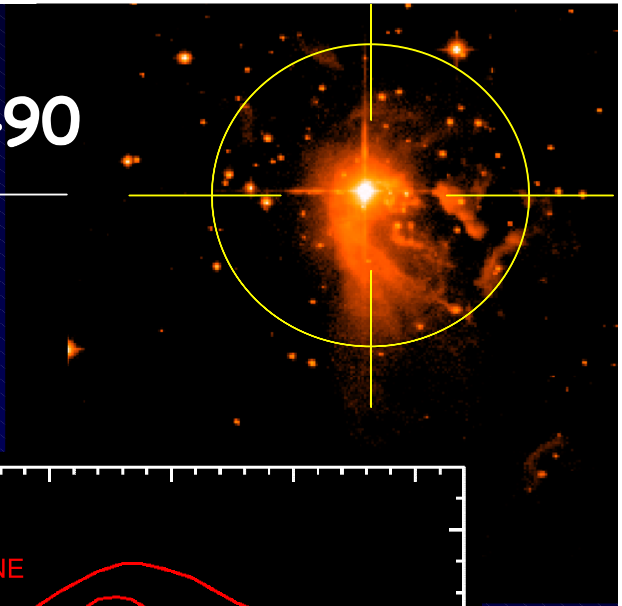
- Typical properties of a
  Becklin Neugebauer Object:
  - weak continuum flux at $\lambda \geq 1$cm
  - broad & strong Brα and Brγ
  (Bunn et al. 1995)

- Ionized region $R \leq 100$ AU
  (Simon et al. 1981, 1983)

K-band image
(Hodapp, 1994)



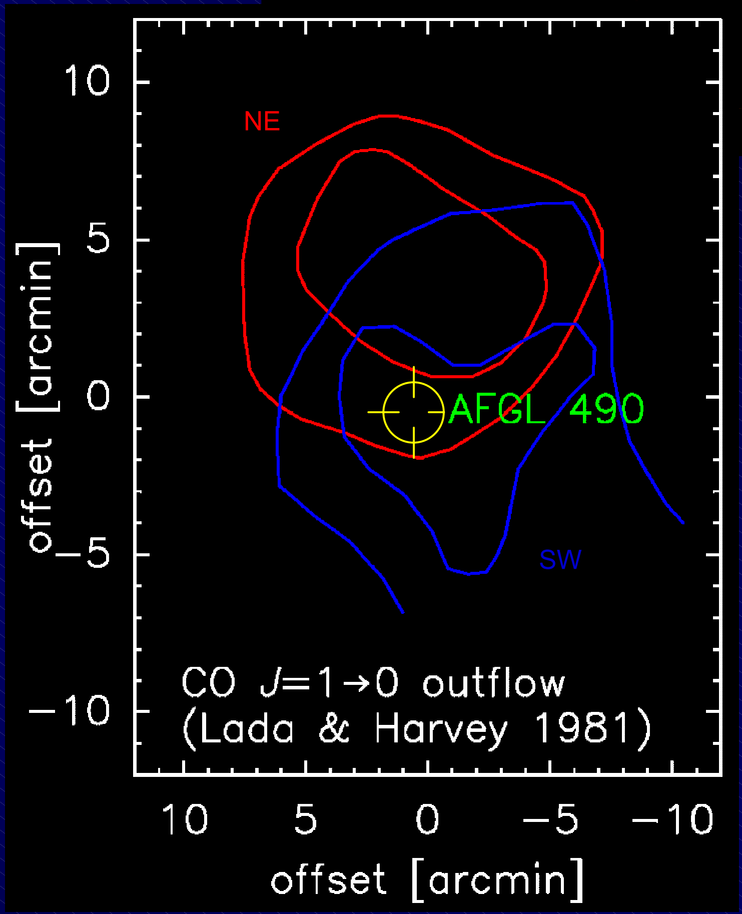
Previously known properties of AFGL 490



- Embedded in a dense cloud core
  (Hodapp 1994, Kawabe et al. 1984, Snell et al. 1984)

- Poorly collimated high-velocity outflow *(Lada & Harvey, 1981)*
  $t_{dyn} \approx 2\mathrm{x}10^4$ yr *(Churchwell, 1999)*

- Previous interferometer studies: presence of a huge disk with a diameter ≈ 25 000 AU
  (Mundy & Adelmann, 1988, Nakamura et al. 1991)



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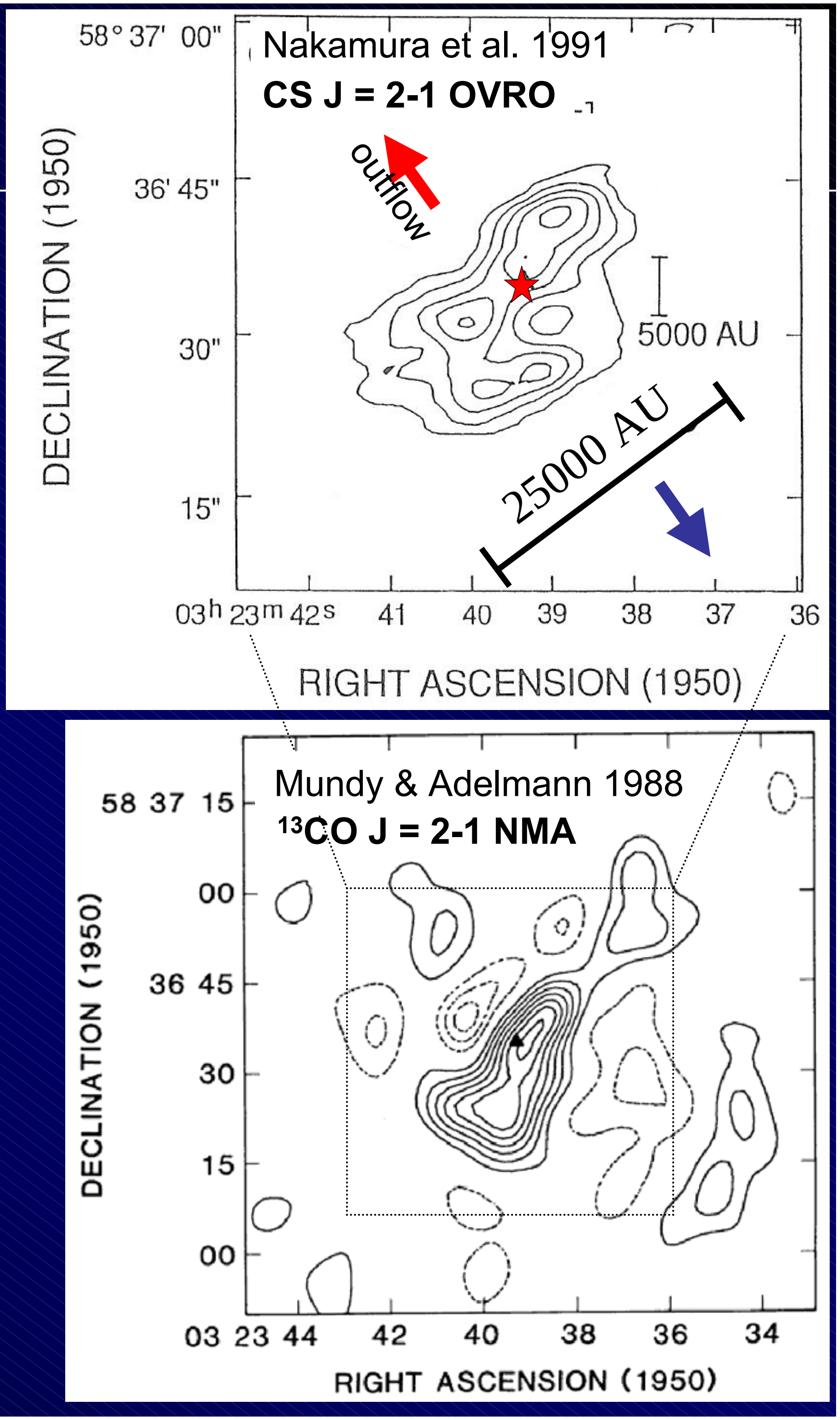


Observations for AFGL 490

JCMT & IRAM 30m Observations

Mapping in :

- CS J = 2-1, 3-2, 5-4, 7-6, $C^{18}O$ J = 2-1: IRAM 30m, JCMT
- Continuum SCUBA 450µm, 870µm; 1.3mm MAMBO

Plateau de Bure Interferometer Observations

Mapping in:

- CS J = 2-1 + λ3mm (2.7″ x 2.2″)
- $C^{34}S$ J = 2-1, CH_3OH (1.8″ x 1.4″)
- $C^{17}O$ J = 2-1 + λ1mm (0.9″ x 0.8″)

