Kinematics and 3D dust mapping of S147

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Summary

- We summarize the LAMOST observations in the S147 region, redo the sky subtraction, and obtain fundamental kinematic information of S147, such as
  - radial velocity field,
  - line width map,
  - line intensity ratio map ,
  - expansion velocity

- We present a 3D extinction analysis in the S147 region using data from XSTPS-GAC, 2MASS and WISE and isolate a previously unrecognised dust structure likely to be associated with SNR S147, term as "S147 dust cloud". The cloud
  - have a distance $d=1.22 \pm 0.21$ kpc, consistent with the conjecture that S147 is associated with pulsar PSR J0538+2817.
  - have morphology suggesting complicate interaction between the SNR S147 and the surrounding molecular clouds.

Outline

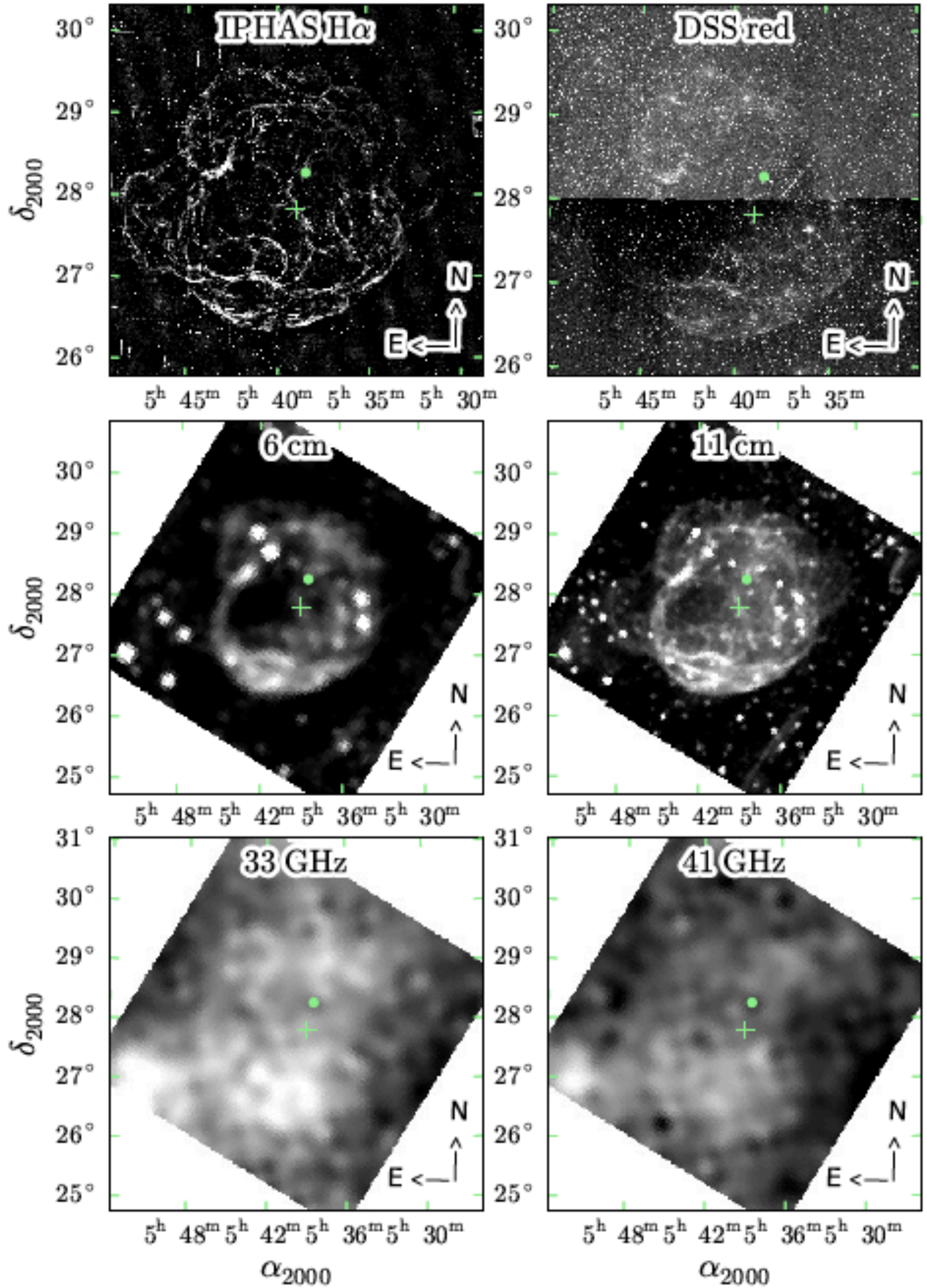
- The supernova remnant S147
- Kinematics of S147 based on LAMOST data
  - Introduction
  - Observation and data reduction
  - Parameter determination and analysis
- Mapping the 3D dust extinction toward S147 – the S147 dust cloud
  - Introduction
  - Data and method
  - The S147 dust cloud
- Summary

Introduction

- SNRs are beautiful astronomical objects that are of high scientific interest.
  - likely sources of Galactic cosmic rays
  - insights into supernova explosion mechanisms.
  - distributing various elements through the ISM
- Simeis 147, Sh2-240, SNR G180.0-01.7
  - Location: α=05h39m00s, δ=+27°50'00”
  - Size: ~200 arcmin (76pc)
  - Age: ~30,000 yr
  - Radio: Large faint shell
  - Optical: Wispy ring.
  - X-ray: Possible detection.
  - Point sources: Pulsar within boundary, with faint wind nebula.
  - Extinction: Av=0.7 mag (Fesen, Blair & Kirshner 1985, d=0.8 kpc)

Table 1. An updated list of distance estimates for S147 based on Table 1 of Dinçel et al. (2015). (R^l) denotes the lower limit radius of the SNR.

Distance (kpc)	Method	Reference
1.6±0.3	Σ−D	Sofue et al. (1980)
0.8–1.37	R^l, Σ−D	Kundu et al. (1980)
0.6	R^l	Kirshner & Arnold (1979)
0.9	Σ−D	Clark & Caswell (1976)
0.8±0.1	A_V	Fesen et al. (1985)
1.06	Σ−D	Guseinov et al. (2004)
< 0.88	High Vel Gas	Sallmen & Welsh (2004)
1.2	Pulsar DM	Kramer et al. (2003)
$1.47^{+0.42}_{-0.27}$	Pulsar Plx	Ng et al. (2007)
$1.3^{+0.22}_{-0.16}$	Pulsar Plx	Chatterjee et al. (2009)
$1.333^{+0.113}_{-0.112}$	OB runaway star	Dinçel et al. (2015)
1.22±0.21	3D dust mapping	this work



The S147 images in different bands.

- The green cross: S147 center
- The green dot: the Pulsar J0538+2817 related to S147

Kinematics of S147 based on LAMOST data

Juanjuan Ren (任娟娟, jjren@nao.cas.cn) et al., to be submitted

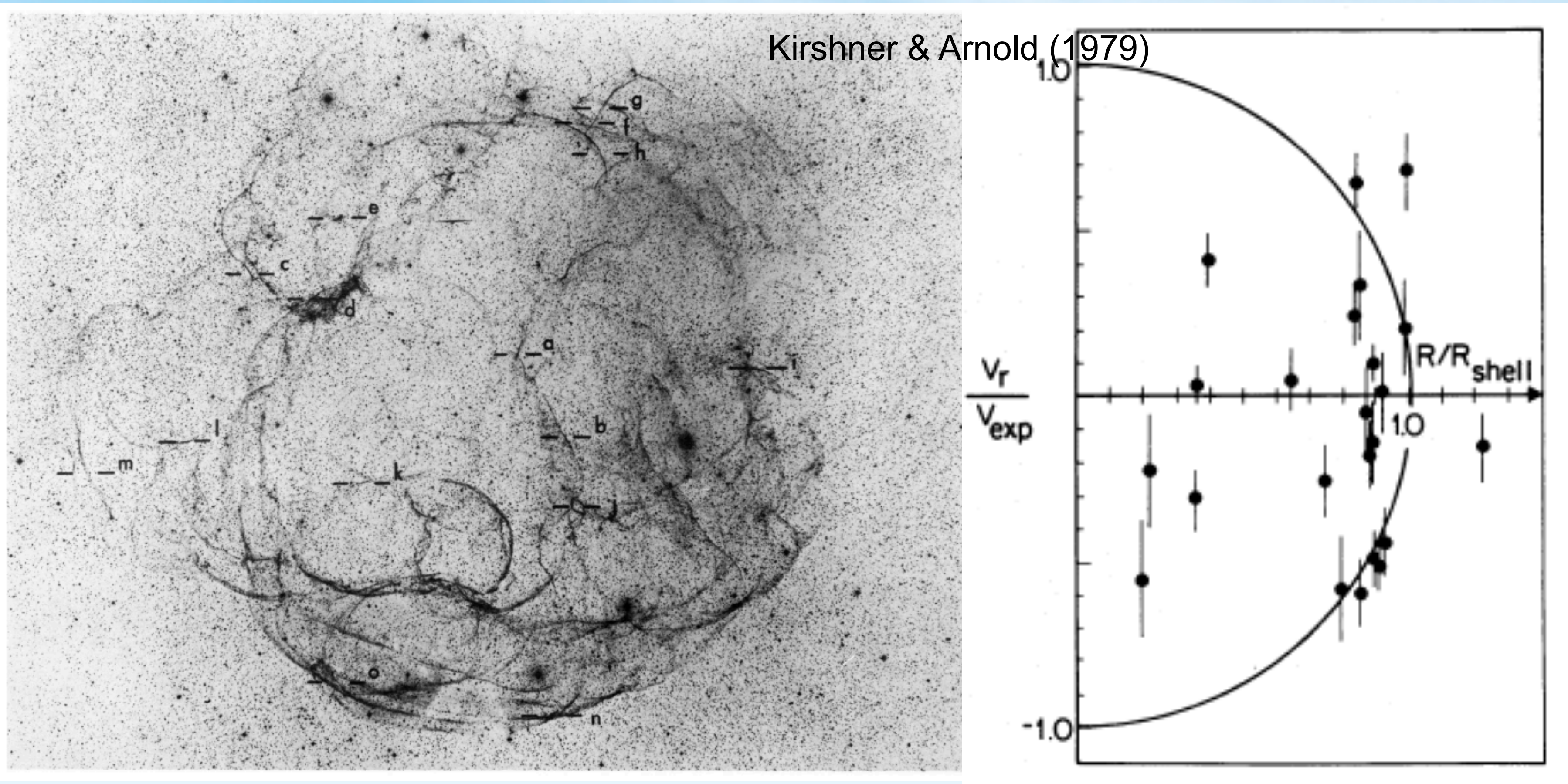
Introduction

- Optical spectra of filaments of evolved SNRs show strong lines of H, [OII], [OIII], [NII] and [S II]. A complete sampling of the optical line emission in Galactic SNRs would allow the study of
  - Additional criteria besides the Ha/[S II] ratio for distinguishing shocked nebulae from photoionized nebulae
  - The range of line-emission strengths found within an individual remnant
  - Whether there are significant evolutionary variations in a remnant's optical emission properties for different filaments

- Currently 294 Galactic SNRs (Green 2014) have been discovered. However, a few evolved remnants have been well studied optically, relatively few spectral data are available on many of the fainter optical remnants, especially for those with large angular size.

