Millimetre/Submillimetre Astronomy Studies in Ha Noi

Pham Ngoc Diep

on behalf of the Department of AstroPhysics (DAP)

Vietnam National Satellite Center (VNSC)

Vietnam Academy of Science and Technology (VAST)

Da Nang, March 10th, 2017

Department of Astrophysics: Current members

Content

A bit of history

A small radio telescope at home

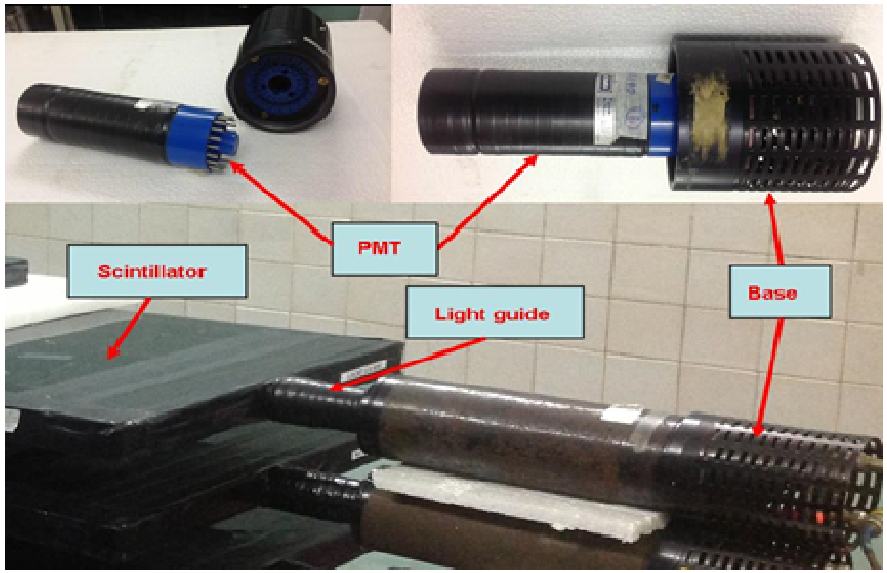
High red-shift galaxies

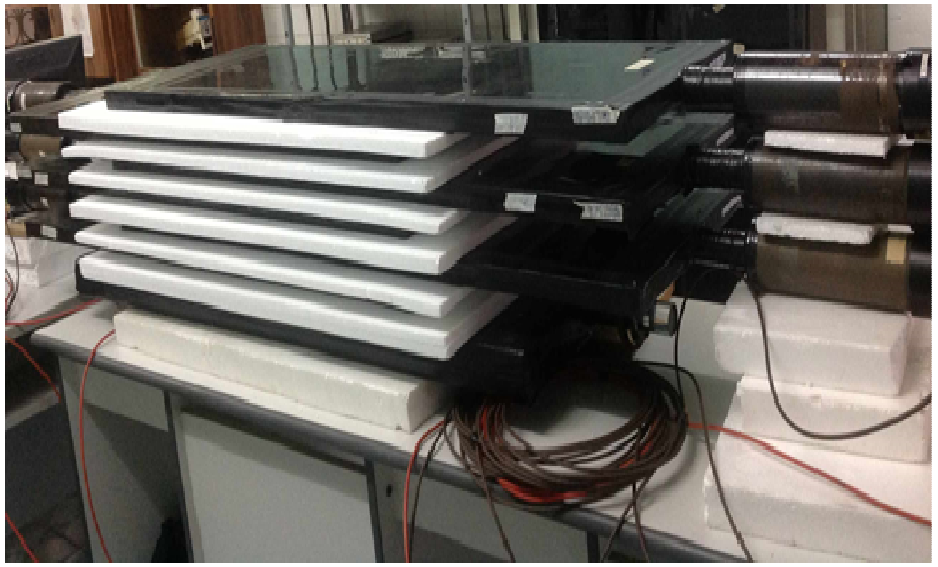
Stellar physics

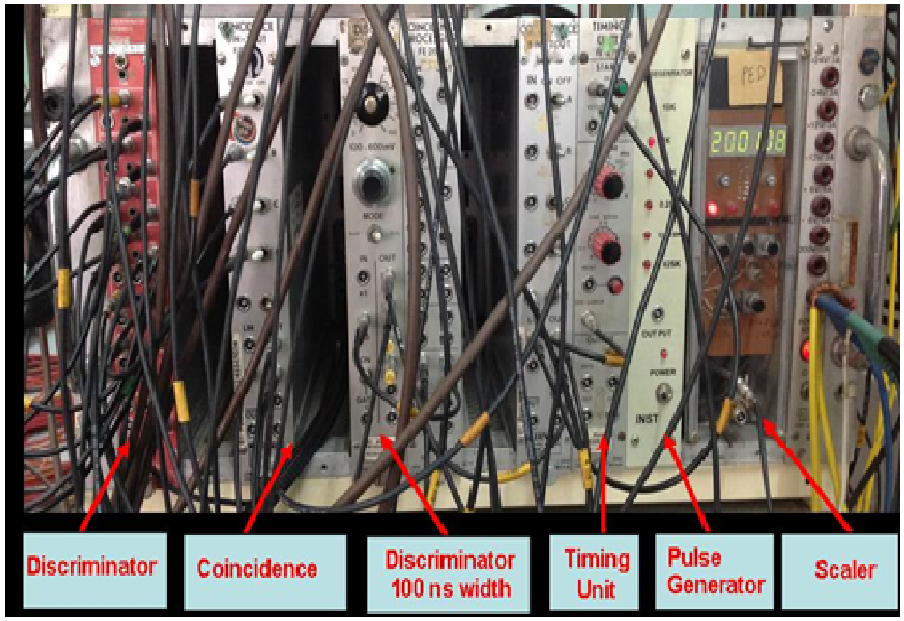
Summary

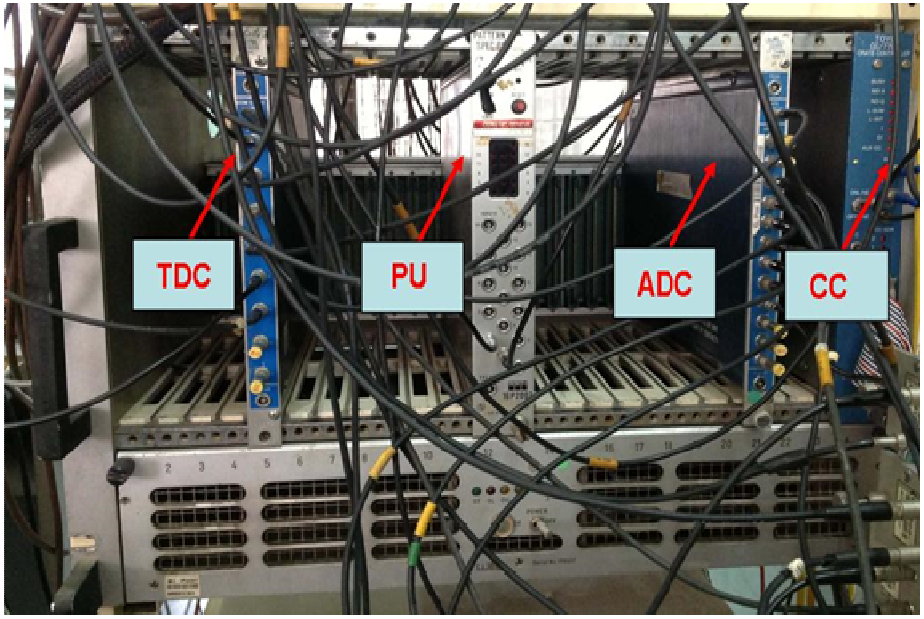
A bit of history

Our team was established in 2001 when Prof. Pierre Darriulat came to Vietnam with detectors.



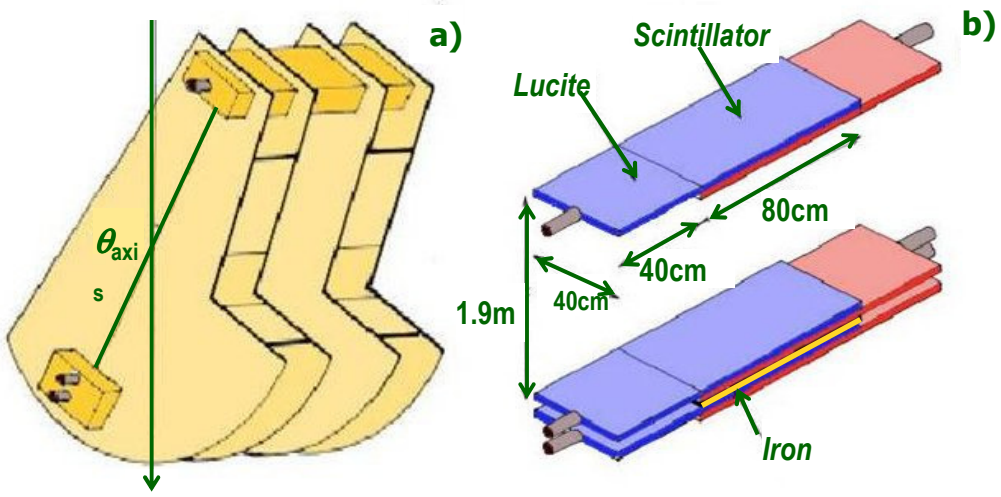


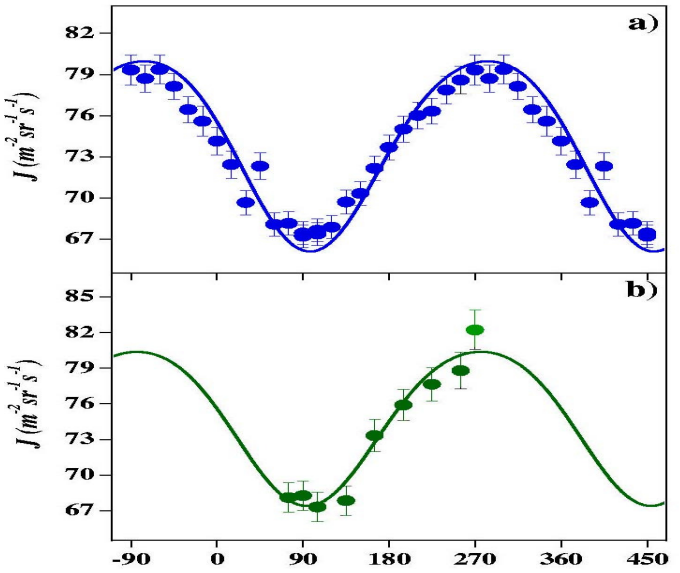


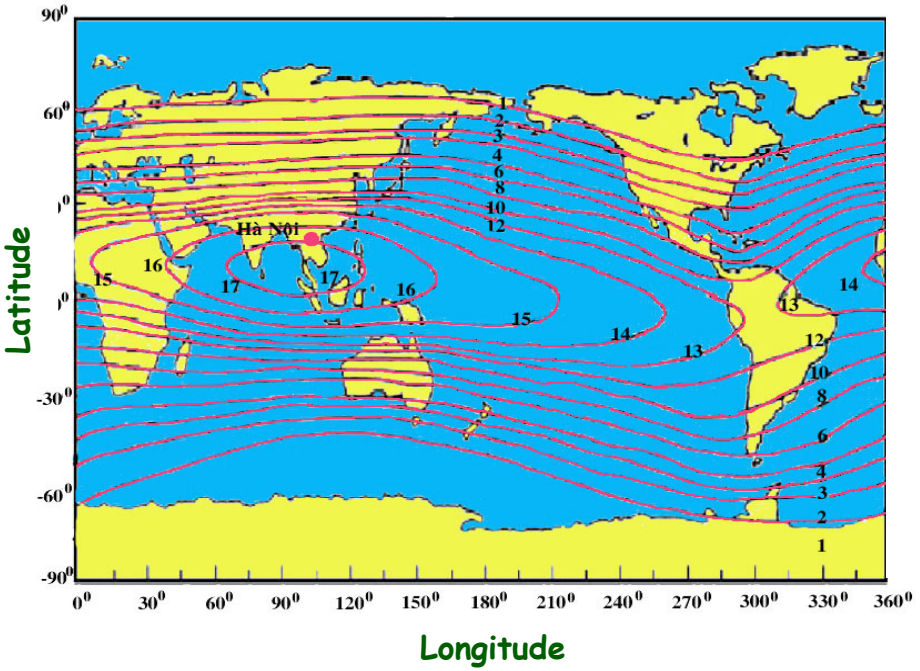


Instrumentation

Measurement of cosmic muon flux in Hanoi







We immediately joined the

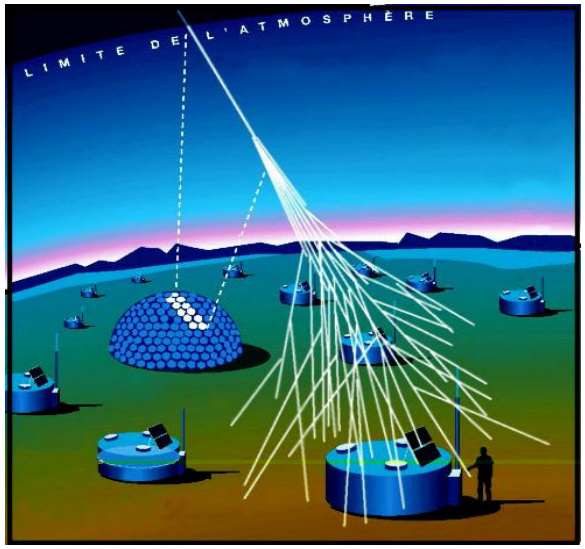
Pierre Auger Observatory

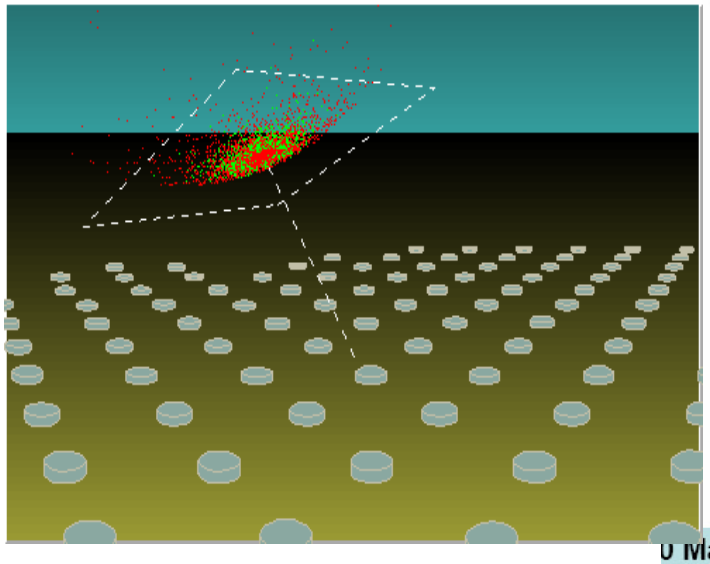
The Auger Observatory is the first large hybrid detector ever built: it combines the strengths of

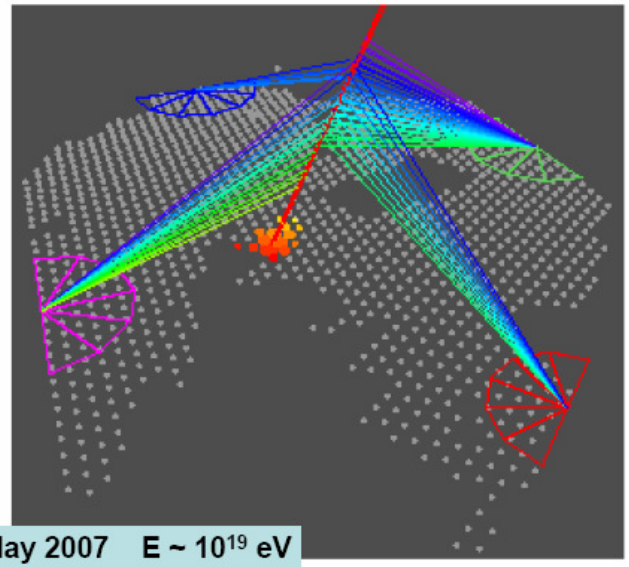
Surface Detector Array & Air Fluorescence Detectors

THE PHYSICS OF ULTRA HIGH ENERGY COSMIC RAYS

- Accurate measurement of the high end of the energy spectrum
- Identification of possible sources
- Nature of the primaries



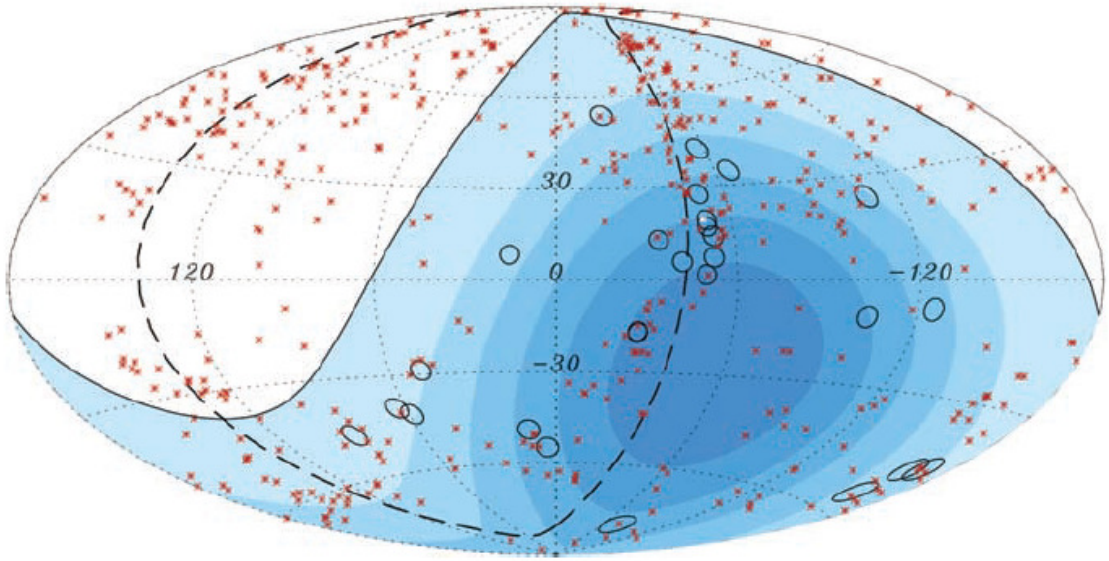




Science
AAAS

Correlation of the Highest-Energy Cosmic Rays with Nearby Extragalactic Objects
The Pierre Auger Collaboration, *et al.*
Science **318**, 938 (2007);
DOI: 10.1126/science.1151124

Top ten physics event of APS



Three of us have made our PhD theses in this field. We made significant contributions to the very successful achievements of this program.