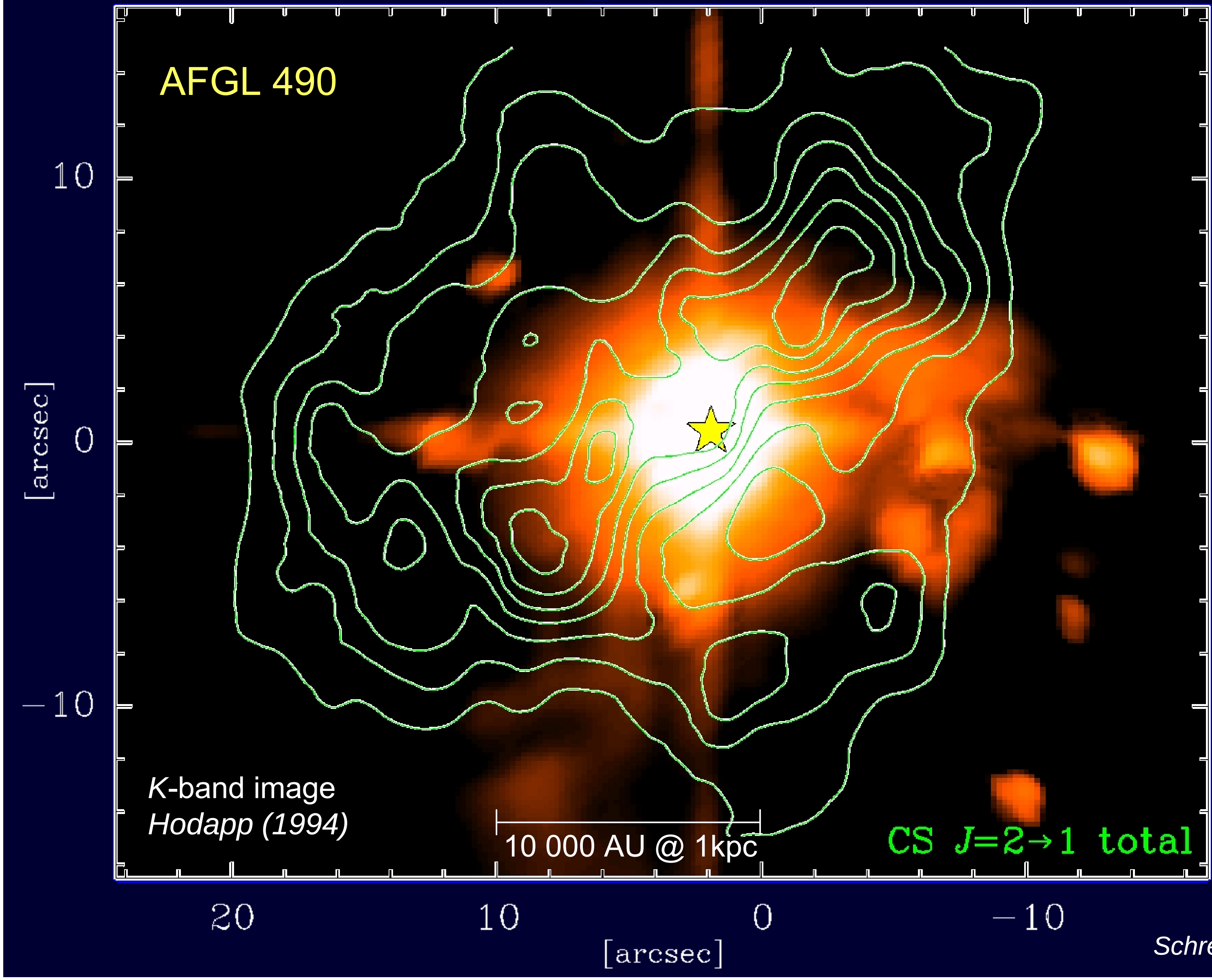
VLA-CD Observations

Mapping in:

- CS J = 1-0 + λ7mm

Our observational results

Plateau de Bure Interferometer Observations in CS J = 2-1



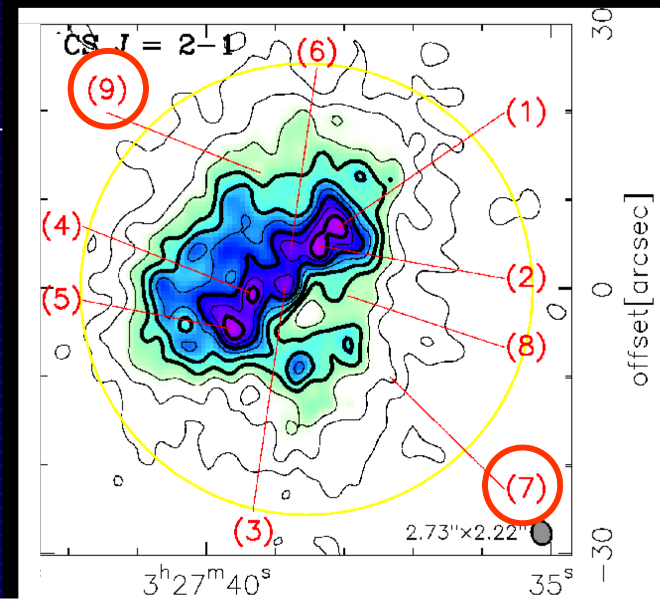
- Embedded in a dense cloud core
- Bar-like dense structure (25 000 AU) centered to AFGL 490

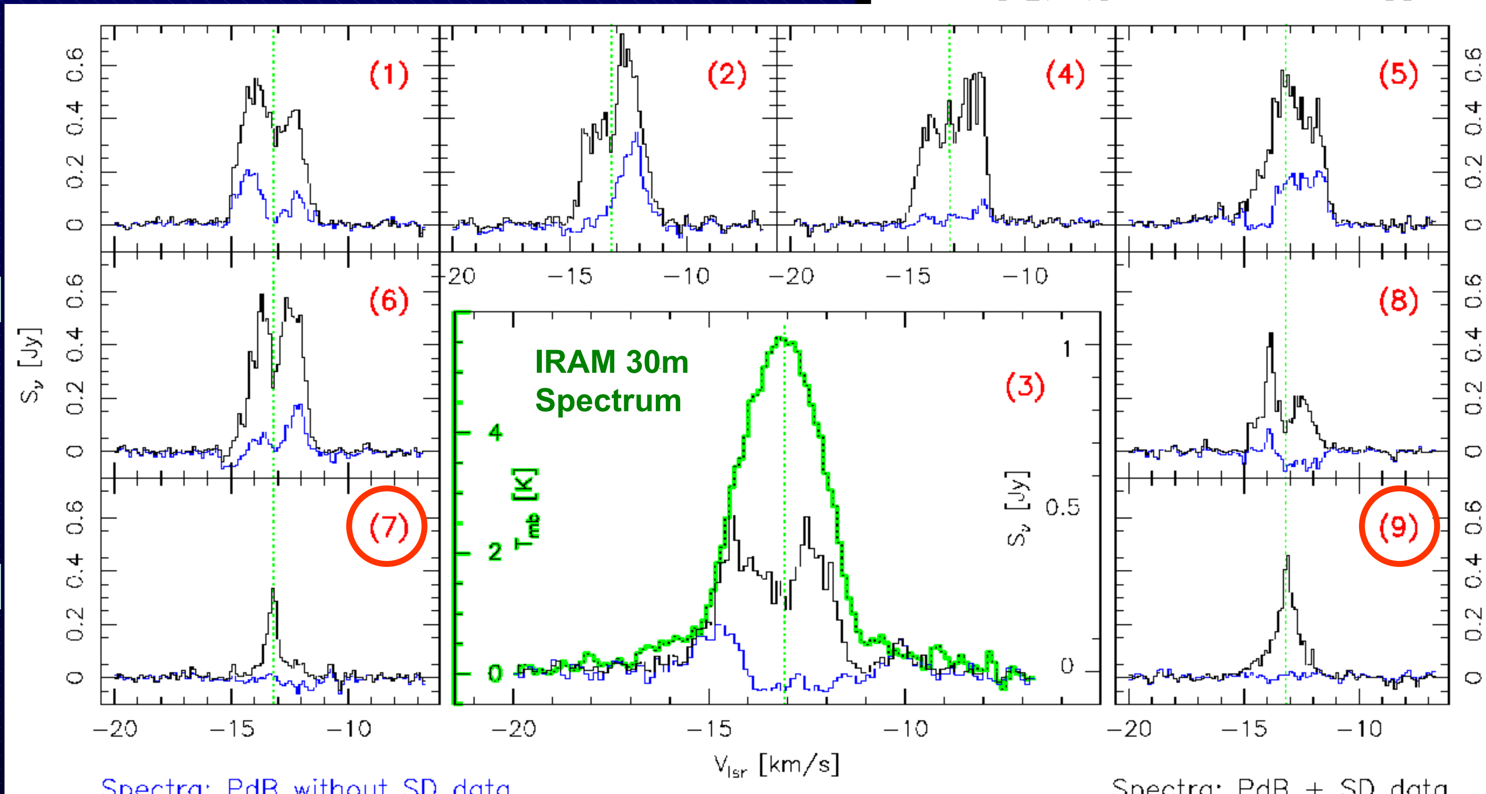
Schreyer et al. (2002)

Our observational results

- PdBI CS J = 2-1 spectra:

  strong (self-)absorption in the line center
  ⇒ no infomation about the internal
  velocity structure of the bar