- For S147: spectrophotometric observations already from Kirshner & Arnold (1979) and Fesen et al. (1985), but they have
  - only dozens of spectra obtained due to the large size and faintness of S147
  - only focused on several bright filaments.

Introduction



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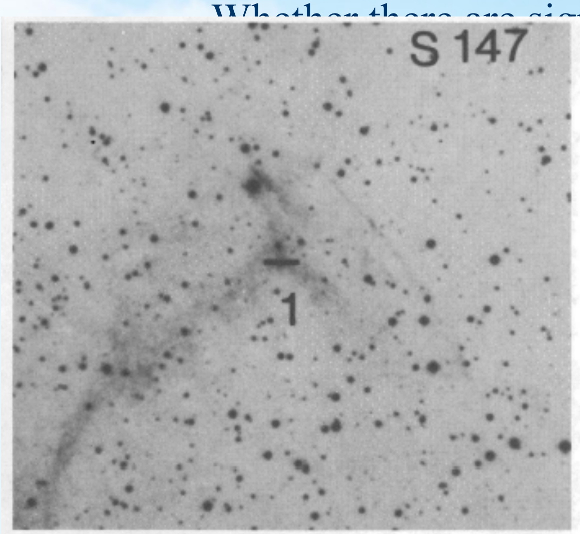

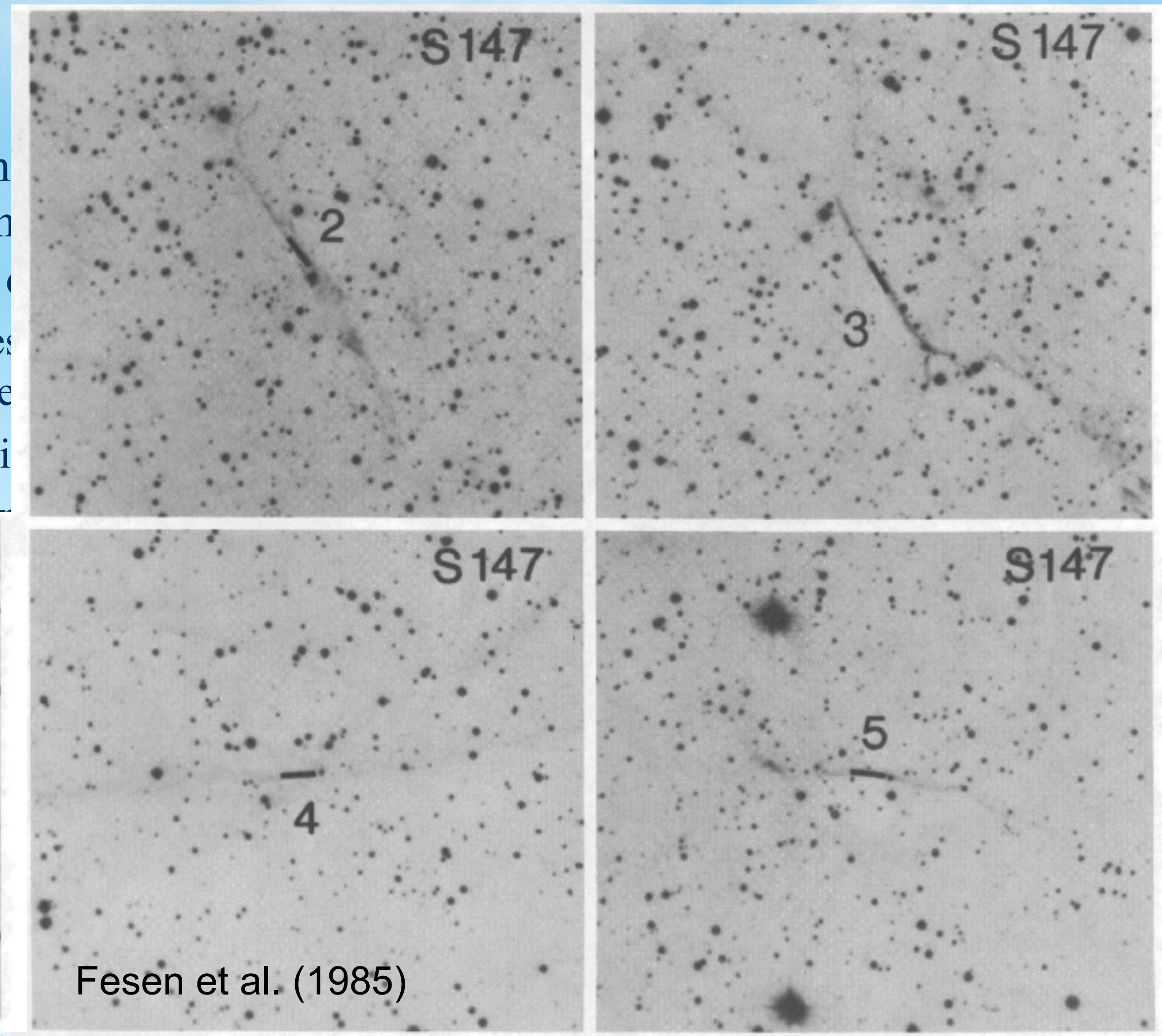

Fesen et al. (1985)

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  - only dozens of spectra obtained due to the large size and faintness of S147
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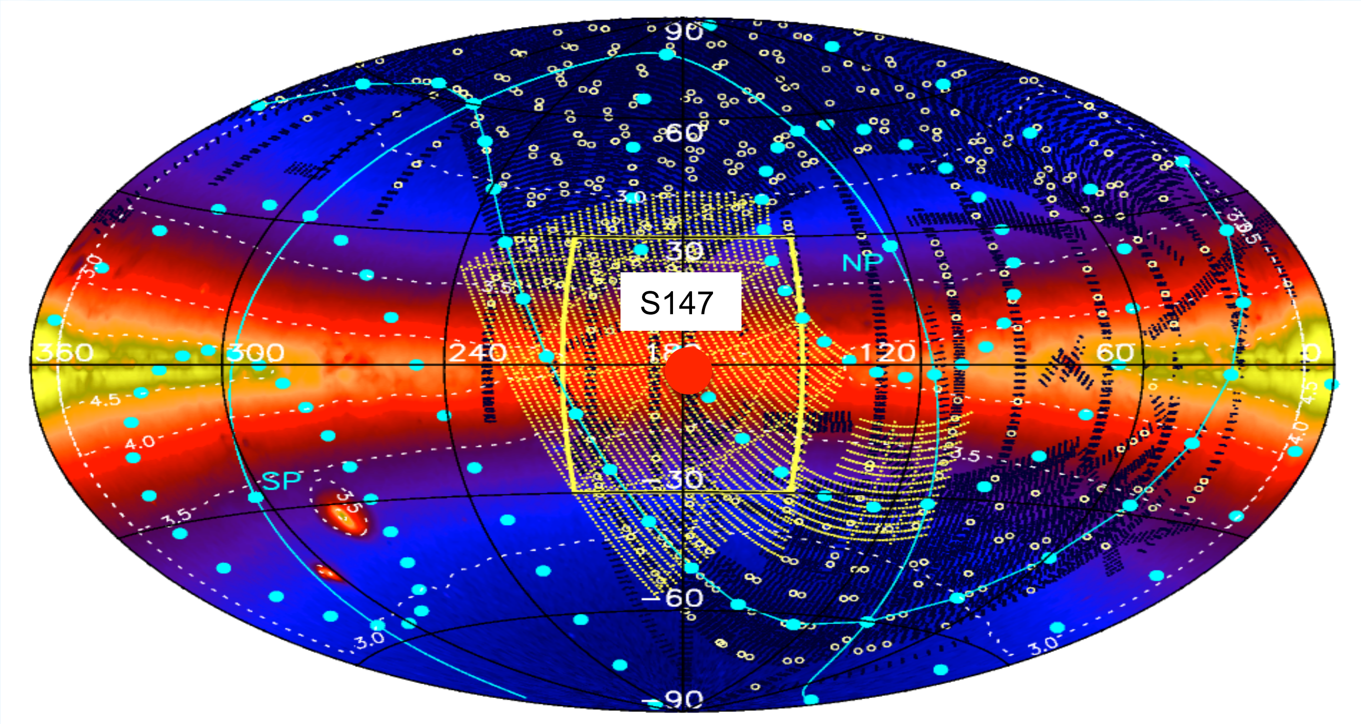
Introduction

- S147 consists of numerous filaments embedded in diffuse emission. The filamentary and diffuse emission components have different physical properties. Thus it is important to obtain a larger spectral sample which has a complete coverage in S147 region.
- The LAMOST telescope and the LSS-GAC survey provides an unique opportunity to study the SNR S147 with unprecedented, large and complete coverage for the first time.

