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Monitoring of ultrarapid flux fluctuations in galactic sources of water-vapour maser emission at a wavelength of 1.35 cm

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Results of a search for ultrarapid flux fluctuations of galactic sources of maser emission in the water-vapour line at a wavelength of 1.35 cm are presented. An observational technique of a search for ultrarapid flux fluctuations has been developed. From 2002 to 2008 a number of observational sessions for about 30 maser sources have been carried out. Several of them have demonstrated such a variability. Possible mechanisms of the variability are discussed, among them internal processes within the sources themselves as well as external ones, including the theoretical possibility of a resonant effect of gravitational waves from galactic objects on the masering region. Clear evidence for the presence of such a variability has been found in several sources (Cep A, W43M3, W49N, W33B). This variability appears not permanently, but only certain states of particular H_2O masers. Of major interest is the behaviour of Cep A in some observational sessions: this source can turn from the state of relative stability to the state of variability by as much as tens per cent in some features on timescales of tens of minutes.

Keywords: Star formation region; Water maser; Very rapid fluctuation

1 Introduction

Since the discovery of cosmic masers radiating in the water-vapour line, various variability timescales have been reported for them. Known at present are:

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(1) long-term cycles of flux variations of H_2O masers, which were described in a number of papers of the joint team of the Pushchino Radio Astronomy Observatory and Sternberg Astronomical Institute [1, 2];

(2) flare activity on a month's timescale [3, 4];

(3) flux variations of spectral features on a timescale of several days (some features change their flux by a factor of two in 2.4 d [5]);

(4) ultrarapid variability on a timescale of an hour or shorter, or intraday variability [6]. This type of variability was discovered for the first time in extragalactic megamasers, namely in a source in the irregular galaxy IC 10, which changed its flux by a factor of two on a time span of one hour [6]. We have set a task to find similar processes in the emission of galactic H_2O maser sources at a wavelength of 1.35 cm.

2 Observation technique

The problems of detection of an ultrarapid variability on timescales of an hour or less are:

(1) inaccuracy in the telescope pointing: the beam may drift within up to $1'$ due to changing mutual position of the Sun and telescope in clear weather;

(2) strong dependence of the flux on the source elevation; for instance, the observed flux from a source at 20° is about two times greater than at 5–7°;

(3) strong dependence of the flux on weather conditions;

(4) calibration stability problems (absence of bright calibration sources etc.);

(5) scintillations of the sources in interstellar plasma inhomogeneities (on a timescale of 30–60 min).

As a result, even the best telescopes under ideal conditions provide a calibration accuracy of the order of 5%. However, all the above-mentioned factors simultaneously affect the whole spectrum. Meanwhile, it is known that spectral features in cosmic masers are produced by an intricate complex of radiating condensations within a region with a size of tens, hundreds and even thousands of astronomical units (see, e.g., [7]). Therefore, rapid fluctuations, if present, may appear in a small number of spectral features without effect on other features. Therefore, we propose the method of data self-calibration, i.e., measuring only changes in relative weights of individual spectral features with respect to the total flux. Thus the majority of the above-mentioned problems are removed.

The observations at $\lambda = 1.35$ cm have been carried out on the 22-metre radio telescope of the Radio Astronomy Observatory (Astrospace Centre, Lebedev Physical Institute, Russian Academy of Sciences) in Pushchino (Russia) in a number of observational sessions for more than 30 maser sources.

We have developed a technique for the detection of ultrarapid flux fluctuations (on timescales from several minutes to an hour). This enabled us to select several sources that demonstrated such a variability. We have considered the causes of this variability, and the most interesting are internal processes within the sources themselves, on scales about 0.1 AU. We have probably detected variability of this kind, at least in the sources W33B, Cep A, W43M3 and W49N.

Then there remain the following causes of variability.

(1) Linear polarization of some spectral features (according to literary data up to 20% or even more) results in flux density variations on timescales of a few hours. The way to overcome this effect is to record data in an extended corridor of unchanged parallactic angles of linear polarization on several consecutive days and then, by comparing the data, to exclude identical diurnal trends in the fluxes of the spectral features.

(2) Multiplicity of the sources: in fact there may be several closely spaced objects within $\sim 2'$, while the RT-22 beamwidth is $2.4'$. A careful telescope pointing control and elimination of such sources are required.

(3) Intrinsic variability of individual spectral features due to rapid internal processes in the sources on scales of a fraction of an astronomical unit.