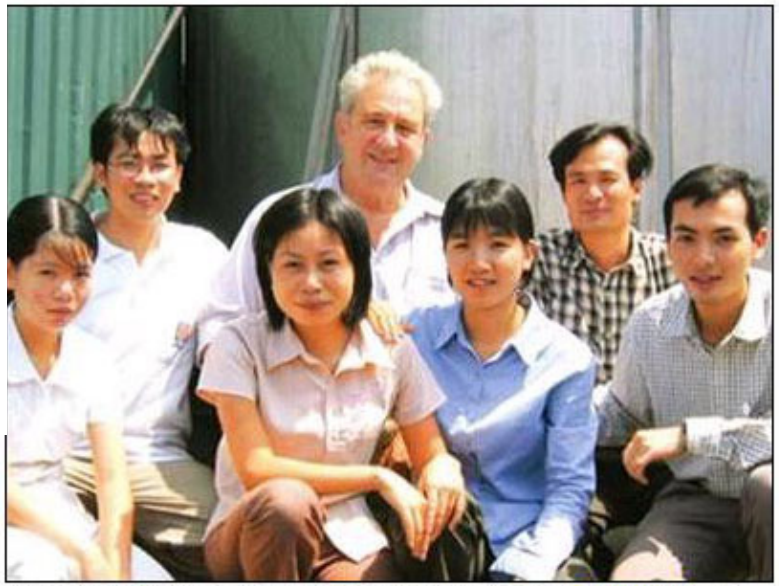
TRANG NHẤT
Thời sự - Xã hội
Kinh tế
Thanh niên-Thời đại
Sau lũy tre làng
Phóng sự
Bạn đọc & Tiền phong
RSS
TRỰC TUYẾN
THÔNG TIN CẦN BIẾT
Thời tiết

KHOA HỌC-CÔNG NGHỆ

Thứ Sáu, 09/11/2007, 06:26

Nhóm Vật lý Việt Nam là đồng tác giả trong phát hiện về tia vũ trụ

P - Các nhà khoa học vừa kết luận: Các trung tâm thiên hà AGN ới lỗ đen siêu nặng đang hoạt động mạnh là nguồn phát khả dĩ hất của tia vũ trụ năng lượng cao đến trái đất. Đáng chú ý, phát inh này có đóng góp của các nhà vật lý trẻ VN.



Các nhà vật lý trẻ thuộc phòng thí nghiệm VATLY và GS Pierre Darriulat - Cố vấn khoa học của Dự án

Phát hiện này nằm trong dự án thí nghiệm Pierre Auger và được đăng trên tạp chí *Science* số ra hôm nay, 9/11.

A radio telescope at home

High energy cosmic rays

Collaboration with the Pierre Auger Observatory in Argentina

Radio astronomy

Collaboration with French institutes
Using 2.6 m radio telescope at home

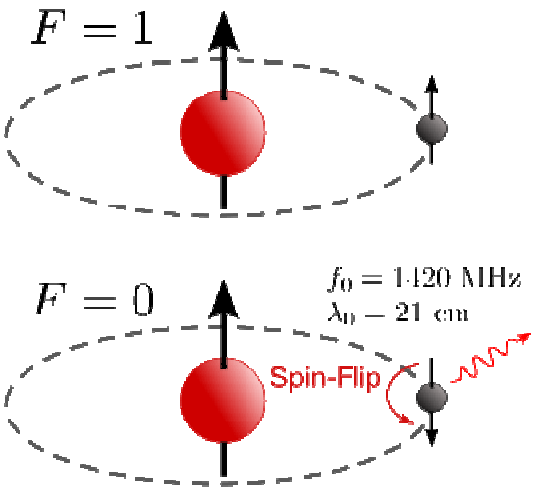
Radio astronomy is at the forefront of current research; observations made from major international observatories.

For training students at home, it is much better adapted to the Vietnamese tropical sky than optical astronomy, for which observations are rarely possible.

For now five years or so, we work exclusively in radio astronomy.

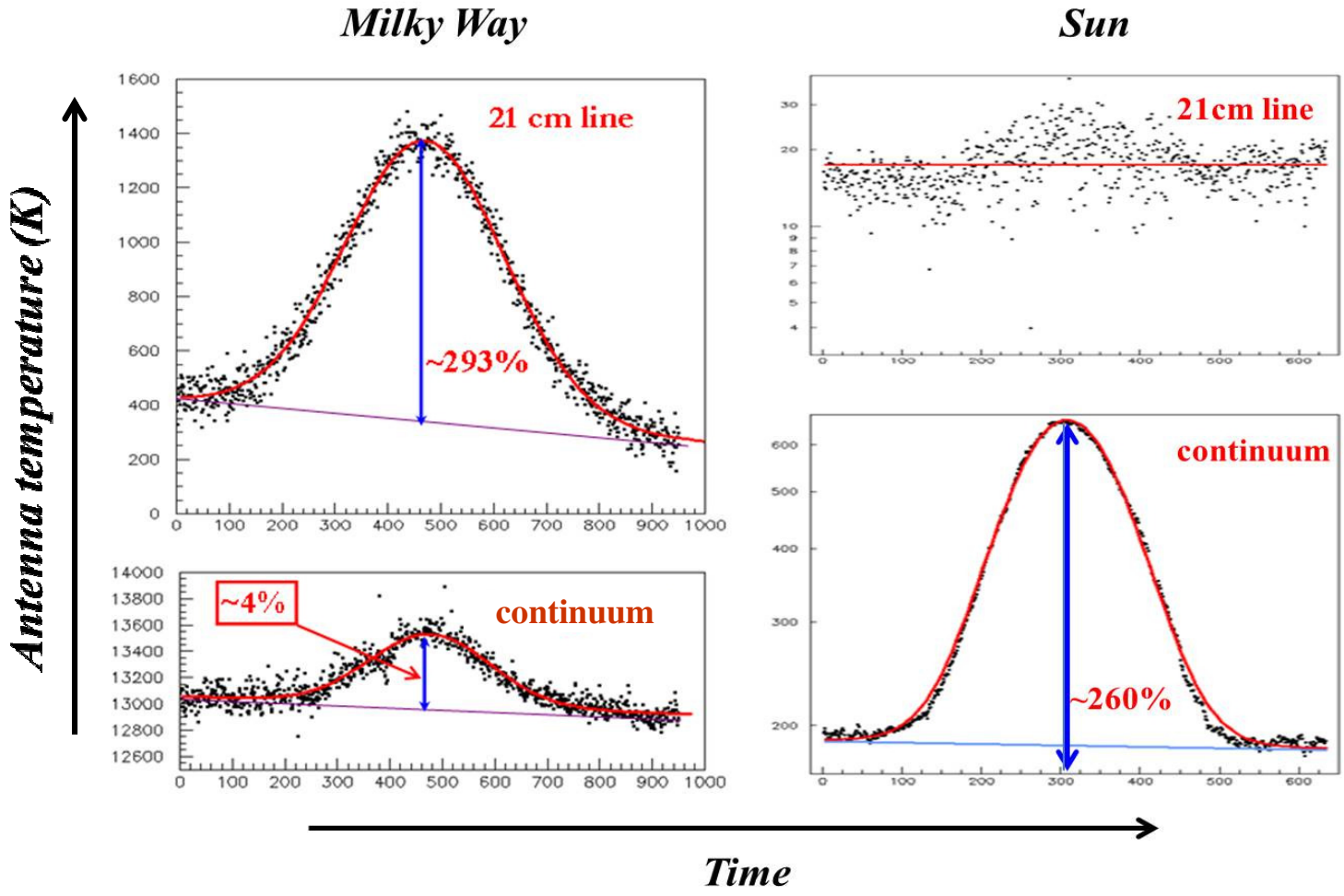
The radio telescope and its performance

- Mobile parabolic dish, 2.6 m in diameter
- Operated at frequencies between 1400 to 1440 MHz (21 cm of neutral hydrogen atoms or HI line)
- Pointing accuracy of 0.22° in $a \times cos(h)$ and 0.11° in h (a: azimuth, h: elevation)

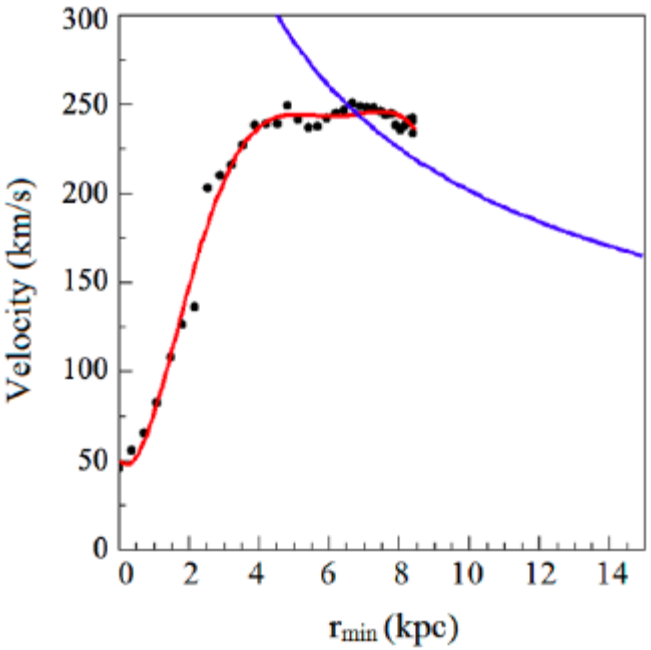


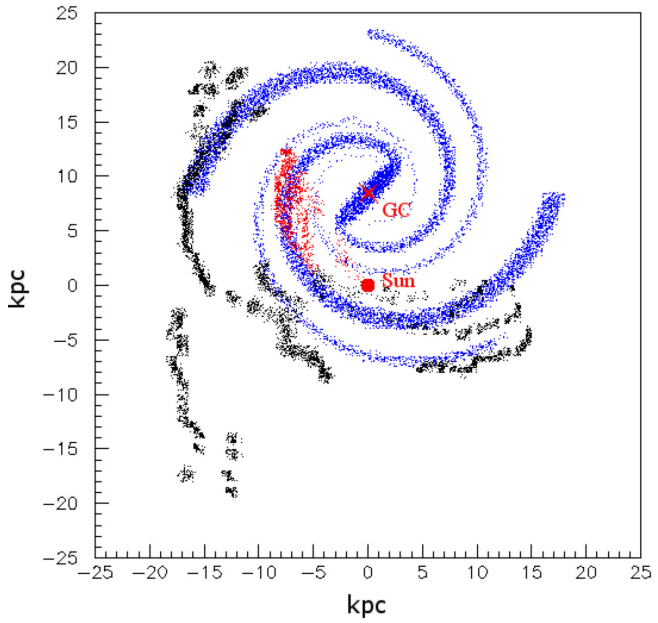
- The angular aperture of the main lobe (the "beam") is well described by a Gaussian having a σ of 2.3°
- Antenna efficiency factor is 65% meaning a conversion factor of 1.25±0.09 K/kJy.
- The sensitivity of the instrument has been evaluated at the level 300 Jy.

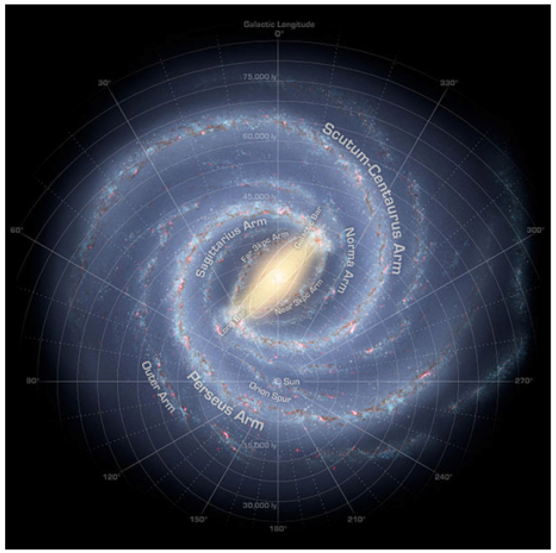
Galaxies such as ours contain many HI clouds and the 21 cm signal of the disk of the Milky Way is particularly strong. On the contrary, the Sun emits exclusively in the continuum.



HI in the Milky Way





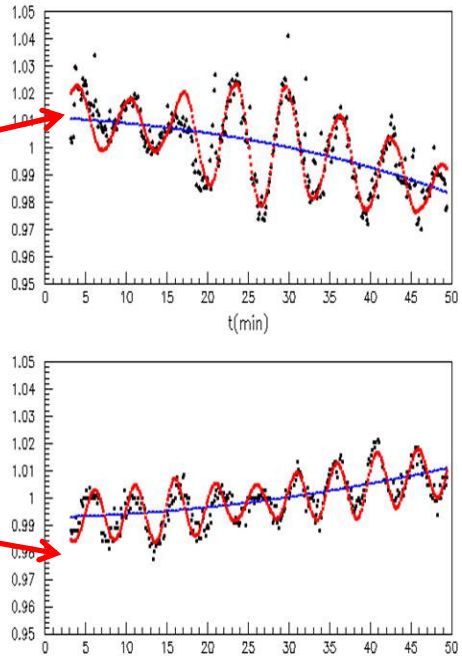


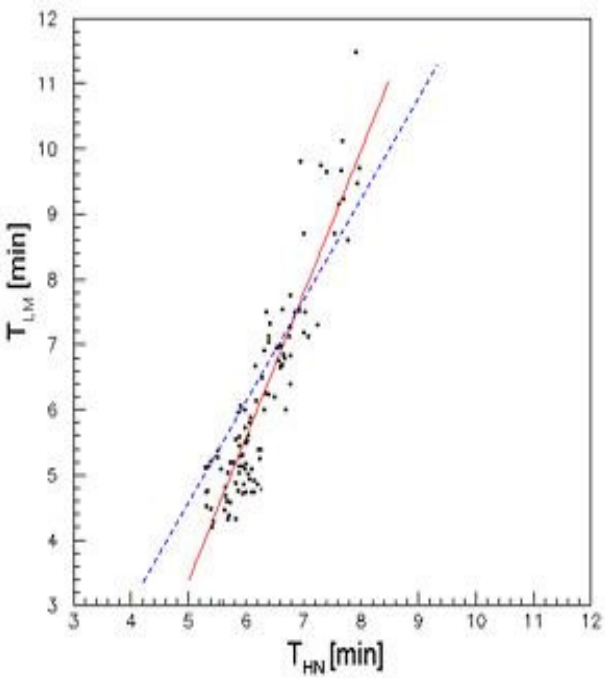
Spitzer Space Telescope

The Sun

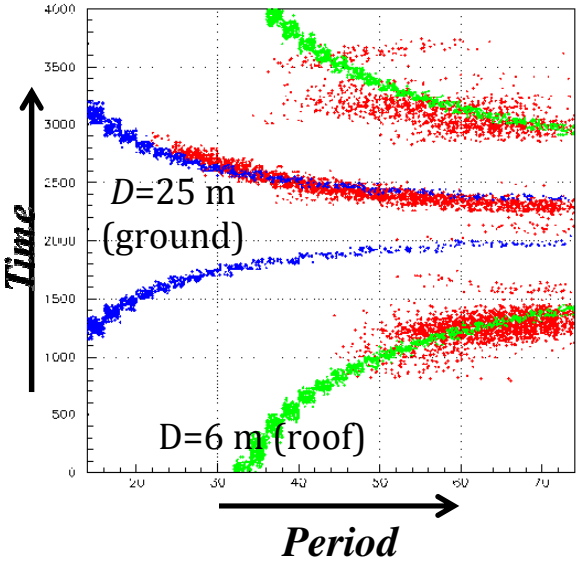
We observed the Sun to study **flares** and **oscillations** in comparison with similar observations made in Australia (Learmonth Observatory).