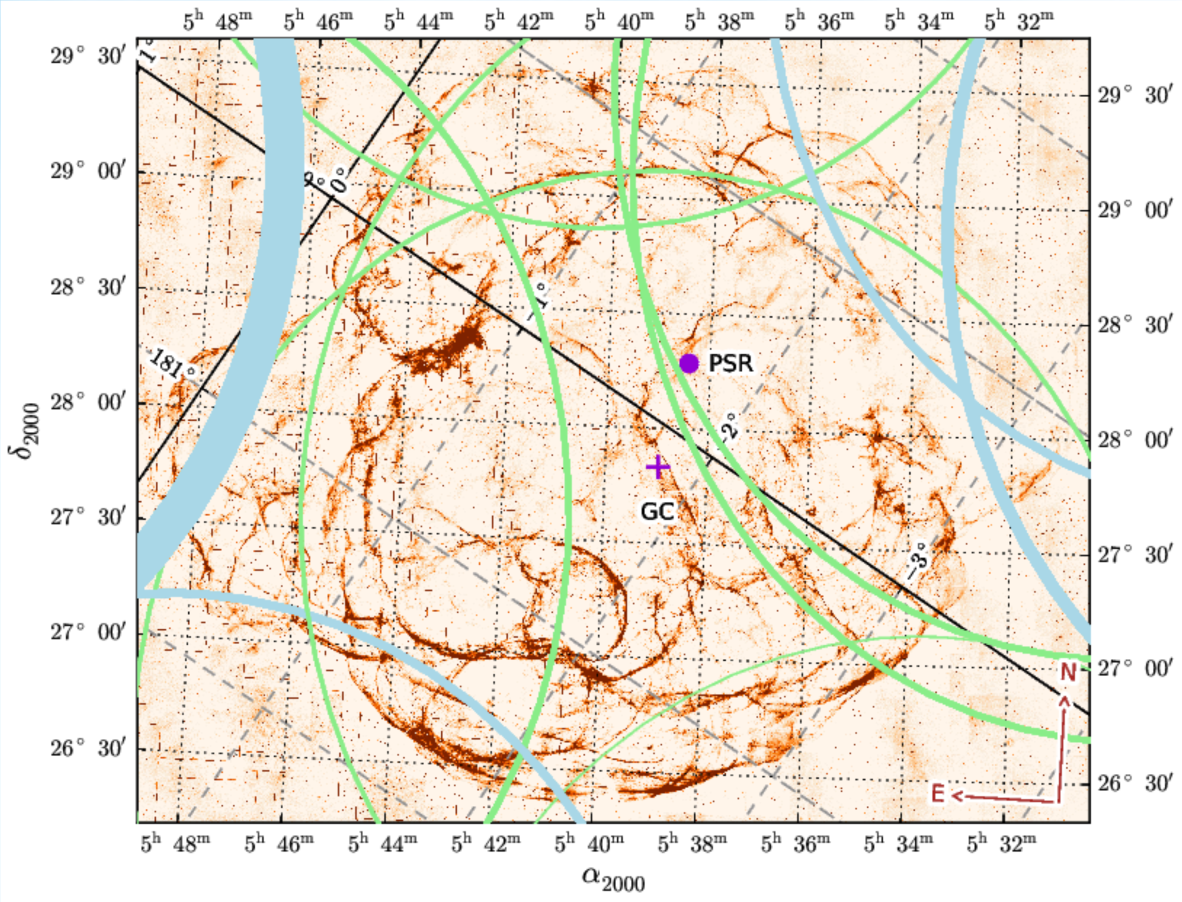


LAMOST observations towards S147

LAMOST DR2: 50 plates

green: 16 plates distance from S147 center ≤ 3.55 deg;
10B + 6M plates ;
pilot: 9 plates;
DR1: 7 plates

blue: 34 plates distance from S147 center between 3.55 and 4.54 deg;
5V + 26B + 16M+ 3F plates ;
pilot: 28 plates;
DR1: 18 plates;
DR2: 4 plates



Data reduction – sky subtraction

- Because of the complicated filamentary structure of S147, some fibers located in the filaments, thus they must affect the sky subtraction.
- S147 has a very regular and circular shape, with the diameter ~ 3 degrees, which is smaller than the LAMOST field of view(5 degrees). Thus, for every plate, there must be some regions which are uncontaminated by S147.
- Our idea here is that: for every plate, use the uncontaminated sky spectra in the non-S147 region to replace the sky spectra in the S147 region, rebuild the super-sky spectra, then redo the sky subtraction.

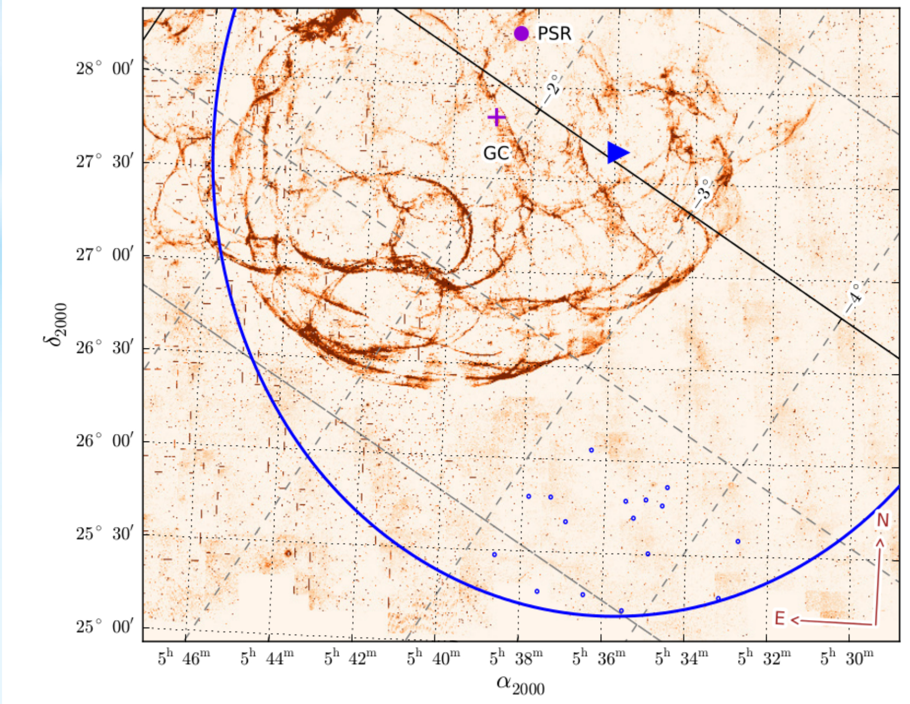


Figure 8. Same as fig 6, but for the uncontaminated spectrograph 1 of plate GAC083N27B1.

Parameters determination

- We obtain the radial velocities, line intensities, line widths of the prominent Hα, [NII], [SII] emission lines by Gaussian fitting.

- We use the emission lines in LAMOST red arms, because they are much more strong and ubiquitous than the lines in blue band, and usually the red band spectra have much higher S/N than the blue band.

- To utilize as many spectra as possible, we use
  - the sky spectra,
  - the stellar spectra of high quality spectra with available stellar parameter determinations: before using, we need to subtract the intrinsic stellar absorption spectra.
  - the stellar spectra of too low quality spectra without available stellar parameters: most are very faint and have very weak stellar absorption spectra which have very little affect for the nebulae emission lines, thus we can use them directly.