3 Results of the search for ultrarapid fluctuations

We have observed about 40 sources with exposures 1.5–10 min and with a number of scans not less than ten for each of them. We selected with a peak line flux density not less than 100 Jy.

1. For faint sources of the sample we cannot achieve on RT-22 an accuracy better than 5% on exposures (integration times) shorter than 5 min. These sources can be used only in a search for variations on timescales of an hour. However, if their flux variations contain a periodic component (e.g., about several minutes, which may suggest the effect of gravitational waves from close binaries on the maser emission, see [8]), it can still be detected by special processing of a long time series of the observations.

2. For sources with bright features (W49N, Ori A, Cep A, W3OH, W51M, VY CMa, IRAS 16293−2422) we have achieved an accuracy of 0.1% on exposures as short as 1.5 min.

3. Some selected sources have demonstrated conspicuous variations by 10–30% on timescales from 10 min to 2–3 h: W33B, Cep A, W43M3 – in some sessions (see Figs. 1, 2, 5, 6). This variability is not always due to intrinsic flux variations because of changing parallactic angle for sources with strongly polarized emission features. In some cases the variations are quite strong on timescales as short as 5–10 min; even the line shape changed.

4. For W49N, VY CMa, Ori A and W33B we have detected in most sessions a variability of the order of 2–3% on timescales of 2–25 min (see Figs. 3 and 4 as an example). This also suggests the existence of compact features with a size of tenths (perhaps, hundredths) of an astronomical unit.

5. As a spin-off, our method allows us to estimate the degree of linear polarization of the spectral features and, from the comparative correlation analysis of their behavior, their spatial relation.

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References

[1] I.I. Berulis, E.E. Lekht, V.A. Munitsyn and G.M. Rudnitskij, *Astron. Zh.*, **75**: 394 (1998); (Engl. transl.: *Astron. Rep.*, **42**: 346 (1998)).
[2] V.A. Samodurov and S.V. Logvinenko, *Astron. Zh.*, **78**: 396 (2001); (Engl. transl., *Astron. Rep.*, **45**: 339 (2001)).
[3] S.H. Knowles, C.H. Mayer, A.C. Cheung *et al.*, *Science*, **163**: 1055 (1969).
[4] W.T. Sullivan, *Astrophys. J., Suppl. Ser.*, **25**: 393 (1973).
[5] P.R. Rowland and R.J. Cohen, *Mon. Not. R. Astron. Soc.*, **220**: 233 (1986).
[6] A.L. Argon, L.J. Greenhill and J.M. Moran, *Astrophys. J.*, **422**: 586 (1994).
[7] R. Genzel, D. Downes, J.M. Moran *et al.*, *Astron. Astrophys.*, **78**: 239 (1979).
[8] S.V. Siparov, *Astron. Astrophys.*, **416**: 815 (2004).

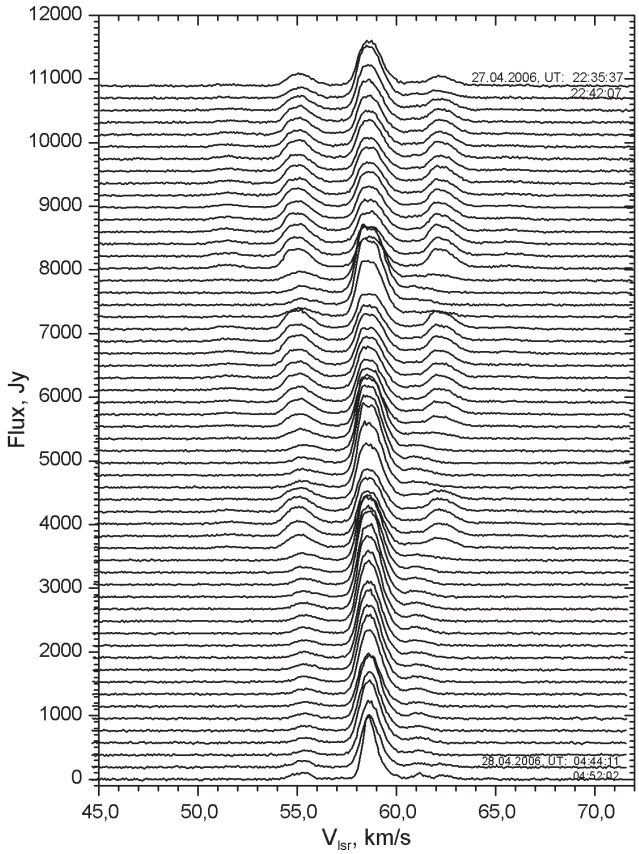


Figure 1 Observations of W33B, in total 58 spectra, exposures 6 min 30 s each, 27–28 April 2006 (UT 22:35:37–04:52:02). Phase transitions in the shape of the spectrum are seen: from the state with a strong central peak to the state with appreciable side features. Unfortunately, however, the spectrum changes all at once along the entire axis of radial velocities (axis X), and this can be partly due to an unstable operation of the receiver.