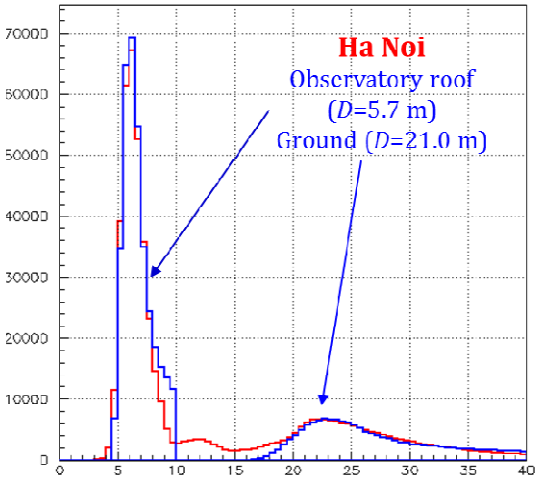
mHz oscillations (T~6 minutes) were observed simultaneously in both observatories with correlated periods, which was not understood originally.



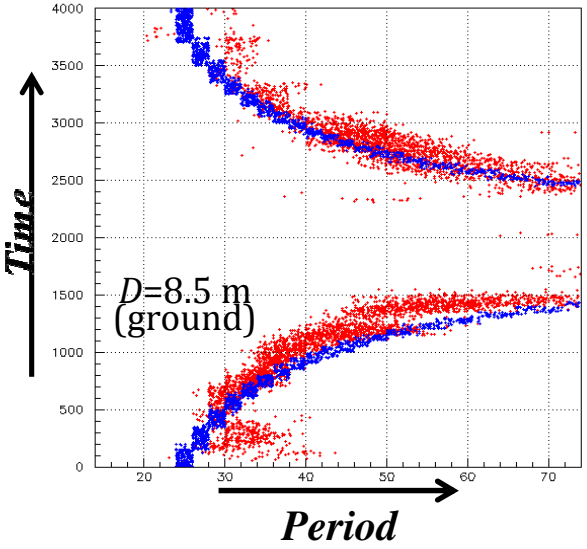


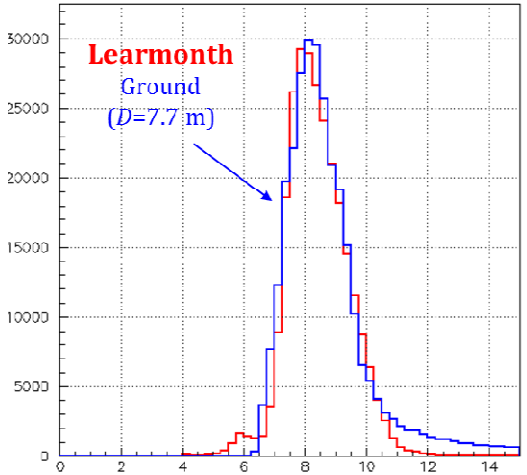
Ha Noi



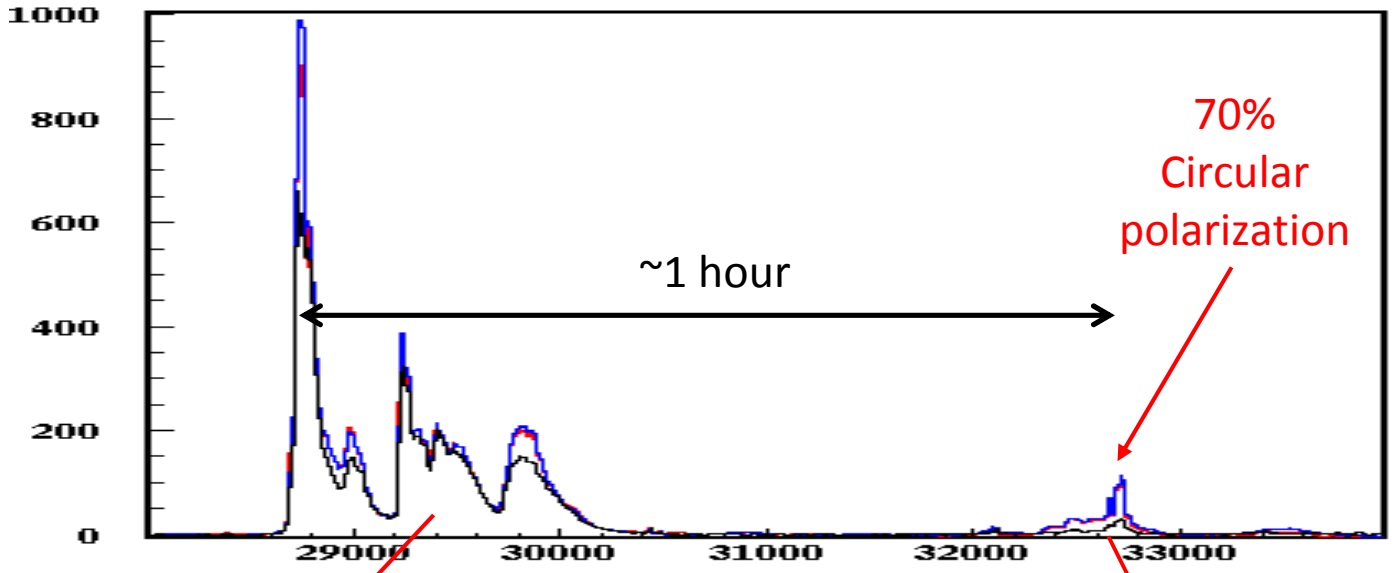


Learmonth



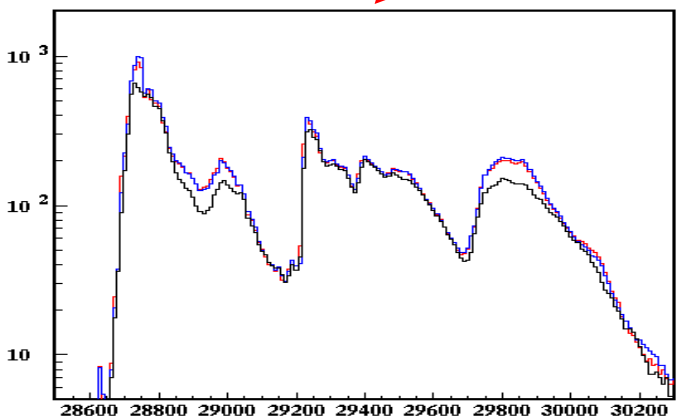


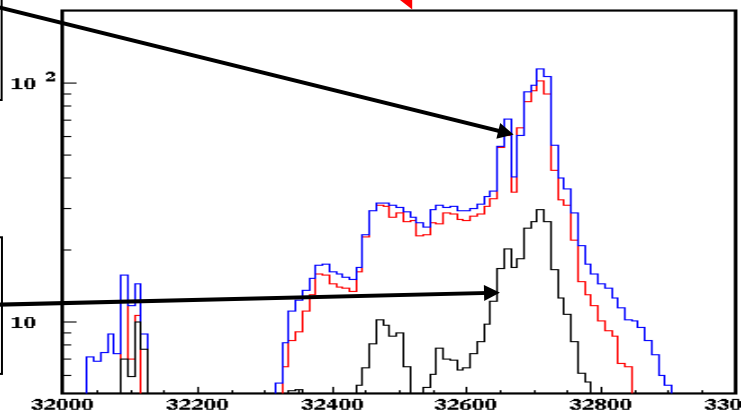
Polarization of Solar Flares



Learmonth & San Vitto Dipole feeds

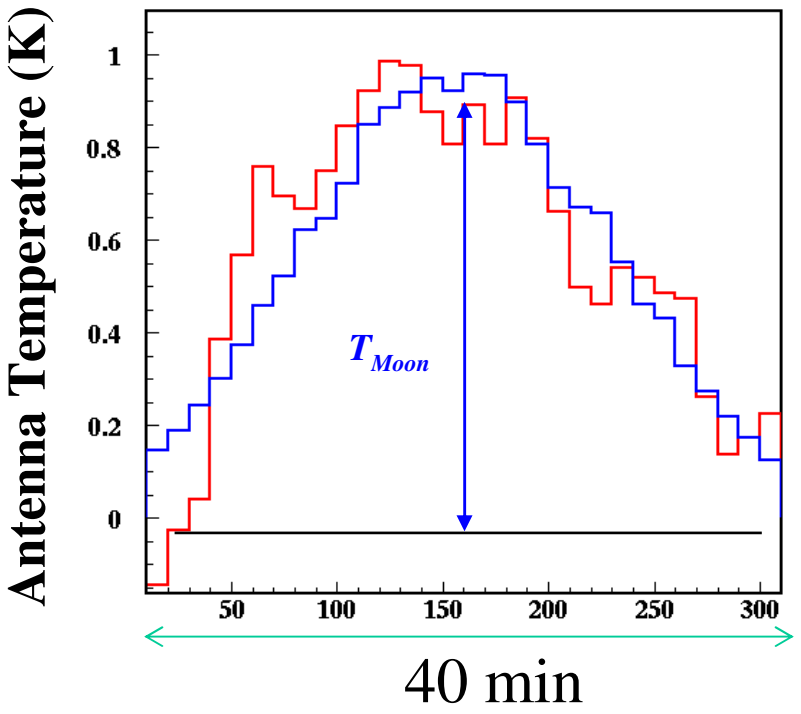
Ha Noi Helical feed

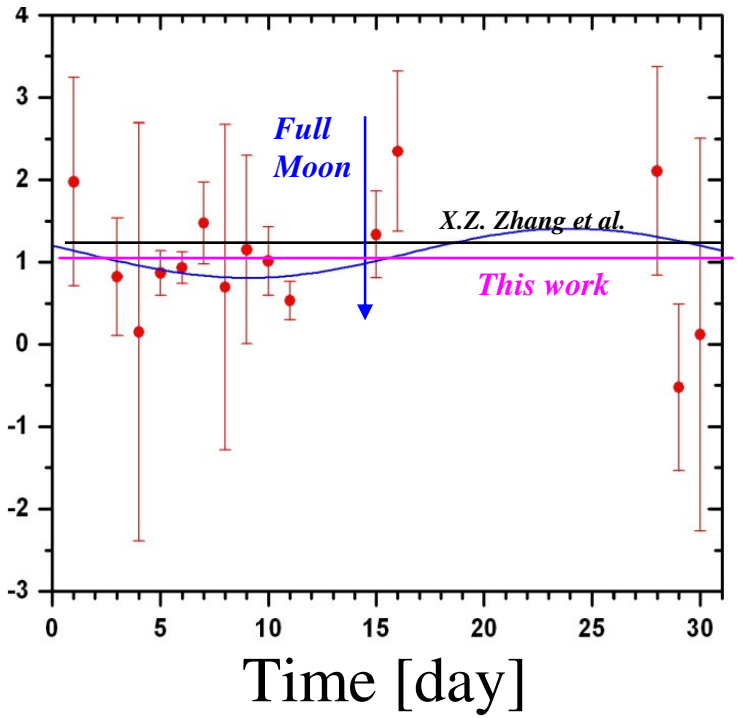




Measurement of the Moon's temperature

Detection of the Moon (drift scans)
Black body temperature 207±40 K
Limit sensitivity ~300 Jy





Our telescope has produced 2 master theses and 7 publications (2 in ISI journals and 5 in Communications in Physics/Viet Nam).

It is now installed on top of a university (USTH) building for the training of undergraduate and master students.

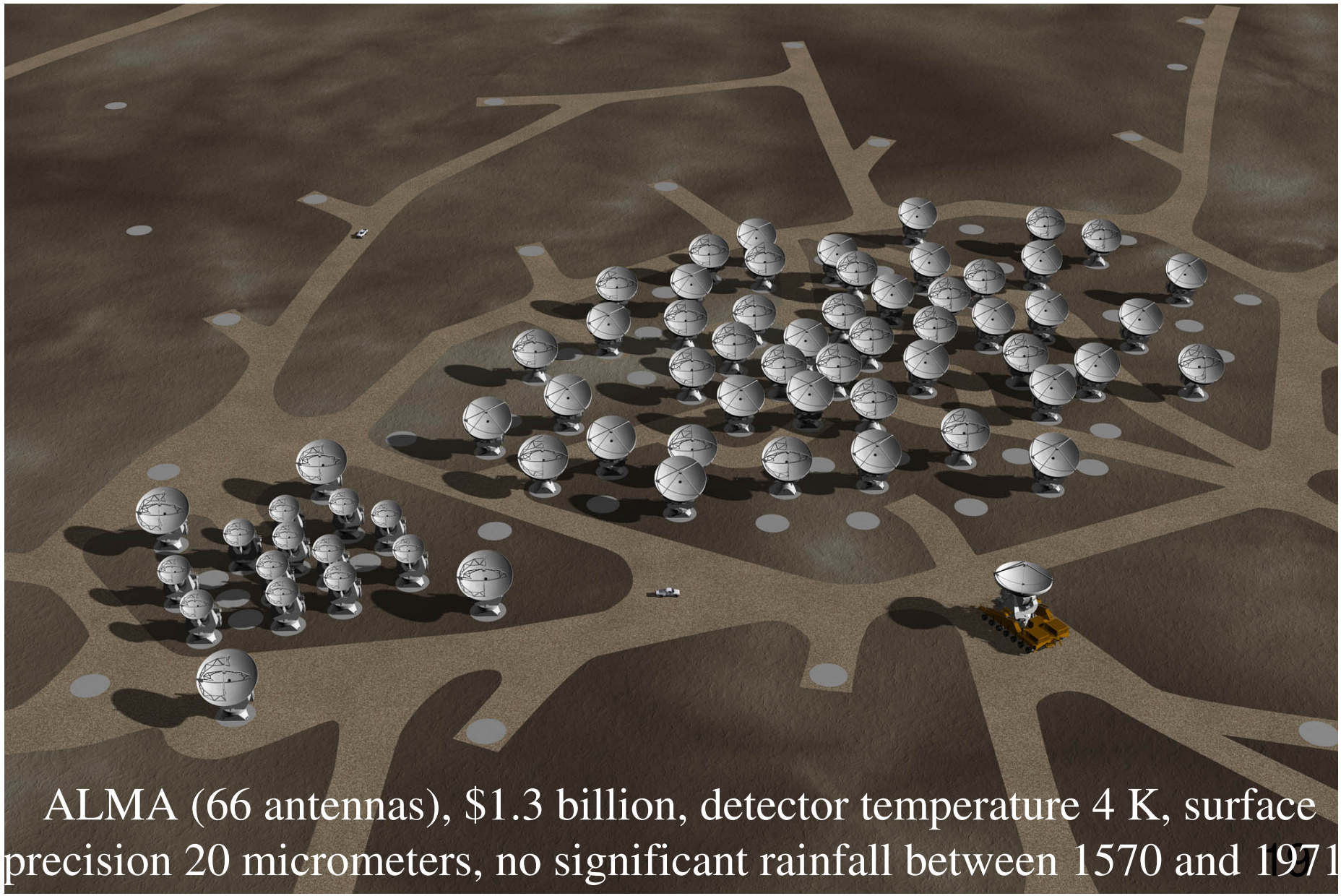
We use observations made with **radio interferometers**: Plateau de Bure (6 antennas), VLA (27 antennas) and ALMA (66 antennas).