❖The radial velocity field

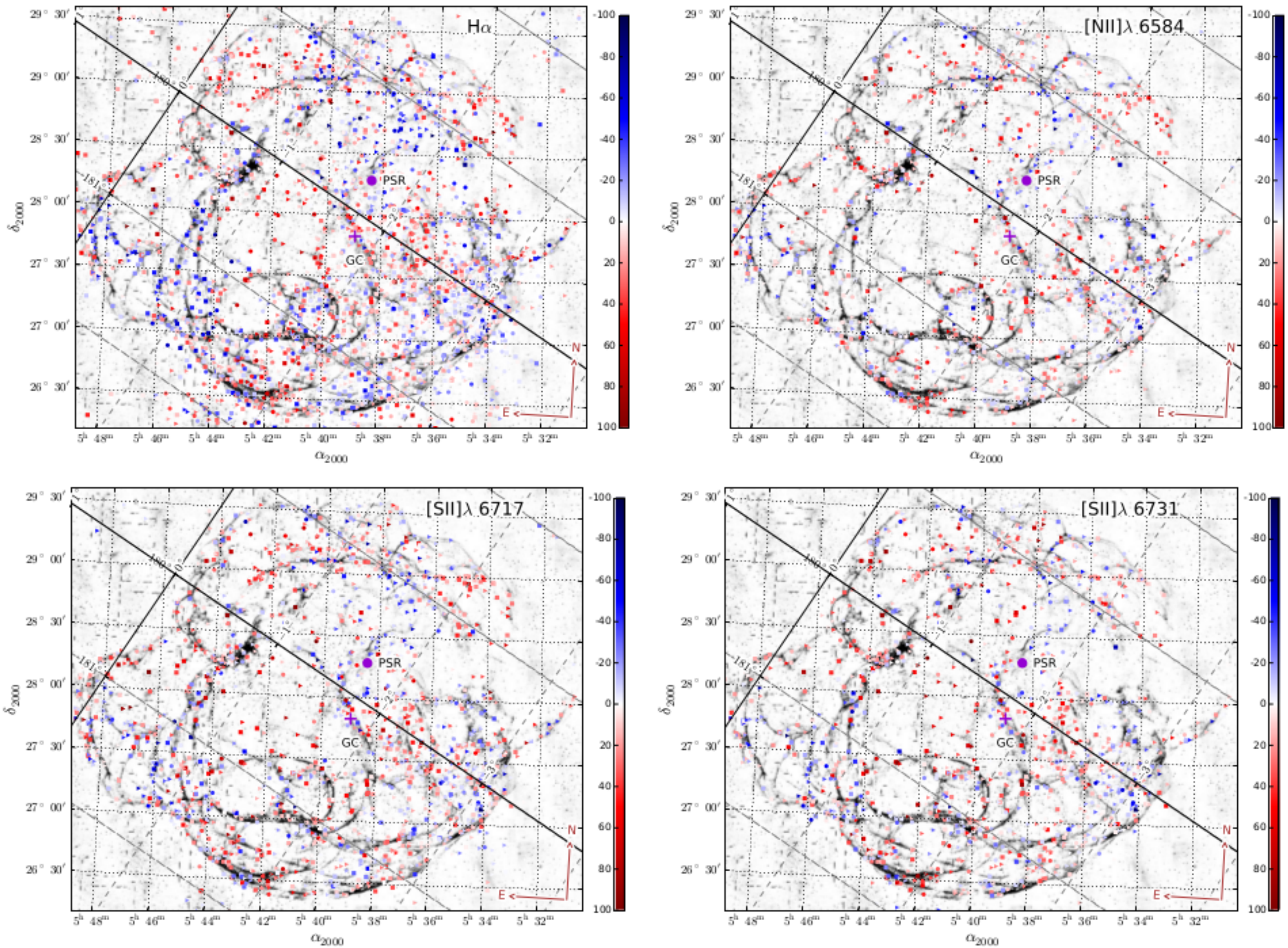
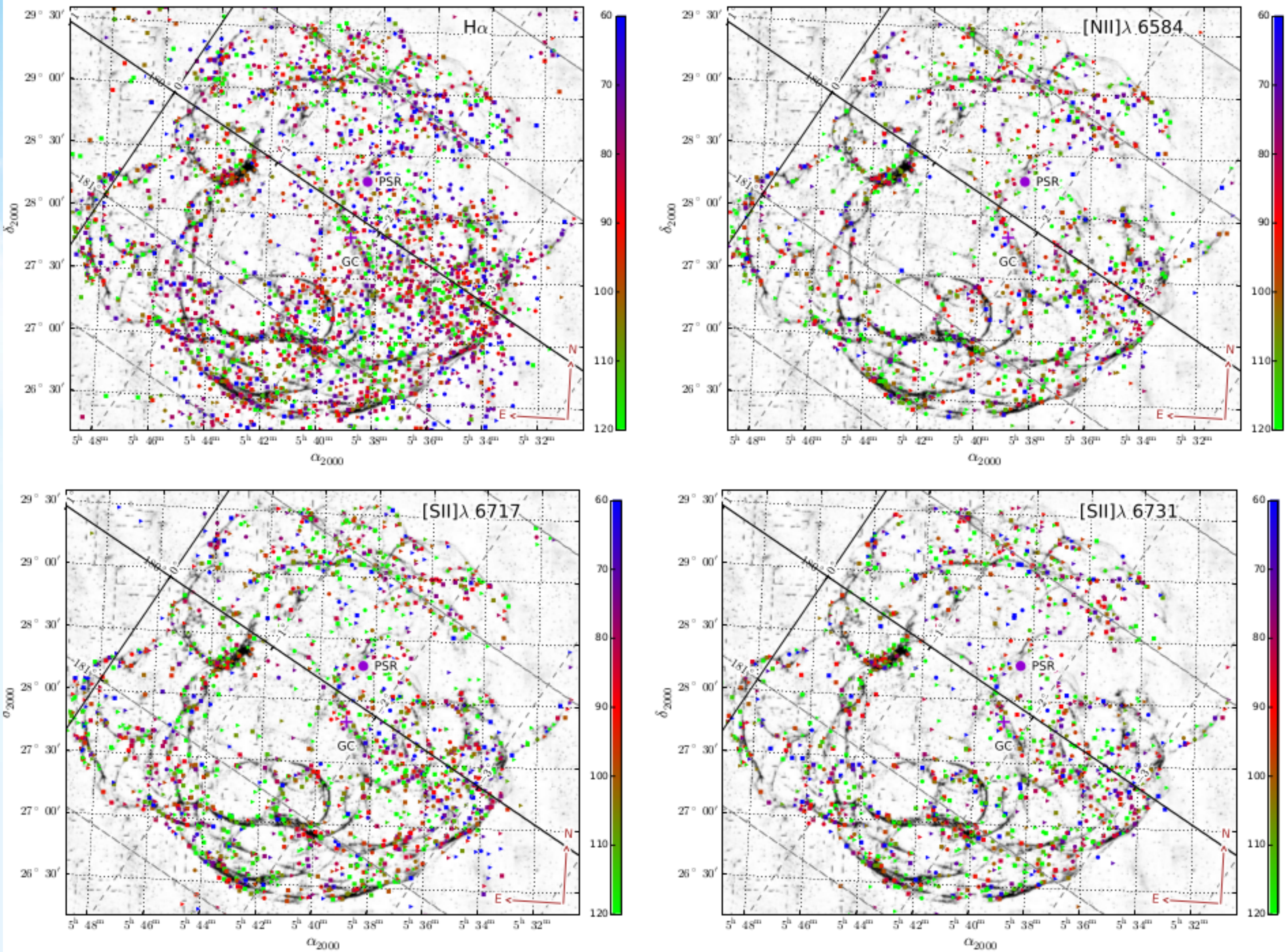
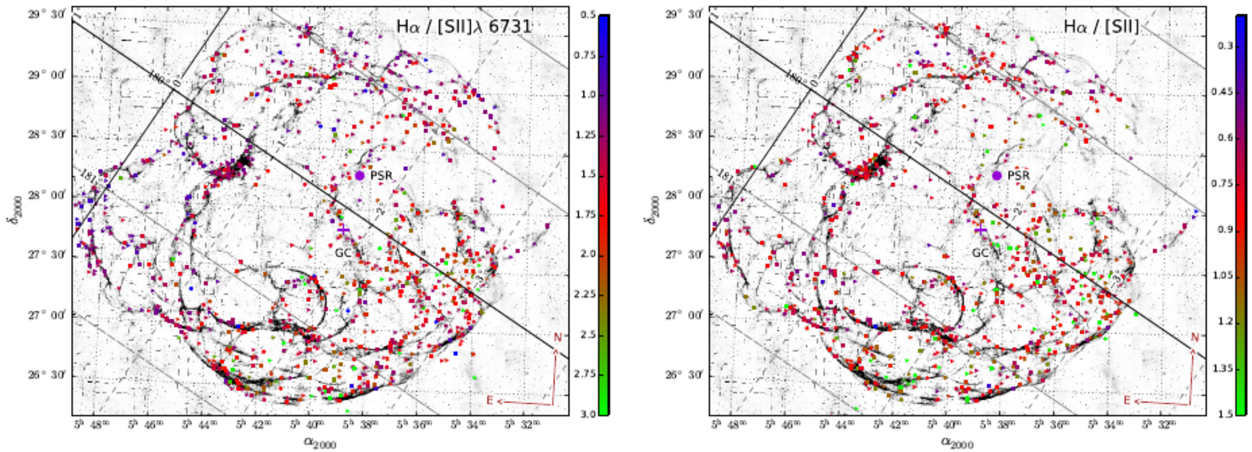


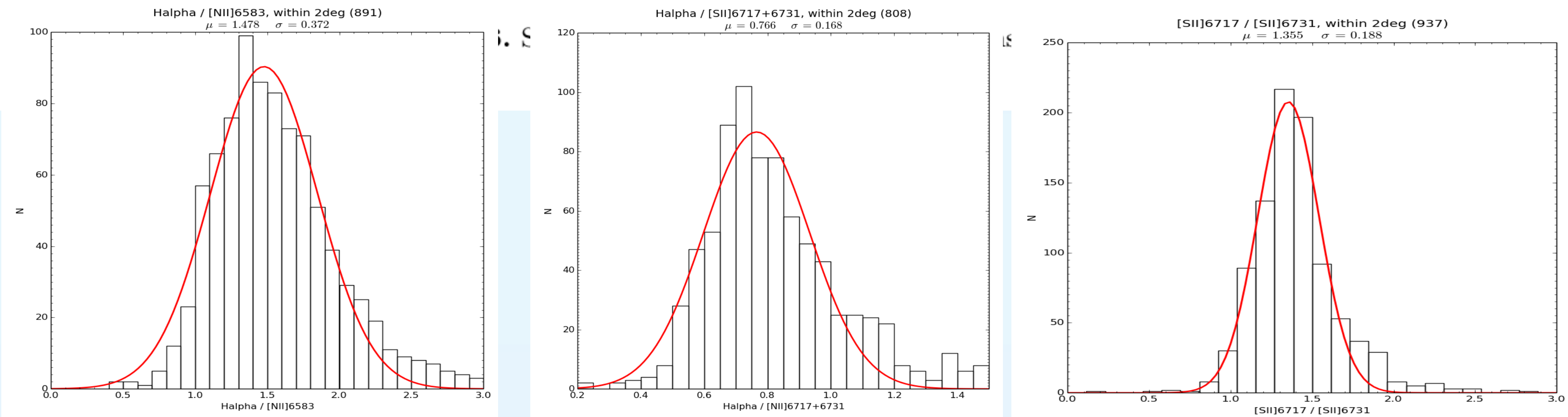
Figure 14. The radial velocity field revealed by Hα, N II λ 6584, and [S II] λλ 6717, 6731 emission lines. Where, the circle, square, and triangle shows the corresponding data from sky spectra, stellar spectra with available stellar atmospheric parameters, and low S/N spectra (i.e., the flag a, b anc c in table 4). The color bar shows the radial velocity values.