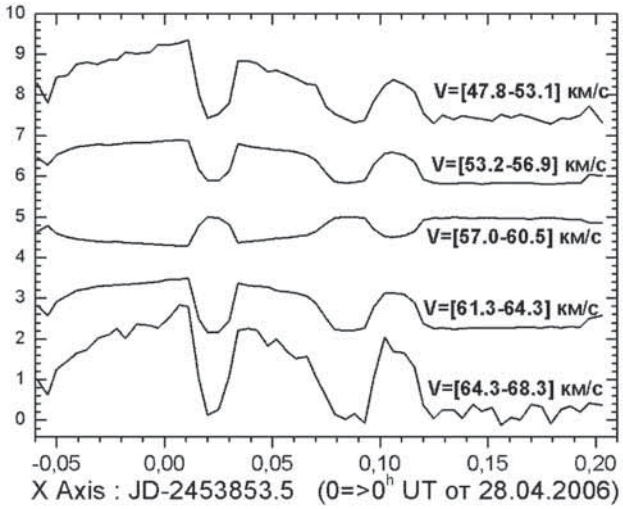


Figure 2 Variation in the relative weights of the spectral features in W33B on 27–28 April 2006. The spectrum is noticed to be changed in all spectral ranges simultaneously, which can also be caused by unstable operation of the receiver.

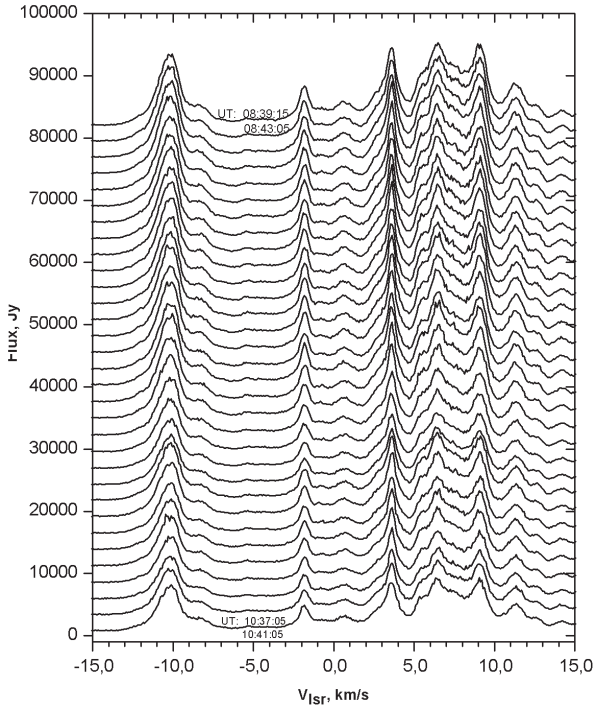


Figure 3 Observations of W49N, 32 spectra, 4-min exposures, 23 March 2006 (UT 08:39:15–10:41:05). Slight "jitter" is visible in the shape and relative intensities of individual spectral features, which have very high flux densities; the measurement errors are negligible as compared to the scale of the figure.

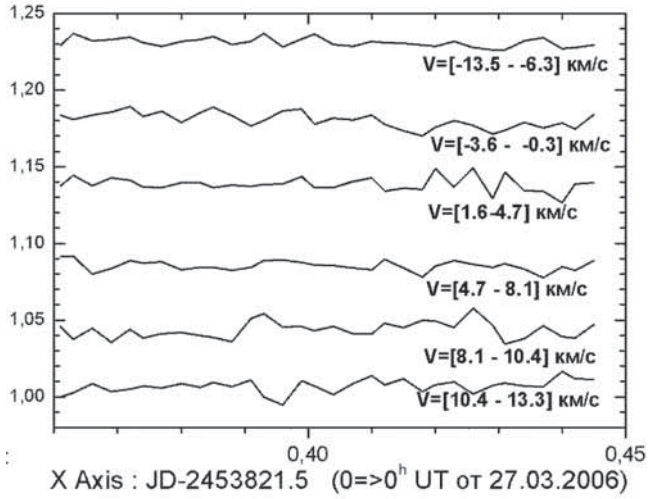


Figure 4 Variation in the relative weights of the spectral features in W49N on 27 March 2006 (the relative measurement error is 0.001).

