PHYSICAL PARAMETERS OF PROTOPLANETARY DISK SURROUNDING IRAS 22150+6109 YOUNG STAR

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ABSTRACT. IRAS 22150+6109 star belongs to L 1188 star forming region in Perseus, according to [1] located at distance of 910 pc from the Sun. Photometric observations in the visible range that were carried out in 1997-1999 have revealed the following features of the object: source variability 0.2^m, interstellar absorption reaches the value of $A_V = 2^m$ [2], visual brightness of $V \approx 10.8^m$ [3]. In near IR region (JHK bands) the emission excess is observed around 1^m in comparison with visible range: $J \approx 9.8^m$, $H \approx 9.7^m$, $K \approx 9.6^m$ [4]. Flux data in four bands contained in WISE catalog [5], confirmed the further increase of IR-excess in wavelength range of 3.4-21 μm. According to AKARI catalog [6] where the emission fluxes are in wavelength range of 18-160 μm, IR-flux increase continues nearly about 60 μm, thereafter it starts to decrease. Such star's spectral energy distribution (SED) is typical in the presence of dust disk surrounding it.

According to the analysis of color average data in optical range and optical spectrum, star's spectral class can be determined as B2-B3 of initial main sequence [7]. Fundamental parameters assessment according to [8] is as follows: weight – 6.5±0.5 M_{sun} and radius – 5 R_{sun}.

The aim of the work is to carry out the analysis of star's coherent astrophysical parameters and on their basis to determine parameters of the disk surrounding it.

1. Astrophysical characteristics of IRAS 22150+6109 star

Distinguishing characteristic of stars evolution before output on the main sequence is the presence of circumstellar matter, often in the disk form, from the material of protostar cloud. However, thermodynamics of disk surrounding it depends on star's definite parameters value that is important for obtaining the agreed parameters between it, surrounding it disk and observed spectral energy distribution.

For object's fundamental parameters determination the modern scale of stars astrophysical parameters was used (except radii easily determined from represented data), one of recent variations is contained in electronic form as summary table[1] compounded, generally, according to works data [9, 10]. Apparent stellar magnitude value in the band $V = 10.64^m \pm 0.06^m$ [3] is consistent with previously calculated weight 6.5±0.5 M_{sun} [8] and absolute visual stellar magnitude values $M_V = -1.5^m$ and B2V spectral type, on the condition that the studied system is located at the distance from the Sun in 950 pc, and its interstellar absorption is equal to $A_V = 2.2^m$. At these parameters the star radius should be equal to 3.7 R_{sun} rather than 5 R_{sun} as it was fore-quoted in the work [11]. Divergence of these values can be explained by the fact that the star has not yet passed to main sequence. In this case its radius can be slightly larger than the one with which it falls on main sequence, and remaining parameters nearly correspond to star's zero age values. At the same time, there are several fundamentals to assign the studied object to young systems where the disks can exist. Effective temperature value equal to $T_{eff} \approx 20\,000\,K$ corresponds to star assessed parameters.

2. Circumstellar disk parameters that follow from SED system

2.1. Simulation method of SED from the star and protoplanetary disk

Calculating SED from the system it was expected that emission flux on all wavelengths is the sum of fluxes from the star and from the disk. Flux from the star was calculated in black-body approximation using effective

temperatures and radii described above. Emission flux from disk was determined by expression:

$$F_{disk} = d^{-2} \int_{R_{in}}^{R_{out}} B_\nu(T_r)\, Q_\nu\, 2\pi r\, \mathrm{d}r,$$

$$Q_\nu = 1 - e^{-\tau}; \quad \tau = \Sigma_r\, \kappa_\nu,$$

where r – radial distance in disk, d – distance from the system to the Sun, $B_\nu(T_r)$ – Planck function, R_{in} and R_{out} – inner and outer radius of the disk, respectively. Q – dust particles radiation efficiency, τ – disk optical thickness that is the product of surface density Σ_r depending on the distance from the star, and absorption coefficient κ_ν depending on frequency ν. Absorption coefficient was calculated with Mie theory (as in [12] work) for flush particles composed from astronomical silicates of 0.1 – 100 μm dimensions. Relation of gas mass to dust mass was excepted equal to 100. Surface density and disk temperature change with the distance under the laws (as in [13] work):

$$\Sigma_r = \Sigma_{in} \left(\frac{r}{R_{in}} \right)^p,$$

$$T_r = T_{sub} \left(\frac{r}{R_{sub}} \right)^q,$$

where p and q – surface density radial change and effective temperature exponents, respectively. R_{sub} – distance from the system center where disk temperature is equal to 1500 K – dust particles sublimating temperature [14].