The data

Plateau de Bure (PdBI)

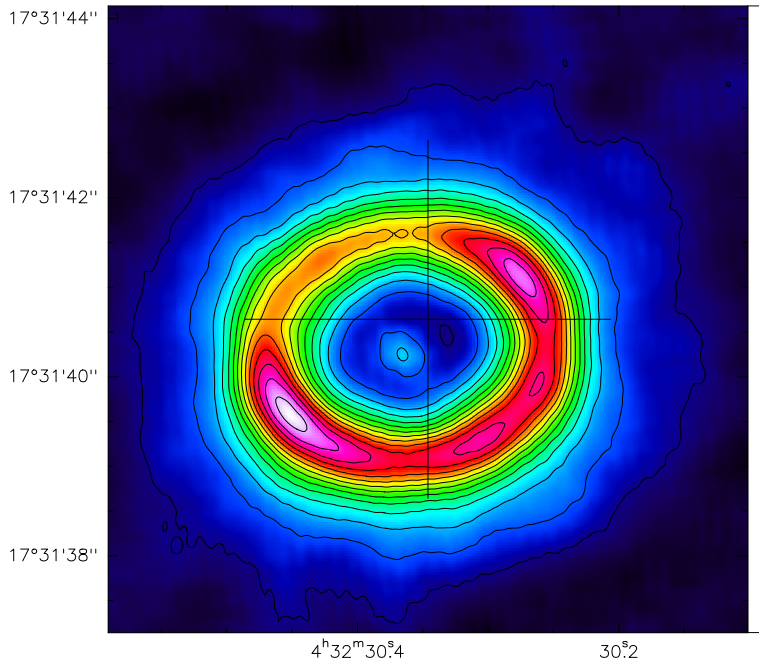
NOEMA (NOrthern Extended Millimeter Array)

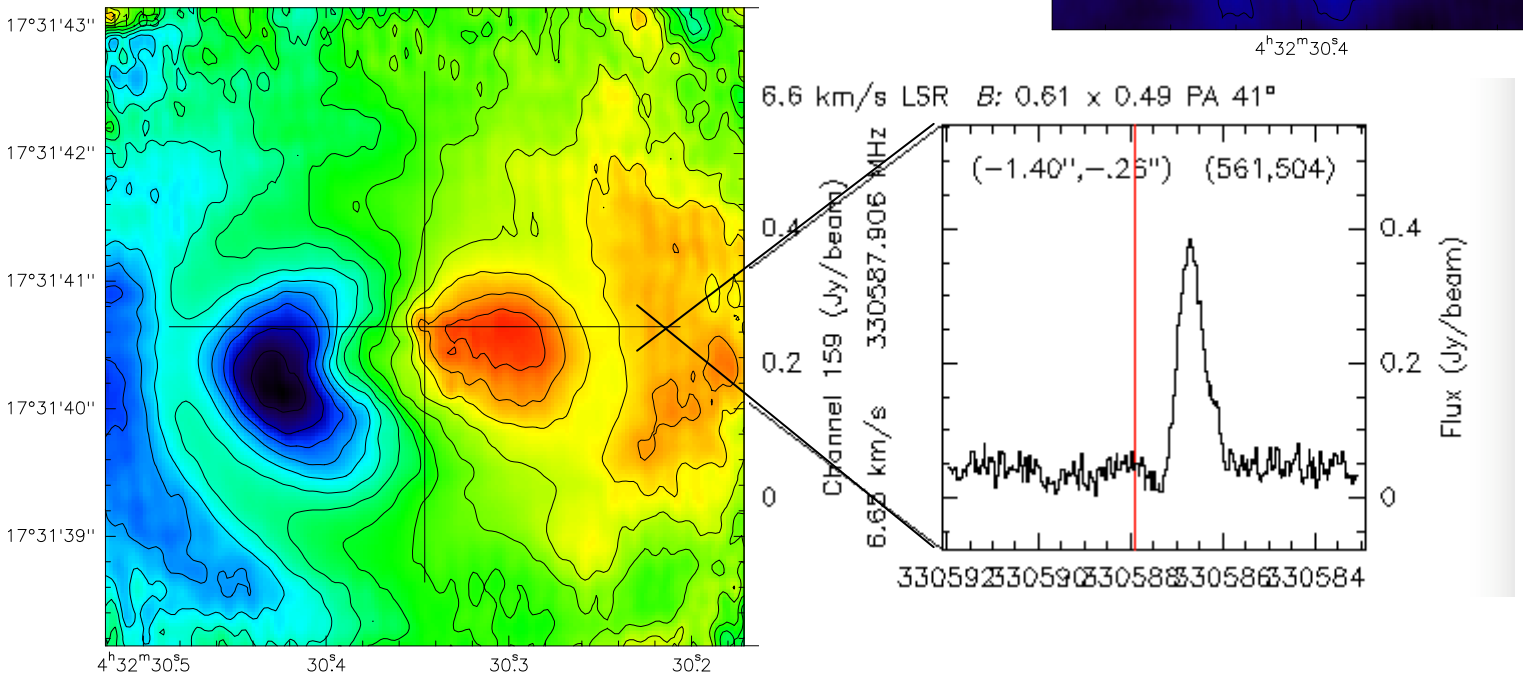
Atacama Large Mm/sub-mm Array (ALMA)



ALMA (66 antennas), $1.3 billion, detector temperature 4 K, surface precision 20 micrometers, no significant rainfall between 1570 and 1971

The data


17°31'44''
17°31'42''
17°31'40''
17°31'38''
4h32m30s.4
30s.2


17°31'43''
17°31'42''
17°31'41''
17°31'40''
17°31'39''
4h32m30s.5
30s.4
30s.3
30s.2
6.6 km/s LSR B: 0.61 x 0.49 PA 41°
(−1.40'',−.25'') (561,504)
330587.906 MHz
Channel 159 (Jy/beam)
6.62 km/s
Flux (Jy/beam)
0.4
0.2
0
330592
330590
330588
330586
330584

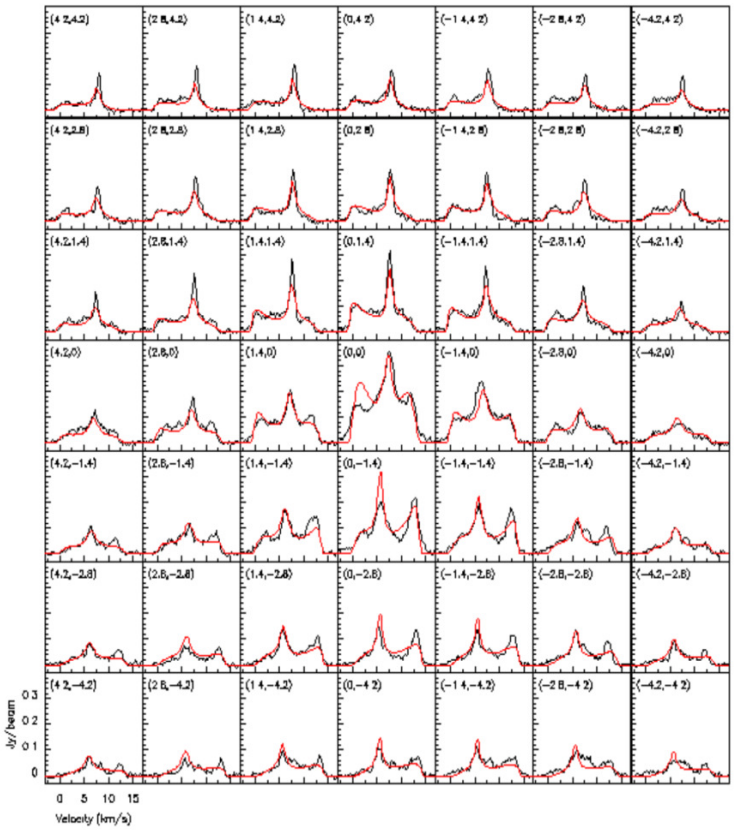
Data analysis

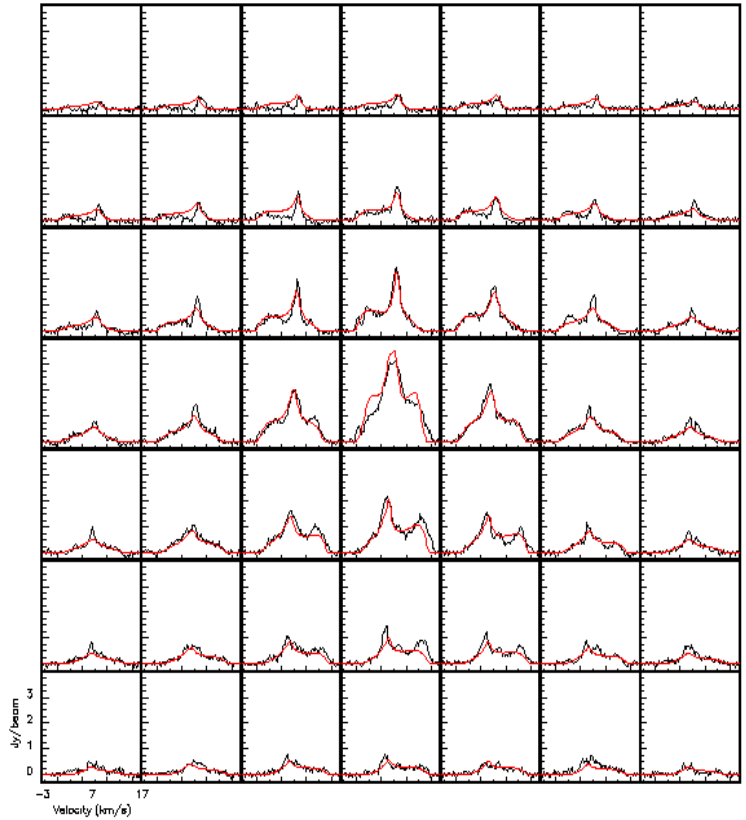
Construct models
(morphology and kinematics)

adjusting
parameters

χ^2 minimization of the fit to the Doppler velocity distribution in each pixel

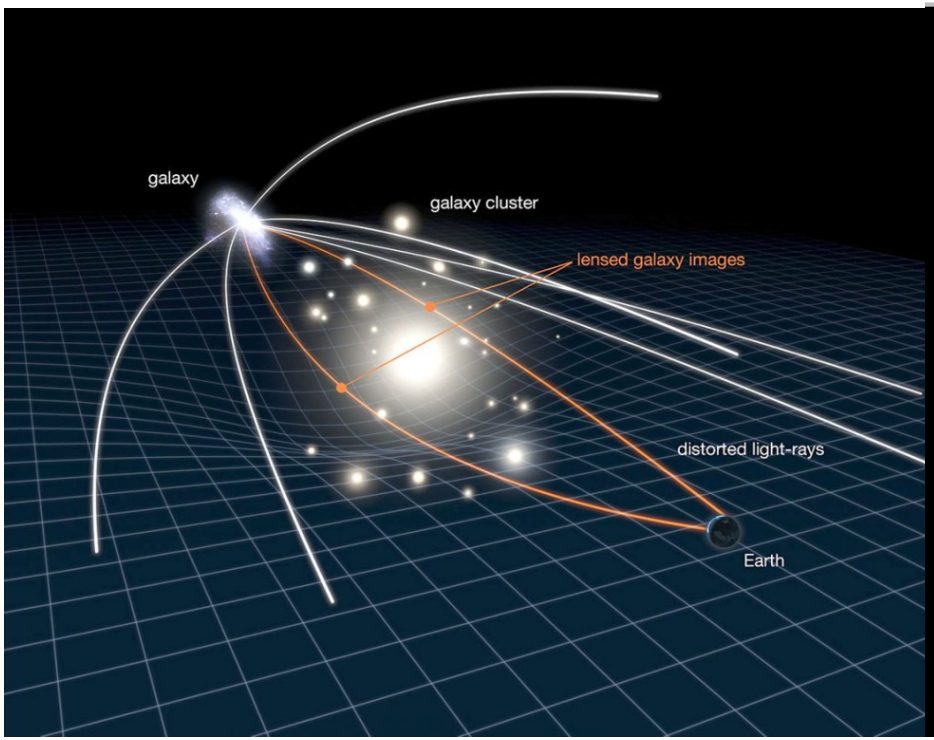
CO(1-0) **RS Cnc** CO(2-1)

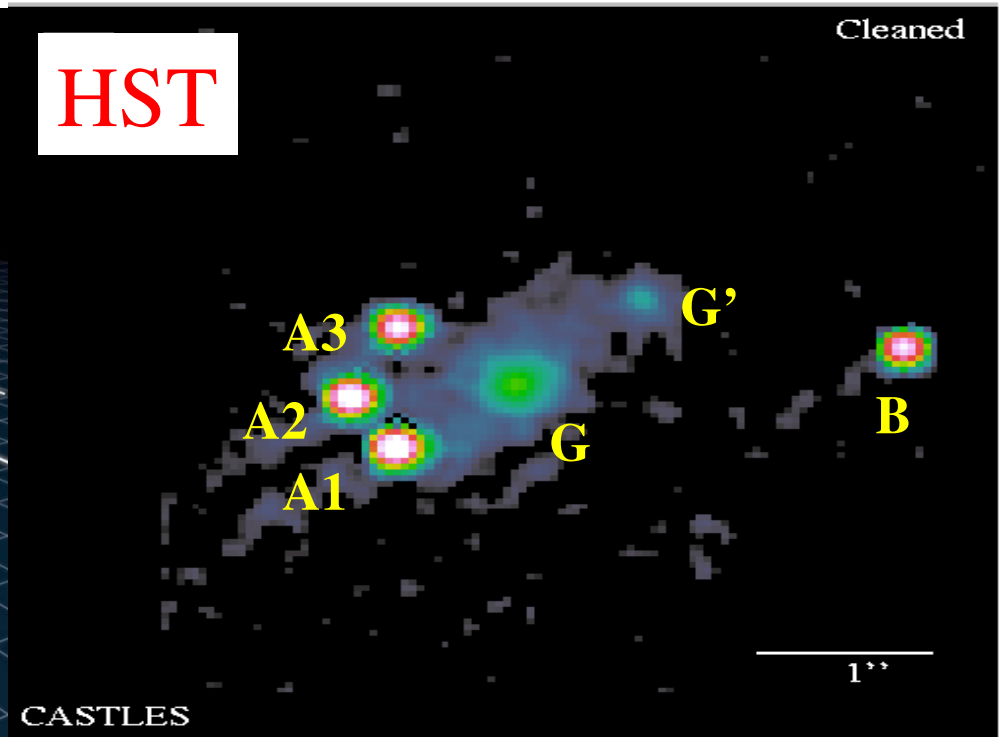




High redshift galaxies: a typical example, RX J0911

RX J0911: the host galaxy of a gravitationally lensed high redshift quasar (z~2.8, look back 11.3 Gyr). Detection of the CO(7-6) line by Plateau de Bure measures its gas content; and of the continuum underneath by ALMA, its dust content.