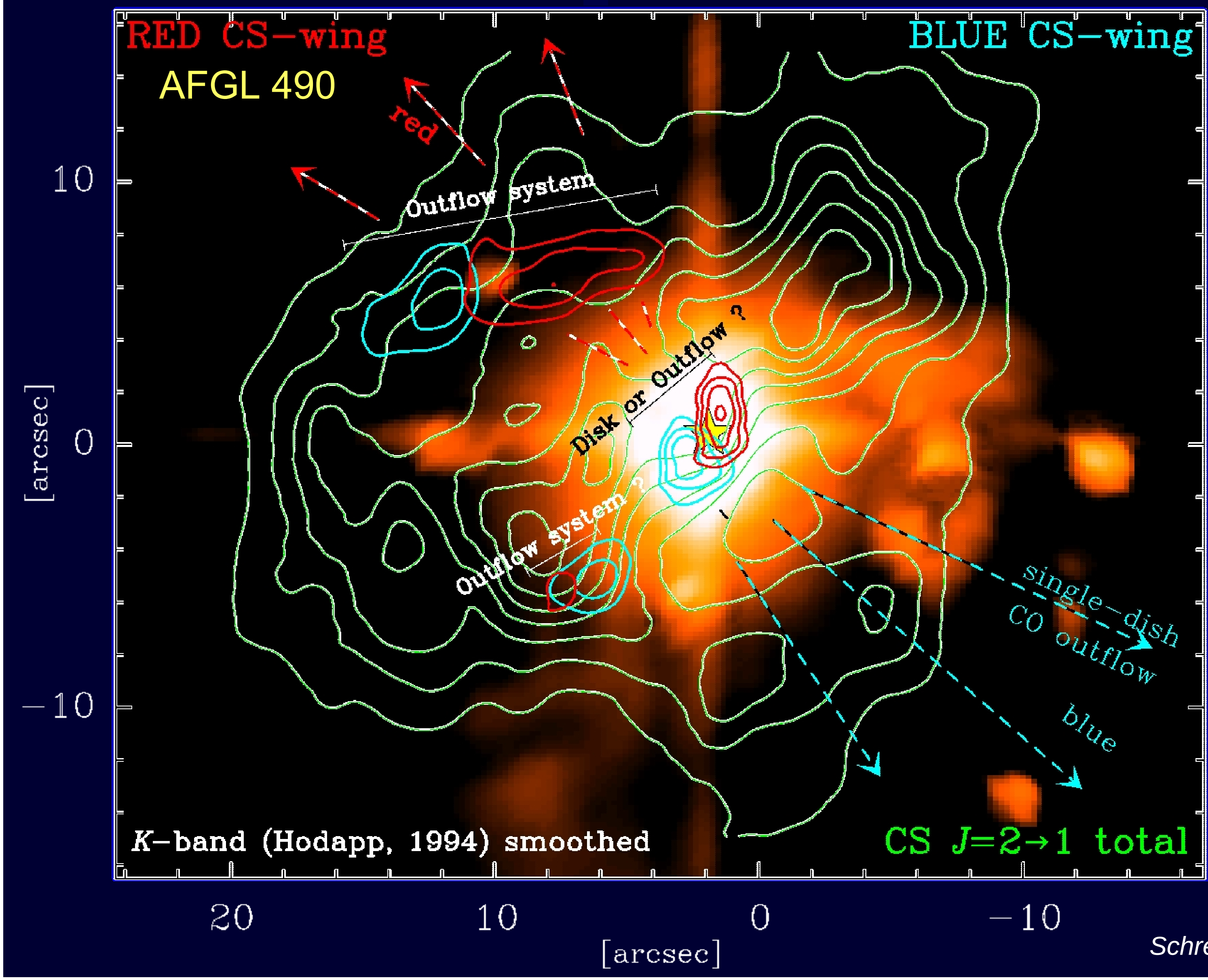


Black spectra:
single-dish measurements are included

Blue spectra:
without zero-spacing correction

Our observational results

Plateau de Bure Interferometer Observations in CS J = 2-1

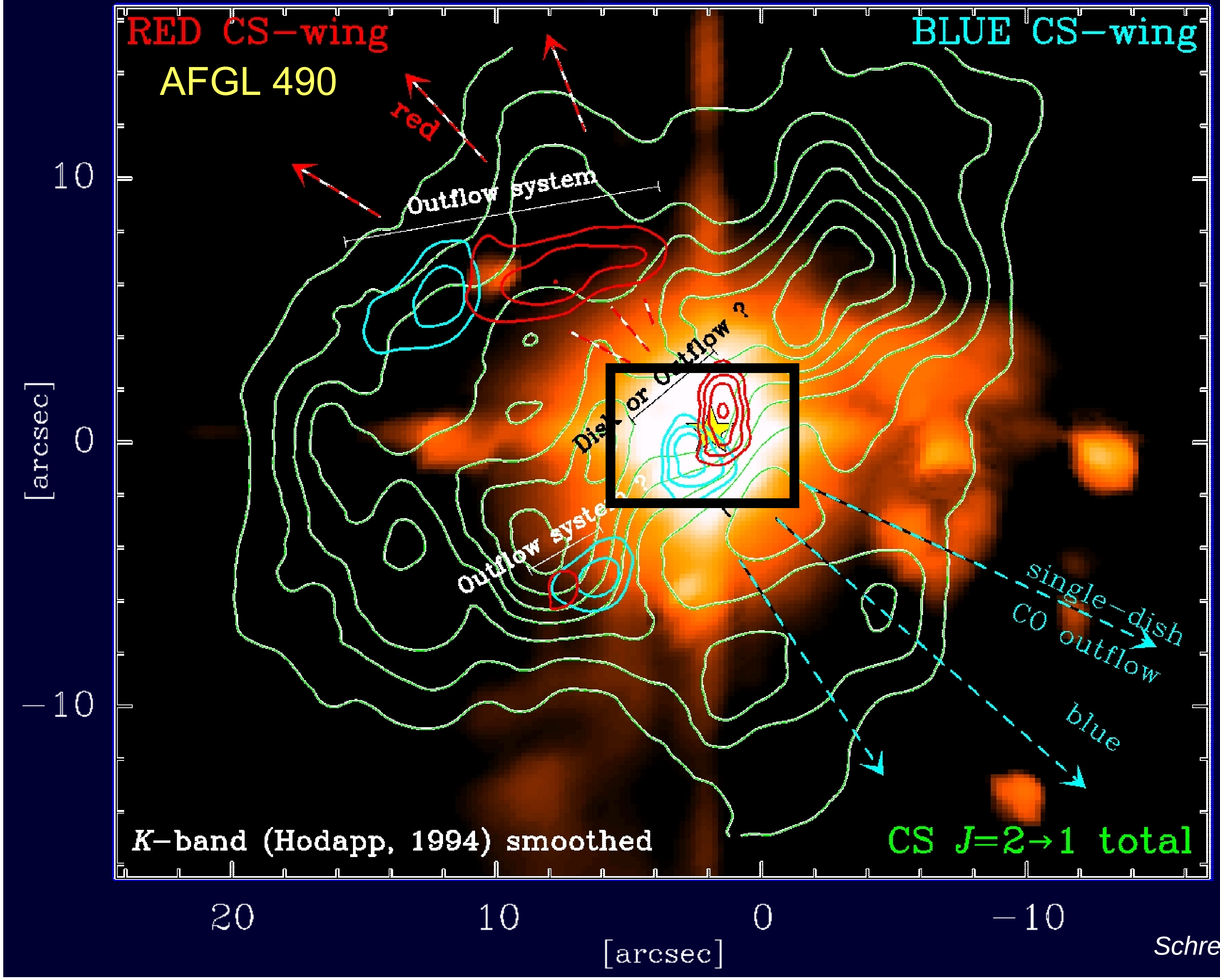


- Embedded in a dense cloud core
- Disk-like system around AFGL 490
- Mass inside R = 4000 AU $M_{disk} \approx M_{\star} \approx 8\ M_{\odot}$

Schreyer et al. (2006)

Our observational results

Plateau de Bure Interferometer Observations in CS J = 2-1



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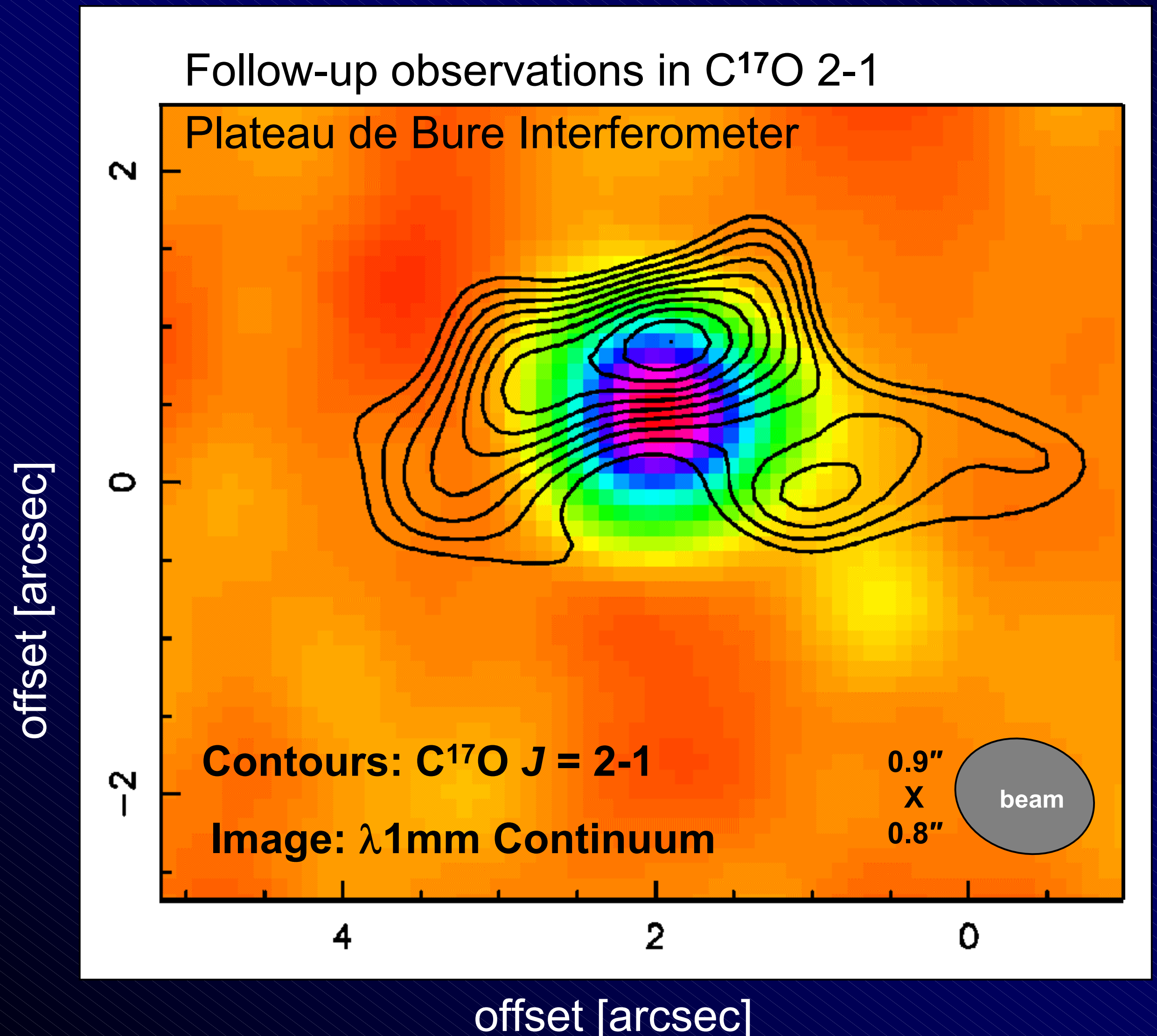
Our observational results