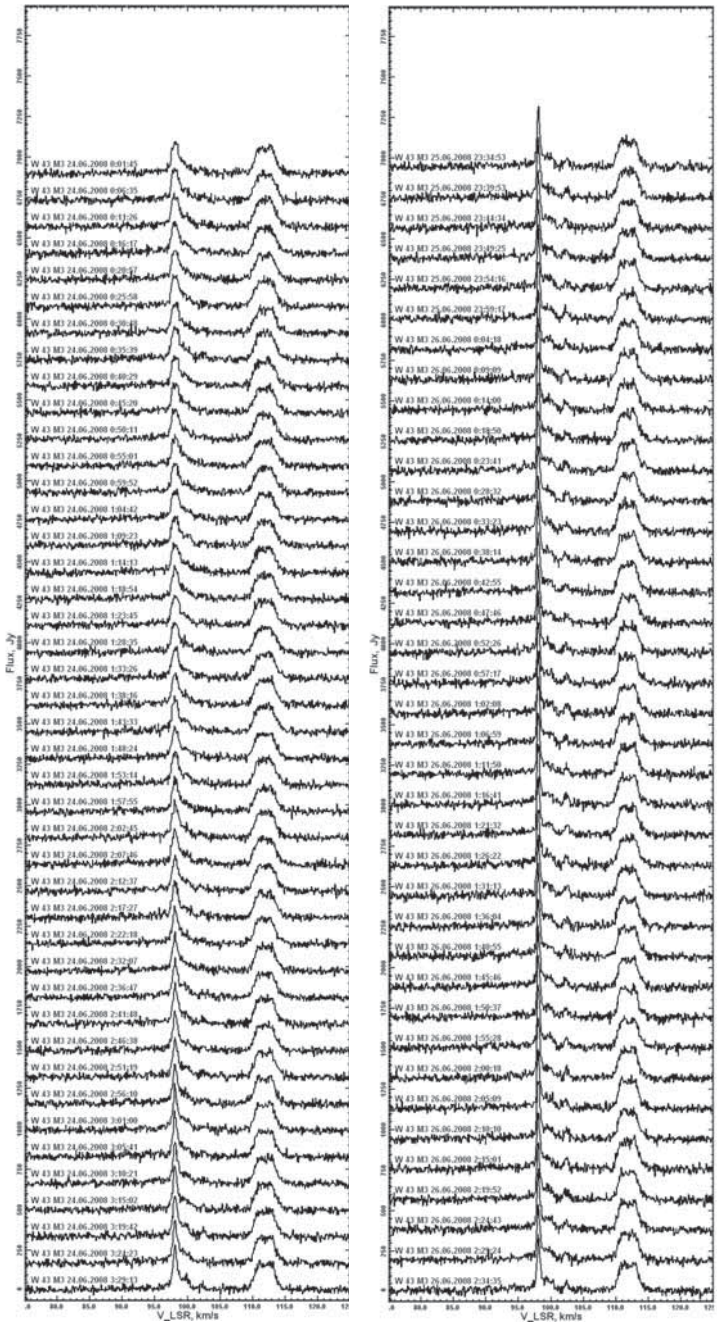


Figure 5 Observations of the source W43M3 at approximately the same time on two consecutive days. In the first session a growth by a few scores per cent in only 3.5 h is visible in the right-side feature; the transition itself occurred during an hour; the feature narrowed. The second session demonstrated stability of the spectrum: the shape of the features was approximately the same as that achieved a day before; though the right-side feature became still stronger and narrower.