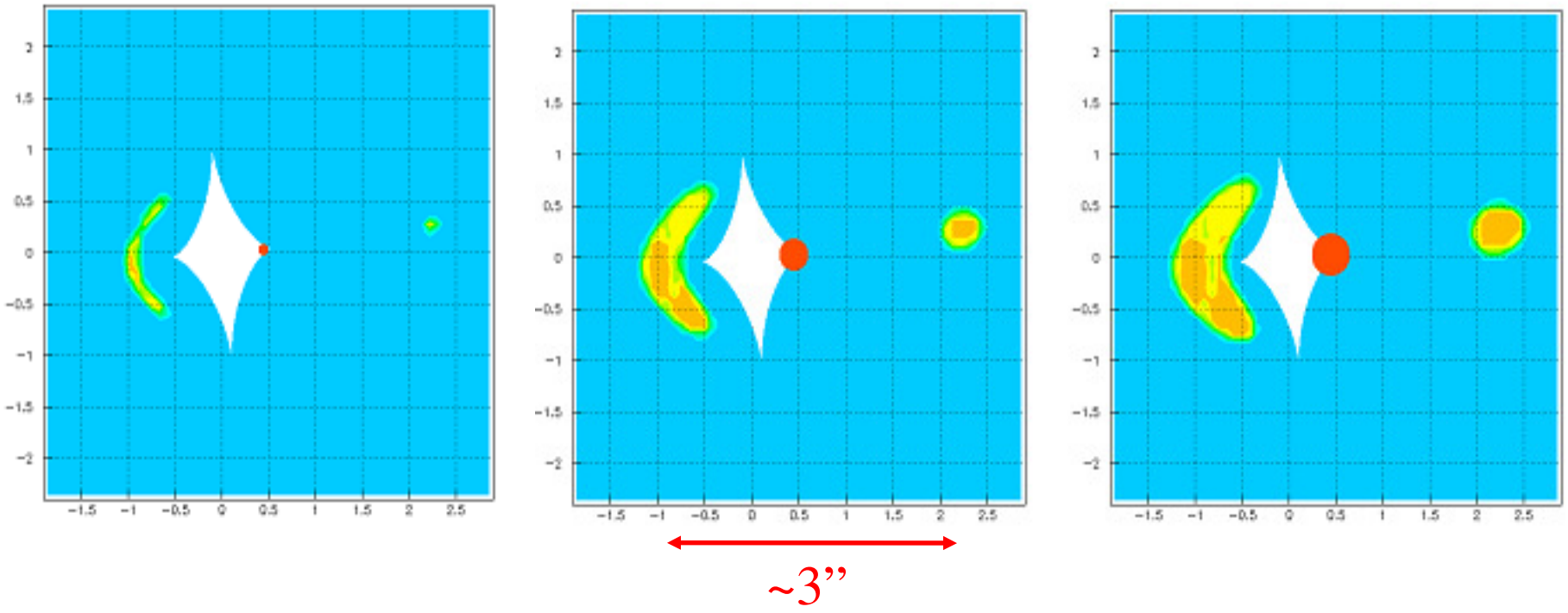




Gravitational lensing effect

RX J0911

Lensing is complicated by the fact that the extended source overlaps the lens caustic. We studied this peculiar situation in detail.

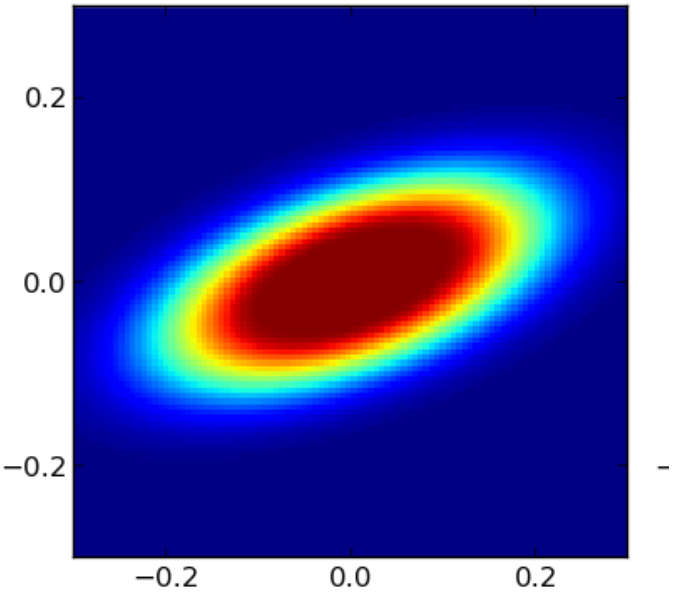


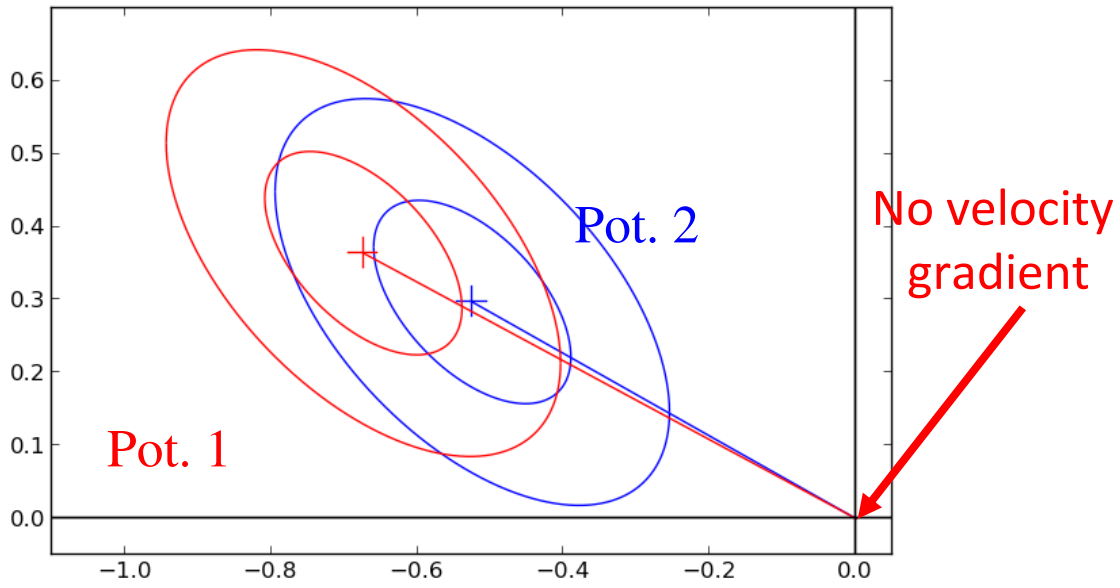
RX J0911: Gas properties

The results show that the gas source has a **radius of 850±120 pc** on the line (~7 s.d.) and provide evidence for **ellipticity** and for a significant **velocity gradient** (molecular outflow and/or rotation).

Ellipticity: 3.3 s.d. away from circular

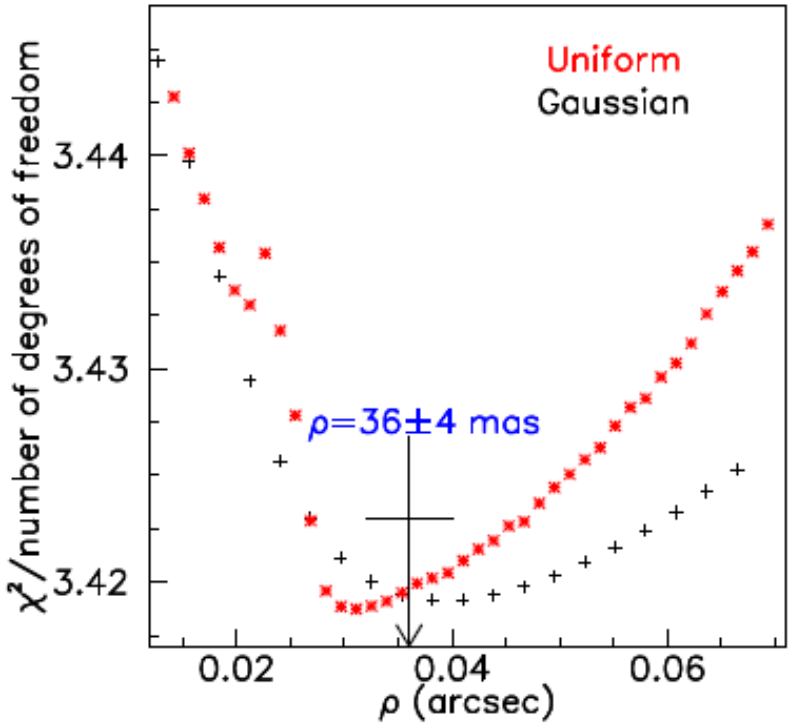
Evidence for velocity gradient at 4.5 s.d.





RXJ0911: Dust component

The dust component is found much more compact than the gas component, ~3.4±0.4 times less extended and too small to allow for an ellipticity measurement.



This measurement makes RX J0911 one of the few high-z galaxies for which the dust and gas are resolved with dimensions being measured.

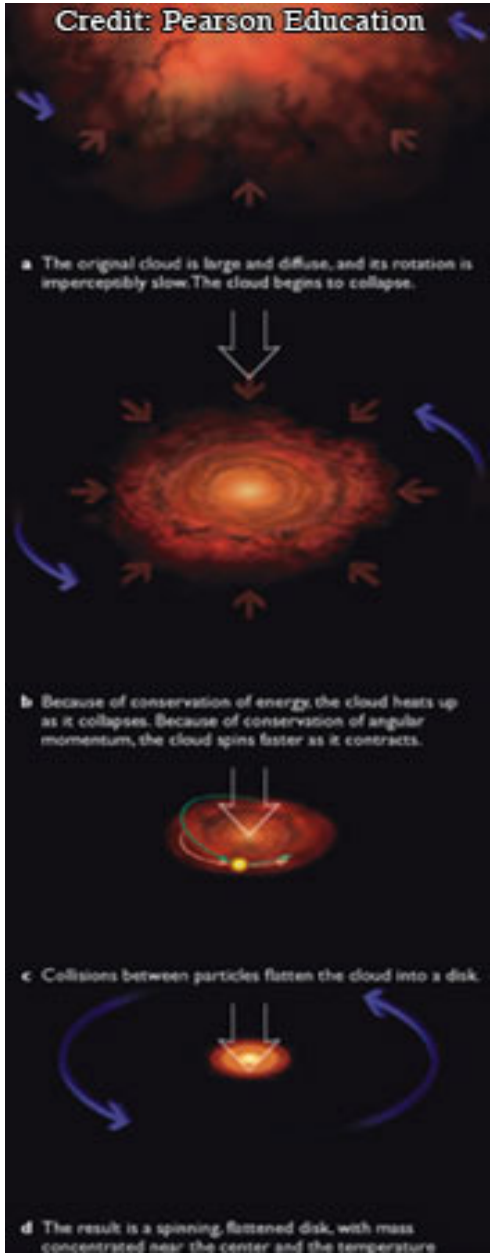
Remote galaxies: HE 1104-1805

We propose to observe and measure the **CO(3-2), CO(7-6)** and **associated continuum** emissions of the gravitationally lensed host galaxy of QSO HE 1104-1805 using ALMA.

The **main astrophysical interest** is to measure the **morphology and kinematics** of the gas and dust volumes of a high redshift (z=2.32) galaxy, at the epoch of maximal SFR and AGN activity, hosting a **supermassive black hole** in its centre (2.4 10^9 solar masses) and being in an **early stage of its evolution** (SFR of 220 solar masses/yr).

The relative positions, morphologies and kinematics of the gas and dust volumes will be measured with **sub-kpc resolution** in the source plane.

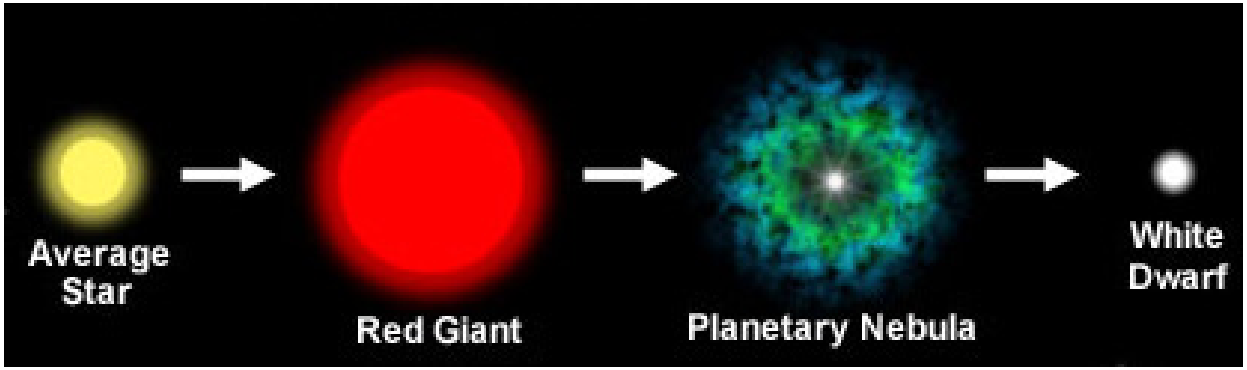
Star formation



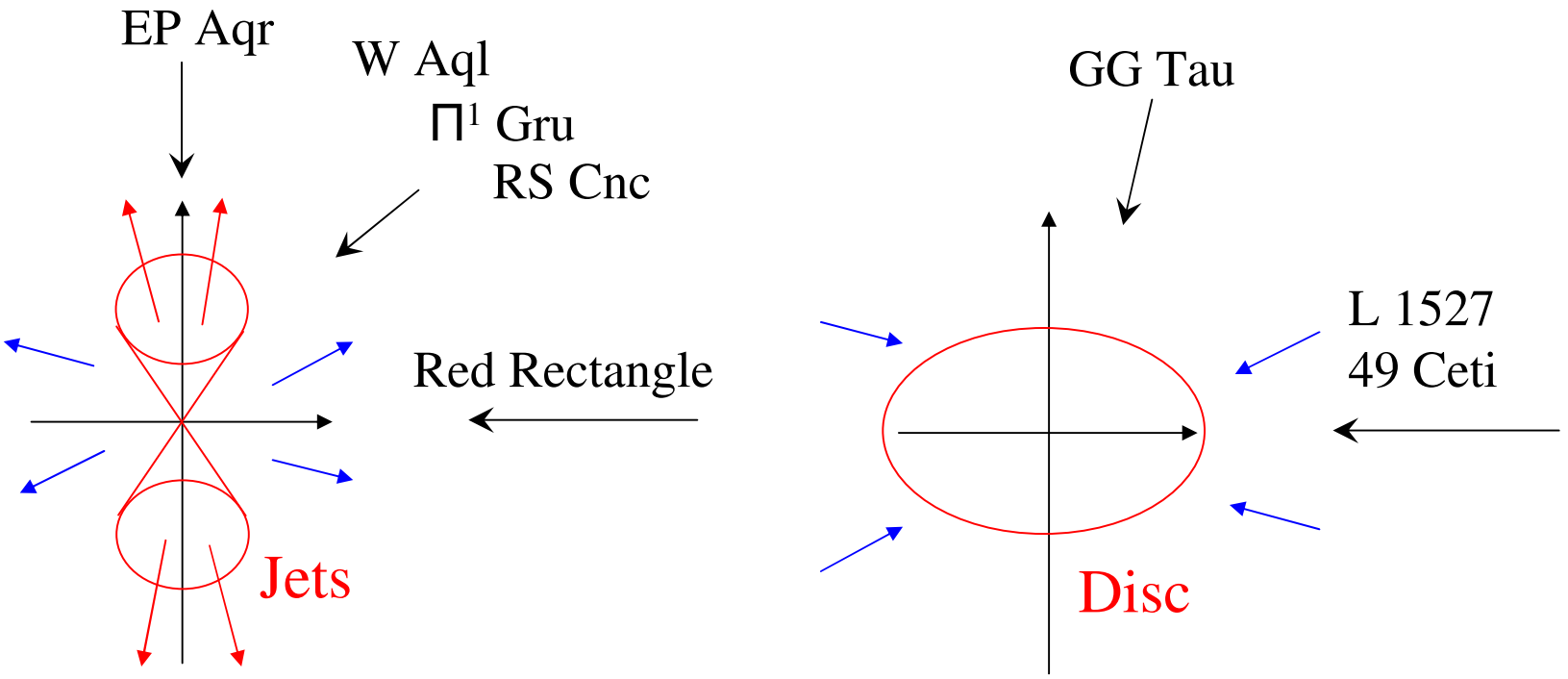
Stellar Physics

Similarities between the two processes are many: dust plays a very important role; importance of symmetries; the importance of periodic oscillations, taking the form of pulsed accretion in protostars and of thermal pulses in AGB stars.