AFGL 490



- Clumpy gas ring centered at the 1mm continuum point source

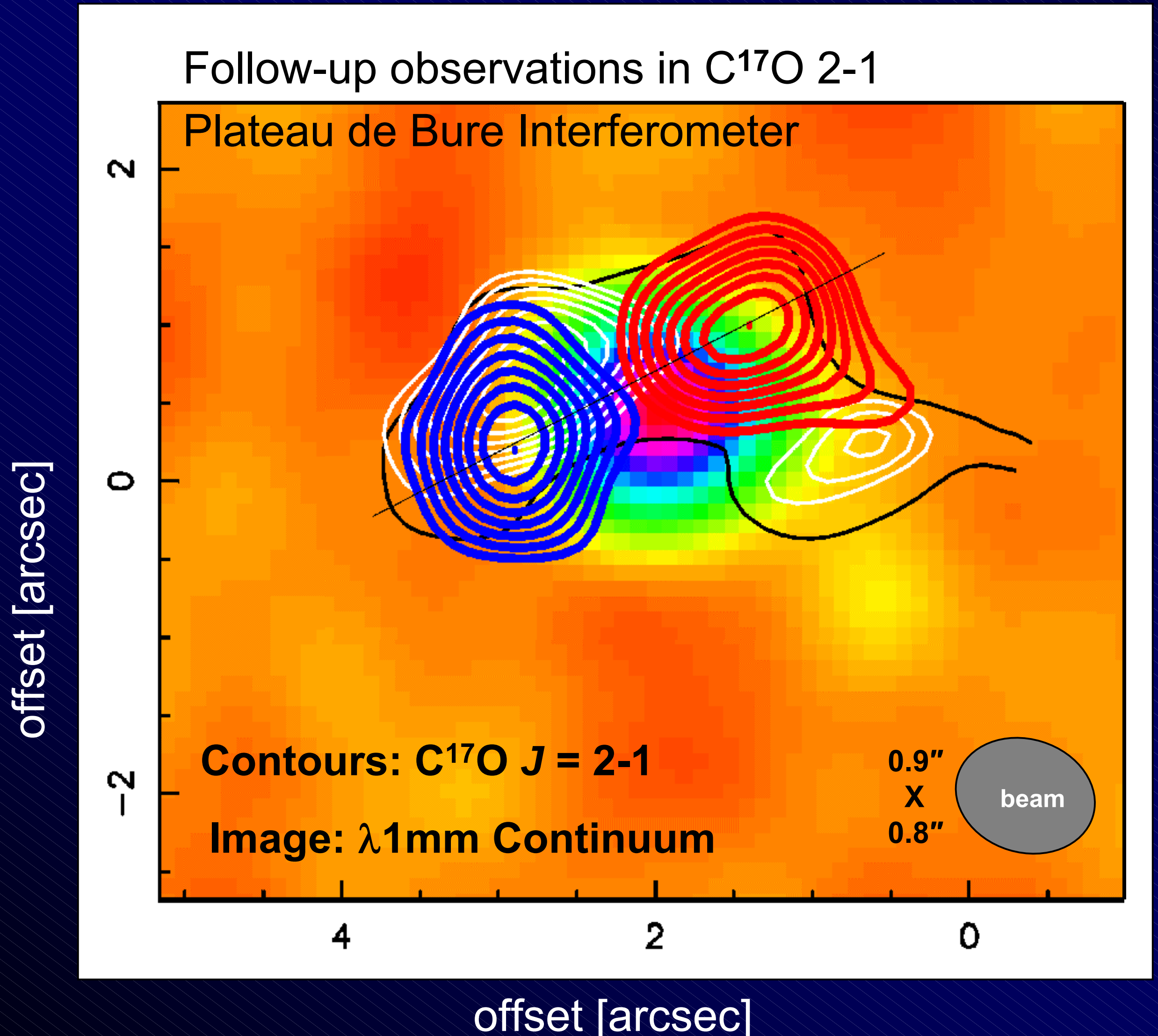
←
$C^{17}O$ contour levels: 20%-90% of the peak emission
10% = 1σ

Color-coded image: 1mm continuum point source, peak intensity = 0.6 Jy $beam^{-1}$

Schreyer et al. (2006)

Our observational results

AFGL 490



- Clumpy gas ring centered at the 1mm continuum point source
- Well separated **red-** and **blue-**shifted $C^{17}O$ emission

Red & blue $C^{17}O$ contour levels:
30%-90% of the peak emissions

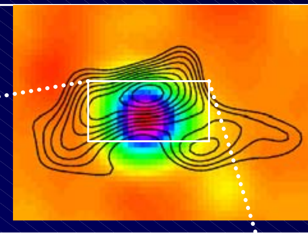
V_{lsr}-Red: -12.5…-9.5 km/s
V_{lsr}-Blue: -15.5…-13.4 km/s

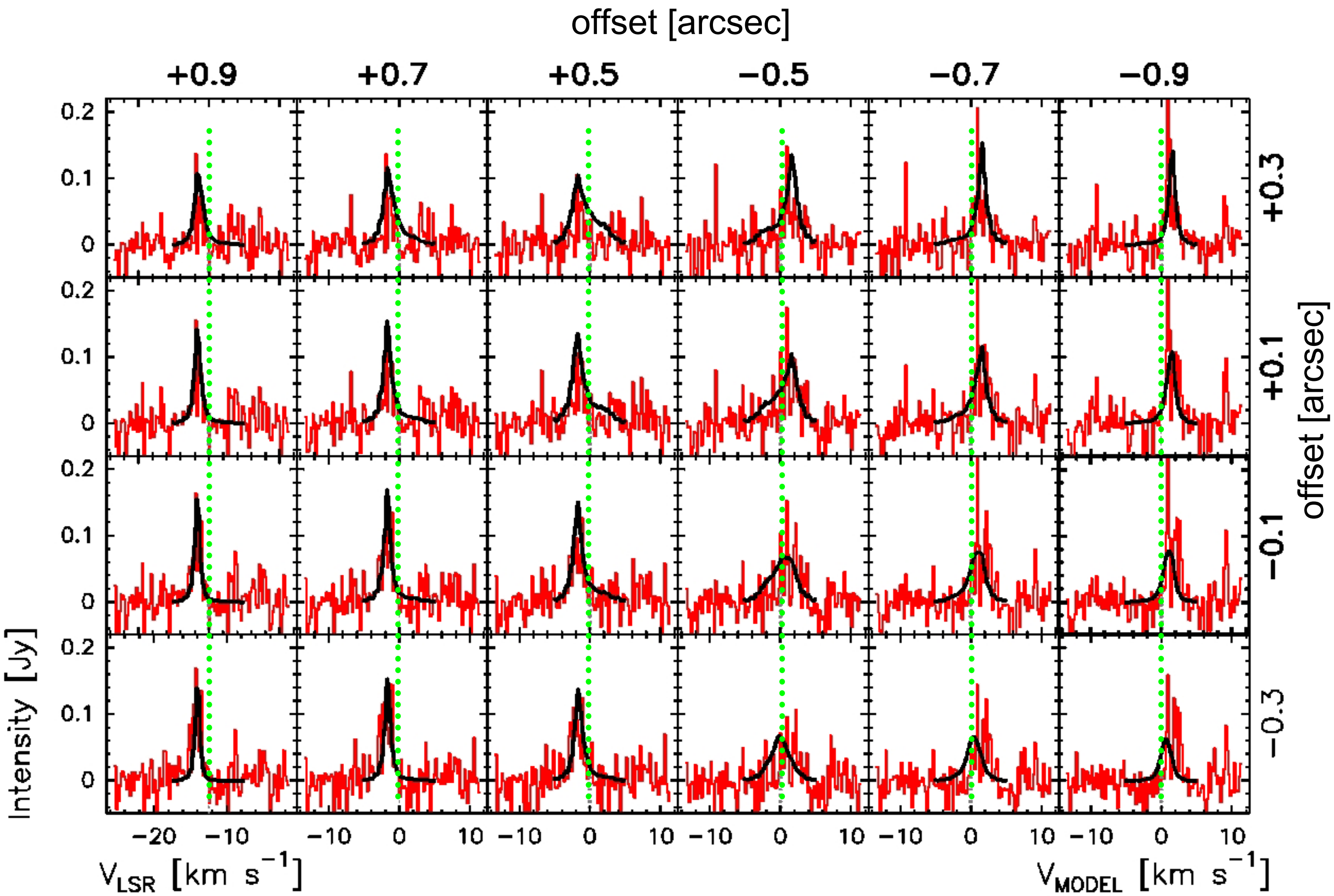
Schreyer et al. (2006)

Modelling of the $C^{17}O$ emission

AFGL 490

Iterative Modelling of the $C^{17}O$ 2-1 line profiles





Observed spectra - **Simulated line profiles**

Complete cycle:

Step I
2D model for the continuum emission *by C.P. Dullemond*
(MPIA Heidelberg)

Step II
1+1D modelling of the chemistry in the disk *by D. Semenov*
(MPIA Heidelberg)

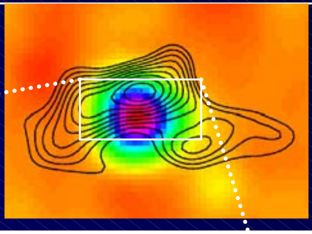
Step III
2D modelling of the line profile *by Y. Palyuchenkov*
(MPIA Heidelberg)