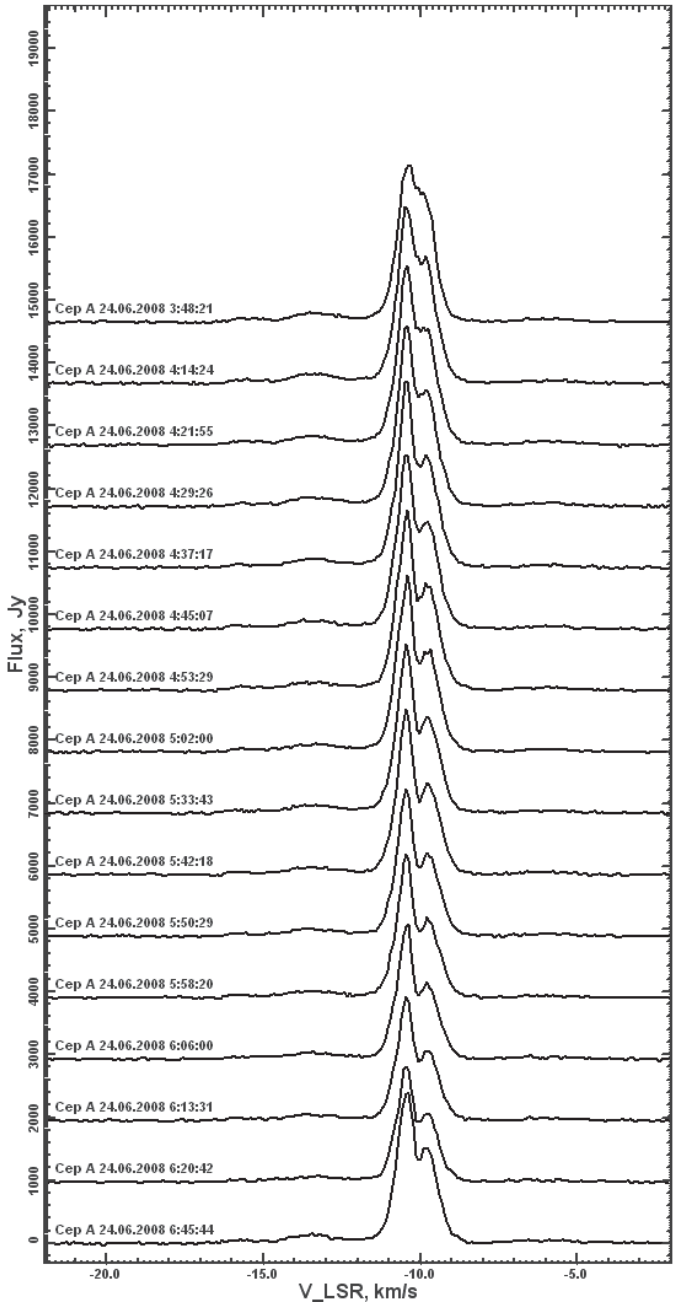


Figure 6 Observations of the source Cep A at approximately the same time on two consecutive days. Strong session-to-session changes as well as inatrasessional variations on 24 and 26 June are visible. A the same time there are intervals of stability (25 June 2006). The variability of the features is probably due to their mutual displacement and by enhanced maser amplification of overlapping features.