❖The line width map



❖The line intensity ratio map

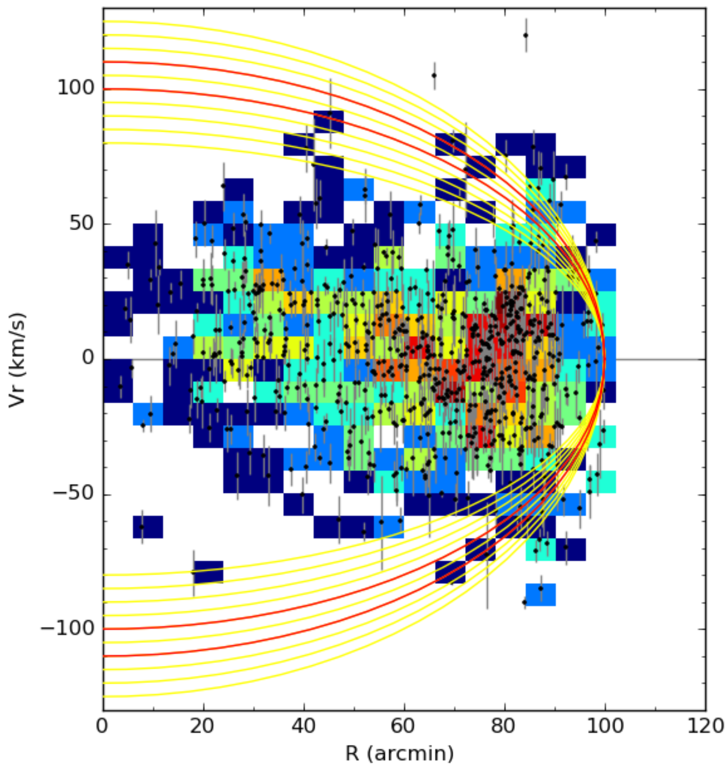


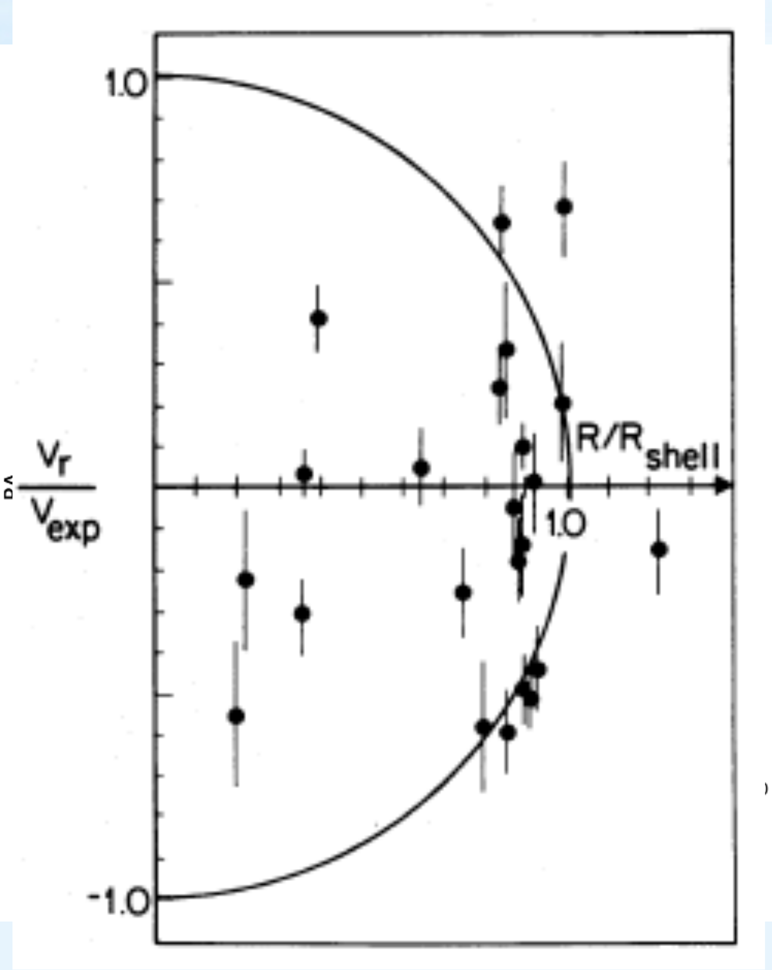


❖Previous study:

- Halpha/[SII] : 0.7 – 1.08 ; Halpha/[NII] : 1.20 – 1.58 ; [SII] 6717/6731 : ~1.4

Expansion velocity: **100 - 110 km/s**





~80 km/s, Kirshner & Arnold (1979)

3D dust mapping of S147: the S147 dust cloud

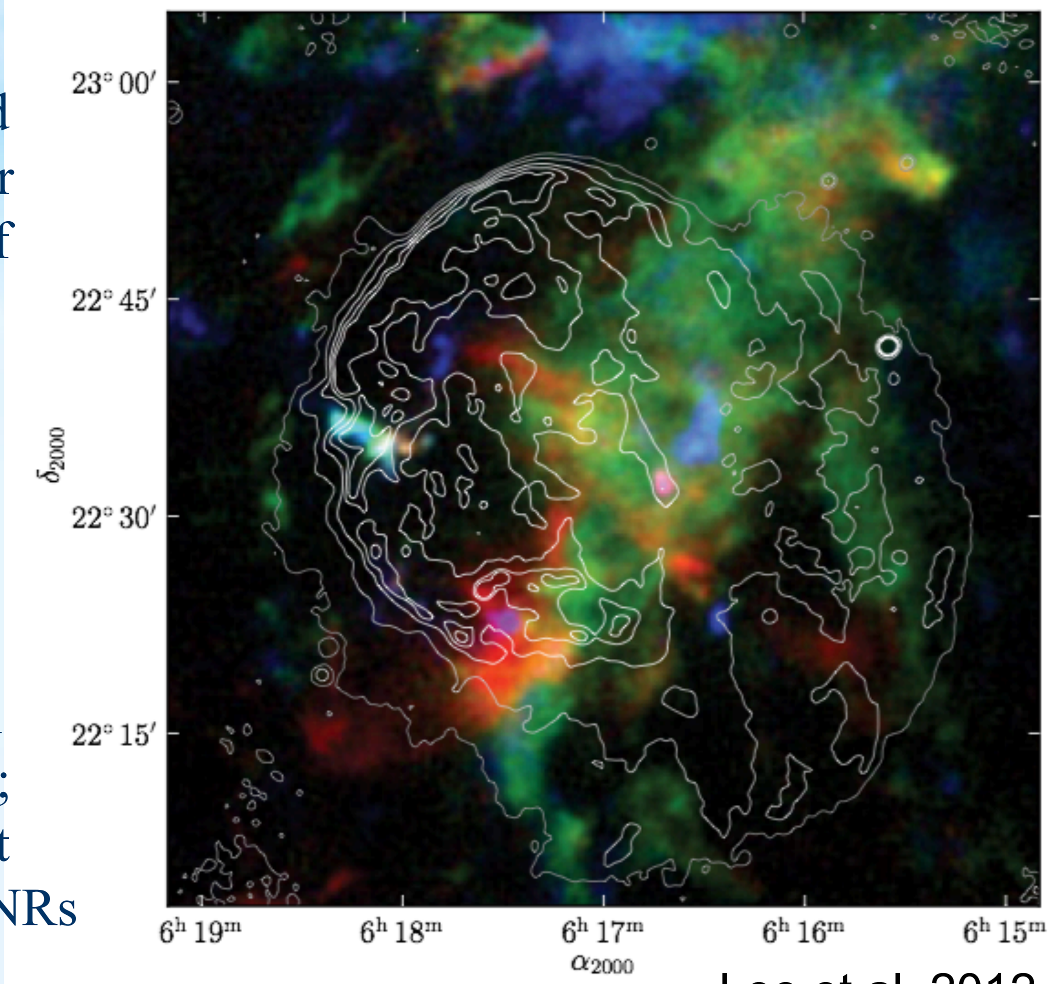
Chen et al., to be submitted

The SNR interacted with molecular cloud

- SN explosions: strongly modify the environment, and at the same time, the evolution of a supernova remnant (SNR) is governed primarily by the environment itself.

- O-type star, a large area around them to be cleared of molecular clouds; while the destruction of natal molecular clouds would not be as effective for early B stars

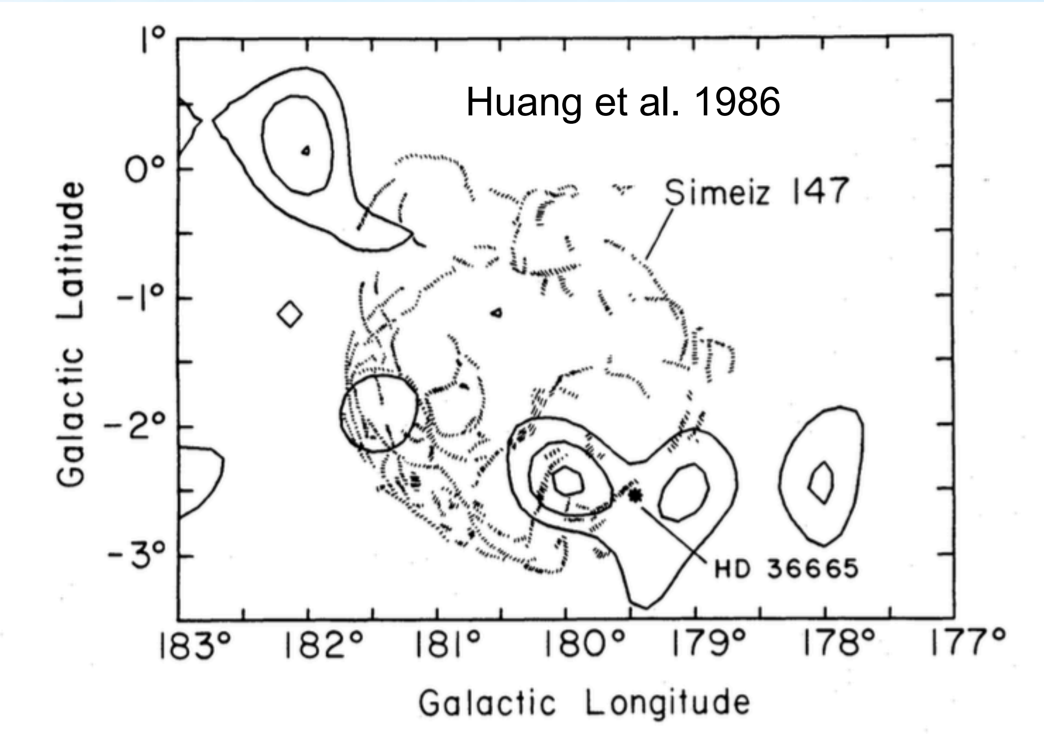
- Known 294 Galactic SNRs: ~70 of them show direct or indirect evidence of interaction with ambient molecular clouds; while S147 is claimed to be not one of those MC-interacting SNRs

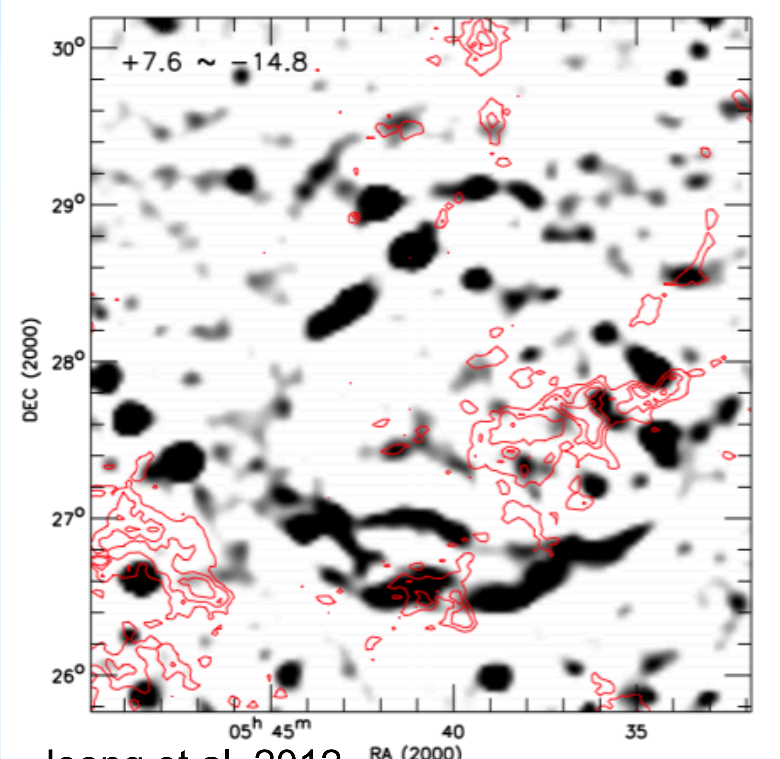


Lee et al. 2012

The molecular cloud associated with S147?