2.2. Simulation results and analysis

Simulation of SED from central stars was carried out using above described algorithm and geometrical models [15, 16]. In fluxes from disks calculation it was assumed that disk's minimal inner radius is equal to the distance from the star surface on which conditions of temperature balance the dust particles will sublimate (for studied system parameters $R_{sub} = 2\,\mathrm{AU}$). Surface density radial change exponent p varied from 0 to –1.5, in increments of 0.5. Effective temperature radial change exponent q varied from –0.35 to –0.75, in increments of 0.01. Inclination angle value (i) varied from 0° to 60° in increments of 10°. Disk's inner and outer radii values R_{in} and R_{out} varied from minimal inner radius value to 1000 AU (in increments of 1 AU) and to 2000 AU (in increments of 10 AU), respectively.

Model that has best match with the observations was selected using minimum value determination χ^2,

$$\chi^2 = \sum_{i=1}^{n} \left(\frac{F_{obs,i} - F_{mod,i}}{\sigma_{obs,i}} \right)^2,$$

where $F_{obs,i}$ – observed flux, $\sigma_{obs,i}$ – observation error, $F_{mod,i}$ – model flux for every wavelength.

Figure 1 shows approximation result of observed SED of IRAS 22150+6109 system and calculations results according to stated algorithm. Distribution curve of SED

IRAS 22150+6109 system has minimal value χ^2 over star parameters obtained in previous section and disk characteristics: $R_{in} = 135 \pm 15$ AU, $R_{out} = 850$ (+1000/ –250) AU, $p = -0.5$ (+0.5/–1.0), $q = -0.65 \pm 0.1$ and inclination angle to observer = 20°–40°. Disk weight should not be less than 4% of star weight. Model parameters error was determined from system parameters values with which χ^2 does not exceed minimal value more than on 10%.

3. Conclusion

As it follows from above described researches, Herbig Ae/Be star and surrounding it disk are included in IRAS 22150+6109 system. Hence, the age of such system does not exceed Kelvin-Helmholtz time of 200 thous.years, according to its power-mode dependence on stellar mass (7 M_{sun}) with –2.8 exponent (see, e.g. [8, 17]). Stellar radius exceeds typical for moment of passing on main sequence, and dimensions of circumstellar disk significantly differ from analogous protoplanetary disks of solar type stars: $R_{in} \approx 135$ a.e. and $R_{out} \geq 600$ a.e. Such systems are significantly larger than Solar system.

Protoplanetary disks around stars with such mass evolve sufficiently fast. Whereby, disk loses the gas and main part of its mass. Therefore, massive disk presence around such a star means that this system is one of few observable on this stage of stellar evolution.
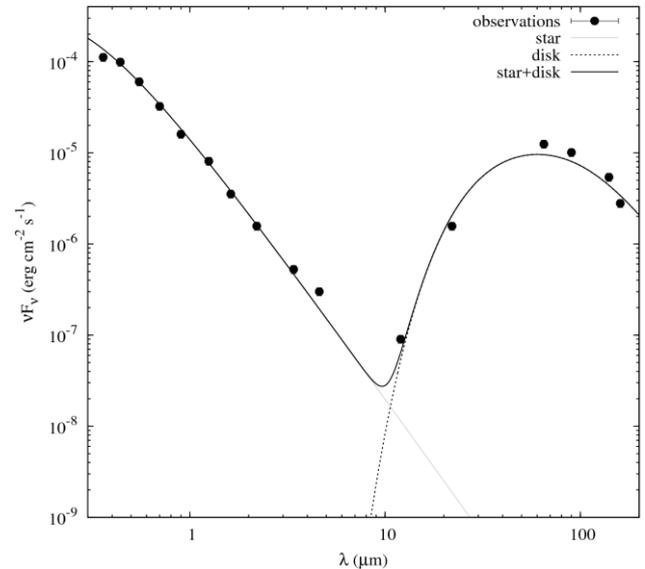
Figure 1: Observed (points) and SED calculation values of the star with didk surrounding it and calculation values of star SED with disk surrounding it approximated by two functions, the first (left) is the Planck curve (describing star's SED), and the second (right – IR-excess by means of circumstellar disk).

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