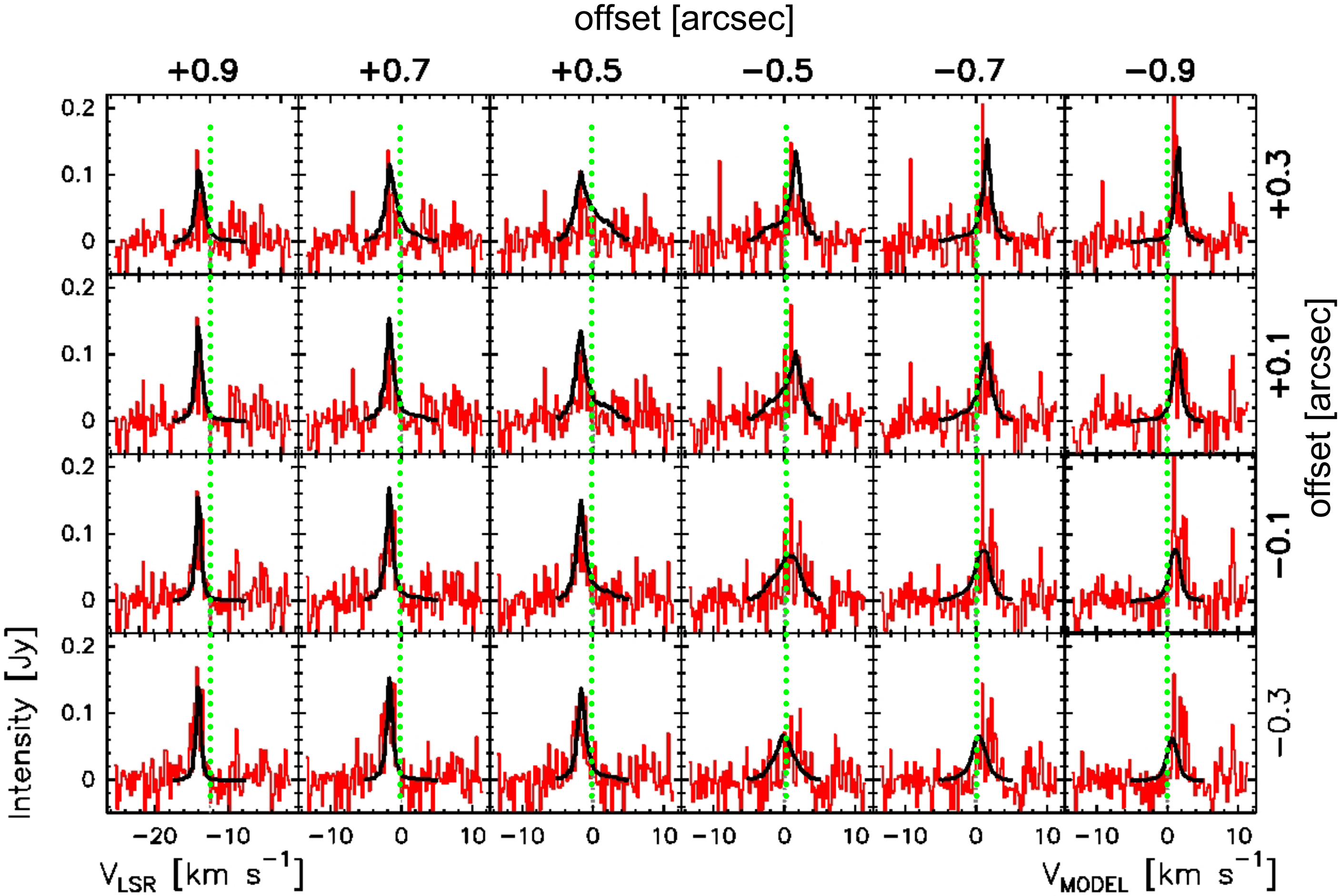
Schreyer et al. (2006)

Modelling of the $C^{17}O$ emission

AFGL 490

Iterative Modelling of the $C^{17}O$ 2-1 line profiles





Observed spectra - **Simulated line profiles**

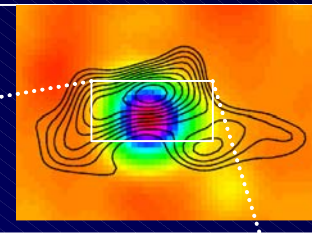
Assumptions for the model:

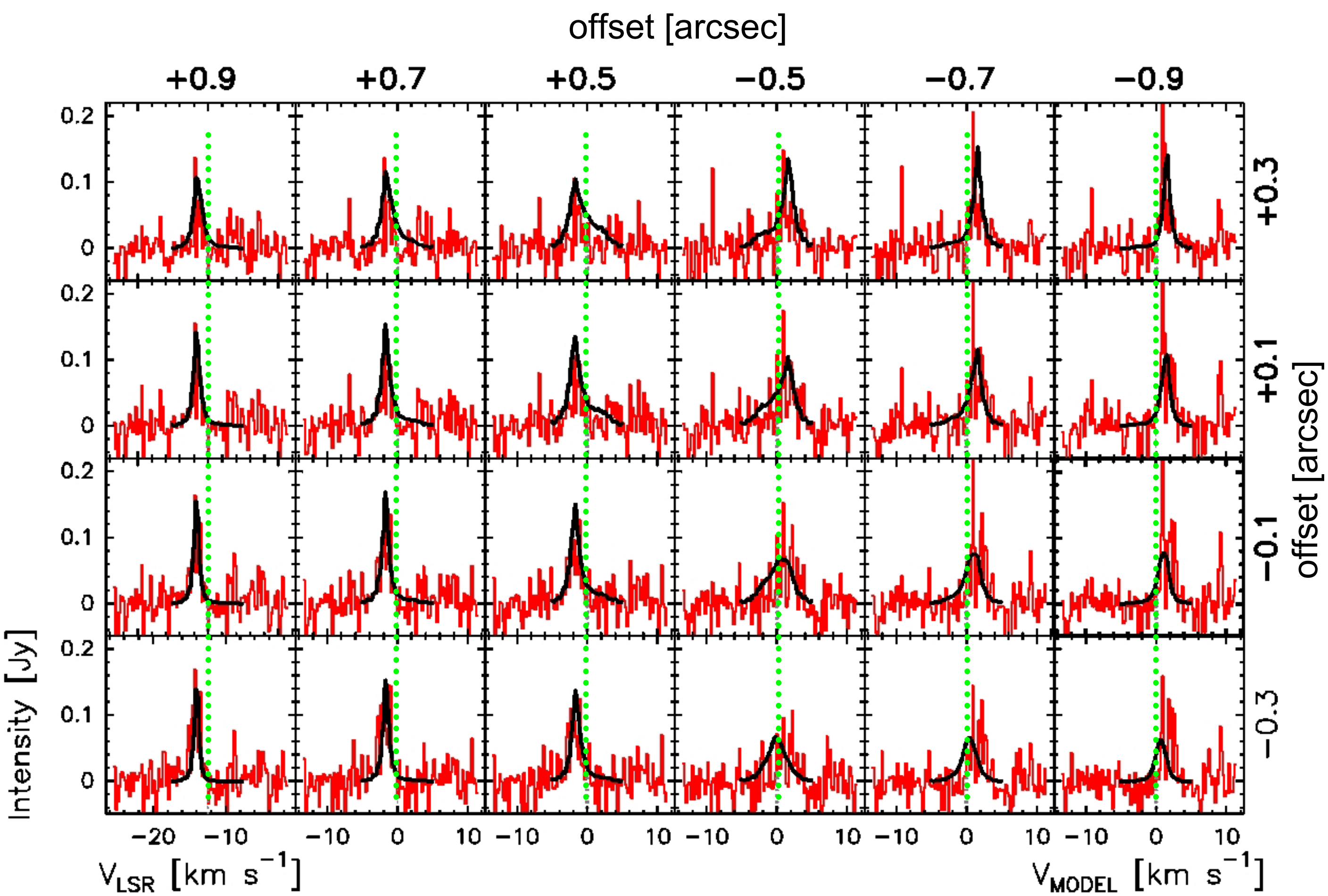
- Flared-disk model
- Velocity profile $V(r) = V_o(r_o/r)^{-s}$
- Surface density gradient $\Sigma(r) = \Sigma_o(r_o/r)^{-p}$
- Dust grains: MRN-like size distribution (Mathis et al. 1977)
- $M_{gas} : M_{dust} = 100$
- Age: 0.1 Myr

Modelling of the $C^{17}O$ emission

AFGL 490

Iterative Modelling of the $C^{17}O$ 2-1 line profiles





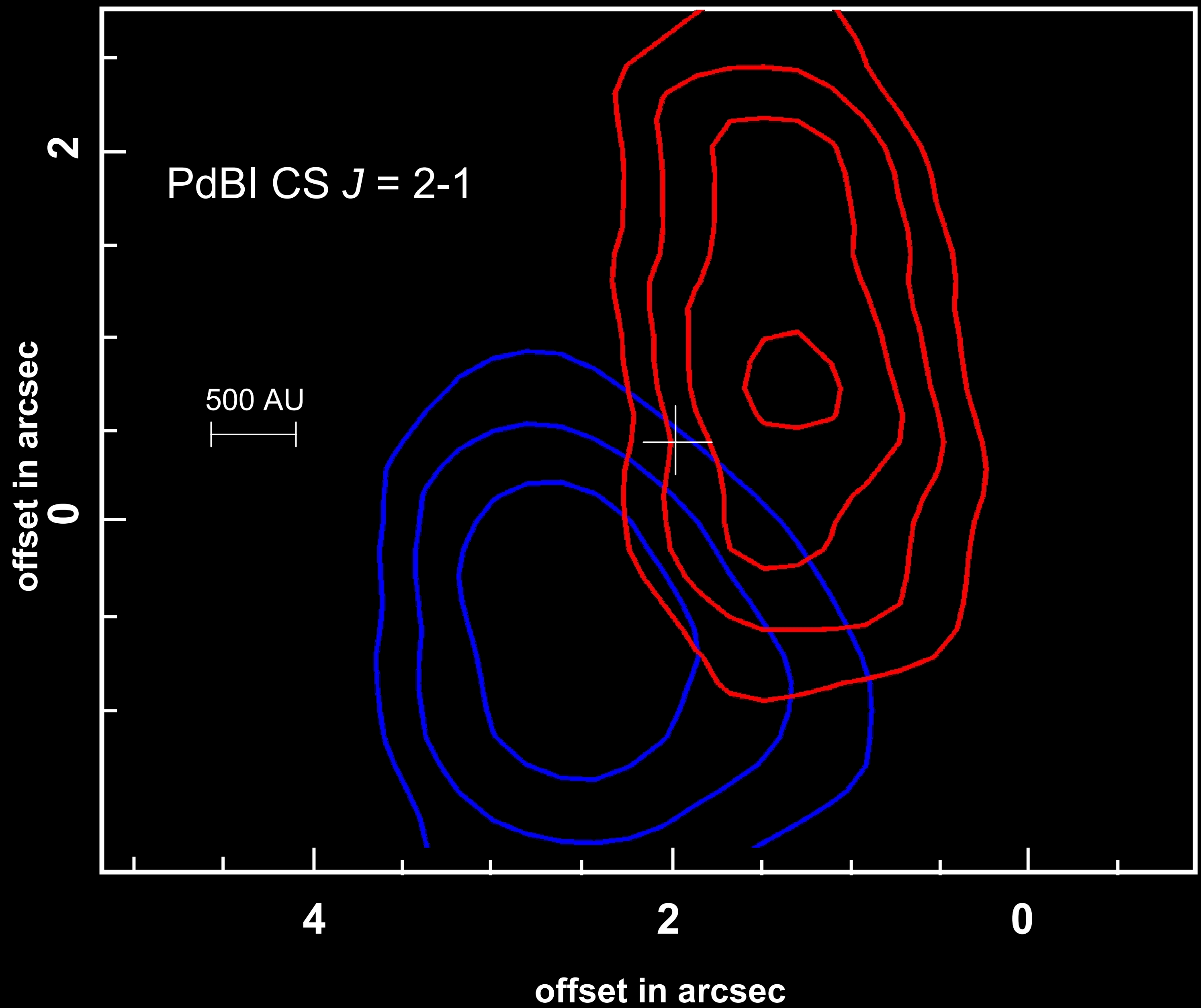
Observed spectra - **Simulated line profiles**