- Phillips et al. 1981: low-velocity interstellar CO absorption toward HD36665 (d=0.9kpc)
- Huang et al. 1986: A weak cloud with peak velocity of 4 km/s.
- Sallmen et al. 2004: HD 36665 (880 pc) and HD 37318 (1380 pc): complex absorption; while HD 37367 (360 pc): no absorption
- Jeong et al. 2012: some molecular clouds from ~ −14 to +5 km/s.

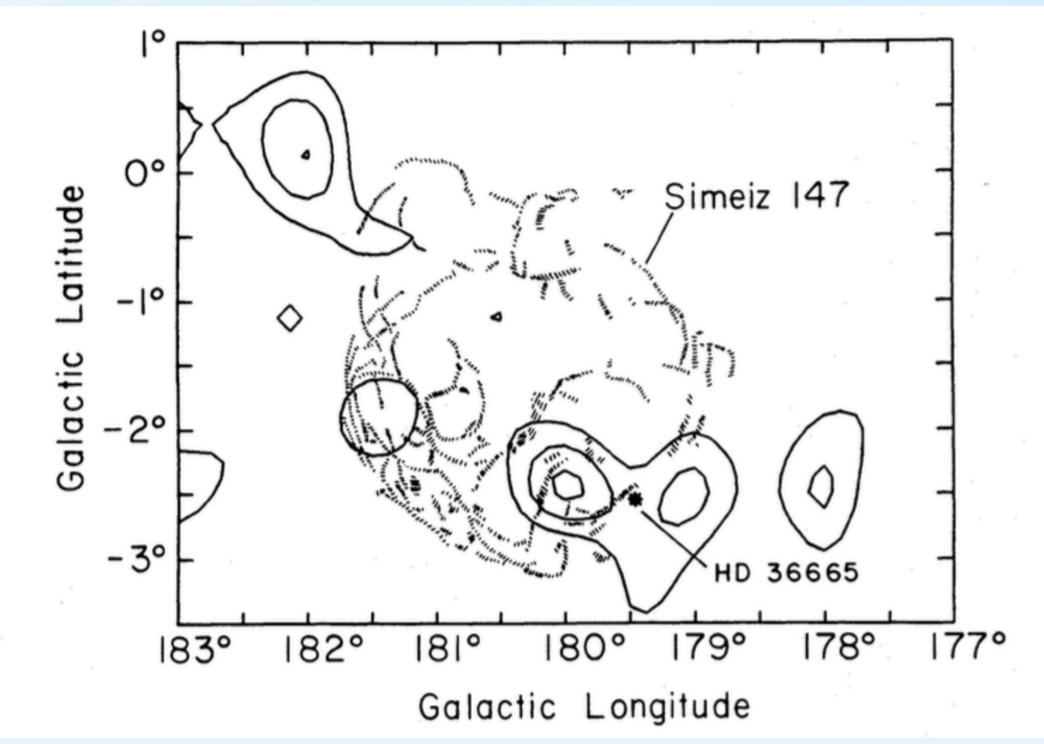


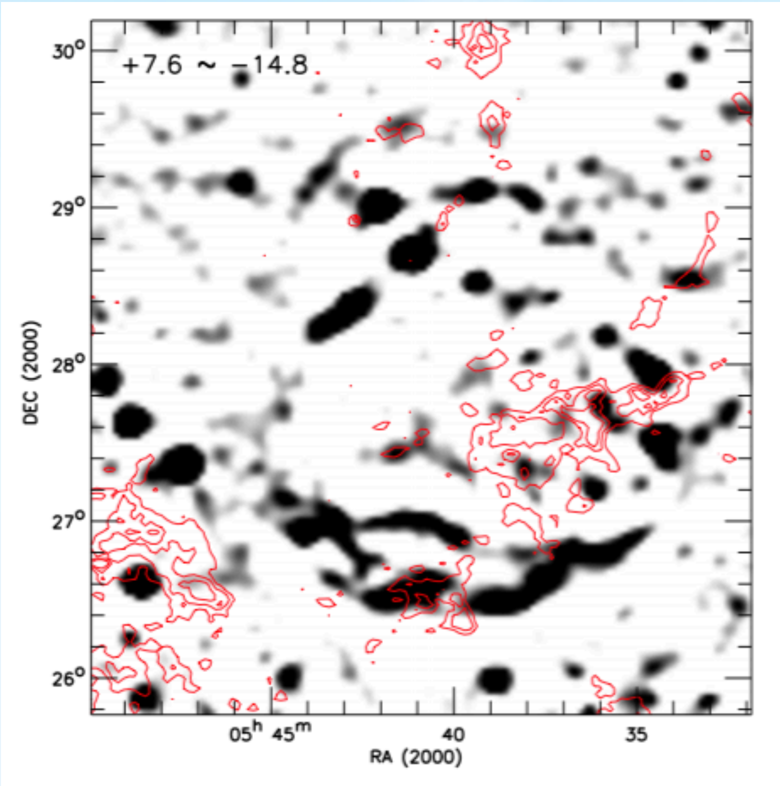


Jeong et al. 2012

The molecular cloud associated with S147?

- Huang et al. 1986: A weak cloud with peak velocity of 4km/s.
  "*Whether the cloud is associated with the SNR remains unknown, but it probably does lie in front of the SNR.*"
- Jeong et al. 2012: some molecular clouds from −14 to +5 km/s.
  "*Although we detected molecular clouds near the SNR, none of them show correlated features with the remnant.*"