Evolved star

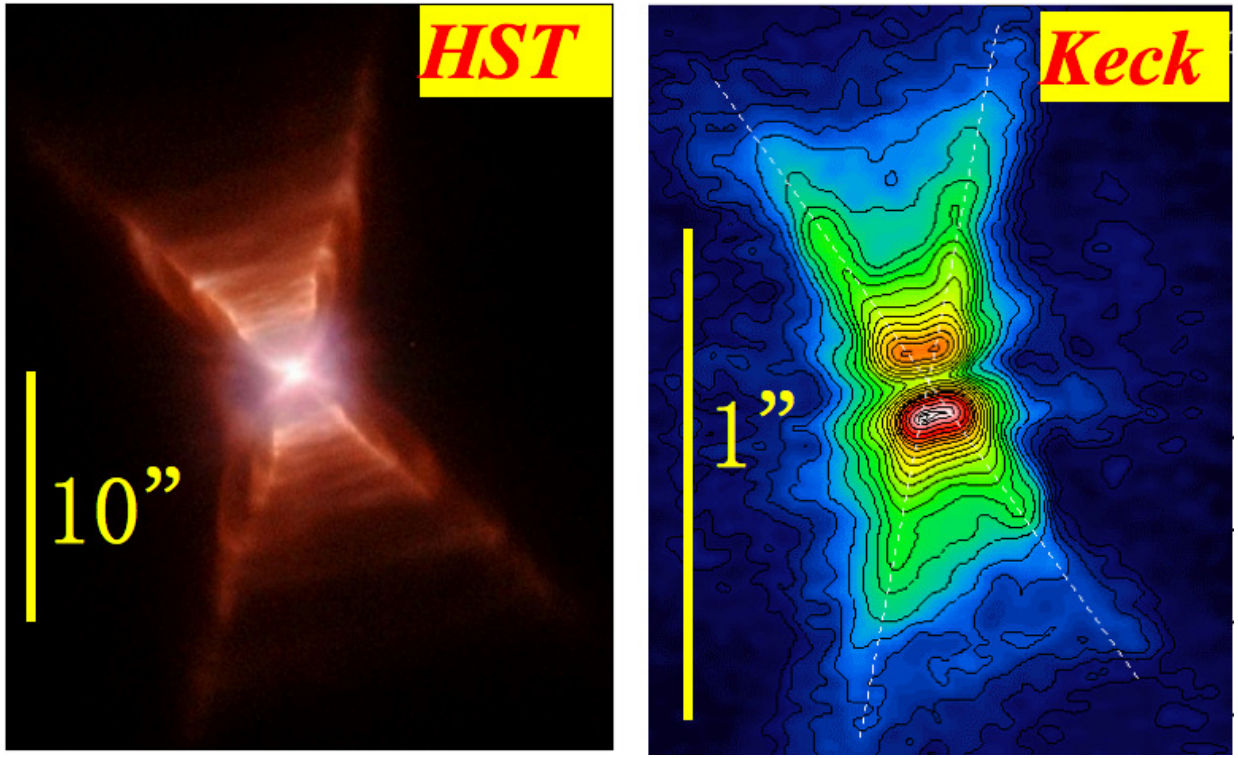


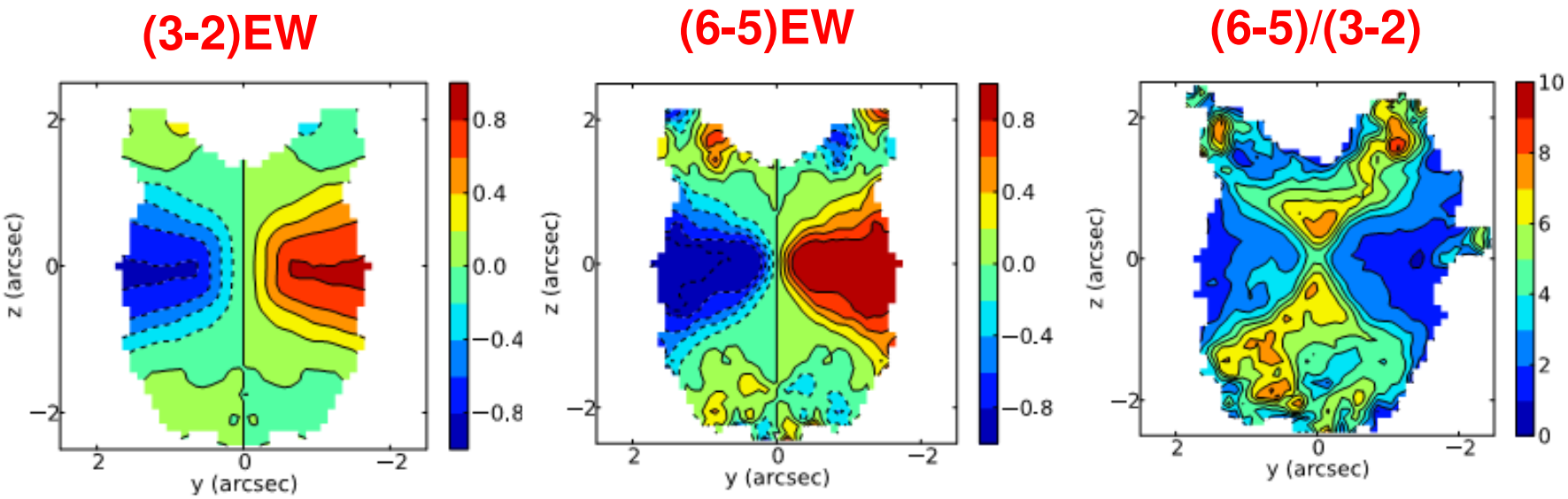
Partly in collaboration with French astronomers and partly on our own, we studied evolved stars and protostars using high resolution CO emission lines. The former often feature a **bipolar molecular outflow**, the latter the formation of a **disc**.



Example 1: an evolved star, the Red Rectangle

The Red Rectangle is a Post-AGB source, having its axis perpendicular to the line of sight. It displays a polar biconal outflow surrounded by a rotating equatorial gas volume. We studied CO(6-5) and (3-2) emissions measured by ALMA.





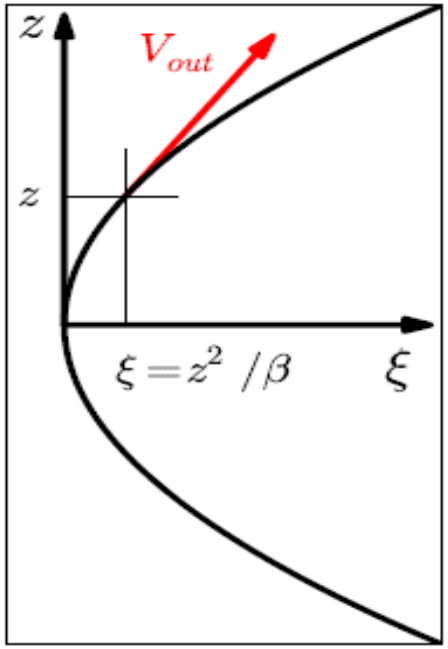
The East-West Doppler velocity asymmetry reveals a very clear **rotation of the equatorial region** about the star axis.

CO(6-5)/CO(3-2) intensity map: evidence for a **temperature distribution** dominated by the biconical structure down to low distances from the star.

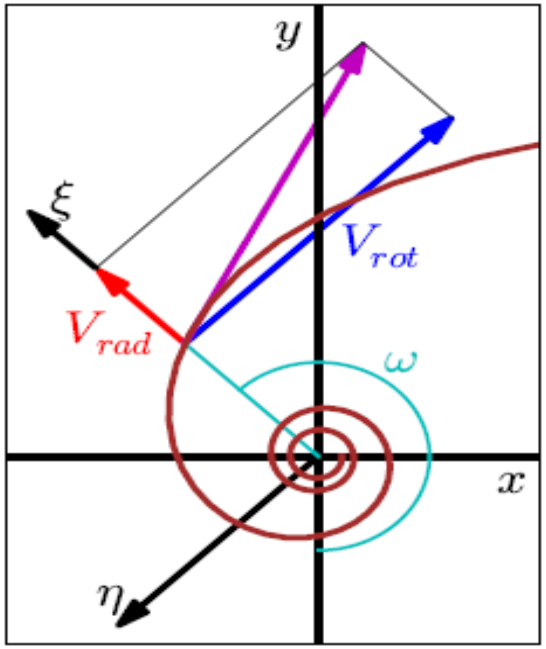
Gas kinematics

Polar regions: parabolic meridian trajectories joining smoothly between the equatorial torus and the star axis with a constant wind velocity.

Equator region: spiraling trajectories with rotation and expansion.



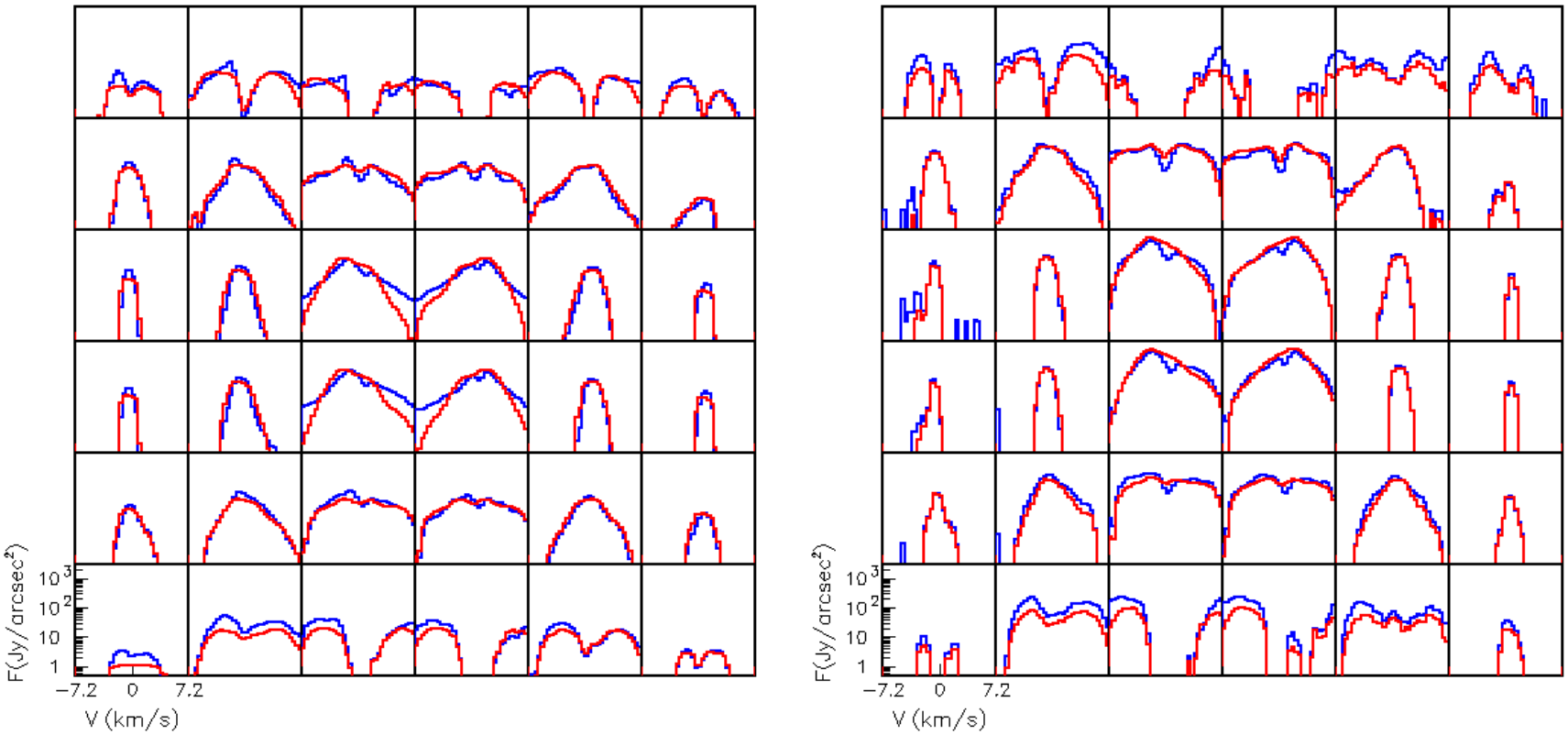
Polar region



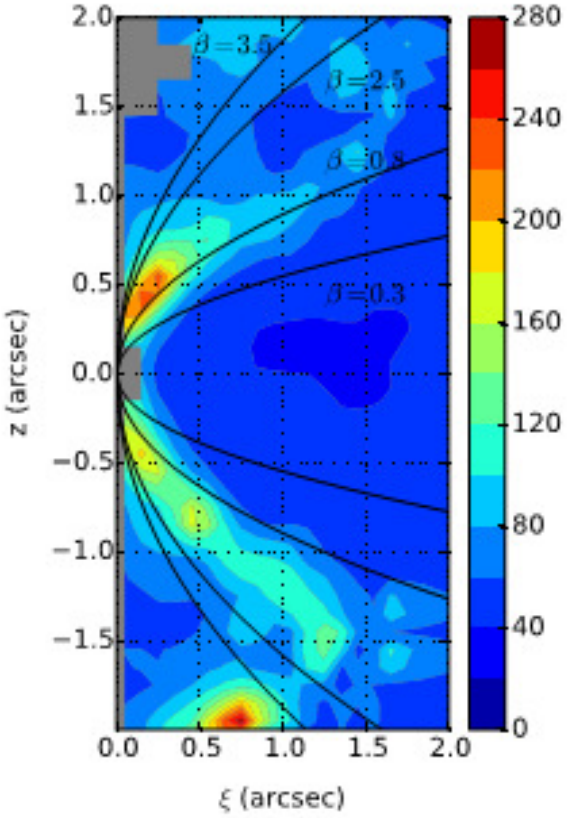
Equatorial region

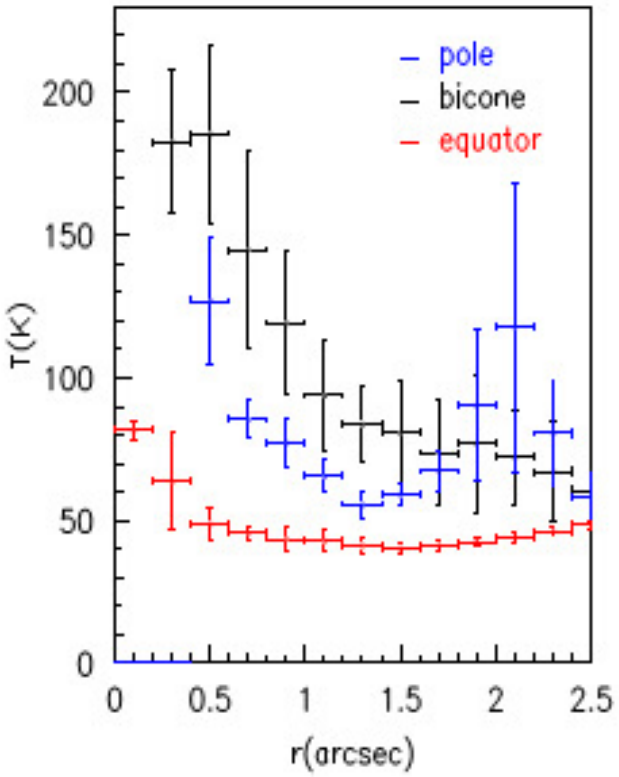
We find V_{rot}~*–1.0 km/s*, V_{rad}~*1.6 km/s*

The fit is surprisingly good in view of the crudeness of the model.

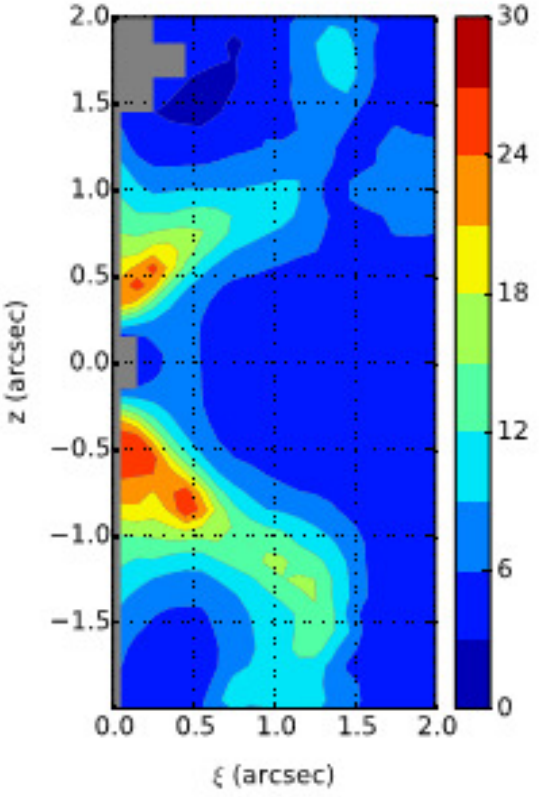


Temperature





Density×r^2



The gas morphology is reconstructed in space (here shown in the meridian plane). Sharp separation between the equatorial and polar regions.