Best Fit Results:

- Inclination & position angle i = 30°±5°
- $M_\star$ = 8…10 $M_\odot$
- M_{disk} = 0.2…1 $M_\odot$
- Velocity profile $V(r) = V_o(r_o/r)^{-0.5}$
- Surface density gradient $\Sigma(r) = \Sigma_o(r_o/r)^{-1.5}$
- Optical depth $\tau < 0.01$
- R_{out} = 1500 AU (±200 AU)

Schreyer et al. (2006)

AFGL 490 Overlay of different velocity coded line transitions



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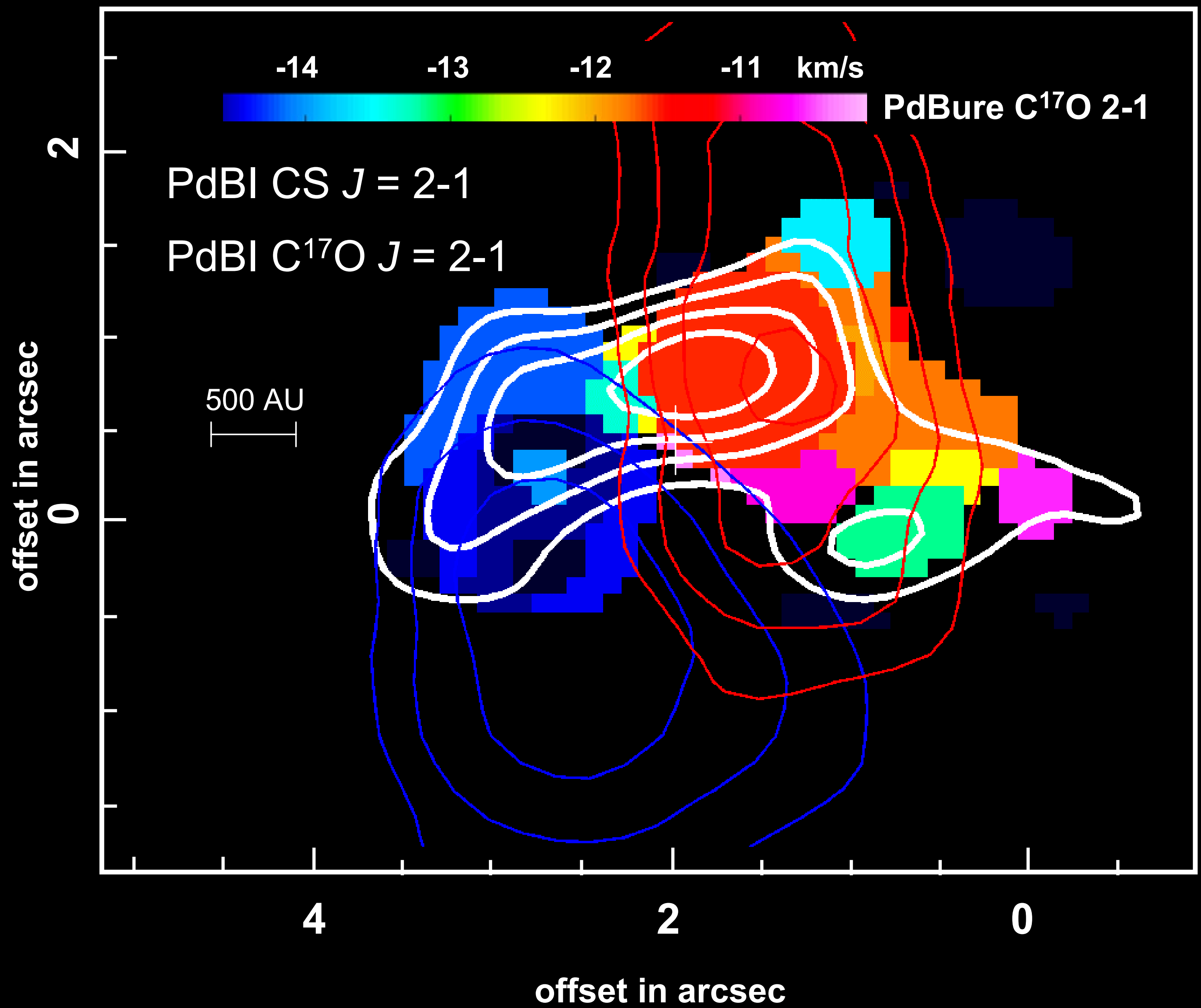

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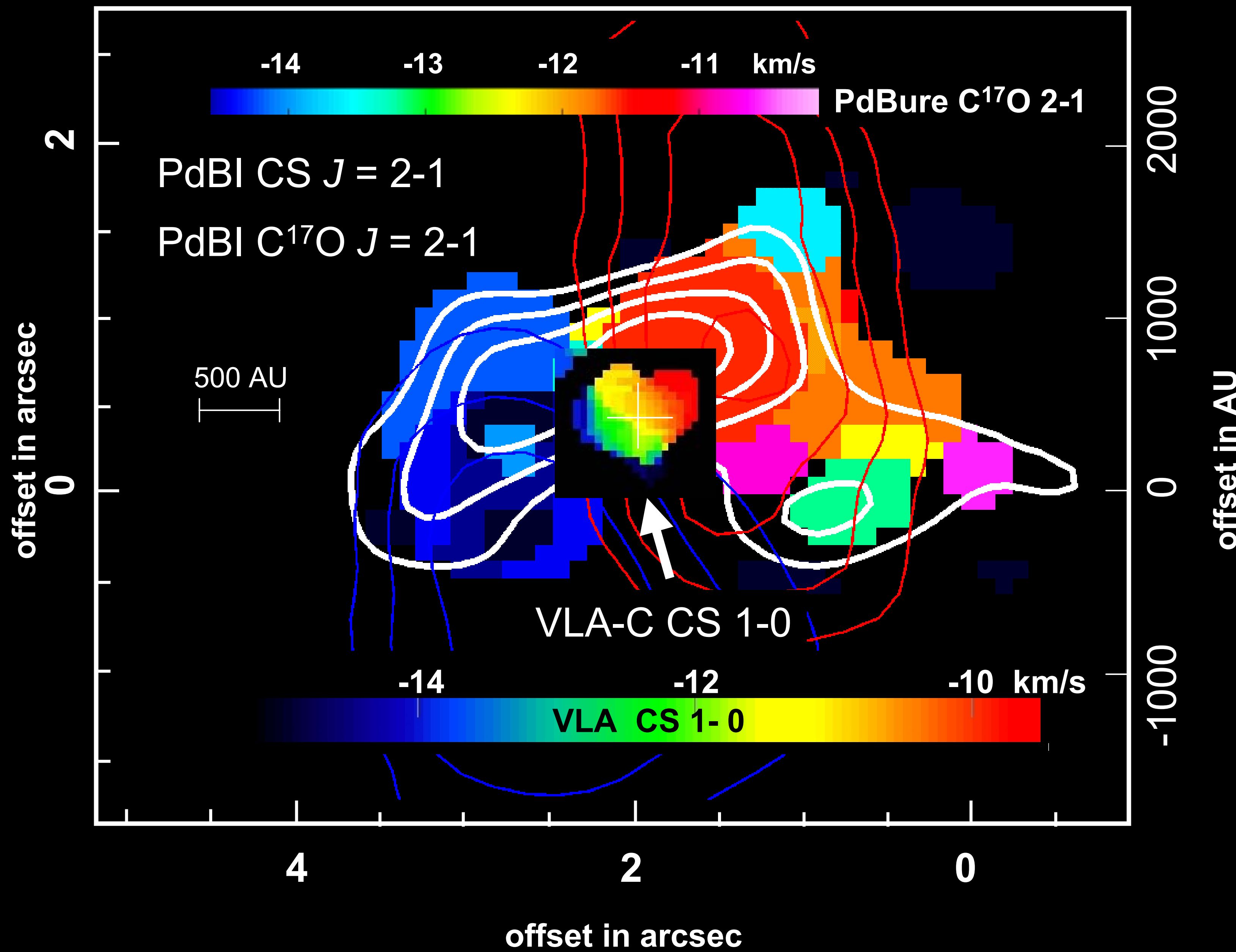