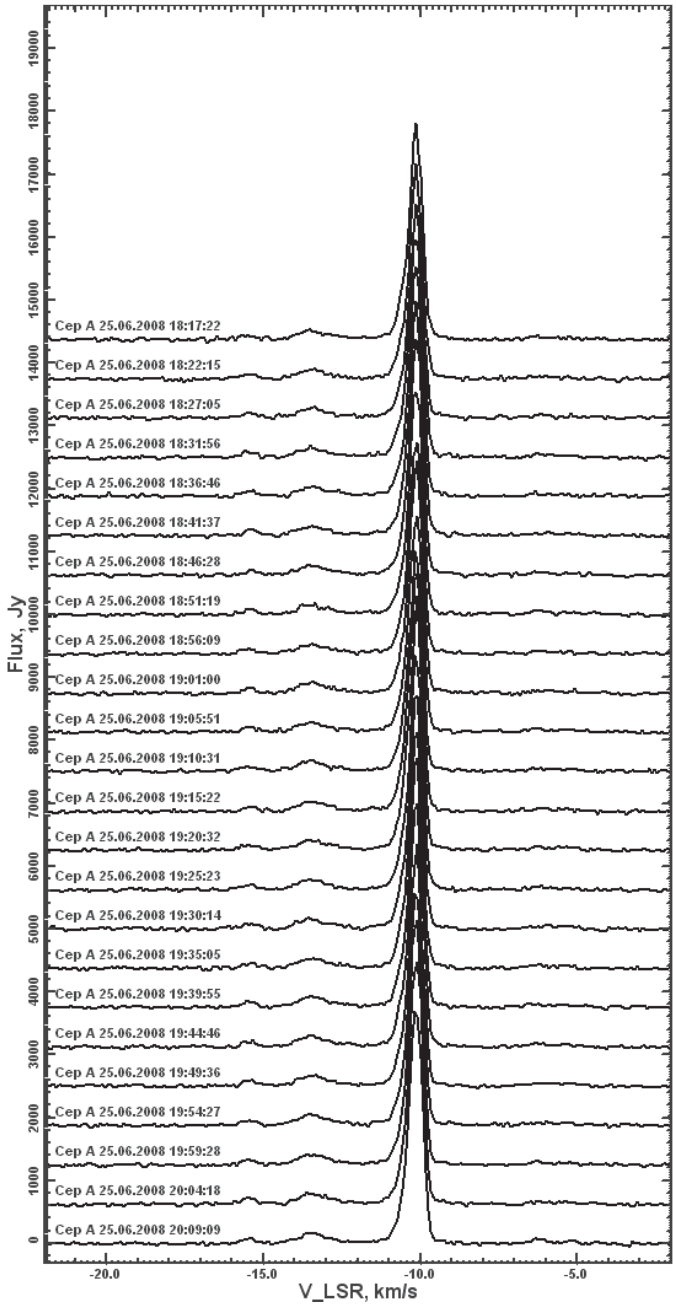


Figure 6 (Continued)

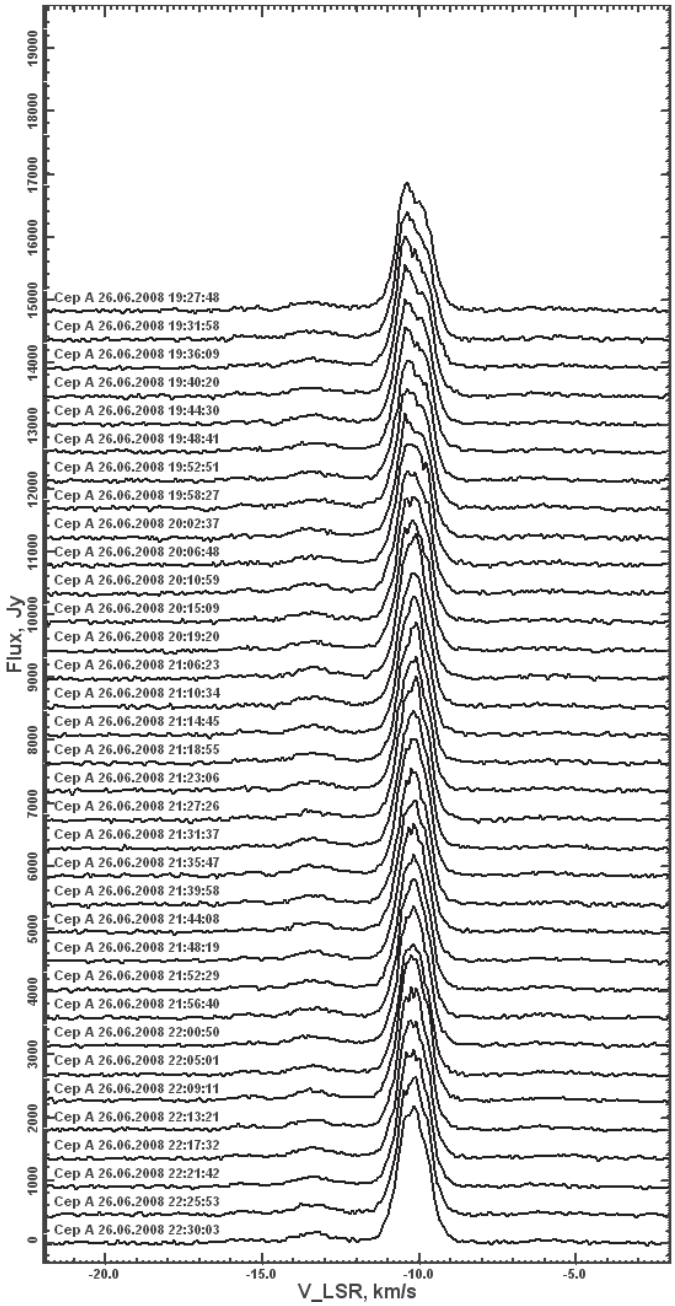


Figure 6 (Continued)