Example 2: 49 Ceti, a debris disc

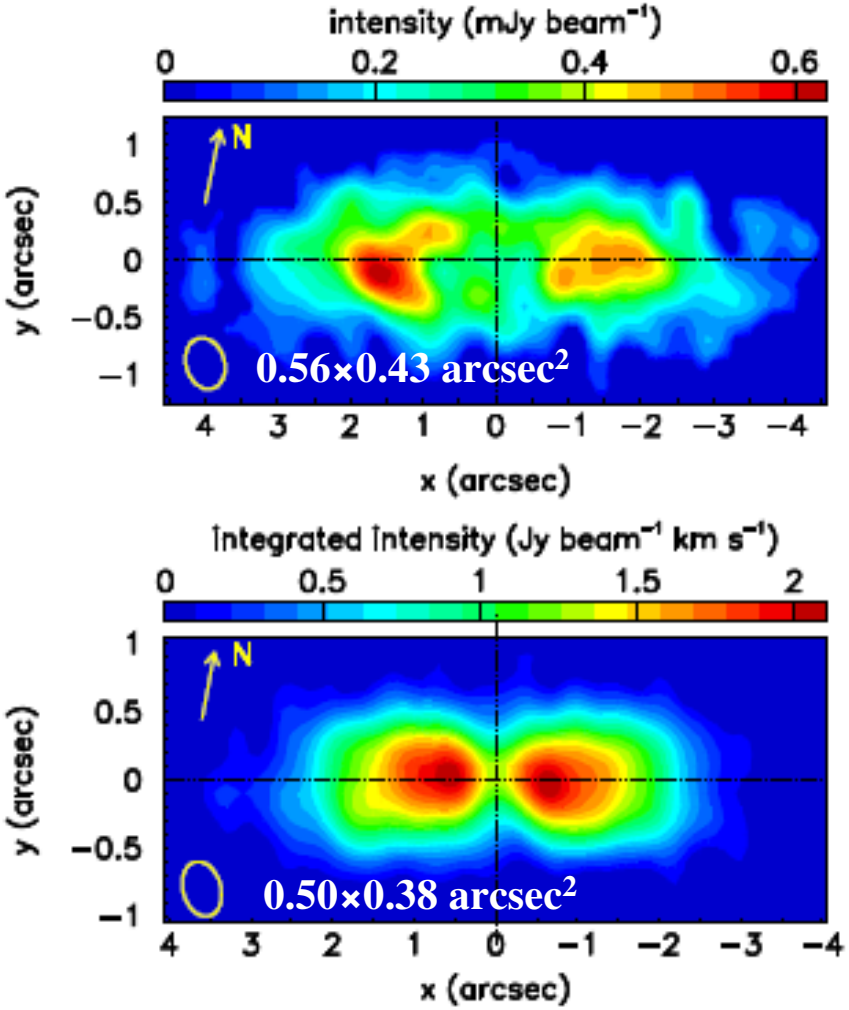
49 Ceti, a bright debris disc, seen close to edge on at a distance of 59 pc

Age: in 49 Myr range

Dust: dusty, ~0.3 Earth masses (SED)

CO: 2×10^{-4} Earth masses

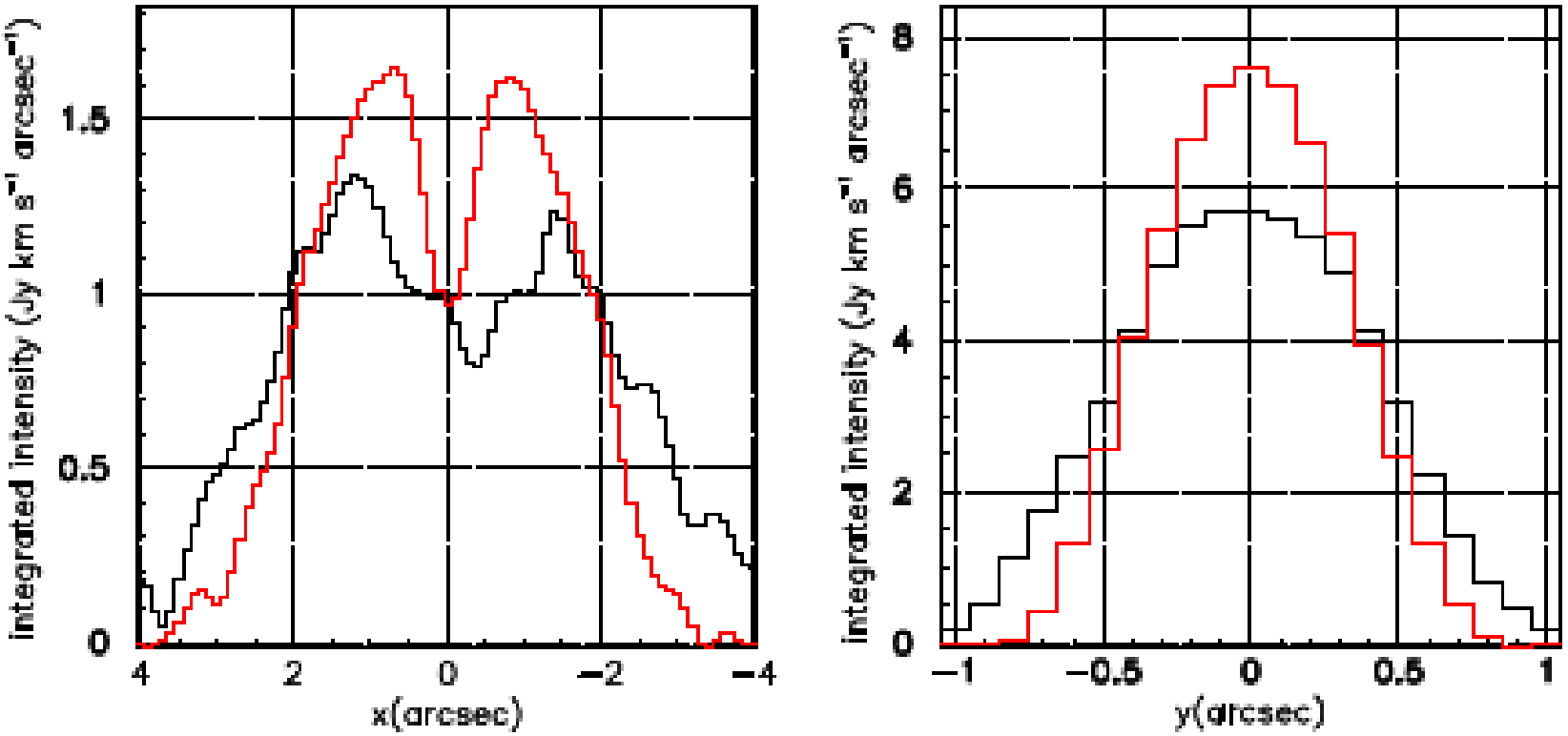
We studied its 350 GHz continuum and ^{12}CO(3-2) emissions measured by ALMA.



Continuum and ^{12}CO(3-2): main features

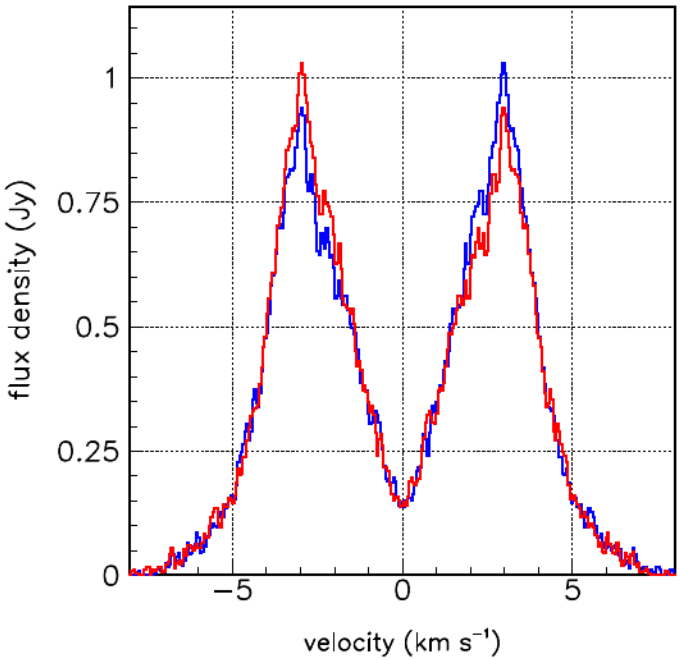
CO(3-2) (red)

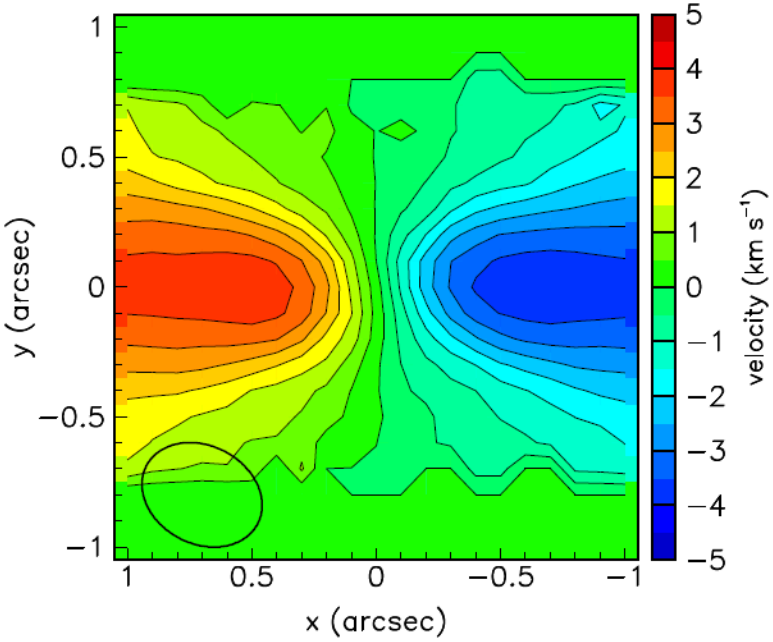
Continuum (black)

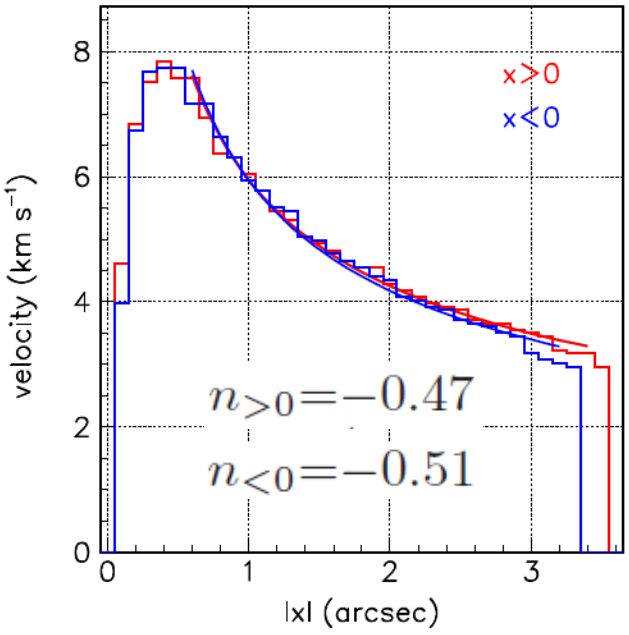


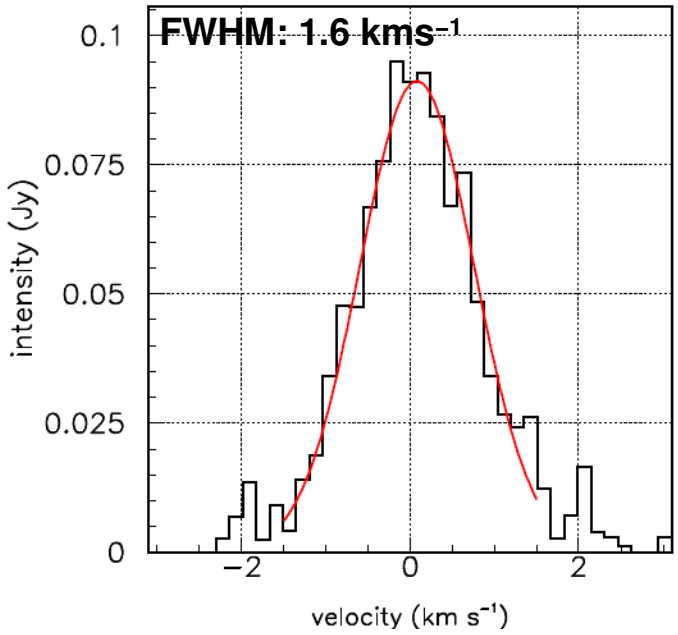
Distribution of observed intensity

Gas kinematics



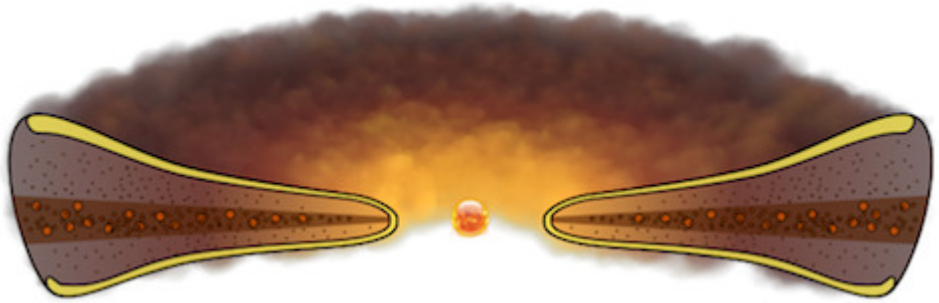






Model of CO(3-2) emission

Morphology: rotation invariance about the disc axis + symmetry about the disc mid-plane + flaring disc + flat disc mid-plane (no warping)



Important constrain: along the line of sight ρ[CO] ≤ 5×10^{12} cm^{-2}

$$\rho(x,y,z) = f(x,y,V_z)\frac{dV_z}{dz} \rightarrow F(x,y) = \int f(x,y,V_z)\,dV_z = \int \rho(x,y,z)\,dz$$

Flaring disc: $R^{-1}\exp(-\frac{1}{2}h^2/\Delta_h^2)$ with $\Delta_h = \eta_h R$

$R = y/\sin(i) - h/\tan(i)$: radius in disc plane

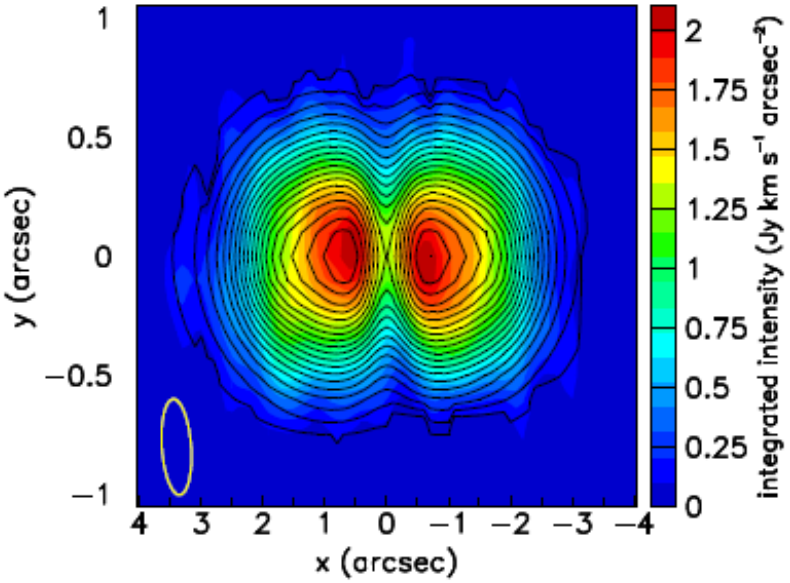
Kinematics: $\boxed{V=V_0 r^n}$

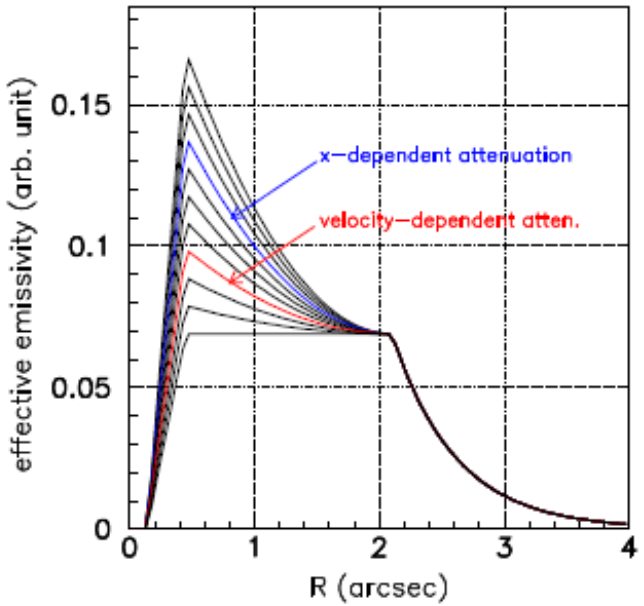
$$A(x) = 1 - \lambda_x\, exp(-\frac{1}{2}x^2/\Delta_x^2)$$