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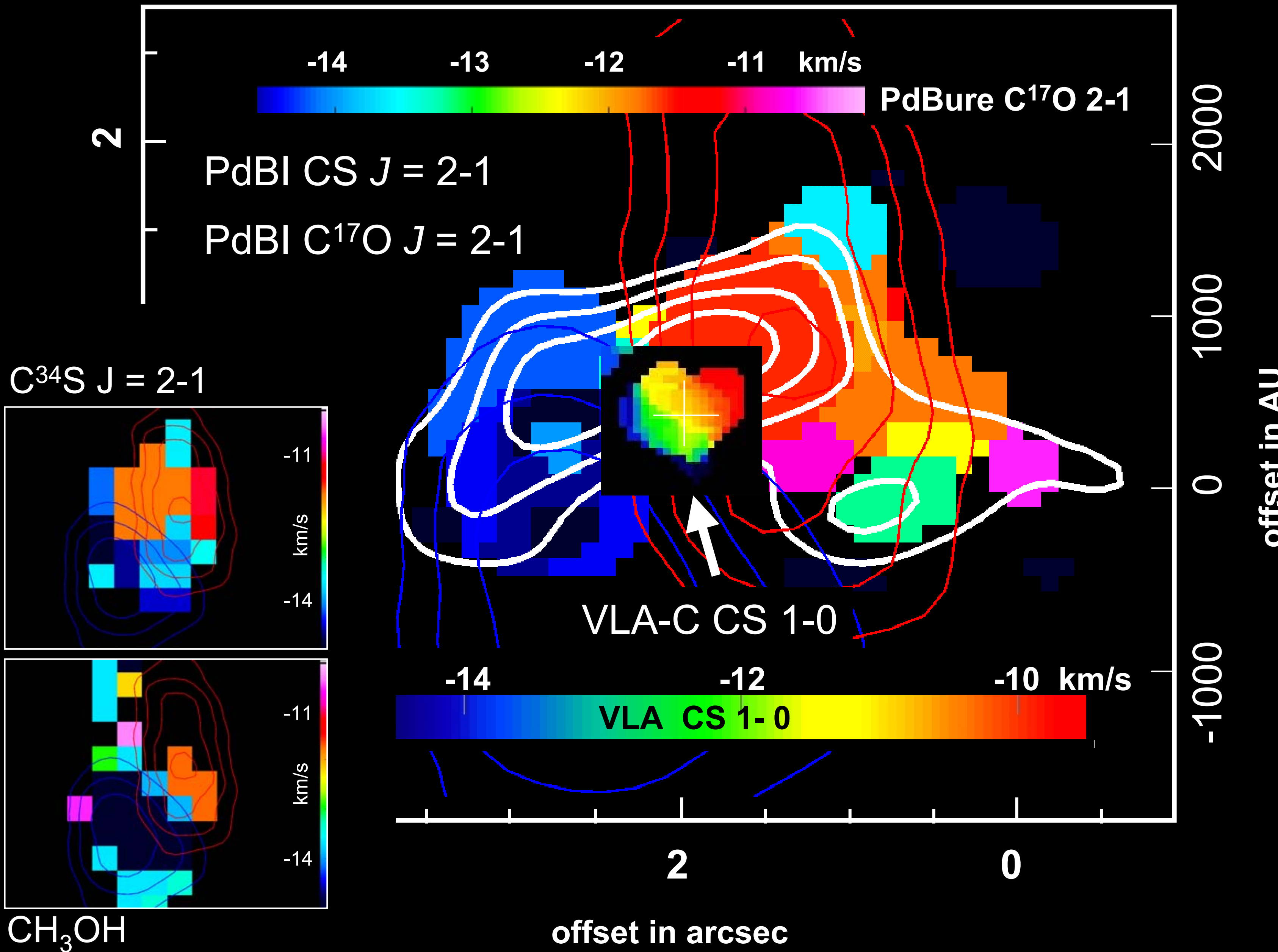
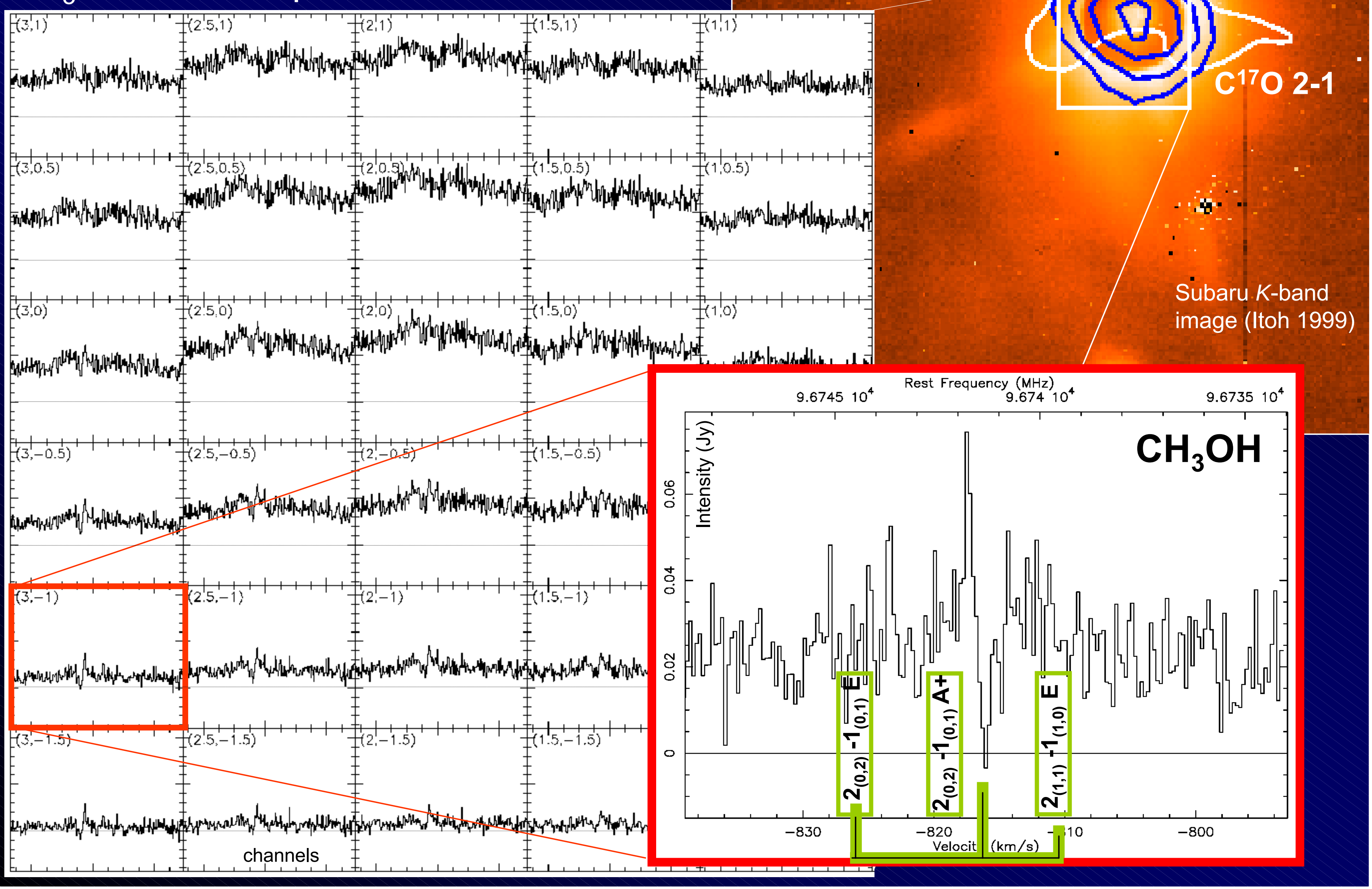


Evidence for accretion

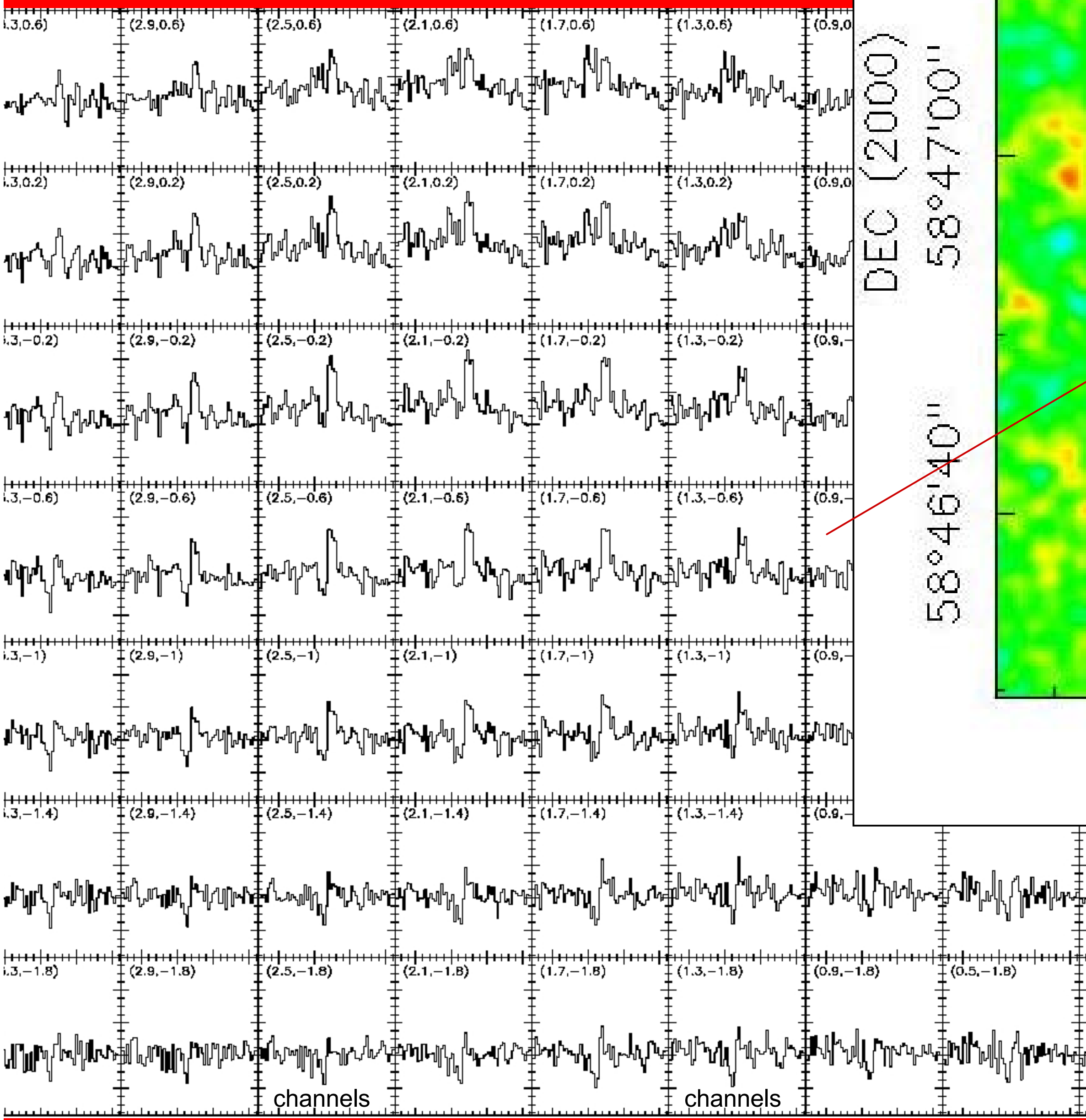
CH_3OH *J* = 2-1 spectra without continuum subtraction