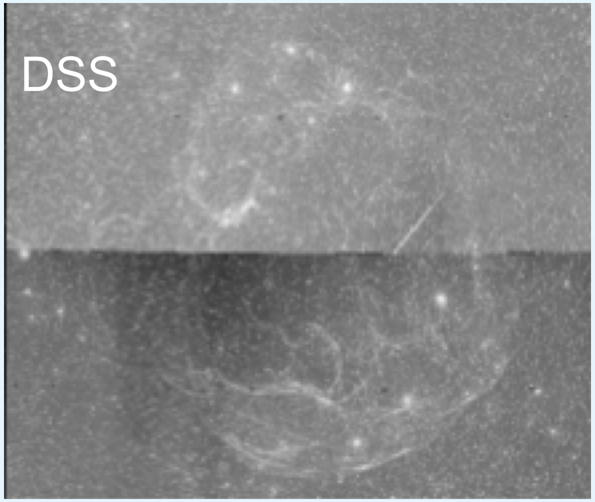


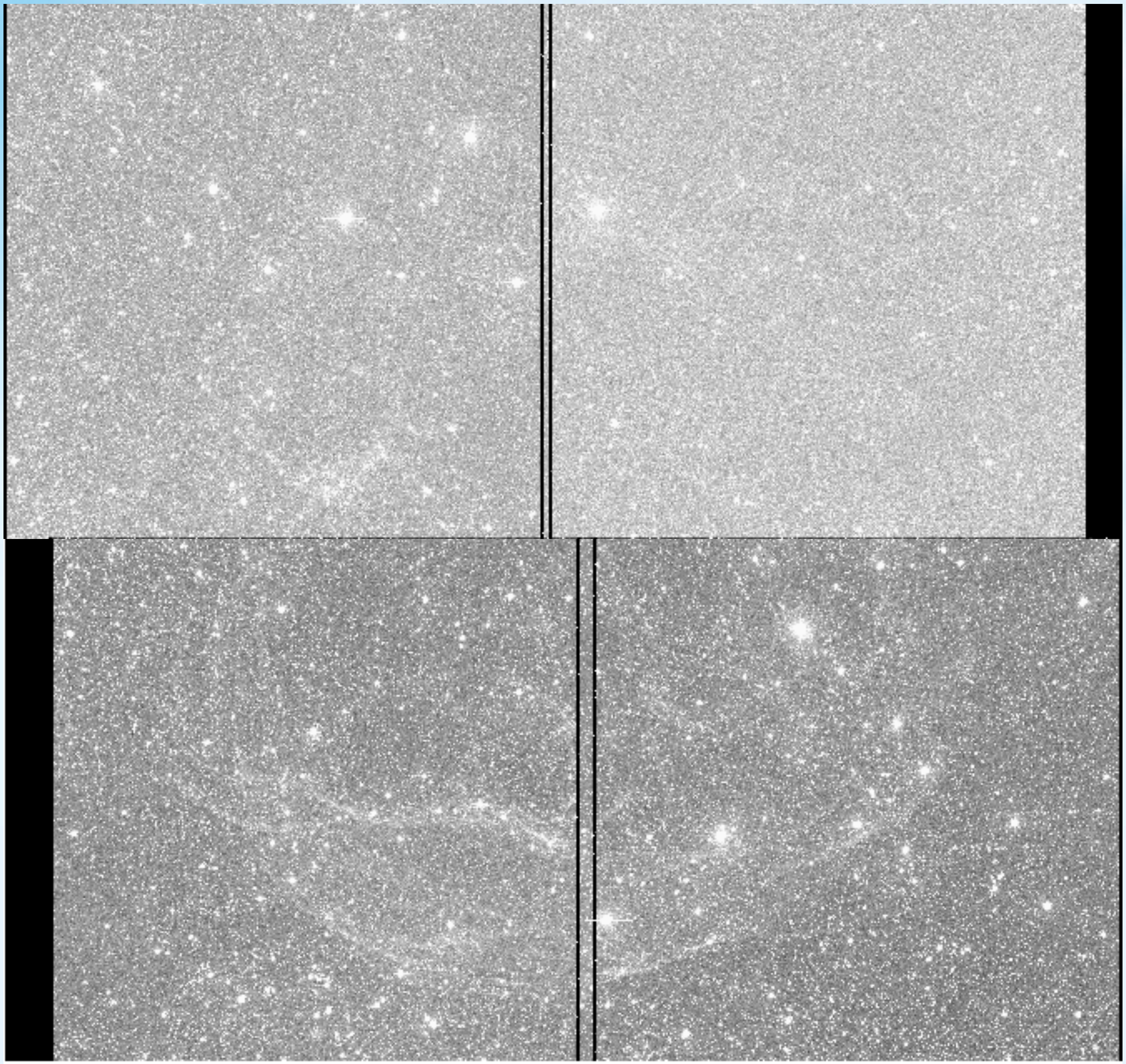
The 3D dust map: perfect tool

- Dust: a better column density tracer than molecular gas CO
- Dust extinction, in particular, more robust measurements
- The sensitivity by optical and near-infrared dust extinction techniques is essential to investigate the low-density regions of molecular
  - To estimate the mass of the diffuse gas that acts as a pressure boundary around the clumps.
- Distance information
  - To confirm if the molecule cloud be associated with the SNR
  - An independent method to determine the distance of SNR
- Chen et al. (2014): a 3D extinction map of the Galactic anticentre based on the data from XSTPS-GAC, 2MASS and WISE