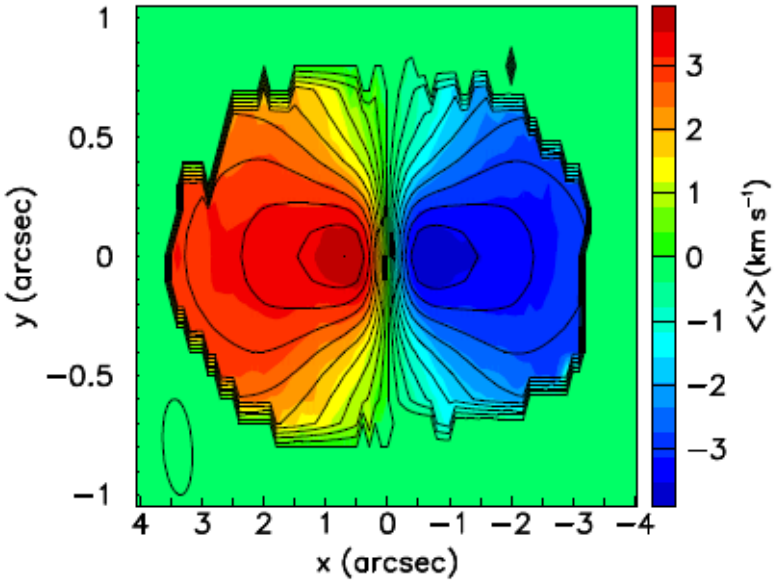
$$A(V_z) = 1 - \lambda_V \exp(-\frac{1}{2}V_z^2/\Delta_V^2)$$

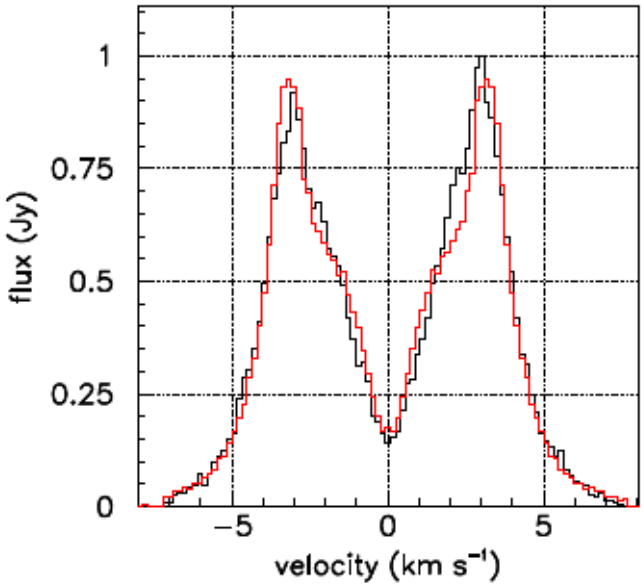
Parameters to be adjusted: *i*, *k*, *h*, V_0 and *n*.

CO(3-2) emission : fit results

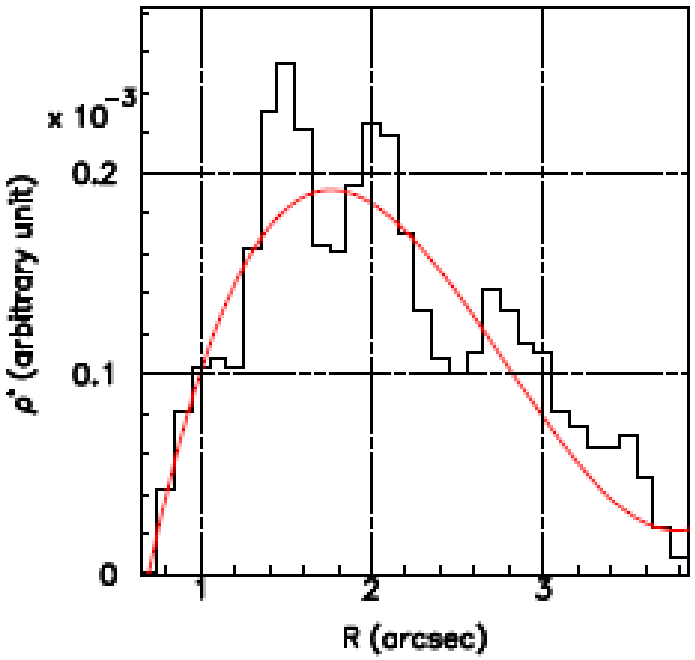


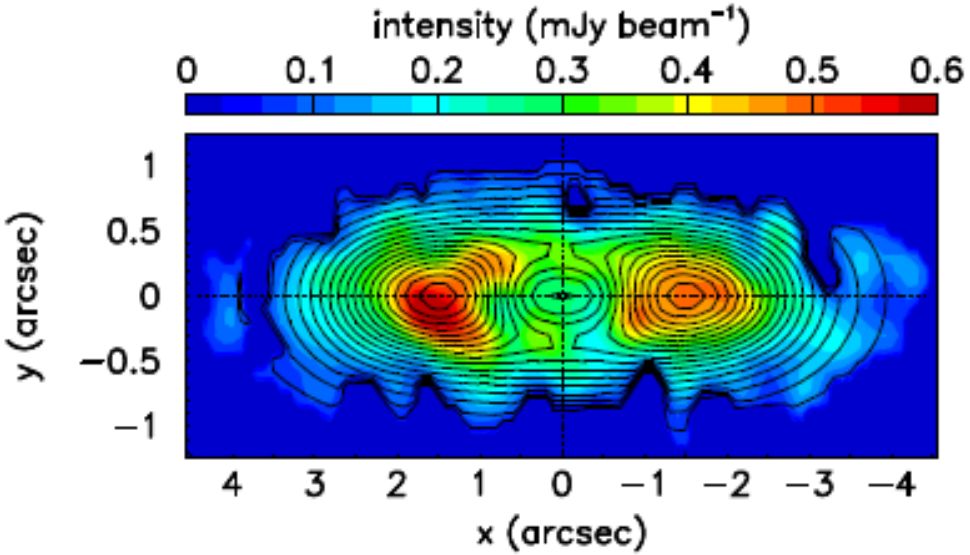


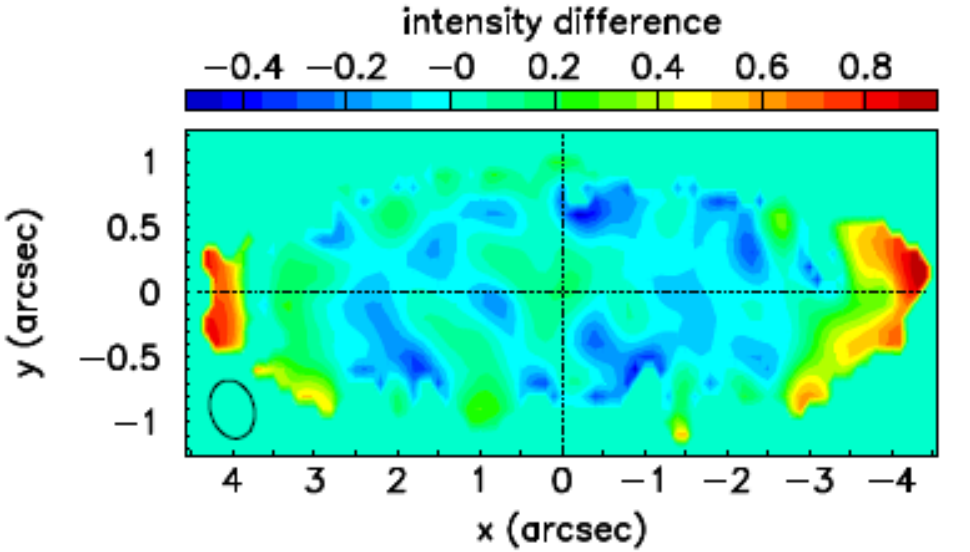




49 Ceti: dust emission







Two parameters to be adjusted:

i **and** $\Delta_h = \eta_h R$

Summary: best fit results

CO(3-2)

Description	Name	Value	
Intensity morphology			
Inclination	i (degrees)	$\mathbf{11.1 \pm 0.9}$	
Flaring angle	η_h (rad)	$\mathbf{0.041}^{+0.028}_{-0.019}$	
Radial dependence	k	$\mathbf{0.29}^{+0.31}_{-0.22}$	$\mathbf{0.70}^{+0.37}_{-0.22}$
Rotation velocity			
Velocity at r=1 arcsec	V_0 (km s^{-1})	$\mathbf{5.1 \pm 0.1}$	
Power index	n	$\mathbf{-0.46}^{+0.05}_{-0.02}$	
Attenuation at small $\|Vz\|$ or small $\|x\|$ values			
Amplitude	λ	$\mathbf{0.66}\pm0.15$	$\mathbf{0.60}\pm0.12$
FWHM in V_z or x	2.355 Δ_V (km s^{-1}) or 2.355 Δ_x (au)	$\mathbf{1.5}\pm0.5$	$\mathbf{49}\pm17$
χ^2 per degree of freedom		$\mathbf{0.76}$	$\mathbf{0.80}$

Dust emission

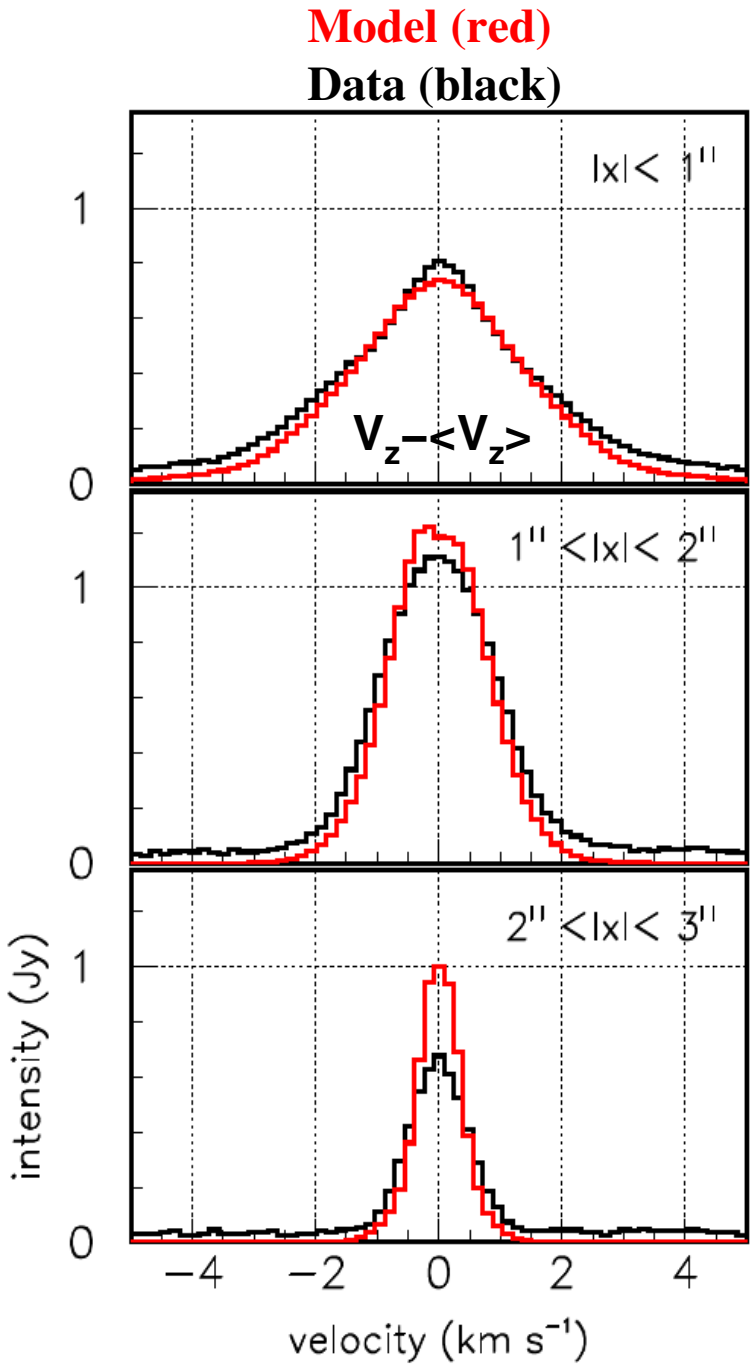
***i*=11.1°±1.4°** and η_h=0.10±0.06

Line width effects

Subtracting in quadrature the observed line widths from model values (3.2, 1.8 and 0.9 kms^{-1} FWHM) gives upper limits to the intrinsic line widths: 1.4±0.3, 1.2±0.2 and 0.8±0.1 kms^{-1}FWHM.

Thermal broadening ~√T (0.29 kms^{-1} FWHM at 50 K), spectral resolution 0.11 kms^{-1}

→ other effects contribute important broadening



Results: 49 ceti

i) both CO and dust discs share a same position angle and a same inclination but the gas disc is more homogeneous, more central and thinner than the dust disc;

ii) evidence is obtained for a significant deficit of observed CO(3-2) emission at Doppler velocities differing from the star systemic velocity by less than 1 km s^{-1};

iii) the source brightness is measured to correspond to a CO mass of 3×10^{-4} Earth masses and the continuum flux density is in good agreement with current SED estimates;

iv) gas velocities are accurately measured and found Keplerian over a broad range of disc radii;

v) the observed CO(3-2) line width is dominated by Keplerian shear and upper limits are obtained to the intrinsic line width

Summary

- A number of evolved stars and protostars have been studied. The next challenge, which the high resolution and sensivity observations becoming available, in particular from ALMA, is to understand the precise symmetry breaking mechanism at the beginning of the expansion and initial conditions for planet formation in protoplanetary dics.
- We have also contributed to the study of high red-shift galaxies, in particular with the detailed study of a quasar host at z=2.8.
- In the near future, we shall actively pursue both lines of research.

Summary

• We are making extensive use of the open data policy of the ALMA collaboration. This generous policy is an invaluable asset to teams such as ours, working in developing countries having otherwise no direct access to frontier astrophysics. We are immensely indebted and grateful to the ALMA partnership.

• In the past 2.5 years, we have published 15 articles in international journals, of which 8 with our team as only author.

• Astrophysics, one of the most dynamic branches of modern physics matches well the needs of a team such as ours. In particular, it does not require joining very large collaborations in which it would be difficult for us to preserve our identity.

Home

Department of AstroPhysics (DAP)

Vietnam National Satellite Center, Vietnam Academy of Science and Technology

Address: 18 Hoang Quoc Viet, Nghia Do, Cau Giay, Hanoi, Vietnam

Email: vatlyhanoi@yahoo.com.vn

Introduction

The aim of the Department of AstroPhysics (DAP) is to establish in Hanoi a team of researchers of international stature having the ambition to promote in the country teaching and research in fundamental sciences, and in particular in astrophysics. It is installed in the premises of the Vietnam National Satellite Center (VNSC), Vietnam Academy of Science and Technology (VAST) in Hanoi. It publishes a Newsletter and maintains a web site where useful information can be found: http://www.vnsc.org.vn/dap/Introduction.htm

The staff includes Pr. Pierre Darriulat, Drs Pham Tuan Anh, Pham Ngoc Diep, Pham Thi Tuyet Nhung, Nguyen Thi Thao, a PhD student Do Thi Hoai and a master student Nguyen Thi Phuong. Research interests are radio astronomy. Much of it is made in collaboration with other institutes, using data collected by major research installations abroad. In particular most PhD theses are made under an agreement of joint supervision with prestigious foreign universities.

The laboratory is equipped with instruments that are used for training and for domestic research. We receive support from the VNSC/VAST (running expenses), from the Ministry of Science and Technology (following a budget request made through NAFOSTED) and from

https://dap.vnsc.org.vn

Thank you for you attention!