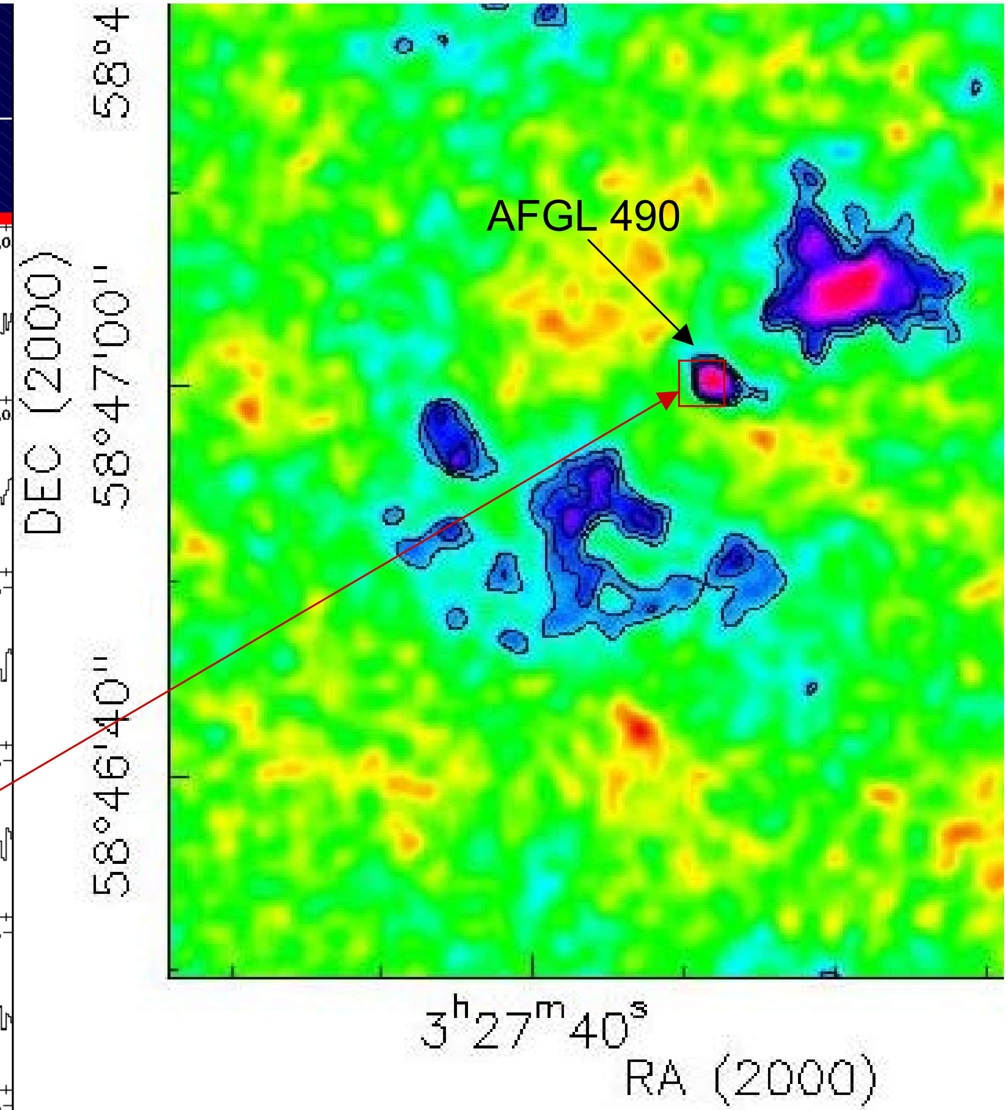


Evidence for accretion

AFGL 490

VLA-D CS J = 1-0

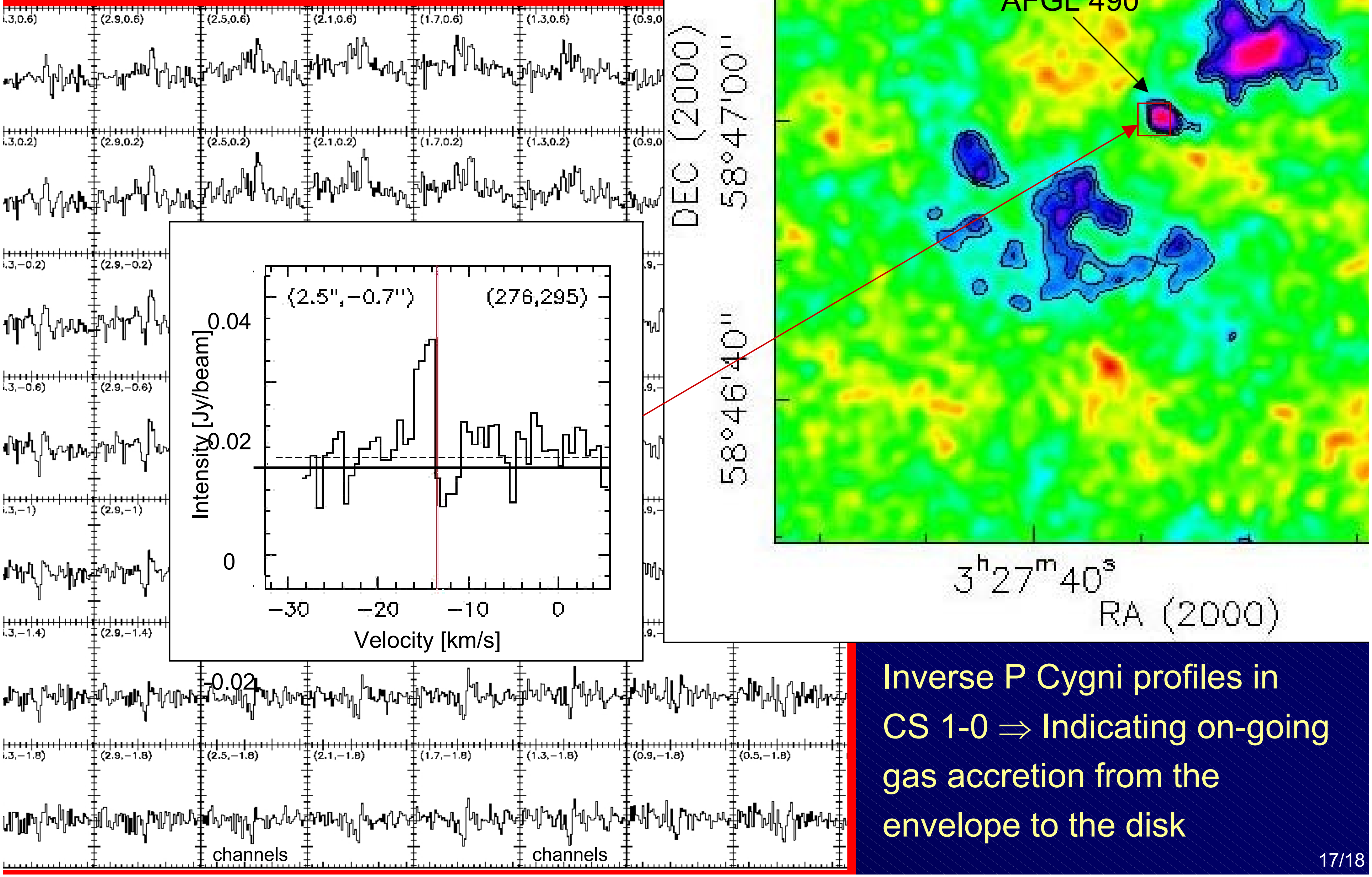




Inverse P Cygni profiles in CS 1-0 ⇒ Indicating on-going gas accretion from the envelope to the disk

Evidence for accretion

AFGL 490 VLA-D CS J = 1-0



Inverse P Cygni profiles in CS 1-0 ⇒ Indicating on-going gas accretion from the envelope to the disk

Summary - Conclusions

- AFGL 490 is surrounded by a gaseous disk

  Basic physical parameters are:

  - Position and inclination angle is ≈ 30°,
  - R_{out} ≈ 1500 AU (not 10 000 AU),
  - M_{disk} ≈ 1 $M_{\odot}$,
  - Disk rotation: close to Kepler's law
  - Clumpy structure

- Evidence for gas infall

  - Inverse P Cygni profiles in CH_3OH & CS ⇒ on-going gas infall *from* the envelope *to* the disk