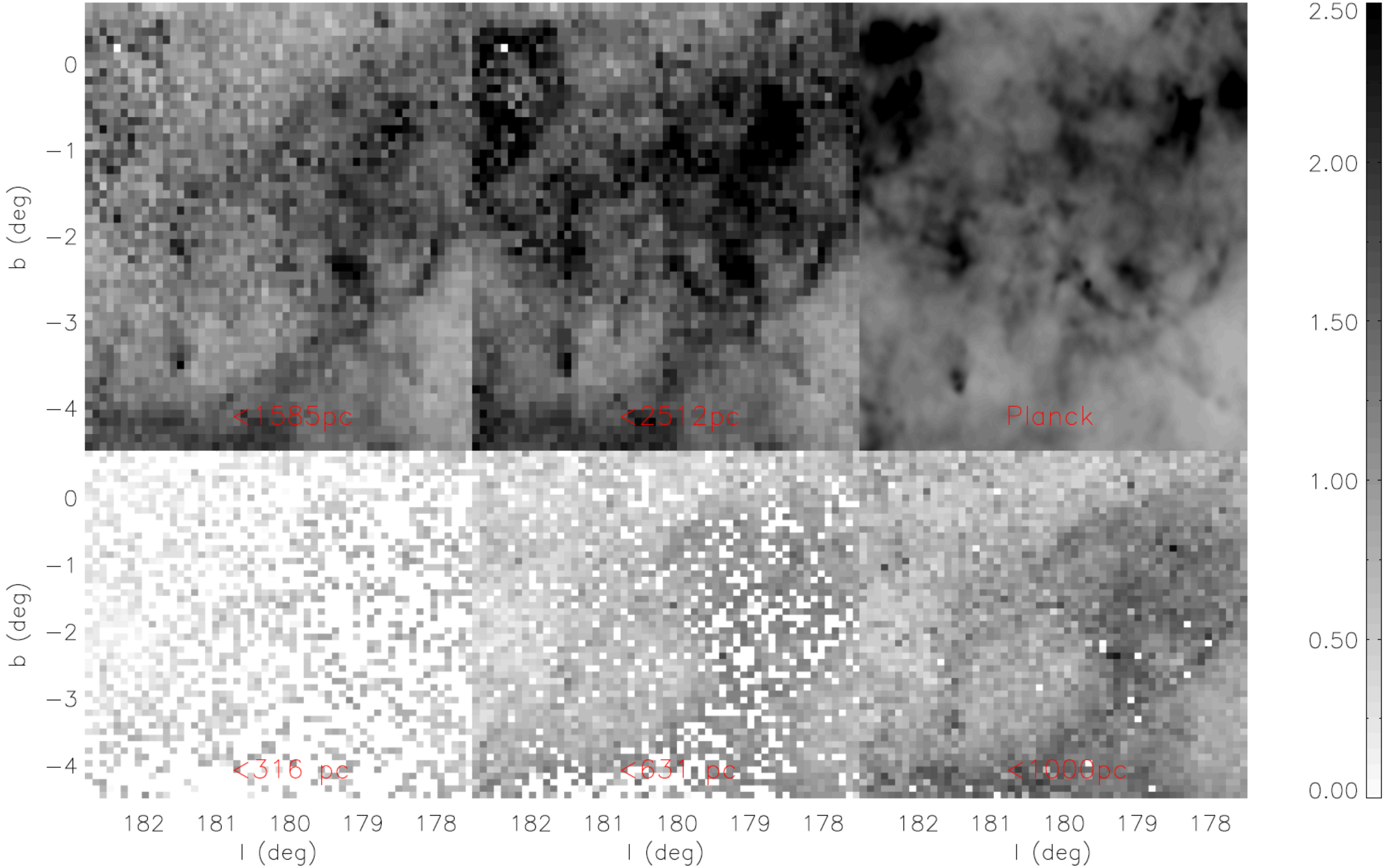
S147 viewed by XSTPS-GAC

XSTPS-GAC r-band image
FoV: 1.94 x 1.94
integration time: 90 s

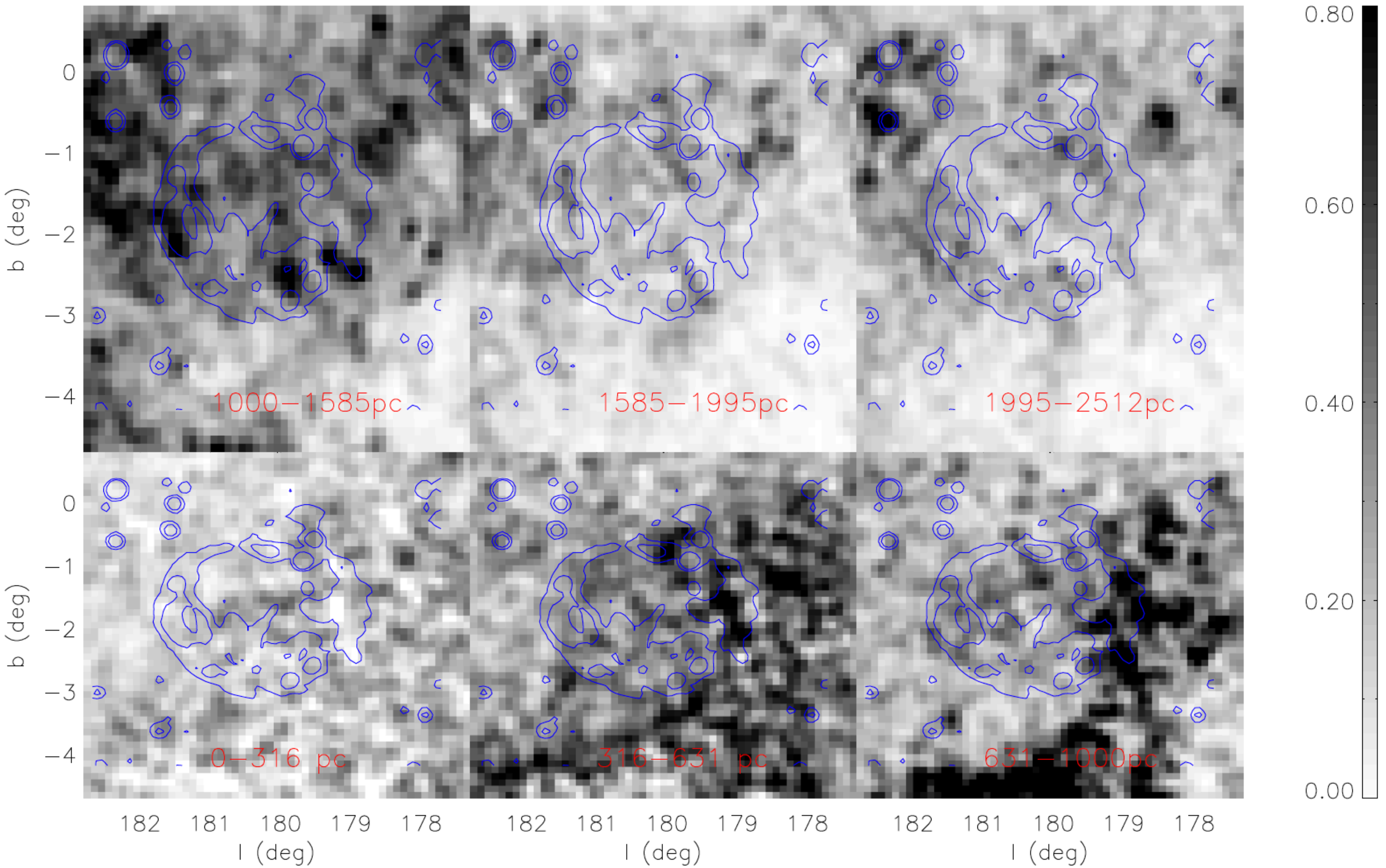




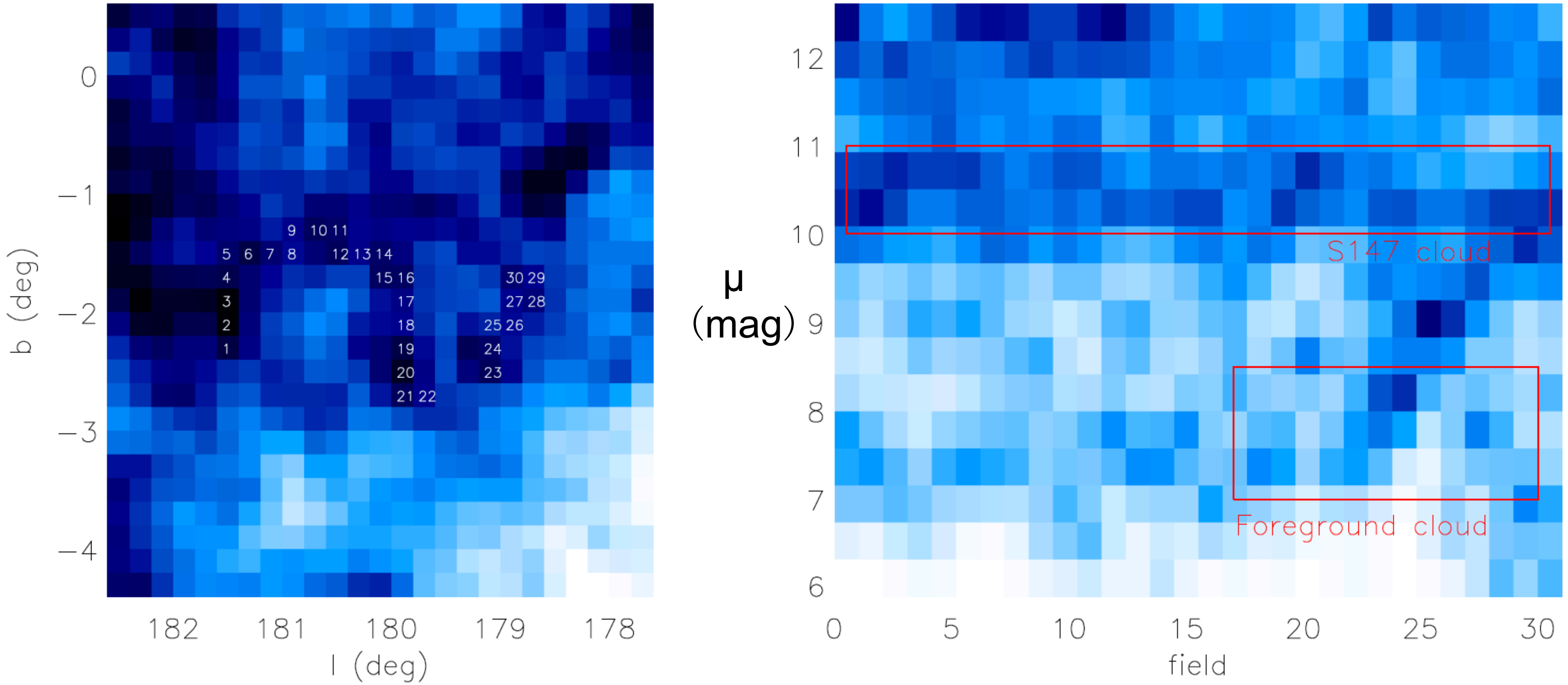
3D dust mapping of S147



3D dust mapping toward S147



The S147 dust cloud and foreground cloud



Distance of S147

- We fit the distance–extinction relation by:

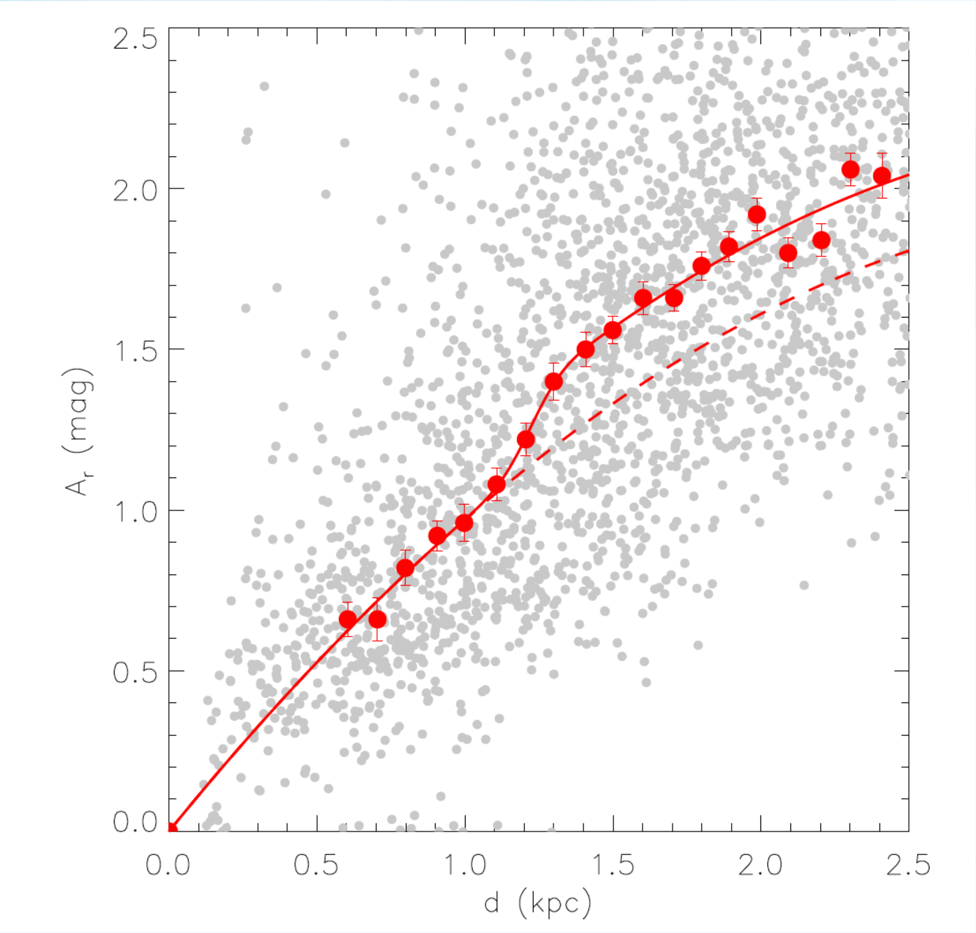
$$A_r(d) = A_r^0 + A_r^1,$$

  - MW background dust: Chen et al. 1998

$$A_r^0 = ad + bd^2$$

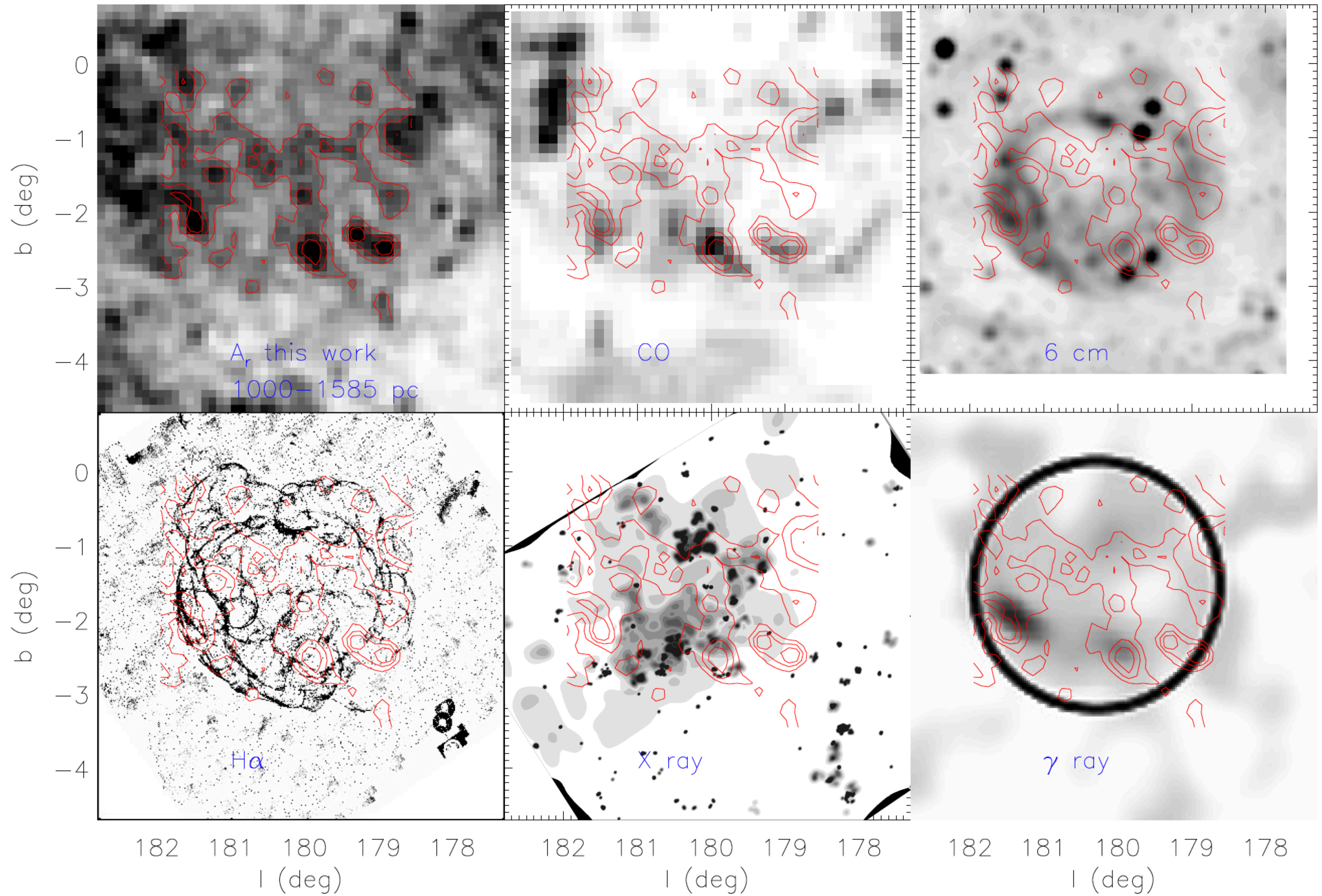
  - S147 dust:

$$A_r^1 = \frac{\Delta A_r}{2} \mathrm{erf}\left(\frac{d - d_0}{\sqrt{2} * \Delta d}\right)$$



d0=1.22 kpc ΔAr=0.24 mag Δd= 0.08 kpc

The S147 dust cloud morphology



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